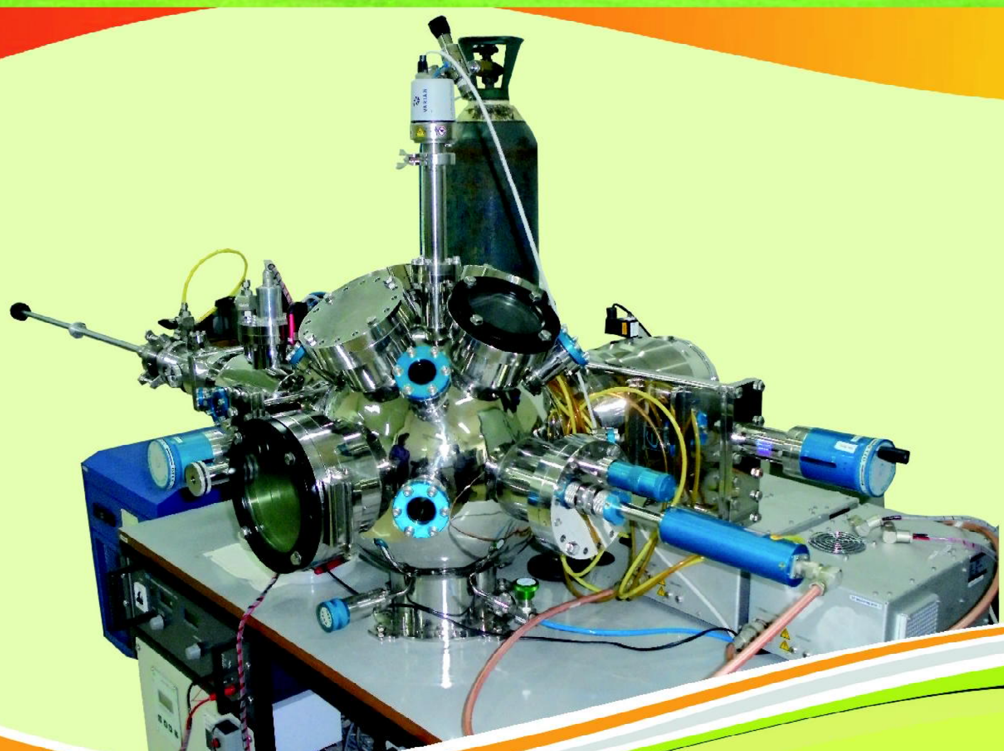
ANNUAL REPORT
2013-2014



INSTITUTE OF PHYSICS
BHUBANESWAR

Annual Report

2013-2014

INSTITUTE OF PHYSICS

BHUBANESWAR

INSTITUTE OF PHYSICS

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Published by
B. C. Parija, Officiating Registrar

Compilation, Layout and Designed by
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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 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

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Prof. Sudhakar Panda *(From 23.01.2014)*
Director, Institute of Phsics
Bhubaneswar - 751005

Shri K. Padmanabhan
Officer on Special Duty,
Institute of Physics,
Bhubaneswar - 751005

From Director's Desk . . .

It is my great pleasure to present you the Annual Report of Institute of Physics (IOP), Bhubaneswar for the financial year 2013 – 2014. This document provides a comprehensive account of our many activities, developments / improvements and accomplishments.

Institute of Physics is a premier research Institute, an autonomous organization of Department of Atomic Energy (DAE) from the year 1985. Before 1985 the Institute was functioning with the support of the Government of Odisha. Basic research in Physics (both theoretical and experimental) is the main mandate of IOP. This report describes various exeperimental facilities available at the Institute and provides a brief description of academic programs including the scientific publications from the Institute in last one year. The report also contains list of seminars held in the Institute, conferences/workshops organized by IOP.

Like previous years, IOP has been able to attract many talented young students to pursue their Ph.D. degrees. We are in the process of hiring new faculty members to strengthen our academic activities.

I thank members of Governing Council of IOP, specially Prof. S. K. Joshi, Chairman for their support. Finally, I would like to congratulate all the members of the team for Annual Report for bringing out this comprehensive report.

Let us look forward for a fruitful year ahead of us.

(Professor Sudhakar Panda)

1 FACILITIES

1.1 EXPERIMENTAL FACILITIES

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 -45° is used for RBS, ERDA and ion channeling. Radiocarbon AMS is carried out in the -15° beam line. A general purpose scattering chamber suitable for PIXE experiments is available in the 0° line. This beam line also has the potential to perform external PIXE experiments in atmosphere. The 15° 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 30° beam line. The 45° 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

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.

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

Ion beam etching induced surface nanostructuring

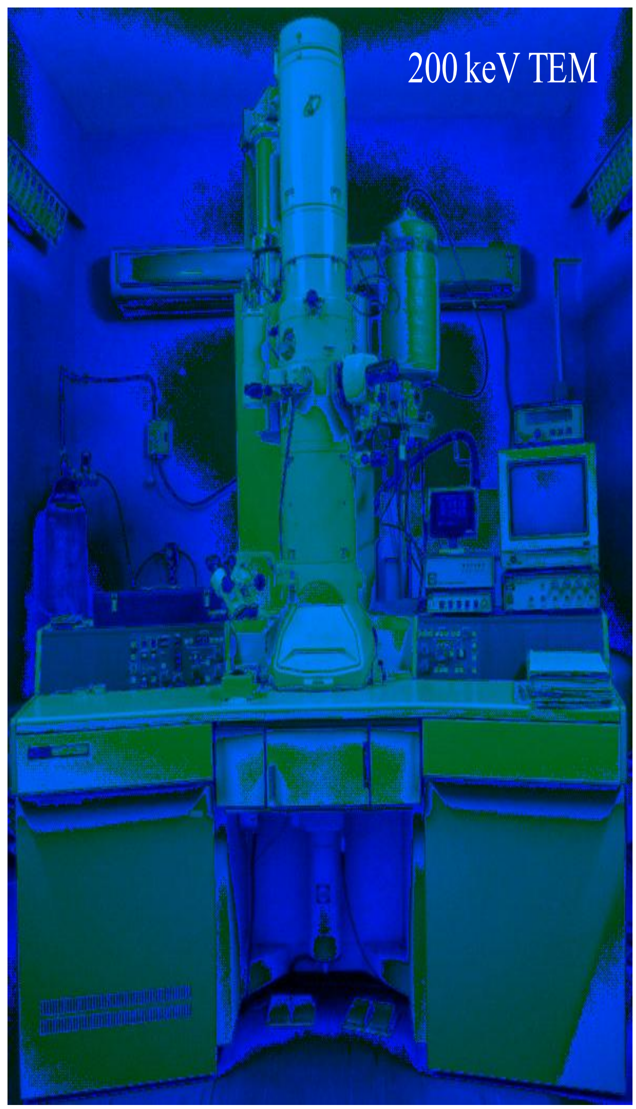
At Surface Nanostructuring and Growth (SUNAG) Laboratory, we have facilitated a low energy (50 eV – 2 keV), broad beam (I in. diameter) electron cyclotron resonance (ECR) source based ion beam etching facility for creating self-organized surface nanostructures. The source is equipped with a differential 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.

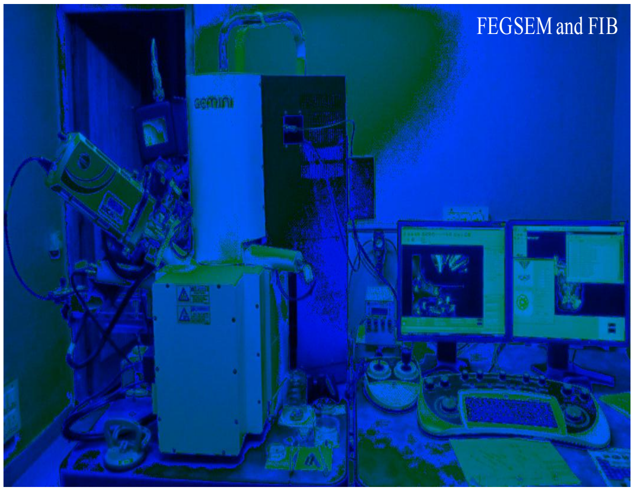
MICROSCOPY FACILITEIS

HRTEM Laboratory

The 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

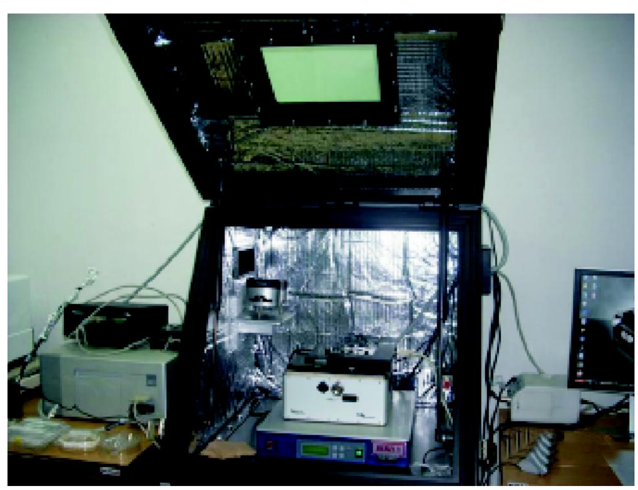


A combination of Field Emission Gun based Scanning Electron Microscope and Focused Ion Beam imaging (FEGSE-FIB) is used to image nanoscale features and modify these structures while observing the structural evaluation with SEM. The above facility is model Neon 40 Cross Beam, from Ziess GmbH, Germany.

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.

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

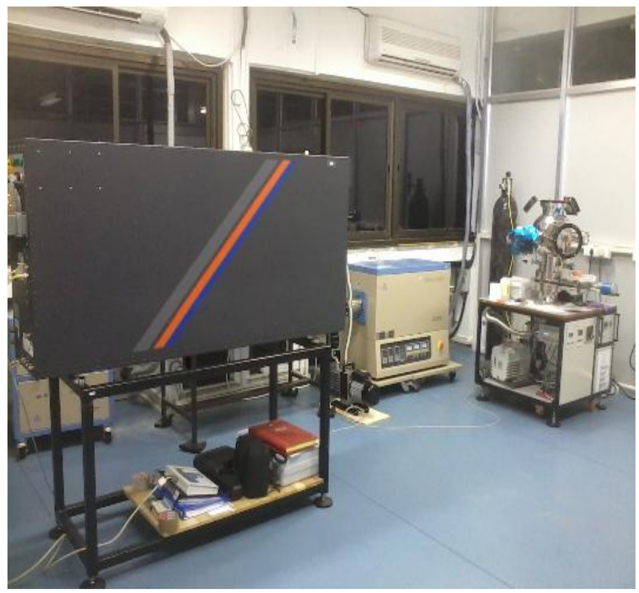
distinguish different chemical environments of atoms; these appear in XPS spectra as core level binding energy shifts. The origin of chemical shifts arises from enhanced or reduced electronic screening of electrons due to charge transfer. Small mean free paths of the photo-ejected electrons make XPS 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

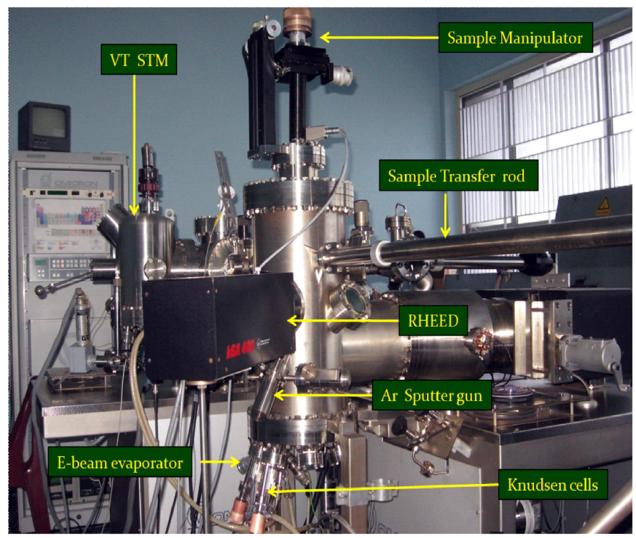


This is a newly installed facility. PLD system helps growing epitaxial thin films of various materials albeit the most prefered materials are oxides. The newly installed system was developed in a piece-wise manner by procuring several modules from different sources. We are depositing epitaxial bi- and 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 degree Centigrade) 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 7Tesla(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

Micro-Raman Spectrometer

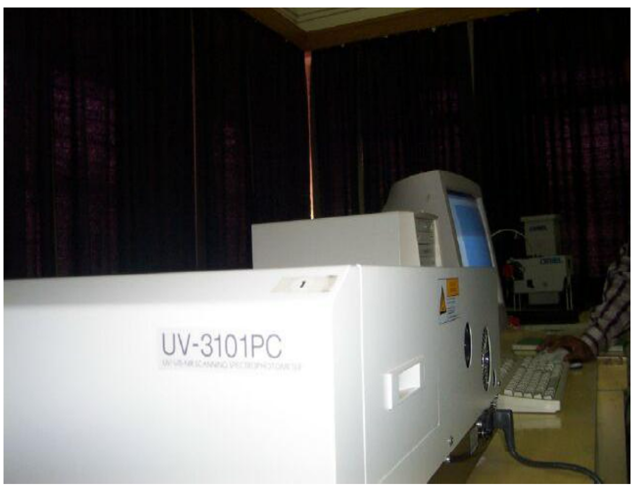
Micro Raman (Jobin Yvon U1000) spectrometer with double monochromator configuration and optimal resolution 0.1 cm^{-1}. Both solid and liquid samples can be used to perform Raman experiments. Spectra can be recorded through a PC and analysis can be carried out using SPEX software. Lattice vibrational modes of characteristic elements/ compounds/ semiconductors can be studied. Apart from this, crystalline structure/orientation, impurity effects and crystalline size can also be estimated.

FTIR Spectrometer

FTIR (model : Avtar-370) spectrometer. It consists of an Ever-Glow source capable of producing IR signal in the spectral range of 200-4000 cm^{-1} while glowing at 1200 to 1250°C. The modulator consists of a CsI beam splitter and two metallic mirrors to generate the interferogram. The transmitted IR is detected by a DTGS-CsI detector with

1cm-1 resolution. There are two modes of operation. In case of transmittance mode, the sample is directly fixed in front of IR source and the transmitted signal is allowed to the detector. In order to carry out the FTIR measurement of the solid, opaque sample in grazing angle specular reflectance mode, SAGA NEXUS accessory has been provided. The instrument can identify organic compounds and inorganic oxides.

UV-Vis-NIR Spectrophotometer



Shimadzu-make UV-3101PC spectrophotometer with PbS detector (for longer wavelengths) is available at Cluster & Nanostructure Lab. The spectrophotometer uses two sets of gratings to cover a wide range of wavelengths (200-3200 nm). Both solid and liquid samples can be used for experiments. Optical properties viz. band gap estimation, quality of the crystal etc. can be studied. The instrument can operate in absorbance, transmission and diffused reflectance mode.

Fluorescence Spectrometer

Oriel-make fluorescence assembly comprising of double monochromators, excitation source (Hg-Xe lamp) and PMT

(250-850 nm) detector is available at Cluster & Nanostructure Laboratory. Temperature (down to liquid-nitrogen temperature) effect on luminescence can be studied for semiconductors, oxides and organic compounds. This instrument can identify trap states, band edges of semiconductors and also new organic compounds based on luminescence properties of materials.

Spectral Response System

This system (procured from Sciencetech, Canada) includes a 150 W Xenon light source, a monochromator to tune the light source, and the necessary probes to attach to the sample. A source meter used as an active load permits operating the test cell at various load conditions, including short-circuit, compensating for a series resistor required to sense the current produced by the modulated monochromatic light. This sensed current plus a reference signal at the frequency of the light modulation are

both fed into the precision lock-in amplifier to allow measurement of thephotocurrent generated by the modulated monochromatic light.

By a combination of resistivity setup and spectral response system, one can measure these parameters of thin films:

(1) Photocurrent versus voltage characteristic with fixed or variable wavelength.

(2) Current versus time (response of photocurrent) or in simple word one can measure switching effect.

(3) Photoconductivity of a thin film.

(4) Band gap

(5) Defect density in the band gap

X-Ray Fluorescence (SRF) Spectrometer

A small portable XRF facility based on fixed tube source (0.1 kW) and using a energy dispersive system to study the toxic elements (high Z) in fly ash products and elemental analysis in some wood samples.

ELECTRICAL PROPERTY MEASUREMENT FACILITIES

Cyclic Voltametry

A Potentiostat- Galvanostat, from Autolab, has been procured which can be utilized to investigate the electroanalystical properties like electrocatalysis, electrodepostion for semiconductors, dielectric materials, polymers, membranes etc. Cyclic Voltametry is an effective technique to study redox systems. It enables the electrode potential to be rapidly

scanned. In cyclic Voltametry experiment the working electrode potential is ramped linearly versus time. The voltagrams are utilized to study the electrochemical properties of an analyte solution. Application areas include conductive coatings, polymers, semiconductors, batteries, fuel cell, super capacitors etc.

L CR Meter

The interfacial capacitance-voltage (C-V) measurement can be carried out using the LCR meter, HP make

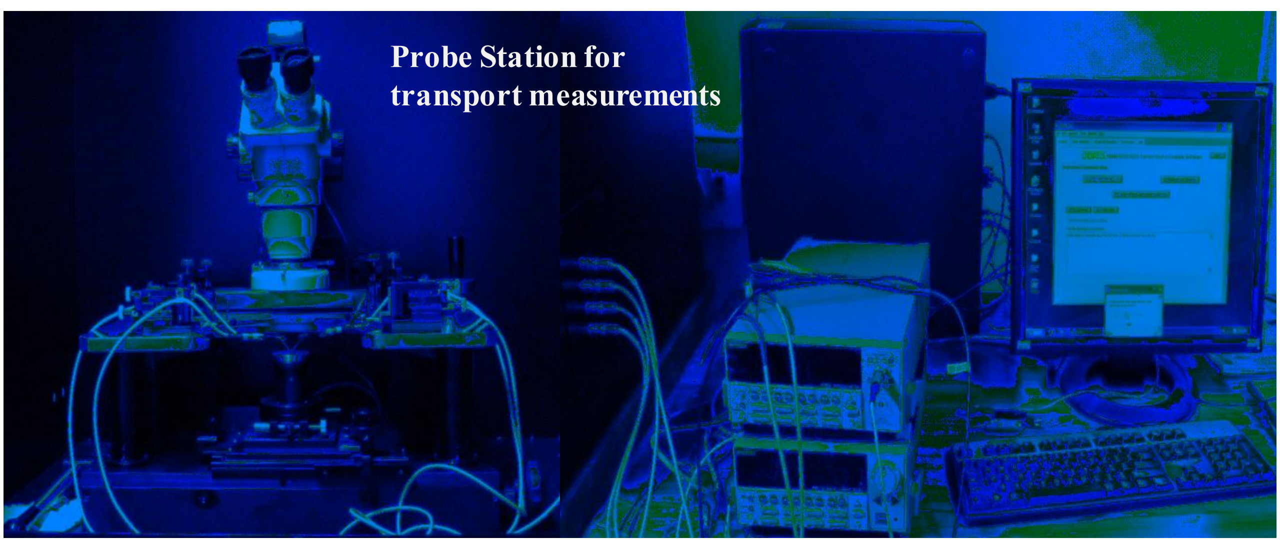
LCR meter (model: 4284A) in SUNAG lab.

The LCR meter has the capability to measure the conductance (L), capacitance (C), and resistance (R) of the semiconductor device over a wide range of frequencies (20Hz to 1MHz) and test signal levels (5 mV to $2V_{rms}$, 50 μA to 20 mA_{rms}).

We have other facilities like

- Chemical Labs (with ductless fumehood (Esco-make), centrifuge, LB film deposition set-up (Nima-make), Spin coater, MilliPore Water purifiers)
- Furnaces : Rapid Thermal Annealing Unit, Low Vacuum Furnace.
- CVD set-up (indigenously build)
- HV thin film deposition unit (Hind Hivac-make)
- Ion Miling Station
- Plasma Cleaner for TEM specimen preparation

PROBE STATION FOR TRANSPORT MEASUREMENTS



A Keithley-make probe station is used to study electrical transport properties of nanostructured thin films and individual nano structures.

For details of contact persons for the IOP experimental facilities, please visit : http://www.iopb.res.in/exp-fac.php

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 PCs installed in the computer centre, laboratories and offices of faculties, scholars and administration in the Institute. The servers, the central network hub, firewall, about twenty PCs and network printers are installed in the computer centre. User's data and general utilities are centrally stored in the file server and are made available on the user's desktop PCs by NFS over LAN. Programs which require large amount of computation are run in HPC's. Number of software packages such as Mathematica, Maple, Origin, IDL, Numerical Recipes are available for carrying out numerical computation, symbolic calculation, graphical analysis, modelling and simulation. GUPIX and SIMNRA softwares are available for analysis of experimental data. For preparing scientific documents Latex is available in the PCs running under Linux. Number of printers are installed at different locations for 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. Wirelss access points have been set up in the library, computer centre, main building, auditorium, lecture hall and access to LAN by wireless is being extended to other locations in the Institute. Access to LAN has been provided to the quarters of faculty in the campus through ADSL system using telephone lines. The LAN is made secure by installation of firewall. Antispam software is used to filter unwanted mails. Antivirus software has been installed in the PCs running under MS Vista operating system in offices and laboratories.

