Annual Report

2015-2016

INSTITUTE OF PHYSICS

BHUBANESWAR

INSTITUTE OF PHYSICS
Sachivalaya Marg
P.O. Sainik School
Bhubaneswar - 751 005
Odisha, India
Phone: +91-674- 2306 400/444/555
Fax: +91-674- 2300142
URL: http://www.iopb.res.in

Editor
Prof. D. Topwal
Prof. A. Saha

Published by
Prof. B. R. Sekhar, Registrar

Compiled by
Shri Rajesh Mohapatra

Contents

About the Institute

Institute of Physics, Bhubaneswar is an autonomous research institution within the Department of Atomic Energy (DAE), Government of India. The Institute was established in 1972 by the Government of Odisha and continues to receive financial assistance from DAE and Govt. of Odisha.

The Institute has a vibrant research programme in the fields of theoretical and experimental condensed matter physics, theoretical high energy physics and string theory, theoretical nuclear physics, ultra-relativistic heavy-ion collisions and cosmology, quantum information and experimental high energy nuclear physics. The accelerator facilities include a 3MV Pelletron accelerator and a low-energy implanter. These are being used for studies in low energy nuclear physics, ion beam interactions, surface modification and analysis, trace elemental analysis, materials characterization, and radiocarbon dating studies. One of the important areas in the Institute is in the field of Nanoscience and Nanotechnology in general and surface and interface studies in particular. The Institute has several advanced facilities for sample preparation and for the study of various physical and chemical properties of nanostructures and bulk condensed matter systems. The Institute is actively involved in the International Collaborations with CERN (Switzerland), BNL (USA), ANL (USA), GSI (Germany), and other laboratories abroad. The Institute is also participating in various research activities related to India-based Neutrino observatory.

The Institute offers Ph.D. programme to the scholars who successfully complete the one year pre-doctoral course at the Institute. The selection for the pre-doctoral programme is through the Joint Entrance Screening Test (JEST). Candidates qualifying the CSIR-UGC NET examination and those having high GATE scores are also eligible for an entry to the pre-doctoral program.

The Institute campus has housing facilities for the employees and hostels for the scholars and post-doctoral fellows. Compact efficiency apartments are available for post-doctoral fellows and visitors. Both indoor and outdoor games and sports facilities are also available in the campus. The Institute has a mini-gym in the New Hostel. The Institute also has a guest house, auditorium, and dispensary in the campus.

The Foundation Day of the Institute is celebrated on 4th of September every year.

The Governing Council

Chairman

Prof. S. K. Joshi

Distinguished Emeritus Scientist CSIR
and
Honorary Vikram Sarabhai Professor (JNCASR)

Members

Prof. V. Chandrasekhar,
Director,
National Institute of Science Education and Research,
P.O. : Bhimpur- Padanpur,
Via-Jatni, Khurda - 752 050.

Prof. J. K. Bhattacharjee,
Director
Harish-Chandra Research Institute,
Chhatnag Road, Jhunsi,
Allahabad-211019.

Dr. S. L. Chaplot,
Director (Physics Group),
Bhabha Atomic Research Centre,
Trombay, Mumbai-400 085.

Smt. Nisha Singh, IAS,
Joint Secretary,
Department of Atomic Energy (B.S),
Room No.145- A, South Block,
Central Secretariat, New Delhi-110011

Shri R.A.Rajeev, IAS, (from 01.10.2014)
Joint Secretary (Finance),
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai-400001

Sri L. N. Gupta, IAS,
Principal Secretary, Govt. of Odisha,
Employment and Technical Education & Training Department,
Bhubaneswar-751001.

Prof. Saroj Kumar Nayak,
Head,
School of Basic Sciences,
Indian Institute of Technology,
Bhubaneswar-751013.

Prof. Simanchal Panigrahi,
Department of Physics,
National Institute of Technology,
Rourkela-769008, Odisha.

Prof. Sudhakar Panda,
Director,
Institute of Physics,
Bhubaneswar-751005.

Secretary to the Governing Council
Prof. B. R. Sekhar,
Registrar, Institute of Physics,

From Director's Desk . . .

Greetings!

The Institute of Physics (IOP), Bhubaneswar is one of the premier research institutions in India and has vibrant research programmes in the frontier areas of both experimental & theoretical physics and materials science. This annual report briefs about the research and academic activities carried out during the preceding year 2015-16 at Institute of Physics.

The 40th year academic activities of IOP was celebrated during the year 2015-2016. A year-long academic programme and scientific events like colloquium fest, schools, conferences, meetings, workshops, and activities related to recharging of school teachers were organized as a part of this commemoration and celebration. Outreach programmes *via* popular lectures and experimental demonstrations were also organized at regular intervals of time. Eminent national/international scientists were invited to visit IOP on a short term basis, and work in collaboration with the faculty members and research scholars. During the academic year 2015-2016, the faculty/scientific members of IOP have carried out excellent research work and published about 140 research papers in the International Peer Reviewed Journals. Besides, the faculty members and research scholars of IOP have received many academic accolades like distinguished faculty award from HBNI, Ramanujan Fellow, best thesis award from HBNI and best poster award at different conferences. A Max Planck Partner Group in the field of high energy physics is also set up at IOP.

To enhance the academic and scientific activities at IOP, seven young and dynamic faculty members working on forefront research areas in condensed matter physics, statistical physics, string theory and experimental high energy physics are hired. Also, two adjunct faculty members have joined the institute. We believe that their research experience and expertise will strengthen as well as add a new direction to the ongoing research activities at IOP. Moreover, to streamline the administration, computing, and library related work in IOP, a Registrar, a System Administrator and a Librarian are hired. IOP is very much pleased to host an integrated online calendar page BASE, (Bhubaneswar Area Scientific events) in partnership with Utkal University, NISER & IIT Bhubaneswar that displays various scientific events focused on Physics and Materials Science taking place at the partnering institutes. This calendar aims to foster better academic coordination & interaction, visibility & dissemination of information and be a resource platform.

IOP is seriously looking forward to expand its research and academic activities while the research in various branches of physics is progressing through an exciting phase worldwide in the recent days. IOP has excellent potential to grow and be among the leading institutions in India and worldwide, however, limited faculty-member strength in some of the major frontier areas is becoming a hindering factor. Therefore, IOP is keen to hire more faculties in various emerging fields of Science and proposes to build *a center of excellence* that will focus on the research areas which are expected to flourish in the coming years. At the same time, IOP is also aiming to enhance the Ph.D and Post-doctoral fellows intake capacity.

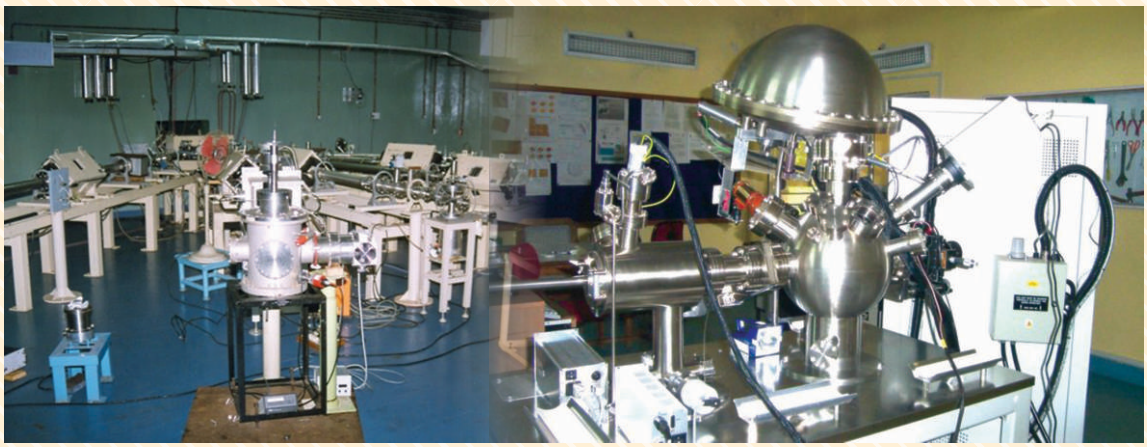
We are actively working on a wider plan to enhance & strengthen the academic activities and expand & develop the overall infrastructure of IOP for carrying out top class research.

I very much hope that IOP will continue to flourish and pioneer the research in various areas of applied and fundamental physics and will emerge as one of the leading institutions in India and worldwide.

(Prof. Sudhakar Panda)

1

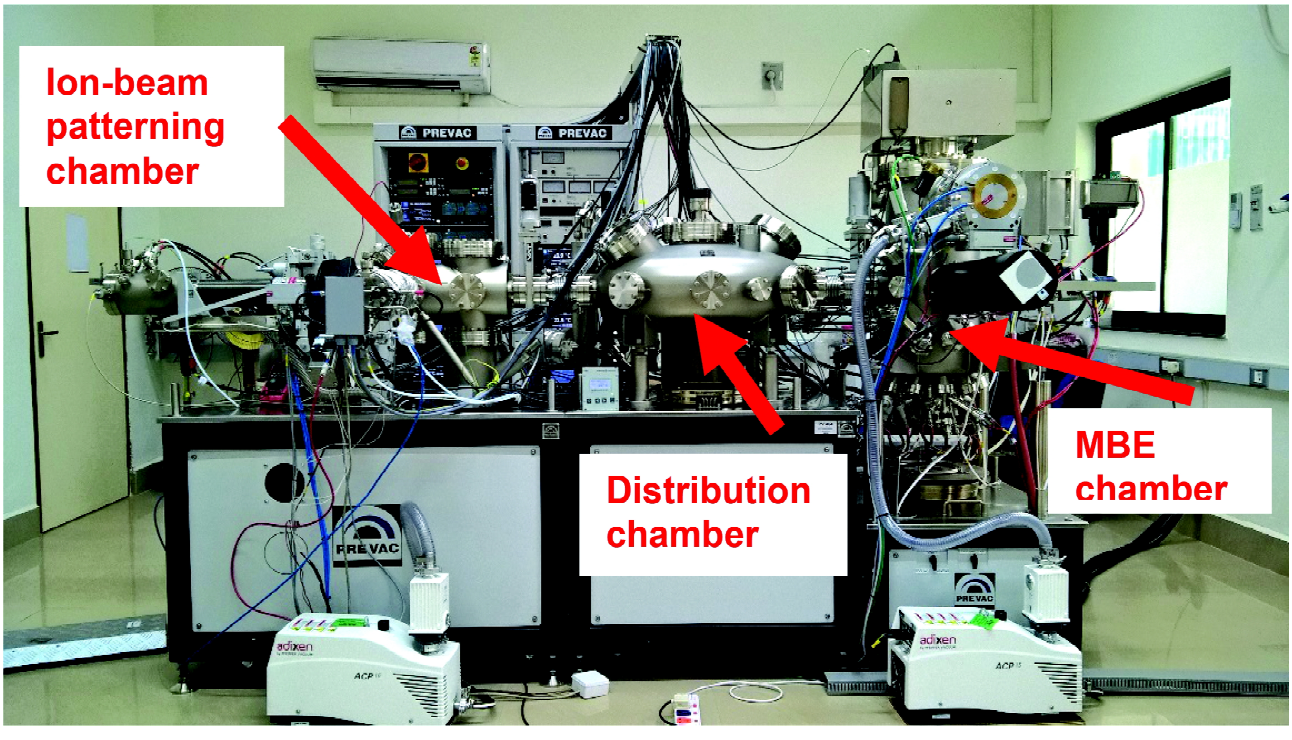
FACILITIES



1.1 MAJOR EXPERIMENTAL FACILITIES

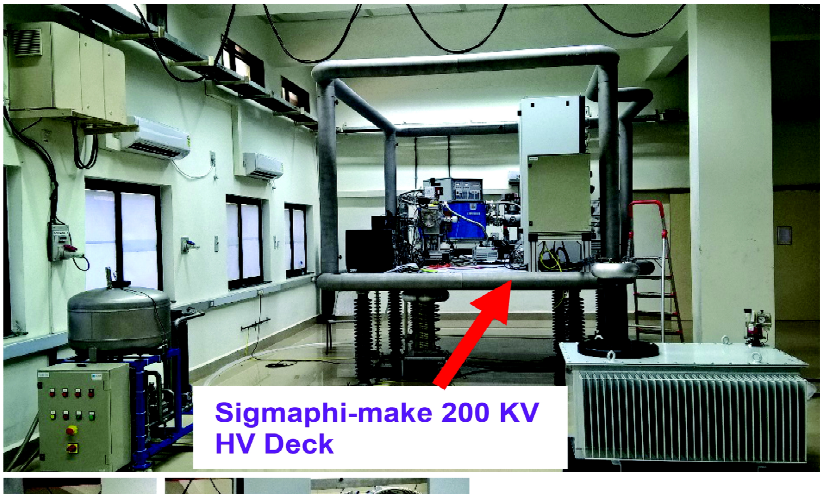
New Facility

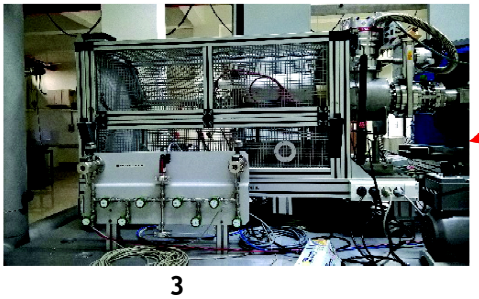
Integrated low Energy ion patterning and UNV Growth System



Recently, we have installed and commissioned a low energy ion patterning unit integrated with molecular beam epitaxy system for fabrication of self-organized patterned susbstrates, *in-situ* ultrathin films and self-assembled nanostructures to achieve nanoscale functionalities, viz. plasmonics, magnetism and optical properties. This facility is having structural characterization module and we are in the process of adding the in-situ compositional module as well which will make it a unique system in the country.

Development of an ECR ion Source-based low-to-medium energy ion-beam facility



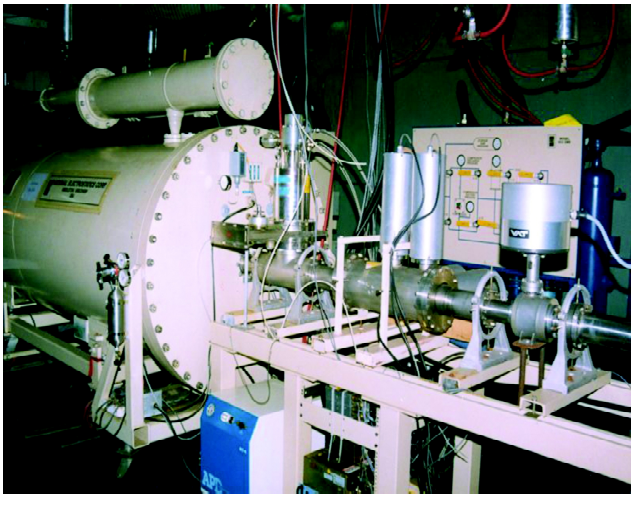


We installed electron cyclotron resonance (ECR) ion source on a 200 KV high voltage deck. This will enable us to accelerate ions to hundreds of keV to a few MeV energy for ion implantation, nanoscale patterning, ion-beam induced epitaxial crystallization, ion-beam mixing, ion-beam shaping, synthesis of embedded nanostructures and so on. This facility will help us bridging the gap of not being able to use inert gas ions (other than helium) and energies below 1 MeV from the existing Pelletron accelerator.

ION BEAM FACILITIES

Ion Beam Laboratory

The Ion Beam Laboratory houses the NEC 3 MV tandem Pelletron Accelerator which is one of the major facilities used by researchers from all over the country. The accelerator provides ion beams of energies typically 1-15 MeV starting from protons and alphas to heavy ions. Commonly used ion beams are that of H, He, C, N, Si, Mn, Ag and Au. Multiple charge states are possible for the MeV energy positive ion beams. Argon is used as the stripper gas to produce positive ions. The most probable charge state for heavy ions (carbon or above) is 3+ for terminal potentials above 2 MV.

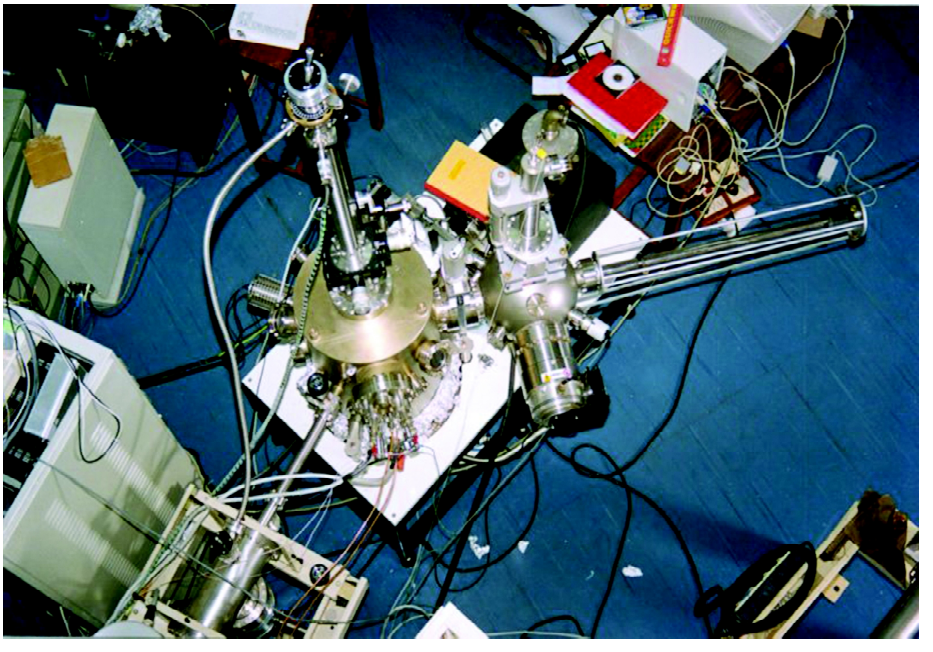


The beam hall has six beam lines. The beam line at -45º is used for Rutherford Backscattering (RBS), Elastic Recoil Detection Analysis (ERDA), Proton induced X-ray Emission (PIXE), Ultra high vacuum (UHV) and ion channeling. Radiocarbon AMS is carried out in the -15º beam line. A general purpose scattering chamber suitable for PIXE experiments is available in the 0º line. This beam line also has the potential to perform external PIXE experiments in atmosphere. The 15º beam line is equipped with a raster scanner and is being used for ion implantation. There is a UHV chamber for surface science experiments in the 30º beam line. The 45º beam line houses the micro-beam facility.

The types of experiments that are being carried out in the IBL are mainly ion beam modification and ion beam analysis. These include ion implantation, irradiation, channeling, Rutherford backscattering, and particle induced X-ray emission. The accelerator is also being used for radiocarbon dating by Accelerator Mass Spectrometry (AMS) . The facilities for research in surface sciences include an ultra-high vacuum chamber on the surface physics beam line at IBL which is equipped with a thin film deposition facility, Auger spectroscopy and the low energy electron diffraction (LEED) units.

Ion Beam Analysis Endstation

We have also added an ion beam analysis endstation in the general-purpose beam line at the Ion Beam Laboratory. This endstation is a unique one in the country which is dedicated for user experiments based on ion beam analysis



techniques, viz. Rutherford backscattering spectrometry (RBS), RBS-channeling, and elastic recoil detection analysis (ERDA). While RBS is meant for depth profiling of heavy elements, RBS-channeling is capable of analysis of single crystals and epitaxial layers to determine crystalline quality, amorphous layer thickness, degree of disorder, and atomic site. In addition, it can be used for accurate determination of thickness of an amorphous thin film, consisting of light elements, deposited on a single crystalline substrate of a relatively heavier element. On the other hand, low-energy ERDA helps in absolute determination of hydrogen and its isotopes in a simultaneous fashion and in a non-destructive way. The system can be upgraded to add proton induced x-ray emission (PIXE) technique for trace elemental analysis in materials. The endstation is equipped with a slam load lock chamber and a rectangular sample holder, which can accommodate more than ten samples at a single go. These eliminate the need for exposing the scattering chamber to the ambient and frequent disruption in experiments. The samples can be precisely positioned in front of the ion beam with the help of XYZ motors and monitored by a CCD camera. All gate valves and the vacuum pumps are coupled to the interlocking system which rules out meeting a vacuum related accident. In addition, the chamber is equipped with two surface barrier detectors – one dedicated for RBS measurements and the other one for ERDA measurements. They are coupled to the respective set of electronic modules and the data acquisition system is interfaced with a computer.

Ion beam etching induced surface nanostructuring

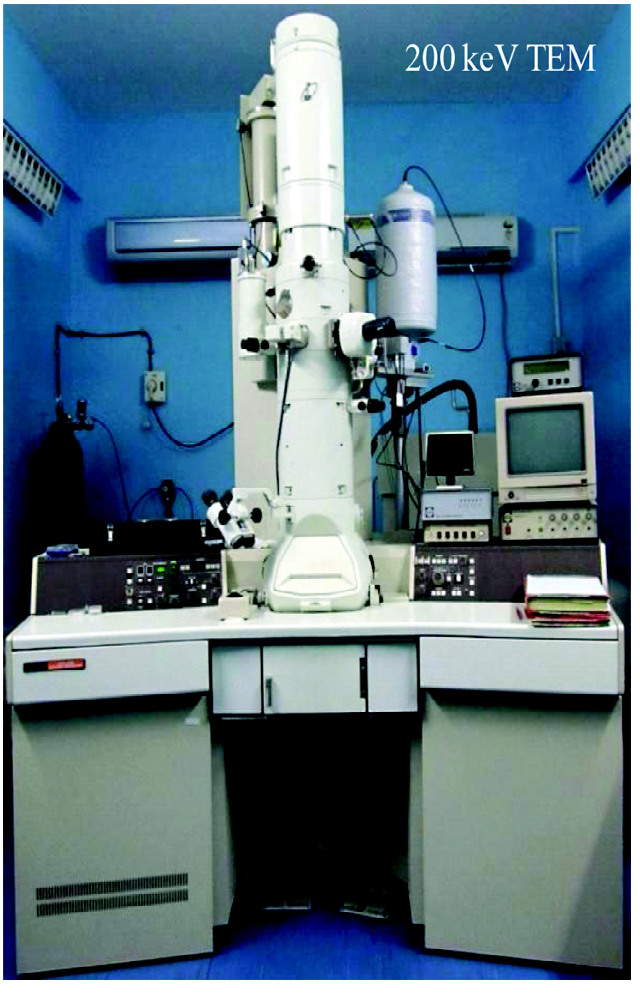
At Surface Nanostructuring and Growth (SUNAG) Laboratory, we have facilitated a low energy (50 eV – 2 keV), broad beam (I in. diameter) electron cyclotron resonance (ECR) source based ion beam etching facility for creating self-organized surface nanostructures. The source is equipped with a differential pumping unit for working at a better chamber vacuum during the ion etching process. The ion source is coupled with a UHV compatible sample processing chamber which is equipped with a load lock chamber and a 5-axes sample manipulator. The sample stage has both low (LN2) and high-temperature (1000°C) stages

for creating nanostructures at different sample temperatures. One can measure the target current from the sample stage itself, while the ion current is measured by bringing in a shutter in front of the ion beam path.

MICROSCOPY FACILITEIS

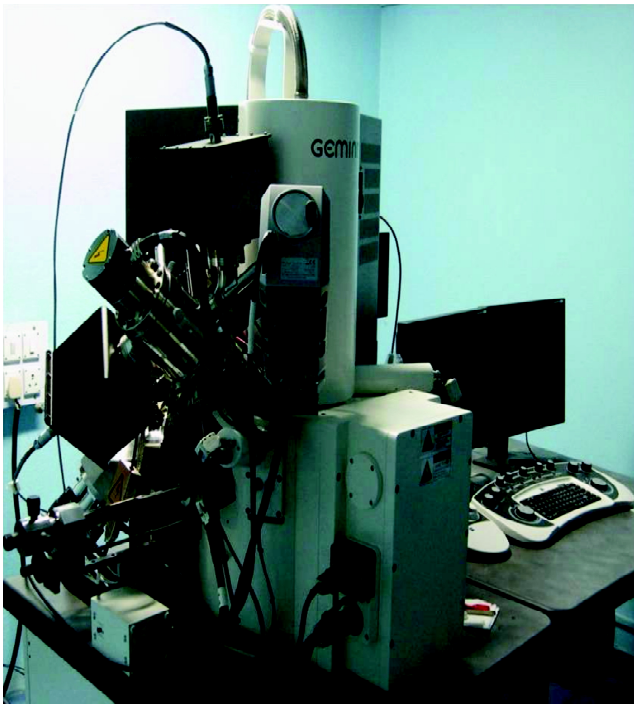
HRTEM Laboratory :

The High Resolution Transmission Electron Microscope (HRTEM) facility consists of two components: Jeol 2010 (UHR) TEM and Associated Specimen Preparation system. High-Resolution Transmission Electron Microscopy (HRTEM) with an ultra-high resolution pole-piece (URP22) working at 200 keV electrons from LaB_6 filament assures a high quality lattice imaging with a point-point to resolution of 0.19 nm. For in-situ elemental characterization and compositional analysis, an energy dispersive system using Si(Li) detector (INCA from Oxford, UK) is regularly used. The facility carries out both planar and cross-section TEM analysis of systems. For the specimen preparation, Grinder-cum-polisher, Ultra-Sonic Disc Cutter, Dimple Grinder, Low Speed Diamond Wheel Saw, Wire Saw, Tripod Polisher, Precision Ion Polishing System (PIPS) and Millipore water purifier system facilities are used. Recently, a low-temperature cooling sample stage holder (cooling with LN_2 – minimum temperature achievable is $\approx$110 K to room temperature, Model 636 from M/S Gatan Inc.) and a dry pumping system have been installed. the system is also equiped with low and high temperature stages and fast CCD camera to carry out *in-situ* and real time studies.



FEGSEM-FIB facility:

The Cross-Beam facility consists of a field emission based scanning electron microscope (FEGSEM) and a focused ion beam (FIB) system. The facility also has other useful accessories to elemental mapping with x-ray florescence (using energy dispersive spectrometry (EDS)), canning transmission electron microscopy (STEM), e-beam lithography (M/S Raith GmbH) and transmission electron microscopy specimen preparation using lift-out methods. The objective is to understand the combination of

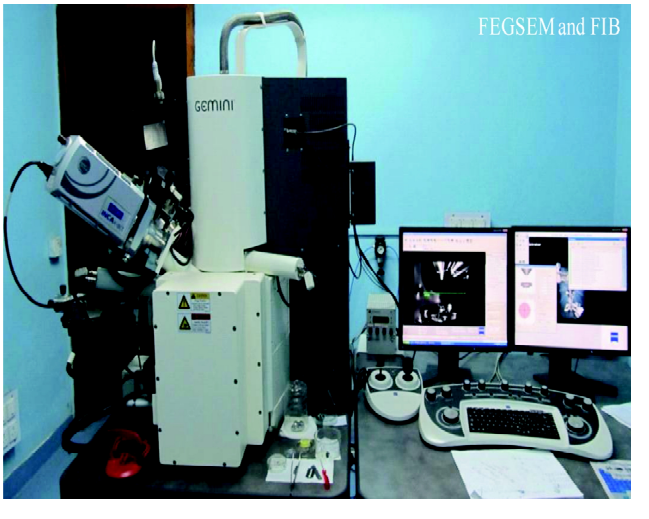


bottom-up and top down process in self-assembly of nanostructures. This would help us to create a new methodology that would help to grow atomic scale devices, to understand the structural aspects of nano to micro – scale structures, and to prepare site-specific TEM specimen using the SEM and FIB facilities. The electron beam energy can be varied between 100 eV to 20 keV and the Ga ion beam energy can be varied in the range of 2 – 30 keV. The images can be made with sub-nm resolution while the features can be made of dimensions ~20 nm.

Multi-Mode Scanning Probe Microscope Facility

At IOP we have a Multimode SPM (Scanning Probe Microscope) facility. SPM is being primarily utilized for the research in the fields of surface science and nanoscience for investigating surface topography, nanostructures, magnetic structures, phase imaging, electrical force imaging, STM, STS and electrochemical STM. The two primary techniques present in our SPM are: Scanning tunneling Microscope (STM), where the tunneling current between the probe and the sample surface is imaged, and Atomic Force Microscope (AFM), where the forces are imaged. AFM can further operate in two modes viz. Contact mode and Tapping mode. In addition the AFM can be utilize to perform Lateral Force Microscopy (LFM), Force Modulation Microscopy (FMM), Magnetic Force Microscopy (MFM), Electric Force Microscopy (EFM) and Phase Imaging. Studies in Liquid environment are also possible.

In addition, we have a large-area, high-precision AFM setup which is equiped with low Z-axis noise facility. This AFM is mostly dedicated for studying nanoscale self-organizedpatterned substates and thin films. Conductive AFM mode offers a gamut of physical properties to be studied. Further it has in-built nano-indentation and nano lithography facilities.



A combination of Field Emission Gun based Scanning Electron Microscope and Focused Ion Beam imaging (FEGSE-FIB) is used to image nanoscale features and modify these structures while observing the structural evaluation with SEM. The above facility is model Neon 40 Cross Beam, from Ziess GmbH, Germany.

ELECTRON SPECTROSCOPY FACILITIES :

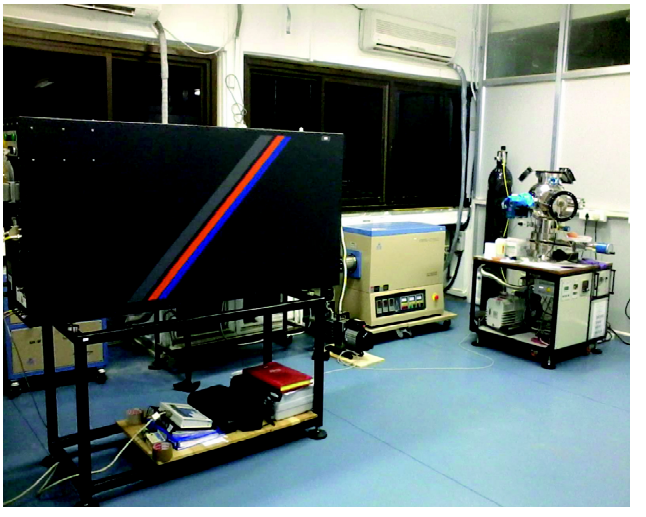
X-Ray Photoelectron Spectroscopy Setup

The present XPS system has a dual X-ray Aode (Mg/Al). The sample can be aligned by a manipulator. Photoelectrons are energy analyzed by a hemispherical mirror analyzer. The system also has the facility for sample annealing and Ar ion sputtering. Sputtering technique can be utilized for doing depth profiling studies. All the experiments are carried out under ultra high vacuum (UHV) conditions at the vacuum of $1x10^{-10}$ Torr.

X-ray photons while impinging on the sample surface produce photoelectrons which can be utilized for elemental identification. The kinetic energy distribution of electrons photo-ejected by x-rays from a sample provides a map of the discrete atomic levels, specially the core levels of the constituent atoms with in the material. Another very important aspect of XPS is the ability to distinguish different chemical environments of atoms; these appear in XPS spectra as core level binding energy shifts. The origin of chemical shifts arises from enhanced or reduced electronic screening of electrons due to charge transfer. Small mean free paths of the photo-ejected electrons make XPS very surface sensitive (~1 nm). The technique of XPS is very useful in the studies of thin film structures, heterostructures, bulk samples, and even for the studies of biological samples.

ARUPS Laboratory

The Angle Resolved Ultraviolet Photoelectron Spectrometer (ARUPS) is equipped with facilities for doing both angle integrated valence band measurements as well as angle resolved valence band measurements. This mu metal UHV system is supplied by M/s Omicron NanoTechnology UK. In angle integrated UPS, we probe the valence band electronic structure on polycrystalline and thin film samples. The angle resolved studies are possible on single crystals. The UPS system consists of a main analysis chamber and a sample preparation chamber, both under 10^{-11} mbar vacuum conditions. The main chamber is equipped with R3000, Scienta hemispherical



analyzer for angle-integrated studies. A movable 65mm hemispherical analyzer, mounted on a 2-axis goniometer is also there in this chamber. These energy analyzers have a typical resolution of around 15 meV. He I (21.2 eV) and He II (40.8 eV) lines from an ultra-violet discharge lamp are used for photo excitation. The analysis chamber is also equipped with a 4-axis sample manipulator-cum cryostat, which can go down to 20K. Facility for performing Low Energy Electron Diffraction (LEED) is also available in the analysis chamber. The sample preparation chamber has facilities for scrap cleaning and evaporating metal films.

THIN FILM GROWTH FACILITIES

Pulsed Laser Deposition (PLD) System

PLD system helps growing epitaxial thin films of various materials albeit the most prefered materials are oxides. The newly installed system was developed in a piece-wise manner by procuring several modules from different sources. We are depositing epitaxial bi- and multi-layer thin films of superconducting (viz. YBCO) and colosal magneto-resistance (viz. LSMO) on suitable substrates.

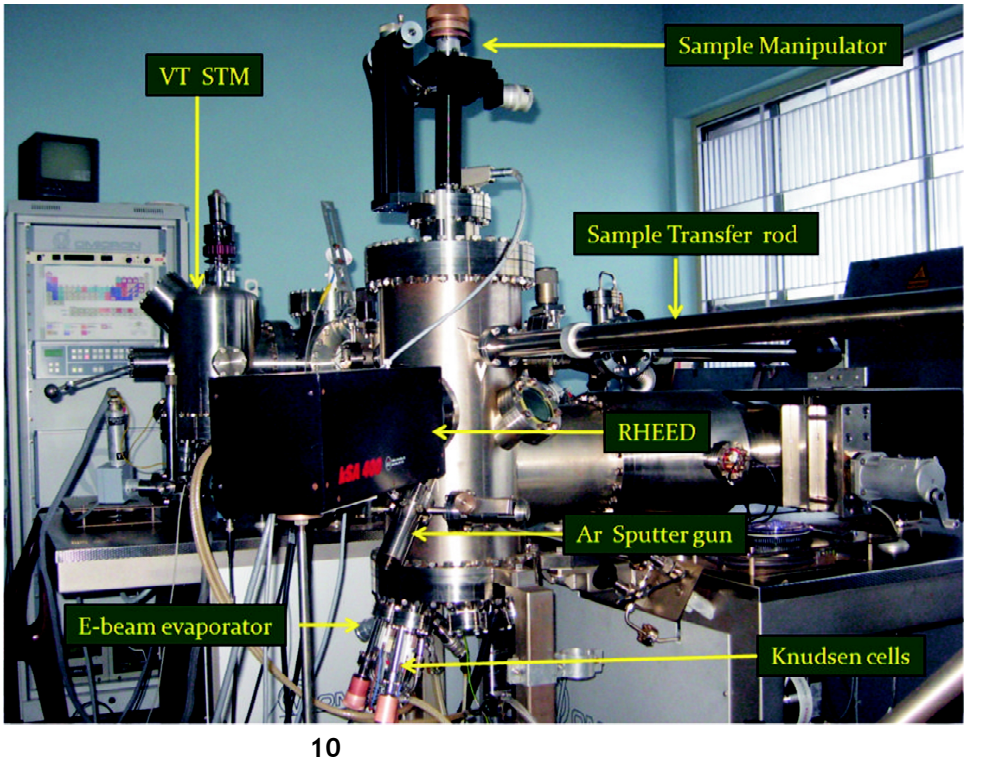
DC/RF Magnetron Sputtering

We have installed a pulsed DC/RF magnetron based sputter deposition unit. The unit has four sputter guns where two are dedicated to operate with pulsed DC supply and the other two are connected to RF power supply. The substrate is made to rotate during film deposition towards having high-quality uniform films. One can put the substrate holder at a high temperature (up to 600^0 C)

for film growth at elevated temperatures. We have an additional and dedicated gun for deposition of three-dimensional nanostructures by using glancing angle deposition. Further, we have a load lock and a plasma chamber for making nitride and/or oxide layers in vacuum. We can grow thin films of semiconductors, metals, and compounds having a wide variety of morphology and grain size. In turn, their physical properties can also be tuned. Research using this facility is aimed at developing advanced materials having novel structures and tunable properties. The system is mainly aimed to grow materials on templated substrates and compare change in their physical properties driven by anisotropy in substrate morphology. We have taken up a program to grow thin films and naostructures having applications in solar cell, spintronics, and nanophotonics.

