ANNUAL REPORT

2011-12

INSTITUTE OF PHYSICS
BHUBANESWAR

Annual Report

2011-2012

INSTITUTE OF PHYSICS

BHUBANESWAR

INSTITUTE OF PHYSICS

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Contents

About the Institute

Institute of Physics, Bhubaneswar is an autonomous research institution within the Department of Atomic Energy (DAE), Government of India. The Institute was established in 1972 by the Government of 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. The accelerator mass spectrometry (AMS) facility has been routinely accepting samples from the external users for dating applications. One of the important areas in our 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 facilitated 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.

The Governing Council

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From the Director's Desk . . .

This is the Annual Report of Institute of Physics, Bhubaneswar for the period 1st April, 2011 to 31st March, 2012

The report describes various facilities available in the Institute. It also gives a brief description about different research activities, being persued by its members, highlighting the publications in the respective areas. In addition, seminars, colloquia, conferences, etc., which were organised during the last one year have also been included along with other significant events.

Arun M. Jayannavar

1 FACILITIES

1.1 NEW EXPERIMENTAL SET-UP

SQUID, VSM

The SQUID-VSM lab consists of Quantum Design MPMS SQUID VSM EVERCOOL. 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 up to 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 up to 7T and temperature ranging from 4K to 400K.

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 the photocurrent 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

1.2. EXISTING EXPERIMENTAL FACILITIES

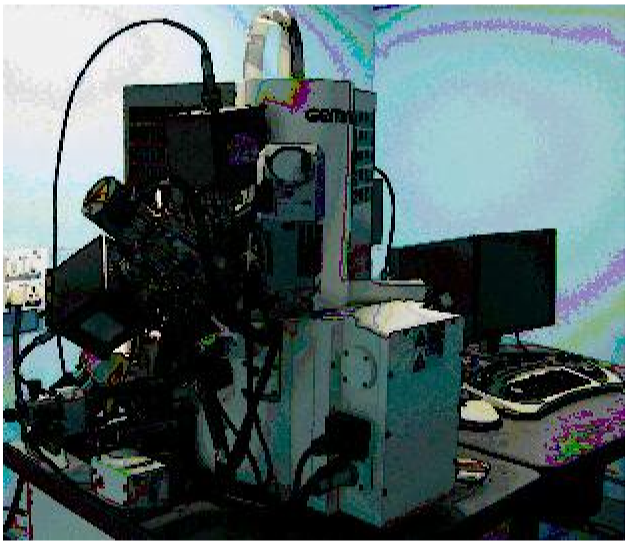
Ion Beam Analysis Endstation

Recently we have installed an ion beam analysis endstation in the general-purpose beam line at the Ion Beam Laboratory. This endstation is a unique one in the country which is dedicated for user experiments based on ion beam analysis techniques, viz. Rutherford backscattering spectrometry (RBS), RBS-channeling, and elastic recoil detection analysis (ERDA). While RBS is meant for depth profiling of heavy elements, RBS-channeling is capable of analysis of single crystals and epitaxial layers to determine crystalline quality, amorphous layer thickness, degree of disorder, and atomic site.

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

FEGSEM-FIB facility

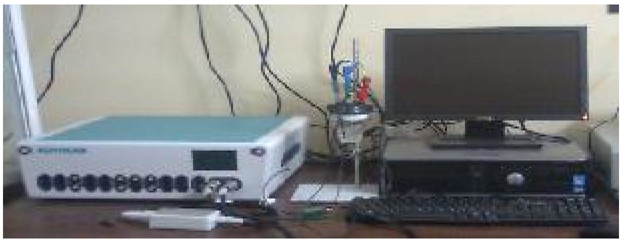
The Cross-Beam facility consists of a field emission based scanning electron microscope (FEGSEM) and a focused ion beam (FIB) system. The facility also has other useful accessories to elemental mapping with x-ray florescence (using energy dispersive spectrometry (EDS)), scanning transmission electron 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.

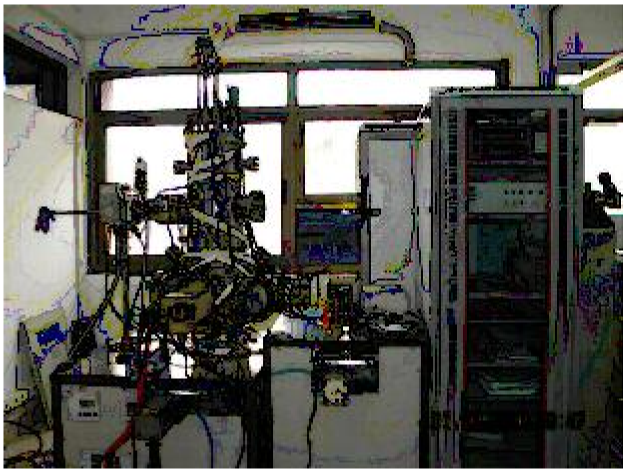
Cyclic Voltametry

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.



Ion beam etching induced surface nanostructuring

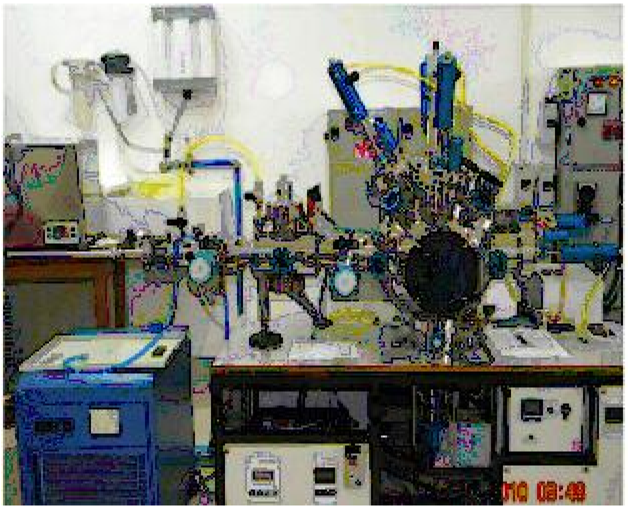
We have facilitated a low energy (50 eV – 2 keV), broad beam (l in. diameter) electron cyclotron resonance (ECR) source based ion beam etching facility for creating self-organized surface nanostructures. The source is equipped with a differential pumping unit for working at a better chamber vacuum during 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.

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.



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 around 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, PIXE and ion channeling. Radiocarbon AMS is carried out in the -15° beam line. A general purpose scattering chamber suitable for nuclear physics experiments using multiple detectors is available in the 0° line. This beam line also has the external beam port to perform 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 has 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) and for low energy nuclear physics experiments. The experimental facilities of AMS and micro-beam provided by the IBL are unique in the country. 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.

HRTEM Laboratory

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

Soft Condensed Matter Laboratory

The soft matter lab is used to grow polymers, nano-polymer composites, and Langmuir-Blodgett films. An LB trough (from M/S NIMA, UK), a spin coater, a fume hood and mili-pore water purifier systems are available.

Grazing Incidence X-ray Diffractometer (GIXRD)

D8 ADVANCE Grazing Incidence X-Ray Diffractometer (GIXRD) from M/S Bruker has been installed in the Cluster and Nanostructure Lab. The equipment can operate in grazing as well as powder XRD mode applications. The GIXRD system has flexibility with possible combinations of x-ray sources, optics, sample stages, and 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 60 mm length, Cu radiation source with a set of slits for Goebel Mirror, flat LiF monochromator, parallel beam attachment (0.23°), fixed divergence slit assembly including 2.5° Soller, short spacer for push plug optics, 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 D8 ADVANCE diffractometer has the ability to perform a full range of applications for qualitative and quantitative phase identification, under ambient or non-ambient conditions, crystal structure identification of different samples, crystallite size determination, strain analysis, residual stress analysis, and preferred orientation for established structures.

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 a 125mm 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.

Multi Mode Scanning Probe Microscope Facility

At IOP we have a Multimode SPM (Scanning Probe Microscope) facility from Veeco which is controlled via a NanoscopeIIIa controller with Quadrex. 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 utilized 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.

The SPM consists of a family of microscopy techniques where a sharp probe (or tip) is scanned across a surface and the probe sample interaction/ interactions are monitored. The cantilever with the sharp tip is housed in the cantilever holder. The top of the cantilever is coated with a Au film. The laser beam falling on the cantilever is reflected into the photosensitive detector. Any changes in the tip position are monitored by the detector. The cantilever holder, laser beam and the photo-detector are located in the "AFM head". The sample is mounted on the scanner which is at the "base" of AFM.