The internet link to Institute is available at two dedicated bandwidths of 64 mbps each provided by commercial internet service providers and at 100 mbps 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 using ANUNET link for analysis.

For the administrative work, such as accounting, personnel management, stores management etc. computers being used with the help of several software packages such as MSOffice, Wings 200 Net and Tally.

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

1.3 LIBRARY

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 holdings include 15,106 books and 23,643 bound volumes of Journals, taking the total collection to 38,749. During the year the Library added 98 books to its collection. The Library has subscribed to 140 Journals. The Library has also acquired IOP (OJA), John Wiley two Online Journal Archives (OJA) perpetual access right to the back files containing all articles published since Volume 1 in electronic format and Springer Physics and Astronomy (OJA), from Vol.1.This year Library also has subscribed to e-Books on Lecture Notes in Mathematics and Lecture Notes in Physics series from vol.1 with perpetual access right to back files and full archives containing all articles published since 2011. Besides this, the Library is a part of the Dept. of Atomic Energy consortium with Elsevier Science from 2003 thus getting access to around 1500 journals electronically. The Library assists

users in obtaining articles from other Libraries in the country under resource sharing program. The Library also sends out articles as Digital inter Library Loan (dill@iopb.res.in).

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. The Library facility is available to the members of the Institute, NISER, as well as members from other academic institutions.

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 the Institute has a regular Pre-doctoral (post M.Sc.) course.

The pre-doctoral program of the Institute of Physics 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 conducting the written test for the Ph.D. program in physics for students across the country. The final selection of a student is made after an interview conducted at the Institute. The Pre-doctoral course began in August, 2013 and ended in June, 2014 leading to a Diploma in Advanced Physics awarded by the Institute. The Utkal, Berhampur and Sambalpur Universities have recognized the diploma as equivalent to their M.Phil degrees. On completion of the Pre-doctoral program, the students are eligible to join research under supervision of faculty members of the Institute, leading to the Ph.D. degree awarded by Utkal University or Homi Bhabha National Institute (HBNI).

To recognize the talent, the Institute has instituted the 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 294 students were called for interview for admission to the predoctoral course in July, 2013. This includes JEST qualifiers, UGC-CSIR qualifiers and valid GATE score holders. Out of those who were admitted, the following students have successfully completed the pre-doctoral course in June, 2014 :

Ms. Arpan Das
Mr. Ashis Kumar Manna
Mr. Bharat Kumar
Mr. Chandan Datta
Mr. Debashis Saha
Mr. Mahesh Saini
Ms. Paramita Maiti
Mr. Pronoy Nandi
Mr. Ranveer Singh

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

Trimester – I (August - November)

Quantum Mechanics	: Prof. K. Kundu
Mathematical Methods	: Dr. A. Virmani
Classical Electrodynamics	: Dr. P. Agrawal
Theory of Experiments	: Dr. T. Som
Experiments	: Dr. D. Topwal

Trimester – II (December - March)

Statistical Mechanics : Prof. A.M.Jayannavar
Adv. Quantum Mechanics : Prof. A.M.Srivastava
Field Theory : Dr. S. Mukherji
Numerical Methods : Prof. S. Varma
Experiment : Dr. D. Topwal

Trimester – III (April - July)

Cond. Matter. Physics : Dr. B. R. Sekhar
Particle Physics : Dr. S. Agarwalla
Nuclear Physics : Dr. P.K. Sahu

As a part of the course work, the pre-doctoral students also worked on projects in the last trimester under supervision of faculty. Titles of the projects undertaken by predoctoral student during 2013-2014 are as given below.

	Title of Project	Name of Student	Name of Supervisor
1.	Solitons and Instantons	Arpan Das	Dr. S. Mukherji
2.	The Scanning tunneling mocroscopy & Atomic force microscopy	Ashis K. Manna	Dr. S. Varma
3.	Shape co-existence and parity doublet in Zr-isotopes	Bharat Kumar	Dr, S. K. Patra
4.	Exploration of Nonlocality	Chandan Datta	Dr. P. Agrawal
5.	Neutrino Osscillation and mass hierarchy	Debashis Saha	Dr. S. K. Agarwalla
6.	Low Energy Ion Induced Nano-Patterning of Surfaces	Mahesh Saini	Dr. T. Som
7.	RHEED study and SEM imaging of silver on Si (111) Surface	Paramita Maiti	Dr. P. V. Satyam
8.	Study of hybrid perovskites for solar cell aplications	Pronoy Nandi	Dr. D. Topwal
9.	Growth of thin film by dc sputtering technique	Ranveer Singh	Dr. T. Som

Mr. Chandan Datta was adjudged the most outstanding pre-doctoral scholar and was awarded the **L. K. Panda Memorial Fellowship** for the year 2013-14.

2.2 DOCTORAL PROGRAM

Presently Institute has presently 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. The progress of each doctoral scholar is reviewed annually by a review committee. The reviews are held normally in the months of July-August every year.

2.3 THESES

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

1. **Mr. Subrata Majumdar** : " Studies of nanostructures, ion beam patterned surfaces and their interaction with DNA".
Supervisor - Prof. Shikha Varma.

2. **Mr. Sourabh Lahiri :** "Fluctuation relations, their consequences and some examples".
Supervisor - Prof. A. M. Jayannavar.

3. **Mr. Ambresh K. Shivaji :** "Gluon Fusion Processes at One Loop within the Standard Model and Beyond".
Supervisor - Prof. P. Agrawal.

4. **Mr. Trilochan Bagarti : "**A Theoretical study of formation of clusters at nanoscale using reaction diffusion models in one and two dimensions"
Supervisor - Prof. K. Kundu.

5. **Ms. Soumia P. S. :** "Flow Anisotropies in Relativistic Heavy-Ion Collisions, CMBR Anisotropies and their Interconnections". Supervisor - Prof. A. M. Srivastava.

6. **Ms. Jaya Maji :** "Efimov-like states and Conformational Transitions of DNA". Supervisor - Prof. S. M. Bhattacharjee.

7. **Mr. Sankhadeep Chakrabortty :** "Aspects of gauge/gravity duality".
Supervisor - Prof. (Late) A. Kumar &
Prof. A. M. Jayannavar.

2.4 SSVP – 2013

The motivation of the SSVP program is to expose the young students to frontline research areas, especially in the areas of research work going on at the Institute.

The Summer Student's Visiting Program (SSVP) was held from 7th May to 15th June, 2013. This year following 10 students *(Subhra Dash, Tanvi Wamorkar, Eneet Kaur, Vishnu T.R. , Sasmita Sahoo, Shikha Binwal, Lakshmi B. Naik, Seema Prasad, Kritika. S. , Stutimayee)* participated in the program. Round trip train fare, accommodation on campus, and a monthly stipend of Rs. 4500/- were provided to the visiting students.

Under this program, each student worked under guidance of a faculty member of the Institute. At the end of the course, the students presented their work in a seminar on the assigned topics.

3 RESEARCH

3.1 THEORETICAL CONDENSED MATTER PHYSICS

1. **Fluctuation theorems in inhomogenious media under coarse graining**

We compare the fluctuation relations for work and entropy in underdamped and over-damped systems, when the friction coefficient of the medium is space-dependent. We find that these relations remain unaffected in both cases. We have restricted ourselves to Stratonovich discretization scheme for the overdamped case. However, the microscopic defination of heat is altered for the coarse grained overdamped case.

Sourabh Lahiri, Shubhashis Rana and A. M. Jayannavar

2. **Persistent currents in absence of magnetic field in graphene nanorings**

The ambiguous role of inter valley scattering Persistent currents can arise in normal-metal rings due to a magnetic flux threading the ring in equilibrium. However, can persistent currents arise in absence of magnetic flux in the same normal-metal rings? Yes they can but in a non-equilibrium set-up. This is known as current magnification. In this work we show that current magnification can be seen in graphene nanorings. Further, graphene can have electrons polarized with a valley quantum number. Electron scattering between valleys can have a non-trivial effect on these persistent currents including inducing a sign change and generating them for parameters where none existed to begin with.

Colin Benjamin, A M Jayannavar

3. **Fluctuation theorems for excess and housekeeping heats for underdamped Systems**

We present a simple derivation of the integral fluctuation theorems for excess house-keeping heat for an underdamped Langevin system, without using the concept of dual dynamics. In conformity with the earlier results, we find that the fluctuation theorem for housekeeping heat holds when the steady state distributions are symmetric in velocity, whereas there is no such requirement for the excess heat. We first prove the integral fluctuation theorem for the excess heat, and then show that it naturally leads to the integral fluctuation theorem for housekeeping heat. We also derive the modified detailed fluctuation theorems for the excess and housekeeping heats.

Sourabh Lahiri and A. M. Jayannavar

4. **Exchange fluctuation theorems for interacting particles in presence of two heat baths**

The exchange fluctuation theorem for heat exchanged between two systems at different temperatures, when kept in direct contact, has been investigated by C. Jarzynski and D. K. W´ojcik, in Phys. Rev. Lett. 92, 230602 (2004). We extend this result to the case where two reservoirs at different temperatures are connected via a conductor made of interacting particles, and are subjected to an external drive. We first derive the Crooks theorem for the ratio between forward and reverse paths, and discuss the first law in this model. Then we derive the modified detailed fluctuation theorems (MDFT) for the heat exchanged at each end. These theorems differ from the usual form of the detailed fluctuation theorems (DFT) in literature, due the presence of an extra multiplicative factor. This factor quantifies the deviation of our MFDT from the DFT. Finally, we numerically study our model, with only two interacting particles for simplicity.

Sourabh Lahiri and A. M. Jayannavar

5. DNA unzipping

The force induced unzipping transition of a double stranded DNA is considered from a purely thermodynamic point of view. This analysis provides us with a set of relations that can be used to test microscopic theories and experiments. The thermodynamic approach is based on the hypothesis of impenetrability of the force in the zipped state. The melting and the unzipping transitions are considered in the same framework and compared with the existing statistical model results. The analysis is then extended to a possible continuous unzipping transition.

Poulomi Sadhukhan and S. M. Bhattacharjee

6. DNA Melting

Thermal denaturation of DNA is often studied with coarse-grained models in which native sequential base pairing is mimicked by the existence of attractive interactions only between monomers at the same position along strands (Poland and Scheraga models). Within this framework, the existence of a three strand DNA bound state in conditions where a duplex DNA would be in the denaturated state was recently predicted from a study of three directed polymer models on simplified hierarchical lattices ($d > 2$) and in 1+1 dimensions. Such phenomenon which is similar to the Efimov effect in nuclear physics was named Efimov-DNA. In this paper we study the melting of the three-stranded DNA on a Sierpinski gasket of dimensions $d < 2$ by assigning extra weight factors to fork openings and closings, to induce a two-strand DNA melting. In such a context we can find again the existence of the Efimov-DNA-like state but quite surprisingly we discover also the presence of a different phase, to be called a mixed state, where the strands are pair-wise bound but without three chain contacts. Whereas the Efimov DNA turns out to be a crossover near melting, the mixed phase is a thermodynamic phase.

Jaya Maji, S. M. Bhattacharjee, F. Seno, A. Trovatto

7. Various simple analytical theories for homopolymers are developed within a unified framework. The common guideline of this approach is the Flory theory, and its various avatars, with the attempt of being reasonably self-contained and self-consistent. A detailed pedagogic review has been published on this.

S. M. Bhattacharjee, A. Giacommetti, A. Maritan

8. We study the cluster size distribution of particles in a multispecies TASEP on a one dimensional

lattice with directional switching of the particles. Such switching has been seen in the context of intracellular transport, wherein organelles, vesicles and lipid droplets are transported in both directions on the microtubule filaments by oppositely-directed motor proteins. Using Monte Carlo simulations, we analyse the cluster size distribution in the steady state as a function of the ratio of the translocation rate of the particles and directional switching rate. We find that for finite system sizes, the cluster size distribution may exhibit a distinct peak which corresponds to the formation of a single large cluster; however, this single cluster vanishes in the thermodynamic limit. We also study the cluster size distribution of some closely related driven lattice gas models and find similar features in these models too. For some constraints on the rates, one of these models could be mapped to the equilibrium 1d Ising model with nearest-neighbour spin exchange. We also make a correspondence of these models with a misanthrope process and discuss the possibility of regions in their parameter space where a steady state has a product measure.

J. Chacko, S. Muhuri, G. Tripathy

9. Effect of quenched disorder in models of interacting particle in flashing ratchets are investigated.

The particles interact via hard core exclusion. Quenched disorder is introduced in the on state potential and it is shown that the disorder can be classified mainly in to two categories viz. weak or strong. In case of weak disorder the partcile flux is finite even in the thermodynamic limit whereas it vanishes in case of strong disorder in the limit of large system size. In the weak disorder case a nonequilibrium phase transition occurs as a function of particle density between a homogeneous phase and one with density segregation on macroscopic scales. It is shown that all the effects observed can be explained by using an equivalent asymmetric exclusion model in each case. This equivalency is verified by using extensive numerical simulations and mean field calculations.

J. Chacko, G. Tripathy

3.2. THEORETICAL HIGH ENERGY PHYSICS

1. Relativistic Heavy-Ion Collisions

1.a. Quarkonium disintegration in relativistic heavy-ion collisions by CP violating Z(3) walls at finite temperature

In this work we extend our study of J/ψ disintegration due the Z(3) domain walls at finite temperatures. We incorporate the effects of Debye-screened potential on J/ψ wave function and study the enhancement in disintegration of J/ψ on interaction with the color field associated with a Z(3) wall.

Abhishek Atreya, Partha Bagchi, and Ajit M. Srivastava

1.b Effect of confining forces on charge fluctuations in relativistic heavy ion collisions

We incorporate long range confining forces in the coalescence model and study its effects on the charge fluctuation observable for relativistic heavy-ion collision experiments.

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

2. Cosmology

2.a. Baryon production from embedded metastable strings

We quantify the baryon anti-baryon production generated by a metastable cosmic string, similar to the embedded pion string. More precisely, we study skyrmion production mediated by instantons generated by a pion-like metastable string in contact with a thermal bath, and interpret these Skyrmions as baryons. As shown in a previous work, the core of such a metastable string can melt due to quantum tunneling in the charged field direction. The specific configuration of our string containing 4 scalar fields out of equilibrium in contact with a thermal bath is shown to yield skyrmion production with partial or integer winding number. In this work, we describe and quantify this skyrmion production per unit length of the string. We also evaluate the skyrmion-anti skyrmions production by a dense string network by invoking similarity with the Skyrmion production in a phase transition.

J. Karouby and A. M. Srivastava

2.b. Reviving quark nuggets as a candidate for dark matter

We discuss a novel mechanism for segregation of baryons and anti-baryons in the quark-gluon plasma phase which can lead to formation of quark and antiquark nuggets in the early universe, irrespective of the order of the quark-hadron phase transition. This happens due to CP violating scattering of quarks and antiquarks from moving Z(3) domain walls. CP violation here is spontaneous in nature and arises from the nontrivial profile of the background gauge field (A0) between different Z(3) vacua. We study the effect of this spontaneous CP violation on the baryon transport across the collapsing large Z(3) domain walls (which can arise in the context of certain low energy scale inflationary models). Our results show that this CP violation can lead to large concentrations of baryons and anti-baryons in the early universe. The quark and antiquark nuggets, formed by this alternate mechanism, can provide a viable dark matter candidate within standard model without violating any observational constraints.

A. Atreya, A. Sarkar, and A. M. Srivastava

2.c. Probing QCD phase transitions in pulsar cores

Exotic phases of quantum chromodynamics (QCD) may exist in the high baryon density core of a pulsar. We propose a technique which allows to probe these phases and associated transitions by detecting changes in rotation of the star arising from density fluctuations during the transition affecting star's moment of inertia. Our results suggest that these changes may be observable, and may even account for glitches and (recently observed) anti-glitches. Accurate measurements of pulsar timing/intensity modulations (arising from wobbling of star due to development of off-diagonal components of moment of inertia) may be used to pin down the particular phase transition occurring inside the pulsar core. We also discuss the possibility of observing gravitational waves from the quadrupole moment arising from these density fluctuations.

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

2.d Some studies related to Cosmology

We present a class of anisotropic brane confugurations which shows BKL oscillations near their cosmological singularities. Near horizon limits of these solutions represent Kasner space embedded in AdS background. Dynamical probe branes in these geometries inherit anisotropies from the background. Amusingly, for a probe M5 brane, wefind that there exists a parameter region where three of its world-volume directions expand while the rest contract.

Souvik Banerjee, Samrat Bhowmick, Sudipta Mukherji.

3. Liquid Crystal Experiments

Isotropic-nematic phase transition in a film on a cylindrical surface

We are carrying out experiments studying the I-N phase transition in a thin film on the surface of an optical fiber of about 50 micron thickness. Resulting string network will be studied and winding of strings per unit correlation length will be determined. Results of this setup will be used to predict the universal winding density (per correlation length) of cosmic strings around any compact extra dimensions. Such theories have been recently proposed in the context of superstring theories.

Ajit M. Srivastava

4. AdS/CFT and deSitter space

4.a Some studies related to AdS/CFT and Desitter Space

Boundary deSitter space can be embedded in (one higher dimensional) AdS space in different ways. We construct one such embedding. We then study behaviour of massive scalar field in this bulk geoemtry and construct retarded Green's function on the boundary using conjectured AdS/CFT duality. The singularities of this two point correlator are then studied

Suomabrata Chatterjee, Suman Ganguly, Sudipta Mukherji

5. Effect of Anomalous Couplings on the Associated Production of a Single Top Quark and a Higgs Boson at the LHC

We have considered the production of a single top quark in association with a Higgs boson at the LHC. In particular, we computed the cross sections for the processes *pp* → *thj, thb, thW, thjj,thjb, thWj, thWb* in the presence of the anomalous Wtb, WWh and tth couplings. We find that the anomalous Wtb and couplings can enhance the cross sections significantly. If these couplings are indeed anomalous, then with enough data, one should be able to observe the production of the Higgs boson in association with a single top quark in the run II of the LHC.

P. Agrawal, Ambresh Shivaji and Subhadip Mitra

6. Multilepton Signatures of the Higgs Boson through its Production in Association with a Top-quark Pair

We consider the possible production of the Higgs Boson in association with a top-quark pair and its subsequent decay into a tau-lepton pair or a W-boson pair. This process can give rise to many signatures of the Higgs boson. These signatures can have electrons, muons, tau jets, bottom jets and/or light flavour jets. We analyze the viability of some of these signatures. We will look at those signatures where the background is minimal. In particular, we explore the viability of the signatures "isolated 4 electron/muon" and "isolated 3 electron/muon + a jet". The jet can be due to a light flavour quark/ gluon, a bottom quark, or a tau lepton. Of all these signatures, we find that "isolated 3 electron/muon + a tau jet", with an extra bottom jet, can be an excellent signature of this mode of the Higgs boson production. We show that this signature may be visible within a year, once the Large Hadron Collider (LHC) restarts. Some of the other signatures would also be observable after the LHC accumulates sufficient luminosity.

P. Agrawal, Siba Prasad Das and S. Bandopadhyay

7. Dilepton Signatures of the Higgs Boson with Tau-jet Tagging

We consider the process . This process can give rise to many signatures of the Higgs boson. The signatures can have electrons, muons and jets. We consider the signatures that have two electrons/muons and jets. Tagging of a tau jet and a bottom jet can help reduce the backgrounds significantly. We show that for the signatures to be useful, it should have at least two tau jets, or same-sign electrons/muons. These requirements reduce the backgrounds due the process with Z-bosons and the production of a pair of top quarks. In particular, we examine the usefulness of the signatures "isolated 2 electrons/muons + a bottom jet + a tau jet , 'isolated 2 electrons/muons + 2 tau jets", "isolated 2 electrons/muons + 2 bottom jets + a tau jet", and "isolated 2 electrons/ muons + a bottom jet + 2 tau jets". We find that signatures with two tau jets are useful. The signatures with one tau jet are also useful, if we restrict to same-sign electrons/muons. We show that these signatures may be visible in less than a year, once the Large Hadron Collider (LHC) restarts.

P. Agrawal, Siba Prasad Das and S. Bandopadhyay

8. Non-supersymmetric Microstates of the MSW System

We present an analysis parallel to that of Giusto, Ross, and Saxena (arXiv:0708.3845) and construct a discrete family of non-supersymmetric microstate geometries of the Maldacena-Strominger-Witten system. The supergravity configuration in which we look for the smooth microstates is constructed using SO(4,4) dualities applied to an appropriate seed solution. The SO(4,4) approach offers certain technical advantages. Our microstate solutions are smooth in five dimensions, as opposed to all previously known non-supersymmetric microstates with AdS3 cores, which are smooth only in six dimensions. The decoupled geometries for our microstates are related to global AdS3 x S2 by spectral flows.

Souvik Banerjee, Borun D. Chowdhury, Bert Vercnocke, Amitabh Virmani

9. An inverse scattering formalism for STU supergravity

STU supergravity becomes an integrable system for solutions that effectively only depend on two variables. This class of solutions includes the Kerr solution and its charged generalizations that have been studied in the literature. We here present an inverse scattering method that allows to systematically construct solutions of this integrable system. The method is similar to the one of Belinski and Zakharov for pure gravity but uses a different linear system due to Breitenlohner and Maison and here requires some technical modifications. We illustrate this method by constructing a four-charge rotating solution from flat space. A generalization to other set-ups is also discussed.

