ANNUAL REPORT

2012-13

INSTITUTE OF PHYSICS

BHUBANESWAR

Annual Report

2012 -2013

INSTITUTE OF PHYSICS

BHUBANESWAR

INSTITUTE OF PHYSICS

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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 Orissa and continues to receive financial assistance from them.

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 at 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. 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, an auditorium, and a dispensary in the campus.

The Institute celebrates the Foundation Day each year on 4th September.

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From Director's Desk . . .

Institute of Physics (IOP), Bhubaneswar is one of the premier research Institutions in the country, engaged in frontline research, both in experimental and theoretical physics. IOP is an autonomous research institution within the Department of Atomic Energy (DAE), Government of India. This is the Annual report of IOP, for the period 1st April, 2012 to 31st March, 2013.

The report describes various facilities available in the Institute. It also gives description of various research programs, academic programs, as well as the visitor program of the Institute. Research activities, including publications, seminars, conferences etc. for the last one year period are described. Outreach program of the Institute as well as other activities at the Institute are also mentioned..

(A. M. Srivastava)

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

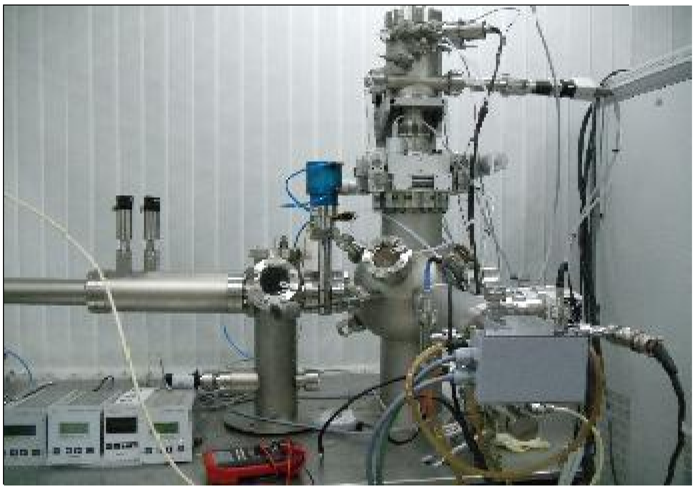
We have also added an ion beam analysis endstation in the general-purpose beam line at the Ion Beam Laboratory. This endstation is a unique one in the country which is dedicated for user experiments based on ion beam analysis techniques, viz. Rutherford backscattering spectrometry (RBS), RBS-channeling, 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

samples can be precisely positioned in front of the ion beam with the help of XYZ motors and monitored by a CCD camera. All gate valves and the vacuum pumps are coupled to the interlocking system which rules out meeting a vacuum related accident. In addition, the chamber is equipped with two surface barrier detectors – one dedicated for RBS measurements and the other one for ERDA measurements. They are coupled to the respective set of electronic modules and the data acquisition system is interfaced with a computer.

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

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 ≈ 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.

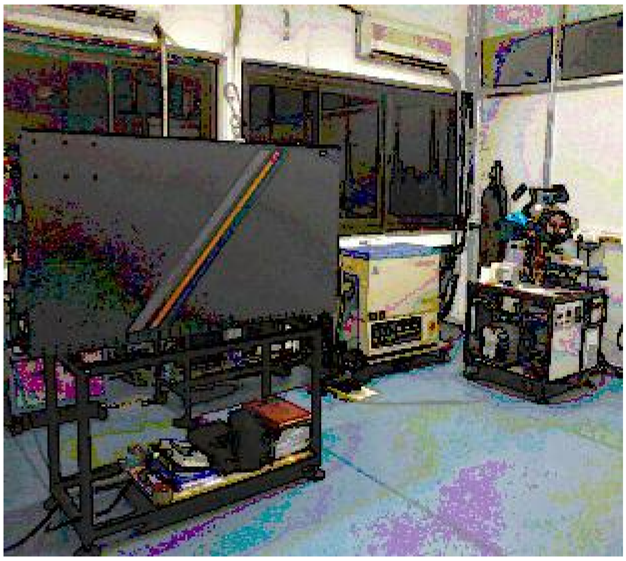
X-ray photons while impinging on the sample surface produce photoelectrons which can be utilized for elemental identification. The kinetic energy distribution of electrons photo-ejected by x-rays from a sample provides a map of the discrete atomic levels, specially the core levels of the constituent 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.

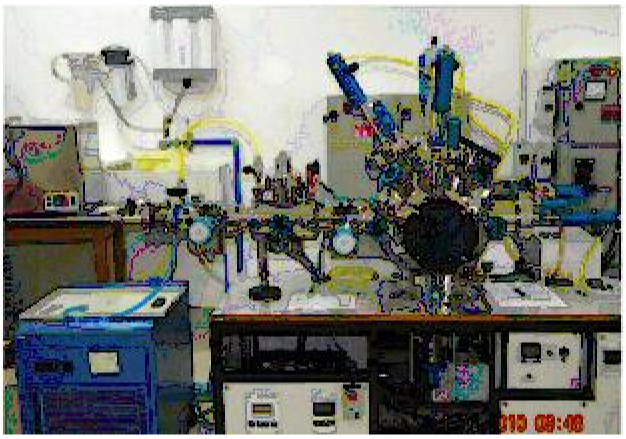
THIN FILM GROWTH FACILITIES

Pulsed Laser Deposition (PLD) System



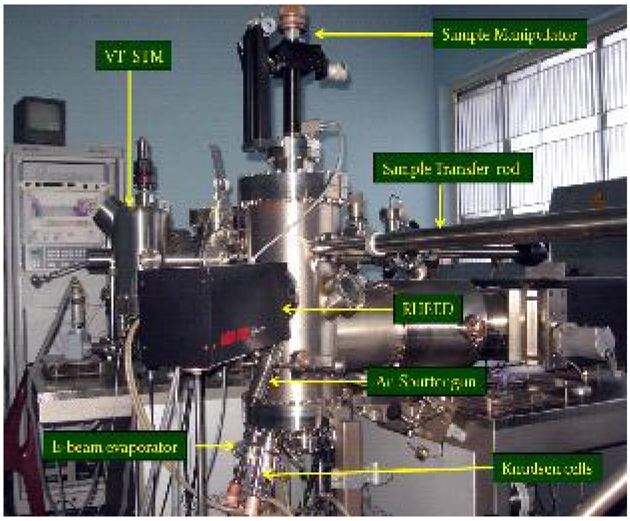
This is a newly installed facility. PLD system helps growing epitaxial thin films of various materials albeit the most prefered materials are oxides. The newly installed system was developed in a piece-wise manner by procuring several modules from different sources. We are depositing epitaxial bi- and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

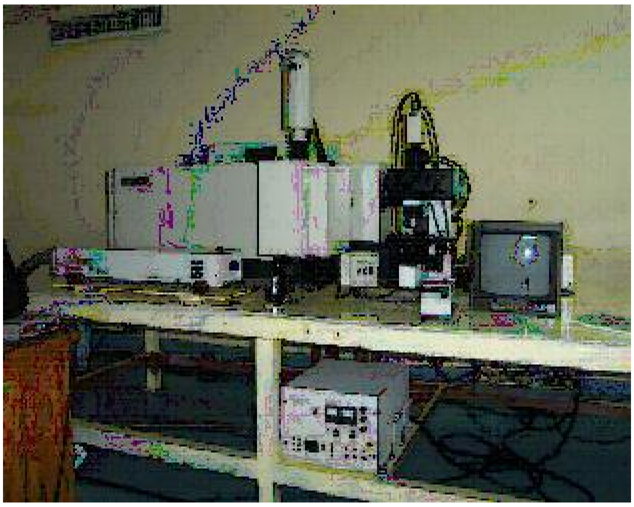
SQUID - VSM

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

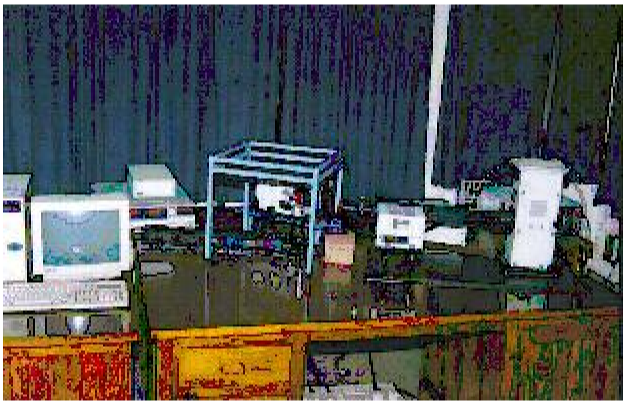
1cm-1 resolution. There are two modes of operation. In case of transmittance mode, the sample is directly fixed in front of IR source and the transmitted signal is allowed to the detector. In order to carry out the FTIR measurement of the solid, opaque sample in grazing angle specular reflectance mode, 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

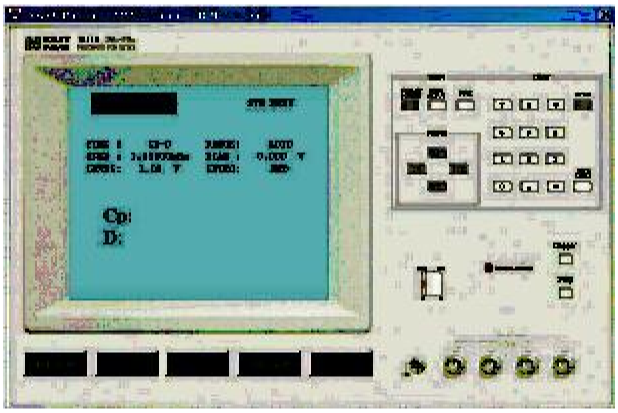
A Potentiostat-Galvanostat, from Autolab, has been procured which can be utilized to investigate the electroanalystical properties like electrocatalysis, electrodepostion for semiconductors, dielectric materials, polymers, membranes etc. Cyclic Voltametry is an effective technique to study redox systems. 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 four probe statio is used to study the electrical transport properties of nano structured thin films and individual nano structures.

1.2 COMPUTER FACILITIES

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 computations, symbolic calculations, 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 for analysis.

For the work, such as accounting, personnel management, stores management etc. computer facilities are being utilised with the help of several software packages such as MSOffice, Wings 200 Net & 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 facility is available to the members of the Institute, NISER, as well as members from other academic institutions. 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 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 is housed in a centrally air conditioned building which is open round the clock for convenience of the users. The books and journals circulation system has become very effective with implementation of bar-codes, online reservation and reminders through e-mail to its individual members.

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

2 ACADEMIC PROGRAM

2.1 PRE-DOCTORAL PROGRAM

One of the most important objectives of the Institute has been to train and guide young scholars to do research in physics. For this, since 1975 the Institute has a regular Pre-doctoral (post M.Sc.) course work followed by the Doctoral research program.

The pre-doctoral program of the Institute of Physics is a very important academic program because it is designed to train the fresh students for conducting research activities. This is aimed at imparting a broad based training in advanced physics and research methodology. 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 runs from August to June every year 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 degree. On completion of the Pre-doctoral program, the students are eligible to join research under the 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 around 260 students were called for interview. This includes JEST qualifiers, UGC-CSIR qualifiers and valid GATE score holders. Of those who were selected finally , the following students have successfully completed the pre-doctoral course:

Ms. Bidisha Chakrabarty
Mr. Priyo Shankar Pal
Mr. Puspendu Guha
Mr. Sabya Sachi Chatterjee
Mr. Shreyansh Shankar Dave
Ms. Sudipta Mahana

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

Trimester – I

Quantum Mechanics	: Prof. K. Kundu
Mathematical Methods	: Dr. G. Tripathy
Classical Electrodynamics	: Dr. P. Agrawal
Theory of Experiments	: Dr. T. Som
Experiments	: Dr. P. V. Satyam

Trimester – II

Statistical Mechanics	: Prof. A.M.Jayannavar
Adv. Quantum Mechanics	: Prof. S.M.Bhattacharjee

Field Theory	: Dr. S. Mukherji
Numerical Methods	: Prof. S. Varma
Experiment	: Dr. P. V. Satyam

Trimester – III

Cond. Matter. Physics	: Dr. B. R. Sekhar
Particle Physics	: Prof. A. M. Srivastava
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 at the end of which there were presentations. Some details of the projects undertaken are as given below.

Sl.	Project Title	Student Name	Supervisor Name
1)	Rotating Black Ring in 5-D	Bidisha Chakrabarty	Dr. A. Virmani
2)	Laughlin Wavefunction	Priyo Shankar Pal	Prof. S. M. Bhattacharjee
3)	Combined TEM and RBS Charactizations of Au / SiO_2 / Si(100)	Puspendu Guha	Dr. P. V. Satyam
4)	Bell's Inequality and more	Sabya S. Chatterjee	Dr. P. Agrawal
5)	Entanglement Entropy for different models near quantum critical point	Shreyansh S. Dave	Prof. S. M. Bhattacharjee
4)	Synthesis and characterization of Tin oxides for gas sensing application	Sudipta Mahana	Dr. D. Topwal

Ms. Bidisha Chakrabarty was adjudged the most outstanding pre-doctoral scholar and was awarded the **L. K. Panda Memorial** Fellowship.

2.2 DOCTORAL PROGRAM

The Institute has presently 37 doctoral scholars working in different areas under the supervision of its faculty members. Starting from 2008, all the scholars are registered with Homi Bhabha National Institute (HBNI), a deemed-to-be University within DAE. It has now become mandatory to hold annual review of the progress of each doctoral scholar. For this purpose, a review committee is constituted to oversee the progress of each scholar. 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. **Ms. Ranjita Kumari Mohapatra** : " Investigating formation and evolution of Z(3) walls and flow anisotropies in relativistic heavy ion collisions" : Supervisor - Prof. A. M. Srivastava
2. **Ms. Rupali Kundu:** "Electronic Structure Studies of Graphite Systems and Some transition Metal Oxides" : Supervisor - Dr. B. R. Sekhar

3. **Mr. Chitrasen Jena** : "Particle Production and Elliptic Flow of Light Nuclei in Relativistic Heavy Ion Collisions at RHIC " : Supervisor - Prof. D. P. Mahapatra.

4. **Mr. Ashutosh Rath: "**Dynamic and Static TEM Studies on the Formation of Au-Si AND Au-Ge Nanostructures" : Supervisor - Dr. P. V. Satyam.

5. **Mr. Jatis Kumar Dash:** "Growth of Si-Ge Nanostructures on high index Silicon Surfaces using MBE and their characterizations." : Supervisor - Dr. P. V. Satyam.

2.4 SSVP – 2012

The Summer Student's Visiting Program (SSVP) was held from May 07 to June 15, 2012. This year following 10 students participated in the program. *(Ms. Subhashree Mishra, B. V. Ramagouri Surya, Subramanyam, Hemalatha M., Suchana Sarangi, Archana Tiwari, K. Vigneshwaran, Rajeev Singh Rashmi M., Vikas Garg, Nivedya. V)*

Under this program, each student worked under a faculty member of the Institute. At the end, the students presented their work in a seminar on their given topics. Round trip train fare, accommodation on campus, and a monthly stipend of Rs. 4500/- were given to the candidates.

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

2.5 12th Five Year Plan Projects.