X-Ray Photoelectron Spectroscopy Setup

The present XPS system has a dual X-ray Anode (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.

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.

XRF

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.

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 programme 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.

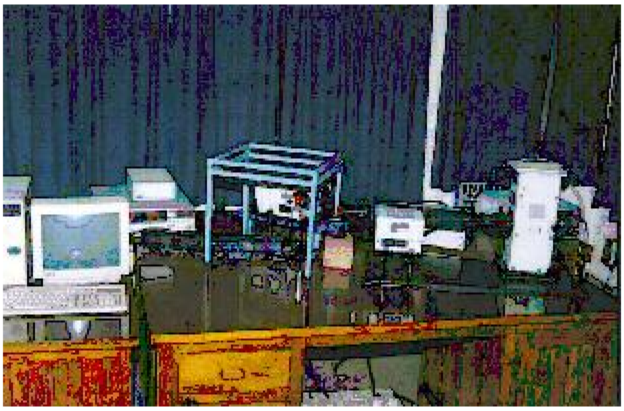
Micro-Raman Spectrometer

Micro Raman (Jobin Yoven U1000) spectrometer with double monochromator configuration and optimal resolution 0.1 cm-1 is available in Cluster and Nanostructure laboratory. 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.

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



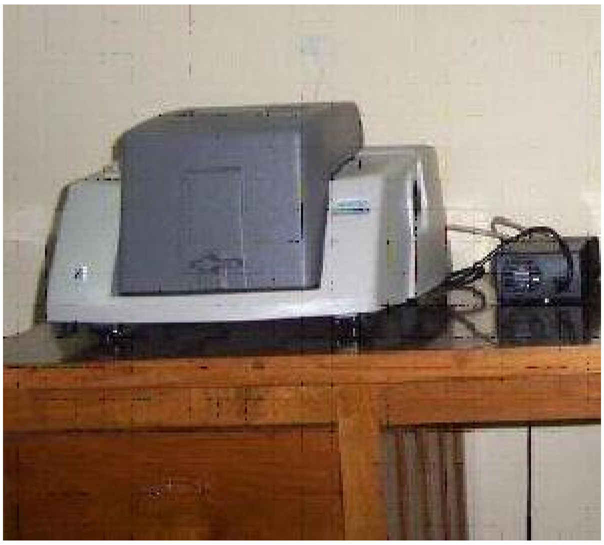
and organic compounds. This instrument can identify trap states, band edges of semiconductors and also new organic compounds based on luminescence properties of materials.

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.

FTIR Spectrometer

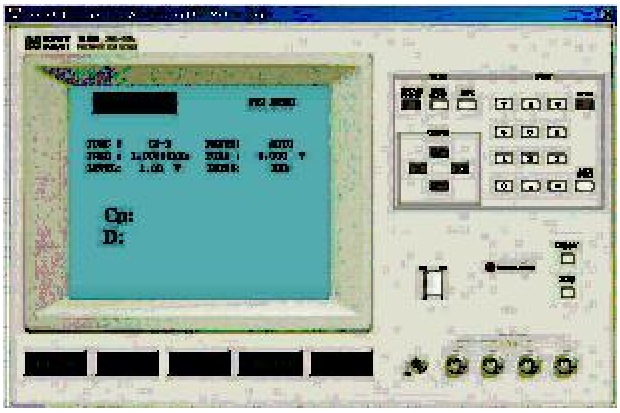
Cluster & Nanostructure Lab has a Nicolet FT-IR model Avtar-370 spectrometer. It consists of an Ever-Glow source capable of producing IR signal in the spectral range of 200-4000 cm^{-1} while glowing at 1200 to 1250°C. The modulator consists of a CsI beam splitter and two metallic mirrors to generate 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.

LCR Meter

The interfacial capacitance-voltage (C-V) measurement can be carried out using the LCR meter, HP make LCR meter (model: 4284A) in Cluster & Nanostructure 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}).



Accelerator Mass Spectrometry

Accelerator mass spectrometry (AMS) is a highly sensitive method for analysis of isotopic compositions of elements. Problems of isobaric interferences from molecular species and other background sources are effectively overcome in AMS, which uses a negative ion source and subjects the ions to very high kinetic energy of several million electron volts, enabling detection of extremely low isotopic abundances of the order of 10^{-12} or less in milligram sized samples. AMS offers a convenient and fast way of analysis of radiocarbon (^{14}C)

in natural samples, which finds several applications in earth sciences and archaeology. Between 1998 and 2003, the 3 MV Pelletron accelerator of IOP was augmented for AMS measurements of ^{14}C and few other isotopes, using funds available from various agencies of Government of India, and soon became the first operational ^{14}C AMS facility of India. Being the only facility of its kind in India, the IOP AMS laboratory regularly provides ^{14}C dates to several external researchers from different organisations, catering to the ^{14}C-dating needs in diverse fields of archaeology and earth sciences.

Development of AMS analysis:

Since IOP AMS laboratory began regular ^{14}C analysis in 2005, significant improvements in analytical precisions were achieved, mainly through automation of the MC-SNICS ion source and adopting rigorous scrutiny of the raw AMS data. Measurement precision of better than 0.5% has been achieved, compared to 1% during the early phase of the AMS project.

Sample preparation laboratory for ^{14}C AMS:

Chemical sample pretreatment methods for a variety of sample types for AMS ^{14}C analysis have been streamlined. Detailed and systematic study was done to evaluate isotopic fractionation of CO_2 during various stages of sample preparation and graphite synthesis for ^{14}C AMS targets. Knowledge of this isotopic fractionation is crucial to obtain accurate ^{14}C dates. A reaction vessel has been specially designed for extraction of CO_2 from dissolved inorganic carbon (from seawater, groundwater or other sample types such as atmospheric CO_2 trapped in alkaline solution), which can minimize contamination from CO_2 in atmospheric air and isotopic fractionation.

1.3. 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 PC's 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 PC's by NFS over LAN. Twentyfour Xeon dual-CPU PC's have been configured in a cluster to execute jobs in parallel implementing PVM. Programs which require extensive numerical computation are run in the 24-CPU PC cluster. 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, XRUMP, and SIMNRA softwares are available for analysis of experimental data based on ion beam analysis. For preparing scientific documents Latex is available in the PCs running under Linux. A number of network 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 XP/Vista operating system in offices and laboratories.

The internet service to Institute is provided at dedicated bandwidth of 16 Mbps. A second internet link at dedicated bandwidth of 16mbps is being installed. 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. Seismic monitoring equipment has been installed in the Institute and seismic data are being continuously transmitted to Bhabha Atomic Research Centre using ANUNET for analysis. Institute of Physics is a node on the National Knowledge Network (NKN) and connectivity to NKN is being set up.

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

In addition to the members of the Institute, the computer facility of the Institute is being used by researchers in several universities and colleges in Odisha for acdemic work.