MBE – VTSTM

The ultra clean surfaces are achieved at a vacuum condition better than $1x10^{-10}$ mbar pressures (ultra high vacuum, UHV conditions) and appropriate cleaning of surfaces. The Molecular Beam Epitaxy (MBE) – Variable Temperature Scanning Tunneling Microscope (VTSTM) system is a custom designed unit procured from M/S Omicron GmBH, Germany. The facility consists of three Knudsen cells, one e-beam evaporation source, sample manipulator with direct and resistive heating attachments, computer controlled Reflection High Energy Electron Diffraction (RHEED) on-line analysis tool, quartz crystal thickness monitor, Residual Gas Analyzer (RGA), in-situ VTSTM through UHV transfer rods. The facility is being used to study ultra clean surfaces reconstructions on Si(100), Si(110), Si(553) and Si(557) systems, Ge, Au and Ag quantum dots deposited epitaxially on clean silicon surfaces, and epitaxially grown thin films. *In-situ* STM is used to study the atomic and electronic structure of the nanostructures and surface reconstructions. On-line RHEED is used to study the real time growth of epitaxial films.



STRUCTURAL PROPERTY MEASUREMENT FACILITIES

High Resolution X-ray Diffractometer (HRXRD)

High Resolution X-Ray defractometer (D8 Discover) can operate in grazing as well as powder XRD mode. The HRXRD system has flexibility with possible combinations of the x-ray source, optics, sample stages, and the detectors. The system consists of goniometer, short tracks, vertical, 150 mm, 3 kW X-Ray generator, grazing incidence attachment for thin film analysis with parallel beam mirror for better data quality, push plug Göbel Mirror, Cu radiation source with a set of slits for Goebel Mirror, flat LiF monochromator and set of plug-in slits, Ni K_β filter for Cu radiation, standard sample stage diffracted slit assembly including 2.5° Soller, dynamic scintillation detector, NaI and ICDD data base for phase identification. The diffractometer has the ability to perform a full range of applications for qualitative and quantitative phase identification, crystal structure identification of different samples, X-ray reflectivities crystallite size determination, strain analysis and preferred orientation for established structures. In addition, we have another XRD Setup (D8, Advance), which is also in operation.

XRR and XSW

The X-ray reflectivity and X-ray standing wave measurements are being carried out using indigenously built facility that consists of an 18.0 kW rotating anode (Mo) X-ray source from M/S Rikagu Co. (Japan), a silicon single crystal based monochromator, a 4-circle Huber goniometer for sample mounting and manipulation, two types of detectors (NaI and Si(Li)), a stand alone MCA and associated nuclear electronics for counting and motor controls. The data acquisition and control is done with a computer which uses few add-on cards for the purposes with control software program under Linux operating system.

X-ray reflectivity measurements are being use to study the roughness (with sub-angstrom resolution) at the surface and interfaces and depth profiling (electron densities) many systems such as multilayers, LB films,

Polymers, and thin films deposited under various conditions like e-beam evaporation, MBE deposition and spin coating methods. In X-ray standing wave method, standing waves are generated in multilayers (due to long period nature in self assembled monolayers and multilayer systems) and used to determine the atomic position across the surface and interfaces, such as Pt distribution in Pt/C multilayers.

This facility is also used as high resolution XRD to study strain profile across the interfaces in thin film structures and in epitaxially grown films.

MAGNETIC PROPERTY MEASUREMENT FACILITY

SQUID - VSM

The SQUID-VSM lab consists of the Quantum Design MPMS SQUID-VSM EVERCOOL system. The magnetic property measurement system(MPMS) is a family of analytical instruments configured to study the magnetic properties of samples over a broad range of temperatures and magnetic fields. Extremely sensitive magnetic measurements are performed with superconducting pickup coils and a Superconducting Quantum Interference Device(SQUID).To optimize speed and sensitivity, the MPMS SQUID VSM utilizes some analytic techniques employed by vibrating sample magnetometers (VSMs). Specifically, the sample is vibrated at a known frequency and phase sensitive detection is employed for rapid data collection and spurious signal rejection. The size of the signal produced by a sample is not dependent on the frequency of vibration, but only on the magnetic moment of the sample, the vibration amplitude and the design of the SQUID detection circuit. The MPMS SQUID VSM utilizes a superconducting magnet (a solenoid of superconducting wire) to subject samples to magnetic fields upto 7 Tesla (70 KOe). The squid and magnet is cooled with the help of liquid Helium. Liquid Helium is also used to cool the sample chamber, providing temperature control of samples from 400K down to 1.8K. The SQUID VSM can be used to basically perform M-T,M-H and ac susceptibility measurements at a magnetic field ranging upto 7T and temperature ranging from 4K to 400K.

OPTICAL PROPERTY MEASUREMENT FACILITY

Facility for Investigation of Photo-luminescence and Raman Spectroscopic Properties :

CMPF system was installed in May 2014 and is equipped with water cooled Argon laser. The Micro Raman facility is operated in backscattering geometry. Confocal mapping capabilities with sub-micron spatial resolution are possible. A wide range of excitation wavelengths, using laser, is possible allowing control of the penetration depth into the material, and thus, control of the volume sampled. By combining these techniques it is possible to characterize both the vibrational and

electronic properties of materials. The system will be utilized to understand the properties of many semiconductor systems including oxide semiconductors. Our group, in general, is involved in investigating the electronic structure as well as physical, optical, magnetic and chemical properties of surfaces, thin films and nanostructures, grown by a variety of techniques involving Ion sputtering, thermal deposition, vapor deposition. The interaction of DNA and polymers with surfaces and nanostructures is also being actively pursued in the group. Oxide semiconductors are energy storage materials displaying excellent UV and Visible light absorption properties when suitably patterned with nanostructures. Interaction of DNA with oxide surfaces can demonstrate many exciting properties which have technological implications for sensors and bio- implants. Our group has shown that DNA can also act as a tiny sensor of Mercury. These systems will be investigated for their vibrational properties.

1.2 COMPUTER FACILITY

The computer facility in the Institute of Physics can be broadly divided into that for scientific computation, Local Area Network (LAN), access to internet and automation of library and administration. There are about two hundred PC's installed in the computer center, laboratories and offices of faculties, scholars and administration in the Institute. About 10 servers, the central network hub, firewall, about twenty PC's and network printers are installed in the computer center. User's data and general utilities are centrally stored in the file server and are made available on the user's desktop PC's by NFS over LAN. Programs which require large amount of computation are run in HPC's. Procurement of a thousand node HPC for the Institute is under process.

Number of software packages such as Mathematica, Maple, Origin, IDL, Numerical Recipes are available for carrying out numerical

computations, symbolic calculations, graphical analysis, modelling and simulation. GUPIX and SIMNRA software's are available for analysis of experimental data. For preparing scientific documents Latex is available in the PC's running under Linux. Number of printers are installed at different locations of academic building for general printing over LAN.

In the Institute, the gigabit capacity LAN is implemented with three levels of CISCO switches. Two core switches are configured in the redundant mode to load-balance the network traffic. Wireless access points have been set up in the library, computer center, main building, auditorium, lecture hall, guest house and hostel. Access to LAN has been provided to the quarters of faculty and some employees of Institute in the campus through ADSL system using telephone lines. Efforts are being made to extend LAN to the Efficiency Apartment and all quarters in the campus. The LAN is made secure by installation of firewall. Antispam software is installed to filter unwanted mails. Antivirus software has been installed in the PC's running under MS Windows operating system in the offices and laboratories.

The internet link to Institute is available at two dedicated bandwidths of 128mbps each provided by commercial internet service providers and at 100mbps by National Knowledge Network. Institute of Physics is a node on ANUNET with the provision to connect other units of DAE directly by VSAT link for voice and data communication. A seismic monitoring equipment has been installed in the Institute and seismic data is being continuously transmitted to Bhaba Atomic Research Centre for analysis using ANUNET.

The administrative work, such as accounting, personnel management, stores management have been computerized. Several software packages such as MSOffice, Wings 200 Net, Tally and multilingual software are in use.

In addition to members of the Institute, computer facility is also being used by researchers of several other universities and colleges in Orissa for their academic work.

1.3 LIBRARY

The Library facility is available to the members of the Institute as well as members from other academic institutions. The Library holdings include 15,661 books and 23,643 bound Journals, taking the total collection to 39,304. Throughout the year the Library added 377 books to its collection. The Library subscribed to 135 Journals. The Library has also acquired IOP (UK), John Wiley, Springer Physics and Astronomy, Scientific American, World Scientific, Annual Reviews Archives (OJA) perpetual access right to the back files containing all articles published since Volume 1 in electronic format. Library also subscribed two e-Books on Lecture Notes in Mathematics and Physics series from Volume.1 with perpetual access right to back files and full

archives containing all articles published since 2011. Besides this, Library is a part of the Dept. of Atomic Energy Consortium with Elsevier Science from 2014 - 2016 getting access to around 2000 journals with access from 1995 onwards electronically. The Library assists users in obtaining articles from other Libraries in the country under resource sharing programme. The Library also sends out articles as Digital inter Library Loan (dill@iopb.res.in).

The Library is housed in a centrally air conditioned building which is open round the clock for convenience of the users. The books and journals circulation system has become very effective with implementation of bar-codes, online reservation and reminders through e-mail to its individual members.

The Library cataloging is fully automated with Libsys4 (Rel.6.2) software on Linux platform which is a fully integrated multi user package with powerful search and query facilities. It supports activities like Acquisition, Cataloguing, Circulation, Serial Control etc. Searching of books and Journals can also be performed using the WEB-OPAC in Library website.

1.4 AUDITORIUM :

We have an auditorium in our campus where we organize Colloquiums, Seminars, Workshops, Conferences, Cultural activities, Social programs regularly. This auditorium can easily accomodate 330 people. It has all the high-quality amenities to organize above mentioned events.

2

ACADEMIC PROGRAM

2.1 PRE-DOCTORAL PROGRAM

One of the most important objectives of the Institute is to train and guide young scholars to do research in physics.

Since 1975 institute has a regular Pre-doctoral (Post M.Sc.) course is a very important academic program because it is designed to train the M.Sc. students for carrying out research activities. The programme is aimed at imparting a broad based training in advanced physics and research methodology to students. The course work is planned with the view that it should help a student not only in doctoral research, but also enable him/her to become a good physics teacher irrespective of whether or not he/she takes up doctoral research. Few years back, the Institute joined the Joint Entrance Screening Test (JEST) for students who are interested in taking research in physics. The final selection of a student is based on the result of written test and an interview conducted at the Institute. This year the Pre-doctoral course began in August, 2015 and ended in July, 2016. Utkal, Berhampur and Sambalpur Universities have recognized our Pre-doctoral program equivalent to their M.Phil degrees. On completion of the Pre-doctoral program, students are eligible to join research under the supervision of faculty members of the Institute, leading to the Ph.D. degree awarded by Homi Bhabha National Institute (HBNI).

To recognize the talent, the Institute has instituted Lalit Kumar Panda Memorial Endowment Fellowship (*L. K. Panda Memorial Fellowship)* for the most outstanding pre-doctoral student. The fellowship consists of an award of Rs.5,000/- and a citation.

A total of 218 students were called for written test and interview for admission to the predoctoral course in July, 2015. This includes JEST qualifiers, UGC-CSIR qualifiers and valid GATE score holders. Following students successfully completed the doctoral course work in July, 2016:

1. Mr. Alapan Dutta
2. Mr. Amir Shee
3. Mr. Atanu Maity
4. Mr. Dibyendu Rana
5. Miss. Dilruba Hasina
6. Mr. Mukaddar Sk

Mr. Dibyendu Rana was adjudged the most outstanding scholar and was awarded the L. K. Panda Memorial Fellowship for the year 2015-16.

Details of the courses offered and course instructors are given below.

Trimester – I (August - November)

Quantum Mechanics	: Prof. A. Saha
Mathematical Methods	: Prof. A. Virmani
Classical Electrodynamics	: Prof. S. Mandal
Experimental Physics	: Prof. P. V. Satyam
Laboratory Experiments	: Prof. P. V. Satyam Prof. T. Som Prof. D. Topwal Prof. P. K. Sahu

Trimester – II (December - March)

Statistical Mechanics	: Prof. G. Tripathy
Adv. Quantum Mech.	: Prof. S. Mukherjee
Field Theory	: Prof. A. M. Srivastava
Numerical Methods	: Prof. S. Varma
Advanced Experiments	: Condensed Matter Experimental faculity members

Trimester – III (April - July)

Cond. Matter. Physics	: Prof. S. Mandal & Prof. S. Sahoo
Particle Physics	: Prof. S. K. Agarwalla
Nuclear Physics	: Prof. S. K. Patra & Prof. P.K. Sahu

As a part of the course work, students also worked on projects in the last trimester under supervision of faculty members of the

institute. Titles of the projects undertaken by student during 2015-2016 are given below along with the name of the supervisor.

Name of Supervisor	Name of Student	Title of Project
Prof. S. Mandal	**Atanu Maity**	Introduction to spin wave and magon excitation
Prof. S. Mandal	**Dibyendu Rana**	Kitaev model
Prof. A. Saha	**Alapan Dutta**	Enhanced thermoelectric performance and anomalous seeback effect in 2D topological insulator
Prof. D. Choudhuri	**Amir Shee**	Spontaneous symmetry breaking of active droplet provides generic route to mobility
Prof. T. Som	**Dilruba Hasina**	Electron Cyclotron Resonance (ECR) ion source and its working Principle
Prof. T. Som	**Sk. Mukaddar**	Low energy ion beam based self organized pattern formation at surfaces

2.2 DOCTORAL PROGRAM

Presently Institute has thirty three doctoral scholars working in different areas under the supervision of its faculty members. Starting from 2009, all the scholars are registered with Homi Bhabha National Institute (HBNI), a deemed-to-be University within DAE. Progress of each doctoral scholar is reviewed annually by a review committee. This year reviews were held in the months of July-August.

2.3 THESES (Defended / Submitted)

The following scholars have been awarded Ph.D. degree by Homi Bhabha National Institute on the basis of thesis submitted.

1. **Sabita Das :** Thesis Title : *Identified Particle Production and Freeze-out Dyanimics in Star at RHIC Beam Energy Scan Program"*, Advisor : Prof. Sudhakar Panda Co-guide : Prof. Bedangadas Mohanty, NISER.

2. **Pramita Mishra:** Thesis Title : *Electronic structure studies of some layered superconductors and semiconductors using Photoemission Spectroscopy*, , Advisor : Prof. B. R. Sekhar.

3. **Partha Bagchi:** Thesis Title : *Time-Dependent Quark-Antiquark Potential and Quarkonia Suppression in Heavy-Ion Collisions*, Advisor : Prof. Shikha Varma.

4. **Tanmoy Pal :** Thesis Title : *DNA Physics Near Melting Point*, Advisor : Prof. S. Bhattacharjee.

5. **Vanaraj Solanki :** Thesis Title : *Studies of oxide Nanostructures of TiO2, ZnO, NiO & Ion Beam Patterned Surfaces for Photo-absorption and Resistive Switching Properties*, Advisor : Prof. Shikha Varma

6. **Shailesh K. Singh :** Thesis Title : *Application of Mean Field Theory to Nuclear Equation of State and Drip-line Nuclei*'', Advisor : Prof. S. K. Patra.

7. **Subhashis Rana :** Thesis Title : *Effect of Thermal Fluctuations on Classical and Quantum Systems at Small Scales*, Advisor : Prof. T. Som.

8. **Arnab Ghosh :** Thesis Title : *Growth, Characterization and Applications of Variable Oxygen Deficient Oxide Hetro-nanostructures (Au-ZnO and Au-GeO2)*, Advisor : Prof. P. V. Satyam.

9. **Srikumar Sengupta :** Thesis Title : *Aspects of QCD Phase Transition with Reaction-Diffusion Equations*'', Advisor : Prof. A. M. Srivastava.

10. **Mohit Kumar :** Thesis Title : *Growth and Characterization of Cu-O Based Solar Cell*, Advisor : Prof. T. Som.

2.4 Summer Student's Visiting Program (SSVP) :

The motivation of the SSVP program is to expose young students to frontline research areas, especially in the areas of research work going on at the Institute. This year the SSVP was held from 18th May to 3rd July, 2015. Ten students participated in the program. Round trip train fare, accommodation on campus, and a monthly stipend of Rs. 5000/- was provided to all the visiting students. Under this program, each student worked under the guidance of a faculty member of the Institute. At the end of the program, students presented their work in a seminar on the assigned topics.

Name of the Student	Topic of the Seminar	Advisor
Abinash Kar	A study on two anyon systems	Prof. S. Mandal
Labanya Ghosh	Atomic force microscopy and its applications	Prof. T. Som
Ranju Nandan	Early universe and cosmic microswave background	Prof. A. M. Srivastava
Ruchika Gupta	Long term stability test of a single mask triple GEM detector	Prof. P. K. Sahu
Tulika Tripathy	Einstein Solid	Prof. S. Mukherji
Deepak K. Behera	Development of thin film by pulsed laser deposition process	Prof. T. Som

3

RESEARCH

3.1 THEORETICAL CONDENSED MATTER PHYSICS

Anomalous Brownian Refrigerator

We have presented a detailed study of a Brownian particle driven by Carnot-type refrigerating protocol operating between two thermal baths. Both the underdamped as well as the overdamped limits are investigated. The particle is in a harmonic potential with time-periodic strength that drives the particle cyclically between the baths. Each cycle consists of two isothermal steps at different temperatures and two adiabatic steps connecting them. Besides working as a stochastic refrigerator, it is shown analytically that in the quasistatic regime the system can also act as stochastic heater, depending on the bath temperatures. Interestingly, in non-quasistatic regime, our system can even work as a stochastic heat engine for certain range of cycle time and bath temperatures. We show that the operation of this engine is not reliable. The fluctuations of stochastic efficiency/ coefficient of performance (COP) dominate their mean values. Their distributions show power law tails, however the exponents are not universal. Our study reveals that microscopic machines are not the microscopic equivalent of the macroscopic machines that we come across in our daily life. We find that there is no one to one correspondence between the performance of our system under engine protocol and its reverse.

Shubhashis Rana, P. S. Pal, Arnab Saha and A. M. Jayannavar

Extended Fluctuation Theorems for Repeated Measurements and Feedback within Hamiltonian Framework

We have derived the extended fluctuation theorems in presence of multiple measurements and feedback, when the system is governed by Hamiltonian dynamics. We use only the forward phase space trajectories in the derivation. However, to obtain an expression for the efficacy parameter, we must necessarily use the notion of reverse trajectory. Our results show that the correction term appearing in the exponent of the extended fluctuation theorems are non-unique, whereas the physical meaning of the efficacy parameter is unique.

Sourabh Lahiri and A. M. Jayannavar

Brownian motion of classical spins : Anomalous dissipation and generalized Langevin equation

In this work, we analyze the relaxation of a classical spin interacting with a heat bath, starting from the fully dynamical Hamiltonian description. An analogous problem in the framework of generalized Langevin equation (GLE) with anomalous dissipation is analyzed in details. The Fokker-Planck equation corresponding to GLE is derived and the concept of equilibrium probability distribution is analyzed. In this process we have identified few difficulties to obtain equilibrium distribution for the non-Markovian case and the remedy to overcome this difficulty is also discussed.

Malay Bandopadhyay and A. M. Jayannavar

Operational characteristics of single particle heat engines and refrigerators with time asymmetric protocol

We have studied the single particle heat engine and refrigerator driven by time asymmetric protocol of finite duration. Our system consists

of a particle in a harmonic trap with time-periodic strength that drives the particle cyclically between two baths. Each cycle consists of two isothermal steps at different temperatures and two adiabatic steps connecting them. The system works in irreversible mode of operation even in the quasistatic regime. This is indicated by finite entropy production even in the large cycle time limit. Consequently, Carnot efficiency for heat engine or Carnot Co-efficient of performance (COP) for refrigerators are not achievable. We further analysed the phase diagram of heat engines and refrigerators. They are sensitive to time-asymmetry of the protocol. Phase diagram shows several interesting features, often counterintuitive. The distribution of stochastic efficiency and COP is broad and exhibits power law tails.

P. S. Pal, Arnab Saha and A. M. Jayannavar

Rotational diffusion under torque: Microscopic reversibility and excess entropy

We consider rotational diffusion for two systems - a macrospin under external magnetic field, and a particle diffusing on the surface of a sphere under external torque. Microstates in the two cases transform differently under time-reversal. This results in Clausius like dependence of stochastic entropy production (EP) for macrospins, and an excess EP for diffusion of particles on sphere. The total EP in both the cases obey fluctuation theorems. For macrospins, we derive analytical expression for probability distribution of total EP in the adiabatic limit. Numerical simulations show that the distribution functions of EP agree well with theoretical predictions.

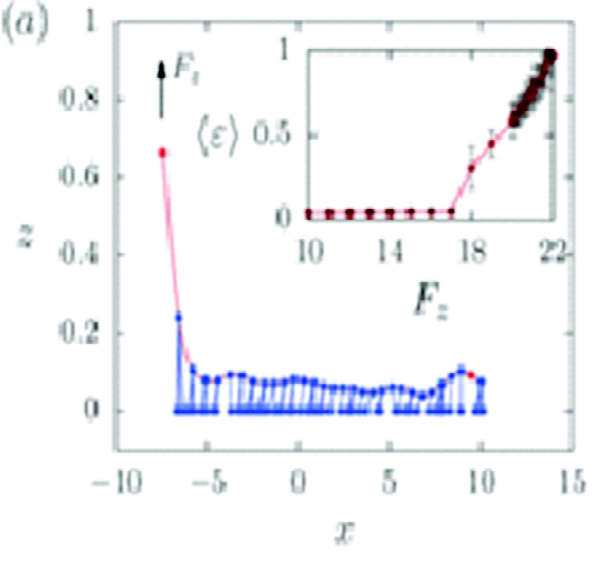
Swarnali Bandopadhyay, Debashish Chaudhuri and A. M. Jayannavar.

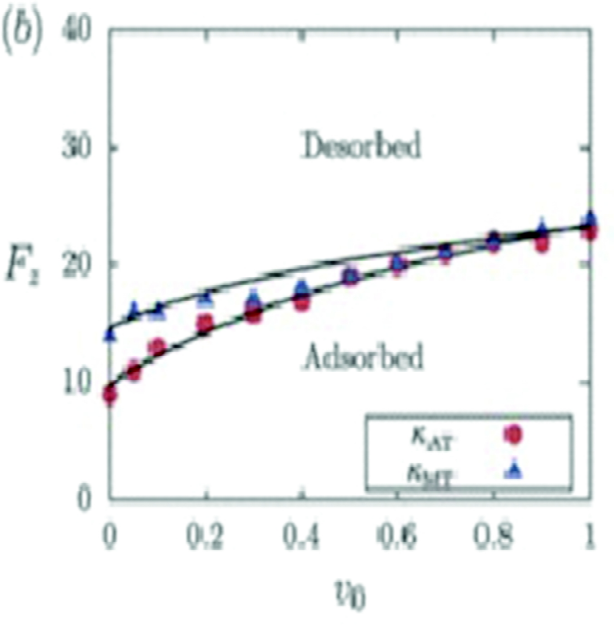
Stochastic thermodynamics of macrospins with fluctuating amplitude and direction

We consider stochastic energy balance and entropy production (EP) in a generalized Langevin dynamics of macrospins, allowing for both amplitude and direction fluctuations, under external magnetic field. EP is calculated using Fokker-Planck equation, distinguishing between reversible and irreversible parts of probability currents. The system entropy increases due to irreversible non-equilibrium processes, and reduces as heat dissipates to surrounding environment. Using path probability distributions of time-forward trajectories and conjugate trajectories under time reversal, we obtain fluctuation theorems (FT) for total stochastic EP. We show that the choice of conjugate trajectories is crucial in obtaining entropy like quantities that obey Fts.

Swarnali Bandopadhyay, Debashish Chaudhuri and A. M. Jayannavar.

(i) **Active polymers:** This is to understand dynamics of cytoskeletal filaments driven by motor proteins. We developed a detailed theoretical model to understand *in vitro* molecular motor assay experiments. The





tangential and transverse responses of semi-flexible polymers have been investigated. Under transverse force, our numerical simulations showed a first order *non-equilibrium phase transition* from adsorbed to desorbed state. The functional form of the phase boundary was obtained using mean field approximation. This depends on bending modulus of the polymer, and activity of motor proteins that depends on local ATP concentration.

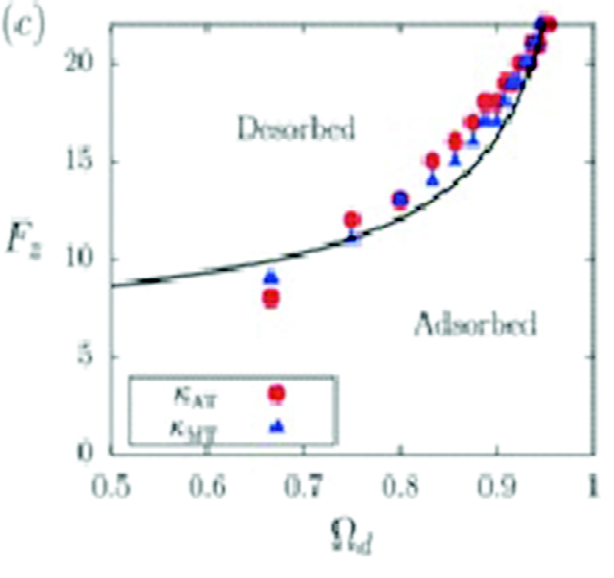
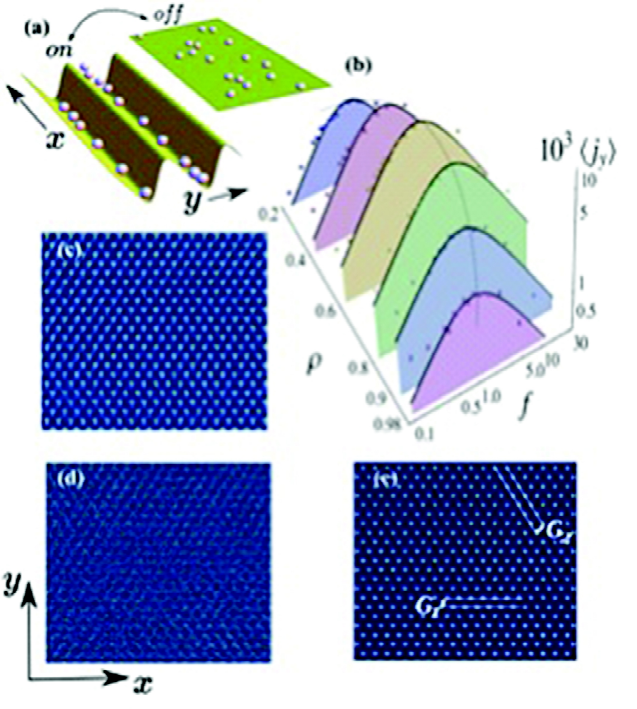
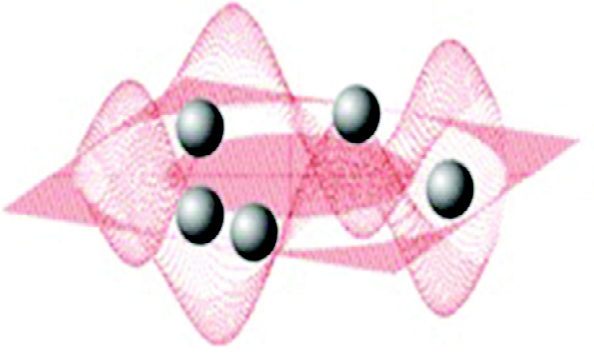


Fig.(a) shows side view of a typical polymer configuration (red line) under transverse force. Blue line-points denote attached molecular motors. When attached motors drag the polymer tangentially. Fig(b) is a phase diagram at constant duty-ratio of motor proteins, but for polymers of two different stiffness, actin-filaments (AT) and microtubules (MT). Fig.(c) is phase diagram in external force- duty ratio plane. Lines denote mean field theory predictions and points denote the simulation data.

We further observed a curious vortex forming *absorbing state* in the dynamics of the polymers allowed to float on the motor-protein bed. The radius of curvature of such vortices is characterized by bending rigidity of the polymer, and the tangential velocity of motor proteins. We are working on the impact of such vortex formation in the collective dynamics of such polymers. Impact of defect formation and their role in active viscoelastic memory of cytoskeleton will be investigated.



(ii) **Driven colloids:** Two-dimensional (2D) dispersion of sterically stabilized colloids are known to undergo a defect mediated continuous transition from a solid to hexatic and eventually to liquid with decreasing density. On the other hand, one-dimensional (1D) system of colloids under a flashing ratchet potential, that doe not generate any directed force on an average, is known to generate time-averaged directed motion. This second effect belongs to a larger class of model known as stochastic pumps, attracting attention recently due to their implication in motion generation in a *force-free* condition in biological systems, starting from sub-cellular machines to tissue flow.



We studied stochastic ratcheting of 2D colloids using molecular dynamics simulations, and scaling theories. The emergent directed of particles vary non-monotonically with driving frequency and system density. As we showed, the variation current is intricately related to a re-entrant *non-equilibrium structural phase transition* from solid and modulated liquid. Analytic expressions obtained from our scaling theory agree well with simulation results.

In a separate study we developed a model for stochastic pump, and presented mean field theory for directed current of strongly interacting particles. This agrees well with simulation results. One intriguing result is, directed current in presence of repulsive interaction can be higher than that of free particles.

(iii) **Stochastic thermodynamics and entropy production**

Starting from stochastic equation of motion of microscopic degrees of freedoms for systems arbitrarily out of equilibrium, it is possible to derive stochastic energy balance and equalities involving stochastic entropy production. These second set of equalities are known as fluctuation theorems. We have extended the formalism for stochastic entropy production to active Brownian motion, due to its implication in biology and novel materials. Our studies for active particles showed important departures from naïve expectation regarding relation between stochastic entropy production and Clausius entropy. Recently, we have found similar departures, the so-called *excess entropy production* in rotational Brownian motion. In this context, our studies on stochastic macro-spin dynamics identify subtle issues regarding entropy production and break down of time reversal invariance. The predictions can be tested against experiments on macro-spins. Our current theoretical endeavor in this direction is expected to help improving feedback control of sub-micron sized memory devices.

Debashish Chaudhuri and Collaborator

Conductance, Valley and Spin polarization and Tunnelling magneto-resistance in ferromagnetic-normal-ferromagnetic junctions of Silicene

We investigate charge conductance and spin and valley polarization along with the tunnelling magneto-resistance (TMR) in silicene junctions composed of normal silicene and ferromagnetic silicene. We show distinct features of the conductances for parallel and anti-parallel spin configurations and the TMR, as the ferromagnetic-normal-ferromagnetic (FNF) junction is tuned by an external electric field. We analyse the

behavior of the charge conductance and valley and spin polarizations in terms of the independent conductances of the different spins at the two valleys and the band structure of ferromagnetic silicene and show how the conductances are affected by the vanishing of the propagating states at one or the other valley. In particular, unlike in graphene, the band structure at the two valleys are independently affected by the spin in the ferromagnetic regions and lead to non-zero, and in certain parameter regimes, pure valley and spin polarizations, which can be tuned by the external electric field. We also investigate the oscillatory behavior of the TMR with respect to the strength of the barrier potential (both spin-independent and spin-dependent barriers) in the normal silicene region and note that in some parameter regimes, the TMR can even go from positive to negative values, as a function of the external electric field.

Arijit Saha and Collaborators

U(1) and SU(2) quantum dissipative systems: The Caldeira-Leggett vs. the Amegaokar-Eckern-Schon approaches

There are two paradigmatic frameworks for treating quantum systems coupled to a dissipative environment: the Caldeira-Leggett and the Ambegaokar-Eckern-Sch\"on approaches. Here we recall the differences between them, and explain the consequences when each is applied to a zero dimensional spin (possessing an SU(2) symmetry) in a dissipative environment (a dissipative quantum dot near or beyond the Stoner instability point)

Arijit Saha and Collaborators

Kitaev Model

We investigated the von Neumann entanglement entropy and Schmidt gap in the vortex-free ground state of the Kitaev model on the honeycomb lattice for square/rectangular and cylindrical subsystems. We find that, for both the subsystems, the free-fermionic contribution to the entanglement entropy *SE* exhibits signatures of the phase transitions between the gapless and gapped phases. However, within the gapless phase, we find that *SE* does not show an expected monotonic behavior as a function of the coupling *Jz* between the suitably defined one-dimensional chains for either geometry; moreover, the system generically reaches a point of minimum entanglement within the gapless phase before the entanglement saturates or increases again until the gapped phase is reached. This may be attributed to the onset of gapless modes in the bulk spectrum and the competition between the correlation functions along various bonds. In the gapped phase, on the other hand, *SE* always monotonically varies with *Jz* independent of the subregion size or shape. Finally, further confirming the Li-Haldane conjecture, we find that the Schmidt gap Δ defined from the entanglement spectrum also signals the topological transitions but only if there are corresponding zero-energy Majorana edge states that simultaneously appear or disappear across the transitions.

S. Mandal

Transport and noise properties of a normal metal-superconductor-normal metal junction with mixed singlet and chiral triplet pairings

In superconductor hybrid junction we have considered a normal metal-superconductor-normal metal (NSN) junction with the

superconductor having mixed singlet and chiral triplet pairings. We have investigated transport and zero frequency shot noise properties of the junction. Our NSN set up comprises of a one dimensional nanowire (NW) placed in close proximity to a bulk superconductor and superconductivity is induced in the NW via the proximity effect. The NW is attached to two normal (N) metal leads and a gate via which the chemical potential of the NW can be controlled. At each junction we have considered two delta function potentials. We have shown that in the subgapped regime when the chiral triplet pairing amplitude dominates over that of the singlet, a resonance phenomena emerges out at zero energy where all the quantum mechanical scattering probabilities acquare a value of 0.25. Also at the resonance, crossed Andreev refection mediating through such junction acquires a zero energy peak. This reflects as a zero energy peak in the conductance as well depending on the doping concentration in the normal metal regime. We have also calculated shot noise for this system and shown that shot noise cross-correlation is negative in the subgapped regime when the triplet pairing dominates over the singlet one. The latter is in sharp contrast to the positive shot noise obtained when the singlet pairing is the dominating one. However, we anticipate that the zero bias peak is due to Andreev bound states at the two interfaces.

Ganesh C. Paul, Paramita Dutta and Arijit Saha

Aharonov-Bohm effect in a helical ring with long-range hopping: Effects of Rashba spin-orbit interaction and disorder

We have studied the electron transport phenomena in a two-terminal helical ring with long-range hopping in presence of Rashba spin-orbit interaction as well as static random disorder. We have used tight-binding framework to describe the helical ring in which two counter-propagating currents flow in opposite direction corresponding to two different spin states by the application of an driving force. This helical current model has recently been reported in literature to describe the 1D edge states of a 2D topological insulator. The pair of counter-propagating states with two opposite spins protected by time- reversal symmetry appeared at the boundary of a topological insulator. The latter is being studied with great attention in recent time. However, the behavior of helical edge states of this lattice model has not yet been analyzed in presence of Rashba spin-orbit interaction and random disorder to the best of our knowledge. This study also enables us to investigate whether the helical edge states proposed earlier in this lattice model is actually topological or not. From the application point of view, we have shown that the ring can behave like a spin-filter depending on the applied magnetic flux and the incoming electron energy. We have calculated the efficiency of spin-filtering also. The most intriguing feature that we articulate in this system is that zero-energy crossings appear in the energy spectra at $\Phi = 0$ and also at integer multiples of half-flux quantum values $\Phi = \Phi 0/2$, n being an integer) of the applied magnetic flux. We investigate the transport properties of the ring using Green's function formalism and find that the zero energy transmission peaks corresponding to those zero energy states disappear in presence of Rashba spin-orbit interaction. We also incorporate static random disorder in our system and show that the zero energy crossings and transmission peaks are not immune to disorder. The latter prevents the possibility of behaving these helical states in the ring like topological insulator edge states which remain unaffected in presence of non-

magnetic impurity. This is also another major finding of our analysis.