1. Development of Research program in Nuclear physics *(S. K. Patra).*

2. Development of Research in High Energy Physics *(P. Agrawal, A.M.Srivastava and S.Mukherji).*

3. Research program in Theoretical Condensed Matter and Quantum Information *(A. M. Jayannavar, G.Tripathy and P. Agrawal)*

4. Strengthening Low Energy Accelerator-based Research Activities *(D. P. Mahapatra and T. Som).*

5. ALICE Utilization and CBM Participation *(P. K. Sahu)*

6. Construction of Additional Housing, Hostels & related infrastructure at IOP campus *(Infrastructure Project).*

7. Study of Growth and Characterization of Advanced Materials *(S.Varma, B.R.Sekhar, P.V.Satyam and T.Som).*

8. Development of Computing and Network Facilities *(P. Agrawal, T. Som, and G. Tripathy)*

3 RESEARCH

3.1 THEORETICAL CONDENSED MATTER PHYSICS

We studied the bipartite von Neumann entropy of two particles interacting via a long-range scale-free potential $V(r) \sim g/r^2$ in three dimensions, close to the unbinding transition. The nature of the quantum phase transition changes from critical ($-3/4 < g < 1/4$) to first order ($g < -3/4$) with g –3/4 as a multicritical point. Here we show that the entanglement entropy has dierent behaviors for the critical and the first order regimes. But still there exists an interesting multicritical scaling behavior for all $g \in (-2<g<1/4)$ controlled by the $g = -3/4$ case.

Poulomi Sadhukhan and S. M. Bhattacharjee

We studied the melting of a three-stranded DNA by using the real-space renormalization group and exact recursion relations. The prediction of an unusual Emov-analog three-chain bound state, that appears at the critical melting of two-chain DNA, is corroborated by the zeros of the partition function. The distribution of the zeros has been studied in detail for various situations. We show that the Emov DNA can occur even if the three-chain (i. e., three-monomer) interaction is repulsive in nature. In higher dimensions, a striking result that emerged in this repulsive zone is a continuous transition from the critical state to the Emov DNA.

Jaya Maji, and S. M. Bhattacharjee

Replication and transcription are two important processes in living systems. To execute such processes, various proteins work far away from equilibrium in a staggered way. Motivated by this, aspects of hysteresis during unzipping of DNA under a periodic drive are studied. A steady state phase diagram of a driven DNA is proposed which is experimentally veriable. As a two state system, we also compare the results of DNA with that of an Ising magnet under an asymmetrical variation of magnetic eld.

Garima Mishra, Poulomi Sadhukhan, S. M. Bhattacharjee, and Sanjay Kumar

We showed that there exists an Emov-like three strand DNA bound state at the duplex melting point and it is described by a renormalization group limit cycle. A nonperturbative RG is used to obtain this result in a model involving short range pairing only. Our results suggest that Emov physics can be tested in polymeric systems.

Tanmoy Pal, Poulomi Sadhukhan, and S. M. Bhattacharjee

Fluctuation relations for heat engines in time-periodic steady states

A fluctuation relation for heat engines (FRHE) has been derived recently. In the beginning, the system is in contact with the cooler bath. The system is then coupled to the hotter bath and external parameters are changed cyclically, eventually bringing the system back to its initial state, once the coupling with the hot bath is switched off. In this work, we lift the condition of initial thermal equilibrium and derive a new fluctuation relation for the central system (heat engine) being in a time-periodic steady state (TPSS). Carnot's inequality for classical thermodynamics follows as a direct consequence of this fluctuation theorem even in TPSS. For the special cases of the absence of hot bath and no extraction of work, we obtain the integral fluctuation theorem for total entropy and the generalized exchange fluctuation theorem, respectively. Recently microsized heat engines have been realized experimentally in the TPSS. We numerically simulate the same model and verify our proposed theorems.

Sourabh Lahiri, Shubhashis Rana and A. M. Jayannavar

Universal interpretation of efficacy parameter in perturbed nonequilibrium systems

The fluctuation theorems have remained one of the cornerstones in the study of systems that are driven far out of equilibrium, and they provide strong constraints on the fraction of trajectories that behave atypically in light of the second law. They have mainly been derived for a predetermined external drive applied to the system. However, to improve the efficiency of a process, one needs to incorporate protocols that are modified by receiving feedbacks about the recent state of the system, during its evolution. In such a case, the forms of the conventional fluctuation theorems get modified, the correction term involving terms that depend on the way the reverse/conjugate process is defined, namely, the rules of using feedback in order to generate the exact time-reversed/conjugate protocols. We have shown that this can be done in a large number of ways, and in each case we would get a different expression for the correction terms. This would in turn lead to several lower bounds on the mean work that must be performed on the system, or on the entropy changes. We have analyzed a form of the extended fluctuation theorems that involves the efficacy parameter, and have found that this form retains a consistent physical meaning regardless of the design of feedback along the conjugate process, as opposed to the case of the previously mentioned form of the modified fluctuation theorems.

Sourabh Lahiri and A. M. Jayannavar

Generalized entropy production fluctuation theorems for quantum systems

Based on trajectory dependent path probability formalism in state space, we have derived generalized entropy production fluctuation relations for a quantum system in the presence of measurement and feedback. We have obtained these results for three different cases: (i) the system is evolving in isolation from its surroundings; (ii) the system being weakly coupled to a heat bath; and (iii) system in contact with reservoir using quantum Crooks fluctuation theorem. In case (iii), we have built on the treatment carried out in [H. T. Quan and H. Dong, arxiv/cond-mat: 0812.4955], where a quantum trajectory has been defined as a sequence of alternating work and heat steps. The obtained entropy production fluctuation theorems retain the same form as in the classical case. The inequality of second law of thermodynamics gets modified in the presence of information. These fluctuation theorems are robust against intermediate measurements of any observable performed with respect to von Neumann projective measurements as well as weak or positive operator valued measurements.

Shubhashis Rana, Sourabh Lahiri and A. M. Jayannavar

Quantum Jarzynski Equality with multiple measurement and feedback for isolated system

In this work, we have derived the Jarzynski equality (JE) for an isolated quantum system in three different cases: (i) the full evolution is unitary with no intermediate measurements, (ii) with intermediate measurements of arbitrary observables being performed, and (iii) with intermediate measurements whose outcomes are used to modify the external protocol (feedback). We have assumed that the measurements will involve errors that are purely classical in nature. Our treatment is based on path probability in state space for each realization. This is in contrast to the formal approach based on projection operator and density matrices. We have found that the JE remains unaffected in the second case, but gets modified in the third case where the mutual information between the measured values with the actual eigenvalues must be incorporated into the relation.

Shubhashis Rana, Sourabh Lahiri and A. M. Jayannavar

3.2 THEORETICAL HIGH ENERGY PHYSICS

A novel mechanism for J/ψ disintegration in relativistic heavy-ion Collisions

In this work we discuss the possibility of **J/**ψ disintegration due the Z(3) domain walls that are expected to form in QGP medium. These domain walls give rise to localized color electric field which disintegrates **J/**ψ, on interaction, by changing the color composition and simultaneously exciting it to higher states of $c\bar{c}$ system. For E = 5GeV (or higher) we find that about 90% (or more) of **J/**ψ interacting with the domain wall make the transition.

Abhishek Atreya, Partha Bagchi, and Ajit M. Srivastava

Relativistic hydrodynamics Simulation in relativistic heavy-ion collisions

We are working on developing codes for relativistic hydrodynamics simulation of flow in relativistic heavy-ion collisions using SHASTA algorithm. We plan to study flow fluctuations using this code. We will be developing another code using Leapfrog algorithm of higher order for carrying out this simulation. The two results will be compared for consistency and for checking the accuracy of the evolution.

P.S. Saumia and A. M. Srivastava

Dual superconductor model of Hadronization

We are continuing our work on simulating the quark-hadron transition in a dual superconductor picture by studying dynamics of magnetic monopole antimonopoles pairs during a superconducting phase transition. Simulation of global U(1) symmetry breaking was earlier simulated in 3-D resulting in a coarsening string network. Gauge fields are being incorporated to represent Abelian Higgs model. There are instabilities arising which need to be resolved. Subsequently, magnetic monopole-antimonopole pairs will be incorporated representing quark degrees of freedom.

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

Cosmology

We present a class of anisotropic brane configurations 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, we find that there exists a parameter region where three of its world-volume directions expand while the rest contract.

Souvik Banerjee, Samrat Bhowmick, and Sudipta Mukherji

Production of baryons-anti-baryons by a pion-string

In this letter we study the Skyrmions production by instantons production from a pions string. It is known how to stabilize the pion string which is topologically unstable, by using plasma effects. The effective potential for this shows that there is a metastable vacuum. Here we study use the decay rate of the false vacuum into the true ground state for a small region of the string in order to compute the Skyrmion-anti-Skyrmion production.

J. Karouby, R.H. Brandenberger, and A. M. Srivastava

Baryon fluctuations in the universe from Z(3) walls with spontaneous CP violation

We calculate the density profiles of quark and antiquark overdensities arising from asymmetric reflections of quarks and antiquarks from Z(3) walls. This asymmetry arises from spontaneous CP violating gauge filed configuration due to Z(3) walls. Such density fluctuations are strongly constrained from nucleosynethsis observations. We discuss the possibility of formation of quark nuggets in this model.

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

Liquid Crystal Experiments : Duality between the dynamics of line-like brushes of point defects in 2-d and strings in 3-d in liquid crystals

We analyze the dynamics of dark brushes connecting point vortices of strength ±1 formed in isotropic-nematic phase transition of a thin layer of nematic liquid crystals, using a crossed polarizer set up. The evolution of the brushes is seen to be remarkably similar to the evolution of line defects in a 3-dimensional nematic liquid crystal system. Even the phenomena like intercommutativity of strings is routinely observed in the dynamics of brushes. We test the hypothesis of a duality between the two systems by determining exponents for the coarsening of total brush length with time as well as shrinking of the size of an isolated loop. Our results show scaling behavior for the brush length as well as the loop size with corresponding exponents in good agreement with the 3-d case of string defects.

Sanatan Digal, Rajarshi Ray, Saumia P.S., and Ajit M. Srivastava

Black Hole

It is possible to construct an off-shell black hole free-energy where the temperature is not fiexed by it's on-shell value. This is done by introducing a conical singularity on the black hole horizon. The vanishing of the conical sigularity works as an on-shell condition. Attempt is being made to construct an off-shell free-energy for the charged black holes, in the grand canonical enseble, where the chemical potential can be made an arbitrary tuning parameter via a construction similar to the one stated above

Souvik Banerjee, Sudipta Mukherji, and Anurag Sahay

Inverse scattering construction of dipole black rings

Schematic representation of some of the known asymptotically flat 5D black holes. From left to right: spherical black hole, black ring, black Saturn, bicycling ring, double black holes, and di-ring.

We describe an approach to systematically generate regular and asymptotically flat dipole black rings in a 5D Einstein-Maxwell-dilaton theory obtained from 6D vacuum gravity by Kaluza-Klein reduction. Our construction employs the inverse scattering method in six dimensions. We illustrate the scheme with the explicit construction of the singly-spinning dipole ring. These techniques can also be used to generate more general ÿÿve-dimensional black ring solutions, displaying rotation along the two orthogonal planes, electric charge and magnetic dipole charge. *(to appear in the proceedings of Spanish Relativity Meeting and also in a special issue of General Relativity and Gravitation)*

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

Subtracted Geometry from Harrison Transformations: II

We extend our previous study to the case of five-dimensional multi-charge black holes, thus showing that these configurations and their subtracted geometries also lie in a 3d duality orbit. In order to explore the 3d duality orbit, we do a timelike reduction from 5d to 4d and a spacelike reduction from 4d to 3d. We present our analysis in the notation of Euclidean N=2 supergravity and its c-map. We also relate our analysis to that of Cveti\v{c}, Guica, and Saleem.

Anurag Sahay, and Amitabh Virmani

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, which has not appeared in the literature before.

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

Resolving the octant of θ_{23} with T2K 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: $\theta_{23} > 45^0$). $\nu_\mu \rightarrow \nu_e$ 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. Because of the hierarchy- δ_{CP} degeneracy and the octant-δ_{CP} degeneracy, the impact of hierarchy on octant resolution has to be taken into account. As in the case of hierarchy determination, there exist favorable (unfavorable) values of δ_{CP} for which octant resolution is easy (challenging). However, for octant resolution the unfavorable δ_{CP} values of the neutrino data are favorable for the anti-neutrino data and vice-versa. This is in contrast to the case of hierarchy determination. In this paper, we compute the combined sensitivity of T2K and NOνA to resolve the octant ambiguity. If $\sin^2 \theta_{23} = 0.41$, then NOνA can rule out all the values of θ_{23} in HO at 2 σ C.L.., irrespective of the hierarchy and δ_{CP}. Addition of T2K data improves the octant sensitivity. If T2K were to have equal neutrino and anti-neutrino runs of 2.5 years each, a 2 σ resolution of the octant becomes possible provided $\sin^2 \theta_{23} \leq 0.43$ or ≥ 0.58 for any value of δ_{CP}

Sanjib Kumar Agarwalla, Suprabh Prakash, and S. Uma Sankar

Analytical Approximation of the Neutrino Oscillation Probabilities at large θ_{13}

We present a simple analytical approximation to the neutrino oscillation probabilities in matter. The moderately large value of θ_{13}, recently discovered by the reactor experiments Daya Bay and RENO, limits the ranges of applicability of previous analytical approximations which relied on expanding in $\sin\theta_{13}$. In contrast, our approximation, which is applicable to all oscillations channels at all energies and baselines, works well for large θ_{13}. We demonstrate the accuracy of our approximation by comparing it to the exact numerical result, as well as the approximations of Cervera et al. and Asano and Minakata. We also discuss the utility of our approach in figuring out the required baseline lengths and neutrino energies for the oscillation probabilities to exhibit certain desirable features.

Sanjib Kumar Agarwalla, Yee Kao, and Tatsu Takeuchi

Production of γZg and associated processes via gluon fusion at hadron colliders

We study the process gg → γZg within the standard model at hadron colliders. Due to large gluon ux at the LHC and the proposed HE-LHC, this process can have signicant cross section at these machines. Several thousand such events have already been produced at the LHC according to the standard model predictions. This process can also be a background to new physics signals. We discuss some of the important features of this process related to the structure of its amplitude. We also compute the total cross section at the hadron colliders and give some important kinematic distributions. A comparison of our results is made with the corresponding NLO calculation using MCFM program. We also briefly discuss the production of γg and $\gamma\gamma$Z via gluon fusion. The amplitude of these processes are closely related to the gg → γZg amplitude.

P. Agrawal, and Ambresh Shivaji

Di-Vector Boson + Jet Production via Gluon Fusion at Hadron Colliders

We study the production of two electro-weak vector bosons in association with a jet via gluon fusion. In particular we consider the production of γZg, ZZg and W^+W^-g at hadron colliders and compute their cross-sections. Such processes have already produced large number of events at the Large Hadron Collider (LHC) by now. These processes can be background to the Higgs boson production and a number of beyond the standard model scenarios. Therefore it is important to know the values of their contribution. The calculation is based on conventional Feynman diagram approach. In particular we find that the process gg → ZZg can make a signicant contribution to the process pp → ZZ + jet.

P. Agrawal, and Ambresh Shivaji

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

We consider the production of a single top quark in association with a Higgs boson at the LHC. In particular, we compute 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 tth couplings can enhance the cross sections signicantly. 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.

P. Agrwal, Subhadip Mitra, and Ambresh Shivaji

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

We have examined the feasibility identifying a Higgs boson using a few multi-lepton signatures. These signatures can be obtained when the Higgs boson is produced via $pp \rightarrow t\bar{t}HX$ and then decays into a tau-lepton pair. It can give rise to 'isolated four-lepton' signatures. In the case of $pp \rightarrow t\bar{t}HX$, the multilepton signatures include tau-leptons, which need to be identied as tau-jets. We nd the tau-jet tagging efficiency and its miss-tagging rate. It appears that, for a Higgs boson of the mass about 125 GeV, the process $pp \rightarrow t\bar{t}HX$ gives useful multilepton signatures.

P. Agrawal, and S. Bandyopadhyay

3.3 THEORETICAL NUCLEAR PHYSICS

Study of nuclear fission for neutron-rich nuclei

The structural properties of the recently predicted thermally fissile neutronrich Uranium and Thorium isotopes are studied using the relativistic mean field formalism. The investigation of the new phenomena of multifragmentation fission is analyzed. In addition to the fission properties, the total reaction cross-section of these nuclei are evaluated taking ^{6,11}Li and ^{16,24}O as projectiles. The possible use of nuclear fuel in an accelerator based reactor is discussed which may be the substitution of $^{233;235}$U and ^{239}Pu for nuclear fuel in near future.