Despoina Katsimpouri, Axel Kleinschmidt, Amitabh Virmani

10. Charged black rings from inverse scattering

The inverse scattering method of Belinsky and Zakharov is a powerful method to construct solutions of vacuum Einstein equations. In particular, in five dimensions this method has been successfully applied to construct a large variety of black hole solutions. Recent applications of this method to Einstein-Maxwell-dilaton (EMd) theory, for the special case of Kaluza-Klein dilaton coupling, has led to the construction of the most general black ring in this theory. In this contribution, we review the inverse scattering method and its application to the EMd theory. We illustrate the efficiency of these methods with a detailed construction of an electrically charged black ring.

Jorge V. Rocha, Maria J. Rodriguez, Oscar Varela, Amitabh Virmani

11. Physics Potential of Long-Baseline Experiments

The discovery of neutrino mixing and oscillations over the past decade provides firm evidence for new physics beyond the Standard Model. Recently, θ_{13} has been determined to be moderately large, quite close to its previous upper bound. This represents a significant milestone in establishing the three-flavor oscillation picture of neutrinos. It has opened up exciting prospects for current and future long-baseline neutrino oscillation experiments towards addressing the remaining fundamental questions, in particular the type of the neutrino mass hierarchy and the possible presence of a CP-violating phase. Another recent and crucial development is the indication of non-maximal 2-3 mixing angle, causing the octant ambiguity of θ_{23}. In this paper, I review the phenomenology of long-baseline neutrino oscillations with a special emphasis on sub-leading three-flavor effects, which will play a crucial role in resolving these unknowns. First, I give a brief description of neutrino oscillation phenomenon. Then, I discuss our present global understanding of the neutrino mass-mixing parameters and identify the major unknowns in this sector. After that, I present the physics reach of current generation long-baseline experiments. Finally, I conclude with a discussion on the physics capabilities of accelerator-driven possible future long-baseline precision oscillation facilities.

Sanjib Kumar Agarwalla

12. Resolving the octant of θ_{23} with T_2K and NOνA

Preliminary results of MINOS experiment indicate that θ_{23} is not maximal. Global fits to world neutrino data suggest two nearly degenerate solutions for θ_{23}: one in the lower octant (LO: $\theta_{23} < 45^0$) and the other in the higher octant (HO: $\theta_{23} > 45^0$). $\nu_\mu \to \nu_e$ oscillations in superbeam experiments are sensitive to the octant and are capable of resolving this degeneracy. We study the prospects of this resolution by the current T2K and upcoming NOνA experiments.

Sanjib Kumar Agarwalla, Suprabh Prakash, S. Uma Sankar

13. Exploring the three flavor effects with future superbeams using liquid argon detectors

Recent measurement of a moderately large value of θ_{13} signifies an important breakthrough in establishing the standard three flavor oscillation picture of neutrinos. It has provided an opportunity to explore the sub-dominant three flavor effects in present and future long-baseline experiments. In this paper, we perform a comparative study of the physics reach of two future superbeam facilities, LBNE and LBNO in their first phases of run, to resolve the issues of neutrino mass hierarchy, octant of θ_{23}, and leptonic CP violation. We also find that the sensitivity of these future facilities can be improved significantly by adding the projected data from T2K and NOνA.

Sanjib Kumar Agarwalla, Suprabh Prakash, S. Uma Sankar

3.3. THEORETICAL NUCLEAR PHYSICS

1. Nuclear Structure Away from Valley-of-Stability

Our research works are about the theoretical study of the structure of exotic nuclei and spectroscopic properties of nuclei. Starting from two nucleon interactions and large shell model spaces, the structure of nuclei (many of them on the neutron-rich side of the valley-of-stability) are studied using Deformed Hartree-Fock and

Relativistic Mean Field models. Spectra of nuclei are obtained by Angular Momentum Projection from various microscopic many-particle configurations. Using these theoretical methods the structure of nuclei situated away from the valley-of-stability in various mass regions have been studied. Excited Deformed and Superdeformed configurations have been analysed using our microscopic approach. Excited deformed configurations in N = 50 nuclei have been studied and the spectroscopic properties (rotational bands and their electromagnetic properties) have been obtained. Superdeformed configurations in the Neon-Sulphur region have been obtained using deformed HF and RMF models. Possibility of parity-mixing in intrinsic states and occurrence of parity doublets in spectra have been predicted. In the heavy mass region, rotational spectra and E2 and M1 properties of nuclei have been obtained for Ba, Nd, Gd, Hf and other nuclei using deformed Hartree-Fock and Angular Momentum Projection. Results have been presented in Journals, Conference and Workshop Proceedings and Symposia.

C. R. Praharaj

2. Gravitational wave strain amplitude from rotating compact neutron star

Using the nuclear equation of states for a large variety of relativistic and nonrelativistic force parameters, we calculate the masses and radii of neutron stars. From these equation of states, we also evaluate the properties of rotating neutron stars, such as rotational and gravitational frequencies, moment of inertia, quadrupole deformation parameter, rotational ellipticity and gravitational wave strain amplitude. The estimated gravitational wave strain amplitude of the star is found to be in the range $10^{-22} \sim 10^{-24}$.

S. K. Patra and Collaborators

3. Cluster radioactive-decay using the relativistic mean field theory within the preformed cluster model

We have studied the (ground-state) cluster radioactive-decays using for the first time in the relativistic mean field (RMF) theory within the preformed cluster model (PCM) of Gupta and collaborators. Following the PCM approach, we have deduced empirically the preformation probability P_0^{emp} from the experimental data on both the α and exotic cluster-decays, specifically of parents in the translead region having doubly magic ^{208}Pb or its neighboring nuclei as daughters. Interestingly, the RMF theory supports the concept of preformation for both the α and heavier clusters in radioactive nuclei. $P_0^{\alpha emp}$ for alpha-decays is almost constant $10^{-2} - 10^{-3}$ for r all the parent nuclei considered here, and for cluster-decays of the same parents decrease with the size of clusters emitted from different parents. The results obtained for are reasonable, and are within two to three orders of magnitude of the well accepted phenomenological model of Blendowske-Walliser for light clusters.

S. K. Patra and Collaborators

4. Structures of exotic and superheavy nuclei

4.a. Nuclear sub-structure in $^{112-122}$Ba nuclei

We study for the first time the clustering structure with the internal or substructure of clusters in $^{112-122}$Ba nuclei within the framework of relativistic mean field theory in an axially deformed cylindrical co-ordinate. We calculate the individual neutrons and protons density distributions. From the analysis of the clustering configurations in total (neutrons-plus-protons) density distributions for various shapes of both the ground and excited states, we find different sub-structures inside the Ba nuclei considered here. The important step, carried out here for the first time, is the counting of number of protons and neutrons present in the clustering region(s). ^{12}C is shown to constitute the cluster configuration in prolate ground-states of ^{112}Ba and ^{114}Ba, and oblate-deformed excited states of ^{118,120}Ba nuclei, with ^{2,3}H and ^{4}He constituting the neck between two symmetrical fragments at the scission stage of all the $^{112-122}$Ba nuclei. Presence of other lighter clusters such as ^{6}Li, ^{8}Be, ^{14}N, and nuclei in the neighborhood of N=Z, ^{22}Na, ^{24}Mg, ^{34}Cl, ^{36}Ar and ^{40}Ca are also indicated in the ground and excited states of these nuclei. Cases of ^{6}Li and ^{8}Be in the neck region are also seen. All these results are of interest for the observed intermediate mass fragments and fusion-fission processes, and the so far unobserved evaporation residues from the decaying Ba* compound nuclei formed in heavy ion reactions.

S. K. Patra and Collaborators

4.b Decay properties of superheavy nuclei

We have calculated the binding energy, root-mean-square radius and quadrupole deformation parameter for the recently synthesized superheavy element Z=117, using the axially deformed relativistic mean field (RMF) model. The calculation is extended to various isotopes of Z=117 element, starting from A=286 till A=310. We predict almost spherical structures in the ground state for almost all the isotopes. A shape transition appears at about A=292 from a prolate to an oblate shape structure of Z=117 nucleus in our mean field approach. The most stable isotope (largest binding energy per nucleon) is found to be the 288117 nucleus. Also, the Q_α – values and the mean-life times T_α for the α – decay chains of ^{293}117 and ^{294}117 are calculated, supporting the magic numbers at N=172 and / or 184.

The calculation is also extended to the ground state and first intrinsic excite state of superheavy nuclei with Z=120 and N=160-204 using both non-relativistic Skyrme-Hartree-Fock (SHF) and the axially deformed Relativistic Mean Field (RMF) formalisms. We employ a simple BCS pairing approach for calculating the energy contribution from pairing interaction. The results for isotopic chain of binding energy, quadrupole deformation parameter, two neutron separation energies and some other observables are compared with the FRDM and some recent macroscopic-microscopic calculations.

We predict superdeformed structures in the ground state for almost all the isotopes. Considering the possibility of magic neutron number, two different mode of α –decay chains $^{292}120$ and $^{304}120$ are also studied within these frameworks. The Q_α – values and the half-life for these two different mode of decay chains are compared with FRDM and recent macroscopic-microscopic calculations. The calculation is extended for the α –decay chains of $^{292}120$ and $^{304}120$ from their exited state configuration to respective configuration, which predicts long half-life (sec.).

S. K. Patra and Collaborators

5. Influence of the symmetry energy

We analyze the in uence of the density dependence of the symmetry energy on the average excitation energy of the isoscalar giant monopole resonance (GMR) in stable and exotic neutron-rich nuclei by applying the relativistic extended Thomas-Fermi method in scaling and constrained calculations. For the active nuclear interaction, we employ the relativistic mean field model supplemented by an isoscalar-isovector meson coupling that allows one to modify the density dependence of the symmetry energy without compromising the success of the model for binding energies and charge radii. The semiclassical estimates of the average energy of the GMR are known to be in good agreement with the results obtained in full RPA calculations. The present analysis is performed along the Pb and Zr isotopic chains. In the scaling calculations, the excitation energy is larger when the symmetry energy is softer. The same happens in the constrained calculations for nuclei with small and moderate neutron excess. However, for nuclei of large isospin the constrained excitation energy becomes smaller in models having a soft symmetry energy. This effect is mainly due to the presence of loosely-bound outer neutrons in these isotopes. A sharp increase of the estimated width of the resonance is found in largely neutron-rich isotopes, even for heavy nuclei, which is enhanced when the symmetry energy of the model is soft. The results indicate that at large neutron numbers the structure of the low-energy region of the GMR strength distribution changes considerably with the density dependence of the nuclear symmetry energy, which may be worthy of further characterization in RPA calculations of the response function.

S. K. Patra and Collaborators

6. Nuclear reaction

We calculate the nuclear reaction cross-sections of exotic nuclei in the framework of the Glauber model, using as inputs the standard relativistic mean field (RMF) densities and the densities obtained from the more recently developed effective field theory motivated RMF (E-RMF). Both light and heavy nuclei are taken as the representative targets and light neutron-rich nuclei as projectiles. We find the increase of nuclear reaction cross-section as a function of mass number for both the target and projectile. For a further application of the method, we suggest a mechanism for the formation of superheavy and highly neutron-rich elements in astrophysical objects. For explaining this mechanism, we have used the nuclear fusion cross-sections obtained from the non-relativistic coupled channel calculations.

For the astrophysical application, here we calculate the reaction and the fusion cross-sections of neutron-rich heavy nuclei taking light exotic isotopes as projectiles. Results of neutron-rich Pb and U isotopes are demonstrated as the representative targets and He, B as the projectiles. The Gluaber Model and the Coupled Channel Formalism are used to evaluate the reaction and the fusion cross-sections for the cases considered. Based on the analysis of these cross-sections, we predict the formation of heavy, superheavy and super-superheavy elements through rapid neutron/light nuclei capture r-process of the nucleosynthesis in astrophysical objects.

We calculate the one neutron removal reaction cross sections () for some stable and neutron-rich halo nuclei with ^{12}C as target, using relativistic mean field (RMF) densities in the frame work of the Glauber model. The results are compared with the experimentally measured data. Studies of stable nuclei with deformed densities have shown a good agreement with the data, however, it difers significantly for halo nuclei cases. Estimating the value from the diference of reaction cross-section of two neighbouring nuclei with mass number A and that of A-1 in an isotopic chain, we get good agreement with the known experimental data for halo cases.

S. K. Patra and Collaborators

7. High Spin States

Deformed Hartree-Fock and Angular Momentum Projection gives a complete description of structure of deformed nuclei in various regions of mass table. We have applied this formalism to study the structure of $_{152}$Ba and $_{148}$Xe and other neighboring exotic nuclei. For $_{152}$Ba a rich band structure is predicted including K and Shape Isomers at 10 MeV or less of excitation energy. This study is extended to Ce, Nd, Sm, Gd, Dy, Er, Yb, Hf and neighbouring nuclei covering a range of neutron numbers. We also calculated the structure of neutron rich even-even $^{150-164}$Sm nuclei and investigated the structure in the framework of deformed Hartree-Fock, Skyrme Hartree-Fock+BCS and relativistic mean field formalisms. We analyzed the bulk as well as microscopic properties of these nuclei to investigate the proposed "island of stability" near the neutron drip-line for N = 100, Z 62.

S. K. Patra and Collaborators

8. Construction of nucleon-nucleon potential and calculation of Half-lives of proton emitters using relativistic mean field theory

A simple form of nonlinear self-coupling of the scalar meson field is introduced and suggested a new nucleon-nucleon (NN) potential in relativistic mean field theory (RMFT) analogous to the M3Y interaction. We investigate the ability of RMFT to reproduce nuclear ground state properties and the surface phenomena like proton radioactivity simultaneously with the proposed NN-interaction. The results obtained are found reasonably well with the widely used M3Y NN-interactions and the experimental data in this first application of nucleon-nucleon potential. Using this NN interaction, the proton radioactivity lifetimes of proton emitters from the ground and the isomeric states are calculated. These interaction potentials are obtained by single folding the densities of the daughter nuclei supplemented by a zero-range pseudo potential. The quantum-mechanical-tunneling probability is calculated within the WKB approximation. The calculated results are found to be in good agreement with the experimental data for both the M3Y and R3Y interactions.

S. K. Patra and Collaborators

.3.4. HIGH ENERGY NUCLEAR PHYSICS

1. ALICE Collaboration

1.a. Heavy-ion collisions at LHC, RHIC and CBM

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 ($pT < 5.5GeV /c$)

R.C. Baral, S. Sahoo and P. K. Sahu

2. STAR Collaboration

2.a. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) is primarily designed to study the properties of a new state of matter, called the Quark Gluon Plasma (QGP). The Beam Energy Scan (BES) program at RHIC is devoted to study the QCD phase diagram which involves searching for the possible QCD phase boundary and the possible QCD critical point. The STAR experiment has collected data for Au+Au collisions at 7.7, 11.5 and 39 GeV energies in the year 2010. The chemical and kinetic freeze-out parameters can be extracted from the experimentally measured yields of identified hadrons within the framework of thermodynamical models. At the chemical freeze-out, no further inelastic collisions between particles occur and the particle composition is fixed. When elastic collisions between particles also cease, the kinetic freeze-out takes place. These freeze-out parameters provide information about the system at different stages of the expansion. We have studied the centrality dependence of freeze-out parameters for Au+Au collisions at mid-rapidity for 7.7, 11.5, and 39 GeV energies. The chemical freeze-out parameters are obtained by comparing the measured particle ratios to those from the statistical thermal model (THERMUS) calculations. This model assumes thermal and chemical equilibrium. The main fit parameters are chemical freeze-out parameter T_{ch} , baryonic chemical potential μ_B strangeness chemical potential μ_s , and strangeness suppression factor S . The grand-canonical ensemble (GCE) approach is used to fit the experimental particle ratios and to obtain the chemical freeze-out parameters. The extracted Tch increases with increasing energy and also shows a slight increase as we go from peripheral to central collisions for all energies. The μ_B increases with decreasing energy. This is because of large baryon stopping at mid-rapidity at low energies. The μ_B also shows a slight increase from peripheral to central collisions for these energies. We also analyze the strangeness particles (Ks, Λ, Ξ , and Ω) in STAR experiment. Strangeness enhancement in heavy ion collisions at p+p collision, allow us in the confirmation of de-confined quark gluon phase, a state of matter believed to exist at sufficiently high energy densities. We have performed invariant mass distribution and raw spectra of Ks, Λ in Au+Au collision with center of mass energy 19.6GeV and efficiency has been corrected. Then we opt for Ξ and Ω particle reconstruction.

S. Das, S. K. Tripathy and P. K. Sahu

3. Nuclear astrophysics and nuclear equation of state

Recent observation of pulsar PSR J16142230 with mass about 2 solar mass had indeed posed a severe constraint on the equations of state (EOS) of matter describing stars under extreme conditions. Compact stars can have hadronic matter, neutron stars (NSs), or can have exotic states of matter like strange quark matter, strange stars (SSs), or color superconducting matter. Stars also can have a quark core surrounded by hadronic matter, known as hybrid stars (HSs). The HS is likely to have a mixed phase region in between. Observational results also suggest huge surface magnetic field in certain NSs called magnetars. NSs can reach the mass limits set by PSR J16142230. But stars having hyperons or quark stars (QSs) having boson condensates, having softer EOS can barely reach such limits and are ruled out. QS with pure strange matter, can barely have such huge masses unless the effect of strong coupling constant or colour superconductivity are taken into account.

We have studied the effect of strong magnetic field on the EOSs of matter under extreme condition. We also have studied the hadron-quark phase transition in the interiors of NS giving rise to hybrid stars (HS) with strong magnetic field. The hadronic matter EOS is described by GM1 parameter set. For the quark phase we use the simple MIT bag model. We have included the effect of strong magnetic fields leading to Landau quantization of the charged particles. We construct the intermediate mixed phase region, using Glendenning construction and enforcing Gibbs criterion. We assume density dependent bag pressure and magnetic field. The magnetic field strength increases going from the surface to the center of the star. We find that the magnetic field softens the EOS of both the matter phases. The effect of magnetic field is insignificant unless the field strength is above 10_{14} G. A varying magnetic field, with surface field strength of 10_{14} G and the central field strength of the order of 10_{17} G has significant effect on both the stiffness and the mixed phase regime of the EOS. We have also studied the mass-radius relationship for such type of mixed HS, and calculate their maximum mass, and compared them with the recent observation of PSR J16142230. HS with a mixed phase region cannot reach the mass limit set by PSR J16142230 unless we assume a low density dependent bag constant. For such a case the mixed phase region is truncated and their is a jump in the EOS curve going from the mixed phase to the quark phase. The maximum mass of a mixed hybrid star obtained with such mixed phase region is 1.98 Msolar. As the state of matter of the resultant SS/HS is different from the initial hadronic matter, their masses also differ. Special theory of relativity relates mass to energy. Therefore, such conversion leads to huge energy release, sometimes of the order of 10^{53} ergs. In the present work we study the qualitative energy released by such conversion. Recent observations reveal huge surface magnetic field found in certain stars, now called magnetars. Such huge magnetic fields can modify the equations of state (EOS) of the matter describing the star. Therefore, the mass of magnetars are different from normal NS. The energy released during the conversion process from neutron magnetar (NM) to strange magnetar / hybrid magnetar (SS/HS) is different from normal NS to SS/HS conversion. In this work we calculate the energy release during the phase transition in magnetars. The energy released during NS to SS/HS conversion exceeds the energy released during NM to SM/HM conversion. The energy released during the conversion of NS to SS is always of the order of 10^{53} ergs. The amount of energy released during such conversion can only be compared to the energy observed during the gamma ray bursts (GRB). The energy liberated during NM to HM conversion is of the order of 10^{52} ergs, and is not likely to power GRB at cosmological distances. However, the magnetars are more likely to lose their energy from the magnetic poles and can produce giant flares, which are usually associated with magnetars.

N. R. Panda, K. Mohanta, R. Mallick and P. K. Sahu

4. 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

Conventionally for observable $n-\bar{n}$ oscillation through Pati-Salam intermediate gauge symmetry in SO(10), the canonical seesaw mechanism is also constrained by $M_R \sim M_c \leq 10^6$ GeV which yields light neutrino masses much larger than the neutrino oscillation data. Recently, this difficulty has been evaded via inverse seesaw mechanism, but with proton lifetime far beyond the experimentally accessible limits. In the present work, adopting the view that we may have only a TeV scale $\acute{Z}$ gauge boson, we show how a class of non-SUSY *SO(10)* models allow experimentally verifiable proton lifetime and the new contributions to neutrinoless double beta decay in the $W_L - W_L$ channel, lepton flavor violating branching ratios, observable $n-\bar{n}$ oscillation, and leptoquark gauge boson mediated rare kaon decays. The occurrence of Pati-Salam gauge symmetry with unbroken D-parity and two gauge couplings at the highest intermediate scale guarantees precision unification in such models. This symmetry also ensures vanishing GUT threshold uncertainy on $sin^2\theta_W$ or on the highest intermediate scale. Although the proton lifetime prediction is brought closer to the ongoing search limits with GUT threshold effects in the minimal model, no such effects are needed in a nonminimal model. We derive a new analytic expression for the $0\nu\beta\beta$ decay half-life and show how the existing experimental limits impose the lower bound on the lightest of the three heavy sterile neutrino masses, $M_{S_1} \geq 14 \pm 4$ GeV. We also derive a new lower bound on the lepto-quark gauge boson mass mediating rare kaon decay, $M_{Lepto} > 1.53 \pm 0.06 \times 10^6$ GeV. The mixing times are predicted in the range sec.