Paramita Dutta, Arijit Saha and A. M. Jayannavar

Spin filtering and switching action in a diamond network with magnetic-nonmagnetic atomic distribution

We propose a model of quantum network and demonstrate possible scenarios for production of spin- filtering and switching action in a diamond network with magnetic-nonmagnetic atomic distribution. Our model consists of diamond-shaped plaquettes with deterministic distribution of magnetic and non-magnetic atoms in presence of a uniform external magnetic flux in each plaquette. The orientations and the amplitudes of the substrate magnetic moments play a crucial role in the energy band engineering of the two spin channels which essentially gives us a control over the spin transmission leading to a spin-filtering effect. The externally tunable magnetic flux plays an important role in inducing a switch on-switch or switch-off effect for both the spin states indicating the behavior like a spintronic switch. Even a correlated disorder configuration in the on-site potentials and in the magnetic moments may lead to disorder-induced spin-filtering phenomenon where one of the spin channel gets entirely blocked leaving the other one transmitting over the entire allowed energy regime. All these features are established by evaluating the density of states and the two terminal transmission probabilities using the transfer-matrix formalism within a tight-binding framework.

Biplab Pal and Paramita Dutta

3.2. THEORETICAL HIGH ENERGY PHYSICS

COSMOS-*e*2 -GTachyon from String Theory

In this article, our prime objective is to study the inflationary paradigm from generalized tachyon (GTachyon) living on the world volume of a non-BPS string theory. The tachyon action is considered here is getting modified compared to the original action. One can quantify the amount of the modification via a power *q* instead of *1=2* in the effective action. Using this set up we study inflation from various types of tachyonic potentials, using which we constrain the index *q* within, $1 = 2 < q < 2$, and a specific combination $(\alpha, \alpha' M_s^4 / g_s)$ of Regge slope α' , string coupling constant g s and mass scale of tachyon M_s, from the recent Planck 2015 and Planck+BICEP2/Keck Array joint data. We explicitly study the inflationar consequences from single field, assisted field and multi-field tachyon set up. Specifically for single field and assisted field case we derive the results in the quasi-de-Sitter background in which we will utilize the details of cosmological perturbations and quantum fluctuations. Also we derive the expressions for all inflationary observables using any arbitrary vacuum and Bunch-Davies vacuum. For single field and assisted field case we derive-the inflationary flow equations, new sets of consistency relations. Also we derive the field excursion formula for tachyon, which shows that assisted inflation is in more safer side compared to the single field case to validate effective field theory framework. Further we study the features of CMB Angular power spectrum from TT, TE and EE correlations from scalar fluctuations within the allowed range of q for each potentials from single field set-up. We also put constraints from the temperature anisotropy and polarization spectra, which shows that our

analysis is consistent with the Planck 2015 data. Finally, using dN formalism we derive the expressions for inflationary observables in the context of multi-field tachyons

Sayantan Choudhury, Sudhakar Panda

Entanglement temperature with Gauss–Bonnet term

We compute the entanglement temperature using the rst law-like of thermodynamics, $\Delta E = T_{ent}\Delta S_{EE}$, up to Gauss-Bonnet term in the Jacobson-Myers entropy functional in any arbitrary spacetime dimension. The computation is done when the entangling region is the geometry of a slab. We also show that such a Gauss-Bonnet term, which becomes a total derivative, when the co-dimension two hypersurface is four dimensional, does not contribute to the nite term in the entanglement entropy. We observe that the Weyl-squared term does not contribute to the entanglement entropy. It is important to note that the calculations are performed when the entangling region is very small and the energy is calculated using the normal Hamiltonian.

Shesansu Sekhar Pal, Sudhakar Panda

Relativistic Magnetohydrodynamics Simulation in relativistic heavy-ion collisions

Very strong magnetic fields can arise in non-central heavy-ion collisions at ultra relativistic energies, which may not decay quickly due to induced currents in the conducting plasma. We carry out magneto hydrodynamics simulations to study the effects of this magnetic field on the evolution of the plasma and on resulting flow fluctuations. Our results show that magnetic field leads to enhancement in elliptic flow. We further find that there are qualitative patterns in the power spectrum of flow fluctuations due to the presence of magnetic field which can be used as signal for the presence of strong magnetic field during initial stages. We also show generation of vorticity arising from nontrivial dependence of magnetosonic waves on pressure gradients and magnetic field direction.

A. Das, S. S. Das, P. S. Saumia and A. M. Srivastava

Adiabaticity violation and Quarkonia Disintegration due to spatial and temporal fluctuations in in Relativistic Heavy Ion Collisions

We show that due to spatial and temporal variations of energy density in relativistic heavy-ion collisions, the assumption of adiabaticity for J/ ψ is violated. We calculate the survival probability of J/ψ and Υ using time dependent perturbation theory and show that quarkonium decay may be significant due to these fluctuation induced transitions to excited states.

P. Bagchi, N. Dutta, and A. M. Srivastava

Disintegration of quarkonia due to dependence of quark masses on Polyakov loop in Relativistic Heavy Ion Collisions

We investigate the possibility of prompt as well as thermal heavy quorkonia disintegration due to non-trivial profile of the Polyakov loop of the Z(3) domain walls that are expected to form in QGP medium. By modeling the dependence of effective mass of the quarks on the Polyakov loop order parameter, we study the interaction of Upsilon with Z(3) interfaces which disintegrates quorkonia by exciting it to higher states of $q\bar{q}$ system.

A. Atreya, P. Bagchi, and A. M. Srivastava

Detection of QCD superuid phases at FAIR and NICA

Various exotic phases of strongly interacting matter are expected to exist in the interior of neutron stars. There is strong observational evidence for nucleon superfluidity inside neutron stars which is supposed to be responsible for the phenomena of glitches of pulsars. At much higher densities, QCD calculations predict possibility of color deconfinement along with novel partonic phases. Some of these partonic phases also allow for superuidity. We investigate the possibility of detecting such superuid phases in heavy-ion collisions. We use the fact that a transition to superfluid phase inevitably leads to formation of superfluid vortices. We carry out hydrodynamic simulations in the presence of vortices and study its qualitative effects on resulting flow pattern. We find three distinctive signals which can provide unambiguous signal for a superfluid phase transition. These signals are, development of strong directed flow, a systematic variation of power spectrum for even and odd flow coefficients, and in certain situations a strong negative elliptic flow for non-central collisions.

A. Das, S.S. Dave, S. De, and A. M. Srivastava

1. Running of Neutrino Oscillation Parameters in Matter with Flavor-Diagonal Non-Standard Interactions of the Neutrino

In this article we unravel the role of matter effect in neutrino oscillation in the presence of lepton-flavor-conserving, non-universal non-standard interactions (NSI's) of the neutrino. Employing the Jacobi method, we derive approximate analytical expressions for the effective mass-squared differences and mixing angles in matter. It is shown that, within the effective mixing matrix, the Standard Model W-exchange interaction only affects θ_{12} and θ_{13}, while the flavor-diagonal NSI's only affect θ_{23}. The CP-violating phase δ remains unaffected.

Sanjib Kumar Agarwalla, Yee Kao, Debashis Saha, Tatsu Takeuchi

Exploring Flavor-Dependent Long-Range Forces in Long-Baseline Neutrino Oscillation Experiments

The Standard Model gauge group can be extended with minimal matter content by introducing anomaly free U(1) symmetry, such as L_e-L_μ or L_e-L_τ. If the neutral gauge boson corresponding to this abelian symmetry is ultra-light, then it will give rise to flavor-dependent long-range leptonic force, which can have significant impact on neutrino oscillations. For an instance, the electrons inside the Sun can generate a flavor-dependent long-range potential at the Earth surface, which can suppress the $\nu_\mu \rightarrow \nu_e$ appearance probability in terrestrial experiments. The sign of this potential is opposite for anti-neutrinos, and affects the oscillations of (anti-)neutrinos in different fashion. This feature invokes fake CP-asymmetry like the SM matter effect and can severely affect the leptonic CP-violation searches in long-baseline experiments. In this paper, we study in detail the possible impacts of these long-range flavor-diagonal neutral current interactions due to L_e-L_μ symmetry, when (anti-)neutrinos travel from Fermilab to Homestake (1300 km) and CERN to Pyh\"asalmi (2290 km) in the context of future high-precision superbeam facilities, DUNE and LBNO respectively.

Sabya Sachi Chatterjee, Arnab Dasgupta, Sanjib Kumar Agarwalla

Discovery Potential of T2K and NOνA in the Presence of a Light Sterile Neutrino

We study the impact of one light sterile neutrino on the prospective data expected to come from the two presently running long-baseline experiments T2K and NOνA when they will accumulate their full planned exposure. Introducing for the first time, the bi-probability representation in the 4-flavor framework, commonly used in the 3-flavor scenario, we present a detailed discussion of the behavior of the $\nu_\mu \rightarrow \nu_e$ and $\overline{\nu_\mu} \rightarrow \overline{\nu_e}$ transition probabilities in the 3+1 scheme. We also perform a detailed sensitivity study of these two experiments (both in the stand-alone and combined modes) to assess their discovery reach in the presence of a light sterile neutrino.

Sanjib Kumar Agarwalla, Sabya Sachi Chatterjee, Arnab Dasgupta, Antonio Palazzo

Physics Reach of DUNE with a Light Sterile Neutrino

We investigate the implications of one light eV scale sterile neutrino on the physics potential of the proposed long-baseline experiment DUNE. If the future short-baseline experiments confirm the existence of sterile neutrinos, then it can have significant impact on mass hierarchy (MH) and CP-violation (CPV) searches at DUNE. The MH sensitivity still remains above 5σ if the three new mixing angles ($\theta_{14}, \theta_{24}, \theta_{34}$) are all close to θ_{13}. In contrast, it can decrease to 4σ if the least constrained mixing angle θ_{34} is close to its upper limit $\sim 30^0$. We also assess the sensitivity to the CPV induced both by the standard CP-phase $\delta_{13} \equiv \delta$ and the new CP-phases δ_{14} and δ_{34}. In the 3+1 scheme, the discovery potential of CPV induced by δ_{13} gets substantially deteriorated compared to the 3ν case. In particular, the maximal sensitivity (reached around $\delta_{13} = \pm 90^0$) decreases from 5σ to 4σ if all the three new mixing angles are close to θ_{13}. It can further diminish to almost 3σ if θ_{34} is large ($\sim 30^0$).

Sanjib Kumar Agarwalla, Sabya Sachi Chatterjee, Antonio Palazzo

Holographic description of non-supersymmetric orbifolded D1-D5-P solutions

Non-supersymmetric black hole microstates are of great interest in the context of the black hole information paradox. We identify the holographic description of the general class of non-supersymmetric orbifolded D1-D5-P supergravity solutions found by Jejjala, Madden, Ross and Titchener. This class includes both completely smooth solutions and solutions with conical defects, and in the near-decoupling limit these solutions describe degrees of freedom in the cap region. The CFT description involves a general class of states obtained by fractional spectral flow in both left-moving and right-moving sectors, generalizing previous work which studied special cases in this class. We compute the massless scalar emission spectrum and emission rates in both gravity and CFT and find perfect agreement, thereby providing strong evidence for our proposed identification. We also investigate the physics of ergoregion emission as pair creation for these orbifolded solutions. Our results represent the largest class of non-supersymmetric black hole microstate geometries with identified CFT duals presently known.

Bidisha Chakrabarty, David Turton, Amitabh Virmani

Charged Vaidya Solution Satisfies Weak Energy Condition

The external matter stress-tensor supporting charged Vaidya solution appears to violate weak energy condition in certain region of the spacetime. Motivated by this, a new interpretation of charged Vaidya solution was proposed by Ori [1] in which the energy condition continues to be satisfied. In this construction, one glues an outgoing Vaidya solution to the original ingoing Vaidya solution provided the surface where the external stress-tensor vanishes is spacelike. We revisit this study and extend it to higher-dimensions, to AdS settings, and to higher-derivative f(R) theories. In asymptotically flat space context, we explore in detail the case when the mass function m(v) is proportional to the charge function q(v). When the proportionality constant \nu = q(v)/m(v) lies in between zero and one, we show that the surface where the external stress-tensor vanishes is spacelike and lies in between the inner and outer apparent horizons.

Soumyabrata Chatterjee, Suman Ganguli, Amitabh Virmani

Smooth non-extremal D1-D5-P solutions as charged gravitational instantons

We present an alternative and more direct construction of the non-supersymmetric D1-D5-P supergravity solutions found by Jejjala, Madden, Ross and Titchener. We show that these solutions – with all three charges and both rotations turned on — can be viewed as a charged version of the Myers-Perry instanton. We present an inverse scattering construction of the Myers-Perry instanton metric in Euclidean five-dimensional gravity. The angular momentum bounds in this construction turn out to be precisely the ones necessary for the smooth microstate geometries. We add charges on the Myers-Perry instanton using appropriate SO(4,4) hidden symmetry transformations. The full construction can be viewed as an extension and simplification of a previous work by

Bidisha Chakrabarty, Jorge V. Rocha, Amitabh Virmani

A Random matrix model for the effects of density fluctuations on pulsar dynamics

We consider a model independent approach of investigating the effects of density fluctuations arising from phase transitions on pulsar dynamics. We model the change in the moment of inertia of the neutron star using a random matrix and study resulting changes in pulse timings as well as pulse profiles. we also estimate resulting gravitational wave intensity.

P. Bagchi, A. Das, B. Layek, and A. M. Srivastava

Cosmology :

Setting initial condition for inflation with Reaction diffusionequations

The issue of initial conditions for inflation during the early stage of theUniverse still remains unresolved. It has not been possible to find anatural model which sets appropriate initial conditions for the inflatonfield with which the universe can successfully enter the inflationary stage.We address this issue within the framework of reaction-diffusion (RD) equations. We have earlier shown than due to propagating front solutionsof RD equation, chiral field does not roll down rapidly towards thetrue vacuum during phase transition in ultra-high energy p-p collisions.We apply this physics to beginning stages of the dynamics of the

inflatonfield. We show that the inflaton field, with appropriate profile in areasonably sized region (of order the thermal correlation length in radiation dominated pre-inflationary stage) does not roll down rapidly due tospecial properties of RD equation solutions. This leads to expansion ofthe profile in the correlation domain, eventually leading to the vacuumenergy dominance in the Hubble volume allowing the region to enterinflationary stage successfully. We are presently determining whethersuch a scenario can arise under very generic conditions, and also theconstraints on resulting density

A. Das, P. Das, S.S. Dave, S. Sengupta, and A. M. Srivastava

Liquid Crystal Experiments

String formation with periodically varying temperature in liquid crystals

We have recently acquired hot stage setup for optical microscope for liquid crystal experiments. Using that we are setting up an experiment for studying defect formation in liquid crystal system with periodically verifying temperature. We plan to investigate the effects of pre-existing defect configurations in the biasing of the dynamics of symmetry restoration and hence nontrivial dependence of defect configuration on oscillating temperature.

Ajit M. Srivastava

Black Hole Singularity, Generalized (Holographic) c-Theorem and Entanglement negativity

We have constructed a holographic c-function using the causal horizon of an empty AdS5 black brane geometry and shown that this function monotonically decreases from the UV to the IR fixed point and thereby established the holographic c-theorem. Here UV fixed point is the asymptotic boundary of the AdS5 and IR fixed point is the black hole singularity. The generalized c-function can be interpreted as a measure of the quantum correlation between different energy scales in the given state of the corresponding boundary CFT. We have also shown that this c-function matches with the entanglement negativity in the UV and IR limits of two dimensional CFT so the later could be a potential candidate for our generalized c-function.

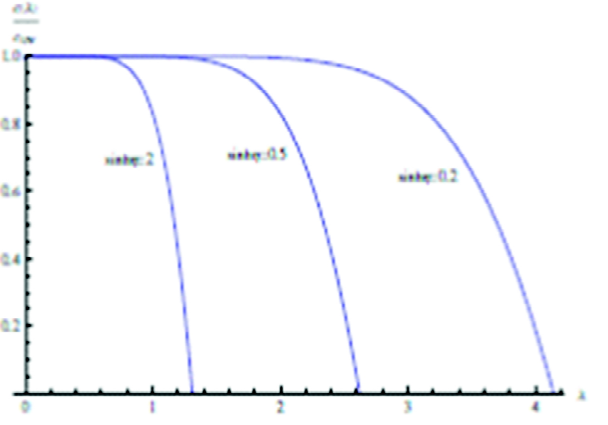


Figure 1: We have plotted the c-function for three different values of η. All of them starts from UV value and monotonically decreases to zero at the curvature singularity. The fact that we have got a family of c-function is no cause for concern, because it is known that if we can construct one c-function (in the field theory side) then we can construct an infinite family all of which contain the same physical information.

Shamik Banerjee and Partha Paul

Setting initial conditions for inflation with Reaction Diffusion equation

The issue of initial conditions for inflation during the early stage of the Universe still remains unresolved. It has not been possible to find a natural model which sets appropriate initial conditions for the inflaton field with which the universe can successfully enter the inflationary stage. We address this issue within the framework of reaction-diffusion (RD) equations. We have earlier shown than due to propagating front solutions of RD equation, the chiral field does not roll down rapidly towards the true vacuum during phase transition in ultra-high energy p-p collisions. We apply this physics to the beginning stages of the dynamics of the inflaton field. We show that the inflaton field, with an appropriate profile in a reasonably sized region (of order the thermal correlation length in radiation dominated pre-inflationary stage) does not roll down rapidly due to special properties of RD equation solutions. This leads to expansion of the profile in the correlation domain, eventually leading to the vacuum energy dominance in the Hubble volume allowing the region to enter inflationary stage successfully. We are presently determining whether such a scenario can arise under very generic conditions.

Arpan Das, Partha Bagchi, S. S. Dave, S. Sengupta and A. M. Srivastava

Probing Superfluid Phases of QCD in Heavy-Ion Collision Experiment

High baryon density regions of the cores of neutron stars are expected to have exotic phases such as color superconducting phases. At the highest baryon density, Color-Flavor Locked phase of QCD exists. This is a superfluid phase, which allows for topological vortices. Even in the lower density region of neutron star, neutron superfluid and associated topological vortices play important role in the dynamics of neutron star, e.g. in pulsar timings and glitches. We consider the possibility of formation of these superfluid phases in heavy-ion collision experiments, e.g. at FAIR and NICA.We carry out Hydrodynamics simulations, and show that existence of superfluid phases can be detected by studying the effect of vortices on power spectrum of flow fluctuations. We also carry out UrQMD (Ultrarelativistic Quantum Molecular Dynamics) simulations to investigate the possibility of neutron superfluidity in low energy heavy-ion collisions at FAIR & NICA.

S. S. Dave, Arpan Das, Partha Bagchi and A. M. Srivastava

3.3. THEORETICAL NUCLEAR PHYSICS

New constrained methode to calculate the excitation energy of ISGMR and IVGDR.

New constrained method to calculate the excitation energy of ISGMR and IVGDR The nucleus is a quantum many-body system. In many-body collective phenomena like giant resonances is ver often. In a collective motion, nucleons prefer for the collective excitation instead of single particle excitation. Giant resonances play a very important role in the nuclear structure physics. There are various types of giant resonances in nature. Out of which, isoscalar giant monopole resonance (ISGMR) and isovector giant dipole resonance (IVGDR) are very important study point of view. In ISGMR, the protons and neutrons vibrate in

a phase to each other., while in IVGDR the protons and neutrons vibrate in an opposite phase to each other. ISGMR is also known as the breathing mode of oscillation. The excitation energy of ISGMR is directly connected to the incompressibility of a finite nucleus *(K_A)*. We can calculate the infinite nuclear incompressibility (K_∞) from the K_A by using lepterdomus expansion. In the macroscopic calculation, we generally use scaling and constrained calculation to compute the excitation energy. In recent year we have formulated a new method of constrained calculation to compute the excitation energy of ISGMR and IVGDR. Our new method of constrained calculation based on the Tylor series expansion of constrained energy functional around the equilibrium. Preliminary results of our model show good agreement with the other microscopic calculation like RPA and as well as experimental data. It is a simple but gives very good results for the excitation energy of nuclei through out the periodic table. Improvement of the model is still going on.

S. K. Biswal, S. K. Patra and X. Vinas

Quest for magicity in hypernuclei

In the present study, we search the lambda magic number in hypernuclei within the framework of relativistic mean field theory (RMF) with an inclusion of hyperon-nucleon and hyperon-hyperon potentials. Based on the binding energy, one- and two-lambda separation energy and two-lambda shell gap, 2, 8, 14, 18, 20, 28, 34, 40, 50, 58, 68, 70 and 82 are suggested to be the lambda magic number within the present approach. The predicted lambda magic numbers are in quite an agreement with earlier prediction. The stability of hypernuclei is also observed by calculating the binding energy per particle, where Ni hypernucleus is found to be most tightly bound triply magic system in considered hypernuclei. In addition, nucleon and lambda density distributions are observed and it is found that introduced lambda hyperons have an impact on total density and reduces the strength of bubble structure. Nucleon and lambda mean field potentials and spinorbit interaction potentials are also observed for predicted triply magic hypernuclei. The single-particle energy levels are also analyzed to see the shell gaps for some of the triply magic multi-lambda hypernuclei.

M.Ikram, Bharat Kumar, S. K. Biswal and S. K. Patra

Effects of isovector scalar meson on static and rotating hyperon star

Using the effective field theory approach, we discussed the effect of isovector scalar meson on hyperon star. The inclusion of δ-meson with G2 parameter set, we have investigated the static and rotating stellar properties of neutron star with hyperons. We fitted the parameters and see the variation of g_ρ and g_δ at a constant symmetry energy for both the nuclear and neutron matter. We also used these (g_ρ , g_δ) pairs to finite nuclei and find a large change in binding energy for asymmetric nuclei. Then we re-fitted the (g_ρ , g_δ) pairs keeping binding energy and charge radius fixed for ^{208}Pb and tested the effects for some selected nuclei and able to reproduced the data similar to the original G2 set. With the help of the G2+δ model, for static and rotating stars without hyperon core,

we get the maximum mass of ~2M_Θ and ~2.4M_Θ, respectively. This prediction of masses is in agreement with the recent observation of M ~2 M_Θ of the stars. However, with hyperon core the maximum mass obtained are ~1.4M_Θ and ~1.6M_Θ for static and rotating hyperon stars, respectively. In addition, we have also calculated the production of whole baryon octet with variation in density. We find that the particle fraction changes a lot in the presence of δ–meson coupling. When there is δ–meson in the system the evolution of baryons is faster compare to a non- δ–system. This effect is significant for heavier masses and minimum for lighter baryon. Hence, one can conclude that the yield of baryon/hyperons depends very much on the mesons couplings. One important information is drawn from the present calculations is that the effect of g_δ is just opposite to the effect of g_ρ. As a consequence, many long-standing anomalies, such as the comparable radii of 40Ca and 48Ca be resolved by adjusting the (g_ρ , g_δ) pairs properly. Keeping in view the importance of δ-meson coupling and the reverse nature of g_ρ and g_δ , it is necessary to get a new parameter set including proper values of g_ρ and g_δ , and the work is in progress.

S. K. Biswal, Bharat Kumar and S. K. Patra

Effects of N N potentials on *p* Nuclides in the A~100 – 120 region

In this work cross-section for low-energy (p, γ) reactions for a number of p nuclei in A~100 –120 region have been calculated using microscopic optical model potential with the HauserFeshbach reaction code TALYS. Mainly, microscopic potential is obtained by folding DDM3Y interaction with densities from RMF approach. Astrophysical reaction rates for (p, γ) and (p, n) reactions are compared with standard NONSMOKER results. Finally, the effect of microscopic optical potential obtained by folding NR3Y(NL3) and NR3Y(TM1) interactions with corresponding RMF densities are employed to fit the experimental S-factor data for 120 Te. The reason of the deviation of theoretical prediction with NR3Y(NL3) potential from experiment at higher energies is mainly because of the magnitude of the coupling terms of the nonlinear components and we concluded that an upper cutoff value for g2 and g3 should be fixed to get proper repulsive component of the NN interaction.

C. Lahari, S. K. Biswal, and S. K. Patra

Nuclear structure and decay properties of even-even nuclei in Z = 70 80 drip-line region

We have calculated quadrupole deformation, hexadecoupole deformation, two neutron separation energy and differential variation of two neutron separation energy for some neutron-rich even-even nuclei in Z = 70 80 region (Yb, Hf, W, Os, Pt and Hg) using RMF theory with pairing correlation from BCS approach (RMF-BCS). The results from S2n and dS2n con_rm the neutron shell closure at N = 82 and 126. As a further con_rmatory test, the single particle energy levels for neutrons in isotopic chains are examined. We observed large gaps at N = 82 and 126. We have also calculated half lives for α and β decay and seen

that neutron-rich nuclei prefer α decay rather than going to β decay mode. Further we concluded that the RMF-BCS theory provides a reasonably good description for all the considered isotopes.

S. Mahapatro, C. Lahiri, Bharat Kumar, R. N. Mishra and S. K. Patra

Examining the stability of thermally fissile Th and U isotopes

The properties of recently predicted thermally fissile Th and U isotopes]are studied within the framework of relativistic mean field (RMF) approach using axially deformed basis. We calculated the ground, first intrinsic excited state for highly neutron-rich thorium and uranium isotopes. The possible modes of decay like α-decay and β-decay are analyzed. β-decay. If these nuclei utilize before their decay time, a lots of energy can be produced with the help of multi-fragmentation fission. Also, these nuclei have a great implication in astrophysical point of view. In some cases, we found the isomeric states with energy range from 2 to 3 MeV and three maxima in the potential energy surface of $^{228-230}$Th and $^{228-234}$U isotopes.

Bharat Kumar , S. K. Biswal, S. K. Singh and S. K. Patra

Signature of the gravitational waves from binary neutron stars

The observation of inspirling binary neutron stars with ground-based gravitaional wave detectors such as a LIGO and VIRGO may provides significant information about the neutron stars structure. Using effective field theory, constrained the equation-of-state to calculated the steller properties of neutron stars. The influence of a star's internal structure on the waveform characterized by single parameter called as tidal polarizibilty λ, which measures the star's quadrupole deformation in reponse to the companion's perturbative tidal field. We calculate the numerical waveforms (h_+,h_x) incorporating with tidal effects upto the 1PN order plus TT4 . We note that the tidal effects accelarate the orbital evolution of the late inspiral phase because the tidal force strengthens the attractive force between two neutron stars for such orbits. Thus, we conclude that the tidal effects are enderestimated in the employed TT4 approximent.

Bharat Kumar, S. K. Biswal, Tanja Hinderer and S. K. Patra

3.4. EXPERIMENTAL HIGH ENERGY PHYSICS

Heavy-ion collisions at ALICE:

The strongly decaying particles having lifetime (τ) of the order of 10^{-23} sec are called resonances. It carries a set of quantum numbers, spin, isospin, etc. It differs from regular particles by its mass smeared and a width. This is based on uncertainty principle between time and energy which implies shorter the life time, the wider is the uncertainty in mass. In heavy ion collisions, during the expansion of the fireball, a stage is reached where the inelastic interactions among hadrons cease and this is known as the chemical freeze-out. Kinetic

freeze-out is reached where there is no further elastic interactions among the produced hadrons. Since the resonances have very short life times (<" few fm/c), a fraction of them decay inside the medium before the thermal freeze-out. In such a case the hadronic decay daughter particles go through a period of elastic interactions with the hadrons in the medium. These interactions alter the momenta of the daughter particles. However, after the chemical freeze-out, there can be pseudo-inelastic interactions among the hadrons in the medium, resulting in an increase in the resonance population. Therefore, both the resonance regeneration and primary production contribute to the total yield of resonance signals detected. Measurement of the resonance yields can therefore serve as a tool to probe the time evolution of the system (from thermal to kinetic freeze-out) and to study the final state interactions in the hadronic medium.

The analysis note presents the results of transverse momentum spectra measurement of Delta star (1520) from p-p collisions at 7 TeV energy at mid rapidity with the ALICE detector at LHC. This analysis is also performed to create the base line for future p-Pb and Pb-Pb analysis. Here the main focus will be on the signal in low and intermediate transverse momentum region (pT <5.5GeV /c)

ALICE Collaboration: R.C. Baral, S. Sahoo and P. K. Sahu

Ks/Lambda/Anti-Lambda/Xi/Anti-xi in U+U 193 GeV :

Enhanced strange quark production in high-energy heavy-ion collisions relative to p+p collisions was proposed as a possible signature of deconfined phase of quarks and gluons. It was suggested that the dominant process for the production of strange quarks in quark gluon plasma is gluonic fusion. Chemical equilibration of strange quarks formed in such medium happens faster than would be the situation in hadronic scenario. With 20% larger energy density expected and a larger lifetime of fireball than Au+Au collisions, we can have a better insight of testing these facts in U+U collisions. Moreover, with its substantial prolate shape U nuclei can have different geometrical orientation during collision. It is interesting to check the dependence of strangeness production in such configurations compared to the geometrically symmetric Au+Au collisions. We will present transverse momentum (pT) spectra of Ks , Λ(Λ) and Ξ(Ξ) in U+U collisions at " sNN = 193 GeV in STAR experiment at RHIC. These strange particles are reconstructed from their weak decay topology via dominant hadronic decay modes using the Time Projection Chamber(TPC) detector of STAR. We are measuring masses of these particles and cgecking centrality dependence. We are also comparing these results with Au+Au 200 GeV results.

ALICE Collaboration: R.C. Baral, S. Sahoo and P. K. Sahu

Spin Structure of Proton :

Transverse spin structure of proton is is being studied at RHIC with transverse polarized proton proton collisions. The STAR experiment with its forward detector, the Forward Meson Spectrometer (FMS) measuring photons, neutral pions in a region where transverse single spin asymmetries (TSSAs) are seems to be large. TSSAs for neural energy jets is being

measured in this rapidity for the first time. The simulation in the STAR integrated software is being tested and we are in a process to produced a large scale simulated data. This is a step forward for publication of the STAR results on measurements of TSSAs for Jets and neural pions at forward rapidity from " s = 500GeV data for polarized proton proton collisions.

STAR Collaboration: S. K. Tripathy, M. M. Mondal and P. K. Sahu

Production of D-mesons in *p*+*p* and *p*+Pb collisions at LHC energies

We present theoretical model comparison with published ALICE results for D-mesons (D0, D+ and D"+) in *p*+*p* at *s*" = 7 TeV and p+Pb at 5.02 TeV. Event generator HIJING, transport calculation of AMPT and calculations from NLO(MNR) and FONLL have been used for this study. We found that HIJING model prediction is matching with published *p*+*p* cross-section, while AMPT calculation matches cross-section in p+Pb. Attempts were made to explain the *RpPb* data using NLO-pQCD(MNR), FONLL and other above mentioned models.

R.C.Baral, S.K.Tripathy, M.Younus and P.K.Sahu

High Energy Experimental Laboratory for ALICE and CBM:

Characterizations of GEM detector prototype:

Triple GEM detector prototype building is started. The detector is tested with a gas mixture of ArCO of 70:30 volume ratio. The count rate of the detector depends on the gas flow rate and it is optimised. This is because due to increase of gas flow rate the gain of the detector increases if there is leak in the detector somewhere. Because increasing gas flow rate the electronegative O2 content decreases. On the other hand increasing gas flow rate further the pressure increases which decreases the gain. When this two effects work simultaneously then a optimum flow rate is observed which gives the maximum gain. The long-term stability test of this detector is performed using Sr90 beta radioactive source. No aging is observed even after operation of the GEM detector for about 350 hours or after an accumulation of charge per unit area of 0.05 mC/cm2

P. K. Sahu and Collaborators.

Development of a 4-channel TTL scaler for detector signal counting:

One 4-channel TTL scaler has been fabricated. The scaler has the following characteristics. (a) The scaler has 4 channel, (b) each channel has 10 digit display, (c) the scaler can accept TTL input, (d) it can accept the maximum count rate of 100 kHz, (e) the maximum preset time can be 120 minutes and (f) count is displayed once the counting is stopped. The count rate of the TTL scaler is calibrated with a commercially available NIM scaler. The calibration curve is found to be a straight line with a calibration factor of 0.93

Long-term stability test of a triple GEM detector:

Triple GEM detector prototype is built and tested with a gas mixture of Ar/ CO2 of 70/ 30 volume ratio. The long-term sta158 bility test of this detector is performed using Fe55 X-ray source. The gain is measured and normalized for the T/ p e ect. Only a fluctuation

about 1 in the normalized gain is observed after T/ p correction. No ageing is observed till an accumulation of charge per unit area > 12.0 mC/ mm2 . From these results it can be concluded that triple GEM detector can safely be used in high-energy physics experiments where a long-term stability of the detector is an essential criterion.

Sagarika Swain, S. K. Sahu and P. K. Sahu

Nuclear astrophysics and nuclear equation of state:

Compact stars are classified into three categories: neutron stars(NS), quark stars(QS) and hybrid stars(HS). Stars having only hadronic matter are NS, QS having only quark matter up to u, d and s quarks and stars having quark core surrounded by a mixed matter (hadronic matter and quark matter) followed by hadronic matter are HS. The mixed matter is well distributed to both hadron and quark matters. A huge magnetic field is predicted in the core of the neutron star and is observed in the surface of the neutron star. We study the effect of such huge magnetic field in the matter inside the compact objects basically the equation of state (EOS) of the matters. Since matter inside the star are very dense both hadronic and quark matter, we consider relativistic mean field theory in the hadronic matter and simple MIT bag model in the quark matter in presence of strong magnetic field. We calculate the phase transition between hadronic and quark phases, maximum mass and eigenfrequencies of radial pulsation of NS, HS and QS in presence of such a huge magnetic field. The mixed phase is constructed by using Glendenning conjecture in between hadron and quark phases. We find in presence of magnetic field, the EOS in both matter become soft as a result the maximum mass is reduced and the period of oscillation is changed significantly and there is a sudden dip in the period of oscillations in the HS, which signifies the transition from one to another matter.

Compact stars are composed of very high density hadron matter. When the matter above nuclear matter density, then there is a chance of different phases of matter such as hadron matter to quark matter. There is a possible phase which having quark core surrounded by mixed phase followed by hadronic matter, may be considered as hybrid phase inside the stars called hybrid star(HS). The star consists of only u, d and s quarks is called quark star (QS) and the star has only hadronic matter is called neutron star (NS). For the equation of state(EOS) of hadronic matter, we have considered Relativistic Mean Field (RMF) theory and we incorporated the effect of strong magnetic fields. For the EOS of quark phase we use the simple MIT bag model. We have assumed Gaussian parametrization to make the density dependent for both bag pressure in quark matter and magnetic field. We have constructed the intermediate mixed phase by using Glendenning conjecture. Eigenfrequencies of radial pulsations of slowly rotating magnetized compact stars (NS, QS, HS) are calculated in a general relativistic formalism given by Chandrasekhar and Friedman. We have studied the effect of central density on square of the frequencies of the compact stars in the presence of zero andstrong magnetic field.

R.C. Baral, N. R. Panda, K. Mohanta and P. K. Sahu

Identification of hadronic decay of τ lepton at CMS experiment using a multivariate technique

The reconstruction and identification of τ lepton is crucial for the studies of Higgs boson and many other new physics searches using the

CMS detector at LHC, CERN, Switzerland. In about one third of the cases τ-leptons decay to a muon or an electron with two neutrinos. In the remaining cases, τ leptons decay to a combination of charged and neutral mesons with a τ neutrino. The hadronic decay of τ lepton proceed via intermediate resonances, such as ρ or a1 mesons.