R. N. Panda, M. Bhuyan and S. K. Patra

Clustering and its radioactivity

The gross nuclear properties like binding energy, deformation parameter, charge radii and the nucleonic density distributions for the isotopic chain $^{20-34}$Mg using an axially deformed relativistic mean field formalism with NL3* and NL075 parameter sets. The results of our calculations show qualitative and quantitative agreement with the experimental observations. We found deformed prolate ground states solution for Mg isotopes, which are consistent with the experimental data. Analyzing the nuclear density distributions, the internal structure i.e. the clusters of Mg isotopes are identified. The sub-structure like ^{16}O or 4 (^{4}He) condensate types along with few more nucleons are found inside Mg isotopes. It is also noticed that the cluster structure of a nucleus remain unaected for different force parameters as long as the solution for that nucleus exist. It is interesting to see these evaporation residues like ^{16}O or ^{4}He for Mg-isotopes in laboratory.

B. B. Sahu, S. K. Singh, M. Bhuyan and S. K. Patra.

Structures of exotic and superheavy nuclei

The ground state and first intrinsic excited state of superheavy nuclei with Z=120 and N=160-204 are investigated 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 $T^{\alpha}_{1/2}$ for these two different mode of decay chains are compared with FRDM and recent macroscopicmicroscopic calculations. The calculation is extended for the α-decay chains of $^{292}120$ and $^{304}120$ from their exited state conguration to respective conguration, which predicts long half-life $T^{\alpha}_{1/2}$ (sec).

An extensive theoretical search for the proton magic number in the superheavy valley beyond Z=82 and corresponding neutron magic number after N=126 is carried out. For this we scanned a wide range of elements Z = 112 - 130 and their isotopes. We have used two well-dened but distinct approaches (i) non-relativistic Skryme-Hartree-Fock (SHF) with FITZ, SIII, SkMP and SLy4 interactions (ii) Relativistic Mean Field (RMF) formalism with NL3, G1, G2 and NL-Z2 parameter sets. We focus on the shell closure properties in the superheavy valley based on these observables such as the average pairing gap for proton and neutron, shell correction energy, nucleon separation energy and single particle energy levels etc. Before going to superheavy region, rst of all, we have tested these observable for a well known and experimentally veried double closed Pb isotopes and isotones. But, our main aim to find the next magic nuclei beyond ^{208}Pb for that, we scanned a wide range of nuclei starting from the proton-rich to the neutron-rich region in the superheavy valley (Z=112 to Z=130). We have analyzed all the above defined observables for the Z=112-130 region covering the proton-rich to neutron-rich isotopes. To our knowledge, this is one of the rst such extensive and rigorous calculations in both SHF and RMF models using a large number of parameter sets. The recently developed effective field theory motivated relativistic mean field forces G1 and G2 are also involved. From the obtained results for the two neutron separation energy, the shell correction energy, pairing gap and single particle energy, we nd Z=120 as the next proton magic and N=172, 182/184 the subsequent neutron magic numbers. The highly discussed proton magic number Z = 114 in the past (last four decades) is found to be feebly magic in nature.

Further, an another attempt to search for spherical double shell closure nuclei beyond Z=82, N=126. All calculations and results are based on a newly developed approach entitled as simple effective interaction. Our results predict the combination of magic nuclei occurs at N=182 (Z=114,120,126). All possible evidence for the occurrence of magic nuclei are discussed systematically. And, the obtained results for all observables compared with the relativistic mean eld theory for NL3 parameter.

We have calculated the binding energy in different states like spherical prolate and oblate shape, root-mean-square radius and quadrupole deformation parameter β_2 density distribution of the nucleons in dierent states like spherical prolate and oblate shape for the recently synthesized Z = 105 to 118 nuclei in dierent laboratories, along with these nuclei Z=120 was also taken for study, using non-relativistic (SHF-SkI4) and relativistic (RMF-NL3* model. Life-time T and α-decay energy Q_α also calculated and we compared our data with FRDM model.
For study of the 'Island of inversion' in the full nuclear landscape, we have taken only these three regions Z=17-24, Z=37-40, Z=60-64. We calculated the ground state binding energy, quadrupole deformation parameter 2, root mean square charge, neutron, proton and matter radii and two neutron separation energy, using relativistic mean eld model with NL3* parameter set. We compared our data with nite range droplet model (FRDM) and innite nuclear matter (INM) model.

The structure of Ne, Na, Mg, Al, Si and S nuclei near the neutron drip-line region is investigated in the frame-work of relativistic mean eld theory and non-relativistic Skyrme Hartree-Fock formalisms. The drip-line of these nuclei are located within these two approaches. We find many largely deformed neutron rich nuclei whose structures are analyzed. At large deformation, low orbits of opposite parities (eg. $(1/2)^+$ and $(1/2)^-$ occur close to each other in energy.

M. Bhuyan, S. K. Singh, S. K. Biswal, S. Mahapatro, M. Shakeb, M. Ikram, R. N. Mishra, S. K. Patra and C. R. Praharaj.

Nuclear reaction

We calculate the nuclear reaction cross-section for some of the ultra neutronrich nuclei in the lighter mass region of the periodic chart which are recently measured. The well known Glauber formalism is used taking deformed relativistic and nonrelativistic densities as input in the calculations. We find reasonable reaction cross-section with both the densities. However with a better inspection of the results, it is noticed that the results obtained with relativistic densities are more closure to the experimental data than the nonrelativistic Skyrme densities.

M. K. Sharma, R. N. Panda, M. S. Mehta and S. K. Patra.

High Spin States

Deformed Hartree-Fock and Angular Momentum Projection gives a complete description of the structure of deformed nuclei in various regions of mass. 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.

S. K. Ghorui, B. B. Sahu, S. K. Patra and C. R. Praharaj.

Equation of State of Nuclear Matter

We study the effect of newly added cross coupling between $\omega-\rho$ mesons in the nuclear matter system. We have calculated the energy density, pressure density under the inuence of this cross coupling. We see the softness of symmetry energy E_{sym} and the correlation between the other coecients which are directly connected to the symmetry energy. Neutron star properties also discussed under the influence of this extra cross coupling on the top of the G2 parameter set. During this work we saw the production point (production density) of hyperons in neuron star changes with this coupling.

S. K. Singh, M. Bhuyan, P. K. Panda and S. K. Patra.

Simple effective interaction: Finite nuclei and Innite nuclear matter

A simple eective interaction is proposed to describe the main trends of microscopic calculations in isospin asymmetric nuclear matter and to reproduce the ground state properties of nite nuclei. Our interaction contains a single Gaussian form factor for describing the nite range part of the force plus a zero-range part that includes a density dependent term to simulate the effect due to threebody forces. The eective interaction contains eleven parameters, out of which nine can be fixed from nuclear matter (NM) study. Two of these nine parameters, the strength of the exchange interaction and the range of the force, completely determine the momentum dependence of the mean field in NM. In our model, the range of the force is chosen to be the same for interactions between pairs of like and unlike nucleons. Under this restriction, the splitting of the exchange strength parameter in ANM is decided using the physical constraint, resulting from the study of thermal evolution of nuclear matter properties, that entropy in PNM. The splitting of the rest two strengths into like and unlike channels in ANM are decided from the value of the symmetry energy and by imposing that the nucleonic part of the energy density in neutron star matter with β-stable conditions. In extending our study to nite nuclei we use this interaction to build up an energy density functional in the framework of the quasilocal Density Functional Theory. In particular we use the semiclassical expansion of the density matrix to deal with the exchange contribution. This procedure allows to write the single particle equations in nite nuclei in a similar form as in the case of the Skyrme-Hartree-Fock equations. We determine the open parameters of our interaction by a simple t to experimental data of three closed shell nuclei ^{16}O, ^{40}Ca and ^{208}Pb. With this choice the binding energies and charge radii of the standard magic nuclei are reproduced in good agreement with the experimental values. With our simplied interaction fully determined, we examine how it predicts for open-shell spherical nuclei.

B. Behera, X. Vi~nas, M. Bhuyan, T. R. Routray, B. K. Sharma and S. K. Patra.

3.4 HIGH ENERGY NUCLEAR PHYSICS

ALICE Collaboration

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.

We work on $\Lambda^*(1520)$, strange baryon, which is an excited state of $\Lambda^*(1115.5)$, has PDG mass 1519.5 ±1.0 MeV and width (Γ) 15.6 ± 1.0 MeV. Its quark structure is (uds) and lifetime ~12.6 fm. It has different decay modes with different branching ratios. We plan to study different systematic studies and calculate invariant mass spectra and Pt spectra for corrected (efficiency and acceptance) data and also calculate the elliptic for Λ^*

R.C. Baral, P. K. Sahu and D. P. Mahapatra

For CBM Collaboration

At FAIR energies the charm sector becomes accessible and measurements of charm will be performed. Particles are produced in the early stage of the nucleus-nucleus collision. But the effect of the QGP formed in the region of production is to make the particle(J/psi) unbound. When this happens the system dissociates into a separate 'c' quark and a anti-quark 'c ' in the plasma. The 'c' quark subsequently hadronize by combining with light quarks or light anti-quarks to form charm mesons (D). The effective mass of D mesons are expected to be modified in dense matter which leads to a change of the relative abundance of charmonium and D-mesons. The anomalous suppression of charmonium due to the screening effect and enhancement of D mesons allow probing the onset of QGP formation.

We study the J/psi suppression and D meson production at moderate temperature and high baryon density at CBM experiments in FAIR energies. Also we study the kinematics, critical point in quark gluon plasma, flow and viscous at these energies.

N. R. Panda, P. K. Sahu and D. P. Mahapatra

STAR Collaboration

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 T_{ch} 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.

S. Das, C. Jena, D. P. Mahapatra and P. K. Sahu

Nuclear astrophysics and nuclear equation of state:

Recent observation of pulsar PSR J1614-2230 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 J1614-2230. 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 J1614-2230. HS with a mixed phase region cannot reach the mass limit set by PSR J1614-2230 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 M_{solar}.

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 1053 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 1053 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.

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

3.5 QUANTUM COMPUTATION

Entangled Brachistochrone: Minimum time to reach the target entangled state

We address the question: Given an arbitrary initial state and a general physical interaction what is the minimum time for reaching a target entangled state? We show that the minimum time is inversely proportional to the quantum mechanical uncertainty in the non-local Hamiltonian. We find that the presence of initial entanglement helps to minimize the waiting time. Furthermore, we find that in a bi-local rotating frame the entangling capability is actually a geometric quantity. We give an universal bound for the time average of entanglement rate for general quantum systems. The time average of entanglement rate does not depend on the particular Hamiltonian, rather on the fluctuation in the Hamiltonian. There can be innite number of nonlocal Hamiltonians which may give same average entanglement rate. We also prove a composition law for minimum time when the system evolves under a composite Hamiltonian.

P. Agrawal, Arun Pati and B. Pradhan

Generalized Form of Optimal Teleportation Witness

We propose a generalized form of optimal teleportation witness to demonstrate their importance in experimental detection of the 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. In addition, we analyze the practical signicance of our study by decomposing our teleportation witness in terms of Pauli and Gell-Mann matrices, which are experimentally measurable quantities.

P. Agrawal, Atul Kumar and Satyabrata Adhikari

Monogamy in multipatrtite qubit and qudit state

One of the most fundamental properties of quantum entanglement is that, diering from classical correlations, they are not shareable at will when distributed among many parties. If two parties, say Alice and Bob share a maximally entangled state then a third party, say Charlie can not share any kind of correlation, quantum as well as classical with the formers. This property of entanglement is termed as monogamy of entanglement. Coman,Kundu and Wootters quan tied this proerty and showed that, for a pure three qubit state ϕ_{abc}, the measure of entanglement called concurrence satisfies the following inequality $C^2_{a|bc} \geq C^2_{a|b} + C^2_{a|c}$ where $C_{a|bc}$ stands for the concurrence between the subsystems S_a and S_{bc}. Recently, Osborne and Verstrate generalised this relation to N-qubit states. However, in this relation, only the single party partition $a_1 \mid a_2 a_3 .... a_n$ is considered. We are looking for similar kind of relations for multipartite qubit system under two qubit partitions and multipartite qudit system.

Sumit Nandi, and Pankaj Agrawal

A comparative study of sending known and unknown quantum information using quantum resource

Suppose Alice and Bob share an entangled state. Now Alice wishes to prepare a state(known to her) in Bob's place. Bob has no knowldge of the state. Remote state preparation is a protocol to accomplish this job. Now we know that remote state preparation fedility is same as the geometric discord of the shared state i.e., non zero remote state preparation fedility signifies the discordant nature of shared state. Again the states which are of zero discordant are classical in nature. In literature it is well known the relation between teleportation fedility and singlet fraction. We are trying to find out a relation between remote state preparation fedility and singlet fraction.

Sumit Nandi, and Indranil Chakrabarty

Ideal gas in a higher dimensional container

In this work we consider ideal gas in a container of dimension d > 3 and we look at the boundary effects of the container to the thermodynamic quantities like entropy, free energy etc. We did it for a d-dimensional box and a d-dimensional sphere. The problem of gas in a (d > 3) box is solved analytically. For sphere an analytic solution is hard to achieve and we addressed the same employing various numerical techniques.

Soumyabrata Chaterjee, Sumit Nandi and Sudipta Mukherji

Quantication of Entanglement of teleportation in Arbitrary Dimensions

We study bipartite entangled states in arbitrary dimensions and obtain different bounds for the teleportation delity. In addition, we establish various relations between teleportation delity and the entanglement measures depending upon Schmidt rank of the states. These relations and bounds help us to determine the amount of entanglement required for teleportation. We call this amount of entanglement required for teleportation as “Entanglement of Teleportation”. These bounds are used to determine the teleportation delity as well as the entanglement required for teleportation of states modeled by a two qutrit mixed system as well as two qubit open quantum systems.

Sk Sazim, S. Adhikari, S. Banerjee and T. Pramanik

A Study of Teleportation and Super Dense Coding Capacity in Remote Entanglement Distribution

In this work we consider a quantum network consisting of nodes and entangled states connecting the nodes. In every node there is a single player. The players at the intermediate nodes carry out measurements to produce an entangled state between the initial and nal node. Here we address the problem that how much classical as well as quantum information can be sent from initial node to nal node. In this context, we present strong theorems which state that how the teleportation capability of this remotely prepared state is linked up with the delities of teleportation of the resource states. Similarly, we analyze the super dense coding capacity of this remotely prepared state in terms of the capacities of the resource entangled states. However, we first obtain the relations involving the amount of entanglement of the resource states with the nal state in terms concurrence.

More specifically, in an arbitrary quantum network when two nodes are not connected, our result shows how much information, both quantum and classical can be transmitted between these nodes. We show that the amount of transferable information depends on the capacities of the inter connecting entangled resources. These results have a tremendous future application in the context of determining the optimal path in a quantum network to send the maximal possible information.

Sk Sazim, and I. Chakrabarty

Complementarity of Quantum Correlation in Cloning and Deleting of Quantum State

We quantify the amount of correlation generated between two different output modes in the process of imperfect cloning and deletion. We use three different measures and study their role in determining the delity of cloning and deletion. We obtain a bound on the total correlation generated in the successive process of cloning and deleting operations. This establishes a new kind of complementary relationship between the quantum correlation required in generating a copy of a quantum state to the amount of correlation required in bringing it back to the original state by deleting and vice versa. Our result shows that better we clone a state, more difcult it will be to bring the state back to its original form by the process of deleting (and vice versa).