1.4. LIBRARY

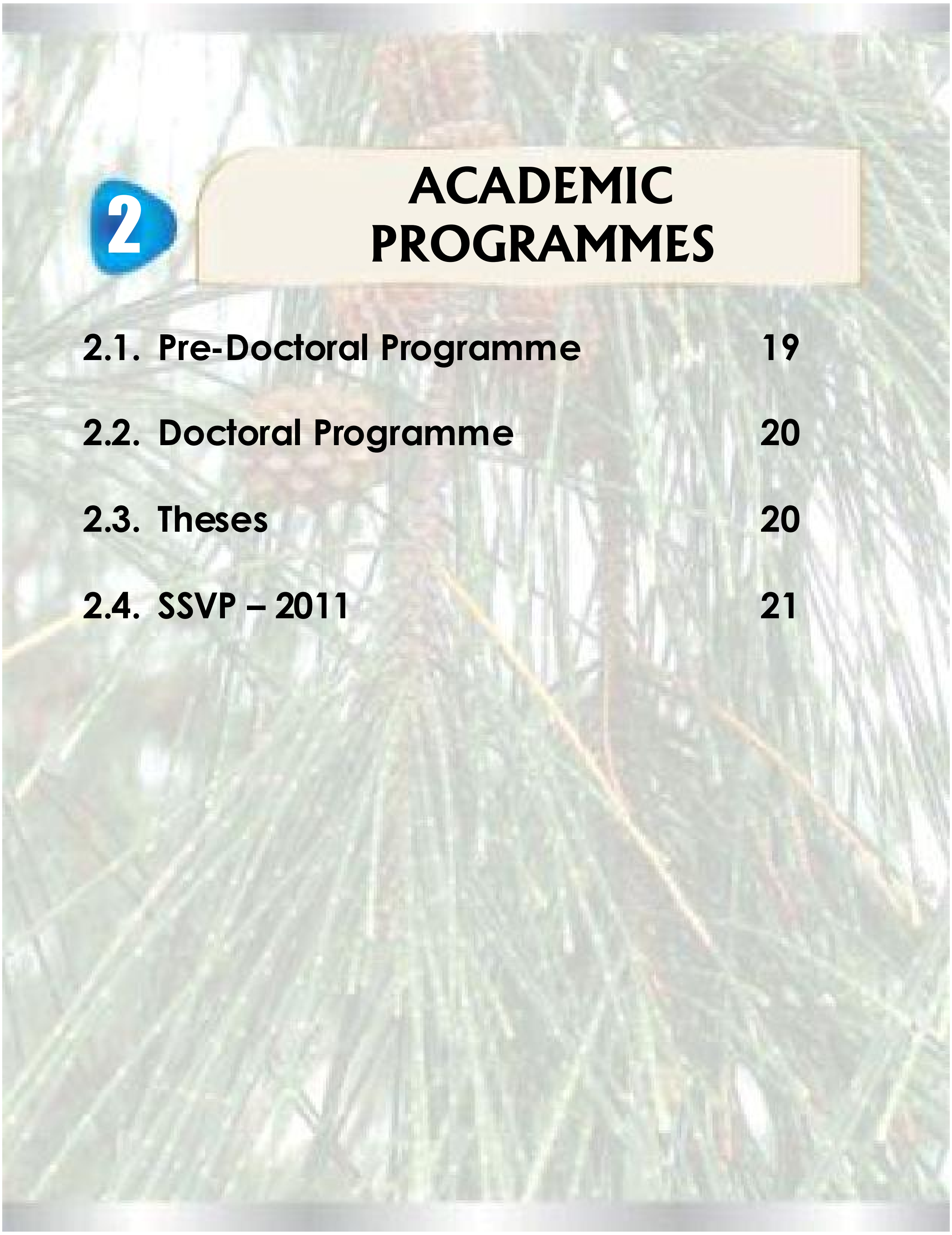
The Library facility is available to the members of the Institute, NISER as well as members from other academic institution. The Library holdings include 15,021 books and 23,570 bound volumes of Journals, taking the total collection to 38,591. Throughout the year the Library added 271 books to its collection. The Library subscribed to 139 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 has added 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 programme. The Library also sends out articles as Digital inter Library Loan (dill@iopb.res.in).

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

The Library cataloging is fully automated with Libsys 4 (Rel.6.0) 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.

Facilities like photocopying have also been automated with user codes. During the year a total no of 60,243 pages were photocopied for research purpose and official work. The Library also takes care of the Auditorium and Lecture hall facilities of the Institutes.



2 ACADEMIC PROGRAMMES

2.1. PRE-DOCTORAL PROGRAMME

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 programme.

The pre-doctoral programme of the Institute of Physics is a very important academic programme 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. programme 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 programme, 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 for the most outstanding pre-doctoral student. The fellowship consists of an award of Rs.5,000/-, and a citation.

A total of around 200 JEST qualifiers were called for interview. Of those who were selected and finally joined the Institute, the following students have successfully completed the pre-doctoral course:

1) Arpan Das
2) Subrata Kumar Biswal
3) Soumyabrata Chatterjee
4) Sumit Nandi

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

Trimester – I

Quantum Mechanics : K. Kundu
Mathematical Methods : G. Tripathy
Classical Electrodynamics : A. M. Srivastava
Theory of Experiments : T. Som
Experiments : P. V. Satyam

Trimester – II

Statistical Mechanics : A.M. Jayannavar
Advanced Quantum

Mechanics	: P. Agrawal
Field Theory	: S. Mukherji
Numerical Methods	: S. Varma
Experiment	: P. V. Satyam

Trimester – III

Condensed Matter Physics	: B. R. Sekhar
Particle Physics	: A. M. Srivastava P. Agrawal
Nuclear Physics	: S.K. Patra

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) Study of pattern formation due to ion bombardment and its applications	Arpan Das	T. Som
2) Nuclear Equation of State	Subrata Kumar Biswal	S. K. Patra
3) Renormanization Group	Soumyabrata Chatterjee	S. Mukherji
4) Polarization : A Berry Phase Approach	Sumit Nandi	S. M. Bhattacharjee

Arpan Das was adjudged the most outstanding pre-doctoral scholar and was given the **L. K. Panda Memorial** Fellowship.

2.2. DOCTORAL PROGRAMME

The Institute has presently 34 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 normallyin 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.

Nabyendu Das : *"Some aspects of quantum phase transition in incipient ferroelectrics"*, Supervisor : S. G. Mishra

Sachin Jain : *"Transport properties of strongly coupled gauge theories from Holography"*, Supervisor : A. Basu.

Binata Panda : *"Phenomenology with Magnetized D-Branes"*, Supervisor : S. Mukherji

2.4. SSVP – 2011

The Summer Student's Visiting Programme (SSVP) was held from May 2 to June 15, 2011. This year 8 students participated in the program. Under this programme, 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.

3 RESEARCH

3.1. THEORETICAL CONDENSED MATTER PHYSICS

DNA Hysteresis

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 verifiable. As a two state system, we also compare the results of DNA with that of an Ising magnet under an asymmetrical variation of magnetic field.

G. Mishra, P. Sadhukhan, S. M. Bhattacharjee & S. Kumar

Entanglement entropy

Two significant consequences of quantum fluctuations are entanglement and criticality. Entangled states may not be critical but a critical state shows signatures of universality in entanglement. A surprising result found here is that the entanglement entropy may become arbitrarily large and negative near the dissociation of a bound pair of quantum particles. Although apparently counter-intuitive, it is shown to be consistent and essential for the phase transition, by mapping to a classical problem of DNA melting. We associate the entanglement entropy to a subextensive part of the entropy of DNA bubbles, which is responsible for melting. The absence of any extensivity requirement in time makes this negative entropy an inevitable consequence of quantum mechanics in continuum. Our results encompass quantum critical points and first order transitions in general dimensions.

P. Sadhukhan & S. M Bhattacharjee

The effect of confinement on stochastic resonance in continuous bistable systems

Stochastic resonance (SR) is a phenomenon in which a feeble input signal applied to a bistable potential gets magnified at a particular noise strength. In this phenomenon noise plays a constructive role as apposed to its being looked upon as unwanted. It has previously been shown that the average injected energy to the system is the best quantifier of SR. Using this quantifier, we have shown that bistability is a necessary but not a sufficient condition for observing SR. It is observed in superharmonic (hard) potentials, but is not observed in subharmonic (soft) potentials, even though the potential is bistable. However, in both soft and hard potentials, we have observed resonance phenomenon as a function of the driving frequency. Some subtleties in the dynamics of the particle in the two different types of potentials are analyzed through the probability distributions of work done on the system over a period.

Shubhashis Rana, Sourabh Lahiri, A. M. Jayannavar

Fluctuation theorems in presence of information gain and feedback

The fluctuation relations have received a major attention in recent years, owing to their validity for systems that are arbitrarily away from equilibrium. We have generalized the fluctuation theorems in presence of feedback and measurements. Intermediate measurements on the system leads to information gain that can be used to extract more work from the system by driving it using appropriate feedback, the system being in contact with a single heat bath. This seems to be in contradiction with second law if we do not take into account information and feedback. Our treatment extends several classical theorems in the presence of information and feedback. Some of these include the Jarzynski Equality, total entropy production and Hatano-Sasa identity for transition between steady states.

We have derived in the presence of information the extended quantum fluctuation theorems in open systems composed of coupled subsystem and bath. No assumption is made on the nature of environment and the strength of system-bath coupling. However, it is assumed that the measurement process involves classical errors. We have also shown that the fluctuation relations are robust agains intermediate projective measurements of any observable.