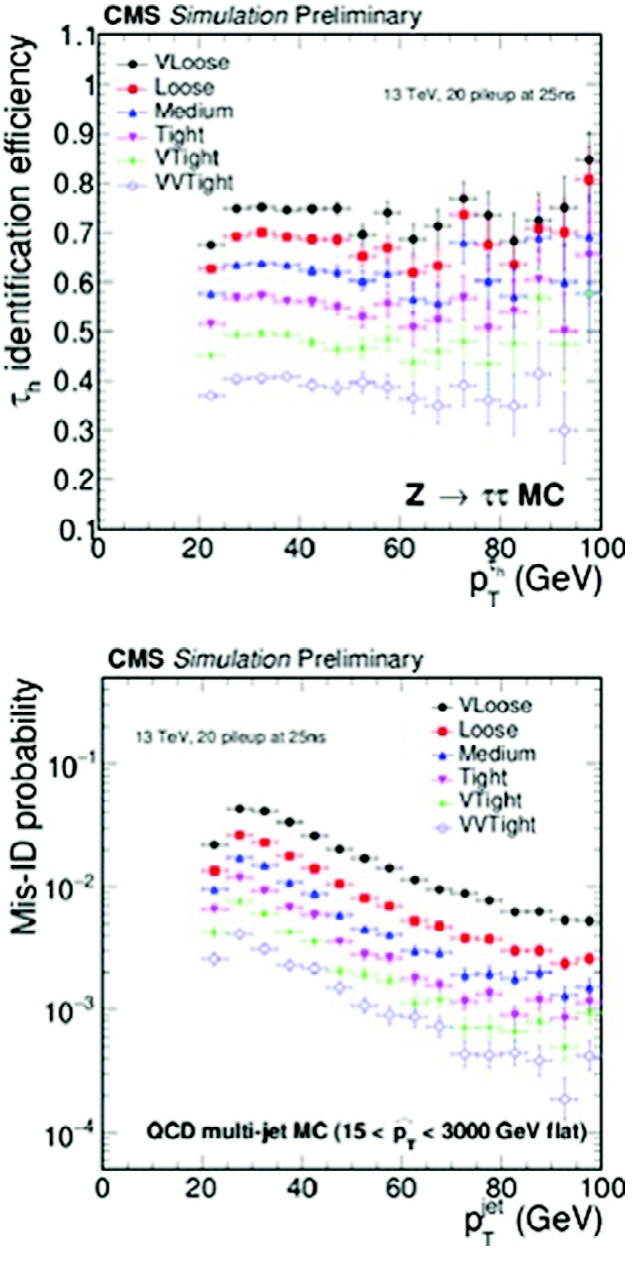


Figure-1: The expected τ_h identification efficiency (left) and the jet → τ_h mis-identification probability (right) as function of transverse momentum for different working points of the MVA-based isolation discriminator.

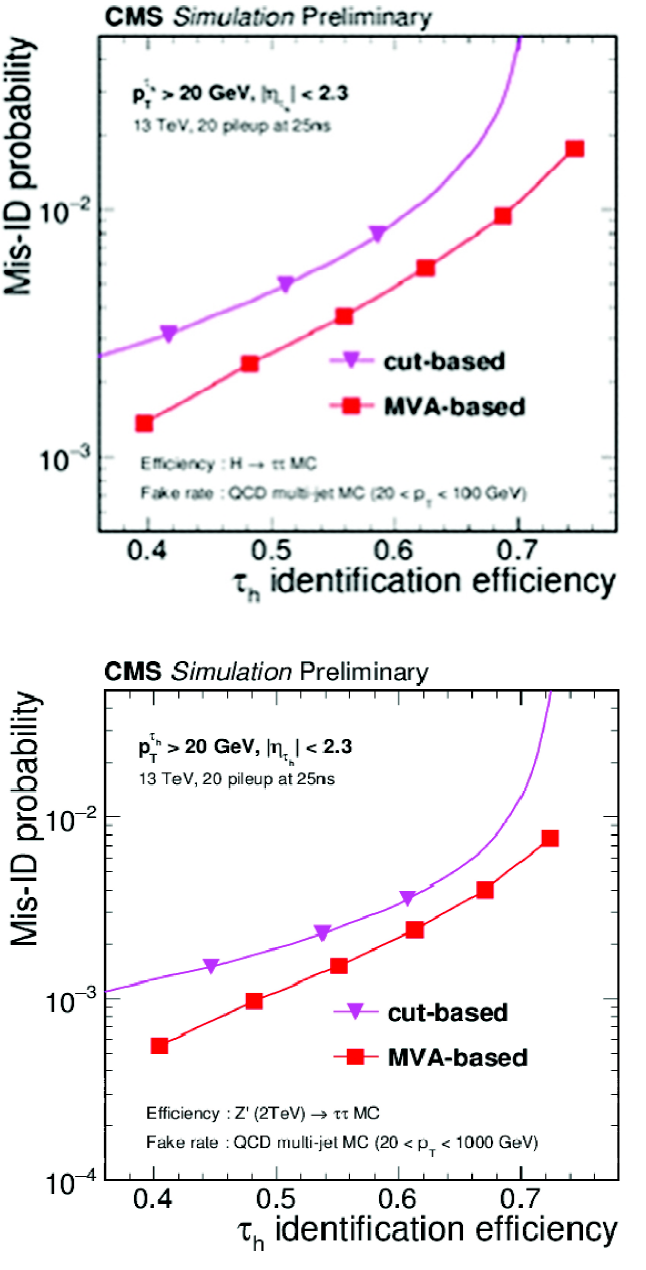


Figure-2: The jet → τ_h mis-identification probability as function of τ_h identification efficiency, evaluated using H → τ τ and QCD MC samples (left), and Z' (2 TeV) and QCD MC samples (right). The MVA-based discriminators are compared to that of the isolation-sum discriminators. The points correspond to working points of the discriminators. The three working points of the isolation-sum discriminator are Loose, Medium, and Tight working points, respectively. The six working points of the MVA-based discriminators are Very Loose, Loose, Medium, Tight, Very Tight, and Very Very Tight working points, respectively. The misidentification probability is calculated with respect to jets, which pass minimal ? reconstruction requirements.

At CMS, the hadronic decays of τ leptons (τ_h) are reconstructed and identified with the so called hadron-plus-strips (HPS) algorithm. The HPS algorithm is seeded by the hadron jets that are reconstructed using the particle-flow algorithm. A particle-flow (PF) algorithm combines the information from the CMS sub-detectors to identify and reconstruct the particles emerging from proton-proton collisions: charged hadrons, neutral hadrons, photons, muons, and electrons. The HPS algorithm looks into the constituents of the jets to reconstruct the neutral pions that are present in most τ_h decays. The neutral pions are reconstructed by combining photon and electron candidates into clusters (strips) to take into account the possible photon conversions to e^+e^- pair. The strips and charged hadrons are then combined to form τ_h candidates by requiring compatibility of the combination with the τ - decay hypothesis. The τ_h candidates are required to pass isolation requirements to suppress mis-identification of hadronic jets as τ_h decay. Two types of τ_h isolation discriminators developed in Run-1, namely the isolation-sum and the multivariate analysis (MVA)-based discriminators, have been further optimized and trained for Run-2. The isolation-sum discriminators are computed by summing the transverse momenta of charged particles and photons in an isolation cone around the τ_h candidate. The jet → τ_h mis-identification probability is significantly reduced using a MVA technique. A boosted decision tree (BDT) has been trained using the monte carlo (MC) simulated events. The BDT combines the isolation-sum variables with that of the variables sensitive to the τ-lifetime information, such as impact parameters and decay lengths, taking into account possible correlations among the variables. In comparison to Run-1 algorithm, the Run-2 MVA algorithm includes additional lifetime and photon cluster variables. The training parameters of the BDT are also optimized to get better performance. The Run-2 MVA algorithm provides significantly better performance compared to Run-1 algorithm. The expected performance of the MVA algorithm is shown in Figure-1 & 2. Figure-1 shows the expected τ_h identification efficiency and the jet → τ_h mis-identification probability as a function of transverse momentum for different working points of the MVA-based isolation discriminator. The comparion of the performance with respect to the cut-based discriminator is shown in Figure-2, which demonstrates a reduction of misidentification probability by a factor of 2 at a similar efficiency with respect to the cut-based approach.

The τ-identification algorithms are validated using the proton-proton collision data collected by the CMS detector in 2015 at a center-of-mass energy of 13 TeV. To validate the τ-identification algorithms, the identification efficiencies and mis-identification probabilities are measured from data and compared to the expectation from MC events. The τ_h -identification efficiency is measured from $Z \rightarrow \tau\tau \rightarrow \mu\tau_h$ events, where one of the τ-lepton from Z-boson decays to muon and neutrinos, while the other τ-lepton decays to hadrons. The jet → τ_h mis-identification probability is measured from W+jets events, where W boson decays to a muon and a neutrino. The electron τ_h mis-identification probability is measured from Z → ee events. The measured value of the efficiencies and mis-identification probabilities agree with the expectation within the uncertainties.

A. K. Nayak

3.5. QUANTUM INFORMATION

Process tomography via sequential measurements on a single quantum system

Recent years have witnessed remarkable progress in the theoretical study and experimental realisation of the manipulation of single quantum systems in the framework of Quantum Information Processing and

Communication. The ability to monitor and control single quantum systems is essential for the development of technology based on these quantum building blocks, hence methods for quantum state monitoring and dynamical parameter estimation are of paramount importance. In this work, We have utilized a discrete (sequential) measurement protocol to investigate quantum process tomography (the task of identifying the dynamical quantum process) of a single two-level quantum system, with an unknown initial state, undergoing Rabi oscillations. The ignorance of the dynamical parameters is encoded into a continuous variable classical system which is coupled to the two-level quantum system via a generalized Hamiltonian. This combined estimate of the quantum state and dynamical parameters is updated by using the information obtained from sequential measurements on the quantum system and, after a sucient waiting period, faithful state monitoring and parameter determination is obtained.Numerical simulations demonstrate that the convergence of the estimated hybrid state to the real state is achievable in real time. It is quite remarkable that the quantum state needed not be known in order to determine the dynamical parameters.

H. Bassa, S. K. Goyal, Sujit K. Choudhary, H. Uys, L. Di–osi, and T. Konrad

Quantum nonlocality via local contextuality with qubit-qubit entanglement

In this work, we have highlighted the role of quantum contextuality in revealing quantum nonlocality. The interconnection between quantum nonlocality and contextuality is a very fundamental research area and has been attracting an increasing attention over the years, resulting in a rich variety of investigations. So far, only qudit-qudit entangled systems (for d > 2) have been considered in this context. Since, contextuality requires local dimension to be greater than two, such study in qubit-qubit entanglement scenario does not seem obvious and remained unexplored so far. In this work, we have explicated that local contextuality plays a fundamental role in the nonlocality exhibited by these systems. We have also found that neither noise nor the lack of perfect entanglement impedes one to observe this eect. This makes the study valuable for observing quantum nonlocality via local contextuality in actual experiments.

D. Saha, A. Cabello, Sujit K. Choudhary and M. Paw lowski

Temporal correlations and Device-Independent randomness

Leggett-Garg inequalities (LGI) are constraints on certain combinations of temporal correlations obtained by measuring one and the same system at two dierent instants of time. The usual derivations of LGI assume macroscopic realism per se and noninvasive measurability. We have derived these inequalities under a dierent set of as sumptions, namely the assumptions of predictability and no signaling in time (NSIT). These assumptions involve only measurement statistics and hence are directly testable in experiments. This derivation of LGI, therefore, allows one to conclude that in a situation where NSIT is satised, the violation of LGI will imply that the underlying model is not predictable. As a novel implication of this derivation, we nd application of LGI in randomness certication. It turns out that randomness can be certied from temporal correlations, even without knowing the details of the experimental devices, provided the observed correlations violate LGI but satisfy NSIT.

S. Mal, M. Banik and Sujit K. Choudhary

The Hardy's nonlocality argument

Quantum theory is not compatible with the dual assumptions of locality and reality. This was rst proved by Bell by means of an inequality; famously known as Bell's inequality. But, Bell's inequality is not the only way to prove Bell's theorem. The alternative proofs of Bell's theorem without using Bell's inequalities are called 'nonlocality without inequality (NLWI) proofs'. Unlike the case of Bell's inequality where we collect statistics of many events, in these proofs the focus is on a single event whose occurrence shows the incompatibility of quantum theory with the notion of local-realism. The rst such proof is due to Greenberger, Horne and Zeilinger. Although their proof is direct, it requires at least an eight-dimensional Hilbert space. In 1992, Hardy [Phys. Rev. Lett. 68, 2981 (1992)] gave a proof of Bell's theorem (without inequality) which like Bell's proof, requires only two qubits. The Hardy's argument of nonlocality without inequiality" has been considered to be the best version of Bell's theorem. In this work, we have reviewed the Hardy's nonlocality argument and its generalizations for various systems. This includes systems of two qubits, two qudits, multiqubits and systems exhibiting temporal non-locality. The applications of Hardy's nonlocality test in various information processing tasks like cryptography, randomness certication and dimension witnessing have also been reviewed.

Sujit K. Choudhary and P. Agrawal

3.6. EXPERIMENTAL CONDENSED MATTER PHYSICS

Effect of Cobalt Implantation on Structural and Optical Properties of Rutile TiO_2(110)

Photo-absorption properties of Co implantation in rutile TiO_2(110) have been investigated. Enhancement in absorbance of visible light and UV light have been observed. Formation of crystalline $CoTiO_3$ and Ti1"xCoxO2 phases at high and low fluences, respectively, demonstrate a crucial role in increasing the photo- absorbance, especially in the visible regime. Ti-rich nanostructures and Ti_3^+ vacancies, that develop after ion implantation, also reveal significant contribution in these observations. These Co implanted rutile TiO2 surfaces will be useful for visible light photo-catalysis.

S. Varma, S.R. Joshi, B.Padmanabhan, V.K. Malik, A Chanda, N.C. Mishra, D. Kanjilal.

Vacancies and crystalline rutile TiO2 nanostructures enhance UV-Vis absorption properties

Nanostructures have been created on TiO_2(110) surfaces by 60 keV Ar ion irradiation at IUAC Delhi. The nanostructured surfaces show the presence of Ti rich zones as well as oxygen vacancies. These vacancy sites become the nucleation centers for the development of nanostructures. These nanostructured surfaces show enhanced UV-Visible properties. The nanostructures observed are of constrained nature i.e. they evolve along [100] direction but not in the perpendicular direction on the surface. AFM, XPS and Raman studies have been performed on these surfaces.

S. Varma, V. Solanki, S. Majumder , I. Mishra, N.C. Misra, D. Kanjilal.

Oxygen vacancy mediated Photo- absorption from ZnO(0001) Nanostructures fabricated by Atom Beam Sputtering

The nanoscale patterns created on the ZnO(0001) surfaces during atom beam

irradiation have been investigated here for their photo absorption response. Preferential sputtering, during irradiation, promotes Zn- rich zones that serve as the nucleation centers for the spontaneous creation of nanostructures. Nanostructured surfaces with bigger nanodots, displaying hexagonal ordering and long ranged periodic behavior, show higher photo absorption and a reduced bandgap. These nanostructures also demonstrate higher concentration of oxygen vacancies which are crucial for these results. Enhanced photo- response has been achieved in absence of any dopant elements.

S. Varma, V, Solanki, S. R. Joshi, I. Mishra, D. K. Avasthi.

Raman Studies of aligned ZnO nanorods

Aligned ZnO Nanorods (NRs) have been synthesized by hydrothermal method and Field emission scanning electron microscopy results show that the ZnO NRs are vertically aligned. Raman studies and photo- absorption measurements indicate blue shift in the NR features. Increase in bandgap is observed which is caused by the quantum confinement effects. These results conjugated with good crystallinity of the NRs can be very useful for applications in optoelectronic devices.

S. Varma, P. Dash, A. Manna, P. K. Sahoo, N. C. Mishra

Scaling studies after Low Energy Ion Irradiation of TiO2(110) Surface

Scaling properties of TiO2(110) surfaces, after irradiation with 3 keV Ar ions, have been investigated here. Ion irradiation leads to the spontaneous formation of self assembled Ti rich nanostructures as well as Ti3+ vacancy states. The nanostructures thus formed are elliptical in shape and exhibit a shape transformation to less elliptical nature at high fluences. Scaling studies also reflect this transition. Scaling studies further reveal that the surfaces are self-affine in nature and with increasing fluence the regions of correlated structures, or fluctuations, spread and become bigger. This is connected to the formation of bigger nanostructures causing the long ranged correlations on the surface. On the other hand, at short length scales the surfaces become less jagged as reflected by the roughness exponent of irradiated surfaces.

S. Varma, I. Mishra, S. R. Joshi, S. Majumder, A. K. Manna.

DNA Fractal Dimension and wetting properties on Natively oxidised Silicon(100)

Self-affine surfaces of natively oxidised Silicon(100) have been investigated here with the aim to assess how scaling morphology with multiple scales in nano- regime affect the water-in- contact wetting properties, scaling behavior and DNA conformations. The surfaces have been prepared by the technique of ion irradiation. Results show that conformational properties and fractal dimension of DNA molecules immobilized on these
surfaces are effected by the fractal dimension of the surfaces prior to immobilization. The adhesive properties of DNA on these surfaces have also been investigated.

S. Varma, I. Mishra, S.R.Joshi, S. Majumder, U Subudhi.

Silver Endotaxial Structures and Their Applications

Our group found a simple method to grow coherently embedded (endotaxial) silver nanostructures in silicon substrates of various substrate orientations. Extensive in-situ X-ray diffraction measurements were carried out at the Indian beam line (developed by Prof. M. K. Sanyal's group in SINP in collaboration with DST). Using the real-time and temperature dependent XRD measurements, we could establish the onset temperatures for the orientation of Ag nanostructures, in particular, in-line with the substrate unit cell orientation. A detailed study using MeV ion scattering (with RBS/Channeling), further characterization has been carried out. With in-situ XRD data, we found a method to freeze a kind of phase of the crystalline phase. At lower temperatures around 500 deg C, it was found that (111) faceted structures were prominent and at higher temperatures (100) related reflections are seen.

R. R. Juluri, A. Ghosh, A. Bhukta, R. Sathyavathi and P. V. Satyam.

Growth of Ag nanostructures on high-index Si (5 5 12) surfaces under UHV conditions: effect of prior surface treatment before deposition

High-index substrates, such as Si (5 5 12), provide self-assembled one-dimensional periodic array of structures upon reconstruction and can be used as templates for growth of aligned nanoscale structures. Crystalline quality of Ag nanostructures grown under UHV conditions using a molecular beam epitaxy system on reconstructed Si (5 5 12) surface is compared with those structures grown on HF-treated and native-oxide-covered Si (5 5 12) surfaces. These have been characterized by using reflection high-energy electron diffraction (RHEED), transmission electron microscopy (TEM) and in situ scanning tunneling microscopy methods. The RHEED and TEM studies confirm the polycrystalline, textured and crystalline nature of the Ag nanostructures grown on Si (5 5 12) with native oxide, HF-treated, and reconstructed surfaces, respectively. The crystalline quality of Ag nanostructures on HF-treated substrate was found to improve at higher substrate temperatures during growth.

A. Bhukta, P.Guha, A.Ghosh, P. Maiti, P. V. Satyam.

Bimetallic Structures grown on high index substrates in using MBE conditions:

Bimetallic thin film on semiconductor substrate has a lot advantages compared to monometallic thin film. We showed that a sub-monolayer of Ag on reconstructed Si(5 5 12) substrate could yield an interesting aspect ratio change and saturation as a function of initial Ag monolayer and Au thickness layers. The reconstructed high index silicon surfaces, such as, Si (5 5 12) composes row-like structures that can be used as templates for growing aligned nanowires. By using a sub-monolayers of Ag, prior to Au deposition on reconstructed Si (5 5 12) surface, intermixing of Au and Ag, enhanced aspect ratio of bimetallic AuAg nanowires with tunable morphology is reported. This is attributed to a combined effect of pre-grown Ag strips as nucleation centers for incoming Au ad-atoms and anisotropic Au-Ag intermixing. To achieve optimum conditions for the growth of larger aspect ratio AuAg nanostructures, the growth

kinetics have been studied by varying growth and annealing temperatures. At ? 400 °C, the Ag diffused into silicon substrate and the inter-diffusion found to inhibit the formation of AuAg bimetallic nanostructures. Kinetic Monte Carlo simulations based on kinematics of ad-atoms on an anisotropic template with a solid on solid model in which the relative ratios of binding energies as obtained from the density functional theory have been exploited. Controlled experiments under ultra-high vacuum condition in a molecular beam epitaxy system and in-situ scanning tunneling microscopy measurements along with ex-situ scanning transmission and secondary electron microscopy measurements are found to be in good agreement with kinetic Monte Carlo simulation results. AuAg bimetallic nanostructures are expected to have high potential for applications in fields such as surface enhanced Raman spectroscopy substrates.

A. Bhukta, P. Guha, P. Maiti, Prof. P. V. Satyam, Dr. T. Bagarti, Dr. B. Satpati, Dr. B. Rakshit.

Tuning the work function of randomly oriented ZnO nanostructures by capping with faceted Au nanostructure and oxygen defects: enhanced field emission experiments and DFT studies

The lowering of the work function (Ö) can lead to a better field emission (FE) behavior at lower threshold fields. We report on enhanced FE from randomly oriented and faceted Au-capped ZnO hetero-nanostructures (HNs) having more oxygen defects. Large-area arrays of non-aligned, faceted Au-capped ZnO HNs, such as nanowires (NWs) and triangular nanoflakes (TNFs) are grown using the chemical vapor deposition (CVD) method. Enhanced FE properties from the TNF sample resulted in a turn-on field as low as 0.52 V ìm”1 at a current density of 0.1 mA cm”2 and a field enhancement factor (â) as high as H”5.16 × 105. Under similar experimental conditions, drawing the same current density from an NW specimen needs a higher turn-on field (0.86 V ìm”1) and to exhibit nearly four times less field enhancement factor compared to the TNFs samples. X-ray photoelectron spectroscopy (XPS) and photoluminescence (PL) measurements confirm the presence of more oxygen defects in the TNF samples compared to the NW samples. Kelvin probe force microscopy (KPFM) measurements show the average local work function to be 4.70 ± 0.1 eV for the TNF sample, which is H” 0.34 eV lower than the NW sample. Using density functional theory (DFT) calculations, the estimated Ö values are found to be 4.98 eV for ZnO(0001), 4.17 eV for Au(001)/ZnO(0001) and 3.91 eV for Au(001)/Ovac-ZnO(0001) surfaces. The DFT results are qualitatively in agreement with our experimental results. The presence of Au nanostructures on top of O-deficient and sharp-tipped TNFs results in enhanced FE performance following their reduced tunneling barrier via pinning of effective Ö.

A. Ghosh, P. Guha, R. Thapa, S.Selvaraj, M.Kumar, Bipul Rakshit, T.Dash, Rajshekhar Bar, Samit K Ray and P. V. Satyam.

Growth of Au capped GeO_2 nanowires for visible-light photodetection

A single step process to grow Au capped oxygen deficient GeO_2 crystalline nanowires via generation of growth species through metal

induced surface decomposition of Ge substrate is reported. Without external source supply, the growth of the Au-GeO_2 nanowires on Ge substrate is addressed with possible mechanism. Despite of high band gap, application of GeO_2 as possible new material for visible light photodetection is presented. Asgrown samples found to have a photo-response of e" 102 with 17 % external quantum efficiency at -2.0 V applied bias upon visiblelight illumination (ë = 540 nm, 0.2 mW/ cm2). This visible-light detection can be attributed to the oxygen vacancy related defect states as well as localized surface plasmon resonance (LSPR) induced absorption and subsequent hot electron injection from Au to conduction band of GeO_2. Photodetection performance of the devices has been understood by proposed energy band diagrams. In addition, H" 4 times enhancement in the efficiency has been achieved by further decoration of Au nanoparticles on the as-grown nanowire surfaces.

A.Ghosh, P. Guha, S. Mukherjee , Rajshekhar Bar , Samit K. Ray, P. V Satyam.

Adsorption of Ru, Ce and Eu radionuclides within naturally precipitated polycrystalline calcium carbonate under acidic environment

^{106}Ru, ^{144}Ce and $^{152+154}Eu$ radiotracers sorption experiments (pH: 1–6) have been carried out with polycrystalline columnar/microcrystalline calcite and aragonite obtained from a stalagmite of Dharamjali cave, India. The different domains of the sample were powdered and thoroughly studied using electron microscopic and X-ray spectroscopic techniques. Both ^{106}Ru and ^{144}Ce exhibited higher sorption within calcite varieties compared to aragonite and increased with rising pH, while it showed reverse relation in case of $^{152+154}Eu$. Further, it is noted that aragonite offers the highest K d values for $^{152+154}Eu$, whereas ^{106}Ru and ^{144}Ce prefer calcite.

J. Sanwal, N. L. Dudwadkar, Arun T, S.C. Tripathi, P. M. Gandhi, P. V. Satyam, P. Sengupta.

Fe_3C-filled carbon nanotubes: permanent cylindrical nanomagnets possessing exotic magnetic properties

The present study aims to deduce the confinement effect on the magnetic properties of iron carbide (Fe_3C) nanorods filled inside carbon nanotubes (CNTs), and to document any structural phase transitions that can be induced by compressive/tensile stress generated within the nanorod. Enhancement in the magnetic properties of the nanorods is attributed to tensile stress as well as to compression, present in the radial direction and along the nanotube axis, respectively. Finally, the growth of permanent cylindrical nanomagnets has been optimized by applying a field gradient. Besides presenting the growth model of *in situ* filling, we have also proposed the mechanism of magnetization of the nanotubes. Magnetization along the tube axis has been probed by confirming the pole formation. Fe_3C has been selected because of its ease of formation, low *T*C and incompressibility.

R. Kumari, L.Krishnia, V. Kumar, S.Singh, H. K. Singh, R. K. Kotnala, R. R. Juluri, U. M. Bhatta, P. V. Satyam, Brajesh S. Yadav, Zainab Naqvia and Pawan K. Tyagi.

Potential application of carbon nanotube core as nanocontainer and nanoreactor for the encapsulated nanomaterial

Fe3C nanorod filled inside carbon nanotube has been irradiated inside transmission electron microscope at both room and high temperature. *In-situ* response of Fe3C nanorod as well as CNT walls has been studied. It has been found that when electron irradiation is performed at room temperature (RT), nanorod first bends and then tip makes at the end whereas at high temperature (<"490 °C) nanorod slides along the tube axis and then transforms into a faceting particle. Extrusion of solid particle filled in the core of CNT has also been demonstrated. It is suggested that these morphological changes in nanorod may have happened due to the compression which was generated either by shrinkage of tube or by local electron beam heating. Presented results demonstrate that CNT core could be used as nano-container or reactor.

Pawan K. Tyagi, Reetu Kumari, U. M. Bhatta, R. R. Juluri, A. Rath, S. Kumar, P.V. Satyam, Subodh K. Gautam, Fouran Singh.

Ion-beam induced synthesis of self organized nanostructures

We are working on synthesis of self-organized nanostructures on semiconductor surfaces by using low-to-medium energy (0.2-100 keV) ions and trying to understand the underlying physical mechanisms in terms of various experimental parameters and the existing theories. In our recent papers, we have shown that both sputter erosion and ion-beam induced prompt atomic redistribution are responsible for ripple formation on Si, Ge, Al_2O_3, and SiO_2 surfaces at medium ion energies. Interestingly, usage of Au ions leads to fascinating ordering in the ripple patterns created on Ge substrates. On the other hand, at low ion energies, ripples are formed on Si surface which is explained in the frame work of solid flow model under ion bombardment. In both these cases, we have constructed parametric phase diagrams which show that ripple formation on Si starts above a threshold incidence angle below which no patterns are formed. We have also shown that for low energy ions, at higher incidence angles, ripple wave vector undergoes a transition from parallel to perpendicular to the ion-beam projection onto the sample surface before patterns disappear at grazing incidence angles.

Ripples are also observed to undergo a transition to facets (in both low and medium energy regimes) for Si, Ge, and SiO_2 over a small angular window due to ion-beam induced shadowing. Further, under concurrent substrate rotation, one creates mounds/dots on surface instead of ripples which are otherwise set to form if no rotation is present. Different types of patterned surfaces are useful for many applications, viz. solar cells, thin film/nanoscale magnetism, optoelectronics, and plasmonics where one can make use of the patterned substrates as templates for deposition of thin films or use as anti-reflecting and self-cleaning substrates.

T. Som, *M. Saini*, *S.A. Mollick*, *S.K. Garg, T. Basu, M. Kumar, D.P. Datta, B. Satpati, R. Mark Bradley, Rodolfo Cuerno, Hans Hofsäss, D. Ghose*,, and *D. Kanjilal*

Surfing self-organized silicon nanofacets for cold cathode electron emission sites

Point sources exhibit low threshold electron emission due to local field enhancement at the tip. However, in case of silicon, the development and implementation of tip emitters have been hampered by unwanted oxidation, limiting the

number of emission sites and the overall current. Here we report a fascinating low threshold (~0.67 V μm^{-1}) cold cathode electron emission from self-organized silicon nanofacets (Si-NFs). The ensembles of self-organized nanofacets fabricated at different time scales, under low energy ion impacts, yield a tunable field emission with Fowler–Nordheim tunnelling field in the range of 0.67 to 4.75 V μm^{-1}. The local probe surface microscopy-based tunnelling current mapping in conjunction with Kelvin probe force microscopy measurements reveal that the valleys and a part of the sidewalls of nanofacets contribute more to the field emission process. The observed lowest turn-on field is attributed to the absence of native oxide on the sidewalls of the smallest facets as well as their lowest work function. Further, first-principle density functional theory-based simulation reveals a crystal orientation-dependent work function of Si, which corroborates well with our experimental observations. The present study demonstrates a novel way to address the origin of the cold cathode electron emission sites from self-organized Si-NFs fabricated at room temperature. In principle, the present methodology can be extended to probe the cold cathode electron emission sites from any nanostructured material.

T. Basu, M. Kumar, J. Ghatak, B. Satrpati, and T. Som

Tunable photoluminescence from conformally grown aluminum-doped zinc oxide thin films on rippled-Si

Al-doped ZnO (AZO) thin films of varying thicknesses were deposited on 500 eV argon ion-beam fabricated nanoscale self-organized rippled-Si substrates at room temperature and are compared with similar films deposited on pristine-Si substrates (without ripples). It is observed that morphology of self-organized AZO films is driven by the underlying substrate morphology. For instance, for pristine-Si substrates, a granular morphology evolves for all AZO films. On the other hand, for rippled-Si substrates, morphologies having chain-like arrangement (anisotropic in nature) are observed up to a thickness of 20 nm, while a granular morphology evolves (isotropic in nature) for 30 nm-thick film. Photoluminescence studies reveal that excitonic peaks corresponding to 5 and 15 nm-thick AZO films, grown on rippled-Si templates, show a blue shift of 8 nm and 3 nm, respectively, while the same is negligible for 20-nm thick film (with respect to its pristine counterpart). The observed blue shift is substantiated by diffuse reflectance study and attributed to quantum confinement effect, associated with the size of the AZO grains and their spatial arrangements driven by the anisotropic morphology of underlying rippled-Si templates.

T. Basu, M. Kumar, S. Nandy, B. Satpati, C.P. Saini, A. Kanjilal, and T. Som

Gold-decorated highly ordered self-organized conducting ridges on Ge surface

Nanoachitecturing by atomic manipulation is considered to be one of the emerging trends in advanced functional materials. It has a gamut of applications to offer in nanoelectronics, chemical sensing, and nanobio science. In particular, highly ordered one-dimensional semiconductor nanostructures fabricated by self-organization methods are in high demand for their high aspect ratios and large number of applications. In this work, we offer a room

temperature process, in which atoms are sputtered away by ion impacts. Using gold ion implantation, the present study results into the formation of highly ordered self-organized long grating-like nanostructures and grooves between them on germanium surface. The ridges of the patterns are shown to have flower-like protruded nanostructures which are mostly decorated by gold atoms. By employing local probe microscopic techniques like Kelvin probe force microscopy and conductive atomic force microscopy, we observe a spatial variation in the work function and different nanoscale electrical conductivity on the ridges of the patterns and the grooves between them, which can be attributed to gold-atom decorated ridges. Thus, the present architecture offers the advantage of using the patterned germanium substrates as periodic arrays of conducting ridges and poorly conducting grooves between them.

S.A. Mollick, M. Kumar, R. Singh, B. Satpati, D. Ghose, and T. Som

Magnetic anisotropy in Co thin films on rippled substrates of Si and Ge

In-plane magnetic anisotropy in Co thin films, of varying thicknesses, grown on rippled Si and Ge substrates are investigated. Thin films were deposited at different oblique angles of incidence by RF magnetron sputtering technique. The results are compared with the films deposited on pristine-Si and Ge substrates as well. Co films grew conformally on rippled substrates and showed a strong uniaxial magnetic anisotropy with the easy axis of magnetization parallel to the ripple direction. Antiferromagnetic exchange coupling has also been observed in selective cases.

S.A. Mollick, R. Singh, M. Saini, T. Basu, M. Kumar, S. Patel, N. Shukla, B. Satpati, and T. Som

Nanoporosity-induced superhydrophobicity and large antireflection in InSb

A porous nanostructure evolves in InSb due to keV ion implantation which leads to superhydrophobic and colossal antireflective property, indicating a single-step facile fabrication to introduce both functionalities. In particular, it is observed that the contact angle of a water droplet on the nanoporous InSb surface exceeds 150°, revealing the transition to a superhydrophobic surface. Correlation between the contact angle and the porous nanostructures is qualitatively understood in light of the Cassie-Baxter model. It is found that a decrease in the fraction of solid surface wetted by the water droplet and a corresponding increase in the air-water interface fraction lead to the enhancement in the hydrophobicity. We further observe that the large broadband antireflection (in the range of 200-800 nm) is also correlated to the nanoporous structure, arising out of a large reduction in the refractive index due to its increasing porosity. Such a surface with the combination of superhydrophobicity and colossal antireflection can be very useful for applications of InSb nanostructures in electronic, photonic devices, or infrared detectors.

D.P. Datta and T. Som

Facile synthesis of superhydrophobic and colossal broadband antireflective nanoporous GaSb surface

This work focuses on the facile synthesis of tunable hydrophobic and colossal antireflective nanoporous GaSb by altering its porosity. In particular, it is observed that the contact angle of a water droplet on the GaSb surface increases as the nanoporous structures undergo different stages of growth and finally exceeds 150°, indicating the transition to a superhydrophobic surface. The observed correlation between the

contact angle and the surface morphology is qualitatively understood in light of the Cassie-Baxter model. It is found that with the temporal evolution of nanostructures, a decrease in the fraction of the solid surface wetted by the water droplet and a corresponding increase in the air-water interface fraction lead to the enhancement in hydrophobicity, where the chemistry of the porous surface also plays a role. The temporal evolution of the contact angle is also studied to understand the interaction of the sessile drop with the hydrophobic surface and the ambient. In addition to an increase in the contact angle, we also observe a colossal broadband antireflection (in the range of 200-800 nm), which is correlated to a large reduction in the refractive index due to increasing porosity. Such a surface with the combination of superhydrophobicity and colossal antireflection can be very useful in application of GaSb nanostructures in thermopotovoltaic cells or photodiodes.

D.P. Datta, S.K. Garg, B. Satpati, D. Kanjilal, and T. Som

Oxide thin films by RF and pulsed DC magnetron sputtering

We are studying growth of transparent conducting oxide (TCO) thin films, viz. In_2O_3:SnO_2 (ITO), ZnO:Al_2O_3 (AZO) on glass and silicon substrates. The main objective is to study three-dimensional columnar growth of these materials by glancing angle deposition technique. It is observed that room temperature (RT) grown ITO and AZO thin films, deposited by RF and pulsed DC sputtering, show high transmittance and low resistance. We have compared the film properties grown by DC magnetron sputtering to improve the junction characteristics and other optoelectronic properties.