I. Chakrabarty, Sk Sazim, A. Dutta and A. K. Pati

Quantum Dissension: An Approach to Characterize Multiparty Quantum Correlation

In this work we generalize the notion of quantum correlation for a n-qubit system. In particular, we extend the concept of Quantum Dissension for a multiparty system by considering equivalent expressions of n-variable mutual information which are same classically but dier in the quantum domain. Our approach encompasses measures of correlation like discord and gives a unied view of the quantum correlation from the perspective of projective measurement done on the subsystem. We propose that quantum correlation in principle are vectors and cannot be represented by a single quantity. We also claim that these multiple definitions of correlation based on the measurement are different components of the correlation vector. This approach paves the way of visualizing quantum correlation from the aspect of vector quantities.

Sk Sazim, A. Deshpande, P. Agrawal and I. Chakrabarty

3.6 EXPERIMENTAL CONDENSED MATTER PHYSICS

Ion Beam Patterned TiO_2 Reveals Superior Bioactivity for Plasmid DNA

Enhanced Biocompatibilty of rutile TiO_2(110) single crystal has been achieved by nanodot patterning of its surfaces. Nanodots have been fabricated through the Ar ion sputtering technique. Due to the sputtering a significant amount of O vacancies are created on the surface, which get reduced after interaction with plasmid DNA. This enhances the hydrophilicity of the surface and assists in a stronger conjugation with the TiO_2 surfaces making them more bioactive.

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

Size Dependent Optical Properties of TiO_2 Nanostructures

The size dependent optical properties of the nanostructures created on the TiO_2(110) surfaces, via low energy ion beam sputtering technique, have been investigated. A significant enhancement in UV and visible light absorption has been observed for TiO_2 surfaces patterned with nanostructures. Moreover, this enhancement depends on the sizes of the nanostructures. Although small sized (10nm) nanostructures display increased absorbance and a higher bandgap, compared to bulk TiO_2, due to quantum effects, much higher absorbance with decreased bandgap is observed from larger (50nm) sized nanostructures. This enhancement in absorbance is due to the presence of well developed (200 and 310) crystalline faces in bigger nanostructures.

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

Monte Carlo Simulation of ion beam patterned surfaces

Monte Carlo Methods of Numerical Simulations are being utilized to investigate the processes responsible for the structure formation on the ion beam bombarded surfaces. The theoretical modelling is compared with the experimental results, obtained in the lab, to tune the parameters to understand the surface evolution.

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

The Effect of Plasma Treatment of PDMS on Biocompatibility

One of the problems associated with plasma surface modication of polymers is potential ageing of treatment effects which is mainly caused due to reorientation of polar chemical groups attached on the treated surface and diffusion of unmodied molecules from the bulk to the surface. In this study ageing behavior of PDMS surface treated by oxygen plasma and nitrogen plasma at two levels was studied. The modication of the polymer surface chemistry was assayed by Fourier transform infrared (FTIR) spectroscopy and X-ray photo-electron spectroscopy (XPS). Morphological studies revealed a clear enhanced surface roughness with plasma treated PDMS. The improved biocompatibility was evidenced from increased cell adhesion and cell viability.

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

Interaction of DNA with patterned semi-conductor surfaces

The interaction of DNA with semiconductor surfaces has immense potential in current research with the issues of linking of biomolecules with electronic. We are investigating absorption and interaction of Lambda DNA and Plasmid DNA on a variety of surfaces. The DNA molecules undergo severe perturbation on their interaction with these surfaces. These perturbations are also seen in variety of motifs, of 2d and sometimes 3d nature, that develop on the surfaces.

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

Shape evolution of MBE grown $Si_{1-x}Ge_x$ structures on high index Si(5 5 12) surfaces: A temperature dependent study.

The morphological evolution and the effect of growth temperature on size, orientation and composition of molecular beam epitaxy grown Ge–Si islands on Si(5 _5_12) surfaces have been investigated in the temperature range from room temperature to 800 °C. Two modes of substrate heating, i.e. radiative heating (RH) and direct current heating (DH) have been used. The post-growth characterization was carried out *ex situ* by scanning electron microscopy, cross-sectional transmission electron microscopy and Rutherford backscattering spectrometry. In the RH case, we found spherical island structures at 600 °C with a bimodal distribution and upon increasing temperature, the structures got faceted at 700 °C. At 800 °C thick (~122 nm) dome-like structures are formed bounded by facets. While in the case of dc heating, after the optimum critical temperature 600 °C, well aligned trapezoidal $Si_{1-x}Ge_x$ structures with a graded composition starts forming along the step edges. Interestingly, these aligned structures have been found only around 600 °C, neither at low temperature nor at higher temperatures.

J. K. Dash, A. Rath, R. R. Juluri and P. V. Satyam.

Universality in Shape Evolution of $Si_{1-x}Ge_x$ Structures on High Index Silicon Surfaces

The shape evolution of MBE grown $Si_{1-x}Ge_x$ islands on ultraclean reconstructed high-index Si(5 5 12), Si(5 5 7) and Si(5 5 3) surfaces has been studied experimentally and explained using a phenomenological kinetic Monte Carlo (kMC) simulation. We show that a self-assembled growth at optimum thickness leads to interesting shape transformations, namely spherical islands to rectangular rods up to a critical size beyond which the symmetry of the structures is broken, resulting in a shape transition to elongated trapezoidal structures. We observe a universality in the growth dynamics in terms of aspect ratio and size exponent, for all three high-index surfaces, irrespective of the actual dimensions of Ge-Si structures. The shape evolution has been simulated using kMC by introducing a deviation parameter (ε) in the surface barrier term (E_D) to take the effect of anisotropic diffusion as one of the plausible mechanisms.

J. K. dash, T Bagarti, A. Rath, R. R. Juluri and P. V. Satyam.

Uniformity of epitaxial nanostructures of $CoSi_2$ via defect control of the Si (111) surface

The morphology and the size distribution of self-organized cobalt silicide nanostructures, grown on Si (111) substrates with controlled defects, have been investigated. An initial defect structure on the Si (111) surface is produced by quenching the substrate from just below the $\sqrt{7}X\sqrt{7} \leftrightarrow 1X1$ (disordered) phase transition temperature. This has produced predominantly the Si (111)-(7×7) reconstructed structure along with some disordered regions and defect lines on the substrate surface. The disordered regions contain randomly placed Si adatom ring clusters or a lattice gas of ring clusters and small patches of $\sqrt{7}X\sqrt{7}$ R 19° structure. These substrates have been pre-annealed for different durations before 0.5 monolayer Co deposition on them for forming $CoSi_2$ by reactive deposition epitaxy. With increasing duration of substrate annealing and consequent reduction of defect density and surface roughness, a change of island morphology, a transition from bimodal to mono-modal size distribution and an increase of average island size have been observed. Reduction of surface defects via substrate pre- annealing appears to lead to the growth of homogeneous nanostructures.

J. C. Mahato, Debolina Das, R. Batabyal, Anupam Roy, R. R. Juluri, P. V. Satyam, and B. N. Dev

Substrate Symmetry Driven Endotaxial Silver Nanostructures by Chemical Vapor Deposition

We report a novel method of growth for endotaxial silver nanostructures on Si(100), Si(110), and Si(111) substrates using a chemical vapor deposition (CVD) method. Our procedure involves a low-temperature thermal etching of native oxide on silicon substrate using GeO_x layer as an etchant to grow substrate symmetry driven endotaxial nanostructures in the atmospheric pressure CVD system. A control over the shapes and sizes of the Ag nanostructures has been obtained by using parameters such as substrate orientation and time of deposition during the growth. High-resolution electron microscopy has been used to elucidate the growth mechanism of these structures.

R. R. Juluri, A. Rath, A. Ghosh, and P. V. Satyam

Shape Controlled Embedded and Endotaxial Growth of Silver Nanostructures on Silicon.

We report a single step method for self-assembled growth of endotaxial and embedded silver nanostructures with controlled shapes on silicon substrate. Role of GeOx film presence and position of it along with the thin Ag film on silicon was discussed. Silicon wafers with (100), (110) and (111) orientations with a thin GeOx layer sandwiched between substrate silicon surface (with native oxide) and an Ag thin film, and upon annealing in air at high temperatures yield endotaxial silver nanostructures with square/ rectangular, rod and triangular shapes respectively. When the configuration exchanged between GeOx and Ag films (i.e., with the deposition GeOx film on top of Ag film), embedded Ag nanostructures (within the GeOx film) of spherical shape were observed. Interestingly, direct deposition of Ag thin films on native oxide covered silicon substrate, without any GeOx thin films at the interface, resulted in endotaxial AgxSiy nanostructures. Electron microscopy was used to understand the structural formation of these nano structures along with Synchrotron X-Ray diffraction technique. Temperatures dependence of aforementioned endotaxial configuration with Si (100) orientation was also investigated. These kind of embedded or endotaxial silver nanostructures would find many applications, such as, enhancing light absorption and other opto-electronic applications.

R. R. Juluri, Ashutosh Rath, Arnab Ghosh ,Anjan Bhukta and P. V. Satyam.

Graphene induced Pd nanodendrites: A highly performance hybrid nanoelectrocatalyst

In this report, a facile and green approach has been developed for in situ synthesis of hybrid nanomaterials based on graphene (RG) supported dendrite-shaped Pd nanostructures. The as-synthesized hybrid nanomaterials (RG-PdnDs) have been thoroughly characterized by high resolution TEM, XPS, AFM, Raman and electrochemical techniques. The formation mechanism of such dendrite-shaped Pd nanostructures on graphene support has been derived using TEM measurements. The RG induces and plays a decisive role in shaping the dendrite morphology of Pd nanostructures on its surface. The cyclic voltammetry and chronoamperometry techniques have been employed to evaluate the electrochemical performance of RG-PdnDs towards oxidation of methanol molecules. The electrochemical (EC) activities of RG - PdnDs are compared with graphene supported spherical-shaped Pd nanostructures, only Pd nanodendrites and commercial available Pd/C counterpart. The combining effect of graphene support and the dendrite morphology of RG-PdnDs triggers the electrocatalytic activity and shows robust tolerant to CO poisoning.

Subash Chandra Sahu, Aneeya K. Samantara, Ajit Dash, R. R. Juluri, Ranjan K. Sahu, B. K. Mishra and Bikash Kumar Jena

A Bioinspired Approach for Shaping Au Nanostructures: The Role of Biomolecule Structures in Shape Evolution.

A new approach for shaping Au nanostructures by tuning the molecular structure of biomolecules has been explored. Different molecules, such as catechol, rutin, and quercetin, which have structural similarity to the catechol ring, were used to induce Au nanostructures under similar conditions. The as-synthesized nanostructures are characterized by using TEM, XPS, XRD, and UV/Vis spectral measurements. The growth mechanism for the formation of these noble metal shapes and the role of the molecular structure of the stabilizing/ reducing agent were investigated by using TEM and UV/Vis spectral measurements. The structure and functional groups of the reducing/ stabilizing agent play a vital role in the shape evolution of nanostructures. The electrocatalytic activity of different nanostructures in the reduction of oxygen was investigated and was found to be shape-dependent.

Subash Chandra Sahu, Aneeya K. Samantara, A. Ghosh, and B. K. Jena

Ion beam induced self-organized pattern formation at semiconductor surfaces

Self-organization during low-to-medium-energy ion induced erosion of semiconductor surfaces has been shown to be an elegant and cost-effective technique for generation of large area nanostructured semiconductor surfaces in a single step processing. Recently, several reports have demonstrated the formation of ripples and nanodots on various semiconductor surfaces by ion sputtering. It is feasible to tune the size of the dots or ripple wavelength and height by varying the ion sputtering parameters such as ion-energy, -fluence, -flux, -incident angle, and the sample temperature. We are working on creating self-organized surface nanostructures on silicon surfaces using ultra low to intermediate ion energies (250 eV to 60 keV) and are trying to understand the pattern formation in both energy regimes in light of similar mechanism, based on the existing theories.

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

Temporal evolution on SiO_2 by low energy argon ions: smoothing, ripple formation, faceting and coarsening

Temporal evolution of surface topography on SiO_2 by low-energy argon ions is being investigated in dependence on the angle of incidence (0-85°) and as a function of beam energy (250-1000 eV) for ion fluences up to 5×10^{17} ions-cm^{-2}. In general, the surface is smoothened at low incidence angles (up to 39°). At angles of around 40°, ripple pattern starts to develop; the wavelength can be tuned by varying ion energy. For higher fluences and/or incidence angles SiO_2 surface becomes faceted, followed by a significant coarsening. The surface roughness maxima is seen to vary depending on the ion energy (within 60-62.5°). At more oblique incidence angles (in the range of 70-85°) the surface gets smoothened again.

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

Growth and characterization of thin films for photovoltaic applications

We are studying growth of oxide thin films, viz. aluminum-doped zinc oxide (AZO) and copper oxide (Cu_2O) on various substrates which are useful for photovoltaic applications. The main objectives are to study three-dimensional growth of these materials by glancing angle deposition technique. We are keen to achieve tunable structural, optical, and electronic transport properties of these films. We observe room temperature grown AZO films also show very low resistance and high optical transmittance. Photoconductivity studies provide the relevant information on defect states and the nature of doping of Al in these films. From conducting atomic force miscroscopic (C-AFM) studies, it is observed that both AZO and Cu_2O films show resistive switching behavior for selective susbstrates and properly chosen experimental parameters.

M. Kumar, S. Chatterjee, T. Basu,, S. Nandy, P.K. Sahoo, P. Ayyub, and T. Som

Investigation on structural, optical, morphological and electrical properties of thermally deposited lead selenide (PbSe) nanocrystalline thin films

Substrate temperature induced changes in physical properties of thermally evaporated lead selenide (PbSe) nanocrystalline thin films from the chemically synthesized nanocrystalline PbSe powders was addressed. A gradual reduction in optical bandgap of films was observed with increasing substrate temperatures, which revealed the crystallization of the films and further supported by X-ray diffraction. These observations are corroborated by photoluminescence spectroscopy study. Changes in surface morphology of the films with respect to substrate temperature were studied by high resolution scanning electron microscopy and atomic force microscopy. Electrical study infers the deposited films are of p-type semiconducting nature.

S.K. Garg, T.S. Shyju, S. Anandhi, R. Sivakumar, and R. Gopalakrishnan

Multiferroic phase transition in CuO

Multiferroics is extremely important in the context of magnetic and ferroelectric phase transitions. These materials also show magneto-electric and inverse magneto-electric effect. Among several compounds RMn_2O_5 (R=Tb, Ho, Dy), $RMnO_3$ (R=Gd, Tb, Dy), $BiMnO_3$ and $Eu_{1-x}Y_xMnO_3$ have been studied. Generally three physically different transitions have been observed in multiferroics which are ferrorlectric, magnetic and structural. The ferroelectric transition temperature (T_E) is generally several times higher than the magnetic transition temperature (T_M) in $BiMnO_3$. For $BiMnO_3$ T_E and T_M are 750 K and 100 K, respectively. In case of $Eu_{0.5}Y_{0.5}MnO_3$ T_M is higher than T_E. The magnetic phase in certain compounds such as CuO undergo more complicated commensurate-incommensurate phase transition.