M. K. Parida, R. L. Awasthi and P. K. Sahu

3.5. Quantum Information

1. Generalized Form of Optimal Teleportation Witness

We have proposed a generalized form of optimal teleportation witness to demonstrate their importance in experimental detection of a larger set of entangled states useful for teleportation in higher dimensional systems. The interesting properties of our witness reveal that teleportation witness can be used to characterize mixed state entanglement using Schmidt numbers. Our results show that while every teleportation witness is also a entanglement witness, the converse is not true. Also, we show that a hermitian operator is a teleportation witness iff it is a decomposable entanglement witness.

P. Agrawal, Atul Kumar and Satyabrata Adhikari

2. Quantum Discord has Local and Nonlocal Quantumness

There has been speculation that there may exist quantum correlations that go beyond entanglement. These correlations are not revealed by conventional measures of entanglement, but can be seen by physical quantities such as discord. We show that such objects probe not only entanglement, i.e., non-local quantumness but also local quantumness. That is why such measures are non-zero when there is no entanglement. We suggest that there does not exist non-local quantum correlations that go beyond what is know as entanglement.

P. Agrawal, Arun Pati and Indranil Chakrabarty

Sometime Less is More Usually, a more entangled state is more useful to carry out tasks that require non-local resources. We show that if the resource state is a multipartite state, then it is not necessarily true. We exhibit the phenomena of "more communication with less entanglement" by considering communication protocols of secret sharing, Quantum Key Distribution, teleportation and superdense coding. We also show that to teleport a n-qubit state with m terms, a partition of the resource should have von Neumann entropy of $log_2 m$.

P. Agrawal, Arun Pati and S. Adhikari

3. A Mutual Information based Vector Measure of the Multipartite Entangle-ment

We have generalized the notion of dissension to n-qubit states. We have introduced two types of dissensions - Track 1 and Track 2. Using these vector measures, one can characterize n-qubit states with various forms of classicality and quantumness.

P. Agrawal and Sk. Sazim

3.6. EXPERIMENTAL CONDENSED MATTER PHYSICS

1. Effect of Oxygen vacancies and Nanostructure size of TiO2 on UV-Vis absorption properties

Size dependant effects of TiO_2 nanostructures on the UV-Vis absorption properties have been explored. The nanostructures have been fabricated by ion beam irradiation of TiO_2(110) single crystals. The nanostructures created by this technique develop due to the competition between roughening and smoothening processes undergoing on the surface. The sputtering processes produce the oxygen vacancies on the surface. The combination of XPS and AFM results show that a competition between the nanostructure size and vacancy concentration control the absorption properties of TiO2 nanostructures.

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

2. Kinetic Monte Carlo Simulation of Sputtering of Metal surfaces and comparsion with Experimental results

Kinetic Monte Carlo Simulations are being carried out to understand the processes responsible and for finding the Universality class of the sputter patterned surfaces of the metals. The simulations are being carried out in (1+1) dimension on the discrete lattice with the inclusion of erosion and relaxation using unrestricted Solid-On-Solid model. KMC results are compared with the experimental results from our Lab to find the universality class.

S. Varma, Shalik R. Joshi and T. Bagarati

3. Enhanced hydrophilic properties for nanostructures on TiO2 Surfaces

An enhanced biocompatibility from nanodot patterned TiO2 surfaces, fabricated by ion beam sputtering, has been observed through its interaction with Plasmid DNA. Investigations of the persistence length and the areal conformation of DNA show that the biocompatibility increases with ion fluence. Presence of nanostructures and increased surfaces roughness, in conjugation with higher oxygen vacancy sites that promote charge transfer from DNA moiety, are responsible for the increased hydrophilicity and biocompatibility of the patterned surfaces.

S. Varma, S. Majumdar, Indrani Mishra and U. Subudhi

4. ZnO nanostructures and their UV-Vis properties

ZnO is a wide band gap semiconductor with exciting applications for short wavelength light emitting devices as well as in areas of gas sensors, solar cells etc.

ZnO nanostructures have been fabricated by atom beam sputtering technique.

It is observed that the low dimensional nanostructures display higher oxygen vacancies as well as new crystalline phases. Both of these factors in conjugation with nano dimensions result in the higher UV absorbance and a slight decrease in the bandgap of ZnO nanostructures.

S. Varma, Vanaraj Solanki, Indrani Mishra, Shalik R. Joshi and D.K. Avasthi

5. Enhanced Biocompatiblity of Polymer PDMS through Plasma Treatment

Polymeric materials successfully applied in biomedical applications have an issue of poor surface properties which may restrict their applications as biomaterials. We have investigated enhancement of biocompatibility through plasma treatment and aim to understand the effect of nitrogen and oxygen plasma treatment of PDMS on its biocompatibility. Physico-chemical properties of PDMS were studied through various characterization techniques. The effect of plasma treatment on biocompatibility was studied through cell adhesion.

S. Varma N. Gomathi, S. Majumder and I. Mishra

6. **Nano-Bio-electronics: Interaction of DNA with Patterned Semiconductor Surfaces**

The studies of Nano-bio surfaces are becoming important for semiconductor surfaces through their role in bio-electronics. We are investigating adsorption properties of biological molecule like DNA on a variety of semiconductor surfaces
like Si, TiO2, ZnO to understand the interaction of DNA with these surfaces from the electronic point of view as well as their morphological evolution. We also observe modification of power spectral distribution (PSD) properties of the DNA polymer on surfaces representing changes in its persistence length and dimensions. These results show important modifications of hydrophilic properties of surfaces necessary also in implant technology.

S. Varma, *Indrani Mishra, Subrata Majumder, and U. Subudhi*

7. Superconductivity:

7.a. '**Observation of flicker 1/f noise in $YBa_2Cu_3O_7$ and GaAlAs diode**

Polycrystalline YBa2Cu3O7-x near TC (70-95 K) and GaAlAs semiconductor diode in the temperature range 50-300 K has been studied. The measured dc voltages in these systems show fluctuations and the standard deviations of the voltage values show the statistics of flicker 1/f noise. In Yba2Cu3O7-x the measured dc voltages showed increased noise near TC which is possibly realted to the 1/f noise due to the motion of vortex lattice. The 1/f noise in GaAlAs diode is found to be temperature independent but current dependent. It is found to increase with decrease in forward current below 0.01 mA.

S. B. Ota and others

7.b. **A15 compounds, strong coupling superconductivity and $YBa_2Cu_3O_{7-x}$**

The electron-phonon coupling constant ë has been calculated for A15 compounds assuming the width of the Ã12 band as 80 meV. ë has been found to be inversely proportional to the molecular weight. Using the values of ë the Coulomb pseudopotential ì* has been found to be negative for $YBa_2Cu_3O_{7-x}$.

S. B. Ota and others

7.c. Vortex lattice melting and irreversibility temperatures in $YBa_2Cu_3O_7$

The dc I-V characteristic of polycrystalline Yba2Cu3O7-x high temperature superconductors (HTSC) is measured near the transition temperature (TC). A difference in voltage was found for forward and reverse current directions near TC. The measured dc voltage showed increased noise near TC which is related to flicker 1/f noise. The experimental results are explained in terms of melting of the vortex lattice and irreversibility temperature which is observed near the superconducting transition in $YBa_2Cu_3O_{7-x}$.

S. B. Ota and others

8. Semiconductor junction

8.a. Calibration of cryogenic Si diode for temperatures between 30-210 K

The variation of forward voltage with temperature of a cryogenic silicon diode of CRYO Industries of America Inc. Model No. DT-470-SD-13 is measured in the temperature range 30-210 K and for current values between 10 nA and 200 ìA. The characteristic is least squares fitted by a 1st order polynomial and the coefficients are given. The least squares fitting has high temperature root between 420 K and 625 K.

S. B. Ota and others

8.b. Semiconductor diodes for measurement of low temperatures

The forward voltage of Si and GaAlAs diodes have been studied in the temperature range 10-300 K and for various current values (10 nA to 0.5 mA). The temperature sensitivity of these diodes have been obtained. Flicker 1/f noise has been observed in the GaAlAs diode. Possible use of GaAlAs diode for measurement of mK temperatures has been suggested. For Si diode the 'reduced' forward voltage at T=0 is found to be 1.0 V.

S. B. Ota and others

8.c. Some new observations in semiconductor diode

The p-n junction forms the basic building block of modern semiconductor electronics and therefore has attracted a great deal of interest. Silicon is tetravalent and indirect band gap semiconductor. Pentavalent dopants such as As, Sb, P are e-donors and give rise to n-type Si. On the other hand tetravalent dopants such as Al, Bo, Ge are e-acceptors and give rise to p-type Si. The forward characteristic of a Si p-n junction (Si diode) can be understood in terms of transport in high electric field which exists at the 'depletion region' of the diode. The dimension of depletion region at the p-n junction is expected to be ~ìm which is generally much smaller than the bulk p or n type semiconductor. A current in the forward direction gives rise to Vf which is temperature dependent. The temperature dependence is generally given by:

$$I \approx \exp(qV_f/\eta K_B T) \quad ....[1]$$

where q is the electronic charge, kB is the Boltzmann constant, T is the temperature and η is the ideality factor. The forward voltage of the diode for a fixed current is approximately linear for temperatures above liquid nitrogen temperatures. This characteristic extrapolates to a value of Vf at T=0 which is found to correspond to the band gap of the bulk semiconductor. The T vs Vf characteristics of the diodes for fixed If were least squares fitted to polynomials and the coefficients were determined. For Si 1n4007 diode a 2nd order polynomial was least squares fitted:

$$V_f=a_0+a_1T+a_2T^2 \quad ....[2]$$

For cryogenic Si diode a 1st order polynomial was least squares fitted:

$$V_f=a_0+a_1T \quad ....[3]$$

For GaAlAs diode a 2nd order polynomial was least squares fitted:

$$V_f=a_0+a_1T+a_2T^2 \quad ......[4]$$

It is seen from Eqs.2-4 that the extrapolated value of the characteristics of the diode at T=0 corresponds to the zeroth order coefficient a0. Table-1 gives the extrapolated values for Si, Cryo-Si and GaAlAs diodes.

Table-1: The coefficient a_0 for various values of current.

Table-1: The coefficient a_0 for various values of current.

Current	Si diode a_0 (V)	Cryo Si diode a_0 (V)	GaAlAs diode a_0 (V)
10 nA	1.17	1.08	1.54
30 nA	-	-	1.54
100 nA	1.17	1.13	1.54
300 nA	-	-	1.54
500 nA	1.17	1.15	-
1 µA	1.17	1.16	1.53
3 µA	-	-	1.53
10 µA	1.17	1.18	1.51
30 µA	-	-	1.52
100 µA	1.17	1.19	1.54
200 µA	1.17	1.20	-
300 µA	-	-	1.58
450 µA	-	-	1.60

It is noted that the band gap energy of Si is 1.2 eV (a0H"1.2 V and the corresponding electron energy is qV or 1.2 eV) and that of GaAlAs diode is 1.5 eV.

At each temperature and current value the average forward voltage was obtained from 50 measured voltage values within ~100 secs. The corresponding voltage standard deviations (Vsd) were also obtained.

The Vsd is shown in figure-1 as a function of number of observations. In GaAlAs diode the voltage standard deviations showed the statistics of flicker 1/f noise. Figure-2 shows the 1/f noise in GaAlAs diode for temperatures between 50-300 K.

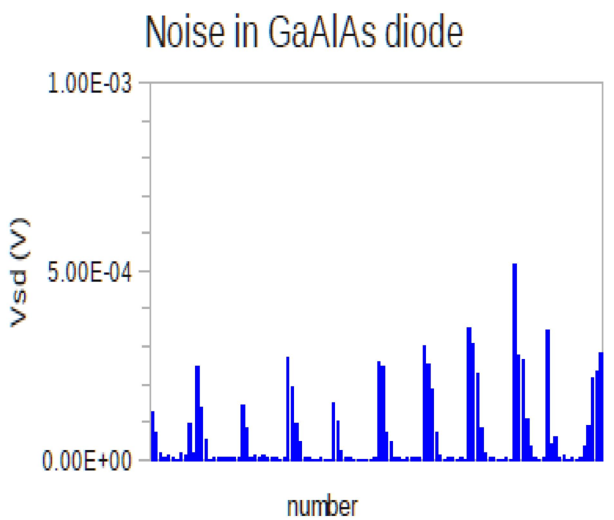


Figure-1: Vsd as a function of number of observations in GaAlAs diode

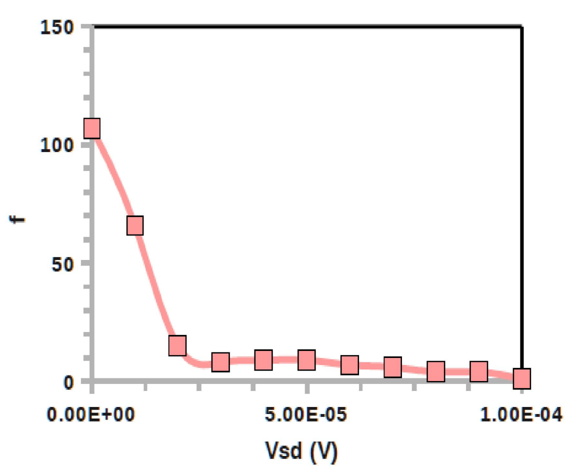


Figure-2: The two constituents of magnetic flux in HTSC in the form of vortex lattice and unsteady arrangement.

S. B. Ota and other

9. Vortex lattice melting in HTSC

There are two types of superconductors (type-I and II) in the presence of an external field. These two types can be classified using the two fundamental length scales coherence length (ξ) and London penetration depth (λ) of superconductors. The ratio of these two length scales defines the dimensionless Ginzburg-Landau parameter κ.

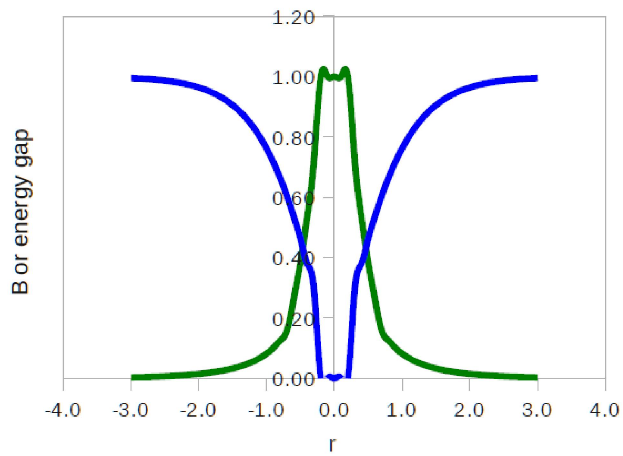


Figure-1: The morphology a vortex in superconductor. The green line represents the magnetic field intensity as a function of distance from the vortex origin. The red line represent the superconducting energy gap as a function of distance from the vortex origin.

$$\kappa=\lambda/\xi \qquad .....[1]$$

defines the crossover from type-I to type-II behavior in superconductors. For many elemental superconductors ξ>>λ and are called type-I. In this case complete flux exclusion from the bulk of the superconductor occurs and the superconductor becomes normal when the external magnetic field exceeds a critical field HC. On the other hand ξ>>λ for many compound superconductors (such as HTSC) and are called type-II. In a type-II superconducting material quantized flux lines (vortices) diffuse for applied magnetic field between HC1 and HC2. Individual quantized flux line has magnetic flux . Typically, type-II superconductors have ξ~100 A and λ~1000 A. The structure of a vortex is shown in figure-1. Such vortices form a triangular lattice (figure-2) and has been observed experimentally with neutron scattering, Bitter pattern technique and STM. Melting of the vortex lattice was observed initially in thin film of In. In HTSC the morphology of the vortex lattice can be similar to thin superconducting films. Signature of vortex lattice melting

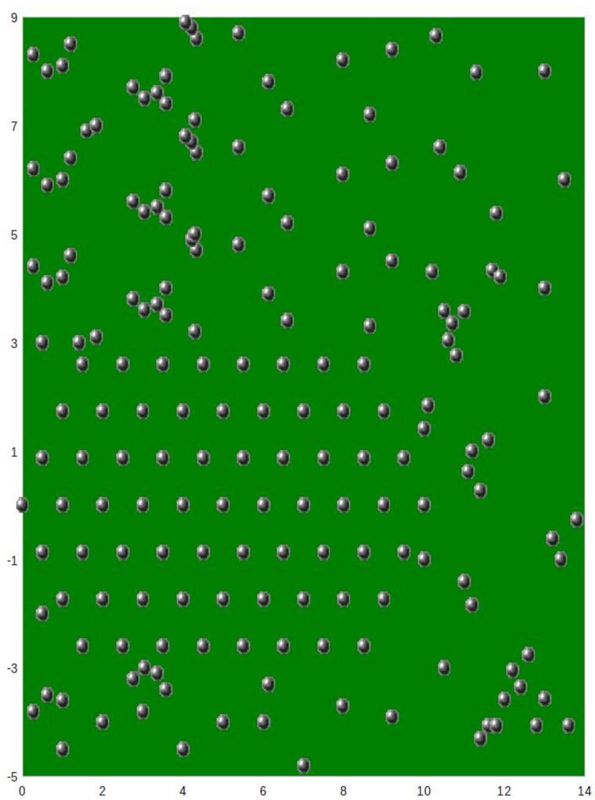


Figure-2: The two constituents of magnetic flux in HTSC in the form of vortex lattice and unsteady arrangement.

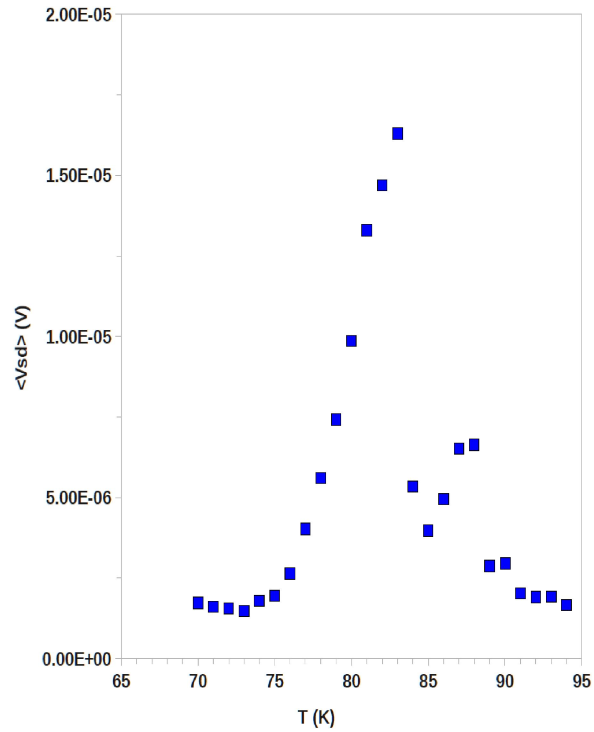


Figure-3: Flicker 1/f noise as a function of temperature in poly-crystalline $YBa_2Cu_3O_3$

has been observed in several experiments. We carried out dynamic magnetization using a Faraday balance and SQUID magnetization measurements at department of physics, Southampton University, England on Bi-2212. Dynamic magnetization on poly-crystalline Bi-2212 showed vortex lattice melting. The melting phase line was obtained in this system subsequently using the Kramer's model. Similar indication of vortex lattice melting was also observed in SQUID magnetization measurements on Bi-2212 single crystal.

We have observed the effect of vortex lattice melting in poly-crystalline $YBa_2Cu_3O_7$ in dc resistance measurement. The vortex in the type-II state occurs in our study of HTSC due to the self field of the current. It is known that fluctuation increase near a phase transition. The measured dc voltage showed increased noise near the superconducting transition temperature (TC) which is identified as flicker 1/f noise. The 1/f noise arises due to the vortex lattice. The flicker noise as a function of temperature showed peaks at 83 K and 88 K (figure-3). The peak at 83 K corresponds to the melting of vortex lattice which is known to be 1st order in nature . It is known that the irreversibility transition occurs below the superconducting transition temperature and criterion dependent. Therefore the peak at 88 K corresponds to the irreversibility transition. This result gives additional evidence of the existence of vortex lattice melting transition from 1/f noise in HTSC.