We are also studying the growth of ordered arrays of amorphous TiO_2 nano-columns by using rf magnetron sputtering. The nano-columnar films show high resistance and are found to be porous in nature which results from glancing angle sputter deposition. In fact, porosity has a linear relationship with increasing deposition angle. Reflectance of the thin films is also studied as a function of porosity. In addition, contact angle measurements show roughness-dependent transition from a hydrophilic to a hydrophobic TiO_2 surface. TiO_2 films have been tested successfully for its possible use as a hole blocking nature in copper oxide-based photovoltaic cells.

Further, we are growing MoO_3 layers to study its use as a hole blocking layer. In fact, our preliminary studies show that MoO_3 posseses better hole blocking properties than TiO_2. A detail growth angle-dependent optical as well as nanoscale and bulk electrical transport measurements are being carried out to optimize the growth of α-MoO_3 thin films on variety of substrates for use in photovoltaic cells.

R. Singh, M. Kumar, S. Nandy, R. Sivakumar, B. Satpati, and T. Som

Tunable optoelectronic properties of pulsed dc sputter-deposited ZnO: Al thin films: Role of growth angle

We have studied the growth angle-dependent physical properties and work function of AZO thin films. It is observed that average grain size and crystal quality increase with higher angle of deposition, yielding improved optical properties. A systematic blue shift as well as a decrease in the resistivity takes place with the increasing growth angle up to 70°, while an opposite trend is observed beyond that. In addition, the work function of AZO films is also measured using Kelvin probe force microscopy.

M. Kumar, R. Singh, S. Nandy, A. Ghosh, S. Rath, and T. Som

Field-induced doping-mediated tunability in work function of Al-doped ZnO: Kelvin probe force microscopy and first-principle theory

We demonstrate that the work function of Al-doped ZnO (AZO) can be tuned externally by applying an electric field. Our experimental investigations using Kelvin probe force microscopy show that by applying a positive or negative tip bias, the work function of AZO film can be enhanced or reduced, which corroborates well with the observed charge transport using conductive atomic force microscopy. These findings are further confirmed by calculations based on first-principles theory. Tuning the work function of AZO by applying an external electric field is not only important to control the charge transport across it, but also to design an Ohmic contact for advanced functional devices.

M. Kumar, S. Mookerjee, and T. Som

Local probe microscopic studies on Al-doped ZnO: Pseudoferroelectricity and band bending at grain boundaries

Using Atomic force microscopy-based piezoforce measurements, we show the presence of opposite polarization at grains and grain boundaries of Al-doped ZnO (AZO). The polarization can be flipped by 180° in phase by switching the polarity of the applied electric field, revealing the existence of nanoscale pseudoferroelectricity in AZO grown on Pt/TiO_2/SiO_2/Si substrate. We also demonstrate an experimental evidence on local band bending at grain boundaries of AZO films using conductive atomic force microscopy and Kelvin probe force microscopy.

M. Kumar, T. Basu, and T. Som

Role of metallic-like conductivity in unusual temperature-dependent transport in AZO

The current–voltage characteristics of an *n*-AZO/*p*-Si heterojunction diode is investigated over a temperature range of 293 and 423 K. The measured current–voltage characteristics show good rectification behavior at all temperatures. It is observed that the AZO/Si heterojunction exhibits different (unusual) types of charge conduction processes in the temperature range under consideration. In addition, temperature-dependent resistivity measurements performed on an AZO thin film grown on a glass substrate show metallic-like conductivity, which is explained on the basis of local annealing of defects, mainly vacancies, in the AZO layer. Finally, based on our experimental findings, we construct a parametric phase diagram to elucidate the transition from one to the other conduction mechanism. The present study will be useful to understand the effect of self-heating for AZO-based devices.

M. Kumar, S.K. Hazra, and T. Som

Ultra-violet absorption induced modifications in bulk and nanoscale electrical transport properties of Al-doped ZnO thin films

Using conductive atomic force microscopy and Kelvin probe force microscopy, we study local electrical transport properties in aluminum-doped zinc oxide (ZnO:Al or AZO) thin films. Current mapping shows a spatial variation in conductivity which corroborates well with the local mapping of donor concentration (<“10^{20} $cm^{”3}$). In addition, a strong enhancement in the local current at grains is observed after exposing the film to ultra-violet (UV) light which is

attributed to persistent photocurrent. Further, it is shown that UV absorption gives a smooth conduction in AZO film which in turn gives rise to an improvement in the bulk photoresponsivity of an n-AZO/*p*-Si heterojunction diode. This finding is in contrast to the belief that UV absorption in AZO layer leads to optical loss for the underneath absorbing layer of a heterojunction solar cell.

M. Kumar, T. Basu, and T. Som

Structural defect-dependent resistive switching in Cu-O/Si

In this study, we show structural defect-dependent presence or absence of resistive switching in Cu-O films. We use Kelvin probe force microscopy and conductive atomic force microscopy to show the presence of resistive switching. In addition, local current mapping provides direct evidence on the formation of nanoscale filament. These findings match well with the existing theoretical model on resistive switching. In particular, understanding the role of structural defects in resistive switching can be considered as critically important to take a step forward for designing nanoscale memory devices.

M. Kumar and T. Som

The influence of surface topography on the field emission of nanostructured copper oxide thin films grown by oblique incidence deposition

We studied the surface morphology-dependent enhanced field electron emission properties of copper oxide thin films, which are sputter deposited at two different incident flux angles. The turn-on field is as low as 1.3 V μm^{-1} for obliquely deposited thin film, with an enhancement factor of ~5144. The emission current also shows good stability. With the help of finite element method analysis, we show that the enhanced field emission behavior is due to the special surface topography of obliquely deposited film. While for the normally deposited film the screening effect plays an important role and thereby condemning the electron emission performance. We expect to have a general applicability of this study in the design of thin film based electron emitters.

S. Chatterjee, M. Kumar, and T. Som

Resistive switching in copper-doped zinc oxide thin films grown by PLD

We have grown 2 wt.% Cu-doped ZnO thin films on Si by pulsed laser deposition (PLD) technique. The films are found to be smooth and uniform over reasonably large surface areas. Preliminary studies reveal that the films show resistive switching property and thus, will be useful for ReRAM applications.

M. Saini, R. Singh, and T. Som

Hole blocking property in bismuth ferrite thin films grown by PLD

Bismuth ferrite $BiFeO_3$ (BFO) has attracted much attention as a multiferroic material in which ferroelectric and antiferromagnetic ordering temperatures are both above room temperature. In our recent study we show that BFO thin films grown on Si substrates using PLD technique, under varying oxygen partial pressures and growth temperatures, show hole blocking properties.

M. Muneeswaran, R. Singh, M. Kumar, and T. Som

Asymmetric band gaps in a Rashba film system

The joint effect of exchange and Rashba spin-orbit interactions was examined on the surface and quantum well states of Ag2Bi-terminated Ag films grown on ferromagnetic Fe(110). The system displays a particular combination of time-reversal and translational symmetry breaking that strongly influences its electronic structure. Angle-resolved photoemission reveals asymmetric band-gap openings, due to spin-selective hybridization between Rashba-split surface states and exchange-split quantum well states. This results in an unequal number of states along positive and negative reciprocal space directions. We suggest that the peculiar asymmetry of the discovered electronic structure can have significant influence on spin-polarized transport properties.

D. Topwal and Collaborators

Giant magnetocaloric effect in Gd_2NiMnO_6 and Gd_2CoMnO_6 ferromagnetic insulators

We investigated the magnetocaloric effect in double perovskite Gd_2NiMnO_6 (GNMO) and Gd_2NiMnO_6 (GCMO) samples by magnetic and heat capacity measurements. Ferromagnetic ordering is observed at ~130 K (~ 112 K) in GNMO (GCMO), while the Gd exchange interactions seem to dominate for $T < 20$ K. In GCMO, below 50 K, antiferromagnetic behaviour due to the 3d–4f negative exchange interaction is observed. A maximum entropy ("ΔS M) and adiabatic temperature change of ~35.5 J Kg"1 K"1 (~ 24 J Kg"1 K"1) and 10.5 K (6.5K) is observed in GNMO (GCMO) for a magnetic field change of 7T at low temperatures. Absence of magnetic and thermal hysteresis and their insulating nature make them promising for low temperature magnetic refrigeration.

D. Topwal and Collaborators

Cold Cathode Emission Studies on Topographically Modified Few Layer and Single Layer MoS_2 Films

We have carried out comparative field emission (FE) studies on topographically-tailored few layer MoS_2 films consist of <0001> plane perpendicular to *c*-axis (i.e. edge terminated vertically aligned) along with planar few layer and monolayer (1L) MoS_2 films. FE measurements exhibited lower turn-on field E_{to} (defined as required applied electric field to emit current density of 10 $\mu A/cm^2$), ~4.5 V/μm and higher current density ~1 mA/cm^2, for edge terminated vertically aligned (ETVA) MoS_2 films. However, E_{to} magnitude for planar few layer and 1L MoS_2 films increased further to 5.7 and 11 V/μm respectively, with one order decrease in emission current density. The observed differences in emission behavior, particularly for ETVA MoS_2 is attributed to the high value of geometrical field enhancement factor (β), found to be ~1064, resulting from the large confinement of localized electric field at edge exposed nanograins. Emission behavior of planar few layers and 1L MoS_2 films are explained under a two step emission mechanism. Our studies suggest that the with further tailoring the microstructure of ultra thin ETVA MoS_2 films would result in elegant FE properties.

A.P.S. Gaur, Satyaprakash Sahoo, F. Mendoza, A. M. Rivera, M. Kumar, S.P. Dash, G. Morell and R. S. Katiyar

Studies on chemical charge doping related optical properties in monolayer WS_2

Thermal stability of quasi particles, i.e. exciton and trion, and strong particle- particle interaction significantly tune the optical properties of atomically thin two-dimensional (2D) metal dichalcogenides. We have studied

the effect of inherent defects upon optical properties of CVD grown 1L-WS_2 and proposes the use of chemical transfer doping as a reversible and simple method for identification of the type of excess charge in the system. Photoluminescence (PL) studies in pristine 1L-WS_2 show an additional band at ~0.06 eV below trion ($X^{\pm}$) PL band was evolved (at low temperature) which was associated to the bound exciton with charged/neutral defect. Using 7,7,8,8-Tetracyanoquinodimethane (TCNQ) and 2,2- bis1,3-dithiolylidene (TTF) as *p* and *n*-type dopants, respectively, we determined that the inherent defects, which could be due to the presence of Tungsten metal deficiency, contributed in *p*-type nature of the pristine 1L-WS_2. Doping of 2D TMDCs materials with organic molecule via surface charge transfer method is not only a way to provide a handy way to tailor the electronic and optical properties but also can be used as a tool to determine the nature of defects in the material.

A. M. Rivera, A. P. S. Gaur, Satyaprakash Sahoo, and R. S. Katiyar

Spin-polarized tunneling through chemical vapor deposited multilayer molybdenum di-sulphide

The two-dimensional (2D) semiconductor MoS_2 has attracted widespread attention for its extraordinary electrical, optical, spin and valley related properties. Here, we report on spin polarized tunneling through chemical vapor deposited (CVD) multilayer MoS_2 (~7 nm) at room temperature in a vertically fabricated spin-valve device. A tunnel magnetoresistance (TMR) of 0.5 – 2 % has been observed, corresponding to spin polarization of 5 - 10 % in the measured temperature range of 300 – 75 K. First principles calculations for ideal junctions find a tunnel magnetoresistance up to 8 %, and that for the spin polarization of 26 %. The detailed measurements at different temperatures and bias voltages, and density functional theory calculations provide information about spin transport mechanisms in vertical multilayer MoS_2 spin-valve devices. These findings form a platform for exploring spin functionalities in 2D semiconductors and understanding the basic phenomenon that control their performance.

A. Dankert, P. Pashaei, M.D. A. Hoque, M. V. Kamalakarand, S. P. Dash, A. P.S. Gaur, S. Sahoo, R. S. Katiyar, M. P. de Jong, I. Rungger, A. Narayan, K. Dolui, S. Sanvito

Non-enzymatic Optical Glucose Sensing Using ZnO Nanorods, Successful Demonstration with Human Serum

The highly sensitive, interference-free and non-enzymatic optical sensing of glucose has been made possible for the first time using the hydrothermally synthesized ZnO nanorods. The UV irradiation of glucose-treated ZnO nanorods decomposes glucose into hydrogen peroxide (H_2O_2) and gluconic acid by UV oxidation. The ZnO nanorods play the role of a catalyst like the oxidase used in the enzymatic glucose sensors. The photoluminescence (PL) intensity of the near-band edge emission of the ZnO nanorods linearly decreased with the increased concentration of H_2O_2. Therefore, the glucose concentration is monitored over a wide range, 0.5 – 30 mM, corresponding to 9 – 540 mg/dL. The concentration range of the linear region in the calibration curve is suitable for its clinical use as a glucose sensor, because the glucose concentration of human serum is typically in the range of 80 – 120 mg/dL. In addition, the optical glucose sensor made of the ZnO nanorods is free from interference by bovin serum albumin, ascorbic acid or uric acid, which is also present in human blood. The non-

enzymatic ZnO-nanorod sensor has been demonstrated with human serum samples from both normal persons and diabetic patients. There is a good agreement between the glucose concentrations measured by the PL quenching and standard clinical methods.

Sachindra Nath Sarangi, Shinji Nozaki, and Surendra Nath Sahu

A Short Review on Physico-Chemical Properties of *Bacopa Monnieri* L.

Material of our interest in the present study is the medicinally important Brahmi (*Bacopa monnieri* L.) herb. The herb has been so chosen because of its various pharmaceutical and medicinal properties. Since the important elemental constituents, phases and complexes of the medicinal plant possess different curative capability of human disease. So, it is important to know the details of the above herb, its chemicals composition, pharmaceutical and medicinal components, important elements and material phases present are defined in this minireview. In pharmacologic studies, the whole plant of *B. monnieri* has been attributed with various medicinal properties including memory enhancing, anti-inflammatory, antioxidant, analgesia, reducing oxidation of fats in the bloodstream, antipyretic; sedative, hepatoprotective, cardiotonic and antiepileptic and these have been correlated to the presence of bacosides. *B. monnieri* has been used in traditional Ayurvedic treatment for epilepsy and asthma. It is also used in Ayurveda for ulcers, tumors, enlarged spleen, indigestion, inflammations, leprosy, anemia, and biliousness, ascites.

In addition to memory boosting activity, it is also claimed to be useful in the treatment of cardiac, respiratory and neuropharmacological disorders like insomnia, insanity, depression, psychosis, epilepsy and stress. It is used also as a tranquillizer. The plant is anticancer, astringent, bitter, sweet, cooling, laxative, intellect promoting, anodyne, carminative, digestive, antioxidant, antimicrobial, anti-inflammatroy, anticonvulsant, depurative, cardiotonic, bronchodialator, diuretic, emmenagogue, sudorfic, febrifuge and a tonic.

S. Behera, B. Mallick, T. N. Tiwari and P. C. Mishra.

Risk of Acid Attack on Plants: A Revie

Acid rain in reality has been well documented for many places, viz. the eastern USA, Canada, Bermuda, etc. Plants are drastically affected by acid rain (AR)-caused acid deposition. One of the main effects of acid rainfall on plants is the leaching of nutrients and cations from leaves. The literature review of acid rain-induced effects on various plants is described in the present paper, which gives the detailed description of different AR-induced effects observed in herbs, crop and vegetable plants, trees and forest, etc.

In conclusion, soil and aquatic ecosystem are two very important environmental components and are directly affected by acid rain. Since soil and water are two essential components for the plant growth, they are directly related to plant kingdom. AR-induced pollution of soil and water impacts an adverse effect on plants. Hence, polluted and water highly affect the plants; this indirect effect may cause even more impact on plants rather than the direct acid rain.

S. Behera, B. Mallick, T. N. Tiwari and P. C. Mishra .

X-Ray diffraction analysis of polymeric solid using Bragg-Brentano geometry

The crystallographic structural parameters were analyzed using X'Pert-MPD XRD a laboratory X-ray source having Bragg-Brentano parafocusing optics. The line profile characteristics was obtained using *ProFit* software based on Pseudo-Voigt profile function and is applicable for the study of interplaner spacing *d*, crystallite size D_{hkl}, percent crystallinity %C, macromolecular orientation and other structural imperfections of polyethylene terephthalate (PET). The X-ray diffraction data obtained for solid PET matched well with the data reported by different researchers using high intense source like synchrotron.

X-ray investigation of PET solid was carried out using high-resolution diffraction geometry applying Bragg-Brentano parafocusing optics. The diffraction profile characteristics was obtained using *ProFit* software based on Pseudo-Voigt profile function. The structure of PET found out to be triclinic in nature with a = 4.56 Å, b = 5.94 Å and c = 10.75 Å. The plane (100) at 2θ =26.01^0 was found to have the most intensity and maximum peak intensity I_{max} . The *d*-value of the 100% peak, i.e; is found to be 3.4229 Å. Percent crystallinity %C of the polymeric solid was found to be 68.5%. Again, both azimuth and helix angles are found to be very small with respect to C-axis confirm the high molecular orientation. The particle size D_{hkl} lies between 58.54 Å to 60.37 Å. The X-ray diffraction data obtained for solid PET matched well with the data reported by others using high intense source like synchrotron. Hence, the present investigation will contribute greatly towards study of structure of polymer materials and to understand various crystallographic parameters of solids.

B. Mallick.

Designing of Collimator and Shielding for High-Energy X-ray Beam: Application to 3MV Tandem Pelletron based HEX-Ray Spectrometry

High-energy X-rays (60-1000 keV) or HEX-ray bear unique advantage over conventional X-rays in the field of diffraction and scattering techniques. HEX-ray is an important experimental technique because of its uniqueness to characterize technically challenging samples (liquids, glass, amorphous materials, nanomaterialas, thick samples, etc.). In the present paper detail designing of lead collimator and shielding for the recently developed HEX-Ray spectrometry [1] experiment using characteristic PbK-lines (75-85 keV) emitted due to bombardment of 3 MeV proton beam generated from the Pelletron accelerator has been reported. Attenuation (%), transmission (%), and energy absorption (%) are calculated using the NIST data based on X-ray interaction cross sections and material densities. Thickness for Pb-shielding possessing highest attenuation (99.99%) for 75 keV and 85 keV X-rays are 3 mm and 4 mm respectively. Hence, shielding thickness about 5 mm is very suitable to cover the experimental table. Again, introducing a source collimator (diameter = 8mm, length = 35mm) between the X-ray target (source) and the sample, the incoherent scattered radiation due to air in the path of the beam and the multiple reflection from the chamber as well as from the detector inserting tube can be suppressed. An extra energetic X-ray line was observed at about 44.5 keV using a high-purity germanium (HpGe)

detector (Detector Systems GmbH (DSG), Germany). This contamination line is not an escape peak and can be suppressed using 8 mm Pb-collimator between X-ray target and sample.

B. Mallick and K. S. Jena

External-Ion Beam Facility at Institute of Physics Bhubaneswar

Advanced materials in it's any form, such as liquids, powders, fibers etc., can be modified or analyzed as-such using External-Ion Beam (EIB) irradiation technique, which is quite impossible applying traditional vacuum chamber based ion beam modification (IBM) and ion beam analysis (IBA) techniques. Material properties viz Structural, Thermal, Optical, Mechanical, Electrical etc. can be modified using the above External-IBM technique. The EIB irradiation is similar to traditional irradiation technique. Advantage of this technique is that the samples of almost any size and type can be irradiated 'as-such'. In case of vacuum incompatible biological materials, biofluids, liquids, powders, volatile materials, large archaeological objects, it is necessary to take the beam outside the experimental chamber in order to carryout any of the IBM and IBA experiment. The merits of EIB over the traditional IBM are: (i) Easy sample handling and positioning in air, (ii) The risk of sample damage due to radiation heating is considerably reduced because of efficient cooling by the air flow etc. Important Ion Beam Techniques viz EPIXE, HETLD, HEDXRF, NAA, PIPAS etc. can be possible by the application of External-Ion Beam. In the present paper, the details of EIB technique and its prospectus have been presented.

B. Mallick

Ag-MoO_3 heterostructures

We have successfully grown MoO_3 structures and Ag-MoO_3 heterostructures (HSs) in CVD chamber under 45 sccm Ar flow on silicon substrates and 4 nm Ag/SiO_2/Si substrates respectively. From XRD, all peaks could be readily indexed to orthorhombic phase of MoO_3 (α-MoO_3), oriented along [0k0] direction, i.e., the MoO_3 structures are mostly aligned parallel to the substrate surface for both the cases. Interestingly, we have seen that silver NPs have been decorated on MoO_3 structures on the specific surfaces of MoO_3 structures, but not all the surfaces of MoO_3. It is observed that not a single silver NP is present on the MoO_3(010) surface. It is also noticeable that silver decoration is higher on MoO_3 (001) surface compared to MoO_3 (100) surface. It is reported that, the (010) surface has a small surface energy that is related to the weak interaction (van der Waals force) between the adjacent bi-layers along [010]. Decoration of Ag NPs on different surface of MoO_3 structures during growth has been examined by electron microscopy and modeled with theoretical binding energy calculation of the three prime systems Ag(111)/MoO_3(100), Ag(111)/MoO_3(010) and Ag(111)/MoO_3(001).

Apart from the silicon substrates, we have tried to grow MoO_3 structures and Ag-MoO_3 HSs on diverse substrates like Ge, GaAs, and ITO coated glass substrates and we have succeeded to synthesize MoO_3 structures and Ag-MoO_3 HSs for all the cases.

Both the samples offer good field emission behavior. Ag-MoO_3 shows 10 times better performance than MoO_3 in terms of turn-on voltage and field emission factor which determine the field emission performance of an emitter. We have also measured the work functions of these two structures via Kelvin probe force microscopy technique.

Puspendu Guha

Bimetallic Nanoparticle

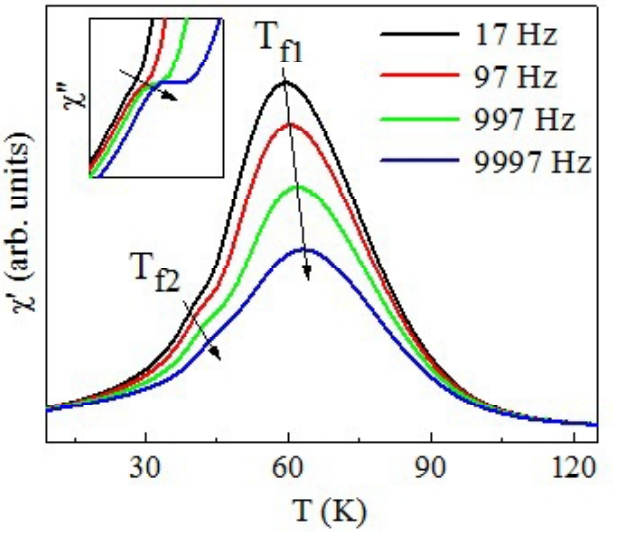
In the diverge field of nanotechnology, bimetallic nanoparticle (BMNP) (*e.g.* Au-Pd, Ag-Pd, Au-Ag, Ru-Ta) is considered as a special class due to its many synergic effects (catalysis, electrocatalysis etc.) which excel its monometallic counterparts. Growth of such BMNPs on the ultra clean reconstructed Si surface with controlled morphology and composition withstands their implication in the Si based technology coupled with advantageous synergic effects. We have studied Au-Ag bimetallic growth on reconstructed Si surface under various molecular beam epitaxy (MBE) conditions. Detailed investigations have been carried out to understand morphological and structural aspects of Au-Ag growth with systematic variation of growth parameters *i.e.* substrate temperature, thickness of the thin film, orientation of the substrate. Some of these aspects have been qualitatively explained in the light of our proposed kinetic monte carlo (KMC) model which incorporates obtained results from density functional theory (DFT). We have also investigated effect of different kinds surface treatment prior to Ag growth on Si(5 5 12) surface on the crystalline quality of the Ag nanostructures. Different kinds of surface treatments are considered as: i) native silicon oxide (SiO_x) covered, ii) hydrofluoric (HF) acid treated in air with its 2-5% water solution and iii) reconstructed. At substrate temperature 300 °C, grown Ag nanostructures comprise polycrystalline, textured and crystalline nature for growth on native oxide covered, HF treated and reconstructed surface respectively.

Anjan Bhukta

Multiglass behavior in $Ga_{2-x}Fe_xO_3$

$Ga_{2-x}Fe_xO_3$ (with x = 0.75, 1.0 and 1.25) show ferrimagnetic behavior due to inherent site disorder, as ionic radii of Ga and Fe are very similar. Ferrimagnetic behavior for all compositions can be well explained by the molecular-field-approximation of three-sublattice ferrimagnetic model. Inherent site disorder driven magnetic inhomogeneity and competing ferromagnetic and antiferromagnetic interactions give rise to the double magnetic glassy behavior in $x = 0.75$ compounds, were it shows cluster glass like Real (χ') part of ac susceptibility data measured at several frequencies for $Ga_{1.25}Fe_{0.75}O_3$ behavior below T_{f1} (~60 K) and spin-glass like behavior below T_{f2} (~40 K). Furthermore, with increasing Fe compositions (x) as magnetic inhomogeneity/ short range magnetic interactions progressively reduces, it leads to change in nature of glassy behavior. These compounds also show electric glassy behavior. The dipolar glassy state and the emergence of polarization can be explained by short-range migration of charged oxygen vacancy.

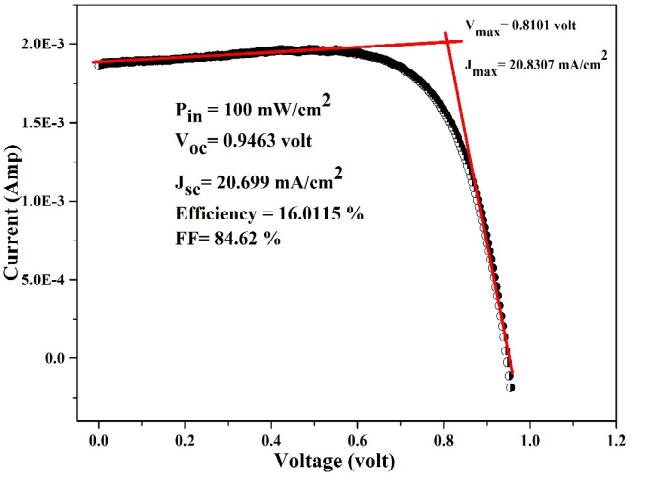
Sudipta Mahana and Dinesh Topwal



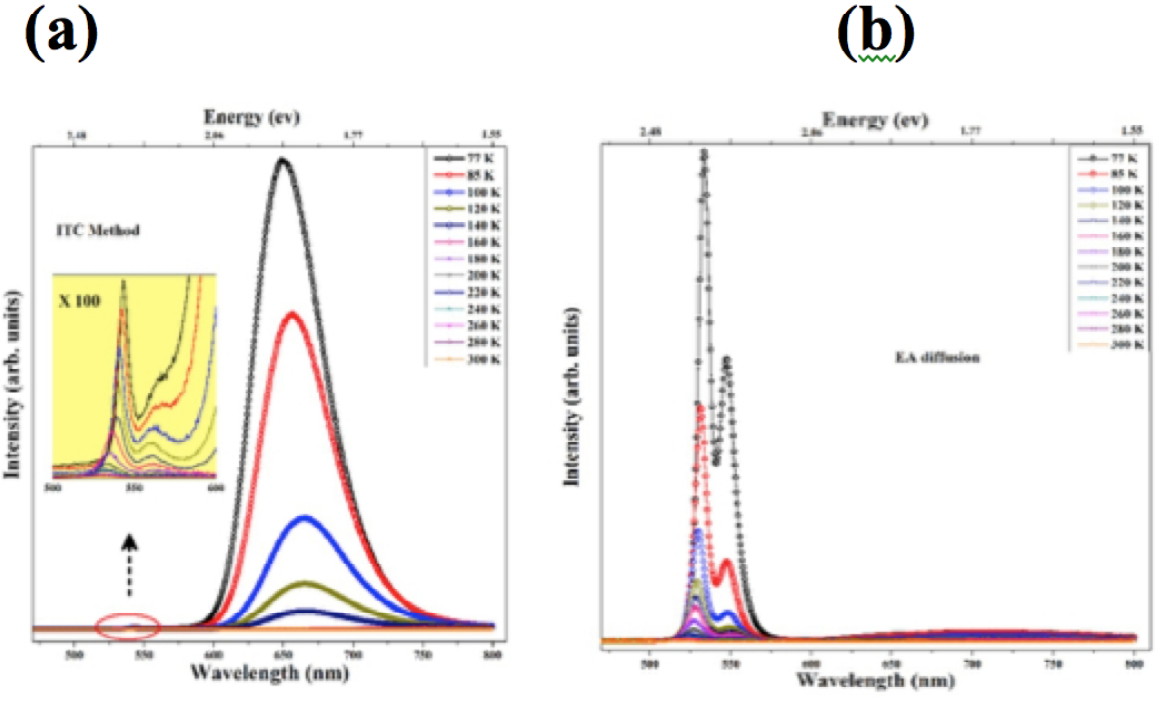
$CH_3NH_3PbX_3$: New class of solar cell material

The hybrid halide perovskite of the type $CH_3NH_3PbX_3$ (X= I, Br, Cl & mixed of them) has made a footmark as promising solar cell materials in material science community and has reached an efficiency of about 20.1% within four years of active research. In our recent study, we have made a solar cell based on $CH_3NH_3PbI_{3-x}Cl_x$ as an absorber material and have achieved efficiency of 16.01% .

Current-Voltage characteristics under simulated AM1.5G 100 mWcm-2 illumination



PL spectrum of $CH_3NH_3PbBr_3$ sample grown by (a) ITC method and (b) Ethyl acetate (EA) diffusion method.



We also synthesized single crystals of $CH_3NH_3PbX_3$ (X = I, Br, Cl) by four different methods (Inverse temperature crystallization (ITC), slow cooling crystallization, ethyl acetate (EA) and dichloromethane (DCM) antisolvent diffusion crystallization methods). Using temperature dependent photoluminescence (PL) and magnetization study we observe that single crystals made by EA diffusion method are of superior quality as it does not have any contributions from defect states.

Pronoy Nandi, Chandan Giri and Dinesh Topwal

4

PUBLICATIONS

4.1. Papers Published in Refereed Journals and Preprints :

1. **Macrospin in external magnetic field: Entropy production and fluctuation theorems,** Swarnali Bandopadhyay, Debasish Chaudhuri, A. M. Jayannavar ; J. Stat. Mech. P11002 (2015)

2. **Extended Fluctuation Theorems for Repeated Measurements and Feedback within Hamiltonian Framework,** S. Lahiri and A. M. Jayannavar : Physics Letters A 380, 1706 (2016)

3. **Stochastic thermodynamics of macrospins with fluctuating amplitude and di-rection,** Swarnali Bandopadhyay, Debasish Chaudhuri, A. M. Jayannavar ; Phys. Rev. E 92, 032143 (2015).

4. **Anamolous Brownian Refrigerator,** S. Rana, P. S. Pal, Arnab Saha and A. M. Jayannavar ; Physica A 444, 783 (2016)

5. **Brownian motion of classical spins : Anomalous dissipation and generalized Langevin equation,** Malay Bandyopadhyay and A. M. Jayannavar ; arXiv:1512.03511

6. **Operational characteristics of single particle heat engines and refrigerators with time asymmetric protocol,** P. S. Pal, Arnab Saha and A. M. Jayannavar ; arXiv:1601.00854

7. **Rotational diffusion under torque: Microscopic reversibility and excess entropy,** Swarnali Bandopadhyay, Debasish Chaudhuri and A. M. Jayannavar ; arXiv:1602.05008.

8. **Conductance, Valley and Spin polarization and Tunnelling magneto-resistance in ferromagnetic-normal-ferromagnetic junctions of Silicene,** Ruchi Saxena, Arijit Saha , Sumathi Rao, Phys. Rev. B 92, 245412 (2015) arXiv:1507.04225 [cond-mat]

9. **U(1) and SU(2) quantum dissipative systems: The Caldeira Leggett vs. the Amegaokar-Eckern-Schön approaches**, Alexander Shnirman, Arijit Saha, Igor S. Burmistrov, Mikhail N. Kiselev, Alexander Altland, Yuval GefenJETP Vol. 149 (3) (2016) arXiv:1508.00807.

10. **Entanglement and Majorana edge states in the Kitaev model,** Saptarshi Mandal, Moitri Maiti, and Vipin Kerala Varma, Phys. Rev. B **94**, 045421

11. **Entropy production by active particles: Coupling of odd and even functions of velocity**", D. Chaudhuri (arXiv:1605.00269).

12. **Rotational diffusion under torque: Microscopic reversibility and excess entropy**, Swarnali Bandopadhyay, D. Chaudhuri, A. M. Jayannavar (arXiv:1602.0508).

13. **Forced desorption of semiflexible polymers, adsorbed and driven by molecular motors**, Abhishek Chaudhuri, D. Chaudhuri, Soft Matter **12**, 2157 (2016).

14. **Macrospin in external magnetic field: Entropy production and fluctuation theorems**, Swarnali Bandopadhyay, Debasish Chaudhuri, A. M. Jayannavar, J. Stat. Mech.: Thoer. Expt. **2015**, P11002 (2015).

15. **Stochastic thermodynamics of macrospins with fluctuating amplitude and direction**, Swarnali Bandopadhyay, Debasish Chaudhuri, A. M. Jayannavar Phys. Rev. E **91**, 050301(R) (2015).

16. **Stochastic ratcheting of two dimensional colloids: Directed current and dynamical transi- tions**, Dipanjan Chakraborty, D. Chaudhuri, Phys. Rev. E **92**, 032143 (2015).

17. **Pumping single-file colloids: Absence of current reversal**", Debasish Chaudhuri, Archishman Raju, and Abhishek Dhar, Phys. Rev. E 91, 050103(R) (2015).

18. **COSMOS-*e*2 -GTachyon from String Theory ;** *Sayantan Choudhury, Sudhakar Panda*. : Eur.Phys.J. C76 (2016) no.5, 278

19. **Entanglement temperature with Gauss–Bonnet term ;** *Shesansu Sekhar Pal, Sudhakar Panda : N*ucl.Phys. B898 (2015) 401-414

20. **Effects of Phase Transition induced density fluctuations on pulsar dynamics**, P. Bagchi, A. Das, B. Layek, and A.M. Srivastava, Phys. Lett. B 747, 120 (2015).

21. **Reaction-diffusion equation for quark-hadron transition in heavy-ion collisions**, Partha Bagchi, Arpan Das, Srikumar Sengupta, and Ajit M. Srivastava, Phys.Rev. C 92, 034903 (2015).

22. **Possibility of formation of a disoriented chiral condensate in pp collisions at energies available at the CERN Large Hadron Collider via the reaction-diffusion equation**, Partha Bagchi, Arpan Das, Srikumar Sengupta, and Ajit M. Srivastava, arXiv:1508.07752, Phys. Rev. C. 93, 024914 (2016).

23. **Power spectrum of flow fluctuations in relativistic heavy-ion collisions**, P.S. Saumia,Ajit M. Srivastava,arXiv:1512.02136

24. **Holographic description of non-supersymmetric orbifolded D1-D5-P solutions,** By Bidisha Chakrabarty, David Turton, Amitabh Virmani. arXiv:1508.01231 [hep-th]. 10.1007/JHEP11(2015)063.

25. **Charged Vaidya Solution Satisfies Weak Energy Condition,** Soumyabrata Chatterjee, Suman Ganguli, Amitabh Virmani. arXiv:1512.02422 [gr-qc].

26. **Smooth non-extremal D1-D5-P solutions as charged gravitational instantons,** Bidisha Chakrabarty, Jorge V. Rocha, Amitabh Virmani. arXiv:1603.06799 [hep-th].