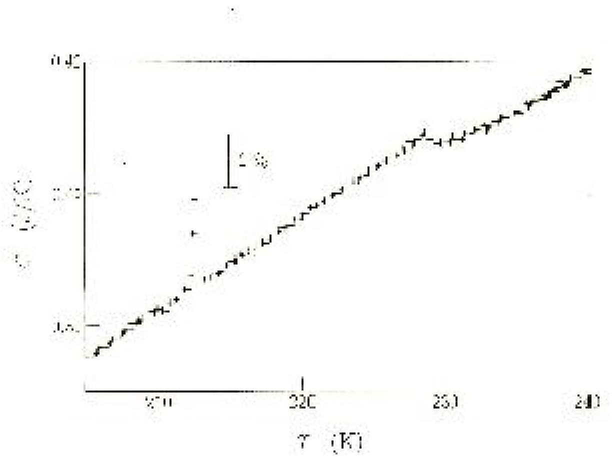
The specific heat measurements on CuO with magnetic field (B_a) up to 6 T were carried out with a Nernst's heat pulse calorimeter at Max-Planck-Institut fur Festkorperforschung, Stuttgart, Germany. The temperature dependence of specific heat of CuO has shown two phase transitions. CuO undergoes a 2nd order paramagnetic-to-incommensurate antiferromagnetic transition at a temperature T_E and a 1st order incommensurate-to-commensurate transition at a temperature T_M. T_E and T_M are 228.5 K and 212.6 K respectively. The two transitions are shown in the temperature dependence of specific heat for B_a=0 (figure-1). Phenomenological theory based on interacting components mechanism has been used to understand the occurrence of incommensurate structure in CuO. Recently presence of ferroelectric polarization parallel to b-axis has been found in CuO in the temperature range 228.5 K to 212.6 K. The magnetic field dependence of T_M has been studied for Ba applied along a-, b- and c-axes. The change in the transition temperature $\Delta T_M = T_M(B_a) - T_M(0)$ was studied as a function of B_a. It was found that ΔT_M increases nonlinearly for B_a || a and c-axes. On the other hand ΔT_M decreases linearly for B_a || b-axis. The magnetic field dependence of ΔT_M are as follows:

$$\Delta T_M = \gamma B_a^2 \quad ......1$$

where $\gamma = 2.6 \times 10^{-3}$ and 5.5×10^{-3} K/T^2 B_a || a- axis and B_a || c-axis respectively

$$\Delta T_M = -\gamma B_a \quad ....2$$

where $\gamma = 1.7 \times 10^{-2}$ K/T for B_a || b- axis. The magnetic field dependence of T_M can be understood considering the recently discovered multiferroic phase transition in CuO. Since ferroelectric polarization and and magnetization compete it is expected that application of magnetic field parallel to b-axis reduce the lock-in transition temperature in CuO.



The specific heat of CuO singlecrystal showing the magnetic transitions at 228.5 K and 212.6 K. The transition at 228.5K is 2nd order in nature and the transition at 212.6K is 1st order in nature. CuO develops electric polarization parallel to b-axix in the temperature range 228.5K to 212.6K

S. B. Ota

Strong coupling superconductivity, A15 compounds and $\gamma Ba_2Cu_3O_{7-x}$

Nearly 53 'elemental-superconductors' are known which are superconducting at ambient or high pressure. Among these the high pressure phase VII of Ca has the highest T_C (29 K). The highest transition temperature occurs for $HgBa_2Ca_2Cu_3O_{8+\delta}$ which is nearly 134 K. Under a pressure of 15 GPa it increases to 150 K. Search for new superconductors is another interest. Such interest has led to the discovery and study of variety of superconductors. Some of these are A15 compound , Chevrel phase compound, heavy Fermion, organic and high-T_C superconductors etc. The superconductivity centennial was held during 2011 APS March meeting, Dallas, USA. The major technological application of superconductors are based on persistent current, perfect diamagnetism and pair tunneling in S-I-S junctions. The applications of such properties include superconducting magnets, generation of uniform field and SQUID magnetometers etc.

The A15 compounds, Chevrel phase and high-T_C superconductors have been studied by our group to a great detail. The BCS theory of superconductivity is the most successful quantum many-body theory. An improvement over the BCS theory was given by the 'strong coupling theory' which is accurate to $\sim(m/M)^{1/2}$ When the electron-phonon coupling is strong the numerically derived equation for T_C is given by:

$$T_C=(\Theta/1.45)\exp[-\{1.04(1+\lambda)\}/\{\lambda-\mu^*(1+0.62\lambda)\}] \quad ......[1]$$

where λ is the electron-phonon coupling constant, μ* is the Coulomb pseudopotential and Θ is the Debye temperature. The electron-phonon coupling constant λ is inversely proportional to the molecular weight M and is given by:

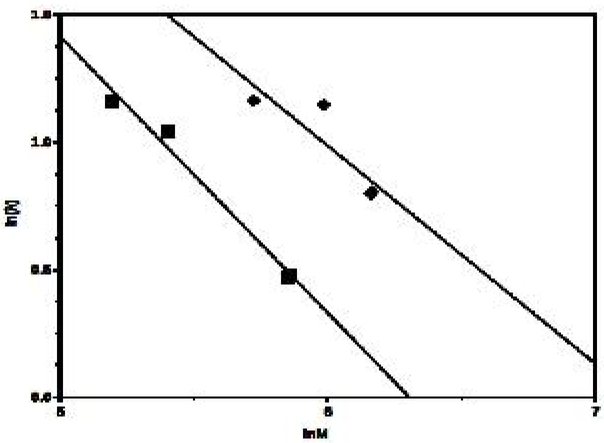
$$\lambda = N(0)<I^2>/M<\omega^2> \quad ....[2]$$

The Coulomb pseudopotential is given by:

$$\mu^*=\mu/[1+\mu\ln(E_B/\omega_0)] \quad ......[3]$$

where ω_0 is the maximum phonon frequency and E_B is an energy cut-off for screened Coulomb interaction in the theory of strong coupling superconductivity. This equation for T_C was obtained considering F(ω) of Nb and should be valid for other materials when structure in F(ω) is important. μ* is then calculated for A15 compounds using the band width Γ_{12} band as 80 meV. λ was then calculated using experimentally determined values of T_C and Θ. It is seen that the dependence of lnλ on lnM falls under two classes; Nb or V based A15 compounds (Figure-1). The data was least squares fitted to straight lines. The R^2 of least squares fitting was 0.76 and 0.98 for Nb based and V based A15 compounds respectively. For Nb-based A15 compounds the fitted equation is ln(λ)=-0.86 lnM+6.12. For V based A15 compounds the fitted equation is ln(λ)=-1.09 lnM+6.84. Therefore λ is nearly inversely proportional to M. In order to understand the superconductivity in HTSC the $YBa_2Cu_3O_{7-x}$ is chosen which is well studied. It has a transition temperature of 92 K which was obtained from the temperature dependence of specific heat. The specific heat measurements were carried out using Nernst heat pulse calorimeter at Max-Planck-Institut fur Festkorperforschung, Stuttgart, Germany. The considerable difference of specific heat anomaly has been explained quantitatively by the phenomenological theory in the Ota limit.

The calculated λ for $YBa_2Cu_3O_{7-x}$ was obtained using the least squares fitting results for A15 compounds. The μ* is then obtained from Eq.1 using the experimentally determined values of Θ and T_C. It is seen that μ* is negative for $YBa_2Cu_3O_{7-x}$. The positive μ* is known to occur for both weak and strong electron-phonon coupling in materials. However, negative μ* probably occurs only for strong electron-phonon coupling superconductors such as HTSC. The unusual features that can suggest negative μ* includes short ξ, van Hove singularity or plasmons. The effect of disorder in superconductors has been considered before. Disorder broadens the electronic band and can also enhance the Coulomb repulsion. In the case of HTSC disorder reduces T_C which can be understood in terms of reduction of density of states at ε_F or due to enhancement of Coulomb repulsion.

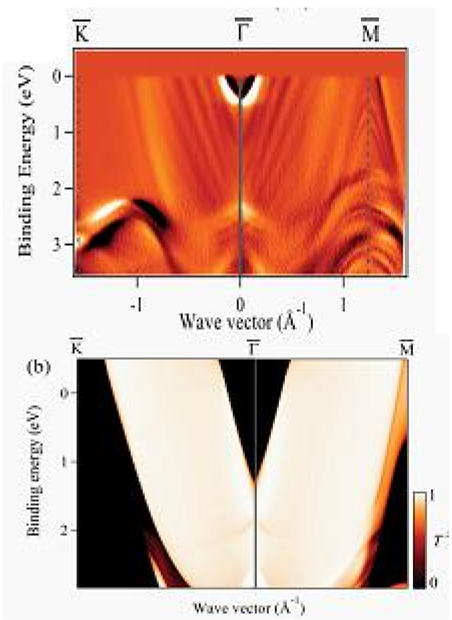


lnM vrsus ln(λ) for A15 compounds. It is seen that the dependence of ln(λ) on lnM falls under two classes; Nb based (■) or V based (◆) A 15 compounds. the solid lines through the data is the least-squares fitted straight lines.

S. B. Ota

Quantum electron confinement in closely matched metals: Au films on Ag (111)

We examined by two-dimensional photoemission band mapping the electronic structure of Au films epitaxially grown on an Ag(111) substrate (Fig. a). The very similar structural and electronic properties of the two metals make this system extremely unfavorable for the occurrence and observation of electron confinement effects. At variance with previous spectroscopic studies, we show that the electron reflectivity at the interface sustains the formation of well-defined sp-derived quantum well states (QWS) and weak quantum well resonance states (QWRS) in the Au layers. The character and degree of confinement of these states are analyzed and quantitatively related to the Au/Ag interface reflectivity on the basis of density functional theory (DFT) band structure calculations (Fig. b).



D. Topwal and Collaborators.

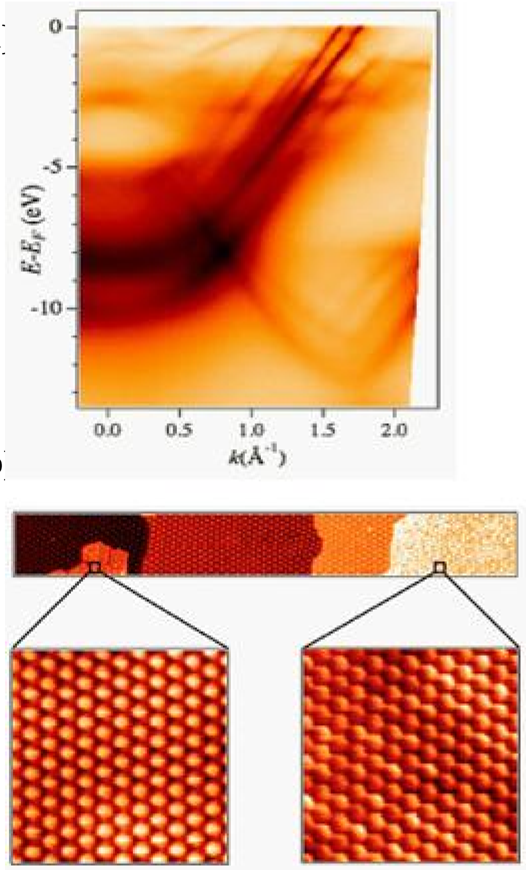
Two Distinct Phases of Bilayer Graphene Films on Ru(0001)

By combining angle-resolved photoemission spectroscopy (Fig. a) and scanning tunneling microscopy (Fig. b) we reveal the structural and electronic properties of multilayer graphene on Ru(0001). We prove that large ethylene exposure allows the synthesis of two distinct phases of bilayer graphene with different properties. The first phase has Bernal AB stacking with respect to the first graphene layer and displays weak vertical interaction and electron doping. The long-range ordered moiré pattern modulates the crystal potential and induces replicas of the Dirac cone and minigaps. The second phase has an AA stacking sequence with respect to the first layer and displays weak structural and electronic modulation and p-doping. The linearly dispersing Dirac state reveals the nearly freestanding character of this novel second-layer phase.

D. Topwal and Collaborators.

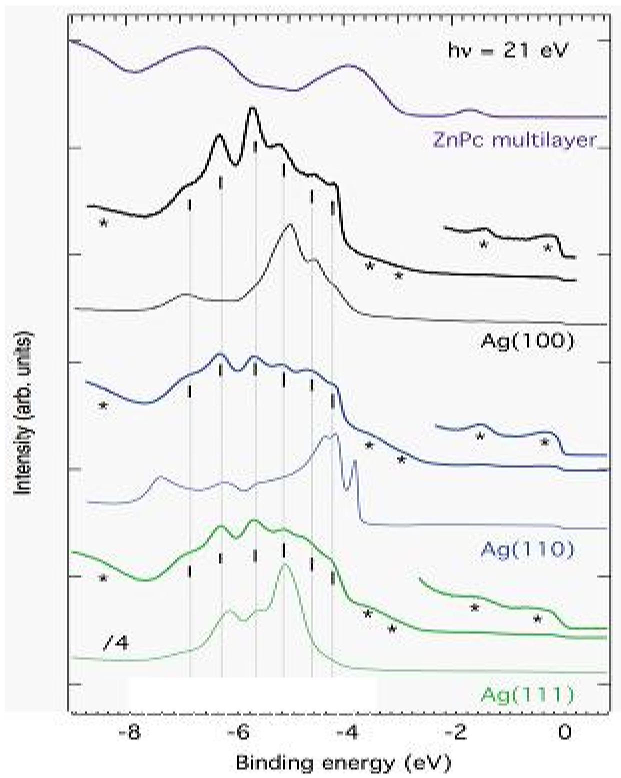
(a)

(b)



Interpretation of valence band photoemission spectra at organic-metal interfaces

Adsorption of organic molecules on well-oriented single-crystal coinage metal surfaces fundamentally affects the energy distribution curve of ultraviolet photoelectron spectroscopy spectra. New features not present in the spectrum of the pristine metal can be assigned as "interface states" having some degree of molecule-substrate hybridization. Here it is shown that interface states having



molecular orbital character can easily be identified at low binding energy as isolated features above the featureless substrate *sp* plateau. On the other hand, much care must be taken in assigning adsorbate-induced features when these lie within the *d*-band spectral region of the substrate. In fact, features often interpreted as characteristic of the molecule-substrate interaction may actually arise from substrate photoelectrons scattered by the adsorbates. This phenomenon is illustrated through a series of examples of noble-metal single-crystal surfaces covered by monolayers of large ð-conjugated organic molecules.

D. Topwal and Collaborators.

Electronic states of moiré modulated Cu films

We examined by low-energy electron diffraction (fig 1b) and scanning tunneling microscopy (fig 1a) the surface of thin Cu films on Pt(111). The Cu/Pt lattice mismatch induces a moiré modulation (fig 1c) for films from 3 to about 10 ML thickness. We used angle-resolved photoemission spectroscopy to examine the effects of this structural modulation on the electronic states of the system. A series of hexagonal- and trigonal-like constant energy contours is found in the proximity of the Cu(111) zone boundaries (fig 2a, 2b). These electronic patterns are generated by Cu sp-quantum well state replicas, originating from multiple points of the reciprocal lattice associated with the moiré superstructure, which is also shown by calculation (fig 2c, 2d). Layer-dependent strain relaxation and hybridization with the substrate bands concur to determine the dispersion and energy position of the Cu Shockley surface state.

Figure - 1

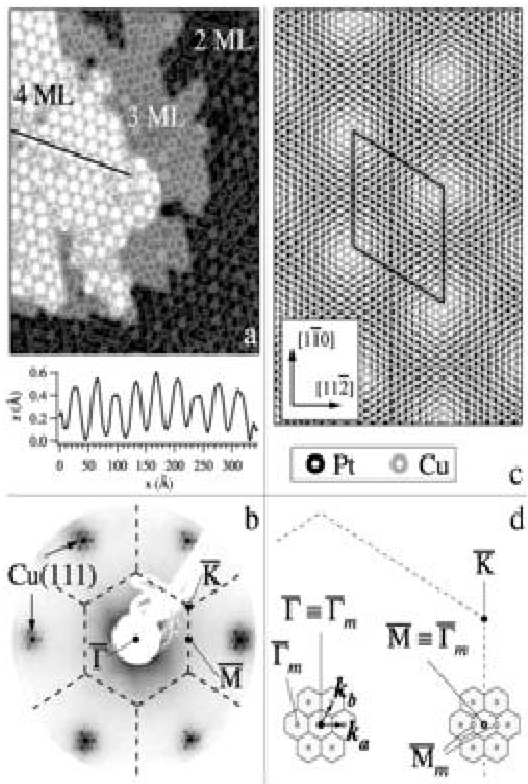
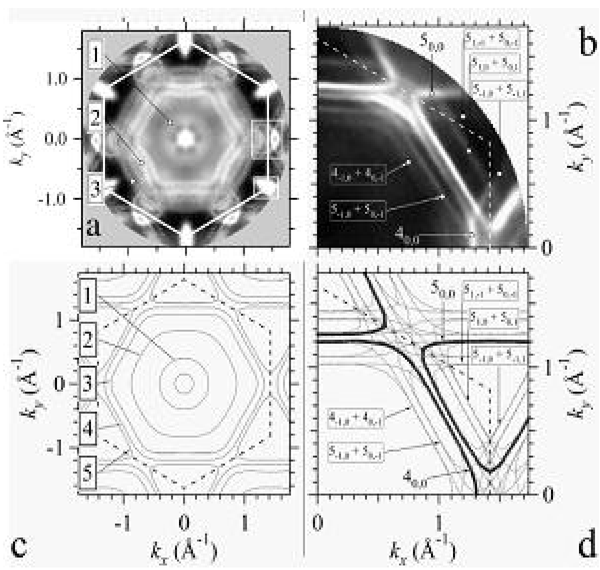


Figure - 2



D. Topwal and Collaborators.

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58. **Inuence of Li-N and Li-F co-doping on defect-induced intrinsic ferromagnetic and photoluminescence properties of arrays of ZnO nanowires,** : Shyamsundar Ghosh, Gobinda Gopal Khan, Shikha Varma, and Kalyan Mandal, Jour. Appl. Phys. 112, 043910 (2012).