S. B. Ota and others

10. On the metal-Insulator transition and pseodogap in Fe-based Superconductors

The unconventional superconductivity in iron based compounds have attracted much attention due to their importance in elucidating a consolidated understanding of superconductivity in general. Unlike the cuprate High T_c materials, superconductivity in these compounds involves some exotic interplay of structural and magnetic degrees of freedom. Although among them, Fe(Se,Te)
is rather simple from a structural point of view, it shows a strong bearing of the spin uctuations and structural and magnetic disorder on its superconducting properties. Despite, a number of reports addressing many of these issues, the roles of electron-phonon coupling, spin density wave states, quasi-particles etc. are still under intense debate. Our valence band photoelectron spectroscopic studies show a temperature dependent spectral weight transfer near the Fermi level in the Fe-based superconductor, $FeSe_{1-x}Te_x$. Using theoretical band structure calculations we have shown that the weight transfer is due to the temperature induced topological changes in the Fe(Se,Te)4 tetrahedra in their structure. These structural changes lead to shifts in the electron occupancy from the xz/ yz and x^2-y^2 orbitals to the $3z^2-r^2$ indicating a temperature induced crossover from a metallic state to an Orbital Selective Mott (OSM) Phase. Our study presents the _rst observation of a temperature induced crossover to a low temperature OSM phase in the family of Fe chalcogenides

B. R. Sekhar

11. Electronic structure of Pb and Sn doped GeSe crystals

Group IV-VI semiconducting compounds, with the structure $A^{N}B^{10-N}$ have been interesting since long due to their potential applications in photovoltaic, long wavelength sensor devices, diode and infrared lasers. These nine compounds are found in three crystalline forms, cubic, rhombhohedral and orthorhombic with an energy difference of ~0.1eV per unit cell. This small energy difference among possible crystal structures results in a variety of exotic electrical and optical properties. A renewd interest in these narrow energy gap materials have come up recently due to their application in the form of nano cystals as absorption layers in photovoltaics devices utilizing their light absorption characteristics in the near infrared and infrared region of the solar spectrum. We made a detailed electronic structure study of cation(Pb/Sn) doped GeSe under Density Functional Theory (DFT) frame work using Local Density Approximation (LDA). Variable cell relaxation has been performed to see the structural changes and Maximally Localized Wannier Functions(MXLF) have been plotted to showing how cation(Ge/Pb/Sn) coordination affected with doping. Role of spin orbit coupling has also been explored by comparing results of fully relativistic and non relativistic calculation. A gradual shift has been observed towards fermi energy both valence and conduction band region in Density of States(DOS) and Band Structure plots. These changes are intimately related to a remarkable reduction of the indirect band gap. We addressed the detailed mechanism, purely electrostatic e_ect of doped cation, for this change. Results of LDA+U calculation for di_erent values of U obtained by TB-LMTO method satisfactorily support our proposed mechanism.

B. R. Sekhar

12. Un-usual spectral weight transfer in the valence spectra of manganite

The tuning of the physical properties of manganites ($R_{1x}A_{x}MnO_{3}$, where R and A are trivalent-rare earth and divalent-alkaline earth ions, respectively) is basically governed either chemically by changing the concentration and nature of the R and A cations or physically by applying external stimuli viz. pressure, magnetic field, electric field, etc. Both physical and chemical parameters can dramatically inuence the internal structure such as Mn^{3+}(d4)/ Mn^{4+}(d3) ratio, lattice distortion, and spin state. The electronic occupation at the Mn site and the lattice distortion controls, respectively the band filling and eg bandwidth, thereby greatly inuence the electronic properties of manganites. Vast majority of the scienti_c literature available so far is based on hole doped manganites because of their alluring colossal

magnetoresistive effect. Relatively less attention is paid to the electron doped system, which possesses somewhat similar as well as significantly different properties from its hole doped counterparts. Concerning the study on $R_{1x}Ca_xMnO_3$, it is known that the paramagnetic (PM) state on the electron doped side exhibits metallic behavior even with a small injection of carriers (x=0.95), in contrast to the hole doped side that exhibits insulating behavior. In particular, the study on electron doped $Sm0.1Ca_{0.9x}Sr_xMnO_3$ has attracted great attention because of its unique structural, magnetic, and charge transport properties. We have studied the concentration-dependent near-Fermi-level valence-band electronic structure of $Sm0.1Ca_{0.9x}Sr_xMnO_3$ (x=0, 0.1, 0.3, and 0.6) using high-resolution ultraviolet photoelectron spectroscopy (HRUPS) across the metal insulator transition. At low temperatures (50 and 100 K), a transformation from pseu-dogap type behavior (x = 0 and 0.1) to insulating behavior (x = 0.3 and 0.6)
is observed with an increase in Sr content. While at the high temperatures, the metallic-like density of states appears up to x = 0.3 and then vanishes at x = 0.6. The temperature-dependent spectra reveal a changeover from pseudogap to metallic-like states for x = 0 above its magnetic cluster-glass ordering temperature (110 K). In the case of x = 0.1, the temperature-dependent change in the density of states is quite di_erent from that of x = 0 due to the weaker cluster-glass component and exhibits an interesting spectral weight transfer in the high-temperature paramagnetic phase. These findings would immensely help in understanding the puzzling charge transport scenario in $Sm0.1Ca_{0.9x}Sr_xMnO_3$ from a microscopic point of view.

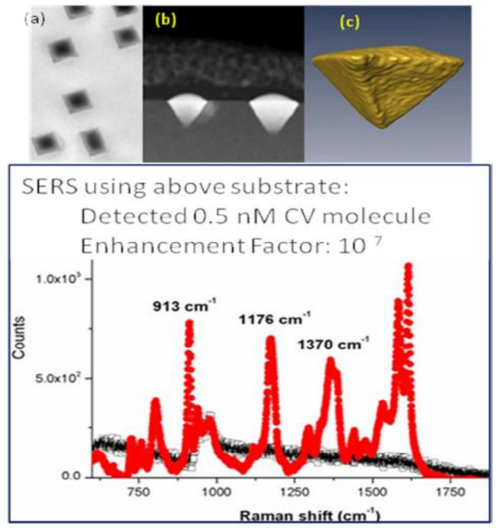
B. R. Sekhar

13. On the band structure of GeSe using ARPES

Recently, the IV-VI narrow band gap semiconductors have attracted much attention due to their application as thermo-electrics, optical fiters, optical recording materials, senors and lasers, infrared detectors and photovolatics. Owing to the small band gap, these materials are potential candidates in the solar cell industry. Though, there has been extensive research in the field of IV-VI compounds, there are very few reports on their intermediate alloys some of which are identified as suitable compositions to tune the band gap. Among various compounds, GeSe and PbSe o_er some of the most interesting properties. GeSe and PbSe exhibits an indirect band gap of 1.07 eV and 0.165 eV, respectively. Doping GeSe with Pb was found to be a tool to tune the band gap for enhanced applications. Tunability of the band gap in GeSe is intimately related to the near Fermi level band structure. Our own electronic structure studies have shown that the reduction in the indirect band gap is controlled by the doping. Direct band gap remains almost unaffected and indirect band gap gradually decreases with both Sn and Pb doping. Since, the lowest conduction band along Γ-Y direction in the Brillouin Zone gradually comes down in contrast to the top most valence band along -X and -Z which gradually goes up towards the fermi level, is responsible for decrease in indirect band gap. On the other hand direct band gap remains almost una_ected because the topmost valence band and lowest conduction band at both goes down in energy scale. Angle resolved ultraviolet photoemission measurements on GeSe single crystals has been undertaken to explore the near Fermi level electronic structure of the system. Angle integrated valence band photoemission $Ge_{1-x}Pb_xSe$ (x = 0.0, 0.2, 0.4) single crystals reveal the changes in valence band DOS with Pb incorporation. The elctronic properties substantiates the results of resistivity. Competition between structural distortion and metallicity classifies the system into two regimes where on one side the structural distortion leading to band gap opening dominates while on the other side cationic and anionic interaction leads to metllicity.

B. R. Sekhar

14. 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. We have analyzed their three-dimensional shape by scanning transmission electron microscopy tomography and demonstrated their use as a highly reproducible and stable substrate for surface enhanced Raman spectroscopy (SERS) measurements. Bi-layers consisting of Ag and GeO_x thin films were grown on native oxide covered silicon substrate using a physical vapor deposition method. Followed by annealing at 800°C under ambient conditions, this resulted in the formation of endotaxial Ag nanostructures of specific shape depending upon the substrate orientation. These structures are utilized for detection of Crystal Violet molecules of 5×10^{-10} M concentrations. These are expected to be one of the highly robust, reusable and novel substrates for single molecule detection. Ref: R R Juluri et al., *Scientific Reports* ***4*** *(2014) 4633* In the process of a proper understanding of the growth mechanism for the silver and gold endotaxial structures in crystalline silicon substrate, 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.

P. V. Satyam and R. R. Juluri

15. 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. I have done some experiments to prepare bimetallic thin film (Au-Ag) on thermally clean Si(5 5 12) substrate using successive depositions of Ag and Au thin films. The growth of the thin films has been studied using in situ RHEED. All the samples have been characterized using ex situ RBS and SEM. We have also carried out some experiments to observe the SERS efficiency of the (Au-Ag)/Si samples.

P. V. Satyam

16. Growth of faceted Au nanoparticle capped various ZnO nanowires and study of their photoluminescence and antireflection properties

ZnO is well known as a good photoluminescent semiconductor because of visible light emission properties. In this work, growth, structural and optical properties of Au nanoparticle capped faceted ZnO nanowires (NW) on 1nm and 5nm Au layer deposited on Si substrate using a high temperature (H"900°C) chemical vapor deposition (CVD) method were presented. In particular, by varying only the initial catalyst layer thickness and hence the dimension and areal density of the aligned NWs array, the resultant photoluminescence (PL) and reflectance characteristics of ZnO NWs coatings were systematically compared. Electron microscopy study confirms majority of the as-synthesized ZnO NWs are single crystalline in a hexagonal structure grown along [0002], facing faceted Au nanoparticle on their top. The areal density of the ZnO NWs array is observed to be proportional to the average Au nanoparticle size. Under excitation of 280 nm at room temperature, they exhibit defect emissions (violet, blue and green) along with near band-edge related UV emission. To investigate the antireflective property of ZnO NWs coated Si substrates, specular reflection experiments were carried out.

By controlling NWs dimension and density, reduction of the average reflectance down to < 1% (~ 0.75%) is achieved over the broad wavelength rage of 250 – 1000 nm. {Both of the substrates containing Au-ZnO heterostructures can be applied in surface-enhanced Raman scattering (SERS) measurement. A typical probe molecule, crystal violet was used to test the SERS activity of the ZnO–Au heterostructures and the results indicated good Raman activity on the substrates. These as-grown substrates were observed to enhance the Raman signal for detection of crystal violet (CV) with an analytical enhancement factor (AEF) of 106, making them potentially suitable as freestanding SERS substrates.

P. V. Satyam

17. Energetic Ion-Beam Based Materials Science

17.a. *Ion-Beam induced surface nanostructuring of semiconductors and their applications.*

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 (50 eV-60 keV) inert gas ions and trying to understand the underlying physics in terms of various experimental parameters and the existing theories. In our most recent paper, we have shown that both sputter erosion and ion-beam induced prompt atomic redistribution are responsible for ripple formation on Si surface at medium ion energies. 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 the low energy regime) 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 there would be no rotation. Different types of patterned surfaces are useful for many applications, viz. solar cells, spintronics, optoelectronics, plasmonics, etc. where one can make use of them as templates for deposition of thin films.

S.K. Garg, T. Basu, M. Kumar, D.P. Datta, D. Kanjilal, and T. Som

17.b. Applications of self-organized (patterned) nanostructured surfaces

Solar energy research

Tailoring photoluminescence of antireflective silicon nanofacets

A fluence-dependent antireflection performance is observed from ion-beam fabricated nanofaceted-Si surfaces. It is also demonstrated that these nanofacets are capable of producing room temperature ultra-violet (UV) and blue photoluminescence which can be attributed to inter-band transitions of the localized excitonic states of different Si-O bonds at the Si/SiOx interface. Time-resolved photoluminescence measurements further confirm defect-induced radiative emission from the surface of silicon nanofacets. It is observed that the spectral characteristics remain unchanged, except an enhancement in the photoluminescence intensity with increasing ion-fluence. The increase in photoluminescence intensity by orders of magnitude stronger than that of a planar Si substrate is due to higher absorption of incident photons by nanofaceted structures.

T. Basu, M. Kumar, P.K. Sahoo, A. Kanjilal, and T. Som

Tunable anti-reflection from conformally grown Al-doped ZnO on faceted-Si

We have shown the efficacy of Al-doped ZnO (AZO) overlayer on ion-beam synthesized nanofaceted silicon for suppressing reflection loss. In particular, we have demonstrated thickness- dependent tunable anti-reflection (AR) from conformally grown AZO layer, showing a systematic shift in the reflection minima from ultra-violet to visible to near-infrared ranges with increasing thickness. Tunable AR property is understood in light of depth dependent refractive index of nanofaceted silicon and AZO overlayer. This improved AR property significantly increases the fill-factor of such textured heterostructure**s** compared to the one**s** based on planar silicon.

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

Electrical transport properties of ZnO:Al thin films on faceted-Si

Current-voltage spectroscopic results show diode characteristics where the turn-on potential decreases with increasing thickness from 30 to 75 nm. This is probably due to the fact that the barrier height becomes less and this leads to an easy conduction of charge carriers. This claim is further substantiated by capacitance-voltage spectroscopic measurements. These two studies show that the photoresponsivity enhancement can be due to the decreasing barrier height of AZO/faceted-Si heterostrctures.

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

Thin film/nanoscale magnetism

Magnetic anisotropy in Co thin films on rippled substrate

In-plane magnetic anisotropy in Co thin films, of varying thicknesses, grown on rippled Si substrate are investigated. Thin films were deposited at a glancing angle of 80° with respect to the substrate normal by rf magnetron sputtering technique. The results are compared with the films deposited on polished Si substrate as well. Co film grows conformally on rippled substrates up to 8 nm where a strong uniaxial magnetic anisotropy is observed with easy axis of magnetization parallel to the ripple direction. Antiferromagnetic exchange coupling has been observed when magnetic field is applied perpendicular to the ripple direction.

S.P. Patel, T. Basu, M. Kumar, and T. Som

18. *Ion implantation induced modification of semiconductors*

Evolution of microstructure

We are investigating the microstructure, composition, and optical properties of 60 keVAr-ion implanted GaSb and InSb. Normally and obliquely incident Ar-ions lead to the formation of porous layers, in both GaSb and InSb, which contain nanofibers (diameter ~15-25 nm). While the nanostructured surfaces are found to be highly oxidized, the presence of nanocrystallites within amorphous nanostructures is detected even at the highest fluence of 3×10^{18} ions cm^{-2}. The nanoporous layer exhibits luminescence in the visible and the infrared wavelength regime due to oxide formation and retained crystallinity. In our model, we interpret structural evolution in terms of vacancy agglomeration and void growth during implantation.

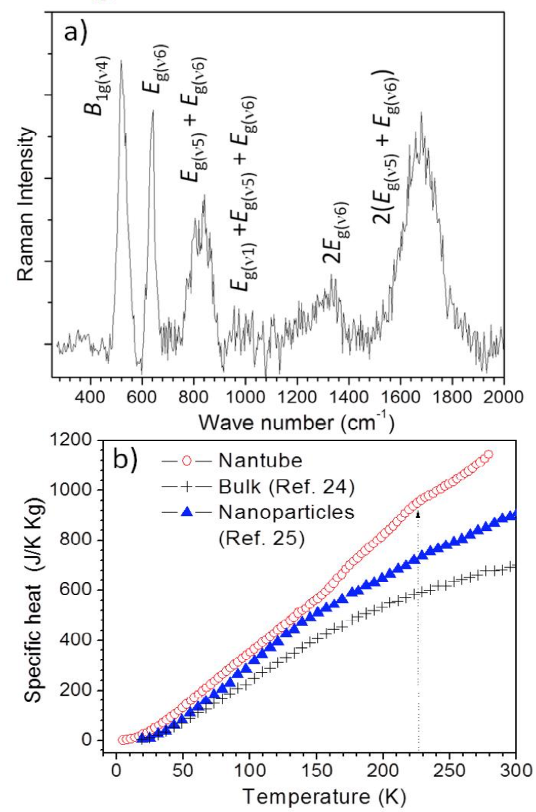
D.P. Datta, S.K. Garg, A. Kanjilal, P.K. Sahoo, B. Satpati, S. Dhara, T.D. Das, P. Das, D. Kanjilal, and T. Som

Amorphization and beyond

Our present study involves a systematic study of MeV ion implantation-induced structural damage evolution in Ge as a function of ion fluence. Ge samples were irradiated at room temperature by MeV Au and Ge ions in the fluence range of 1×10^{12} to 5×10^{16} ions cm^{-2}. The amorphization threshold was determined by Rutherford backscattering spectrometry-channeling (RBS/C) spectrometry. The results were further supported by micro-Raman spectroscopy, high-resolution x-ray diffraction (XRD), and transmission electron microscopy (TEM) studies. Ion induced swelling of Ge is studied by surface profilometry as well as TEM and is explained in light of ion-matter interaction.

D.P. Datta, J. Ghatak, Rajendra Singh, and T. Som

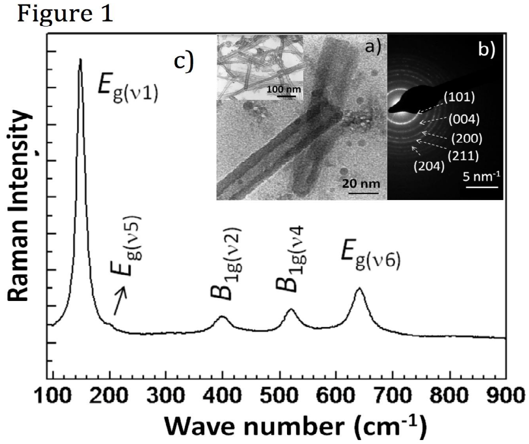
Figure 2



Wettability of surfaces

In our studies, ion irradiation is observed to induce dramatic modification in wettability of semiconductor surfaces. In case of nanoporous GaSb and InSb generated by 60 keV Ar^+ irradiation, the contact angle measurements show a variation from ~110° for pristine sample to ~157° for irradiated surfaces, showing influence of microstructure on hydrophobicity. On the other hand, for 60 keV Ar^+ and Xe^+ ion irradiations on Si, the rippled surfaces become hydrophilic and hydrophobic in nature, respectively. When the ion energy goes down to 500 eV, contact angle measurements on Ar^+ irradiated Si show an enhanced hydrophilic property in case of rippled morphology whereas faceted structures demonstrate a hydrophobic to hydrophilic transition as a function of ion-fluence. We attempt to understand the observations in terms of surface microstructure and composition.

Figure 1

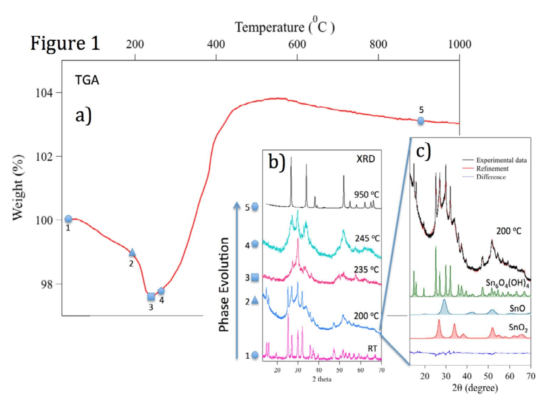


S.K. Garg, D.P. Datta, S. Chatterjee, Krishnacharya, T. Som

19. Growth and characterization of thin films for photovoltaics applications

19.a. 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



rf 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.

M. Kumar, T. Basu, S. Chatterjee, R. Sivakumar, P.K. Sahoo, A. Kanjilal, and T. Som

19.b Spectral response study of nO:Al thin films on flat-Si

The effect of grain boundaries (GBs) of AZO thin films on local electric transport is investigated by conductive atomic force microscopy (cAFM) under dark and after UV exposure. A strong enhancement in the local current with grain-grain variation is observed. In order to understand this phenomenon, the observed variation in local conductivity has well been corroborated with spatial distribution of donor concentration, mapped by scanning Kelvin probe microscopy (SKPM). We have tried to explore the UV induced enhancement in the spectral response of AZO/SiO_x/Si solar cell. These phenomena are explained in terms of defect-induced efficient electron-hole separation at GBs.

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

19.c Pefect induced band-bending in ZnO:Al thin films on flat-Si

We show the experimental evidence of mid-gap defect states at grain boundaries (GBs) of AZO and their contribution in photoconduction. Using conductive atomic force microscopy, we show the evolution of 40 mV potential barrier at GBs and its impact on local charge transport. In addition, electrostatic force microscopy enables detection of electrostatic interaction at GBs, which is further supported by piezoresponse force microscopy. Detail analyses suggest that besides double Schottky potential barrier, change in polarization and induced local inhomogeneous strain at GBs are also responsible for the observed barrier formation.

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

19.d. Temperature-dependent electrical transport in ZnO:Al thin films

To design a high-efficiency oxide solar cell, it is very important to reduce the GB potential barrier. In an attempt to do the same, we performed temperature dependent electrical transport measurements. These studies reveal that AZO films exhibit metallic behavior e”110°C and hence, will be insufficient to reduce the potential barrier at GBs. This in turn would lead to a drop in the optical transmittance which puts a serious restriction on using AZO films, as a TCO material, at higher temperatures for use in solar cells as a window layer.