27. **Running of Neutrino Oscillation Parameters in Matter with Flavor-Diagonal Non-Standard Interactions of the Neutrino,** Sanjib Kumar Agarwalla, Yee Kao, Debashis Saha, Tatsu Takeuchi ; Journal of High Energy Physics 1511 (2015) 035 e-Print arXiv:1506.08464 [hep-ph]

28. **Exploring Flavor-Dependent Long-Range Forces in Long-Baseline Neutrino Oscillation Experiments,** Sabya Sachi Chatterjee, Arnab Dasgupta, Sanjib Kumar Agarwalla ; Journal of High Energy Physics 1512 (2015) 167, e-Print arXiv:1509.03517 [hep-ph]

29**. Discovery Potential of T2K and NO_A in the Presence of a Light Sterile Neutrino,** Sanjib Kumar Agarwalla, Sabya Sachi Chatterjee, Arnab Dasgupta, Antonio Palazzo ; Journal of High Energy Physics 1602 (2016) 111, e-Print arXiv:1601.05995 [hep-ph]

30**. Physics Reach of DUNE with a Light Sterile Neutrino,** Sanjib Kumar Agarwalla, Sabya Sachi Chatterjee, Antonio Palazzo, Submitted in Journal of High Energy Physics (JHEP), e-Print arXiv:1603.03759 [hep-ph]

31. **Search for halo structure in 37 Mg using the Glauber model and microscopic relativistic mea field densities**, Mahesh K. Sharma, R. N. Panda, Manoj K. Sharma, and S. K. Patra , Phys. Rev. C 93 (2016) 014322.

32. **Nuclear Structure study of some bubble nuclei in light mass region using mean field formalism**, R. N. Panda, M. K. Sharma and S. K. Patra . Chinese Physics C39 (2015) 064102.

33. **Examining the stability of thermally fissile Th and U isotopes**, Bharat Kumar, S. K. Biswal , S. K. Singh and S. K. Patra Phys. Rev. C 92 , 054314 (2015) [arXiv:1508.00391v2].

34. **Effects of isovector scalar δ-meson on hypernuclei**, M. Ikram, S. K. Biswal , S. K. Singh and S. K. Patra, Int. J. Mod. Phys. E 3 1550019 (2015).

35. P**roperties of superheavy nuclei: Z = 124 M**. S. Mehta, Harvinder Kaur, Bharat Kumar and S. K. Patra Phys. Rev. C 92 , 054305 (2015)[arXiv:1510.08312].

36. **Effects of NN potentials on astrophysical p-process in the A ~100-120 region,** C. Lahari, S. K. Biswal and S. K. Patra IJMPE 25 1650015 (2016).

37. **Modes of decay in neutron-rich nuclei,** Bharat Kumar , S. K. Biswal, S. K. Singh, Chirashree Lahiri, and S. K. Patra IJMP E 25 (2016) 1650020[arXiv:1602.08871].

38. **Study of superdeformed state of nuclei in Z = 70 80 drip-line region**, S. Mahapatro, C. Lahiri, Bharat Kumar , and S. K. Patra Accepted IJMP E [arXiv:1512.04665v1].

39**. Hybrid compact star in the prsence of strong magnetic field,** Mohanta, K. K., Panda, N. R. and Sahu, P. K: (2015), int. Jour. Mod. Phys. E 24 (2015) 1550096.

40. **Radial modes of oscillations of slowly rotating magnetized compactb stars,** Panda, N. R., Mohanta, K. K. and Sahu, P. K. (2015), Journal of Physics: Conference Series ,599 (2015) 012036.

41. **Maximum masses and radial oscillation of hybrid stars in presence of strong magnetic fields,** Panda, N. R., Mohanta, K. K. and Sahu, P. K.(2015), Proceedings of the Indian National Science Academy, 81, No. 1 February Special Issue 2015 pp. 256-266},

42. **Proton decay and new contribution to neutrino-less double beta decay in SO(10) with low-mass Z-prime boson, observable n-nbar oscillation, lepton flavor violation, and rare kaon decay,** Parida, M. K., Awasthi, R. L., and Sahu, P. K. (2015), arXiv:1401.1412; JHEP 1501 (2015) 045.

ALICE Collaboration ***(Publication No. 36 - 62)*** **:**

43. **Event shape engineering for inclusive spectra and elliptic flow in Pb-Pb collisions at sNN=2.76 TeV,** Phys. Rev. C 93 (2016)

44. **Centrality dependence of the nuclear modification factor of charged pions, kaons, and protons in Pb-Pb collisions at sNN=2.76 TeV,** Phys. Rev. C 93 (2016)

45. **Transverse momentum dependence of D-meson production in Pb-Pb collisions at sNN=2.76 TeV,** JHEP 03 (2016)

46. **Measurement of Ds+ production and nuclear modification factor in Pb-Pb collisions at sNN=2.76 TeV,** JHEP 03 (2016) 082

47. **Multipion Bose-Einstein correlations in pp, p-Pb, and Pb-Pb collisions at the LHC**, Phys. Rev. C 93 (2016) 054908

48. **Production of light nuclei and anti-nuclei in pp and Pb-Pb collisions at LHC energies**, Phys. Rev. C 93 (2015) 024917

49. **Multiplicity and transverse momentum evolution of charge-dependent correlations in pp, p-Pb, and Pb-Pb collisions at the LHC** , Eur. Phys. J. C 76 (2016) 2.76 TeV

50. **Centrality dependence of pion freeze-out radii in Pb-Pb collisions at sNN=2.76 TeV** , Phys. Rev. C 93 (2016) 024905

51. **Direct photon production in Pb-Pb collisions at sNN = 2.76 TeV** , Phys. Lett. B 754 (2016) 235-248

52. **Forward-central two-particle correlations in p-Pb collisions at sNN = 5.02 TeV,** Phys. Lett. B 753 (2016) 126-139.

53. **Centrality evolution of the charged-particle pseudorapidity density over a broad pseudorapidity range in Pb-Pb collisions at sNN = 2.76 TeV** , Phys. Lett. B 754 (2016) 373-385

54. **Λ3H and Λ 3H> production in Pb-Pb collisions at sNN = 2.76 TeV**, Phys. Lett. B 754 (2016) 360-372

55. **Study of cosmic ray events with high muon multiplicity using the ALICE detector at the CERN Large Hadron Collider** , JCAP 01 (2016) 032

56. **Measurement of electrons from heavy-flavour hadron decays in p-Pb collisions at sNN=5.02 TeV** , ALICE Collaboration (P. K. Sahu from IOP), Phys. Lett. B 754 (2016) 81-93

57. **Azimuthal anisotropy of charged jet production in sNN = 2.76 TeV Pb-Pb collisions** , Phys.Lett. B 753 (2016) 511-525

58. **Pseudorapidity and transverse-momentum distributions of charged particles in proton-proton collisions at s = 13 TeV,** Phys. Lett. B 753 (2016) 319-329

59. **Elliptic flow of muons from heavy-flavour hadron decays at forward rapidity in Pb-Pb collisions at sNN=2.76 TeV** , Phys. Lett. B 753 (2016) 41-56

60. **Centrality dependence of high-pT D meson suppression in Pb-Pb collisions at sNN = 2.76 TeV,** JHEP 11 (2015) 205

61. **One-dimensional pion, kaon, and proton femtoscopy in Pb-Pb collisions at sNN =2.76 TeV** , Phys. Rev. C 92 (2015) 054908

62. **Centrality dependence of inclusive J/ψ production in p-Pb collisions at sNN = 5.02 TeV,** JHEP 11 (2015) 127

63. **Coherent ψ(2S) photo-production in ultra-peripheral Pb-Pb collisions at sNN = 2.76 TeV,** Phys. Lett. B 751 (2015) 358-370

64. **Measurement of jet quenching with semi-inclusive hadron-jet distributions in central Pb-Pb collisions at sNN = 2.76 TeV,** JHEP 09 (2015) 170

65. **Measurement of charm and beauty production at central rapidity versus charged-particle multiplicity in proton-proton collisions at s=7 TeV** , JHEP 09 (2015) 148

66. **Coherent ρ0 photoproduction in ultra-peripheral Pb-Pb collisions at sNN=2.76 TeV,** .JHEP 09 (2015) 095

67. **Precision measurement of the mass difference between light nuclei and anti-nuclei,** Nature Physics 11 (2015) 811-814

68. **Measurement of charged jet production cross sections and nuclear modification in p-Pb collisions at sNN=5.02 TeV,** Phys. Lett. B 749 (2015) 68-81

69. **Inclusive, prompt and non-prompt J/ψ production at mid-rapidity in Pb-Pb collisions at sNN = 2.76 TeV** , JHEP 07 (2015) 051

70. **Elliptic flow of identified hadrons in Pb-Pb collisions at sNN = 2.76 TeV,** JHEP 06 (2015) 190

71. **Charged jet cross sections and properties in proton-proton collisions at s=7 TeV,** Phys. Rev. D 91 (2015) 112012

72. **Rapidity and transverse-momentum dependence of the inclusive J/ψ nuclear modification factor in p-Pb collisions at sNN=5.02 TeV,** JHEP 06 (2015) 55

73. **Centrality dependence of particle production in p-Pb collisions at sNN= 5.02 TeV,** Phys. Rev. C 91 (2015) 064905

74. **Measurement of pion, kaon and proton production in proton-proton collisions at s=7 TeV,** EPJC 75 (2015) 226

75. **Forward-backward multiplicity correlations in pp collisions at s=0.9, 2.76 and 7 TeV,** JHEP 05 (2015) 097

76. **Measurement of dijet kT in p-Pb collisions at sNN=5.02 TeV,** Phys. Lett. B 746 (2015) 385

77. **Measurement of jet suppression in central Pb-Pb collisions at sNN = 2.76 TeV,** .ALICE Collaboration (P. K. Sahu from IOP), Phys. Lett. B 746 (2015).

78. **Inclusive photon production at forward rapidities in proton-proton collisions at s = 0.9, 2.76 and 7 TeV** , EPJC 75 (2015) 146

STAR Collaboration ***(Publication No. 63 -74)*** **:**

79. **Azimuthal anisotropy in U+U and Au+Au collisions at RHIC,** Phys. Rev. Lett. 115 (2015) 222301

80. **Observation of charge asymmetry dependence of pion elliptic flow and the possible chiral magnetic wave in heavy-ion collisions** , Phys. Rev. Lett. 114 (2015) 252302

81. **Measurements of Dielectron Production in Au+Au Collisions at sqrt(sNN) = 200 GeV from the STAR Experiment,** Phys. Rev. C 92 (2015) 24912

82. **Observation of Transverse Spin-Dependent Azimuthal Correlations of Charged Pion Pairs in p+p at sqrt(s)=200 GeV,** Phys. Rev. Lett. 115 (2015) 242501

83. **Long-range pseudorapidity dihadron correlations in d+Au collisions at sqrt(sNN)=200 GeV**, Phys. Lett. B 747 (2015) 265

84. **J/psi production at low transverse momentum in p+p and d+Au collisions at sqrt(sNN)=200GeV,** Phys. Rev. C 93 (2016) 64904

85. **Beam Energy Dependence of the Third Harmonic of Azimuthal Correlations in Au+Au Collisions at RHIC**, Phys. Rev. Lett. 116 (2016) 112302

86. **Measurement of the transverse single-spin asymmetry in p+p -> W±/Z0 at RHIC**, S Phys. Rev. Lett. 116 (2016) 132301

87. **Centrality dependence of identified particle elliptic flow in relativistic heavy ion collisions at sqrt(sNN)= 7.7-62.4 GeV**, Phys. Rev. C 93 (2016) 14907

88. **Measurement of interaction between antiprotons** , Nature 527 (2015) 345

89. **Centrality and transverse momentum dependence of elliptic flow of multi-strange hadrons and phi meson in Au+Au collisions at sqrt(s_NN) = 200 GeV,** Phys. Rev. Lett. 116 (2016) 62301

90. **Probing Parton Dynamics of QCD Matter with Omega and Phi Production**, Phys. Rev. C 93 (2016) 21903

91. **Performance of reconstruction and identification of tau leptons in their decays to hadrons and neutrino in LHC Run-2**, A. Nayak et al,CMS Collaboration, CMS-PAS-16-002.

92. **Multivariate τ-identification algorithms for 13 TeV data,** A. Nayak et al, CMS-AN-2015/310.

93. **Tau reconstruction and identification performance in run 2**, A. Nayak et al,CMS-AN-2015/229

94. **Kinetic Monte Carlo simulations of self organized nanostructures on Ta Surface Fabricated by Low Energy Ion Sputtering**, Shalik R. Joshi, Trilochan Bagarti, and Shikha Varma, Surf. Sci. 641 (2015) 170.

95. **Ion beam induced Chemical and Morphological changes in TiO2 films deposited on Si(111) Surface** Rashmi R Mohanta, Venkata Rama Rao Medicherla, Kamal L Mohanta, Nimai C Nayak, Subrata Majumder, Vanaraj Solanki, Shikha Varma, D M Phase, V Sathe, Appl. Surf. Sci., 325 (2015) 185.

96. **Enhancement of thermoelectric power of PbTe:Ag nanocomposite thin films** Manju Bala, S. Gupta, T. S. Tripathi, Shikha Varma, Surya K. Tripathi, K. Asokan and D. K. Avasthi, Royal Soc. Chem. Adv., 5 (2015) 25887.

97. **Surface Modification of poly(dimethylsiloxane) through Oxygen and Nitrogen Plasma Treament to Improve its Characteristics towards Biomedical Applications**. N. Gomathi, Indrani Mishra, Shikha Varma and S. Neogi, Surface Topography: Metrology and Properties 3 (2015) 035005.

98. **Room temperature Superparamagnetism in rutile TiO2 quantum dots produced via ECR sputtering,** V. Solanki, I. Mishra, S.R. Joshi, P. Mishra, P. Dash, N.C. Mishra, D. Kanjilal and Shikha Varma, Nucl. Instr. Res. Meth. B, 365 (2015) 82.

99. **Formation of nanodots and enhancement of thermoelectric power induced by ion irradiation in PbTe:Ag composite thin films**, Manju Bala, R. Meena, Srashti Gupta, Compesh Pannua, Tripurari S Tripathi, Shikha Varma, Surya K Tripathi, K. Asokan, D.K. Avasthi, Nucl. Instru. Meth. B.

100**. Silver Endotaxial Structures and Their Applications**, A. Bhukta, P. Guha, A. Ghosh, Paramita Maiti, P. V. Satyam, *Appl. Phys A* ***122*** *(2016) 356 p*

101**. Growth of Ag nanostructures on high-index Si (5 5 12) surfaces under UHV conditions: effect of prior surface treatment before deposition** ; R. R. Juluri, A. Ghosh, A. Bhukta, R. Sathyavathi and P. V. Satyam, *Thin Solid Films* ***586,*** *(2015) 88 p*

102**. Bimetallic Structures grown on high index substrates in using MBE conditions:** Arnab Ghosh , Puspendu Guha, Ranjit Thapa , Sinthika Selvaraj, Mohit Kumar, Bipul Rakshit, Tapan Dash, Rajshekhar Bar, Samit K Ray and P. V. Satyam, *Nanotechnology* ***27*** *(2016) 125701 p*

103**. Tuning the work function of randomly oriented ZnO nanostructures by capping with faceted Au nanostructure and oxygen defects: enhanced field emission experiments and DFT studies** ; A Ghosh, P Guha, AK Samantara, BK Jena, R Bar, SK Ray, PV Satyam, *ACS applied materials & interfaces 8 (2016), 2879 p .*

104**. Growth of Au capped GeO2 nanowires for visible-light photodetection** ; Reetu Kumari, Lucky Krishnia, Vinay Kumar, Sandeep Singh, H. K. Singh, R. K. Kotnala, R. R. Juluri, U. M. Bhatta, P. V. Satyam, Brajesh S. Yadav, Zainab Naqvi and Pawan K. Tyagi, *Nanoscale 8 (2016) 4299 p*

105**. Adsorption of Ru, Ce and Eu radionuclides within naturally precipitated polycrystalline calcium carbonate under acidic environment** ; Pawan K. Tyagi, Reetu Kumari, Umananda M. Bhatta, Raghavendra Rao Juluri, Ashutosh Rath, Sanjeev Kumar, P.V. Satyam, Subodh K. Gautam, Fouran Singh *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms,* ***379*** *(2016) 181 p*

106. **Fe_3C-filled carbon nanotubes: permanent cylindrical nanomagnets possessing exotic magnetic properties**; Jaishri Sanwal, Nilesh L. Dudwadkar, Arun Thirumurugan, Subhash C. Tripathi, P. M. Gandhi, P. V. Satyam, Pranesh Sengupta, *Journal of Radioanalytical and Nuclear Chemistry* ***309*** *(2016) 751p*

107. **Potential application of carbon nanotube core as nanocontainer and nanoreactor for the encapsulated nanomaterial** ; Sridhar Sanyasi, Rakesh Kumar Majhi, Satish Kumar, Mitali Mishra, Arnab Ghosh, Mrutyunjay Suar, Parlapalli Venkata Satyam, Harapriya Mohapatra, Chandan Goswami, and Luna Goswamib
Sci Rep. 6 (2016) 24929 p

108. **The influence of surface topography on the field emission of nanostructured copper oxide thin films grown by oblique incidence deposition:** S. Chatterjee, M. Kumar, A. Pal, I. Thakur, and T. Som J. Mater. Chem. C 3 (2015) 6389.

109. **Structural defect-dependent resistive switching in Cu-O/Si studied by Kelvin probe force microscopy and conductive atomic force microscopy:** Mohit Kumar and T. Som Nanotechnology 26 (2015) 345702.

110. **Ultra-violet absorption induced modifications in bulk and nanoscale electrical transport properties of Al-doped ZnO thin films:** M. Kumar, T. Basu, and T. Som, J. Appl. Phys. 118 (2015) 055102.

111. **Thickness-dependent blue shift in the excitonic peak of conformally grown ZnO: Al on ion-beam fabricated self-organized Si ripples:** T. Basu, M. Kumar, S. Nandy, B. Satpati, and T. Som J. Appl. Phys. 118 (2015) 104903.

112. **Role of metallic-like conductivity in unusual temperature-dependent transport in n-ZnO:Al/p-Si heterojunction diode:** Mohit Kumar, S. K. Hazra, and T. Som J. Phys. D: Applied Phys. 48 (2015) 455301.

113. **Temperature dependent dual hydrogen sensor response of Pd nanoparticle decorated Al doped ZnO surfaces:** D. Gupta, D. Dutta, M. Kumar, P. B. Barman, T. Som, S. K. Hazra J. Appl. Phys. 118 (2015) 164501.

114. **Statistical analysis of ripple morphology on Si surfaces due to 60 keV Ar^+-ions:** S.K. Garg, D.P. Datta, T. Basu, D. Kanjilal, and T. Som Surf. Topogr.: Metrol. Props. 4 (2015) 015002.

115**. Temporal evolution of Ge surface topography under keV ion irradiation: Combined effects of curvature-dependent sputter erosion and atomic redistribution:** D.P. Datta, S.K. Garg, T. Basu, B. Satpati, H. Hofsäss, D. Kanjilal, and T. Som Appl. Surf. Sci. 360 (2016) 131.

116. **Nanocomposite synthesis and photoluminescence properties of MeV Au-ion beam modified Ni thin films:** V. Siva, D.P. Datta, A. Singh, T Som, and P.K. Sahoo, Appl. Surf. Sci. 360 (2015) 276.

117**. Local probe microscopic studies on Al-doped ZnO: Pseudoferroelectricity and band bending at grain boundaries:** M. Kumar, T. Basu, and T. Som J. Appl. Phys. 119 (2016) 014307.

118. **Temporal evolution of a silicon surface subject to low energy ion irradiation and concurrent sample rotation:** Tanmoy Basu, Daniel A. Pearson, R. M. Bradley, and **Tapobrata Som** Appl. Surf. Sci. (In press).

119. **Self-decorated Au nanoparticles on antireflective Si pyramids with improved hydrophobicity:** J. Appl. Phys. Chetan Prakash Saini, Arabinda Barman, Mohit Kumar, Biswarup Satpati, T. Som, and Aloke Kanjilal, J. Appl. Phys..

120. **Cold Cathode Emission Studies on Topographically Modified Few Layer and Single Layer MoS_2 Films,** A.P.S. Gaur, Satyaprakash Sahoo, F. Mendoza, A. M. Rivera, M. Kumar, S.P. Dash, G. Morell and R. S. Katiyar, Appl. Phys. Lett. 108, 043103 (2016).

121. **Studies on chemical charge doping related optical properties in monolayer WS_2**, A. M. Rivera, A. P. S. Gaur, Satyaprakash Sahoo, and R. S. Katiyar (accepted) J. Appl. Phys. (2016).

122. **Spin-polarized tunneling through chemical vapor deposited multilayer molybdenum di-sulphide**, A. Dankert, P. Pashaei, M.D. A. Hoque, M. V. Kamalakarand, S. P. Dash, A. P.S. Gaur, R. S. Katiyar, Satyaprakash Sahoo, M. P. de Jong, I. Rungger, A. Narayan, K. Dolui, S. Sanvito .

123. **A Short Review on Physico-Chemical Properties of *Bacopa monnieri* L,** S. Behera, B. Mallick, T. N. Tiwari and P. C. Mishra, , *Int. J. Medi. Plants.* Photon, *Int. J. Medici. Plant. Photon*, 110, 735-741, 2016.

124. **Risk of Acid Attack on Plants: A Review,** S. Behera, B. Mallick, T. N. Tiwari, and P. C. Mishra, *Energy. Env. Mat. Sci*. 43, 66-71, 2015.

125. **X-ray Diffraction Analysis of Polymeric Solid using Bragg-Brentano Geometry,** B. Mallick, *Int. J. Mat. Chem. Phys.* 1(3), 265-270, 2015.

126. **Proc. of Workshop on the use of Low Energy Ion Beams** , B. Mallick, External-Ion Beam Facility at Institute of Physics, Bhubaneswar, (WIB-2015), November 7-9, 2015.

127. **Designing of Shielding and Collimator for High-Energy X-ray Beam: Application to 3MV Tandem Pelletron based HEX-Ray Spectrometry,** B. Mallick and K. S. Jena, *Proc. Indian Particle Accelerator Conference* (InPAC- 2016), December 21-24, 2015.

128. **Process tomography via sequential measurements on a single quantum system** H. Bassa, S. K. Goyal, Sujit K. Choudhary, H. Uys, L. Diosi and T. Konrad, Journal: Physical Review A **92**, 032102 (2015).

129. **Quantum nonlocality via local contextuality with qubit-qubit entanglement,** D. Saha, A. Cabello, Sujit K. Choudhary and M. Pawlowski, Journal: Physical Review A **93**, 042123 (2016).

130. **Temporal correlations and device-independent randomness,** S. Mal, M. Banik and Sujit K. Choudhary, Journal: Quantum Information Processing (Springer), DOI: 10.1007/s11128-016-1321-0

131. **Spin filtering and switching action in a diamond network with magnetic-nonmagnetic atomic distribution**, Biplab Pal, Paramita Dutta arXiv:1605.05515.

132. **Transport and noise properties of a normal metal-superconductor-normal metal junction with mixed singlet and chiral triplet pairings**, Ganesh C. Paul, Paramita Dutta, Arijit Saha arXiv:1606.06270

133. **Aharonov-Bohm effect in a helical ring with long-range hopping: Effects of Rashba spin-orbit interaction and disorder**, Paramita Dutta, Arijit Saha, A. M. Jayannavar arXiv:1606.07423

134. **Asymmetric band gaps in a Rashba film system ;** C. Carbone, P. Moras, P. M. Sheverdyaeva, D. Pacilé, M. Papagno, L. Ferrari, D. Topwal, E. Vescovo, G. Bihlmayer, F. Freimuth, Y. Mokrousov, and S. Blügel Phys. Rev. B **93**, 125409 (2016)

135. **Expansion of a Discrete [3 × 3] Mn9 Metallogrid to a ì-Carboxylato-Bridged Polymeric {Mn11}n Assembly ;** Avinash Lakma,Sayed Muktar Hossain,(Rabindra Nath Pradhan, D. Topwal Andrea Cornia,(Akhilesh Kumar Singh European Journal of inorganic Chemistry, 18, 2993–2999 (2016)

136. **Ion irradiation induced phase transition of Co in Co/Au multilayers ;** Vantari Siva, Siddharth S. Sahu, D.P. Datta, P.C. Pradhan, M. Nayak, V. Solanki, D. Topwal, Kartik Senapati , Pratap K. Sahoo, Journal of alloys and compounds, 680, 722 (2016)

137. **Giant magnetocaloric effect in Gd_2NiMnO_6 and Gd_2CoMnO_6 ferromagnetic insulators ;** J. Krishna Murthy, K. Devi Chandrasekhar, Sudipta Mahana, D. Topwal, A. Venimadhav, J Phy D Appl Phys, 48 355001 (2015)

138. **Quantum confinement effects in low-dimensional systems;** D. Topwal, Pramana - J Phys, 84, 1023 (2015)

5

CELEBRATION OF 40TH YEAR OF ACADEMIC ACTIVITIES

5.1 COLLOQUIUM FEST
13th to 23rd April, 2015

Phases of Nuclear Matter

Matter around us exists in distinct forms, like solid, liquid, gas, and a fourth state called the plasma. Nuclear matter, similarly, exists in different phases under different thermodynamic conditions. The nucleus in its normal state exhibits liquid-like characteristics, but when heated up, the nucleus goes through a transition to a gaseous state. Further increase of heat results in extreme high temperature and high energy density conditions of the nuclear matter, where a system of deconfined quarks and gluons, the Quark-Gluon Plasma (QGP), is formed. The QGP state is relevant to understanding the origin of the Universe and how matter behaved immediately after the Big Bang. The phase diagram of nuclear matter spans a vast region of temperature and baryon density. Exploring the QCD phase transition is one of the major goals of dedicated experiments at RHIC and LHC. This task presented the experimental programs with heavy-ion collisions at ultra-relativistic energies and discussed the recent results.

Prof. Tapan K. Nayak, VECC

Hundred Years of Fundamental Physics and a Crisis.

One hundred years of Fundamental Physics have culminated in a theory called Standard Model of High Energy Physics. This theory is now known to be the basis of almost ALL OF KNOWN PHYSICS except gravity. The discovery of the Higgs Boson in 2012 has established this theory. An elementary account of this theory will be given in the first part of the talk. However gravitational force has been left out in this theory. The energy scale of quantum gravity is 16 orders of magnitude higher than the presently accessible TeV energies. This is a Crisis in Fundamental Physics that can be met only by the discovery of new principles of acceleration. The second part of the talk will highlight this theme.

Prof. G.Rajasekaran, IMSc., Chennai

100 years of General relativity — a journey beyond Einstein's gravity

In 1915 Einstein proposed a revolutionary concept, The general theory of relativity, which resulted into a paradigm shift in our understanding of the theory of force of gravitation as formulated by Newton several hundred years before. Since then there have been numerous efforts to look beyond Einstein's theory inspired by either phenomenological motivations or theoretical motivations like the formulation of a consistent quantum theory of gravity and/or geometrical origin of electromagnetic force etc. After a brief introduction on General Relativity some of the alternative ideas developed over last 100 years which take us beyond the realm of General Relativity were presented.

Prof. Soumitra Sengupta, IACS, Kolkata

Mathematics as the language of Nature- a historical view

This Colloquium reviewed in historical terms the changing relationship between mathematics and modern science over the past four centuries. Focussing on physics, it started with the establishment of the Galilean - Newtonian tradition in science. Two phases in the mathematics - physics relationship were described : an earlier one with progress in each going hand in hand with the other; and a later one with new mathematical concepts finding use in physics after a few decades. Instances of mathematical formulations of new physical laws coming well before physical understanding were highlighted. Some lessons that could be drawn about the roles of mathematics in the description of physical phenomena, and ideas about the nature of mathematics itself, were discussed against the background of Kantian ideas on the nature of human knowledge . The depth of the connection between the two was emphasized and illustrated with quotations from the masters

Prof. N. Mukunda, IISc.,Bangalore

Accelerator Development in India: Status and Future Perspectives

History of Accelerators in India goes back to the development of a 37 inch cyclotron at the Calcutta based Institute of Nuclear Physics in 1940's by Prof. Meghnad Saha. The accelerator technology in India took a great leap in 1978 when an indigenously designed and built 224 cm diameter Variable Energy Cyclotron was made operational at Calcutta. Past two decades mark an upsurge of accelerator development in the country that has resulted in growth of expertise in the relevant technologies. This has enabled Indian scientists and engineers to take up several challenging accelerator projects for construction in the country as well as participate in design and construction of some major international accelerator projects.

Prof. Amit Roy, VECC, Kolkata

***B*ackground Independence and its implications**

The demand of background independence is met in Loop Quantum Gravity which has an unusual Hilbert space. Geometrical operators such as area, volume, defined on this Hilbert space have discrete spectra. The geometry also reveals non-commutative features. Adapted to the simplest cosmological model, it resolves the singularity. Generically, for matter fields too, the Hilbert space carries a discontinuous ('polymer') representation of the Weyl commutation relations. This has implications for realization of continuous symmetries. Some recent and ongoing works were described based on the above mentioned arguments.

Prof. G. Date

Active Matter and Nuclear Physics

In recent years, there has been a revolution in our ability to model a variety of biophysical processes in living cells. These developments have their roots in non-equilibrium statistical mechanics and soft matter physics and are referred to as "active matter" approaches. After introducing the field of active matter, I will summarize work from my group and collaborators which uses such ideas to model the large-scale properties of chromosomes contained in the nuclei of living cells. Our work addresses several long-standing questions in the field, among them questions of why chromosomes are positioned non-randomly

within nuclei, why chromosomes form individual "territories" in the nucleus (an observation first made over a hundred years ago) and why chromosomes "reposition" when the DNA they contain is damaged. I hope to illustrate, through examples, how the interaction of biology and physics at a quantitative level enriches both fields. The talk will avoid jargon as much as possible and should be accessible to a wide audience.

Prof. Goutam Menon, IMSc., Chennai

Nuclei, Random Matrices and Chaos

A statistical framework for nuclear spectroscopy and strengths for nuclear excitations and decays, known as the spectral distribution theory, has been developed over the years built on ideas of random matrix theory in shell model spaces. Some of the fluctuation properties of the random matrix ensembles considered, were established as signatures for quantum chaotic many-body systems. With a general introduction to this, the talk will describe the methodology of the spectral distribution theory and its applications to nuclear proper ties. The results will be compared to experimental values as well as to shell model predictions.

Prof. Kamalesh Kar, SINP

Geometrically Frustrated Anti-ferro-magnets

Some insulating solids contain magnetic moments (spins) on a regular lattice of sites. These are formed when electron-electron interaction effects cause electrons to become localized instead of moving freely like they do inside a metal. These spins predominantly interact with each other via antiferromagnetic 'exchange' interactions between neighbours, which typically cause the spins to freeze into an antiferromagnetically ordered state at low temperature. However, if the geometry of the lattice forces various exchange interactions to compete with each other, the spins can

Prof. Kedar Damle, TIFR, Mumbai

5.2. School Teachers'S Program 4th to 8th May, 2015

First meeting in the 40th year of academic activities of IOP, was on a program where in the faculties from IOP, NISER and IIT-Bhubaneswar interacted with the selected teachers from various schools (17 in numbers) in and around Bhubaneswar, such as, KV - 01, 02, 03, 04 , DAV - 01, 02, 03,04. DM School, State Schools - 01, 02, DPS Kalinga, Loyola school, Sai International, St Xavier High School, Mothers Public School, Prabhuji School and BJP College, etc.. About 60 teachers participated in the program. The teachers listened to the talks given in the morning and visited laboratories in IOP for 3 days and one day in NISER and another day in IIT-Bhubaneswar.

Teachers visited various advanced experimental facilities and interacted with eminent scientists of IOP. This program was also a part of social responsibility of the Institute.

5.3. Nuclear Physics Meet – 2016 (NPM - 2015) 26th to 30th June, 2015

Recently many new phenomena such as exotic and superheavy nuclei, relation of finite nuclei observable with the astrophysical objects and many such interesting phenomena have attracted attention of nuclear physics comunity. These have further led to new questions about the structure and their application etc., that need to be answered. Hence, more than ever, there is a strong need for discussions and sharing of new ideas, through meetings of experts and researchers from different areas of nuclear physics. This meeting has the modest aim of achieving the same. Also, special focus was on exposing young researchers and students to the works and achievements of senior scientists.

In this conference about 51 physicists participated from all over the country. A three days collaboration meeting with IOP, Utkal University, IIT Bhubaneswar, NISER Bhubaneswar and IISER Kolkata, was organized soon after the Nuclear physics meet, where about 80 physicists participated.

5.4. ALICE India Meet 2015 at IOP 22nd to 24th July, 2015

There were 80 participants from all over India (IIT- Mumbai, IIT- Indore, VECC-Kolkata, Bose Institute-Kolkata, Gauhati University-Assam, Aligarha Muslim University, Punjab university, Rajastan University, Jammu University, NISER-Bhubaneswar, IOP-Bhubaneswar and CERN-Switzerland. There were presentations from almost all participants. We discussed our present analysis reports, detector developments and list of future tasks.

5.5. YRC 2016 (Young Researchers Conference) 28th to 30th September, 2016

The string theory group of the Institute of Physics organized the Young Researchers Conference as part of the celebrations of 40 years of academic activities of the Institute. The main focus of the workshop was to bring together young researchers from various institutes in India and to have a lively discussion. Some of the most important and emerging topics in string theory were discussed from participants from all over India. The main focus of the conference was on Gravity, Gauge Gravity Correspondence and String Theory.

Particular care was been taken in selecting the speakers of the conference. Several young scientists of various renowned Institute/ Universities in India were invited. The workshop presented presentations on the topics ranging from S-matrix, Cosmology, AdS/CFT, Higher Spin theories, Gravitational Thermodynamics, Fuzzballs, etc. The overall response and enthusiasm of the participants was noteworthy. The workshop was succesful in achieving its goal to connect the young and aspiring researchers of the country. We were careful in selecting speakers so that researchers from various new institutes get to speak at our conference. A special colloqium was arranged by Prof A P Balachandran of Syracuse University, USA. The topics of the colloquium was "Algebraic Quantum Physics". The interest and the response of the audience in the colloqium was remarkable. The colloqium was followed by the conference dinner. A brief description of the worpshop is as follows. Speakers of the Workshop: Total Number of Participants: There were approximately 30 participants. Among these 15 were outside participants and 15 were local participants from various academic Institutes and Universities in Bhubaneswar.

5.6. COSMOASTRO15 30th October to 5th November, 2015

A discussion meeting on Cosmology and Astroparticle physics was organized by the Institute of Physics in collaboration with Physics Dept. Utkal University, Bhubaneswar. The meeting was held during 30th October to 5th November 2015 at the Institute of physics, Bhubaneswar. The theme of the discussion meeting covered the most important and latest results in Astroparticle physics and Cosmology. Special focus was on various aspects of inflationary physics as well as on precision data on cosmic microwave background radiation from Planck for temperature fluctuations as well as polarization which has driven tremendous amount of research in the frontier areas of cosmology and astro-particle physics.

As the community working in this general area in India is relatively small, and sparsely distributed, the purpose of the discussion meeting was to bring some of the practitioners of the field together, in an atmosphere which can provide opportunity for intensive discussions. There were relatively few talks arranged which allowed time for extensive and in-depth discussions. This format was indeed of tremendous benefit to students/postdocs working in this area, and also facilitated interchange of ideas between people working on different aspects in this general area.