59. **Shape evolution of MBE grown $Si_{1-x}Ge_x$ structures on high index Si(5 5 12) surfaces: A temperature dependent study.** - J. K. Dash, A. Rath, R. R. Juluri and P. V. Satyam ; *J. Physics D: Applied Physics 45, 455303(2012)*

60. **Universality in Shape Evolution of $Si_{1-x}Ge_x$ Structures on High Index Silicon Surfaces** - J. K. Dash, T Bagarti, A. Rath, R. R. Juluri and P. V. Satyam ;*Europhys. Lett. 99, 66004 (2012)*

61. **Uniformity of epitaxial nanostructures of $CoSi_2$ via defect control of the Si (111) surface** - J. C. Mahato, Debolina Das, R. Batabyal, Anupam Roy, R. R. Juluri, P. V. Satyam, B. N. Dev, ; *Thin Solid Films 534 296(2013).*

62. **"Oxidation mechanism in metal nanoclusters: Zn nanoclusters to ZnO hollow nanoclusters"** – Amulya Krishna Mahapatra and T. Som: J. Phys. D: Appl. Phys. 45 415303(2012) .

63. **"Unusual pattern formation on Si(100) due to low energy ion bombardment"** – Tanmoy Basu, Jyoti Ranjan Mohanty, and T. Som: Appl. Surf. Sci. 258 9944(2012) .

64. **"Nanometer-scale sharpening and surface roughening of ZnO nanorods by argon ion bombardment"** –S. Chatterjee, A. K. Behera, A. Banerjee, L.C. Trivedi, T. Som, and P. Ayyub: Appl. Surf. Sci. 258 7016(2012) .

65. **"Ion irradiation induced nanostructured semiconductor surfaces"** – V. Venugopal, T. Basu, S. K. Garg, J. K. Tripathi, S. Chandramohan, P. Das, T. K. Chini, S. R. Bhattacharyya, D. Kanjilal, and T. Som: Int. J. Nanotech. 9 1007(2012) .

66. **"Investigation on structural, optical, morphological and electrical properties of thermally deposited lead selenide (PbSe) nanocrystalline thin films"** – T.S. Shyju, S. Anandhi, R. Sivakumar, S.K. Garg, R. Gopalakrishnan: *J. Cryst. Growth* 353 47(2012) .

67. **Observation of vortex lattice related anomalies in poly-crystalline $YBa_2Cu_3O_{7-x}$ near the superconducting transition**, S B Ota, Journal of Modern Physics **3** 1487 (2012).

68. **Calibration of GaAlAs semiconductor diode**, S B Ota and S Ota, Journal of Modern Physics **3** 1490(2012)

69. **Calibration of GaAlAs semiconductor diode for temperatures between 10-300 K**, S B Ota and S Ota, J.Phy.Ast. **2** 7(2013).

70. **Calibration of GaAlAs semiconductor diode around 15 K**, S B Ota and S Ota, J.Phy.Ast. **2** 33(2013).

71. **Temperature-voltage characteristic of Si 1N4007 diode**, S B Ota, J.Phy.Ast. **2** 50 (2013).

4.2 PRE-PRINTS / SUBMITTED / ACCEPTED FOR PUBLICATION

1. **“Domain growth and fluctuations during quenched transition to QGP in relativistic heavy-ion collisions”**, R. K.Mohapatra, A.M. Srivastava, arXiv:1210.4718.

2. **Universal interpretation of ecacy parameter in perturbed nonequilibrium systems** - S. Lahiri and A. M. Jayannavar ; arXiv:1206.3383.

3. **Analytical Approximation of the Neutrino Oscillation Probabilities at large θ_{13} -** Sanjib Kumar Agarwalla, Yee Kao, Tatsu Takeuchi : , arXiv:1302.6773, Submitted in JHEP

4. **Microscopic Description of NN Potential** - B. B. Sahu, S. K. Singh, M. Bhuyan, and S. K. Patra, Communicated to journal. . .

5. **Simple efective interaction: Finite nuclei and Innite nuclear matte**r, - B. Behera, X. Vi~nas, M. Bhuyan, T. R. Routray, B. K. Sharma and S. K. Patra ; J. Phys. G: Nucl. Part. Phys. (2013) in press.

6. **Search of superheavy nuclei in a simple eective interaction,** - S. K. Biswal, M. Bhuyan, S. K. Singh, and S. K. Patra, Communicated to journal. . .

7. **Superdeformed structures and low parity doublet in Ne À– S nuclei near neutron drip-line,** - S. K. Singh, C.R. Praharaj and S. K. Patra, Communicated to journal. . .

8. **Formation of medium-heavy elements in rapid neutron capture process,** - M. Ikram, S. K. Singh and S. K. Patra Communicated to journal. . .

9. **Phase transitions of Neutron stars and its connection with high energetic bursts in astrophysics**; R. Mallick and P. K. Sahu, arXiv:1208.2499 (2012)

10. **Mixed phase in a compact star with strong magnetic field**; R. Mallick and P. K. Sahu, arXiv:1207.4870 (2012)

11. **Oxygen core inside the Magnesium isotopes,** - M. Bhuyan, Communicated to journal. . .

12. **Size dependent optical properties of TiO2 nanostructures,** : V. Solanki, Subrata Majumder, I. Mishra, Shalik R. Joshi, D. Kanjilal and Shikha Varma, Rad. E. and Def in Sol. (2013) in press.

13. **Carbon doped ZnO: synthesis characterization and interpretation,** : D.K. Mishra, J. Mohapatra, M.K. Sharma, R. Chattarjee, S.K. Singh, Shikha Varma, S.N. Behera, Sanjeev K. Nayak, P.Entel, Jour of Mag. Mat.(2013) in press.

14. **Generalized Form of Optimal Teleportation Witness,** Atul Kumar, S. Adhikari, and Pankaj Agrawal, arxiv quant-ph/1204.0983.

15. **Anisotropic branes**, Souvik Banerjee, Samrat Bhowmick, Sudipta Mukherji, arXiv:1301.7194, submitted to Physics Letters B.

16. **Eect of Anomalous Couplings on the Associated Production of a Single Top Quark and a Higgs Boson at the LHC**, Pankaj Agrawal, Subhadip Mitra and Ambresh Shivaji, arxiv hep-ph/1211.4362.

17. **Quantification of Entanglement of teleportation in Arbitrary Dimensions**" by Sk Sazim, S. Adhikari, S. Banerjee and T. Pramanik (arXiv: 1208.4200 (2012)).

4.3 ARTICLES IN PROCEEDINGS

1. **Nuclear matter and nite nuclei propertiesusing simple eective interaction,** M. Bhuyan, S. K. Singh, S. K. Tripathy, T. R. Routray, B. Behera, B. K. Sharma, X. Vi~nas, and S. K. Patra, Proc. DAE Symp. ; Nucl. Phys. Vol. 57, 200, (2012).

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

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

4. **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).

5. **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).

6. **The nucleon-nucleon potential from relativistic mean field theory,** B. B. Sahu, M. Bhuyan, S. K. Singh, and S. K. Patra, Proc. DAE Symp. Nucl. Phys. Vol. 57, 198 (2012).

7. **The role of isoscalar-isovector coupling on symmetry energy of innite nuclear matter,** M. Bhuyan, S. K. Singh, S. K. Patra, P. K. Panda, Proc. DAE Symp. Nucl. Phys. Vol. 57, 608, (2012).

8. **Energy production from neutron rich Uranium and Thorium Isotopes,** R. N. Panda, M. Bhuyan and S. K. Patra, IEEE, conference series, ISBN: 978-1-4673-2267-6 (2012).

9. **Relativistic mean field study of Island of Inversions in neutron rich Z=37-40 nuclei,** S. Mahapatro, S. K. Singh, Proceedings of the DAE Symp. on Nucl. Phys. 57, 308 (2012).

10. **Study of Bubble Structure in the Superheavy Nuclei,** S. K. Singh, M. Ikram, S. K. Patra, Proceedings of the DAE Symp. on Nucl. Phys. 57, 352 (2012).

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

12. **Substrate Symmetry Driven Endotaxial Silver Nanostructures by Chemical Vapor Deposition** - R. R. Juluri, A. Rath, A. Ghosh, P. V. Satyam, ; *Submitted to J. of Physical Chemistry C (2013)*

13. **Shape Controlled Embedded and Endotaxial Growth of Silver Nanostructures on Silicon.** - R. R. Juluri, Ashutosh Rath, Arnab Ghosh ,Anjan Bhukta and P. V. Satyam. ; *Submitted to Nanotechnology 2013* .

14. **Neutron star in presence of strong magnetic field** K. K. Mohanta, R. Mallick, N. R. Panda, L. P. Singh, P. K. Sahu, Paramana (2013)

15. **Graphene induced Pd nanodendrites: A highly performance hybrid nanoelectrocatalyst** - Subash Chandra Sahu, Aneeya K. Samantara, Ajit Dash, R. R. Juluri, Ranjan K. Sahu, B. K. Mishra and Bikash Kumar Jena; *Nano Research (accepted) (2013).*

16. **A Bioinspired Approach for Shaping Au Nanostructures: The Role of Biomolecule Structures in Shape Evolution.** - Subash Chandra Sahu, Aneeya K. Samantara, A. Ghosh, and B. K. Jena ; *Chem. Eur. J.2013,19, 0–0 (Accepted)*

4.4 BOOKS Edited

"Nanofabrication by ion-beam sputtering: Fundamentals and applications", ***Eds. T. Som and D. Kanjilal*** (Pan Stanford, Singapore, 2012).

5 COLLOQUIA AND SEMINARS

5.1 COLLOQUIA

1. **Prof.L.Satpathy,** IOP,BBSR : Mass Formulae for Nuclei, 14.5.2012

2. **Prof. S. Uma Sankar**, IIT, Mumbai : Looking Ahead with Neutrino, 28.05.2012.

3. **Prof. R. Srinivasan,** Former Professor of Physics, IIT, Madras and Former Director of UGC- DAE CSR, Indore) : Laser Cooling of Atoms, 24.09.2012.

4. **Prof. S. D. Mahanti**, Department of Physics and Astronomy, Michigan State University, USA : Topological Insulators, 28.01.2013.

5. **Dr.S.B. Ota**, IOP : Superconductivity centennial and 2011 APS march meeting , 15.02.2013.

6. **Prof. Sudhansu S. Mandal**, IACS : Pairing of Second Generation Composite Fermions in the Lowest Landau Level, 18.02.2013.

7. **Prof. Naba Kumar Mondal**, TIFR, Mumbai (Spokesperson of INO) : NEUTRINOS – A NEW WINDOW TO THE UNIVERSE , 18.03.2013.

5.2 SEMINARS

1. **Dr. P. Balasubramanian,** Department of Physics, Tamkang University, Taiwan : Exploring the physical properties of materials using neutrons and X-rays, 08.5.2012

2. **Dr. Sayan Chakrabarti,** (Centra, Lisbon) Floating Orbits Around Rotating Black Holes and Imprints; of Massive Scalars, 10.5.2012

3. **Dr P. K. Muduli** University of Leipzig, Germany : Spin-polarized tunneling and transport in meso-scale few-layer graphene devices, 18.5.2012

4. **Prof. S. Uma Sankar**, IIT, Mumbai : Super Luminal Neutrino, 01.06.2012.

5. **Dr.Tanumoy Mandal**, IMSc Chennai : LHC Signatures of Color Octet Leptons, 06.07.2012

6. **Dr. Sajal Kumar Ghosh**, Post doctoral fellow, Department of Physics, University of California ,USA : Amphiphiles for soft matter and biophysics, 09.08.2012.

7. **Dr.Niraj Kumar** (UCSD, USA): Non-equilibrium thermodynamics and efficiency of small systems, 27.08.2012.

8. **Dr. Sriparna Chatterjee**, IOP : Growth and applications of $Ti0_2$ nanostructures, 18.09.2012.

9. **Dr. Rajib Biswal,** IOP : Fundamentals and applications of functional oxide materials, 19.09.2012.

10. **Dr. M. Chakraborty** Department of Physics, POSTECH, Pohang, 790-784, KOREA : Stability of Holstein and Frohlich bipolarons, 20.09.2012.

11. **Prof. Sayan Kar**, IIT, Kharagpur : Unusual bound state in quantum mechanics, 21.09.2012.

12. **Dr.Subinoy Das**, (Aachen, Germany) : Dark Matter, Dark Energy and their connection to Neutrinos, 05.10.2012.

13. **Dr. Sachin Jain**, TIFR, Mumbai : Constraints on Fluid Dynamics from Equilibrium Partition Function, 11.10.2012.

14. **Prof. D. P. Roy**, HBCSE, Mumbai : Dark Matter in SUGRA Models with Universal and Nonuniversal Gaugino Masses, 17.10.2012.

15. **Dr. Mriduparna Deka**, Germany : Proton spin, 07.11.2012.

16. **Prof. M.P. Das**, ANU, Australia : Who is afraid of anomalies, 27.11.2012

17. **Ms. Mamata Sahoo**, (Ex-Doctoral Scholar, IOP) : Transcriptional proof reading in dense RNA polymerase traffic , 30.11.2012

18. **Mr. Bodhaditya Santra**, Kernfysisch Versneller Instituut, University ofGroningen, Zernikelaan 25, 9747AA Groningen, The Netherlands : Electric Dipole Moments in heavy atomic systems, 04.12.2012

19. **Mr. Suranita Kanjilal**, Institut fnur Meteorologie und Geophysik, J.-W.Goethe Universitnat Frankfurt Altenhoeferallee 1, 60438 Frankfurt, Germany : 1D and 2D Benchmark of Two phase ow In Geodynamics, 05.12.2012.

20. **Dr. R.Sarkar**, TU Dresden, 01069 Dresden,Germany : Microscopic investigations on the ferromagnetic quantum critical system YbNi4(P1-xAsx), 13.12.2012.

21. **Prof. P. Jena**, Physics Department Virginia Commonwealth University,USA : Nano Materials for Hydrogen Storage, 19.12.2012.

22. **Professor Stephen Lars Olsen** Department of Physics,Seuol National University, Korea : XYZ-meson: Recent results and current status., 21.12.2012.

23. **Prof. Bum-Hoon Lee**,Center for Quantum Spacetime and Department ofPhysics Sogang University Seoul, Korea : Vacuum Bubbles : Revisited, 24.12.2012.

24. **Dr.P. Sekhar Burada** , Institute for Theoretical Physics, Germany : Transport: from passive diffusion to active swimming , 27.12.2012.