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

23.e. Electrical transport properties of Copper Oxide thin films

The main working (absorbing) layer for oxide-based (e.g. ZnO:Al-based) solar cell is copper oxide (Cu-O). Thus, to optimize the properties of Cu-O thin films, we deposited the same on glass and silicon substrates in a simultaneous fashion by using magnetron sputtering technique. It is noticed that the films show the presence of mixed phases of CuO and Cu_2O, denoted as Cu_xO (1 d” x d” 2). Our studies show that defect concentration can be controlled by tuning the deposition parameters. Interestingly, films grown under normally incident flux consist of higher oxygen vacancies and for lower thickness values (~10 nm) show quantum conductance (as studied by conductive atomic force microscopy) which disappear as the thickness increases. However, films of higher thickness values (250 nm) still observe resistive switching behavior suitable for resistive random access memory (RRAM). On the other hand, films grown at 50° incident flux angle are of superior crystalline quality and consist of less number of oxygen vacancies but does not exhibit any resistive switching. Therefore, these films can be ideally used for solar cells because of good electrical conductivity. At present, simulation studies are underway to understand the mechanism of resistive switching as well quantum conductance. We are also studying the field emission properties of Cu-O thin films containing 3-dimensional nanostructures.

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

20. Radial Vibrational Modes in Ultra-Thin Walled TiO_2 Nanotubes using Resonance Raman Spectroscopy

We report the observation of radial vibrational modes (Figure 1c) in ultra-thin walled anatase TiO_2 nanotube powders grown by rapid break down anodization technique. The tubes are around 2-5 nm in wall thickness, 15-18 nm in diameter and few microns in length as seen by TEM (Figure 1a,1b). The $E_{g(\nu 1,\nu 5,\nu 6)}$ phonon modes with molecular vibrations in the radial direction are predominant in the resonance Raman spectroscopy (Figure 2a) using 325 nm He-Cd excitation. Multi-phonons including overtones and combinational modes of $E_{g(\nu 1,\nu 5,\nu 6)}$ are abundantly observed. Frohlich interaction owing to electron-phonon coupling in the resonance Raman spectroscopy of ultra-thin wall nanotubes is responsible for the observation of radial vibrational modes. Finite size with large surface energy in these nanotubes energetically favor only one mode, $B_{1g(\nu 4)}$ with unidirectional molecular vibrations in the parallel configuration out of the three Raman modes with molecular vibration normal to the radial modes. Enhanced specific heat with increasing temperatures in these nanotubes than that reported for nanoparticles of similar diameter may possibly be related to the presence of the prominent radial mode along with other energetic phonon mode. A possible order-disorder phase transition at 225 K is also presumed, for the first time, from the observed kink in the temperature dependent specific heat data (Figure 2b).

D. Topwal and Collaborators

21. Structural and electronic phase evolution of Tin dioxide

We investigate the effect of controlled annealing on the structural and electronic phase evolution of Tin dioxide from Tin (II) oxyhydroxide prepared by simple precipitation method. Thermogravimetric analysis (Figure 1a) suggests a complex weight loss-gain process involved, passing through an intermediate phase of tin oxide nanoparticles. The probable structural and electronic phase evolution is discussed using detailed X-ray diffraction (Figure 1b), compositional analysis (Figure 1c) and X-ray photoelectron spectroscopy investigations.

D. Topwal and Collaborators

22. Intense ultraviolet photoluminescence observed at room temperature from NiO nano-porous thin films grown by the hydrothermal technique

We have successfully formed high-quality nanoporous NiO films by the hydrothermal technique and observed intense ultraviolet (UV) luminescence at room temperature. The SEM image reveals nanoporous NiO films with pore diameters from 70 to 500 nm. The results of XRD, Micro Raman and FTIR characterizations confirm the cubic structure of NiO. The optical band gaps estimated from the absorption spectrum are found to be 3.86 and 4.51 eV. The former is similar to that of bulk NiO, while the latter is much higher than that of bulk NiO. The increased band gap was attributed to the quantum confinement in the NiO nanocrystals, which may be present in the nanoporous NiO film. The room-temperature photoluminescence (PL) spectrum shows a peak of intense luminescence at 3.70 eV and several other peaks in the UV and near-UVwavelength regions. The intense UV luminescence at 3.70 eV was associated with the near band-edge emission and the others with defect-related emission. The high-quality wall of nanoporous NiO with a large surface-to-volume ratio provided the intense UV emission.

Sachindra Nath Sarangi, Dongyuan Zhang, Pratap Kumar Sahoo, Kazuo Uchida, Surendra Nath Sahu and Shinji Nozaki

23. Selective growth of ZnO nanorods by the hydrothermal technique

Zinc oxide nanorods were selectively grown on engineered substrates, Ag-patterned and photoresist-patterned substrates, by the hydrothermal technique using zinc nitrate ($Zn(NO_3)_2$) and hexamethylenetetramine ($(CH_2)_6N_4$). The nanorod growth was affected by the substrate to be used. The nanorods were vertically grown on a GaN substrate but not on a Si substrate because of lattice mismatch. However, since the nanorods were grown on a thick Ag film no matter what substrate was used, a thick Ag film was deposited on a Si substrate to prepare the Ag-patterned substrate. Accordingly, the nanorods were grown only on the Ag pads. When the sizes of Ag pads were small such as 100 nm × 100 nm, one single nanorod was grown on an Ag pad. As another engineered substrate, the photoresist was patterned to prepare an array of holes on a GaN-on-sapphire substrate by e-beam lithography. When the hole size was 10 nm × 10 nm and higher, concentrations of $Zn(NO_3)_2$ and $((CH_2)_6N_4)$ were employed, all holes were successfully filled with a single nanorod.

Shinji Nozaki, Sachin N Sarangi, Surendra N Sahu and Kazuo Uchida

24. Hydrothermal growth of Zinc Oxide nanorods and Glucose-sensor application

High-quality zinc oxide nanorods were grown on various substrates using zinc nitrate ($Zn(NO_3)_2$) and hexamethylenetetramine ($(CH_2)_6N_4$). The substrates greatly affect the hydrothermal growth of ZnO nanorods. Making the best use the substrate effect, we engineered substrates to make a single nanorod in each hole of 100 nm × 100 nm in the array of the holes on the photoresist-patterned substrate. It is also interesting to note that high-quality ZnO nanorods grown on GaN substrates by the hydrothermal growth technique have demonstrated the potential application as a glucose sensor without oxidase for the first time. The photoluminescence in the UV wavelength range was quenched by immobilizing glucose on the ZnO surface. The peak intensity decreased increased with the increased glucose concentrations. A good linearity and high sensitivity were obtained for the glucose concentrations of 0.5 - 30 mM in the calibration curve. The calibration curve was not influenced by the presence of bovin serum albumin (BSA), ascorbic acid (AA) and uric acid (UA), which are also included in human blood and could cause interference in estimating glucose concentrations in human blood. The PL quenching was attributed to the H_2O_2 molecules, which were produced by the photo-oxidation of glucose during exposure to UV light. The PL-quenching glucose sensor made of ZnO nanorods has been evaluated for the first time by estimating the glucose concentrations in the human serum samples which include those of diabetes, and a good correlation was obtained between the concentrations by the PL quenching and the clinical data provided by a local hospital.

Shinji Nozaki, Sachindra N. Sarangi, Kazuo Uchida, Surendra N. Sahu

25. Substrate effect of hydrothermally grown ZnO nanorods and its luminescence properties

We report the hexagonal wurtzite crystalline structure of ZnO nanorod growth by hydrothermal chemical wet synthesis at low temperature (90°C). We have used p-Si (100), n-Si (100), á-quartz (0001), MgO (0001) and ITO (polycrystalline) substrates to understand the growth mechanism of ZnO nanorods with a low pressure environment. X-ray diffraction study confirms the hexagonal structure of the ZnO nanorod. Scanning electron microscopy (SEM) also shows the hexagonal structure along with different size and width of the nanorods. The substrate effect of nanorods has been explained on the basis of adatom kinetics during the growth. We observed that the nanorods were grown from a single nucleation point with 4–5 different branches on the ITO substrate with uniform length and width, whereas MgO substrate shows curled flower architecture across the whole area. The photoluminescence illustrates strong substrate effect. A wide range of UV emission bands along with visible emission has been observed from the ZnO nanorods deposited on different substrates.

Siddhant K Das, Surya N Sahoo, S. N Sarangi & P. K Sahoo

26. Development of a high-energy transmitted beam EDXRF setup at Institute of Physics for nondestructive analysis of ornaments

High-energy X-rays or HEX-ray are very hard X-rays, with typical energies of 60-1000 keV about one order of magnitude higher than conventional X-rays. The HEX-rays bear unique advantage over conventional hard X-rays for the analysis of technically challenging samples (liquids, thick samples, gold, glass etc.). In the present experimental setup, characteristic X-ray of PbK-lines (75-85 keV) emitted due to bombardment of 3 MeV proton beam generated from the Pelletron accelerator has been used for the energy dispersive X-ray fluorescence (EDXRF) analysis. The main objective of the setup is to develop a high-energy transmitted beam EDXRF for the analysis of thick target of high-Z elements viz. gold and silver.

B. Mallick, A. K. Behera, K. S. Jena, D. K. Ray, P. K. Biswal, A. Sahoo, R. R. Dash, M. Majhi, K. C. Patra, P. C. Marndi, N. Behera, R. K. Sahoo, S. Mishra.

4 PUBLICATIONS

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1. **Universal interpretation of efficacy parameter in perturbed nonequilibrium systems :** S. Lahiri and A. M. Jayannavar Physica A. 392, (2013) 5101..

2. **Fluctuation theorems in inhomogenious media under coarse graining.** : S. Lahiri, S. Rana and A. M. Jayannavar**.** Phys. Lett. A. 378, (2014) 979.

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34. **Observation of flicker 1/f noise in Yba2Cu3O7 and GaAlAs diode :** S B Ota and Smita Ota, J.Phy.Ast.**2(3)**.

35. **Calibration of cryogenic Si diode for temperatures between 30-210 K :** S B Ota, J.Phy.Ast. **2(3)** (2014).

36. **A15 compounds, strong coupling superconductivity and Yba2Cu3O7-x** : S B Ota, J.Phy.Ast. **2(3)** (2014).

37. **Vortex lattice melting and irreversibility temperatures in Yba2Cu3O7 :** S B Ota, J.Phy.Ast. **2(4)** (2014).

38. **Semiconductor diodes for measurement of low temperatures :** S B Ota and Smita Ota, J.Phy.Ast. **2(4)**.

39. **Nature of lack-of-ergodicity in finite systems of two-dimensional Potts model :** Smita Ota and S B Ota, J.Phy.Ast.**3(1)**.

4.4 Articles in Proceedings

1. **Surface Delta Interaction and properties of medium mass nuclei :** S.K. Ghorui and C.R. Praharaj, Proceedings of the DAE Symposium on Nuclear Physics **58** (2013) 230.

2. Yrast Spectra of 140Ba in DHF and J Projection Model : SK Singh, BB Sahu, CR Praharaj, SK Patra, Z Naik and RK Bhowmik, Proc. DAE Symp Nucl Phys **58** (2013) 248.

3. High Spin States of 168Hf Nucleus : BB Sahu, SK Singh, Z Naik, SK Patra, CR Praharaj, Proc. DAE Symp Nucl Phys **58** (2013) 246.

4. High Spin Structure of 161,163Re by DHF model : C Pradhan, S. Sahu, S. Pattanayak, CR Praharaj, Z Naik, Proc. DAE Symp Nucl Phys **58** (2013) 254.

5. α**"decay half-lives of superdeformed superheavy nuclei**, Shakeb Ahmad, M. Bhuyan and S. K. Patra AIP Conf. Proc. 1524, pp. 85-88 (2013).

6. **The effect of isoscalar-isovector coupling in infinite nuclear matter :** S. K. Singh,M. Bhuyan, P. K. Panda and S. K. Patra, AIP Conf. Proc. 1524, pp. 77-80 (2013).

7. **The relativistic Lagrangian: Nucleon-nucleon potential :** B. B. Sahu, S. K. Singh, M. Bhuyan and S. K. Patra, AIP Conf. Proc. 1524, pp. 3-6 (2013).

8. **Reaction dynamics of halo nuclei using Glauber model :** M. K. Sharma, Manoj
Sharma and S. K. Patra, AIP Conf. Proc. 1524, pp. 186-189 (2013).

9. **An effective Nuclear Model: from Nuclear Matter to Finite Nuclei** : T. R. Routray, X. Vi˜nas, S. K. Tripathy, M. Bhuyan, S. K. Patra and B. Behera, J. Phys.: Conf. Ser. 420 012114 (2013).

10. **High Spin Spectroscopy of 168Hf Nucleus** : B. B. Sahu, S. K. Singh, Z. Naik, S. K. Patra and C. R. Praharaj, Proceedings of the DAE Symp. on Nucl. Phys 58, 246 (2013).

11. **Yrast Spectra of ^{140}Ba in Deformed Hartree-Fock and J Projection Model** : S. K. Singh, B. B. Sahu, C. R. Praharaj, S. K. Patra, Z. Naik and R. K. Bhowmik, Proceedings of the DAE Symp. on Nucl. Phys 58, 248 (2013).

12. **Structure and decay properties of Francium isotopes :** S. Mahapatro, M. Bhuyan, S. K. Singh and S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys 58, 290 (2013).

13. **Comparative study of the effective force parameters NL3 and NL3 :** S. K. Singh, M. Ikram, S. K. Biswal, M. Bhuyan and S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys 58, 116 (2013).

14. **The effect of mass asymmetry in infinite nuclear matter :** S. K. Singh, S. K. Biswal, M. Bhuyan and S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys 58, 828 (2013).

15. **Effect of isospin on compressibility of drip line and superheavy nuclei :** S. K. Biswal and S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys 58, 146 (2013).

16. **Reaction dynamics for some halo nuclear system using Glauber model with relativistic mean field densities**, M. K. Sharma, Manoj K. Sharma and S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys 58, 460 (2013).

17. **Structural properties and reaction dynamics of some light highly neutron-rich Si, S and Ar isotopes**, M. K. Sharma, R. N. Panda, Manoj K. Sharma and S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys 58, 352 (2013).

18. **From 4th kind of natural radio activitity to the extension of periodic table to superheavy nuclei**, Raj K. Gupta's contribution to cold nuclear phenomena, B. B. Singh, Manoj K. Sharma and S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys 58, 450 (2013).

19. **Superdeformed ground state of superheavy nuclei**, S. Ahmad, M. Bhuyan and S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys 58, 260 (2013).

20**. Neutrino Mass Hierarchy in Future Long-baseline Experiments :** Sanjib Kumar Agarwalla, Prepared for NOW 2012, Otranto, Lecce, Italy, 9th-16th September, 2012, Nucl.Phys.Proc.Suppl. 237-238 (2013) 196-198

21**. Deformed structure of N=50 Ge Nucleus :** C.R. Praharaj and S.K. Ghorui, Proceedings of the 5th International Conference on Fission and Neutron-rich nuclei, Ed. J.H. Hamilton and A.V. Ramayya, World Scientific 516 (2013).

5 COLLOQUIA AND SEMINARS

5.1 COLLOQUIA

1. **Professor Sunanda Banerjee**, SINP, Kolkata : New Particle at the Large Hadron Collider, 27.05.2013

2. **Professor K. Sridhar**, Tata Institute of Fundamental Research, Mumbai : NRQCD — How effective a theory of charmonium is it?, 12.08.2013

3. **Dr. Shakti Nanda**, BBSR : Journey of a photographer through the green corridors of motherland, 02.09.2013

4. **Prof. Hans Hofsäss**, University Göttingen, Germany : Dot and ripple patterns - self organized-ion induced impurity triggered, 18.10.2013

5. **Dr. Vipin K. Yadav** ,Planetary Science Branch (PSB) , Space Physics Laboratory (SPL ,Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram : Mangalyaan - Indian Mars Orbiter Mission, 02.12.2013

6. **Dr. Ayan Mukhopadhyay**, Postdoctoral Researcher, CPHT Ecole Polytechnique and IPHT CEA-Saclay : Applications of the holographic correspondence, 10.12.2013

5.2 SEMINARS

1. **Prof. Naresh Dadhich,** Jamia Milia Islamia University : Einstein is Newton with space curved, 16.04.2013

2. **Mr. Suprabh Prakash**, IIT, Bombay : Exploring 3-flavor effects with present and next generation long baseline superbeam neutrino experiments, 17.04.2013

3. **Dr. Gauhar Abbas** (IMSc, Chennai) : Strong coupling from the tau hadronic width, 18.04.2013

4. **Dr. Sourabh Lahiri,** KIAS (Seoul, S. Korea) : Steady State Fluctuation Theorems, 19.04.2013

5. **Prof. Prasanta Tripathy**, IIT Chennai : Attractor Mechanism in String Theory and Gauged Supergravity, 06.05.2013

6. **Dr. Tarun K. Jha**, BITS, Pilani, Goa : Gravitational waves from neutron stars, 31.05.2013

7. **Prof. Hiranmaya Mishra**, PRL, Ahmedabad : KINETICS OF CHIRAL TRANSITIONS IN DENSE QUARK MATTER, 05.06.2013

8. **Dr. Moumita Maiti**, Department of Physics, Indian Institute of Technology Roorkee, Roorkee : Production of neutron deficient radionuclides for applications: An interdisciplinary approach, 06.06.2013

9. **Prof. B.Rout**, University of North Texas, Denton, Texas : Material Analysis and Fabrication Using Ion Micro Probe, 12.06.2013

10. Dr. Sutap Mukherji, IIT, Kanpur : A Seminar on Physics, 17.06.2013

11. Dr. Debajyoti Sarkar, City University, New York. : Black Hole Formation at the Correspondence Point, 02.07.2013

12. Dr. Tim Grieb, University of Bremen, Germany : Chemical Analysis of Dilute GaNAs and InGaNAs by TEM/ STEM, 08.07.2013

13. Dr. Pradipta Ghosh, Instituto de Fisica Teorica UAM/CSIC, Universidad Autonoma de Madrid : Displaced multi-leptons at the LHC — probing a 125 GeV new boson in munuSSM, 23.07.2013

14. Prof. Soumitra Sengupta, Indian Association of Cultivation of Sciences, Kolkata, India : Hidden mysteries of space and time, 25.07.2013

15. Prof. Soumitra Sengupta, Indian Association of Cultivation of Sciences, Kolkata, India : Origin of brane cosmological constant in warped geometry models

16. Dr. Natasha Sharma, USA Affiliation: University of Tennessee, Knoxville, Tennessee, USA. : Study of light (anti)-nuclei production in ALICE at the LHC, 26.07.2013

17. Dr. Sarira Sahu, Institute of Nuclear Science National Autonomous University of Mexico, Mexico City : Hadronic Origin Orphan TeV Flare from Blazer

18. Prof. K. Sridhar, Tata Institute of Fundamental Research, Mumbai : NRQCD — How effective a theory of charmonium is it?, 12.08.2013

19. Dr. Sinu Mathew, NUSNNI-NanoCore and Dept. of ECE, NUS Singapore : Tailoring of the two-dimensional electron gas conductivity in LaAlO3/SrTiO3 interfaces, 20.08.2013

20. Prof.A.M.Srivastava, IOP,BBSR : Learning Science, Doing Research, Three Idiots' Way, 23.08.2013

21. **Dr. A. Rath,** Post Doctoral Fellow, I I Sc., Bangalore : Deceptive lattice spacings in HRTEM Imaging of nanocrystals

22. Prof. Sreerup Raychaudhuri,, TIFR, Mumbai : The Future of Supersymmetry, 02.09.2013

23. Dr. Priti Sundar Mohanty (Lund University, Sweden) : Soft colloids with an interaction potential tunable from long-range to soft and dipolar, 09.09.2013

24. Prof. Pushpa Khare, IUCAA, Pune : Radiation a key to understanding the universe, 23.10.2013

25. Prof. Avinash Khare, IISER, Pune : Forced Nonlinear Schrodinger Equation in 1+1 with arbitrary nonlinearity, 24.10.2013

26. Dr. Rabinarayan Mishra, Ravenshaw University, Cuttack : Nuclear Equation of state in a relativistic independent quark model with chiral symmetry and dependence on quark masses, 25.10.2013

27. Dr. Shankha Deep Chakrabortty, IMSc., Chennai : Emergence of a frequency dependent conductivity due to quantum correction in Sakai-Sugimoto model, 04.10.2013

28. Dr. Biswajit Ransingh, NIT, Rourkela : Lie Super Algebras, 04.10.2013

29. Dr. Sarbani Majumdar, Bose Institute, Kolkata : Astroparticle Physics, 1.1.2013

30. **Prof. Soma Sanyal,** Physics Department, Hyderabad University : Charge Fluctuations and its Consequences in the Early Universe, 11.11.2013

31. Dr. Sasmita Mishra, PRL, Ahmedabad : QCD / Neutrinos, 12.11.2013

32. Dr. Vivek Vyas , IISER, Kolkata : Superconductivity without spontaneous symmetry breaking, 13.11.2013

33. Dr. Somnath De, VECC, Kalkata : EoS of strongly interacting matter and intensity interferometry of thermal photons , 19.11.2013

34. Dr. D.P. Datta, PDF,IOP, Bhubaneswar : Evolution of nanofibrous layer due to Ar-ion irradiation of GaSb and InSb, 20.11.2013

35. Dr. Subroto Mukherjee, Head, FCIPT, IPR, Gandhinagar : Plasma based surface engineering, 02.12.2013

36. Dr. Vipin K. Yadav ,Planetary Science Branch (PSB) , Space Physics Laboratory (SPL) , Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram : Mangalyaan - Indian Mars Orbiter Mission, 02.12.2013