5.7. Workshop on the Use of Low Energy Ion Beams
7th to 9th November, 2015

The meeting provided a platform for scientists, students and other faculty working in the area of low energy ion beams for Physics, Materials Science, Chemistry, Biology, Geology, Mineralogy, Medicine, Earth sciences, etc. There were 33 invited talks mostly from within India. Prof. V.S. Ramamurthy (former Secretary, DST and Director, IOP) and presented a Keynote Address emphasizing the multi-faceted use of the low energy ion beams. Prof. D. Kanjilal (Director, IUAC, New Delhi) presented overview of accelerator facilities in India and in particular about the facilities at IUAC, New Delhi. Prof. A. K. Sinha, Director, UGC-DAE-CSR, Indore talked about the initiative taken by his Institute in supporting accelerator users through the sponsored projects by his Institute. He suggested to take a lead role in implementation of microbeam line facility at IOP accelerator. Prof. Stephen Donnelley, University of Huddersfield, UK gave a talk on insitu TEM and Ion Beam studies. Prof. B. N. Dev presented a overall all use of ion beam facilities for materials analysis. From IOP, Prof. S. Varma, Prof. P. V. Satyam and Prof. T. Som presented on various applications of ion beams. Besides, these talks, there were 25 talks from members of various other Institutes and Universities all over India.

5.8. Int. School and Conference on Quantum Information - 16
9th to 18th February, 2016

The International School and Conference on Quantum Information was held at Institute of Physics (IOP), Bhubaneswar during Feb 9-18, 2016. It had two parts. First was a five-day school from February 9-13, 2016 followed by a conference from February 15-18, 2016. The school was for those who are new to the field of quantum information, while conference exposed students to the frontier area topics. One of the major goals of the meeting was to bring together quantum physicists, computer scientists and mathematicians to discuss the current status of the field.

5.9. Emerging trends in Advanced Functional Materials – 16 (ETAFM 2016) 18th January – 21st January, 2016

ETAFM was organized from 18th – 21st January 2016 to highlight the importance of material science and growing demand of the society for smarter and multifunctional materials. About 30 invited speakers and experts from various fields (national and international) provided a

comprehensive overview of cutting edge research in various topics like:

- Magnetism and magnetic materials
- Topological insulators
- Low dimensional systems/Nanomaterials
- Thermoelectrics, Dielectrics, Ferroelectrics
- Superconductivity, etc.

The Director of IOP, Prof Sudhakar Panda inaugurated the conference along with the key note speaker of the conference Prof. D. D. Sarma who is one of the most distinguished condensed matter physicist of our country having several national and international laurels to his credit. Further, stalwarts like Prof. S. D. Mahanti, Prof. P. Jena, etc. also graced the occasion.

The scope and objective of the conference was to provide a platform to the young researchers to discuss recent advancements in condensed matter and material science. This conference was one of the largest conferences organized under the banner of 40th year of academic activities celebration with about 100 Ph. D. students and postdoctoral scholars from various parts of India and about 30 eminent speakers attending the conference. Most of the participants presented their research work through oral presentations and posters sessions. To encourage competitive research environment jury comprising of invited speakers selected 5 best posters out of 75.

As a part of the conference a cultural evening was organized at IOP auditorium showcasing the rich culture of Odisha in terms of Odyssey and Sambalpuri dance. Also, a trip to Konark temple and Chandrabhaga beach was organized. Further from the sponsorship money generated from this conference LCD projector and sound system was procured.

5.10. CONDMAT-2016
22nd to 27th February, 2016

About the Workshop: The condensed matter theory group of the Institute of Physics has organised the above Workshop as a part of celebration of 40th year academic activities of the Institute. The main focus of this workshop was to present a pedagogical overview or understanding some of the most important and emerging topics in condensed matter physics to young researchers all over India. This workshop was aimed also to encourage them to pursue their future research career in those

frontier topics. Various topics that has been discussed in the workshop are the following:

(1) Introduction to Topological Insulator
(2) Physics of Majorana fermions
(3) Frustrated Magnetism
(4) Disordered Physics
(5) Mott Phenomen

Particular care has been taken in selecting the speakers of the workshop which has witnessed a perfect blend of senior professors as well as young scientists of various renowned Institute/ Universities in India. The workshop has presented theoretical as well as experimental aspects of the topics mentioned above. The overall response and enthusiasm of the participants was noteworthy and we were quit hopeful that the workshop was successful in achieving its target to make the bridges between the young and aspiring researchers and the established academicians of our country.

We were careful in selecting the participants as well so that students from various lesser known universities can also get opportunity to attend the workshop and get acquainted with these frontier topics. A special colloquium was arranged on 24/02/2016 which was delivered by Prof G. Baskaran from IMSc, Chennai. The topics of the colloquium was "There is room for room temperature superconductivity". The interest and the response of the audience in the colloquium was remarkable.

5.11. Seminar series in Complex Systems

14th to 24th March, 2016

The seminar series held between 14th to 24th March, 2016 was aimed at bringing together experts from all over India working on various aspects of the multidisciplinary area of Complex Systems. The main goal of the seminar series was to give broad overview of this active field of research to local participants, from Institute of Physics, and neighboring academic institutes like NISER and IIT Bhubaneswar. The list of speakers included biologists, statistical physicists, soft condensed matter physicists, covering experimental and theoretical aspects of this challenging multidisciplinary area. Some key topics covered included (a) physical processes in bacterial cytoskeleton, (b) biological membrane, (c) epithelial tissue growth and dynamics, (d) active mechano-chemical coupling in cell biology, (e) mechanical properties of solids and disordered material, (e) dynamic pattern formation, (f) molecular motors, (g) cell division, (h) active hydrodynamics, (i) modeling infectious diseases, (j) non-equilibrium statistical mechanics etc. In total we had 16 speakers, with three speakers from Bhubaneswar, and the rest coming from various places of India. The list of speakers is given below:

Outcome: From discussions started during the seminar series new collaborative research has been initiated in the field of non-equilibrium processes in cell biology.

6

COLLOQUIA AND SEMINARS

6.1 COLLOQUIA

1. Prof.Dharam Vir Ahluwalia , University of Canterbury, New Zealand : *Connections in Physics* on 1.4.15

2. Prof. G. Rajasekaran, IMSc., Chennai. : *Hundred years of Fundamental Physics and a Crisis,* on 15.4.15

3. Professor Soumitra Sengupta, IACS, Kolkata : *100 years of General relativity - a journey beyond Einstein's gravity* on 16.4.15

4. Professor N. Mukunda, IISc., Bangalore : *Mathematics as the language of Nature- a historical view* on 17.4.15

5. Prof. Amit Roy, VECC, Kolkata : *Accelerator Development in India: Status and Future Perspectives* on 20.4.15

6. Professor Ghanashyam Date, IMSc., Chennai : *Background Independence and its implications* on 20.4.15

7. Professor G.I. Menon, IMSc., Chennai : *Active Matter and Nuclear Physics*on 21.4.15

8. Professor Kamalesh Kar, SINP, Kolkata : *Nuclei, Random Matrices and Chaos* on 22.4.15

9. Prof. Kedar Damle, TIFR, Mumbai : *Geometrically Frustrated Antiferromagnets* on 23.4.15

10. Prof. Bikash Sinha, INSA Emeritus Scientist, VECC, Kolkata. Homi Bhabha Professor, DAE Former Director, SINP & VECC : *The Finite and the Infinite From Collider to Cosmology* on 11.5.15

11. Dr. Jagjit Nanda, Materials Science and Technology Division Oak Ridge National Laboratory, Oak Ridge TN 37831 : *New Frontiers in Electrochemical Energy Storage: Materials and Systems* on 24.6.15

12. Dr. Nigel D. Browning , PNNL, USA : *In-Situ (S)TEM/DTEM: From HighSpatial Resolution to High Temporal Resolution (Environmental Transmission Electron Microscopy)* on 6.7.15

13. Prof. Federico Antinori , INFN, Padova, Italy and CERN, Geneva, Switzerland : *Characterising QCD matter at the CERN Large Hadron Collider* on 24.7.15

14. Prof. A.P. Balachandran , Physics Dept. Syracuse University, USA : *Algebraic Quantum Physics* on 30.9.15

15. Prof. T.R. Govindarajan, I.M.Sc., Chennai : *Pages from the History of Maths in India* on 1.10.15

16. Prof. M.P.Das, Australian National University,Australia : *Right and wrong in the conduct of science* on 15.12.15

17. Professor Jogesh C. Pati , SLAC, Stanford University, USA : *Unity in particle physics: A quest for beauty and simplicity* on 4.1.16

18. Prof. Rajaram Nityananda Azim Premji University, Bangalore : *Many faces of entropy and information* on 6.1.16

19. Professor Sandip Pakvasa University of Hawaii, USA : *The Stern-Gerlach experiment and the Discovery(?) of Electron Spin* on 15.1.16

20. Prof. Rajeev Bhalerao, Theory Division, TIFR, Mumbai : *Quark-Gluon Plasma and Relativistic Heavy-Ion Collisions – An Overview and Recent Advances* on 29.3.16

21. Prof. Aninda Sinha,*CHEP, IISc Bangalore* : Quantum bounds from classical limits on 15.9.15

6.2 SEMINARS

1. Dr. Debottam Das IACS, Kolkata **:** *Discovery of Higgs boson and its impacts on Models with Low energy supersymmetry* on 7.4.15

2. Prof. S.R.Shenoy,TCIS, TIFR Hyderabad : *Re-equilibration by crossing entropy barriers: Athermalmartensite models* on 8.4.15

3. Dr. Pradipta Ghosh, UAM, Madrid, Spain : *Searching new physics with extended supersymmetric model: A case study of the m n SSM* on 13.4.15

4. Dr. Sarira Sahu, Institute of Nuclear Science National Autonomous University of Mexico, Mexico City, Mexico *: Some possible sources of IceCube TeV-PeV neutrino events* on 4.5.15

5. Dr. Vikram Rentala , *JNU, New Delhi* : Physics beyond the Standard Model on 5.5.15

6. Dr. Mohammed Younus, PDF, S. N. Bose National Centre for Basic Sciences *: Heavy quark dynamics in quark gluon plasma* on 22.5.15

7. Dr. Sanjoy Biswas , Korea Institute for Advanced Study : *Higgs and its interplay with the top* on 22.6.15

8. Dr. Jyotirmoy Bhattacharya , Durham University : *The geometry of strong coupling phenomenon* on 1.7.15

9. Prof. Prabhat K. Giri , Dept. Of Physics, IIT Guwahati : *Graphene based hybrid 0D and 1D Nanostructures and their applications*

10. Dr. Suratna Das , IIT Kanpur : *Assessing Cosmic Inflation* on 14.7.15

11. Dr. Somnath Choudhury , IISER, Bhopal : *Higgs Boson Physics and DetectorUpgrade at the CMS Experiment* on 31.7.15

12. Dr. Dipak Paramanik , Iowa State University, USA : *Fabrication of vertically aligned core-shell nanopillar structure for high sensitive photonic devices* on 11.8.15

13. Dr. Rajesh Kumar Gupta , ICTP, Italy : *Localization in Supersymmetric Extremal black hole* on 13.8.15

14. Manimala Mitra, IISER, Mohali : *Seesaw and Massive Neutrinos: From Collider to Cosmology* on 24.8.15

15. Dr. R. Suriakarthick, Crystal Research Laboratory, Department of Physics, Anna University, Chennai : *Development of Abundant and Non-Toxic Semiconducting Materials for Absorber Layer of Thin Film Solar Cells by Chemical and Physical Deposition* on 8.9.15

16. Kolahal Bhattacharya, DHEP, TIFR,Mumbai : *Reconstruction methods and neutrino mass hierarchy analysis in INO- ICAL* on 9.9.15

17. Dr. Tuhin Ghosh IAS, Orsay, France : *BICEP2 and post Planck status of CMB B-mode polarization* on 18.8.15

18. Prof. T. N. Narayanan, TIFR-Centre for Interdisciplinary Sciences Tata Institute of FundamentalResearch,Hyderabad*: Engineering the Atomic Layers Interfaces for Novel Solids* on 14.9.15

19. Chitta Ranjan Das , JINR, Dubna : *Why we need Sterile Neutrinos ?* on 15.9.15

20. Prof. T.R. Govindarajan, I.M.Sc., Chennai : *Fermionic Edge states and Moving Boundaries* on 30.9.15

21. Dr. Narayan Behera , IISc. Bangaore : *Finding the cancer genes by evolutionary computation* on 6.10.15

22. Dr.Jaishri Sanwal, Research Scientist,JNCASR, Benguluru : *Reconstruction of climate changes using optical geochemistry* on 14.1.16

23. Satyaprasad P Senanayak, Royal Society Newton Fellow, Cavendish Laboratory, University of Cambridge, United Kingdom. *: New era of solution processed semiconductors* on 28.1.16

24. Ranjan Kumar Bhowmik, Inter University Accelerator Centre, New Delhi : *EVOLUTION OF SHELL STRUCTURE IN Z=50 REGION* on 28.1.16

25. Sanjib Sabhapandit , RRI, Banglore : *Fluctuations and large deviations in nonequilibrium systems.* on 2.3.16

26. Dr. Debottam Das, IACS, Kolkata : *Dark matter and LHC searches of Supersymmetric particles* on 9.4.15

27. Dr. Pradipta Ghosh, UAM, Madrid, Spain : *Exploring non-minimal supersymmetric models with light singlet states* on 15.4.15

28**. Dr. Vikram Rentala,** JNU, New Delhi : *Measuring a strongly coupled Higgs sector at the LHC using quantum interference of helicity amplitudes* on 7.5.15

29. Prof. Srubabati Goswami PRL, Ahmedabad : *Probing leptonic CP violation in neutrino oscillation experiments* on 11.5.15

30. Prof.Ashok Das, Univ. of Rochester : *Introduction to Yang-Mills theory* on 5.6.15

31. Prof. Ashok Das, Univ. of Rochester : *Canonical quantization of Yang-Mills theory* on 8.6.15

32. Dr. Ashit K. Pattanaik, Research Associate, Materials Science Division, BARC, Mumbai : *Radiation Induced Characterization of Cr-rich Ni-Cr alloys* on 15.6.15

33. Dr. Raghunath Acharya,SO(G) Nuclea Chemistry Section. BARC, Mumbai : *Proton Induced Gamma Ray Emission technique for Quantification of low atomic numbers (Z) elements in Nuclear Technology Materials* on 16.6.15

34. Dr. Sanjoy Biswas, Korea Institute for Advanced Study : *Exploring the Higgs-sector at the Large Hadron Collider* on 24.6.15

35. Dr. Jyotirmoy Bhattacharya, Durham University : *A quasi-local measure of quantum entanglement* on 30.6.15

36. Prof.A.K.Das, Univ. of Rochester : *Path integral quantization of gauge theories* on 2.7.15

37. Dr. Shankhadeep Chakrabortty , IISER, PUNE : *Tensionless Strings from Worldsheet Symmetries* on 2.7.15

38**. Prof. Ashok Das,** Univ. of Rochester : *BRST symmetry* on 6.7.15

38. Prof. Ashok Das, Univ. of Rochester : *Slavnov-Taylor identities* on 9.7.15

39. Prof.Ashok Das, Univ. of Rochester : *Hilbert space structure of Yang-Mills theory* on 13.7.15

40. Dr. Suratna Das , IIT Kanpur : *Quantum origin to Classical existence : A plausible explanation* on 16.7.15

41. Dr. R. K. Bommali, Department of Physics, IIT Delhi : *Tuneable Opto-electrical properties from partially phase separated a-SiNx:H thin films* on 22.7.15

42. Dr. Satya N. Tripathy, Institute of Physics, University of Silesia, Poland : *Glass Transition Dynamics and Conductivity Scaling in Super cooled Liquids* on 24.7.15

43. Dr. Tanumoy Pramanik , Telecom ParisTech, France : *Theoretical and Experimental Study of Quantum Steering* on 4.8.15

44. Analabha Roy, NiTheP, South Africa : *Persistence of many body freezing in periodically driven quantum spin systems: From simple quantum magnets to disordered, non-integrable and long range models* on 17.8.15

45. Rajeev Kumar Jain, Denmark : *Cosmological Inflation and Primordial Magnetic Fields* on 21.8.15

46. Rajeev Kumar Jain, Denmark : *On the Origin of Neutrino Mass: Neutrinoless Double Beta Decay and Collider Searches* on 25.8.15

47. Dr. C. Jebarathinam, IISER, Mohali : *Discord in generalized probabilistic theory* on 28.8.15

48. Mr. Mukesh Mishra, Research Scholar (SRF), JNU, Delhi : *Study of Optical and Surface Electronic Properties of Graphene and Graphene Based Nanocomposites* on 11.9.15

49. Dr. Shidharth Sankar Ram, PDF, National Central University, Taoyuan 32001, Taiwan : *Application of X-ray based analytical techniques in Environmental Studies* on 16.9.16

50. Dr. Somnath De, PDF, IOP : *Local Thermal Equilibrium of Dense Hadronic Matter at CBM* on 18.9.15

51. Mainak Chakraborty, SINP, Kolkata : *Neutrino masses, mixing and baryogenesis via leptogenesis: probing physics beyond standard model* on 22.9.15

52. Dr. Haripriya Rath, PDF, IOP : *Thermal Annealing and Swift Heavy Ion Irradiation Induced Modifications in TiO2 - Examination of the validity of different models of ion-matter interaction* on 22.9.15

53. Utkarsh Mishra, HRI : *Local decoherence-resistant quantum states of large systems* on 7.10.15

54. Dr. Muniyandi Muneeswaran, Department of Physics, National Institute of Technology Tiruchirappalli, TN : *Investigations on the synthesis and properties of pure and Rare earth (Dy, Pr and Tb) modified multiferroic BiFeO3 nanoparticles* on 8.10.15

55. Safiul A Mollick, PDF, IOP : *Ion beam patterning of semiconduct surfaces* on 19.10.15

56. Dr.Arijit Kundu, Technion Institute, Israel : *Topology and Transport in Periodically Driven Systems* on 12.11.15

57. Dr. Soumya Bera, Max-Planck Institute for Complex Systems, Germany : *Disorder driven quantum phase transition* on 13.11.15

58. Dr. Abhinav Saket, Bihar **:** *Orbital phase transition in 2-d pyrochlore.* on 18.11.15

59. Dr.Bijaya Kumar Agarwalla, PDF, Univ. of Toronto : *Charge and energy transfer in molecular junctions : models, methods, mechanisms and fundamental aspects* on 20.11.15

60. Prof. M.P.Das, Australian National University, Australia : *Revisiting Fermi Surfaces in Electronic Structure Studies* on 8.12.15

61. Dr. Urbashi Satpathy, SNBNCBS, Kolkata : *Coherence Phenomenon in Mesoscopic Systems* on 10.12.15

62. Sanjib Ghosh, SNU, Singapore : *Probing Anderson transition by Coherent backscattering* on 18.12.15

63. Mr. Sreeraj T.P S N Bose National Center for Basic sciences : *Gauge theories, spin models and hydrogen atoms* on 29.12.15

64. Himadri R. Soni, Lehrstuhl für Theoretische Chemie,Friedrich-Alexander Universität Erlangen- Nürnberg Egerlandstraße 3, 91058 Erlangen, Germany : *Reactivity of Graphene* on 31.12.15

65. Dr. Amit Gupta, Banaras Hindu University (BHU), India : *Thermoelectric studies in topological system due to superconductivity and spin-density wave* on 11.1.16

66. Dr. Amit Sharma, University of Gothenburg, Sweden : *Protein Structure Determination Using Serial Femtosecond Crystallography and Solution Structural Dynamic Studies* on 12.1.16

67. Dr.Pankaj Sharma, Adelaide University, Australia : *High Energy Physics@LHC: A TOP Perspective* on 18.1.16

68. Dr. Moitri Maiti, JINR,Dubna, Russia : *Superconducting junctions as detectors of Dirac fermions and Majorana modes.* on 22.1.16

69. Dr.S.B.Ota, IOP : *Micro coronial Monte Carlo Study of spin wave excitation in 2D XY model* on 22.1.16

70. Dr. Ayon Patra Seoul National University of Science & Tech. : *Higgs Boson spectra in Supersymmetric Left-Right Models* on 25.1.16

71. Trilochan Bagarti, HRI Allahabad : *Synchronization of Kuramoto oscillators on networks* on 27.1.16

72. Prof. S.D.Mohanti, Michigan State University and IOP, Bhubaneswar : *probe studies of excitations and dynamics of interacting systems* on 29.1.16

73. Dr.Firoz Islam , NISER, Bhubaneswar,India : *Electronic and transport properties of Rashba spin-orbit coupled two dimensional electron systems* on 29,1,16

74. Dr. Aruna Kumar Nayak, IOP, Bhubaneswar : *Search for new physics in high mass diphoton events at LHC* on 1.2.16

75 Dr. Sudipta Kanungo, Max Planck Institute for Chemical Physics of Solids, Dresden, Germany : *Interplay of spin, lattice and orbitals in the 5d oxides:microscopic insight from first principles approach* on 2.2.16

76. Dr. Pritibhajan Byakti , CHEP, IISc, Bangalore : *Coxeter groups and the PMNS matrix* on 9.2.16

77. Dr. Kush Saha, Department of Physics and Astronomy University of California, Irvine, USA : *Phonon-induced topological phase transition* on 10.2.16

78. Dr. Sachin Jain, Cornell Univ., Ilhaca, New York : *Causality constraints on conformal field theory* on 16.2.16

79. Dr. Chaitra Hegde , RRI, Bangalore : *Diffusion in one dimension: attempts at a simple picture* on 3.3.16

80. Dr. Ashmita Das , IACS, Kolkata : *Lightest Kaluza-Klein graviton mode in a backreacte Randall-Sundrum scenario* on 8.3.16

81. Dr. Subhajit Sarkar, S.N.Bose National Centre, Kolkata : *Can conventional excitation generate stable topological excitations in quantum feromagnetic spin systems on two dimensional lattice.* on 9.3.16

82. Dr. K.N. Deepthi, Hyderabad Central University : *Some aspects of neutrino mixing and oscillations* on 10.3.16

83. Dr. Gauhar Abbas, IFIC, University of Valencia, Spain : *Top FCNC decays in the aligned two-Higgs doublet model* on 11.3.16

84. Bipasha Bhowmick : *Strange Nuclear Systems Within Mean Field approach* on 16.3.16

85. Dr.R.R.Juluri, Aarhag Univ.,Denmark : *GaN Growth on Si* on 17..3.16

86. Mr.Deb Sankar Bhattacharya, SINI, Kolkata and Saclay, Grance : *Micro pattern Gas detector for Expt, HEP* on 17.3.16

6.3 . Lectures delivered by the Institute Members

1. Seminars in the National Seminar at the Physics Dept., Assam University, Silchar, Oct. 5-6, 2015: A. M. Srivastava, **Thermal history of the Universe and microwave background radiation**.

2. Seminars in the National Seminar at the Physics Dept., Assam University, Silchar, Oct. 5-6, 2015: A. M. Srivastava, **Dark matter and dark energy in the universe.**

3. **Initial conditions for Inflation**" at COSMOASTRO15, A. M. Srivastava, Discussion meeting on Cosmology and Astroparticle physics, held at IOP, Bhubaneswar, 30th Oct. - 5th Nov., 2015.

4. **Power spectrum of flow fluctuations in relativistic heavyion collisions**, at "CNT QGP Meet 2015" A. M. Srivastava, workshop, held at VECC, Kolkata during 16-20 Nov 2015.

5. **Initial conditions for inflation** , A. M. Srivastava, in the working group on Astro-particle physics at WHEPP14 (Workshop on High Energy Physics Phenomenology), 4-13 Dec. 2015.

6. **Propagation of heavy quarks in QGP in the presence of spatially and temporally varying potential**, A. M. Srivastava, in the Second Heavy Flavour Meet at SINP, Kolkata, Feb. 4 - 6, 2016.

7. **Investigating Cosmic string theories with Liquid Crystal Experiments**, A. M. Srivastava, at following places.

8. Popular Talk on "**frontiers of technology**", A. M. Srivastava, at Regional Science Center, BBSR, for school children, 11th May, 2015.

9. **Aviation science in ancient India: Claims and Reality**, A. M. Srivastava, 16th Aug. 2015, 'All Odisha Workshop-2015 on "The development of science in ancient India: Myth and Reality".

10. **Universe, dark energy and cosmic microwave background radiation**, A. M. Srivastava, Talk at IIIT BBSR 12 Feb. 2016.

11. Popular talk on "**Detection of gravitational waves, a new window to the universe**" A. M. Srivastava, given at: Ravenshaw University, Dept. of Chemistry, 3rd March, 2016.

12. National Science Day celebration, A. M. Srivastava, IOP, Bhubaneswar, 26th March, 2016.

13. **Studies of nanostructures created on TiO2(110) by Low Energy Ion Beam Sputtering Technique: Role of Oxygen Vacancy at Surface Characterization,** S. Varma, Workshop: XPS,AES,TOF-SIMS, Physics Department, IIT Kharagpur, Kharagpur (Apr. 2015).

14. **Fabrication of Nanostructure on rutile TiO2(110) surfaces by Low Energy Ion Beams : Enhanced Photoabsorption Improved DNA Interaction through improved Hydrophilicity** S. Varma, at Workshop on Interdisciplinary investigations of Ion Beam Interactions with Matter: From Fundamental Aspects to Nanotechnology and Hadron- biology organized by IFCPAR (India French Center for the Promotion of the Advanced Research) in Caen, France (May 2015).

15. **Low Energy Ion Beams: TiO2(110), Si(100), Tantalum Patterning, Photoabsorption, DNA Interaction, KMC modelling at Low Energy Ion Beam Facility** S. Varma, workshop at IUAC Delhi (Nov. 2015).

16. **Tuning of Bandgap Parameters for Photo-Catalysis and Enhancement of Bio-compatibility on Ion Beam Patterned TiO2** S. Varma, at International Conference on Energy Materials and nanotechnology-EMN Photocatalysis-2015 Conference at Las Vegas, USA (Nov. 2015).

17. **DNA as a sensor of Merury Nanoparticles** S. Varma, at Syracuse University, Syracuse(NY), USA (Dec. 2015).

18. **Nanodot Patterned surfaces for Photocatalysis** S. Varma, at an International Conference on Frontiers in Material Science and Technology- ICFMST-2015 at National Institute of Science and Technology, NIST Behrampur, (Dec. 2015)

19. **Bandgap Tuning, Better Photoabsorption and DNA Biocompatibility on TiO2(110) surfaces** S. Varma, at the 60th DAE Solid State Physics Symposium held at Amity Univ., New Delhi (Dec. 2015).

20. **Photo- absorption properties of nanostructures fabricated by atom beam sputtering interaction of nanostructures with plasmid DNA,** S. Varma, at theWorkshop on Future Directions in Ion Beams in Materials Engineering and Characterizations, held at IUAC, New Delhi (Dec. 2015).

21. **Photoabsorption, bandgap modification and DNA biocompatibility on ion irradiated TiO2(110) surfaces** S. Varma, at Workshop on the use of Low Energy Ion Beams (Nov. 2015).

22. Aspects of Strings Cosmology" S. Panda, in COSMOASTO-16, Institute of Physics.

23. Brane Inflation" S. Panda, in IACS, Kolkata

24. **Reconstructed high index surfaces for graded Si_xGe_y and Au-Ag bimetallic nanostructure,** P. V. Satyam, Discussion Meeting on Nano-scale and Atomic-scale Quantum Structures and Devices, 16-17 February, 2016, IACS, Kolkata.

25 **STEM Imaging of Epitaxial and Endotaxial Ag and Au-Ag nanostructures,** P. V. Satyam, International Conference on Electron Microscopy, July 8 – 10, 2015, Mumbai

26. **Use of Low Energy Accelerators and Update on the future directions at IOP programs,** P. V. Satyam, Seminar on the use of low energy ion accelerators, November 7 – 9, 2015, IOP

27. **Experimental Methods using Scattering Methods,** P. V. Satyam, School Teachers Refreshers Program May 2015 at IOP

28. **Coherent Endotaxy of Ag nanostructures in Si,** P. V. Satyam, June 2, 2015 at BARC center at Visakhapatnam (invited talk).

29. **Electron Microscopy Studies of Au, Ag, Au/Ag, ZnO and GeO_2 nanostructures,** P. V. Satyam, January 12, 2016, CGCRI, Kolkata (invited talk)

30. **Synergetic effects of sputter-erosion and mass-redistribution in medium energy ion-beam patterning of materials**., T. Som, 14.07.2015 at *8th International Workshop on Nanoscale Pattern Formation at Surfaces*, Jagiellonian University, Krakow, Poland.

31. **Tunable field emission from self-organized Si nanofacets: Dual pass tunnelling current microscopy and role of native oxide** , T. Som, 15.07.2015 at *8th International Workshop on Nanoscale Pattern Formation at Surfaces*, Jagiellonian University, Krakow, Poland.

32. **Pattern formation on SiO_2 surface under low-energy Ar-ion irradiation: Roles of sputtering, mass redistribution, and shadowing,** T. Som, 30.10.2015 at *18th International Conference on Radiation Effects on Insulators (Rei-18)*, Jaipur.

33. **Surfing electron emission sites on ion-beam fabricated self-organized Si nanofacets**, T. Som, 08.12.2015 at *25th Annual Meeting of MRS-J International Symposium on Innovative Material Technologies Utilizing Ion Beams*, Yokohama City, Japan.

34. **Surfing electron emission sites on ion-beam fabricated self-organized Si nanofacets**, T. Som, 07.03.2016 at Saha Institute of Nuclear Physics, Kolkata.

35. **Surfing cold cathode electron emission sites on ion-beam fabricated self-organized Si nanofacets**, T. Som, 08.03.2016 at *National Thematic Workshop on Recent Advances in Materials Science, University of Burdwan*.

36. **Ion implantation and its possible applications**, T. Som, 07.05.2015 at *Teachers' Research Programme*.

37. **Surfing electron emission sites on self-organized Si nanofacets**, T. Som, 27.08.2015 at *IOP Internal Symposium to commemorate 40th Year of IOP Academic Activities*.

38. **Low energy ion-beam patterning on Si surface and its Applications**, T. Som, 07.09.2015 at *Workshop on the Use of Low Energy Ion Beams (WIB)-2015*.

39. Soft and active matter, D. Choudhuri, on 18th June, 2015 at National Center for Biological Sciences, Bangalore

40. The Race for Neutrino Mass Hierarchy, Sanjib Agarwalla, Invited talk given at the Frontiers in High Energy Physics III meeting, IMSc, Chennai, 22nd March, 2016

41. **Future Prospects for Mass Hierarchy Discovery,** Sanjib Agarwalla, Nu HoRIzons VI Conference, HRI, Allahabad, 17th March, 2016

42. **Opening a New Era in Neutrino Physics**, Sanjib Agarwalla, the School of Physics, Sambalpur University, Odisha, India, 19th February, 2016

43. **Flavor-Dependent Long-Range Forces in Long-Baseline Experiments**, Sanjib Agarwalla, the DUNE Physics Working Group meeting, Fermilab, USA, 13th October, 2015

44. **Can Daya Bay Probe Non-Standard Neutrino Interactions?** Sanjib Agarwalla, the IPP15 Conference, School of Physics, IPM, Tehran, Iran, 27th September, 2015

45. **Unraveling Neutrino Properties at the India-based Neutrino Observatory,** Sanjib Agarwalla, the Internal Symposium of Institute of Physics (IOP) to celebrate 40th year of Academic Activities, Bhubaneswar, Odisha, India, 27th August, 2015.

46. Standard and Non-Standard Oscillation Physics at ICAL-INO, Sanjib Agarwalla, Crossroads of Neutrino Physics Workshop, MITP, Johannes, Gutenberg University, Mainz, Germany, 28th July, 2015

47. Roadmap for Neutrino Mass Hierarchy Plenary, Sanjib Agarwalla, the INO Collaboration meeting, IIT Madras, Chennai, India, 3rd April, 2015

48. Constraining Active - Sterile mixing at ICAL detector with atmospheric neutrinos, Sanjib Agarwalla, the INO Collaboration meeting, IIT Madras, Chennai, India, 2nd April, 2015

49. **Recent Developments in Field Theory,** A. Virmani, On Non-extremal black hole micro-states, Conference titled, Jul 2015 at IOP Bhubaneswar

50. **Black Holes in String Theory**, A. Virmani, Physics Colloquium, IIT Gandhinagar, Nov 2015

51. **Non-extremal black hole micro-states**, A. Virmani, National Strings Meeting, IISER, Mohali, Dec 2015

52. Non-extremal black hole micr o-states, A. Virmani, 4th Indo-Israel Meeting on String Theory, Goa, December 2015.

53. **Integrability in 2d gravity**, A. Virmani, Plenary talk at International Conference on Gravitation and Cosmology (ICGC) 2015, IISER Mohali, Dec 2015

54. **Inverse Scattering Construction of the JMaRT Fuzzball, deSitter and Microstate Landscapes in String Theory**, A. Virmani, IPhT, CEA Saclay, France, June 2015

55. **Internal structure of AdS black holes, Field Theoretic Aspects of Gravity**, A. Virmani, S N Bose Centre for Basic Sciences, Kolkata, Feb 2016

56. **Internal structure of AdS black holes,** A. Virmani, Invited seminar at HRI Allahabad, Mar 2016

57. **On Non-extremal black hole micro-states**, A. Virmani, Invited seminar at HRI Allahabad, Mar 2016

58. **Black Holes in String Theory, UGC-DRS** A. Virmani, National Seminar titled ``Advances in Astro-Particle Physics (AAP-2016)," Feb 2016 at Sambalpur University

59. **Novel transport phenomena through hybrid junctions of nanowires**, Arijit Saha, 27.08.2015 at IOP, Bhubaneswar

60. Dynamics in spin-orbit coupled bosons in cold atom system, S. Mandal, IOP 40th year academic activities.

61. Search for new physics in high mass diphoton events at LHC, A. K. Nayak, HEP seminar, 01 February 2016, IoP, Bhubaneswar.

62. **Unraveling the mysteries in particle physics at the Large Hadron Collider**, A. K. Nayak, Seminar at Indira Gandhi Institute of Technology, Sarang, Odisha, 13 March 2016.

63. Electric field induced localization phenomena in a ladder network with superlattice configuration: Effect of backbone environment, P. Dutta, held at Department of Physics, Visva-Bharati University, Shantiniketan, Bolpur, India

64. Quantum Transport in Low-dimensional Systems, P. Dutta, Poster Presented at DAE-BRNS Solid State Physics Symposium (DAESSPS-2015) held at Amity University UP, Noida, Uttar Pradesh, India

65. Renormalization Group method for persistent current in a finite width quasiperiodic ring, P. Dutta, Poster Presented at Emerging Trends in Advanced Functional Materials (ETAFM-2016) held at Institute of Physics, Bhubaneswar, India

66. Magnetoanisotropic Andreev Reflection in Ferromagnet-Superconductor Junctions, P. Dutta, Journal Club talk at Condensed Matter Physics Group (Theory), Institute of Physics, Bhubaneswar, India

6.4. CONFERENCE / WORKSHOP ATTENDED BY IOP MEMBERS

Prof. A. M. Srivastava

1) National Seminar at the Physics Dept., Assam University, Silchar, Oct. 5-6, 2015:

2) COSMOASTRO15, Discussion meeting on Cosmology and Aastroparticle physics, held at IOP, Bhubaneswar, 30th Oct. - 5th Nov., 2015.

3) CNT QGP Meet 2015 workshop, held at VECC, Kolkata during 16-20 Nov 2015.

4)WHEPP14 (Workshop on High Energy Physics Phenomenology), 4-13 Dec. 2015.

5) Attended the Second Heavy Flavour Meet, SINP, Kolkata, Feb. 4-6, 2016.

6) Attended the National Seminar on Advances in Astro-Particle Physics (AAP-2016), Feb. 19-20, 2016, Sambalpur University.

Prof. S. Varma

1. Surface Characterization Workshop: XPS,AES,TOF-SIMS, Physics Department, IIT Kharagpur, Kharagpur (Apr. 2015).

2. Workshop on Interdisciplinary investigations of Ion Beam Interactions with Matter: From Fundamental Aspects to Nanotechnology and Hadron- biology, organized by IFCPAR (India French Center for the Promotion of the Advanced Research) in Caen, France (May 2015).

3. Low Energy Ion Beam Facility workshop at IUAC Delhi (Nov. 2015).

4. International Conference on Energy Materials and nanotechnology EMN

Photocatal-ysis 2015 Conference at Las Vegas, USA (Nov. 2015).