25. **Dr.S.B.Ota**, IOP : Alpha15 Superconductors, 28.12.2012.

26. **Dr. Amitabh Virmani** , IOP : Substracted Geometry from Harrisson Transformations, 03.01.2013

27. **Dr.S.B. Ota**,IOP : Measurement of low temperatures with diodes, 17.01.2013.

28. **Prof. Jogesh.C. Pati**, SLAC, Stanford University, USA : Unification of Forces and the Evolution of The Universe, 31.01.2013.

29. **Dr. Joydeep Chakrabortty** (PRL, Ahmedabad) : Investigating Beyond Standard Model, 05.02.2013.

30. **Prof. Bidhan Candra Bag**, Department of Chemistry, Visva Bharati, Santiniketan, India : Non Linear Dynamics of Particle in Presence of a Magnetic field , 08.02.2013

31. **Prof. Sudhir Vempati**, IISc, Bangalore : Status of Supersymmetric Standard Models, 11.02.2013.

32. **Dr. Arnab Kundu**, University of Texas : Gauge-gravity duality and aspects of strongly coupled physics., 12.02.2013.

33. **Dr. Arnab Kundu,** University of Texas : Dynamics of fundamental flavours in holographic duals of large N gauge theories, 13.02.2013.

34. **Dr. Sayantani Bhattacharya,** ICTS, TIFR, Bangalore : Fluid / Gravity Correspondence, 19.02.2013.

35. **Prof. Arunava Chakrabarti,** University of Kalyani, West Bengal : Metal-insulator transition and engineering of extended states in disordered systems beyond one dimension, 20.02.2013.

36. **Dr. Ritam Mallick**, PDF, IOP : The maximum mass of Neutron Star, 27.02.2013.

37. **Prof. R.Palit**, TIFR, Mumbai : Exotic Rotations of Atomic Nuclei, 28.02.2013

38. **Dr. Vijay Kumar**, Sant Longowal Institute of Engineering & Technology [A Govt of India Institute] : Electrochemical synthesis of different metal-conducting polymer composites and their modifications by gamma and heavy ion radiations, 28.02.2013.

39. **Dr. Bindusar Sahoo**, (NIKHEF) : Topologically massive higher-spin gravity , 01.03.2013.

40. **Dr. Sibashisa Dash**, University of Milan, Italy: Electronic Properties and Magnetization of Mn-Doped Semiconductor Surface/Interface, 01.03.2013.

41. **Prof. Anindya Datta**, Calcutta University : Vacuum Stability constraints on Universal Extra Dimensional Models in the light of Higgs Discovery and its impact on LHC search, 13.03.2013

42. **Prof. Rahul Sinha** , IMSc., Chennai Inferring the nature of the boson at 125-126 GeV., 19.03.2013.

43. **Prof. D. P. Roy**, HBCSE : Determination of the third neutrino mixing-angle,. 25.03.2013.

5.3 LECTURES GIVEN ELSEWHERE BY IOP MEMBERS

Prof. S. M. Bhattacharjee

1. **Fluctuations in small systems** : Oct 2012, Venice, Italy

Prof. A. M. Srivastava

2. **From the universe to relativistic heavy-ion collisions : CMBR fluctuations and flow anisotropies** in the Symposium on Contemporary Subatomic Physics held for Joe Kapusta's 60th birthday. McGill Univ., Canada, June 2012.

3. **CMBR fluctuations in the universe and flow anisotropies in heavy ion collisions :** Raman Research Institute, Bangalore, June 2012.

4. **CMBR fluctuations in the universe and flow anisotropies in heavy ion collisions :** Physics Dept. IIT Madras, Chennai, Aug. 2012.

5. **CMBR fluctuations in the universe and flow anisotropies in heavy ion collisions :** Physics Dept. Hyderabad Univ. Aug. 2012.

6. **CMBR fluctuations in the universe and flow anisotropies in heavy ion collisions :** Institute of Mathematical Sciences, Aug. 2012.

7. **From the universe to relativistic heavy-ion collisions: CMBR fluctuations and flow anisotropies** in International Conference ATHIC2012, Pusan, Korea, Nov. 2012.

8. **Laboratory cosmology: Studying cosmic strings in liquid crystal experiments**, in the Conference on "Condensed Matter and Biological Systems (CCMB13), BHU, Varanasi, January, 2013.

9. **Seven lectures given on Quantum Chromodynamics** in the 2nd SERC School on Nuclear Physics Nuclear Matter Under Extreme Conditions, at Variable Energy Cyclotron Centre, Kolkata, Jan. 2013.

10. **Investigating the Universe in simple table top liquid crystal experiments** at the National students symposium in physics 2013 (NSSP2013), Feb. 2013.

Prof. S. Varma

11. ***Making Nanostructures*** at Institute of Radio Physics and Electronics, University of Calcutta, Kolkata (May 2012).

12. ***Looking at Nanostructures*** at Institute of Radio Physics and Electronics, University of Calcutta, Kolkata (May 2012).

13. ***DNA as a sensor*** at Institute of Radio Physics and Electronics, University of Calcutta, Kolkata (May 2012).

14. ***Bandgap Engineering, Enhanced UV-Vis Absorbance and Higher PL Emission from Ion Beam Modified and Nanodot Patterned Rutile TiO2(110) Surfaces*** in International Conference on Advances and Trends in Engineering Materials and their Applications' (Tenth AES-ATEMA-2012) at Montreal University, Montreal, Canada (June 2012).

15. ***Bandgap Engineering and Enhanced Absorbance from Nanodot Patterned Rutile TiO2(110) Surfaces*** at IIT Madras, Chennai (Aug 2012).

16. ***Bandgap Tailoring Biocompatibility in TiO2(110) Surfaces via Low Energy Ion Beam*** in International conference on Swift Heavy ions in Materials Engineering and Characterization' (SHIMEC 2012) at Inter -University Accelerator Center (IUAC), New Delhi (Oct 2012).

17. ***Undestanding and Fabricating Nanostructures*** at Institute of Radio Physics and Electronics, University of Calcutta, Kolkata (Nov 2012).

18. ***Characterizing Nanostructures*** at Institute of Radio Physics and Electronics, University of Calcutta, Kolkata (Nov 2012).

19. ***Using Biomolecules as Sensors of Nanoparticles*** at Institute of Radio Physics and Electronics, University of Calcutta, Kolkata (Nov 2012).

20. ***Biomolecules as Functional Nanomaterials*** in Conference on Condensed Matter and Biological Systems' (CCMB13) at Physics Department, Banaras Hindu University, Varanasi (Jan 2013)

21. ***Nanodot Patterned Rutile TiO2(110) Surfaces for Photocatalysis*** in Conference on 'Nano-materials as catalysts' at Dept. of Chemistry, ITER, S O A University, Bhubaneswar (Jan, 2013)

Dr. Pankaj Agrawal

22. **Multi-Vector Boson Production via Gluon-Gluon Fusion', in Physics** at LHC : Vancouver, Canada, June 4-9, 2012.

Dr. P. V. Satyam

23. **Shape Evolution of Si_xGe_{1-x} Nanostructures on High Index Silicon Surfaces"** : 10 May 2012, Department of Physics, RPI, Troy, USA.

24. **Role of Oxide at the Interface in the growth of AuSi and Au nano/micro structures on Silicon substrates:** In-situ TEM" studies : 11 May 2012: Department of Physics, RPI, Troy, USA.

25. **Shape Transformation of Gold and Germanium Nanostructures on Clean Silicon Surfaces :** 17 May 2012, MSU, USA.

26. **Advances in Nanoscience and Nanotechnology :** 19 October 2012. Indian Science Congress Association, Bhubaneswar Chapter, (18 – 19, October 2012.).

27. **Shape controlled, embedded and endotaxial growth of silver and gold nanostructures on Silicon :** February 2013, ISJPS, IIT-Kharagpur.

28. **Structure of Solids** : 4 January 2013, Refreshers Course for School Teachers, KV Bhubaneswar.

29. **In-situ TEM** : March 7, 2013; ASTEM 2013 (Advanced School on High Resolution TEM, 4 – 8 March 2013).

Dr. S. K. Patra

30. **Nuclear Energy,** KIIT, Bhubaneswar

31. **The relativistic Lagrangian : Nucleon - Nucleon potential,** Chitkara University, November 19, 2012.

32. **Formation of heavy elements in rapid neutron capture process,** Calcutta University, Feb 05, 2013

33. **Microscopic Origin of NN-interaction,** Sambalpur University, March 01, 2013.

Dr. T. Som

34. **Pattern formation on semiconductor surfaces by medium energy ion beams**: 12.09.2012 *Discussion Meeting on Low Energy Ion Beam Facilities, IUAC, New Delhi*.

35. **Patterning semiconductor surfaces by energetic ions** : 05.10.2012 at *National Seminar on Nanotechnology and MEMS, Trident Academy of Technology, Bhubaneswar*.

Dr. S. K. Agarwalla

36. **Status of Sterile Neutrinos** : Invited Review talk given at the XX DAE-BRNS HEP-Symposium, Visva-Bharati, Santiniketan, India, 15th January, 2013

37. **Expectations from T2K and NOνA in light of recent Neutrino Data** : Talk given at the e-NuMI phone meeting, Fermilab, USA, 27th February, 2013

Dr. A. Virmani

38. Inverse Scattering and the Geroch Group, Invited talk, Indian Strings Meeting, Puri, December 16 - 21, 2012

5.4 LECTURES GIVEN AT THE INSTITUTE BY IOP MEMBERS

Dr. T. Som : Pattern formation on semiconductor surfaces by energetic ion beams, 26.09.2012 *Prof. Alok Kumar Memorial Lecture, Institute of Physics.*

5.5 POPULAR LECTURES GIVEN BY IOP MEMBERS

Dr. A. M. Srivastava

1. **The God Particle** : at Institute of Mathematics and Applications, Bhubaneswar, Aug. 2012.

2. **Higgs Boson** : at SCAAA meeting, Sept. 2012.

3. **Dark energy** : at "National Seminar on exploration of space for dark energy" at Gopabandhu Science College, Athgarh, Odisha, Sept. 2012.

Dr. P. V. Satyam

4. **Structure of Solids** : Refreshers Course for School Teachers, Kendriya Vidyalaya, Bhubaneswar, 4 January 2013.

5. **Advances in Nanoscience and Nanotechnology** : Indian Science Congress Association, Bhubaneswar, 18th - 19th October, 2012.

5.6 CONFERENCE / SYMPOSIUM / WORKSHOP ATTENDED BY IOP MEMEBERS

Prof. S. M. Bhattacharjee

1. International Conf in BHU, Varanasi, Jan 2013

2. Workshop on Condensed Matter Physics, RKM Vivekananda University, Belur, Sept 2012.

Prof. A. M. Srivastava

3. Symposium on Contemporary Subatomic Physics held for Joe Kapusta's 60th birthday. McGill Univ., Canada, June 2012

4. International Conference ATHIC2012, Pusan, Korea, Nov. 2012.

5. Conference on "Condensed Matter and Biological Systems (CCMB13), BHU, Varanasi, January, 2013.

6. National students symposium in physics 2013 (NSSP2013), Feb. 2013.

7. National Seminar on Exploration of space for dark energy, Gopabandhu Science College, Athgarh, Odisha, Sept. 2012.

Prof. S. Varma

8. Tenth AES-ATEMA-2012 at Montreal, Canada

9. SHIMEC 2012 at IUAC, New Delhi

10. 'CCMB13' at BHU, Varanasi,

11. Nano-materials as Catalysts' at ITER, Bhubaneswar

Dr. P. V. Satyam

12. 53rd International Field Emission Symposium 2012, University of Alabama, Tuscaloosa, USA, May 21 – 25, 2012

13. Electron Microscope Society of India EMSI) International Conference on Electron Microscopy, Indian Institute of Science, Bangalore, India, July 1 – 4, 2012

14. Indian Science Congress Association, Bhubaneswar Chapter, Utkal University, Bhubaneswar, October 18 – 19, 2012

15. 6th India Singapore Joint Physics Symposium on Physics of Advanced Materials 2013, Indian Institute of Technology Kharagpur, India, Feb. 25 – 27, 2013.

16. Advanced School on High Resolution Transmission Electron Microscopy, Institute of Physics, Bhubaneswar, March 4 – 8, 2013

17. 12th International Conference on Surface X-ray and Neutron Scattering, Saha Institute of Nuclear Physics, Kolkata, July 25 – 28, 2012.

Dr. T. Som

18. Discussion Meeting on Low Energy Ion Beam Facilities, IUAC, New Delhi.

19. National Seminar on Nanotechnology and MEMS, Trident Academy of Technology, Bhubaneswar.

Dr. D. Topwal

20. 2th International Conference on Surface X-ray and Neutron Scattering, Saha Institute of Nuclear Physics, Kolkata

21. Advanced School on High Resolution Transmission Electron Microscopy, Institute of Physics, Bhubaneswar

6 CONFERENCES AND OTHER EVENTS

6.1 ALUMNI DAY

The 32nd Alumni Day was celebrated on September 3, 2012. The program started with an academic session which consisted of a series of lectures by our alumni members and a colloquium by an invited distinguished physicist.

In this session, we had lectures by eminent Alumni members of IOP Prof. Shreekantha Sil, Viswa-Bharati, West Bengal *("Impact of Rashba and Dresselhaus spin-orbit Interaction on the charge and spin Transport in Mesoscopic ring");* Prof. A. K. Das, Indian Institute of Technology, Kharagpur *("The Cantilever Beam Magnetometer : A Versatile Technique for Magnetic Characterization "); Prof.B. Chandrasekhar,* Indian Institute of Technology, Bhubaneswar *("Partition Fuction and Localization in curved beta-gamma like Systems").*

The colloquium entitled " *Scaling and Renormalization of Random walks on a class of Fractals*" was given by distinguished scientist Prof. V. Balakrishnan, Indian Institute of Technology, Chennai.

The evening program started with prize distribution to the winners of various competitions in the year-long program. It was followed by a talk entitled *"Growth and Poverty in the Indian Economy"* by eminent economist Prof. Prabhat Patnaik, Jawaharlal Nehru University, New Delhi Chief Guest of the evening. This was followed by Excellent Solo Tabla Recital by Sri Rupak Bhattacharjee and Flok Dance viz. *Chadheiya Dance, Tiger Dance, Ranapa Dance and Sankha Dance* by Narendrapur Loka Nrutya, Badakusasthali Ashram, Ganjam, Odisha.

Following were the office bearers

Secretary	:	Subhadip Ghosh
Asst. Secretary	:	Mohit Kumar
Treasurer	:	Himanshu Lohani
Faculty Advisor	:	Dr. B. R. Sekhar

6.2 FOUNDATION DAY

The 38th Foundation day of the Institute was celebrated on September 4, 2012. 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. V. Balakrishnan, Professor Emeritus, Department of Physics, IIT Madras. He deliver the Foundation Lecture on the topic " A Miracle of Rare Device : The Genius of Scientific Discovery.

6.3 Advanced School on High Resolution Transmission Electron Microscopy –ASTEM2013

Institute of Physics organized a one week "Advanced School on High Resolution Transmission Electron Microscopy – ASTEM 2013" jointly with Indian Institute Technology Bhubaneswar as the co-organizing Institute. The emphasis on the school was to give advanced lectures by the leaders (recognized in the world) in the Electron Microscopy in the morning sessions and hands on experimentation using the facilities at IOP, in the afternoon session. There were a total of 53 registered participants. The participants came from all parts of India. These participants were nominated by the renowned TEM experts in India, and enough representation was given to all major TEM groups in India. Some of these Institutes are Indian Institute of Science, Bangalore, SINP, Kolkata; BARC, Mumbai; IGCAR, Kalpakkam; JNCASR, Bangalore; SSPL, Delhi; IIT's – Madras, Bhubaneswar; IACS Kolkata, Jadavpur University, NISER Bhubaneswar etc.