37. Dr. Dibakar Raychowdhury, IISER, Bhopal : Gravitational Aspects of String Theory, 10.12.2013

38. Dr. Ayan Mukhopadhyay, Postdoctoral Researcher, CPHT Ecole Polytechnique
and IPHT CEA-Saclay : Spacetime emergence from holographic RG flow, 11.12.2013

39. **Dr. Sanjit Das**, IIMs, Chennai : RICCI FLOW/ BACH FLOW, 11.12.2013

40. Prof. Dipankar Banerjee, Indian Institute of Astrophysics, Bangalore : Magnetic Waves in the Solar Atmosphere, 13.12.2013

41. Dr.A.K.Sarangi, UCIL : Nuclear Power, Uranium Resources and Production: Indian Scenario and Global Development, 16.12.2013

42. Dr. Gaurav Narian, IMSc., Chennai : Heat Kernel and Loop Calculations, 16.12.2013

43. Dr. Manimala Mitra,IPPP, Durham : On the Origin of Neutrino Mass and Lepton Number Violating Searches, 23.12.2013

44. Dr. Kenji Nishiwaki (HRI) : Origin of fermion flavor is deciphered by geometry, 24.12.2013

45. Dr. Areejit Samal ,ICTP, Trieste, Italy : Design principles of metabolic networks: Role of biochemical and Functionalconstraints, 24.12.2013

46. Dr. Poulomi Sadhukhan, University of Gottingen, Germany : Elasto-plastic response of reversibly crosslinked biopolymer bundles, 30.12.2013

47. Dr. Prasana Sahoo, Instituto de F??sica Gleb Wataghin , Universidade Estadual de Campinas, Campinas, SP, Brazil : One Dimensional Group III-V Semiconductor Based Nanostructures: Growth Kinetics, Physical Properties and Application, 03.01.2014

48. **Dr. Satyanarayan Mohapatra,** Physics Dept.,Syracuse University, USA : Listening to the universe by the ground based gravitational wave detectors, 03.01.2014

49. Dr. Ritam Mallick, Frankfurt am Main, Germany : Magnetars: new frontier in Neutron star Physics, 06.01.2014

50. Prof. Rupak Mahapatra (TEXAS A&M University) : Shedding Light on Dark Matter, 07.01.2014

51. Dr. Kalpataru Pradhan (Univ. of Augsburg, Germany) : Magnetically Disordered Interfaces in Magnetic Tunnel Junctions, 08.01.2014

52. Prof. Mukunda P. Das, Department of Theoretical Physics, Research School of Physics and Engineering,The Australian National University, Australia : Physics of Vortex Matter of Novel Superconductors, 15.01.2014

53. Dr. Sachin Jain, TIFR, Mumbai : How Fermion becomes bsosn : S-matrix in Chern-Simons matter theory, 22.01.2014

54. Prof. Vikram Soni, Centre for Theoretical Physics, Jamia Millia Islamia University, New Delhi : Maximum Stars, 28.01.2014

55. Dr. Mansi Dhuri, IIT, Roorkee : Aspects of D3/D7 mu-split Supersymmetry, 30.01.2014

56. Dr. Prabwal J. Phukon, IIT, Knpur : R - Charged Black hole and Holographic Optics, 03.02.2014

57. **Dr. Victor Roy,** Central China Normal University, Wuhan, 430079, China : Scaled distributions of anisotropic flow as probes of initial conditions in high-energy heavy-ion collisions, 12.02.2014

58. Prof. T R Govindrajan (CMI) : Life at the edge: Novel bound states on manifolds with boundary, 19.02.2014

59. Prof. T R Govindrajan (CMI) : India's nuclear program : problems and prospects, 20.02.2014

60. **Prof. J. Fassbender**, Institute for Ion-beam Physics and Materials, Research, Helmholz-Zentrum Dresden-Rossendorf, Germany : Nanomagnets created and tailored by ions, 21.02.2014

61. Dr. Swarnali Bandopadhyay (BITS, Hyderabad) : Spin transport under spin transfer torque, 05.03.2014

62. **Mr. Prashanta Kumar Khandai** Research Scholar Dept. of Physics B.H.U., Varanasi : Study of hadron production in nucleus nucleus interactions at
Relativistic Heavy Ion Collider, 06.03.2014

63. Prof. Mohammad Sami, Centre for Theoretical Physics, Jamia Millia Islamia, New Delhi-110025. : Cosmic acceleration: Dark Energy and Modified theories of gravity, 18.03.2014

64. Prof. Sudipta Sarkar, IISER Mohali : Black hole Thermodynamics: Beyond General Relativity, 19.03.2014

65. Sudipto Paul Chowdhury, IMSc., Chennai : BCS Instability and Finite Temperature Corrections toTachyon Mass in Intersecting D1-Branes, 21.03.2014

5.3 LECTURES GIVEN ELSEWHERE BY IOP MEMBERS

Prof. A. M. Srivastava :

1. **Talk on Learning Science, doing Research, Three Idiots Way**, at IOP, Aug. 2013

2. Seminar on "Flow fluctuations and CMBR anisotropies" at the STAR regional meeting and discussions on phases of QCD, NISER, July, 2013.

3. Seminar on Dark Energy in the Universe, at Sreegopal Banerjee College, Mogra, Hooghly, Sept. 2013.

4. Lecture given on Quark-gluon plasma in the HEP Experimental SERC school At IIT Madras in Dec. 2013.

5. Seminar given on "Reviving quark nuggets as dark matter candidates" at WHEPP, Puri, Dec. 2013.

6. Summary Talk on Theory at the conference on Matter at extreme Conditions, then and now, Bose Institute, Kolkata, Jan. 2014.

7. Six lectures given on Introduction to Field theory and QCD in Conference on Compressed Baryonic Matter, at Bose Institute, Kolkata, Jan. 2014.

8. Colloquium on Investigating cosmic string theories with liquid crystal experiments, at Physics Dept. IIT Madras, Chennai, Jan. 2014.

Popular talks :

9. Guest scientist talk on "Inspiration for science research" in the Face to Face Session at the National Childrens Science Congress, at the Temple City Institute of Technology & Engineering(TITE),Khordha, Nov. 2013

10. Lecture on "How to make a telescope" for school students at the telescope making workshop jointly arranged by SCAAA and IOP, at IOP, July, 2013.

<u>Prof. S. Varma :</u>

11. *Plenty of Room at the Bottom: Nanotechnology today* at 'One Day seminars on Feynman's Birthday' organized at IOP Bhubaneswar (May. 2013)

12. ***Oxide Semiconductors: Bandgap Engineering Optical Properties*** at Interaction Meeting on 'Photoemission' organized by Raja Rammana Centre for Advanced Technology, RRCAT(Aug. 2013)

13. ***Fabrication of Nanostructures on TiO2 (110) surfaces by Low Energy Ion beam Sputtering: Enhanced Visible-Photoabsorption and Hydrophilicity*** at Discussion meeting on 'Low Energy Ion Scattering at Molecular Solids' organized by IIT Madras Chennai (Jan. 2014).

14. ***X-ray Photoelectron Spectroscopy in Elucidation of Chemical States*** at Theme meeting on 'Recent Advances in Material Characterization by Surface Analytical Techniques' organized by NCCCM, BARC, Hyderabad (Feb. 2014).

15. ***Tuning Bandgap Parameters for Photocatalysis Enhancing Bio-compatibilty TiO2 (110) Nanostructures*** at Third International Conference on Physics at Surfaces and Interfaces, PSI organized by Electron Microscopy Society of India,EMSI, Puri (Feb. 2014).

<u>Prof. P. Agrawal :</u>

16. **Searching the Missing Piece – the Higgs Boson'**, at Indian Institute of Astrophysics, Bangalore, May 13, 2013.

17. **Sometime Less is More', in Quantum Correlations and its Applications in Communication and Cryptography**, ISI, Kolkata, September 2-3, 2013.

18. **Di-Vector Boson + Jet Production via Gluon-Gluon Fusion'**, in "11th International Symposium on Radiative Corrections (RADCOR 2013)", U. of Durham, UK, September 22-27, 201.

19. **Gravitational wave from rotating neutron star, 6th Asian nuclear physics symposium**, ANPhAS-2014, VECC, Kolkata, February 19-21, 2014.

20. **Gravitational wave from rotating neutron star, Indo-UK seminar on ISOLDE**,
Department of Physics, Panjab University, Chandigarh, January 21-23, 2014.

21. **Microscopic origin of NN interaction**, **National Conference on Double Beta Decay and Neutrinos,** Department of Physics, IIT Ropar and Department of Physics, Panjab University, Chandigarh, April 20-21, 2013.

22. **The Puzzle of the Nucleus**, Seminar given at Ravenshaw University, April 5, 2013.

<u>Prof. S. B., Ota :</u>

19. **Strong coupling superconductors and Coulomb screening',** Institute of Physics, 30 August 2013.

22. **Nature of lack-of-ergodicity in finite systems of two-dimensional Potts model'**, Institute of Physics, 2 September 2013

<u>Prof.. P. V. Satyam :</u>

23. **SiGe structures on high index planes :** ISSP, Japan, 4 June, 2013 .

(2) PF User Meeting, SINP, Kolkata: 7 October 2013 - **insitu XRD study of endotaxial growth**

24. **Coherent Endotaxy and its Applications :** Talk at Osaka, 28 Nov, 2013 .

25. **Self assembled nanostructure growth on high index planes :** Talk at IISc. Bangalore - 18 Dec 2013 -

<u>Prof. T. Som :</u>

26. **Pattern formation by energetic ions"** on 13.01.2014 at *IOP Experimental Condensed Matter Physics Journal Club*, Bhubaneswar.

27. "**Nanoscience at schools**" on 29.03.2014 at *Science Day Celebration at IOP & NISER*, Bhubaneswar **(Popular)**.

28. I**on induced pattern formation: Some case studies and possible applications**. on 30.05.2013 at *International Symposium on Nanoscale Pattern Formation at Surfaces*, Copenhagen, Denmark.

29. **Ion-beam induced self-organized pattern formation on semiconductor surfaces and their possible applications** on 17.09.2013 at *18th International Conference on Surface Modification of Materials by Ion Beams (SMMIB)*, Kusadasi, Turkey.

30. **A one-step pattern formation technique on materials: Basics and applications**" on 05.10.2013 at *National Seminar on Nanosensors and applications(NSNA-2013)*, Bhubaneswar.

31. **A one step ion-beam synthesized silicon template for tunable antireflection of aluminum-doped zinc oxide nanostructures**" on 24.10.2013 at *International Conference on Nanostructuring by Ion Beams* (*ICNIB*), Jaipur.

31. **Ion-beam induced nanoscale pattern formation at surfaces** on 29.11.2013 at *International Workshop on Bringing The Nanoworld Together (BTNT)*, Mohali.

32. **A one step ion-beam synthesized silicon template for tunable antireflection of aluminum-doped zinc oxide nanostructures"** on 12.12.2013 at *17th International Workshop on Physics of Semiconductor Devices (IWPSD)*, Noida.

33. **Ion-beam induced self-organized pattern formation and their possible applications** on 14.02.2014 at *International Conference on Advances in Polymeric Materials (APM-2014)*, Bhubaneswar.

34. **Pattern formation on Si surface by energetic ions** on 26.02.2014 at *3rd International Conference on Physics at Surfaces at Interfaces (PSI-2014)*, Puri.

35. **Nanofabrication by energetic ion beams: Fundamentals and applications** on 14.03.2014 at the National Workshop on Development of Nanoscience & Nanotechnology, Delhi.

Prof. S. K. Agarwalla :

36. Neutrino Oscillation Experiments: Latest Results & Future Roadmap Invited talk given at WHEPP 2013 workshop, Puri, Orissa, India, 15th December, 2013

37. Neutrino Program in India, Invited talk given at the ICFA Neutrino Panel: Asian Neutrino Community Meeting, Kavli IPMU, Kashiwa, Japan, 13th November, 2013

38. Status and Prospects of India-based Neutrino Observatory, Invited plenary talk given at the NNN13 International Workshop, Kavli IPMU, Kashiwa, Japan, 12th November, 2013

39. Recent Advances in Neutrino Physics and Future Roadmap, Talk given at Institute of Physics, Bhubaneswar, India, 26th September, 2013

40. Implications of Recent Measurements in Neutrino Sector & Future Directions, Invited plenary talk given at the International Conference on 'Triggering Discoveries in High Energy Physics', University of Jammu, India, 10th September, 2013

41. Resolving q_{23} Octant in Current and Future Oscillation Facilities, Invited talk given at the NUFACT 2013 workshop, Institute of High Energy, Physics (IHEP), Beijing, China, 20th August, 2013

42. India-based Neutrino Observatory, Talk given at Institute of Physics, Bhubaneswar, India, 24th May, 2013

43. **Three Flavor Effects in Current and Future Oscillation Facilities,** Invited plenary talk given at the IPM international school and workshop on Particle, Physics (IPP13), Tehran, Iran, 4th May, 2013

44. Electroweak Measurements with nuSTORM, Talk given at the nuSTORM workshop, Virginia Tech, Blacksburg, USA, 14th, April, 2013

Dr. S. P. Das (Post-doctoral Fellow) :

45. **A short overview on Higgs physics at the Large Hadron Collider : Place and Date:** Physics and Applied Mathematical Unit (PAMU), ISI, Kolkata,India, Feb-2014.

46. **A short overview on Higgs bosons phenomenology at the Large Hadron Collider** : Place and Date: Theory Physics Seminar, School of Physics, Sambalpur University, Orissa, India in September, 2013.

47. **Higgs bosons phenomenology at the Large Hadron Collider in light of recent observations** : Place and Date: Theory Physics Seminar, IIT-Hyderabad, Hyderabad, India in August, 2013.

48. **Higgs bosons phenomenology at the Large Hadron Collider in light of recent observations** : Place and Date: ITER, S'O'A University, Bhubaneswar, India in May, 2013.

Dr. S. N. Sarangi (Scientific Officer) :

49. **Hydrothermal Growth of ZnO Nanostructures on the Metal Films** AVS 60th International Symposium andExhibition, Long Beach, California USA, October 2013.

50. **Effect of Highly Charged Bi^{+} Ion Irradiation on Carbon Nanorods and HOPG** Invited talk at Institute of Laser Science, University of Electrocommunication, Tokyo, Japan on during July 2013

52.Selective growth of ZnO nanostructures on metal films: Demonstrations of a gas sensor devices, oral presentation at PSI-2014 organized by Institute of Physics at Puri on February 2014.

5.4. Conference / Symposium / Workshop attended by IOP Members

Prof. A. M. Srivastava

1. **STAR regional meeting and discussions on phases of QCD**, NISER, July, 2013.

2. **UGC-Sponsored National Seminar on Modern Physics: Some Aspects** at a Glance at Sreegopal Banerjee College, Mogra, Hooghly, Sept. 2013.

3. **Workshop on High Energy Physics and Phenomenology (WHEPP13)** Puri, Dec. 2013.

4. **The conference on Matter at extreme Conditions, then and now**, Bose Institute, Kolkata, Jan. 2014.
5. **The Conference on Compressed Baryonic Matter**, at Bose Institute, Kolkata, Jan. 2014.

Prof. S. Varma

1. **Interaction Meeting on 'Photoemission'** organized by Raja Rammana Centre for Advanced Technology, RRCAT(Aug. 2013)

2. **Discussion meeting on 'Low Energy Ion Scattering at Molecular Solids'** organized by IIT Madras Chennai (Jan. 2014).

3. **Theme meeting on 'Recent Advances in Material Characterization by Surface Analytical Techniques'** organized by NCCCM, BARC, Hyderabad (Feb. 2014).

4. **Third International Conference on Physics at Surfaces and Interfaces, PSI** organized by Electron Microscopy Society of India, EMSI, Puri (Feb. 2014).

5. **One Day seminars on Feynman's Birthday'** organized at IOP Bhubaneswar (May. 2013)

Prof. P. Agrawal

1. **International Program on Quantum Information (IPQI 2014) from February 17-28, 2014. There were about 60 student participants and about 40 invited speakers.**

2. **Discussion Meeting on Radiative Corrections (DMRC) from January 9-14, 2014. The participation was restricted to about 20.**

Prof. P. V. Satyam

1. **3rd International Conference on Physics at Surface and Interfaces, PSI2014 in collaboration with Electron Microscope Society of India**, Indian Association for Cultivation of sciences, Kolakatta, and IIT - Bhubaneswar. This has been organized as an EMSI event (as Co-Chair of the conference).

2. **International Conference on Electron Microscopy and EMSI XXXIV Annual General Meeting** held at Kolaka (as Joint Convener, EMSI2013 Conference)

Prof. P. K. Sahu

1. Visited to CERN for ALICE collaboration from May 22June 3, 2014.

2. Organized STAR Regional Meeting January 18-19, 2014, at Institute of Physics,
Bhubaneswar.

3. Attended the International Conference on "Matter at Extreme Conditions: Then & Now" January 15-17, 2014, at Bose Institute, Kolkata.

4. Attended the ALICE-India Collaboration Meeting January 12-14, 2014, VECC, Kolkata.

5. Attended the ALICE India Collaboration Meeting September 7-8, 2013, Jammu University, Jammu.

6. Organized "STAR Regional Meeting and Discussion on Phases in QCD" jointly with NISER along with Institute of Physics, Bhubaneswar, from July 8-10, 2013.

7. Visited to CERN for ALICE collaboration from May 10-20, 2013.

8. Attended the ALICE India Collaboration Meeting – April 27-28, 2013, IIT, Bombay.

Prof. S. K. Agarwalla

1. **Workshop on High Energy Physics Phenomenology (WHEPP-2013)**, Puri, Orissa, India, 12th to 21st December, 2013

2. **International Workshop on Next generation Nucleon Decay and Neutrino Detectors (NNN13)**, Kavli IPMU, Kashiwa, Japan, 11th-13th November, 2013

3. **India-based Neutrino Observatory collaboration meeting**, Madurai Kamaraj University, Madurai, Tamil Nadu, India, 13th-15th September, 2013

4. **International Conference on 'Triggering Discoveries in High Energy Physics'**, University of Jammu, India, 9th-12th September, 2013

5. **NUFACT 2013 workshop, Institute of High Energy Physics (IHEP)**, Beijing, China, 19th-24th August, 2013

Director with Padmabhusan Shri Raghunath Mohapatra, Chief Guest and Dr. A. Virmani on the occasion of Alumni Day Celebration of Instiute.

Prof. Sreerup Raychaudhuri, TIFR, Mumbai delivering Alumni Day Talk

5

COLLOQUIA AND SEMINARS

Inaugural Talk by Director during 3rd International Conference on PSI

Inaugural Talk by the Co-ordinator during 3rd International Conference on PSI

6.1 ALUMNI DAY

The 33rd Alumni Day was celebrated on 3rd September, 2013. 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 lectures by eminent Alumni members of IOP Prof. Bedangadas Mohanty, NISER, Bhubaneswar ("Studying the QCD phase diagram through Relativistic Heavy Ion Collisions") ; Prof. Rajeev Kapri, IISER, Mumbai ("Hysteresis and nonequilibrium work theorem for DNA unzipping"); Prof. Munshi Golam Mustafa, Saha Institute of Nuclear Physics ("Thermodynamics of Hot and Dense Matter in an improved Perturbation Theory").

The colloquium entitled "The story of particle physics from its earliest beginnings till the discovery of the Higgs boson" was given by distinguished scientist Prof. Sreerup Raychaudhuri, Tata Institute of Fundamental Research, Mumbai.

The evening program started with prize distribution to the winners of various competitions in the year-long program. It was followed by a talk by Padmabhushan Shri Raghunath Mohapatra, a legendary Sculptor . This was followed by Excellent Solo Tabla Recital by cultural programe.

Following were the office bearers

Secretary	:	Arpan Das
Asst. Secretary	:	Subrat Biswal
Treasurer	:	S. Chatterjee and Sumit Nandi
Faculty Advisor	:	Dr. A. Virmani

6.2 FOUNDATION DAY

The 39th Foundation Day of the Institute was celebrated on September 4, 2013. 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. Sunil Mukhi, Department of Physics, Indian Institute of Science Education & Research, Pune. He delivered the Foundation Lecture on the topic " Consistent and Symetric : The Evolution of Fundamental Theory from Gauge Fields to Strings".

6.3 IPQI - 2014

Quantum information science is one of the frontier area of science and technology. It is also an interdisciplinary area of research where scientists from Physics, Mathematics, and Computer Science can contribute. One of the main goal is how well one can process information using laws of quantum theory. Quantum Information theory aims to process information that is not amendable with classical devices. At the same time this also provides new insights into the nature of quantum world. Quantum information processing includes quantum computation, quantum communication, quantum cryptography and various information processing tasks. Not only this provides fundamental arena to investigate quantum phenomena but also gives new technological benefits like quantum teleportation, remote state preparation and secure communications.

In the proposed programme, we hope to bring experts from all over world and focus on various issues related to quantum information science and general quantum theory. These issues will be characterization and quantification of entanglement, quantum channels and quantum operations, role of entanglement in quantum algorithms and quantum computation, developing new quantum algorithms, understanding of capacities of quantum channels, and new communication tasks in the multiparty case.

The International programme on Quantum Information will be held at Institute of Physics (IOP), Bhubaneswar during Feb 17-28, 2014. One of the major goals is to bring together quantum physicists, computer scientists and mathematicians to discuss the current status of the field. We also encourage to present important recent developments in the area of quantum information science and pure quantum theory. It is hoped that all the participants and invited speakers will raise many open questions and fundamental issues which are yet to be understood. We will give emphasis on reviewing the major challenges in the field.