Sourabh Lahiri, Shubhashis Rana, A. M. Jayannavar

Stochastic Resonance in Periodic Potentials

The phenomenon of stochastic resonance (SR) is known to occur mostly in bistable systems. However, the question of occurrence of SR in periodic potential systems is not conclusively resolved. Our work shows that the periodic potential system indeed exhibits SR in the high frequency regime, where the linear response theory yields maximum frequency dependent mobility as a function of noise strength. The existence of two (and only two) distinct dynamical states of trajectories in this moderately feebly-damped periodically driven noisy periodic potential system plays an important role in the occurrence of SR.

S. Saikia, A.M. Jayannavar, Mangal C. Mahato

Scattering properties of PT-symmetric quantum systems

We analyze the properties of scattering matrix for 1-D PT -symmetric systems in view of both bound and continuum states. For continuum states, conservation properties are utilized to extract physical conclusions. Asymptotic states necessarily correspond to broken PT -symmetry, leading to restricted boundary conditions, some resembling the proposed PT CPA laser [S. Longhi, Phys. Rev. A 82 (2010) 031801(R); S. Longhi, Physics 3 (2010) 61], with inelastic scattering process. It is shown that transmission is possible, only if incidence takes place from both sides of the system, which is unique to a PT -symmetric quantum mechanical system. These systems require additional conditions for scattering and transfer matrices, indicating a unique algebraic structure. The S-matrix is found to be non-unitary, satisfying a duality condition, having known optical analogues [J. C. J. Paasschens, T. Sh. Misirpashaev, C. W. J. Beenakker, Phys. Rev. B 54 (1996) 11887]. Finally, a suggestive approach towards a physical PT -symmetric norm is made.

Kumar Abhinav, P. Panigrahi and A. M. Jayannavar.

Patterns in Ge cluster growth on clean and oxidized *Si(111) - (7X7)* surfaces

Ge atoms have been deposited on domain-patterned clean Si(111) - (7X7) and Oxidized Si(111) - (7X7) surfaces. Clustering of Ge from the deposited Ge adatoms on these two kinds of surfaces shows contrasting patterns. On the clean Si surface, clustering predominantly occurs on domain boundaries, which include step edges on two sides. This leaves small domains denuded. Ge diffusion length has been estimated from the size of these denuded domains. For large domains, additional clustering is observed within the domains. For the oxidized Si surface, the pattern formation is in sharp contrast with that for the clean Si surface. In this case the domain boundaries remain relatively empty and there is strong clustering within the domains leading to the formation of dense Ge nanoislands within the domains. This contrasting pattern formation has been explained via a reaction diffusion model.

Anupam Roy , Trilochan Bagarti , K. Bhattacharjee , K. Kundu , B.N. Dev

Surface Science : A reaction diffusion model of pattern formation in clustering of adatoms on silicon surfaces

We study a reaction diffusion model which describes the formation of patterns on surfaces having defects. Through this model, the primary goal is to study the growth process of Ge on Si surface. We consider a two species reaction diffusion process where the reacting species are assumed to diffuse on the two dimensional surface with first order interconversion reaction occurring at various defect sites which we call reaction centers. Two models of defects, namely a ring defect and a point defect are considered separately. As reaction centers are assumed to be strongly localized in space, the proposed reaction-diffusion model is found to be exactly solvable. We use Green's function method to study the dynamics of reaction diffusion processes. Further we explore this model through Monte Carlo (MC) simulations to study the growth processes in the presence of a large number of defects. The first passage time statistics has been studied numerically.

Trilochan Bagarti, Anupam Roy, K. Kundu and B. N. Dev

Transport of nutrients across cell membranes:

The understanding of coupled transports of various nutrients, like glucose, fructose etc. and various ions, Na^+, K^+, Ca^{2+} etc. across cell membranes of living biological systems is a very important and challenging problem in Physics and Chemistry. Usually ions like Na^+ and nutrients are present in high concentrations inside the cell. While a large amount of nutrients is necessary for the supply of energy required for various activities of a living system, the presence of Na^+ in high concentration inside the cell is very detrimental for life. As the natural direction of movement of a species is from the higher to the lower concentration regime, Na^+ inside the cell can move out of the cell by diffusion through the membrane. As this process does not require any energy, it is called a "passive transport". On the contrary, as the transport of nutrients into the cell occurs against the gradient of concentration, it requires energy. This type of transport is called "active transport".

In order to facilitate the active transport of nutrients, many times, it is coupled to the passive transport of ions through the membrane. This coupling occurs through carrier proteins or carrier enzymes. Because of the coupling the free energy of the total process becomes negative and the transport of nutrients against the concentration gradient becomes a thermodynamically allowed process.

We note that it is a very standard process in Chemistry, where one reaction which is not thermodynamically allowed is coupled to another thermodynamicaly allowed chemical reaction with a very large free energy change so that the overall process becomes thermodynamically allowed.

We are modeling this coupled transport using an one-dimensional reaction-diffusion model. In our model reactions are occurring on the surfaces of a cell membrane. It is further assumed that that the carrier enzyme can exist in two conformations, E_1 and E_2. The conformational change happens on the surfaces. One form binds ions strongly, and releases nutrients very efficiently. The other form is a strong receptor of the nutrients, and releases ions with high efficacy. It is further assumed that enzyme bound species can diffuse through the membrane, and can undergo dissociation inside the membrane while diffusing. The diffusion process here is assumed to be one-dimensional.

The theoretical analysis of this model is under progress.

Kalyan Kundu

Local electronic properties of atomic nanowires on a Cu-nitride surface

Self-organized growth of surface supported nano-structures like atomic nanowires are likely to play important role in future electronic devices where the confined electrons show quantization phenomena. The formation and the growth behavior of epitaxial atomic nanowires of 3d, 4d and 5d elements on a corrugated Cu_3N molecular network on a Cu(110) surface have been reported. An element independent growth of nanowires consisting of 5 atomic rows (~ 1 nm in width) running along [1-10] direction on Cu_3N-Cu(110) surface was observed . The charge density of Cu(110) surface can be dramatically altered by terminating the surface with a (2 * 3) copper nitride (Cu_3N) layer. A proper understanding of the local electronic properties of the corrugated Cu_3N-Cu(110) molecular network and the atomic nanowires grown on this surface would be fundamentally important. We report here the low temperature (4.7 K) scanning tunneling spectroscopy (LT-STS) studies of both the Cu_3N layer and the Cu, Fe & Au atomic nanowires grown at room temperature on this surface. Constant height and constant current tunneling spectroscopy measurements have been carried out on the Cu_3N network and on the atomic nanowires. LT-STS studies on the Cu_3N surface show various N 2p Cu 3d hybridized states which provide important information about the chemical composition of N-Cu(110) network. Tunneling spectroscopy measurements performed on the atomic nanowires of Cu, Fe & Au show appearance of two pronounced unoccupied electronic states at ~ 1.8 eV and ~ 3.8 eV. These observations are to be understood from the electronic structure of the Cu/Fe/Au-Cu_3N-Cu(110) system by giving a theoretical model.

For the theoretical understanding of the STS spectra, we need to calculate the local density of (electronic) states (LDOS) of a nano-wire or a collection of nano-wires. In the tight binding Hamiltonian (TBH) formalism with each site of a nano-wire contributing a single Wannier orbital, LDOS at a given energy, *E* is given by

$$\rho_{ni} = \sum_i \left| C_{ni} E_i \right|^2 \delta(E - E_i)$$

where *n* is the site index and *i* is the index for the eigenstate. E_i denotes the energy of the i^{th} eigenstate. We note that in STS spectra we observe the local density of density of states.

In our calculation we are using transfer matrix method. Though it is simple and elegant for one-dimensional problems, it can be used for complex structures. Our aim is to calculate ρ_n(E) for various types of potential energy. In TBH formalism this translates to various types of site-energies. Then the calculated LDOS is compared to experimentally obtained STS spectra of a nano-wire sample. When a complete or a good matching is obtained, we get a plausible potential, though the solution may not be unique. Conceptually our approach is analogous to the inverse scattering problem in which the potential energy is found from the scattering data using "Marchenko Equation".