Main theme of the school was to understand the image formation from the first principles and quantifying the images using the image simulation. Prof. C. B. Carter (University of Connecticut, USA and Editor-in-Chief, Journal of Materials Science) and Prof. A. Rosenauer (University of Bremen, Germany, Expert on STEM imaging and image simulations) have taken the major share of the course. Besides these two experts, Prof. N. Ravishankar (IISc), Dr. G. K. Dey (BARC), Dr. K. Muraleedharan (DMRL/DRDO), Prof. S. K. Nayak (IIT Bhubaneswar), Dr. Knut Mueller (University of Bremen), Dr. D. Sridhara rao (DMRL) and Dr. P. V. Satyam gave the lectures. Groups Dr. P. V. Satyam and Prof. Rosenauer have taken the laboratory courses.

Financial sponsorship has been given by DRDO, Delhi and Electron Microscope Society of India (EMSI) – East zone chapter, Indo-USSTF (New Delhi) and few companies (Icon Analytic, Zeiss India, Gatan India) and nominal registration fee from the participants

7

OUTREACH

Science Modelling co-ordinated by Alumni Association

Quiz Competition co-ordinated by Alumni Association

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 celebrated at the Institute of Physics on 23rd March 2013 (due to various constraints of school timings and classes etc.). This was jointly organized by the Institute of Physics and National Institute of Science Education and Research, Bhubaneswar. The program was attended by about 220 school students from Bhubaneswar (both English medium and Oriya medium schools). About 30 students from IOP/ NISER, and the local Basti participated in the program. The program started with the following popular level talks (in English/Oriya) at the Institute Auditorium.

1. Seminar Talk on "Origin of Mass and the Higgs Boson", by Prof. Bedangadas Mohanty, NISER.

2. Seminar Talk on "Atmospheric Resource and threat to it" by Prof. M.C. Dash, Ex-Vice Chancellor, Sambalpur University.

Following this, student visits were arranged, in small groups, to IOP experimental facilities, as well as Demonstration Experiments at NISER Labs. There was a very enthusiastic participation of NISER students/faculty in arranging these demonstrations (for Physics, Chemistry, Mathematics, and Biology), and also by IOP research scholars/faculty and scientific assistants in explaining various experimental facilities to school students.

7.2. Observation of Transit of Venus

Observation of Transit of Venus was arranged at Institute of Physics on 06.05.2012. The event was organized jointly by IOP and Samanta Chandrasekhar Amateur Astronomer Association(SCAAA) for members of IOP, NISER, SCAAA, with their families and for the general public.

7.3. Night sky viewing sessions

Night sky observation sessions were carried out at IOP (on 20th Dec. 2012, and 15th Feb. 2013) for IOP/NISER members and their families using two telescopes which have been recently acquired at IOP, (along with a binocular

17X 70mm). Brief details of the two telescopes are as follows:

1) 8" Schmidt-Cassegrain 2 meter focal length telescope, computer controlled with GPS system, 2 inch eye piece kit, Sky scout for finding deep sky objects in the sky. This is a sophisticated telescope for viewing sessions primarily at the Institute.

2) 4" refractor telescope, manual controls with fine adjustment knobs. This is a robust, user friendly telescope, (particularly useful for the outreach programs away from the Institute).

7.4. Visits of school students:

The Institute regularly receives requests from various schools in Odisha and outside for visits which are arranged and managed under the Outreach Program. For this year following visit was arranged: About 100 selected students (toppers of Class XI Science) from various Jawahar Navodaya Vidyalayas (coordinated by JNV, visited IOP for a scientific program on 29th Nov. 2012. There was a 40 minute talk/discussion session, followed by IOP Lab visits.

8 OFFICIAL LANGUAGE PROGRAM


भौतिकी संस्थान, भुवनेश्वर
हिंदी दिवस समारोह - 2012
दिनांक - 14.09.2012


हिन्दी पखवाड़ा समापन तथा
पुरस्कार वितरण समारोह

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. Institute celebrated the Hindi fortnight during 14-28, September, 2012. The various competitions like, Hindi Essay, Hindi Debate, Hindi Translation, Noting & Drafting in Hindi were organized in the Institute. Hindi Day was celebration on 14.09.2012. Hindi fortnight Valedictory and Prize Distribution Celebration was held on 28.09.2012. Dr. (Mrs.) Anjuman Ara, Reader in Hindi, Ravenshaw University, Cuttack was the Chief Guest of this occasion. Institute conducted the Hindi Workshop & Training Program on the subject of "Noting & Drafting in Hindi, the Official Language Act & their implementation". Most of the employees as well as officers participated in the workshop. Eligible employees are nominated for Hindi Training program conducted by Hindi Teaching Scheme, Bhubaneswar. A popular Lecture in Hindi on DAE Activities was also conducted in the Institute. Institute of Physics regularly participates in the Town Official Language Implementation Committee, Bhubaneswar.

9 PERSONNEL

9.1 LIST OF INSTITUTE MEMBERS

A. Faculty members and their research specialisation

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

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

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

4. **Kalyan Kundu**
   Professor
   Condensed Matter Phyiscs (Theory)

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

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

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**
    Reader-F
    Nuclear Physics (Theory)

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

17. **Amitabh Virmani**
    Assistant Professor
    High Energy Physics (Theory)

18. **Sanjib Kumar Agarwalla**
    Assistant Professor
    High Energy Physics (Theory)

B. Post-Doctoral Fellows

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

C. Doctoral Scholars

1. Sankhadeep Chakraborty
2 Rupali Kundu
3. Ranjita Kumari Mohapatra
4. Subrata Majumdar
5. Saumia P.S.
6. Poulomi Sadhukhan
7. Jatis Kumar Dash
8. Sachin Jain
9. Sourabh Lahiri
10. Ashutosh Rath
11. Ambresh Kumar Shivaji
12. Abhishek Atreya
13. Souvik Banerjee
14. Sandeep Kumar Garg
15. Jaya Maji
16. Raghavendra Rao Juluri
17. Pramita Mishra
18. Tanmoy Basu
19. Vanarajsinh J. Solanki
20. Indrani Mishra
21. Partha Bagchi
22. Rama Chandra Baral
23. Sabita Das
24. Subhashis Rana
25. Tanmoy Pal
26. Anjan Bhukta
27. Arnab Ghosh
28. Himanshu Lohani
29. Mohit Kumar
30. Shailesh Kumar Singh
31. Shailik Ram Joshi
32. Sk. Sazim
33. Subhadip Ghosh
34. Arpan Das
35. Sumit Nandi
36. Soumyarata Chatterjee
37. Subrata Kumar Biswal

D. Pre-doctoral Scholars

1. Bidisha Chakrabarty
2. Priyo Shankar Pal
3. Puspendu Guha
3. Sabya Sachi Chatterjee
4. Shreyansh Shankar Dave
5. Sudipta Mahana

E. Administration

1. Mr. C. B. Mishra, Registrar.
2. Mr. K. Padmanabhan, OSD *(From 4th February, 2013)*

(i) Director's Office:

1. Sk Kefaytulla
2. Raja Kumari Patra
3. Rajesh Mohapatra
4. Brahmananda Nayak
5. Rabi Narayan Sahoo
6. Gopal Naik

(ii) Registrar's Office

1. Bira Kishore Mishra
2. Abhimanyu Behera
3. Samarendra Das

(iii) Establishment

1. M.V. Vanjeeswaran
2. Jaya Chandra Patnaik
3. Bhagaban Behera
4. Prativa Choudhury
5. Soubhagya Laxmi Das
6. Daitary Das

(iv) Stores & Transport

1. Pramod Kumar Senapati
2. Sadananda Pradhan
3. Sri Binjaban Digal
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 Kanta Biswal
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. Sahadev Jena
2. Purastam Jena
3. Ghanashyam Naik
4. Dhobei Behera
5. T. Ramaswamy
6. Gangadhar Hembram
7. Tikan Kumar Parida
8. Kailash Chandra Naik
9. Banamali Pradhan
10. Gokuli Charan Dash
11. Biswanath Swain
12. Bijoy Kumar Swain
13. Bijoya Kumar Das
14. Babuli Naik
15. Pradip Kumar Naik

16. Meena Dei
17. Sudhakar Pradhan
18. Sanatan Pradhan
19. Bhaskara Mallick
20. Kulamani Ojha
21. Pitabas Barik
22. Dhoba Naik
23. Charan Bhoi
24. Jatindra Nath Bastia
25. Rajan Kumar Biswal
26. 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
10. Pratap Kumar Biswal
11. Arakhita Sahoo
12. Bala Krushna Dash
13. Soumya Ranjan Mohanty
14. Kshyama Sagar Jena
15. Nityananda Behera
17. Purna Chandra Marndi
18. Srikanta Mishra
19. Ranjan Kumar Sahoo

(xiv) Workshop

1. Ramakanta Nayak
2. Rabi Narayan Naik

9.2 New Members

Dr. Dinesh Topwal
Assistant Professor

Date of Joining : 01.11.2012

Dr. A. Virmani
Assistant Professor

Date of Joining : 13.12.2012

Dr. S. K. Agarwalla
Assistant Professor

Date of Joining : 13.12.2012

Shri K. Padmanabhan
Officer on Special Duty

Date of Joining : 04. 02. 2013
He is also the Chief Adm. Officer,
Nuclear Recycle Board,
Bhabha Atomic Research Centre, Mumbai

9.3 RETIREMENT

Shri Maheswar Baliarsingh

Date of Retirement : 31.05.2012
Date of Joining : 23.06.1977
Last post held : Tradesman - E

Shri Prabhakar Acharya

Date of Retirement : 31.10.2012
Date of Joining : 27.12.1984
Last post held : Scintific Officer - C

Shri Judhistira Senapati

Date of Retirement : 31.08.2012
Date of Joining : 10.04.1975
Last post held : Sr. Assistant

Shri Ramesh Chandra Nayak

Date of Retirement : 31.01.2013
Date of Joining : 24.06.1977
Last post held : Scintific Officer - D

9.4 OBITUARY

LATE SHRI DULLABHA HEMBRAM

Date of Joining:12.04.1975

Last post held:Tradesman - C

Date of Birth : 23.01.1957, Date of Death:04.11.2012

10 AUDITED STATEMENT OF ACCOUNTS

10.1. Balance Sheet

INSTITUTE OF PHYSICS, BHUBANESWAR

BALANCE SHEET AS AT 31ST MARCH 2013

(Amount - Rs.)

CORPUS/ CAPITAL FUND AND LIABILITIES	Schedule	Current Year	Previous Year
CORPUS/ CAPITAL FUND	1	698,338,343	647,235,818
EARMARKED/ ENDOWMENT FUNDS	2	194,455	156,781
CURRENT LIABILITIES AND PROVISIONS	3	59,402,115	140,207,633
TOTAL		**757,934,913**	**787,602,232**
ASSETS			
FIXED ASSETS	4	715,862,637	665,949,155
CURRENT ASSETS, LOANS, ADVANCES ETC.	5	42,072,276	121,653,077
TOTAL		**757,934,913**	**787,602,232**
SIGNIFICANT ACCOUNTING POLICIES	19		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS			

In terms of our report of even date annexed

Place : Bhubaneswar
Date : 25.09.2013

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10.2. Income & Expenditure Account

INSTITUTE OF PHYSICS, BHUBANESWAR

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD/YEAR ENDED 31ST MARCH 2013

(Amount - Rs.)

INCOME	Schedule	Current Year	Previous Year
Grants/ Subsidies	6	159,424,166	141,737,601
Interest Earned	7	1,448,518	3,170,913
Other Income	8	1,160,011	1,075,457
Prior period Income		-	-
TOTAL (A)		**162,032,745**	**145,983,971**
EXPENDITURE			
Establishment Expenses	9	103,037,518	94,776,540
Other Administrative Expenses etc	10	57,736,225	53,505,457
Depreciation	4	70,374,359	78,504,355
Loss of Assets		69,949	-
TOTAL (B)		**231,218,051**	**214,586,383**
Balance being excess of Expenditure over Income (B-A)		(69,185,306)	(68,602,412)
BALANCE BEING SURPLUS/(DEFICIT) CARRIED TO CORPUS/ CAPITAL FUND		(69,185,306)	(68,602,412)
SIGNIFICANT ACCOUNTING POLICIES	15		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS			

In terms of our report of even date annexed

Place : Bhubaneswar
Date : 25-09-2013

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10.3. Receipts & Payments

INSTITUTE OF PHYSICS, BHUBANESWAR
RECEIPTS & PAYMENTS FOR THE FINANCIAL YEAR 2012-13

(Figure in Rs.)

	RECEIPTS	SCH	Current Year	Previous Year
I.	**Opening Balance**			
	a) Cash in hand		9,376	9,787
	b) Bank balances			
	i) In current accounts SBI		368,685	38,231,551
	ii) In deposit accounts LK Panda (SBI Term Deposit)		100,000	100,000
	iii) Savings accounts			
	Indian Overseas Bank (NP)		24,927,995	29,310,014
	Indian Overseas Bank (Plan)		24,180,173	-
	Union Bank (NP)		3,509,627	5,197,608
	Union Bank (Plan)		19,917,252	-
	SBI (LK Panda)		91,454	54,396
	Union Bank (TPSC)		7,327	90,174
II	**Grants Received**			
	a) From Govt. of India - Plan		3,850,000	126,990,000
	Non Plan		175,700,000	151,900,000
	b) From State Government		600,000	1,300,000
	c) Raja Ramana Fellowship		725,356	647,364
III.	**Receipts against Sponsored Projects**			
	TPSC		100,000	100,000
IV.	**Income on Investments from**			
	LK Panda A/c		2,024	2,050
	TPSC A/c		3,129	3,167
V.	**Interest Received**	11	1,096,917	1,173,515
VI.	**Other Income (Specify)**			
	Misc Receipts		32,618	180,924
	Sale of Tender paper		4,700	15,800
	House/Guest House Rent		895,560	874,133
	Advance from NISER		-	-
	Sale of Asset		-	-
VII.	**Other Receipts**			
	Earnest Money Deposit		246,870	20,554
	Security Deposit		(252,104)	(280,239)
	Security Deposit BSNL		-	-
	Caution Money		1,200	800
	RECOVERY OF STAFF LOAN	17	535,365	521,470
	TOTAL		260,458,527	368,460,926

	PAYMENTS	SCH	Current Year	Previous Year
I.	**Expenses**			
	a) Establishment Expenses	12	102,261,566	99,166,040
	b) Administrative Expenses	14	35,895,306	31,553,261
	c) Maintenance Expenses	15	15,183,895	14,102,801
II.	**Payments made against funds for various projects**			
	TPSc		64,479	195,814
	LK panda Scholarship		5,000	5,000
III.	**Expenditure on Fixed Assets & Capital W.I.P**			
	a) Purchase of Fixed Assets	16	67,298,958	155,055,928
IV.	Interest Receivable		-	
V.	**Project Revenue Expenses**	17	2,774,957	3,857,503
VI.	**STAFF LOAN**	18	287,921	443,085
VII	Security Deposit with CESU		-	-
IX	**Closing Balance**			
	a) Cash in hand		8,770	9,376
X.	b) Bank balances			
	i) In current accounts SBI		32,011,593	368,685
	ii) In deposit accounts			
	LK Panda (SBI Term Deposit)		100,000	100,000
	iii) Savings accounts			
	Indian Overseas Bank (NP)		1,426,320	24,927,995
	Indian Overseas Bank (Plan)		1,021,465	24,180,173
	Union Bank (NP)		128,854	3,509,627
	Union Bank (Plan)		110,449	19,917,252
	SBI (LK Panda)		48,474	91,454
	Union Bank (TPSC)		45,977	7,327
	TOTAL		260,458,527	368,460,926

ACCOUNTS OFFICER
INSTITUTE OF PHYSICS
BHUBANESWAR

DIRECTOR
INSTITUTE OF PHYSICS
BHUBANESWAR

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वार्षिक रिपोर्ट

भौतिकी संस्थान

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