6.4 PSI - 2014

The 3rd International Conference on Physics at Surfaces and Interfaces (PSI-2014) was jointly organized by Electron Microscope Society of India (EMSI) , Kolkata, Institute of Physics (IOP), Bhubaneswar, Indian Institute of Technology, Bhubaneswar (IITBBS), and Indian Association for the Cultivation of Science (IACS), Kolkata from February 24 - 28 , 2014. The conference was being held as an event of Electron Microscope Society of India (EMSI). The conference was be held in the beach resort of Puri on the Bay of Bengal.

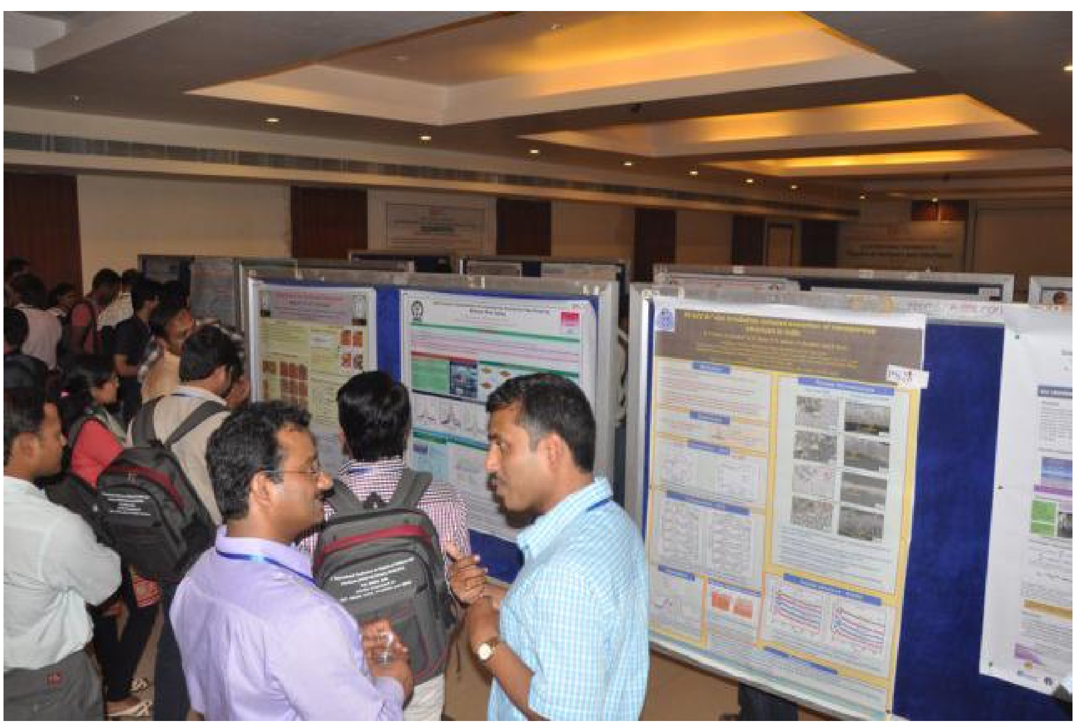
6.5 DMRC

The Large Hadron Collider has collected significant amount of data during its two years of operation. Apart from discovering the Higgs boson, it has severly constrained the models that go beyond the standard model. To compare the data with the models, there has been requirement for precise theoretical predictions. For most of the proceeses, NLO QCD and Electroweak corrections have already been computed. Now there is emphasis on the NNLO calculations. This frontier area was the main topic of discussion in this meeting.

The field of Radiative Corrections is not a very active area of research in

India. One of the goals of the meeting is to bring together those who are interested in this area to learn from one another, encourage collaboration and strengthen the field in India. Another goal of the meeting is to get aquainted with the leading trends in the field and train man-power by inviting and interacting with the experts.

Lectur by one of our guest on the 3rd International Conference on PSI



Poster Presentation Session

7 OUTREACH

The Outreach Program of the Institute of Physics is aimed at spreading scientific awareness among common people, especially regarding various research activities being carried out at the Institute. The special focus of the program is on school children, involving them in various scientific programs to generate their interest in basic sciences and stimulate scientific thinking. The program is carried out by a joint committee of the Institute of Physics and the National Institute of Science Education and Research.

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

7.1 National Science Day

National Science Day was jointly organised by Institute of Physics and National Institute of Science Education and Research (NISER) on 29th March, 2014. About 150 students from nearby schools participated in the program. In the morning session Prof. Swadhin Pattnaik dlivered a talk titled ***"Why Mathematics"*** , which was followed by talk by Prof T. Som titled ***"Nanoscience at Schools"***. In the afternoon session students visited experimental faciluty / laboratory of the Institute and NISER. About 40 experiments were demonstrated to students.

7.2 Night Sky Viewing

Institute conducted night sky watch using 8" telescope for children and general public. Members of local Samanta Chanrasekhar Amateur Astronomers Association (SCAAA) collaborated with Institute in this program.

7.3. Program for School Students

Alumni Association of Institute, with active suport from Institute, conducted science modelling, debate and quiz competitions for school students during 2013-14.

8 OFFICIAL LANGUAGE PROGRAM

Directors and OSD with Guest on the occasion of Hindi Workshop

Directors and OSD with Guest on the occasion of World Hindi Day - 2014

8.1 Activities related to the Official Language implementation in the Institute

Along with the Scientific activities, Institute of Physics has also implemented the Official Language Act in the official works.

IOP continued to carry out its activities to promote the use of Rajbhasha Hindi in various disciplines of the institute. Some of the efforts made in this direction are highlighted below :

- Incentive Scheme for use of Hindi in official work, incentive scheme for Stenographers for doing their official work in Hindi and incentive scheme for Officers to give dictation in Hindi introduced in the Institute.
- Hindi Day and Hindi Fortnight celebrated.
- World Hindi Day on 10.01.2014 celebrated.
- Various Hindi competitions among staff conducted and winners were awarded.
- Three Hindi workshops were organized.
- Various sections were inspected.
- Annual Reports and other documents furnished to various committee prepared bilingually.
- Hindi Books worth Rs.9000/- were purchased.

Quarterly meeting of OLIC were held regularly and progress of Hindi was monitored through OLIC meetings with review of the quarterly progress reports.

9 PERSONNEL

9.1 LIST OF INSTITUTE MEMBERS

Prof. Sudhakar Panda
Director *(From to 23.01.2014)*
High Energy Physics (Theory)

A. Faculty members and their research specialisation

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

2. **Durga P. Mahapatra** ***(Up to 30.06.2013)***
Professor
Condensed Matter Physics (Experiment)

3. **S. M. Bhattacharjee**
Professor
Condensed Matter Physics (Theory)

4. **Kalyan Kundu** ***(Up to 31.10.2013)***
Associate Professor
Condensed Matter Phyiscs (Theory)

5. **Shikha Varma**
Professor
Condensed Matter Physics (Experiment)

6. **Ajit M. Srivastava**
(Director I/C from 05.06.2013 to 22.01.2014)
Professor
High Energy Physics (Theory)

7. **Pankaj Agrawal**
Associate Professor
High Energy Physics (Theory)

8. **Biju Raja Sekhar**
Associate Professor
Condensed Matter Physics (Experiment)

9. **P. V. Satyam**
Associate Professor
Condensed Matter Physics (Experiment)

10. **Snehadri B. Ota**
Reader - F
Condensed Matter Physics (Experiment)

11. **Sudipta Mukherji**
Associate Professor
High Energy Physics (Theory)

12. **Suresh K. Patra**
Associate Professor
Nuclear Physics (Theory)

13. **Tapobrata Som**
Associate Professor
Condensed Matter Physics (Experiment)

14. **Goutam Tripathy**
Reader-F
Condensed Matter Physics (Theory)

15. **Pradip Kumar Sahu**
Associate Professor
Nuclear Physics (Theory)

16. **Dinesh Topwal**
Assistant Professor
Condensed Matter Physics (Experiment)

17. **Amitabh Virmani**
Assistant Professor
High Energy Physics

18. **Sanjib Kumar Agarwalla**
Assistant Professor
High Energy Physics

B. Post-Doctoral Fellows

1. Indranil Chakrabarty
2. Subhadip Mitra
3. Samrat Bhowmick
4. Ritam Mallick
5. Anurag Sahay
6. Sudhanwa Patra
7. Rajib Biswal
8. Sriparna Chatterjee
9. Anupama Chanda
10. Shiv Poojan Patel
11. Padmanabhan Balasubramanian
12. Debi Prasad Datta
13. Soumya Saswati Sarangi

C. Doctoral Scholars

1. Rupali Kundu
2. Poulomi Sadhukhan
3. Abhishek Atreya
4. Souvik Banerjee
5. Sandeep Kumar Garg
6. Raghavendra Rao Juluri
7. Pramita Mishra
8. Tanmoy Basu
9. Vanarajsinh J. Solanki
10. Indrani Mishra
11. Partha Bagchi
12. Rama Chandra Baral
13. Sabita Das
14. Subhashis Rana
15. Tanmoy Pal
16. Anjan Bhukta
17. Arnab Ghosh
18. Himanshu Lohani
19. Mohit Kumar
10. Shailesh Kumar Singh
21. Shailik Ram Joshi
22. Sk. Sazim
23. Subhadip Ghosh
24. Arpan Das
25. Sumit Nandi
26. Soumyarata Chatterjee
27. Subrata Kumar Biswal
28. Bidisha Chakrabarty
29. Priyo Shankar Pal
30. Puspendu Guha
31. Sabya Sachi Chatterjee
32. Shreyansh Shankar Dave
33. Sudipta Mahana

D. Pre-doctoral Scholars

1. Arpan Das
2. Ashis Kumar Manna
3. Bharat Kumar
4. Chandan Datta
5. Debashis Saha
6. Mahesh Saini
7. Paramita Maiti
8. Pronoy Nandi
9. Ranveer Singh
10. Subhadip Ghosh

E. Administration

Shri K. Padmanabhan, OSD.

(i) Director's Office:

1. Sk Kefaytulla
2. Raja Kumari Patra
3. Rajesh Mohapatra
4. B. Nayak *(Upto31.08.2013)*
5. R. N. Sahoo *(Upto 31.03.2014)*
6. Gopal Naik *(Upto 28.02.2014)*
7. Rajan Biswal *(From 18.03.2014)*

(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. Prativa Choudhury
6. Soubhagya Laxmi Das
7. Samarendra Das

(iv) Stores & Transport

1. Pramod Kumar Senapati
2. Sadananda Pradhan
3. Binjaban Digal *(Upto 28.02.2014)*
4. Sanatan Jena
5. Sarat Chandra Pradhan
6. Sanatan Das

(v) EPABX

1. Srikanta Rout

(vi) Despatch

1. Krushna Chandra Sahoo

(viii) Accounts

1. Ranjan Kumar Nayak
2. Pravat Kumar Bal
3. Ambuja K. Biswal *(Upto 01.01.2014)*
4. Kali Charan Tudu
5. Jitendra Kumar Mishra
6. Bhaskara Mishra
7. Baula Tudu
8. Aviram Sahoo
9. Priyabrata Patra
10. Chandramani Naik
11. Bansidhar Panigrahi

(ix) Maintenance

1. Arun Kanta Dash
2. Subhabrata Tripathy
3. Patita Sahu
4. Debaraj Bhuyan
5. Bansidhar Behera
6. Brundaban Mohanty
7. Deba Prasad Nanda
8. Rama Chandra Murmu
9. Naba Kishore Jhankar
10. Baikuntha Nath Barik
11. Purna Ch. Maharana
12. Sajendra Muduli
13. Pabani Bastia
14. Rabi Narayan Mishra
15. Umesh Ch. Pradhan
16. Gandharba Behera
17. Biswa Ranjan Behera
18. Kapilendra Pradhan
19. Martin Pradhan

(x) Estate Management

1. Purastam Jena *(Upto 31.01.2014)*
2. Ghanashyam Naik
3. Dhobei Behera
4. T. Ramaswamy
5. Gangadhar Hembram
6. Tikan Kumar Parida
7. Kailash Chandra Naik
8. Banamali Pradhan
9. Gokuli Charan Dash
10. Biswanath Swain
11. Bijoy Kumar Swain
12. Bijoya Kumar Das
13. Babuli Naik
14. Pradip Kumar Naik
15. Meena Dei

16. Sudhakar Pradhan
17. Sanatan Pradhan
18. Bhaskara Mallick
19. Kulamani Ojha
20. Pitabas Barik
21. Dhoba Naik
22. Charan Bhoi
23. Jatindra Nath Bastia
24. Rajan Kumar Biswal
25. Basanta Kumar Naik

(xi) Library

1. Prafulla Kumar Senapati
2. Dillip Kumar Chakraborty
3. Ajita Kumari Kujur
4. Duryodhan Sahoo
5. Rama Chandra Hansdah
6. Rabaneswar Naik
7. Kisan Kumar Sahoo
8. Sri Kailash Chandra Jena

(xii) Computer Centre

1. Bishnu Charan Parija
2. 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. Nityananda Behera
15. Purna Chandra Marndi
16. Srikanta Mishra
17. Ranjan Kumar Sahoo

(xiv) Workshop

1. Ramakanta Nayak
2. Rabi Narayan Naik

9.2. RETIREMENT

Prof. D. P. Mahapatra

Date of Retirement : 30.06.2013
Date of Joining : 03.06.1987
Last post held : Professor

Shri Brahmananda Nayak

Date of Retirement : 31.08.2013
Date of Joining : 24.03.1976
Last post held : Tradesman - A

Prof. Kalyan Kundu

Date of Retirement : 31.10.2013
Date of Joining : 03.10.1989
Last post held : Professor

Shri Ambuja Kanta Biswal

Date of Retirement : 01.01.2014
Date of Joining : 30.08.1976
Last post held : Sr. Accountant

Shri Purastam Jena

Date of Retirement : 31.01.2014
Date of Joining : 24.03.1976
Last post held : Tradesman - A

Shri Binjaban Digal

Date of Retirement : 28.02.2014
Date of Joining : 08.04.1982
Last post held : Driver Gr-I

Shri Gopala Naik

Date of Retirement : 28.02.2014

Date of Joining : 23.06.1977

Last post held : Tradesman - A

Shri Rabi Narayan Sahoo

Date of Retirement : 31.03.2014

Date of Joining : 20.09.1979

Last post held : Tradesman - A

10

AUDITED STATEMENT OF ACCOUNTS

10.1. Balance Sheet

INSTITUTE OF PHYSICS, BHUBANESWAR

BALANCE SHEET AS AT 31ST MARCH 2014

(Amount - Rs.)

CORPUS/ CAPITAL FUND AND LIABILITIES	Schedule	Current Year	Previous Year
CORPUS/ CAPITAL FUND	1	55,57,68,545	69,83,38,343
EARMARKED/ ENDOWMENT FUNDS	2	1,57,696	1,94,455
CURRENT LIABILITIES AND PROVISIONS	3	18,61,35,692	5,94,02,115
TOTAL		**74,20,61,933**	**75,79,34,913**
ASSETS			
FIXED ASSETS	4	67,84,17,971	71,58,62,637
CURRENT ASSETS, LOANS, ADVANCES ETC.	5	6,36,43,962	4,20,72,276
TOTAL		**74,20,61,933**	**75,79,34,913**
SIGNIFICANT ACCOUNTING POLICIES	19		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS			

In terms of our report of even date annexed

For Samal & Associates
Chartered Accountants
Partner

लेखा अधिकारी / ACCOUNTS OFFICER
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

रेजिस्ट्रार/REGISTRAR
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

निदेशक / DIRECTOR
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

Place : Bhubaneswar
Date : 14|10|2014

10.2. Income & Expenditure Account

INSTITUTE OF PHYSICS, BHUBANESWAR

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD/YEAR ENDED 31ST MARCH 2014

(Amount - Rs.)

INCOME	Schedule	Current Year	Previous Year
Grants/ Subsidies	6	15,51,68,889	15,94,24,186
Interest Earned	7	19,21,758	14,48,548
Other Income	8	12,40,542	11,60,011
Prior period Income		-	-
TOTAL (A)		**15,83,31,189**	**16,20,32,745**
EXPENDITURE			
Establishment Expenses	9	19,76,05,560	10,30,37,518
Other Administrative Expenses etc.	10	6,58,50,762	5,77,36,225
Depreciation	4	7,16,18,680	7,03,74,359
Loss of Assets		-	69,949
TOTAL (B)		**33,50,75,002**	**23,12,18,051**
Balance being excess of Expenditure over Income (B-A)		(17,67,43,813)	(6,91,85,306)
BALANCE BEING SURPLUS/(DEFICIT) CARRIED TO CORPUS/ CAPITAL FUND		**(17,67,43,813)**	**(6,91,85,306)**
SIGNIFICANT ACCOUNTING POLICIES	19		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS			

In terms of our report of even date annexed

For Samal & Associates
Chartered Accountants
Partner

लेखा अधिकारी / ACCOUNTS OFFICER
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

रेजिस्ट्रार / REGISTRAR
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

निदेशक / DIRECTOR
भौतिकी संस्थान / INSTITUTE OF PHYSICS
भुवनेश्वर / BHUBANESWAR

Place : Bhubaneswar
Date : 14/10/2014

10.3. Receipts & Payments

INSTITUTE OF PHYSICS, BHUBANESWAR
RECEIPTS & PAYMENTS FOR THE FINANCIAL YEAR 2013-14

(Figure in Rs.)

	RECEIPTS	SCH	Current Year	Previous Year		PAYMENTS	SCH	Current Year	Previous Year
I.	**Opening Balance**				I.	**Expenses**			
	a) Cash in hand		8,770	9,378		a) Establishment Expenses	13	11,25,75,727	10,22,51,866
	b) Bank balances					b) Administrative Expenses	14	3,75,34,327	3,68,95,306
	i) In current accounts SBI		3,20,11,693	3,68,688		c) Maintenance Expenses	15	1,64,51,172	1,51,63,895
	ii) In deposit accounts				II.	**Payments made against funds for various projects**			
	LK Panda (SBI Term Deposit)		1,00,000	1,00,000		TPSc		91,204	64,479
	iii) Savings accounts					LK panda Scholarship		5,000	5,000
	Indian Overseas Bank (NP)		14,25,320	2,49,27,995					
	Indian Overseas Bank (Plan)		18,21,465	2,41,80,173					
	Union Bank (NP)		1,28,953	35,09,627	III.	**Expenditure on Fixed Assets & Capital W.I.P**			
	Union Bank (Plan)		1,15,449	1,99,17,252					
	SBI (LK Panda)		48,478	51,454		a) Purchase of Fixed Assets	16	4,76,68,590	6,72,98,998
	Union Bank (TPSC)		45,977	7,327					
II.	**Grants Received**				IV.	Interest Receivable		-	-
	a) From Govt. of India - Plan		6,91,83,000	38,50,000					
	Non-Plan		17,08,00,000	17,97,00,000	V.	**Project Revenue Expenses**	17	1,00,00,491	27,74,957
	b) From State Government		-	5,00,000	VI.	**STAFF LOAN**	18	5,93,466	2,97,921
	c) Raja Ramana Fellowship		7,14,153	7,25,356					
III.	**Receipts against Sponsored Projects**				VII.	Security Deposit with CESU		-	-
	TPSC		55,000	1,00,000					
IV.	**Income on Investments from**				IX.	**Closing Balance**			
	LK Panda A/c		1,914	2,024		a) Cash in hand		16,427	8,770
	TPSC A/c		2,531	3,129	X.	b) Bank balances			
V.	**Interest Received**	11	22,38,241	10,36,917		i) In current accounts SBI		37,59,422	3,20,11,693
VI.	**Other Income (Specify)**					ii) In deposit accounts			
	Misc Receipts		878	32,616		LK Panda (SBI Term Deposit)		1,00,000	1,00,000
	Sale of Tender paper		24,800	4,700		iii) Savings accounts			
	House/Guest House Rent		10,96,476	8,95,560		Indian Overseas Bank (NP)		1,24,96,771	14,25,320
	Advance from NISER		-	-		Indian Overseas Bank (Plan)		3,01,75,979	18,21,465
	Sale of Asset		-	-		Union Bank (NP)		6,24,506	1,28,953
VII.	**Other Receipts**					Union Bank (Plan)		84,77,010	1,15,449
	Earnest Money Deposit		6,92,848	2,48,870		SBI (LK Panda)		45,392	48,478
	Security Deposit		(2,52,373)	(2,52,104)		Union Bank (TPSC)		12,304	45,977
	Security Deposit BSNL		-	-					
	Caution Money		2,000	1,200					
	RECOVERY OF STAFF LOAN	12	3,62,215	5,38,365					
	TOTAL		**28,06,27,788**	**26,04,58,527**		**TOTAL**		**28,06,27,788**	**26,04,58,527**

For Samal & Associates
Chartered Accountants
Partner

लेखा अधिकारी / ACCOUNTS OFFICER
भौतिकी संस्थान / INSTITUTE OF PHYSICS

रेजिस्ट्रार / REGISTRAR

निदेशक / DIRECTOR

NOTES












INSTITUTE OF PHYSICS

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Printed at: AD PRINT @ 9337264944