5. International Conference on Frontiers in Material Science and Technology- ICFMST-2015 at National Institute of Science and Technology, NIST Behrampur, (Dec. 2015)

6. 60th DAE Solid State Physics Symposium held at Amity Univ., New Delhi (Dec. 2015).

7. Workshop on Future Directions in Ion Beams in Materials Engineering and Characterizations, held at IUAC, New Delhi (Dec. 2015).

8. Workshop on the use of Low Energy Ion Beams organized at IOP (Nov. 2015).

Prof. D. Topwal

1. Emerging trend in advanced functional material (ETAFM 2016), IOP, Bhubaneswar

2. Workshop in frontiers in condense matter physics (CONDMAT 2016), IOP, Bhubaneswar

3. Discussion Meeting on the Science Using X-ray Free Electron Laser, JNCASR, Bangalore

4. Frontiers in advanced materials (FAM 2015), IISc, Bangalore

5. XRD1 beamline, Elettra Synchrotron light source, ITALY

6. Circular polarization beamline, Elettra Synchrotron light source, ITALY

7. BaDElPh beamline, Elettra Synchrotron light source, ITALY

Prof. S. K. Agarwalla

1. Frontiers in High Energy Physics (FHEP) III meeting, IMSc, Chennai, India, 22nd-25th March, 2016.

2. Nu HoRIzons VI Conference, HRI, Allahabad, India, 17th-19th March, 2016.

3. Crossroads of Neutrino Physics Workshop, Mainz Institute for Theoretical Physics, Johannes Gutenberg University, Mainz, Germany, 20th July-14th August, 2015.

4 India-based Neutrino Observatory (INO) collaboration meeting, IIT Madras, Chennai, India, 2nd-4th April, 2015.

6.5. AWARDS / HONOURS AND RECOGNITIONS

1. Prof. A. K. Nayak was awarded with Ramanujan Fellowship 2015, DST Govt. of India.

2. Prof. A. M. Jayannavare was Elected as 1. Distinguished faculty award -2015 HBNI, Mumbai.

7

CONFERENCES AND OTHER EVENTS

7.1 ALUMNI DAY

The 36th Alumni Day was celebrated on 3rd September, 2015. It was chaired by Prof. S. Panda, Director, Institute of Physics and President Alumni Association, IoP. The program started with an academic session which consisted of a series of lectures by our alumni members of IOP and a colloquium by an invited distinguished physicist.

In this session, we had organised many lectures viz. Aswini Kumar Rath Memorial talk delivered by Prof. Aninda Sinha from IISc, Bangalore on 23rd August, 2015. The Alumni day lectured by eminent Scientist / Alumni members. Prof. D.K Goswami, IIT Kharagpur delivered Alumni Day Talk entitled *" Effect of polarization of polar dielectric layer on the performance of organic field-effect transistors based sensors"* , Prof. Supriya Kar, University of Delhi delivered delivered Alumni Day Talk entitled *" Non-perturbative Quantum Gravity: Quintessential Cosmology and D-instanton"* and Prof. Bijay Agarwal, SINP, Kolkata delivered Alumni Day Talk entitled *" Probing the nuclear symmetry energy"*. Prof. Jayanta Kumar Bhattacharjee, Director, HRI delivered the Coolquium talk entitled "*Time Dependent Perturbation Theory in QM and the Renormalization group*" on the eve of morning session of the Alumni Day function of the Institute.

The evening program started with prize distribution to the winners of various competitions such as debate, science modeling and many other competition organised by the Alumni association of the IOP, the year-long program like science modeling essay competition among the school students of various group. It was followed by a talk by Eminent Archaelogist, Prof. Vasant Shindhe , South Asian Archaeology entitled *"Ancient India's Contribution to Development of Science and Technology"*. This was followed by the evening cultural programe. Vice-Chancellor, Deccan college.

Office Bearers :

Secretary	:	Mr. Arpan Das (Jr.)
Asst. Secretary	:	Ms. B. Chakrabarty
Treasurer	:	Mr. Puspendu Guha
Faculty Advisor	:	Prof. A. Virmani

7.2. FOUNDATION DAY

The 41st Foundation Day of the Institute was celebrated on September 4, 2015 (Friday). This is one of the most important events of the Institute, where a large number of persons from academia, media, and administration of the Odisha Government and DAE were invited. Members of the Institute family took active part in the proceedings. This year the Chief Guest was Prof. Jayant Kumar Bhattacharjee, Director, Harish Chandra Research Institute. Prof. Bhattacharjee delivered the Foundation Day talk titled *" What drives Scientific Progress?"*. The programme was concluded by performance of classical, odishi and folk dances of the state of Odisha by Adruta Dance Troupe, a unit of RAWA Academy of the underprivileged children of the society.

On this eve Prof. Bhattacharjee delivered a popular Talk.

Doctoral Course Work (Diploma in Advanced Physics equivalent to M.Phil) awardee Scholar-2015

7.3. Recent Developments in Field Theory (17th - 19th July, 2015)

Conference on "Recent Developments in Field Theory" (RDFT) IOP, Bhubaneswar Jointly organised by IOP, Bhubaneswar; NISER, Bhubaneswar, IISER Kolkata, Utkal University, Bhubaneswar and IIT Bhubaneswar, July 17th-19th, 2015. Here recent times significant developments and subsequent applications of field theory in diverse physical systems, supporting exotic phenomena like fractional statistics, anyonic superconductivity, quantum Hall effect, gauge-gravity duality, quark-gluon plasma and many more had been discussed. These has further led to new questions regarding renormalizability, gauge-independence and confinement etc., that need to be answered for the self-consistency of the theory itself. Interestingly, cold atoms and condensed matter systems have led to the possibility of directly answering some of these theoretical questions. Hence, more than ever, there is a strong need for discussions and sharing of new ideas, through meetings of experts and researchers from different areas of physics. This conference has the modest aim of achieving the same. Also, special focus will be on exposing young researchers and students to the works and achievements of senior scientists. One day of the conference was specially dedicated to honor and celebrate the works and life of eminent field theorist and much-loved teacher of physics, Prof. Ashok Das. More than anybody else, he has left his footprints in all parts of India, initiating young researchers into the art of field theory. This is in addition to his numerous books and notes, lucidly devoted to bring-out the joys of physics to its seekers and practitioners.

7.4. Int. workshop on Recent Trends in Nuclear Structure and its Implication in Astrophysics *(jointly organized by TIFR, Mumbai and IOP, Bhubaneswar)* 4th to 8th January, 2016

The matter composed of the nucleus is a quantum-mechanical interacting many-fermionic system. However, the shell and classical liquid drop have been taken as the two main features of nuclear dynamics, which have guided the evolution of nuclear physics. These two features can be considered as the macroscopic manifestation of the microscopic dynamics of the nucleons at fundamental level. Various mass formulae have been developed based on either of these features over the years,resulting in many ambiguities and uncertainties posing many challenges in this field. Keeping this in view, Infinite Nuclear Matter (INM) model has been developed during last couple of decades with a many-body theoretical foundation employing the celebrated Hugenholtz-Van Hove theorem, quite appropriate for the interacting quantum-mechanical nuclear system. A mass formula called INM mass formula based on this model yields rms deviation of 342 keV being the lowest in literature. Some of the highlights of its result includes its determination of INM density in agreement with the electron scattering data leading to the resolution of the long standing 'r-paradox' it predicts new magic numbers giving rise to new island of stability in the drip-line regions. This is the manifestation of a new phenomenon where shell -effect over comes the repulsive component of nucleon-nucleon force resulting in the broadening of the stability peninsula. Shell quenching in N= 82,and N= 126 shells, and several islands of inversion have been predicted. The model determines the empirical value of the nuclear compression modulus, using high precission 4500 data comprising nuclear masses, neutron and proton separation energies.

8

OTHER ACTIVITIES

8. 1. Outreach

As a part of the Outreach Program of the Institute of Physics, following programs were carried out.

National Science Day

National Science Day was celebrated at the Institute of Physics on 26th March 2016 (due to various constraints of school timings and classes etc.). The program was attended by about 210 school students from Bhubaneswar (both English medium and Oriya medium schools) along with students from IOP, and students from the local Basti. The program started at 10:00 a.m. with following popular level talks at the Institute Auditorium.

1. Talk on "What does a carrier in Science offer you?" by Prof. B. Ravindran, Director, Institute of Life Sciences, Bhubaneswar

2. Talk on "Detection of Gravitational waves: A new window to the Universe" by Prof. A.M. Srivastava, Institute of Physics, Bhubaneswar.

Following this, student visits were arranged, in small groups, to IOP experimental facilities. There was a very enthusiastic participation by research scholars/faculty and scientific assistants in explaining various experimental facilities to school students. The program ended at about 5:30 p.m.

Night sky viewing session

At IOP: A night sky observation session was held on 23rdMay, 2015 for Children from local Basti and for SSVP students visiting IOP. Objects viewed: *Jupiter and its moons, Venus, craters of the Moon*. Before the skyview session, basics of astronomy were explained to the students from the Basti.

Outside IOP: Discussion was carried out with students and their family members on "learning science and looking at sky", followed by a night sky watch session at the St. Xaviers school, Bhubaneswar, 16th March, 2016.

Visits of school students:

The Institute regularly receives requests from various schools in Odisha and outside for visits to its Laboratory facilities which are arranged and managed under the Outreach Program. For this year also several such visits were organized.

Social outreach:

Several Institute scholars as well as other members, through the organization Zaria, have been volunteering to teach children of the local Basti and are helping them to enroll in schools.

8.2. Implementation of Official Language :

Institute of Physics, Bhubaneswar continued to carry out its activities to promote the use of Rajbhasha Hindi in the official works. During 2015-16, some of the efforts made in the direction are highlighted below :-

Ø Annual Report and other documents which will be furnished to the Parliament were prepared bilingually.

Ø Total 70 employees were imparted through training programmes/ Hindi workshops. A workshop on " Committee of Parliament on Official Language-Inspection Questionnaire on 10.11.2015 was organized. For Technical/Scientific Employees a technical workshop in Hindi on "Safety, Health & Environment" was organized on 25.06.2015 in the Institute.

Ø 06 employees under the Incentive Scheme for doing original noting and drafting in Hindi were awarded.

Ø Total 07 officials were imparted training in Hindi and eligible candidates were given incentives for successfully passing Hindi examination.

Ø Hindi Books worth Rs. 9600.00 were purchased during the year.

Ø 04 nos. Quarterly meetings of OLICs were held regularly and the progress of implementation of Hindi was monitored regularly through OLIC.

Ø During 2015-16 Hindi Day, Hindi Fortnight and International Hindi Day were organized. On 14.09.2015 Hindi Days was celebrated. During this celebration, Prof. Sudhakar Panda, Director of this Institute was Chief Guest to the function and Sri K. Padmanabhan, Dy. Legal Adviser was also invited as a Speaker to the function. The function started with the song " Hindi Bharat Ki Bindi" written by Her Excellency Smt. (Dr.) Mrudula Sinha, Governor of Goa was recited. The message on the Hindi Day sent by the Chairman, AEC & Secretary, Atomic Energy Department and Hon'ble Home Minister, Govt. of India was also recited.

During the fortnight, Hindi Essay, Noting & Drafting, Letter writing, Speech, Debate, Hindi & English Translation, Hindi Dictation, Hindi Handwritting etc competitions were conducted.

During the fortnight, a workshop on CCS (Conduct) Rules was oganised on 15.09.2015 for the employees of the Institute.

The valedictory function was organized on 30th September, 2015 . During this valedictory function Prof. S. K. Joshi, Chairman, IOP Governing Council was the Chief Guest to the function. All winners of the different competitions were distributed cash awards.

Ø One Scientific Seminar in Hindi on " Role of Scientific & Technical Institutions in Start-up India" was organized on 17 03.2016. This scientific seminar was organized with collaboration of CSIR-IMMT, NISER, IACR-Central Institute of 03 employees were imparted training Data Processing in Hindi conducted by Hindi Teaching Scheme, Bhubaneswar.

8.3. The Women's Cell at IOP :

The Women's Cell looks after the welfare of the Women members, visiting members and the workers of the Institute. It also facilitates redressal of issues and grievances concerning them. Following the 1997 Supreme Court judgment in the case of Vishaka and others versus the State of Rajasthan, the Women's cell in IOP was constituted, in accordance with the mandate that it shall be the duty of the Employer to prevent or deter the commission of acts of sexual harassment and to provide the procedures for the resolution, settlement or prosecution of acts of sexual harassment by taking all steps required, and to be proactive by developing a conducive atmosphere on the campus, where women can work safely with dignity and without any Discrimination.

The objectives of the TWC are:

1. Prevent gender discrimination and sexual harassment, by promoting gender amity amongst all members.
2. Make recommendations to the Director for changes/elaborations in the Rules, Standing orders and Bye-Laws etc, to make them gender just and to lay down procedures for the prohibition, resolution, settlement and prosecution of acts of sexual harassment by and of IOP members.
3. Deal with cases of sexual harassment, in a time bound manner, aiming at ensuring support services to the victimized and termination of the harassment;
4. Recommend appropriate punitive action against the guilty party to the Director.

The main functions of the TWC are:

1. Promotion of Gender amity : Providing information/consultation on gender amity to any student or members .

2. Programmes concerning women's welfare: Bring out publications/posters on promoting gender amity and preventing gender discrimination and sexual harassment at work place.

3. Documentation and Dissemination: Notice board and web page provide everyone with names and phone extensions of the TWC members.

4. Deal with Cases of Gender Discrimination/Sexual Harassment: Committee looks into complaint of gender discrimination/sexual harassment and makes an inquiry into the case. Committee provides support service to the victimized and recommends an early action to the Director to ensure termination of the harassment with immediate effect. Submits a report to the Director, recommending appropriate punitive action against the accused found guilty.

The Constitution of TWC is:

Prof. Shikha Varma,IOP	: Chairperson
Prof. B.R. Sekar (Registrar, IoP)	: Member
Dr. Debsmita P. Alone, NISER	: Member
Dr. Rooplekha Khuntia, NISER	: Member
Smt. Nageswari Majhi, IOP	: Member

8.4 Implementation of Swachh Bharat Mission

As per directives of the Department of Atomic Energy, Swachh Bharat Abhiyan has been launched at this Institute. The Swachh Bharat Mission (SBM) program started at the Institute on 2nd October 2014. Prof. Sudhakar Panda, Director and staff members and the scholars voluntarily participated in a cleanliness drive covering the office rooms, laboratories, workshops, hostels, canteen, gardens and residential colony of the campus. Periodic cleaniliness is being taken up by the staff members and scholars on regular basis every

month. On 18th August, 2015, a Comittee consisting of the Director, the Registrar, the Administrative Office and the Junior Admnistrative Office made an periodic inspection to the above.

8.5. Sports and Cultural Activities

The Sports and Cultural activities promote a values of solidarity, fitness, social justices, gender equality and respect for biodiversity and the environment. Along with the scientific and research works, IOP continued to carry out sports and cultural activities to encourage different sports and cultural programs as well as to keep all the members fit. To carry out different sports and cultural activities a committee was formed. The members of the committee are Prof. Suresh Kumar Patra (Chairman), Dr. Tapobrata Som, Mr. Dillip Kumar Chakraborty, Mr. Santosh Kumar Choudhury, Mr. Prabhat Kumar Bal, Mr. Sahadev Jena, Mr. Shryansh

Sekhar Dave, Mr. Debashis Saha, Mr. Pramod Kumar Senapati, Mr. Brundaban Mohanty and Mr. Balakrushna Dash (Secretary).

Following are the different activities conducted during the year 2015-16:

1. A Football match was conducted on 15th August, 2015. This was a friendly match between Director's Team (Faculties, Doctorial Scholars) and Registrar's Team (Staffs) of the Institute. Registrar's Team won the match. Mr. Brundaban Mohanty was the captain of the Champion team and Mr. Shryansh Sekhar Dave was the captain of the runner's team. It was a very interesting match. Around 100-viewers joined and make the event successful.

2. A friendly Cricket match was conducted on the occasion of 26th January, 2016. This match was played between Director's Team (Faculties & Doctorial Scholars) and Registrar's Team (Staffs). Mr. Shreyans Shankar Dave was the captain of Director's Team and Mr. Pramod Kumar Senapati was the captain of Registrar's Team. Director's Team won the match. Around 100 spectators were there to enjoy the football match.

3. Social activities generate a lot of interest and pleasure among staffs and their dependents. For this purpose a program was organized on 14th November, 2015 being celebrated as the children's day throughout the country. On that day the campus children performed various activities like song, dance and playing instruments on the stage. Participants from the age of 5-years to 16-years showed their art in front of 300 viewers in the IOP auditorium.

4. Institute also organized the Annual Sports and Cultural Meet in the month of August, 2015. These events started on 08.08.2015 and got completed on 04.09.2015. The total numbers of events were 18. Around 65 staff members participated in Gents group, 35 family members participated in the Ladies events, and 45

tural Meet 2015-16, IOP cultural team presented an Odia dramatic art "Ebam Kiea" in SINP, Kolkata on 17th December, 2015. This was highly appreciated by the judges. The team members are Sri S. Jena, Mr. J. K. Mishra, Sri B. Mishra, Miss L. Sahoo, Sri P. Bastia, Sri K. C. Sahu, Sri R. K. Sahoo, Sri D. Naik, and Sri S. Das.

children participated in children's event. Among staffs, 20 volunteers coordinated for a successful completion of the Annual day. The winners of different events were awarded with silver medals in the Annual day program.

5. In the DAE zonal selection for Drama, i.e. in cultural group of DAE Sports and Cultural Meet 2015-16, IOP cultural team presented an Odia dramatic art "Ebam Kiea" in SINP, Kolkata on 17th December, 2015. This was highly appreciated by the judges. The team members are Sri S. Jena, Mr. J. K. Mishra, Sri B. Mishra, Miss L. Sahoo, Sri P. Bastia, Sri K. C. Sahu, Sri R. K. Sahoo, Sri D. Naik, and Sri S. Das.

6. Dr. Biswajit Mallick, Mr. Srikant Mishra and Mr. Chandra Mohan Hansdah were nominated on the behalf of Konark Group for the final of DAE Sports and Cultural Meet 2015-16, to participate in swimming event. It was organized by Kakrapar, Gujarat on 17th March 2016.

9

PERSONNEL

Prof. Sudhakar Panda
Director
Theoretical High Energy Physics

9.1. Faculty members and their research specialisation

1. **Prof. Arun M. Jayannavar**
   Sr. Professor
   Condensed Matter Physics (Theory)

2. **Prof. S. M. Bhattacharjee**
   Sr. Professor
   Condensed Matter Physics (Theory)

3. **Prof. Shikha Varma**
   Professor
   Condensed Matter Physics (Experiment)

4. **Prof. Ajit M. Srivastava**
   Professor
   High Energy Physics (Theory)

5. **Prof. Pankaj Agrawal**
   Professor
   High Energy Physics (Theory)

6. **Prof. Biju Raja Sekhar**
   Professor
   Condensed Matter Physics (Experiment)

7. **Prof. P. V. Satyam**
   Professor
   Condensed Matter Physics (Experiment)

8. **Prof. Snehadri B. Ota**
   Reader - F
   Condensed Matter Physics (Experiment)

9. **Prof. Sudipta Mukherji**
   Professor
   High Energy Physics (Theory)

10. **Prof. Suresh K. Patra**
    Professor
    Nuclear Physics (Theory)

11. **Prof. Tapobrata Som**
    Associate Professor
    Condensed Matter Physics (Experiment)

12. **Prof. Goutam Tripathy**
    Reader-F
    Condensed Matter Physics (Theory)

13. **Prof. Pradip Kumar Sahu**
    Associate Professor
    Nuclear Physics (Theory)

14. **Prof. Dinesh Topwal**
    Reader - F
    Condensed Matter Physics (Experiment)

15. **Prof. Amitabh Virmani**
    Reader - F
    High Energy Physics (Theory)

16. **Prof. Sanjib Kumar Agarwalla**
    Reader - F
    High Energy Physics (Theory)

17. **Prof. Arijit Saha**
    Reader - F
    Condensed Matter Physics (Theory)

18. **Prof. Saptarshi Mandal**
    Reader - F
    Condensed Matter Physics (Theory)

19. **Prof. Satyaprakash Sahoo**
    Reader - F
    Condensed Matter Physics (Experiment)

20. **Prof. Aruna Kumar Nayak**
    Reader-F
    High Energy Physics (Experiment)

21. **Prof. Debashis Choudhury**
    Reader - F
    Condensed Matter Physics (Theory)

22. **Prof. Shamik Banerjee**
    Reader - F
    Condensed Matter Physics (Theory)

23. **Prof. Debakanta Samal**
    Reader - F
    Condensed Matter Physics (Experiment)

9.2.Post-Doctoral Fellows

1. Suman Ganguli
2. Chirashree Lahiri
3. Somnath De
4. Bipul Rakshit
5. Chandan Giri
6. Priyadarshini Dash
7. Anirudha Ghosh *(Upto 9th October, 2015)*
8. Pranati Kumari Rath
9. Arnab Dasgupta
10. Paramita Dutta
11. T. Arun
12. Dinesh Kumar Ray
13. Maguni Mahakhud
14. Ravi Kumar Bomali
15. Md. Younus
16. Shidharth Shankar Ram
17. M. Muneeswaram
18. S. Bhattacharjee
19. Harapriya Rath

A. Research Associate

1. Sujit K. Choudhury
2. Tanmoy Basu *(Upto 31st May, 2015)*
3. Indrani Mishra
4. Partha Bagchi
5. Rama Chandra Baral
6. Sabita Das
7. Subhashis Rana
8. Tanmoy Pal

B. Teaching Assistant

1. Pramita Mishra
2. Vanaraj J. Solanki

9.3.Doctoral Scholars

1. Anjan Bhukta
2. Arnab Ghosh
3. Himanshu Lohani
4. Mohit Kumar
5. Shailesh Kumar Singh
6. Shailik Ram Joshi
7. Sk. Sazim
8. Subhadip Ghosh
9. Arpan Das
10. Sumit Nandi
11. Soumyarata Chatterjee
12. Subrata Kumar Biswal
13. Bidisha Chakrabarty
14. Priyo Shankar Pal
15. Puspendu Guha
16. Sabya Sachi Chatterjee

17. Shreyansh Shankar Dave
18. Sudipta Mahana
19. Arpan Das *(Junior)*
20. Ashis Kumar Manna
21. Bharat Kumar
23. Chandan Datta
24. Debashis Saha
25. Mahesh Saini
26. Paramita Maiti
27. Pronoy Nandi
28. Ranveer Singh
29. Amit Kumar
30. Biswajit Das
31. Debashis Mallick
32. Ganesh Chandra Paul
33. Partha Paul
34. Pratik Roy
35. Sujay Shil
36. Vigigiri Vikas
37. Alapan Dutta
38. Atanu Maity
39. Amir Shee
40. Dibyendu Rana
41. Dilruba Hasina
42. Mukaddar Sk.

9.4.Administration

Prof. B. R. Sekhar, Registrar.

(i) Director's Office:

1. Sk Kefaytulla
2. Raja Kumari Patra
3. Rajesh Mohapatra
4. Rajan Biswal
5. Sudhakar Pradhan

(ii) Registrar's Office

1. Bira Kishore Mishra
2. Abhimanyu Behera

(iii) Establishment

1. M.V. Vanjeeswaran
2. Jaya Chandra Patnaik
3. Sahadev Jena
4. Bhagaban Behera
5. Baula Tudu
6. Samarendra Das

(iv)Stores & Transport

1. Pramod Kumar Senapati
2. Sadananda Pradhan
3. Sanatan Jena
4. Sarat Chandra Pradhan
5. Sanatan Das
6. Jahangiri Khan

(v) EPABX

1. Srikanta Rout *(Expired on 25.08.2015)*
2. Ghanashyam Naik

(vi)Despatch

1. Krushna Chandra Sahoo

(viii)Accounts

1. Ranjan Kumar Nayak
2. Pravat Kumar Bal
3. Kali Charan Tudu *(upto 30/11/2015)*
4. Jitendra Kumar Mishra
5. Bhaskara Mishra
5. Prativa Choudhury
6. Soubhagya Laxmi Das
7. Aviram Sahoo
8. Priyabrata Patra
9. Chandramani Naik
10. Bansidhar Panigrahi

(ix) Maintenance

1. Arun Kanta Dash
2. Subhabrata Tripathy
3. Debaraj Bhuyan
4. Bansidhar Behera
5. Brundaban Mohanty
6. Deba Prasad Nanda
7. Rama Chandra Murmu
8. Naba Kishore Jhankar
9. Baikuntha Nath Barik
10. Purna Ch. Maharana
11. Sajendra Muduli
12. Pabani Bastia
13. Rabi Narayan Mishra
14. Umesh Ch. Pradhan
15. Gandharba Behera
16. Biswa Ranjan Behera
17. Kapila Pradhan
18. Martin Pradhan
19. Chandra Mohan Hansdah

(x) Estate Management

1. Sri Saroj Ku. Jena.
2. Dhobei Behera
3. Gangadhar Hembram
4. Tikan Kumar Parida
5. Kailash Chandra Naik
6. Banamali Pradhan
7. Gokuli Charan Dash
8. Biswanath Swain
9. Bijoy Kumar Swain
10. Bijoya Kumar Das
11. Babuli Naik
12. Pradip Kumar Naik
13. Meena Dei
14. Sanatan Pradhan
15. Bhaskara Mallick
16. Kulamani Ojha
17. Pitabas Barik
18. Dhoba Naik
19. Charan Bhoi
20. Jatindra Nath Bastia
21. Basanta Kumar Naik
22. Daitari Das

(xi) Library

1. Prafulla Kumar Senapati *(Upto 30/4/2015)*
2. Dillip Kumar Chakraborty
3. Ajita Kumari Kujur
4. Rama Chandra Hansdah
5. Rabaneswar Naik
6. Kisan Kumar Sahoo
7. Sri Kailash Chandra Jena

(xii) Computer Centre

1. Nageswari Majhi

(xiii) Laboratory

1. Sanjib Kumar Sahu
2. Anup Kumar Behera
3. Sachindra Nath Sarangi
4. Khirod Chandra Patra
5. Madhusudan Majhi
6. Ramarani Dash
7. Santosh Kumar Choudhury
8. Biswajit Mallick
9. Pratap Kumar Biswal
10. Arakhita Sahoo
11. Bala Krushna Dash
12. Soumya Ranjan Mohanty
13. Kshyama Sagar Jena
14. Purna Chandra Marndi
15. Srikanta Mishra
16. Ranjan Kumar Sahoo

(xiv) Workshop

1. Ramakanta Nayak
2. Rabi Narayan Naik

9.5. LIST OF NEW FACULTY MEMBERS

Prof. Arijit Saha
Date of Joining - 05.05.2015
Designation - Reader - F

Prof. Saptarshi Mandal
Date of Joining - 05.05.2015
Designation - Reader - F

Prof. Satyaprakash Shoo
Date of Joining - 18.09.2015
Designation - Reader - F

Prof. Aruna Kumar Nayak
Date of Joining - 20.10.2015
Designation - Reader - F

Prof. Debashis Choudhury
Date of Joining - 01.02.2016
Designation - Reader - F

Prof. Shamik Banerjee
Date of Joining - 01.03.2016
Designation - Reader - F

Prof. Debakanta Samal
Date of Joining - 30.03.2016
Designation - Reader - F

9.6. LIST OF NEW ADMINISTRATIVE STAFF

Shri Abhishek Maharik
Date of Joining - 16.04.2015
Designation- LDC, Esst. Section

Shri Ghansshyam Pradhan
Date of Joining - 21.04.2015
Designation- LDC, Esst. Section

Ms. Lipika Sahoo
Date of Joining - 01.05.2015
Designation - LDC, A/c. Section

Shri Raj Kumar Sahoo
Date of Joining - 01.05.2015
Designation - LDC, A/c. Section

9.7. LIST OF RETIRED MEMBERS

Shri P. K. Senapati
Date of Retirement - 30.04.2015
Date of Joining - 09.09.1974
Designation - SA-F

Shri Kali Charan Tudu
Date of Retirement - 30.01.2015
Date of Joining - 13.12.1983
Designation- Sr. Asst, Accounts

9.8. OBITUARY

Shri Srikanta Kumar Rout
Date of Joining - 19/09/1979
Date of Expired - 25/08/2015
Designation - SA - D

10

AUDITED STATEMENT OF ACCOUNTS

10.1. Balance Sheet

INSTITUTE OF PHYSICS, BHUBANESWAR

BALANCE SHEET AS AT 31ST MARCH 2016

(Amount - Rs.)

CORPUS/ CAPITAL FUND AND LIABILITIES	Schedule	Current Year	Previous Year
CORPUS/ CAPITAL FUND	1	59,86,78,612	52,64,34,053
RESERVES AND SURPLUS	2	-	-
EARMARKED/ ENDOWMENT FUNDS	3	2,72,697	1,49,700
SECURED LOANS AND BORROWINGS	4	-	-
UNSECURED LOANS AND BORROWINGS	5	-	-
DEFFERED CREDIT LIABILITIES	6	-	-
CURRENT LIABILITIES AND PROVISIONS	7	23,38,44,204	27,33,80,525
TOTAL		**83,27,95,513**	**79,99,64,278**
ASSETS			
FIXED ASSETS	8	72,72,81,742	65,52,72,750
INVESTMENTS FROM EARMARKED/ ENDOWMENT FUNDS	9	-	-
INVESTMENTS OTHERS	10	-	-
CURRENT ASSETS, LOANS, ADVANCES ETC.	11	10,55,13,771	14,46,91,528
TOTAL		**83,27,95,513**	**79,99,64,278**
SIGNIFICANT ACCOUNTING POLICIES CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	24		

In terms of our report of even date annexed

For LAL DASH & CO
Chartered Accountants

'CA.A.K. SAMANTARAY FCA)
PARTNER
M.No.063226

लेखा अधिकारी / ACCOUNTS OFFICER
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

रजिस्ट्रार/Registrar
भौतिकी संस्थान/Institute of Physics
भुवनेश्वर/Bhubaneswar

निदेशक / DIRECTOR
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

Place : Bhubaneswar
Date : 07-10-2016

10.2. Income & Expenditure Account

INSTITUTE OF PHYSICS, BHUBANESWAR

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD/YEAR ENDED 31ST MARCH 2016

(Amount - Rs.)

INCOME	Schedule	Current Year	Previous Year
Income from sale or servces	12	-	-
Grants/ Subsidies	13	22,87,04,220	19,71,97,434
Fees/ Subscriptions	14	-	-
Income from investments	15	-	-
Income from royalty, Publication etc	16	-	-
Interest Earned	17	25,21,772	24,45,529
Other Income	18	16,68,181	17,15,735
Increase decrease in stock of finised goods/ WIP	19	-	-
Profit on Sale of Asset		9,264	35,000
TOTAL (A)		**23,29,03,437**	**20,13,93,698**
EXPENDITURE			
Establishment Expenses	20	15,06,35,280	12,59,08,173
Other Administrative Expenses etc.	21	8,60,17,654	7,60,98,097
Expenditure on grants Subsidies etc	22	-	-
Interest Paid	23	-	-
Depreciation		9,34,73,984	7,14,47,263
Loss of Assets		32,710	-
TOTAL (B)		**33,01,59,628**	**27,34,53,533**
Balance being excess of Expenditure over Income (B-A)		(9,72,56,191)	(7,20,59,835)
BALANCE BEING SURPLUS/(DEFICIT) CARRIED TO CORPUS/ CAPITAL FUND		**(9,72,56,191)**	**(7,20,59,835)**
SIGNIFICANT ACCOUNTING POLICIES CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	19		

In terms of our report of even date annexed

For LAL DASH & CO
Chartered Accountants
('CA.A.K. SAMANTARAY FCA)
PARTNER
M.No.063226

Place : Bhubaneswar
Date : 07-10-2016

लेखा अधिकारी / ACCOUNTS OFFICER
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

रजिस्ट्रार/Registrar
भौतिकी संस्थान/Institute of Physics
भुवनेश्वर/Bhubaneswar

निदेशक / DIRECTOR
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

10.3. Receipts & Payments

INSTITUTE OF PHYSICS, BHUBANESWAR
RECEIPTS & PAYMENTS FOR THE FINANCIAL YEAR 2015-16

(Figure in Rs.)

	RECEIPTS	SCH	Current Year	Previous Year		PAYMENTS	SCH	Current Year	Previous Year
I.	**Opening Balance**				I.	**Expenses**			
	a) Cash in hand		33,592	16,427		a) Establishment Expenses	C	13,88,90,783	11,69,37,494
	b) Bank balances					b) Administrative Expenses	D	4,49,30,180	4,35,84,081
	i) In current accounts SBI		1,22,72,793	37,59,422		c) Maintenance Expenses	E	2,02,36,539	1,74,26,337
	ii) In deposit accounts				II.	**Payments made against funds for various projects**			
	LK Panda (SBI Term Deposit)		1,00,000	1,00,000		TPSc		29,530	1,07,001
	iii) Savings accounts					LK panda Scholarship		5,000	5,000
	Indian Overseas Bank (NP)		1,74,25,370	1,24,96,771					
	Indian Overseas Bank (Plan)		3,31,53,164	3,01,75,979					
	Union Bank (NP)		81,339	6,24,506	III.	**Expenditure on Fixed Assets & Capital W.I.P**			
	Union Bank (Plan)		75,07,354	84,77,010					
	SBI (LK Panda)		42,142	45,392		a) Purchase of Fixed Assets	F	11,67,21,534	11,36,62,098
	Union Bank (TPSC)		7,558	12,304					
II.	**Grants Received**				IV.	Interest Receivable		-	-
	a) From Govt. of India - Plan		11,00,00,000	9,40,00,000					
	Non-Plan		24,84,00,000	22,00,00,000	V.	**Project Revenue Expenses**	G	2,34,49,994	1,03,60,905
	b) From State Government		-	-	VI.	**STAFF LOAN**	H	11,17,435	12,58,708
	c) Raja Ramana Fellowship		-	-					
III.	**Receipts against Sponsored Projects**				VII.	Security Deposit with CESU		-	-
	TPSC		94,000	1,00,000					
IV.	**Income on Investments from**				IX.	**Closing Balance**			
	LK Panda A/c		60,691	1,750		a) Cash in hand		4,138	33,592
	TPSC A/c		2,836	2,255	X.	b) Bank balances			
V.	**Interest Received**	A	25,91,746	25,60,420		i) In current accounts SBI		99,74,635	1,22,72,793
VI.	**Other Income (Specify)**					ii) In deposit accounts			
	Misc Receipts		3,26,000	4,10,917		LK Panda (SBI Term Deposit)		1,00,000	1,00,000
	Sale of Tender paper		1,42,300	34,100		iii) Savings accounts			
	House/Guest House Rent		12,15,329	10,45,539		Indian Overseas Bank (NP)		2,32,32,003	1,74,25,370
	Advance from NISER		-	-		Indian Overseas Bank (Plan)		4,43,07,151	3,31,53,164
	Sale of Asset		-	32,500		Union Bank (NP)		24,68,336	81,339
VII.	**Other Receipts**					Union Bank (Plan)		84,74,715	75,07,354
	Earnest Money Deposit		5,23,992	1,64,350		SBI (LK Panda)		97,833	42,142
	Security Deposit		(2,79,336)	(4,78,706)		Union Bank (TPSC)		74,864	7,558
	Security Deposit BSNL		-	-					
	Caution Money		1,000	1,600					
	RECOVERY OF STAFF LOAN	B	4,12,800	3,82,400					
	TOTAL		**43,41,14,670**	**37,39,64,936**		**TOTAL**		**43,41,14,670**	**37,39,64,936**

For LAL DASH & CO
Chartered Accountants

(CA.A.K. SAMANTARAY FCA)
PARTNER
M.No.063226

लेखा अधिकारी / ACCOUNTS OFFICER
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

रजिस्ट्रार/Registrar
भौतिकी संस्थान/Institute of Physics
भुवनेश्वर/Bhubaneswar

निदेशक / DIRECTOR
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

NOTES