K. Bhattacharjee and Kalyan Kundu

Bidirectional transport in a multispecies TASEP model

We analyse the interplay between the switching dynamics of individual particles (vesicles) and their collective movement on the cellular filament. When switching is much faster than translocation, the steady state density and current profiles of the particles are homogeneous in the bulk and are well described by a Mean-Field (MF) theory, as determined by comparison to a Monte Carlo simulation. In this limit, we can map this model to the exactly solvable Partially Asymmetric Exclusion process (PASEP) model. Away from this fast switching regime, the MF theory fails, although the average bulk density profile still remains homogeneous. We study the steady state behaviour as a function of the ratio of the translocation and net switching rates, Q, and find a unique first-order phase transition at a finite Q associated with a discontinuous change of the bulk density. When the switching rate is decreased further (keeping translocation rate fixed), the system approaches a jammed phase with a net current that tends to zero as $J \sim 1/Q$. We numerically construct the phase diagram for finite Q.

S. Muhuri

Phase segregation and transport in a two species multi-lane system

We study a two channel driven lattice gas model with oppositely directed species moving on two parallel lanes with lane switching processes. We study correlated lane switching mechanism for particles so that switching may occur with finite probability only when oppositely directed species meet on the same channel. The system is analyzed for closed ring with conserved total particle number. For asymmetric particle exchange between the lanes, the system exhibits unique polarization phenomenon with segregation of oppositely directed species between the two lanes. For symmetric exchange rate of particles between the lanes, the system remains unpolarized, with equal particle density on both the lanes in the *thermodynamic limit* of large system size. The features observed for this model will have ramifications for biofilament based intracellular transport, wherein cellular cargo are transported by oppositely directed particles on multiple filament tracks.

S. Muhuri

Instrinsic oscillations of polymerizing antiparallel microtubules in a motor bath

We analyze the dynamics of overlapping antiparallel treadmilling microtubules in the presence of crosslinking processive motor proteins that counterbalance an external force. We show that coupling the force-dependent velocity of motors and the kinetics of motor exchange with a bath in the presence of treadmilling leads generically to oscillatory behavior. In addition, we show that coupling the polymerization kinetics to the external force through the kinetics of the crosslinking motors can stabilize the oscillatory instability into finite-amplitude nonlinear oscillations and may lead to other scenarios, including bistability.

S. Muhuri

3.2. THEORETICAL HIGH ENERGY PHYSICS

Gauge/Gravity Duality:

For charged black hole, within the grand canonical ensemble, the decay rate from thermal AdS to the black hole at a xed high temperature increases with the chemical potential. We check that this feature is well captured by a phenomenological matrix model expected to describe its strongly coupled dual. This comparison is made by explicitly constructing the kink and bounce solutions around the de-connement transition and evaluating the matrix model eective potential on the solutions.

B. Chandrasekhar, Sudipta Mukherji, Anurag Sahay, Swarnendu Sarkar

Holographic Cosmology

We consider general black hole solutions in ve-dimensional space-time in the presence of a negative cosmological constant. We study cosmological evolution of a time-like hypersurface via holography including the eect of shear viscosity.

S. Banerjee, S. Bhowmick, S. Mukherji

Associated production of a KK-graviton with a Higgs boson via gluon fusion at the LHC

In order to solve the hierarchy problem, several extra-dimensional models have received considerable attention. We have considered a process where a Higgs boson is produced in association with a KK-graviton (GKK) at the LHC. At the leading order, this process occurs through the gluon fusion mechanism $gg \to hG_{KK}$ via a quark loop. We compute the cross section and examine some features of this process in the ADD model.We find that the quark in the loop does not decouple in the large quark-mass limit just as in the case of $gg \to h$ process. We compute the cross section of this process for the case of the RS model also. We examine the feasibility of this process being observed at the LHC.

P. Agrawal, Ambresh Shivaji and Subhadip Mitra

Production of a KK-graviton and a vector boson in ADD model via gluon fusion

In the models with large extra-dimensions, we examine the production of a vector boson (γ/Z) in association with the Kaluza-Klein (KK) modes of the graviton via gluon fusion. At the leading order, the process takes place through quark-loop box and triangle diagrams and it is ultraviolate finite. We report the results for the LHC. We also discuss the issues of anomaly and decoupling of heavy quarks in the amplitude.

P. Agrawal, Ambresh Shivaji and V. Ravindran

Four-lepton Signature of the Higgs Boson with tau-jet tagging

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 identified as tau-jets. We find 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, Somnath Bandopadhyay

Production of Two Vector Bosons in Association with a jet via gluon fusion at LHC

We have computed the cross-sections and distributions for the production of two vector bosons and a jet via the process $gg \rightarrow VV'g$. Here V or V' could be a γ, W or Z^0 vector bosons. These processes will produce large number of events at the LHC. They can provide a way to test the standard model. These processes are also backgrounds to Higgs boson, scalar particles in supersymmetric theories, and techni-particles. In the standard model these processes occur at one loop through pentagon and box diagrams. The calculation is based on conventional Feynman diagram approach. We have developed our own numerical code, based on the method of Oldenborgh and Vermaseren, to perform the one-loop tensor reduction.

P. Agrawal, Ambresh Shivaji

Single top quark production in association with Higgs boson and anomalous vector bosons couplings

We have considered the processes $pp \rightarrow tqhX, tbhX, tWhX, tqbhX$ at the LHC to investigate the anomalous tbW, WWh, and tth couplings. We find that these couplings can enhance the cross-sections significantly. Using these processes, one can put more stringent bounds on the anomalous couplings.

P. Agrawal, Subhadip Mitra and Ambresh Shivaji

Relativistic Heavy-Ion Collisions Effect of quarks on the formation and evolution of Z(3) walls and strings in relativistic heavy-ion collisions

We investigate the effects of explicit breaking of Z(3) symmetry due to the presence of dynamical quarks on the formation and evolution of Z(3) walls and associated QGP strings within Polyakov loop model. We carry out numerical simulations of the first order quark-hadron phase transition via bubble nucleation (which may be appropriate, for example, at finite baryon chemical potential) in the context of relativistic heavy-ion collision experiments. Using appropriate shifting of the order parameter in the Polyakov loop effective potential, we calculate the bubble profiles using bounce technique, for the true vacuum as well as for the metastable Z(3) vacua, and estimate the associated nucleation probabilities. These different bubbles are then nucleated and evolved and resulting formation and dynamics of Z(3) walls and QGP strings is studied. We discuss various implications of the existence of these Z(3) interfaces and the QGP strings, especially in view of the effects of the explicit breaking of the Z(3) symmetry on the formation and dynamical evolution of these objects.

U. Gupta, R.K. Mohapatra, A. M. Srivastava, and V.K. Tiwari

Spontaneous CP violation in quark scattering from QCD $Z(3)$ interfaces

In this paper, we explore the possibility of spontaneous CP violation in the scattering of quarks and anti-quarks from QCD $Z(3)$ domain walls. The CP violation here arises from the nontrivial profile of the background gauge field (A_0) between different $Z(3)$ vacua. We calculate the spatial variation of A_0 across the Z(3) interface from the profile of the Polyakov loop $L(\vec{x})$ for the Z(3) interface and calculate the reflection of quarks and antiquarks using the Dirac equation. This spontaneous CP violation has interesting consequences for the relativistic heavy-ion collision experiments, such as baryon enhancement at high P_T. It also acts as a source of additional J/ψ suppression. We also discuss its implications for the early universe.

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

Analyzing flow anisotropies with excursion sets in relativistic heavy-ion collisions

We show that flow anisotropies in relativistic heavy-ion collisions can be analyzed using a certain technique of shape analysis of excursion sets recently proposed by us for CMBR fluctuations to investigate anisotropic expansion history of the universe. The technique analyzes shapes (sizes) of patches above (below) certain threshold value for transverse energy/particle number (the excursion sets) as a function of the azimuthal angle and rapidity. Modeling flow by imparting extra anisotropic momentum to the momentum distribution of particles from HIJING, we compare the resulting distributions for excursion sets at two different azimuthal angles. Angles with maximum difference in the two distributions identify the event plane, and the magnitude of difference in the two distributions relates to the magnitude of momentum anisotropy, i.e. elliptic flow.

R.K. Mohapatra, P.S. Saumia, and A. M. Srivastava

Quench induced oscillations and flow anisotropies in relativistic heavy-ion collisions

We model the initial confinement-deconfinement transition in relativistic heavy-ion collisions as a quench in view of expected rapid thermalization to a QGP state. The phase transition is studied using the Polyakov loop model, with the initial field (in the confining phase) covering a small neighborhood of the confining vacuum $l \simeq 0$. During the quench l rolls down in different directions from the top of the central hill in the effective potential of l when explicit Z(3) symmetry breaking effects (arising from dynamical quark effects) are small. In such a situation we find vacuum bubble like configurations arising during the quench. This first order transition like behavior occurs even though there is no metastable vacuum separated by a barrier from the true vacuum for the parameter values used. When the initial field configuration rolls down roughly along the same direction (due to large explicit symmetry breaking) then we do not find such bubble-like configurations. However, in this case we find huge oscillations of l with large length scales. We find that the different dynamics of the quench case (with large oscillations), and the equilibrium case where field evolves more slowly and uniformly, can lead to large differences in growth of flow anisotropies. These results point out that the dynamics of the order parameter field (the Polyakov loop condensate) may play an important role in determining observables such as flow anisotropies.

R.K. Mohapatra and A. 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. This is being done using SHASTA algorithm.

P.S. Saumia and A. M. Srivastava

Dual superconductor model of Hadronization

Quark confinement can be modeled using the picture of QCD vacuum as dual chromomagnetic superconductor. Using this picture we are working on simulating the process of hadronization by studying dynamics of magnetic monopole-antimonopoles pairs during a superconducting phase transition. Simulation of global U(1) symmetry breaking has been simulated in 3-D resulting in a coarsening string network. Gauge fields are being incorporated to represent Abelian Higgs model. Subsequently, magnetic monopole-antimonopole pairs will be incorporated representing quark degrees of freedom.

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

Probing the anisotropic expansion history of the universe with cosmic microwave background

We propose a simple technique to detect any anisotropic expansion stage in the history of the universe starting from the inflationary stage to the surface of last scattering from the CMBR data. We use the property that any anisotropic expansion in the universe would deform the shapes of the primordial density perturbations and this deformation can be detected in a shape analysis of superhorizon fluctuations in CMBR. Using this analysis we obtain the constraint on any previous anisotropic expansion of the universe to be less than about 35 %.

R.K. Mohapatra, P.S. Saumia, and A. M. Srivastava

Baryon inhomogeneities from CP violating Z(3) walls in the Universe

We explore the consequences of CP violating scattering of quarks from a network of Z(3) walls in the early Universe. We show that it can lead to large concentrations of baryons and antibaryons separately. This will lead to strong constraints from nucleosynthesis. It can also lead to novel models of electroweak baryogenesis.

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

Liquid Crystal Experiments
Cross-polarizer studies of vortex system: dual string model for coarsening dynamics

We investigate the coarsening dynamics of dark brushes for a 2-D vortex system in nematic liquid crystal phase. Its similarity with the coarsening dynamics of string defects in a 3-D system are explored.

Ajit M. Srivastava

String winding studies in extra compact dimensions

We are continuing to develop a setup with rotating cylinder of optical fiber (of 50 micron diameter) where a thin film of nematic liquid crystal on the cylinder will be heated and cooled. Resulting string network will be analyzed to determine the universal winding number per correlation length. New digital camera with low light sensitivity, high resolution, and relatively fast frame speed is being procured, along with special objectives for hot stage and with large working space.

Ajit M. Srivastava

3.3. THEORETICAL NUCLEAR PHYSICS

Study of nuclear fission for neutron-rich nuclei

The structural properties of the recently predicted thermally fissile neutron-rich Uranium and Thorium isotopes are studied using the relativistic mean field formalism. The investigation of the new phenomena of multifragmentation fission is analysed. 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, S.K. Patra

Half-lives of proton emitters using relativistic mean field theory

The proton radioactivity lifetimes of proton emitters from the ground and the isomeric states are calculated using the microscopic M3Y + Ex and R3Y + Ex (proposed) nucleon-nucleus interaction potentials. These interaction potentials are obtained by single folding the densities of the daughter nuclei supplemented by a zero-range pseudopotential. The quantum-mechanical-tunneling probability is calculated within the WKB approximation. The calculated results are found to be in good agreement with the experimental data for both the M3Y and R3Y interactions.

B. B. Sahu, S. K. Agarwalla and S. K. Patra, Phys. Rev. C84, 054604 (2011); BirBikram Singh, M. Bhuyan, S. K. Patra and Raj K. Gupta.

Structures of exotic and superheavy nuclei

We have calculated the binding energy, root-mean-square radius and quadrupole deformation parameter for the recently synthesized superheavy element Z=117, using the axially deformed relativistic mean field (RMF) model. The calculation is extended to various isotopes of Z=117 element, starting from A=286 till A=310. We predict almost spherical structures in the ground state for almost all the isotopes. A shape transition appears at about A=292 from a prolate to an oblate shape structure of Z=117 nucleus in our mean field approach. The most stable isotope (largest binding energy per nucleon) is found to be the $^{288}117$ nucleus. Also, the Q_α-values and the mean-life times T_α for the α-decay chains of $^{293}117$ and $^{294}117$ are calculated, supporting the magic numbers at N=172 and/ or 184.

The 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 macroscopic-microscopic calculations. The calculation is extended for the α-decay chains of $^{292}120$ and $^{304}120$ from their exited state configuration to respective configuration, which predicts long half-life $T^{\alpha}_{1/2}$ (sec.).

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 different states like spherical prolate and oblate shape for the recently synthesised $Z=105$ to 118 nuclei in different laboratories, along with these nuclei Z=120 was also taken for study, using non-relativistic (SHF) and relativistic (RMF-NL3* model. Life-time T_α 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 β_2, root mean square charge, neutron, proton and matter radii and two neutron separation energy, using relativistic mean field model with NL3 parameter set. We copared our data with finite range droplet model (FRDM) and infinite nuclear matter (INM) model.

M. Bhuyan, S. K. Patra and Raj K. Gupta, M. Shakeb, S. K. Singh, M. Ikram, S. Mohapatro

Nuclear reaction

We calculate the nuclear reaction cross-section for some of the ultra neutron-rich 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, M. S. Mehta and S. K. Patra

High Spin States (Nuclear Spectroscopy)

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

B. B. Sahu, S. K. Singh, M. Bhuyan, S. K. Ghorui, Z. Naik, S. K. Patra and C. R. Praharaj

Equation of state in Infinite Nuclear Matter

Recently, the isospin and density dependence of the nuclear symmetry energy E_{sym}, is the current interest for its implications not only in the above problem as well as in astrophysics. Mean while the novel phenomena like formation of superheavy nuclei in astrophysical system also improved by using a proper value E_{sym}, which also front learning about the island of stability at superheavy regions. Here, we introduce a new term in the Lagragian, which is the combined effect of isoscalar-vector and isovector-vector field with coupling constant (Λ_v). The effect of newly added term to the E_{sym}, K_0 and all other co-efficient are studied. The quest in EOS is the stiffness of the E_{sym} with respect to baryonic density may solve by introducing the adove defined coupling constant Λ_v without affection all other observables quantatively in the infinite nuclear matter and finite nuclei. It is worthy to mention that, without this additional constant, one cannot overcome the hindrance. As a results the modofied Lagrangian with the new coupling term used here for the study of nuclear matter properties. From the Lagrangian, we derived the energy and pressure density along with all meson field equations. All the equations are solved self-consistent by numerical methods.

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

Simple effective interaction

The study of nuclear properties from finite nucleus to highly isospin asymmetric dense nuclear matter in a given model is a promising area of current nuclear research. The relativistic and non-relativistic microscopic models, such as, Dirac-Brueckner-Hartree-Fock (DBHF), Brueckner-Hartree-Fock (BHF) and calculations using realistic interaction are considered to be standard calculations for reference in the regime of nuclear matter (NM), but *ab initio* extension to finite nucleus calculation in these models is still in rudimentary stage. To overcome this quest, we defined a simple effective interaction (SEI) and apply this to infinite nuclear matter as well as finite nuclei study. For the same, the *ab initio* extenation of the SEI having Gaussian form for $f(r)$ to finite nuclei has been performed in the quasilocal Density Functional Theory (DFT) model. We note here that all the nine parameters adjusted initially for infinite nuclear matter and used these parameters for finite nuclei along with W_0 (spin-orbit strength) are adjusted to produced the bulk properties and single particle spectra of double closed nuclei. We have done this *ab initio* calculation for infinite nuclear matter and finite nuclei.

M. Bhuyan, T. R. Routray and S.K. Patra

Nuclear Astrophysics:

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_{odt}.

The conversion of NS to SS/HS is a highly energetic process, as in such conversion processes the EOS of matter changes, leading to a change in the mass of the star. Special theory of relativity gives mass in terms of energy, such conversion leads to huge energy release, of the order of 10^{53} ergs. We have studied the energy released by such conversion, with stars having mass close to that suggested by PSR J1614-2230. We studied the energy released by normal pulsars and also by magnetars. As already stated the final state of the star may be a SS or a HS, we have calculated the energy release for the different final states. We have found that the energy released in the conversion of NS to SS is greater than the conversion of NS to HS. Huge magnetic fields modifies the EOS of the matter and thereby affects the conversion process, whose effect can be seen in the difference of the amount of the energy released by normal NS and magnetars. The energy released by magnetars is less than that of normal pulsars. The amount of energy released by such conversion can only be compared to the energy observed in the gamma ray bursts (GRBs). Calculating such energies we have tried to see whether we can have any observable signatures which can point to the difference between NS and magnetars.

R. Mallick and P. K. Sahu

SO(10) model at LHC

We show how gauge coupling unification is successfully implemented through non-supersymmetric grand unified theory, $SO(10)\times G_f \sim G_f=S_4$, SO_{3_f}, SU_{3_f}, using low-scale flavor symmetric model of the type SU_{2_L} X U_{1_Y} X SU_{3_C} X S_4 recently proposed by Hagedorn, Lindner, and Mohapatra, while assigning matter-parity discrete symmetry for the dark matter stability. For gauge coupling unification in the single-step breaking case, we show that a color-octet fermion and a hyperchargeless weak-triplet fermionic dark matter are the missing particles needed to complete its MSSM-equivalent degrees of freedom. When these are included the model automatically predicts the nonsupersymmetric grand unification with a scale identical to the minimal supersymmetric standard model/grand unified theory scale. We also find a two-step breaking model with Pati-Salam intermediate symmetry where the dark matter and a low-mass color-octet scalar or the fermion are signaled by grand unification. The proton-lifetime predictions are found to be accessible to ongoing or planned searches in a number of models. We discuss grand unified origin of the light fermionic triplet dark matter, the color-octet fermion, and their phenomenology. We plan to to extend our model SO(10) to find natural Higgs boson mass scales for observable matter and antimatter oscillations.

M. K. Parida and P. K. Sahu

3.4. HIGH ENERGY NUCLEAR PHYSICS

Heavy-ion collisions:

The strongly decaying particles having lifetime (ô) of the order of 10^{-23} sec are called resonances. It carries a set of quantum numbers (spin, isospin, etc) like normal particles. It differs from regular particles in that its mass is smeared and has 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 when the inelastic interactions among hadrons cease and this is known as the chemical freeze-out. Kinetic freeze-out is reached when there is no further elastic interactions among the produced hadrons. As 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 (unscattered resonances) 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 are working on Ë* (1520), which is an excited state of Ë (1115.5), has PDG mass 1519.5 ±1.0 MeV and width (Ã) 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 the elliptic for Ë*.

For ALICE Collaboration :

At FAIR energies the charm sector becomes accessible and measurements of charm will be performed for the first time in heavy ion collisions. 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 antiquark 'c ' in the plasma. The 'c' quark subsequently hadronize by combining with light quarks or light antiquarks to emerge as open 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 Jpsi supression and D meson production at low temperature and high baryon density theoretically and compare our calculation with data available from CBM experiments later. Also we study the kinematics, flow ansd viscous effect in heavy ion collision at high baryon density and low temperature for these particles.

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

For CBM 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 sN N = 7.7, 11.5 and 39 GeV in the year 2010. The chemical and kinetic freeze-out pa- rameters 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 sN N = 7.7, 11.5, and 39 GeV. 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 Tch , baryonic chemical potential μB , strangeness chemical potential μS , and strangeness suppression factor S . The grand-canonical ensemble (GCE) approach is used to fit the experimental particle ratios and to obtain the chemical freeze-out parameters. The extracted Tch increases with increasing energy and also shows a slight increase as we go from peripheral to central collisions for all energies. The μB increases with decreasing energy. This is because of large baryon stopping at mid-rapidity at low energies. The μB also shows a slight increase from peripheral to central collisions for these energies.

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

STAR Collaboration:

One of the most important experimental findings at RHIC has been the evidence of coalescence of quarks as the dominating mechanism for hadronization from a deconfined plasma at the intermediate transverse momentum (1.5 < pT < 5 GeV/c). However, it is experimentally difficult to study how local correlations and energy/entropy play a role in coalescence since the partonic constituents are not directly observable. In relativistic heavy-ion collisions, light nuclei and anti-nuclei are formed through coalescence of nucleons and anti-nucleons. The advantage of nucleons over the partonic coalescence phenomena is that both the nuclei and the constituent nucleon space-momentum distributions are measurable quantities in heavy-ion collisions. By studying the elliptic flow of nuclei and comparing to those of their constituents (nucleons), we will have a better understanding of coalescence process for hadronization.

We have studied v2 of d(d) and 3 H e(3 H e) in Au+Au collisions at sN N = 200 GeV and 39 GeV. The Au+Au 200 GeV and 39 GeV data were taken with the STAR detector at RHIC in the year 2007 and 2010, respectively. The v2 values for light nuclei are scaled to the number of constituent quarks (NCQ) of their constituent nucleons and are consistent with NCQ scaled v2 for baryons and mesons. The dominance of partonic collectivity in the transverse expansion dynamics in these collisions naturally produces such a consistent picture. The v2 of light nuclei are in good agreement with the dynamical coalescence model calculation in Au+Au collisions at sN N = 200 GeV. In this model, the probability for producing a cluster of nucleons (d, t and 3 H e) is determined by the overlap of its Wigner phase-space density with the nucleon phase-space distributions at freeze-out. To determine the Wigner phase-space densities of the d, t and 3 H e, we take their hadron wave functions to be those of a spherical harmonic oscillator. The coordinate and momentum space distributions of hadrons at freeze-out are obtained from AMPT model calculation. We have also studied the mass dependence of average transverse momentum (< pT >) and the average v2 and compared those with Tsallis Blast-Wave (TBW) model predictions. Both v2 and < pT > trends are consistent with expectations from TBW model fit.

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

3.5. QUANTUM COMPUTATION

Quantum States, Entanglement and Closed Timelike Curves

We investigate the nature of quantum states (density operators) and entanglement in quantum theory with closed timelike curves. One of the key concepts in the standard quantum theory is that given any mixed state we can always purify it in an enlarged Hilbert space by bringing an ancillary system. The purified state does not depend on the state of any extraneous system with which the mixed state is going to interact and on the physical interaction. Here, we prove that it is not possible to purify a mixed state that traverses a closed time like curve (CTC) and allowed to interact in a consistent way with a causality respecting (CR) quantum system. Thus, in general for arbitrary interactions between the CR and the CTC systems there is no universal Church of the larger Hilbert space for mixed states with CTC. This shows that in quantum theory with CTCs there can exist proper and improper mixtures. Also, we suggest what kind of entangled states are allowed in the presence of CTCs. We argue that the nature of entanglement can be different in the presence of such exotic objects. We also discuss how the no-hiding theorem in the presence of CTCs may allow quantum information pop-up.

P. Agrawal, Arun Pati and Indranil Chakrabarty

CTC assisted PR box type correlation can lead to signaling

It has been shown that there exist non-local correlations that respect no-signalling criterion, but violate Bell-type inequalities more than quantum-mechanical correlations. Such superquantum correlations were introduced as the Popescu-Rohrlich (PR) box. This box has two binary inputs and two binary outputs. These boxes have been generalized to three inputs and outputs. We consider such non-local boxes with two/three inputs and two/ three outputs. We show that these superquantum correlations can lead to signaling when at least one of the input bit has access to a word line along a closed time-like curve.

P. Agrawal, Arun Pati, Tanumoy Pramanik and Indranil Chakrabarty

Discord and Quantumness

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

P. Agrawal, Arun Pati and Indranil Chakrabarty

3.6. EXPERIMENTAL CONDENSED MATTER PHYSICS

During this period, 2011 – 12, major work has been carried out in understanding the interfaces and their active role various interesting structural evaluations. extensive study on the formation of Au-Si and Au-Ge nano structures under different thermal annealing conditions achieved by varying parameters such as, pressure, film thickness, substrate, presence or absence of native oxide on the substrate, temperature etc.

Mr. Rath's and Mr. J. K. Dash.

Oriented growth of Gold Nanostructures under Low Vacuum and High Temperature conditions

Various thicknesses of gold thin films were deposited using MBE as well as thermal evaporation technique. Difference in the temperature dependent behavior of gold nanostructures on Si (100) surfaces in presence and absence of native oxide layer were studied in-situ using a hot-stage holder (GATAN, Model 628). In case of MBE samples, formation of highly oriented square /rectangular shape nano structures were observed at high temperatures (500°C). Strain relaxation and substrate symmetry plays a major in the alignment of these Au-Si nanostructures. In case of samples with native oxide layer, formation of bigger sized rectangular structures was observed at higher temperatures (850°C). At these high temperatures, desorption of the gold silicide followed the symmetry of the substrate. Native oxide at the interface was found to act like a barrier for the inter-diffusion phenomena. At these higher temperatures, due to desorption of native oxide present at the interface, rectangular structures were formed. We observed desorption of gold and /or gold silicide structures and formation of symmetric hole like structures in some cases. Using different thicknesses of gold films in both cases (with and without native oxide layer), size of the nanostructures could be controlled.

A. Rath, J. K. Dash, R. R. Juluri, A. Ghosh, A. Bhukta , A. Rosenauer, Marcos Schoewalter and P.V. Satyam

Thickness Dependence on the shape control of oriented Au structures:

In thickness dependent studies (5, 11.7 and 50 nm Au on SiO_x/Si) at low vacuum (H"10^{-2} mbar) annealing did not reveal any alloy formation, rather well oriented gold nanostructures at high temperature (H" 975° C) was observed. The shape of the oriented structures can be tuned with a variable initial thickness of gold films: Au films with lower thickness (d"5 nm) lead to spherical particles. Increasing the film thickness result in the formation of oriented and faceted gold structures. The effects of native oxide layer on morphology, orientations of the structures were studied in detail. Interfacial oxide layer, low vacuum and high temperature annealing conditions are found to be necessary to grow oriented gold structures. We also showed that oriented microstructures cannot be fabricated without oxide layer at the interface (using MBE method). These gold structures can be transferred by simple scratching method.

Vacuum Dependence and Surface Morphology variations:

We extended our understanding of the influence of vacuum conditions upon the formation of nanostructures in presence and absence of oxide layer. A ~2 nm Au deposited on SiOx/Si by thermal evaporation method was annealed at high temperature (850°C) under both high vacuum (HV) and low vacuum (LV) conditions. In HV, gold silicide rectangles were observed following the four-fold symmetry of the substrate due to selective thermal decomposition of native oxide layer, where as in LV does not show any such formation. This has been explained as due to low vacuum which ensures that the rate of formation(redeposition) of oxide over takes over the rate of oxide decomposition in a relatively oxygen rich environment compared to high vacuum conditions. To study the effect of vacuum conditions on MBE grown samples (without oxide layer), 2nm Au/Si(100) sample was annealed at 500°C in three different vacuum conditions: (i) LV external furnace (H”10^{-2} mbar), (ii) ultra high vacuum (UHV at H”10^{-10} mbar) chamber (MBE chamber), (iii) HV(H”10^{-7} mbar). Although well aligned nano rectangles were formed in both HV and LV, corner rounding is more prominent in LV. Furthermore in UHV, random structures were formed having sharp corners. In all the above three cases, samples were exposed to air before annealing. To study the effect of surface oxide, *in-situ* annealing inside UHV-MBE chamber was done without exposing to air. Well aligned rectangles with sharp corners (no corner rounding) were formed.

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

Nano scale phase separation in Au-Ge system on ultra clean Si(100) surfaces:

One of the utilization of such Au-Si nanostructures as a catalyst is to study the controlled formation of lobe-lobe (bi-lobed) Au-Ge nanostructures under UHV conditions on clean Si(100) surfaces. For this study, H”2.0 nm thick Au films were grown by molecular beam epitaxy (MBE). Nearly square shaped Au_xSi_{1-x} nano structures of average length H” 48 nm were formed after UHV annealing at temperature H”500°C. A H”2 nm Ge film was further deposited on the annealed sample while the substrate was kept at H”500°C. Well ordered Au-Ge nanostructures where Au and Ge residing side by side (lobe-lobe structures) were formed. In our systematic studies, we show that, gold-silicide nano alloy formation at the substrate (Si) surface is necessary for forming phase separated Au-Ge bilobed nanostructures. The morphology of such bi-lobed structures has been tuned by varying thickness (amount) of the Ge, substrate temperature and sequence of material deposition. It has been studied that the bonding between Au and Ge is unstable which leads to the phase separation. Our results also indicate that Si-Ge bonding is more preferred to Au - Ge bond. This observation of phase separation at nanoscale would be very useful for proper understanding of gold contacts on Si Ge based devices.

To study this nanoscale phase separation and its effect on the formation bilobed structures, we replaced the Si(100) with Ge(100) substrate. For this study, H”2.0 nm thick Au films were grown by MBE. Nearly square shaped Au_xGe_{1-x} nano structures were formed after UHV annealing at temperature H”500°C. A H”2 nm Ge film was further deposited on the annealed sample while the substrate was kept at H”500°C. Well distributed Au-Ge nanostructures with Au on the top of the pedestal Ge were formed. It is very interesting to notice that no Au-Ge bilobed structures were formed like previous case. To study the temperature dependence, similar Ge deposition was performed at the substrate temperature of 600°C. The height of the pedestal Ge increased with temperature. The detailed study of the Au-Ge interface has been done in this work.

A. Rath, J. K. Dash, R. R. Juluri, Marco Schowalter, Knut Mueller, A. Rosenauer and P.V. Satyam

Ge growth on High Index Si surfaces: Si (5 5 12), Si (5 5 7) and Si (5 5 3):

The shape evolution of Si-Ge nanostrucrures on various high index silicon surfaces, grown by Molecular Beam Epitaxial (MBE) under ultra-high vacuum (UHV) would be reported. The morphological dynamics have been analyzed in different thermodynamic growth conditions and substrate orientations. A comparative study of the Si-Ge structures on the ultraclean reconstructed high index surfaces, such as, Si(5 5 12), Si(5 5 7) and Si(5 5 3), has been presented in terms of shape transformations with varying substrate temperature, growth coverage and mode of annealing condition. The anisotropic surface reconstruction inherent to high-index silicon surfaces makes them potentially significant substrates for electronic device fabrication. These surfaces, consisting of periodic steps and terraces, have attracted renewed attention as templates for the controlled growth of aligned one dimensional (1D) nanostructures. The implementation of Ge nanostructures into Si based devices is of great potential for future high-speed devices, due to advantages like enhanced carrier mobilities and smaller bandgap, and hence is attracting an increasing interest in fundamental and applied research. A large number of experimental works were devoted to investigate the formation of Si-Ge islands on clean silicon substrates of various orientations due to its use as a model system to understand complex issues related to hetero-epitaxy and technological application. Application of Ge/Si may be found in silicon-based optoelectronics. Due to the indirect band gap, Si devices are not well suited for optoelectronic applications. New devices employing Ge/Si epitaxial layers are expected to overcome this restriction. $Si_{1-x}Ge_x$ alloys show smaller fundamental bandgaps compared to Si, because of larger lattice constant and altered lattice constituents and, due to the acquired tetragonal symmetry in pseudomorphic layers. Strained Si-Ge technology has been recognized as a promising solution for high-performance devices, because of its cost-eûectiveness and high carrier mobility. To maximize the transport properties, it is required to tailor the defect morphology as well as the surface morphology properly. Composition grading is one of the well-established techniques to prevent dislocations from reaching the surface.

In the past, the growth of Ge nanostructures on low index silicon substrates (such as Si(100), Si(111)) has been studied extensively. However, less attention has been paid to Ge growth on high-index Si substrates. Hence, the study of self-assembly of Ge on high-index silicon surfaces would be an important field of research in obtaining various types of aligned nanostructures that may be useful in optoelectronic devices. Among the high index silicon surfaces oriented between (001) and (111), Si(5 5 12) exhibits 1D symmetry with a $(1\bar{1}0)$ mirror plane. Si(5 5 12) is oriented 30.5° away from (001) towards (111) with one-dimensional periodicity over a large unit cell . Si(5 5 7) has a vicinal angle of 9.45° from (111) towards $(11\bar{2})$. The highly corrugated triple step structure of the Si(5 5 7) surface is easier to detect than other long-range surface reconstructions. A Si(5 5 3) surface, which is tilted at -12.27° from the (111) plane towards the (0 0 1) plane, is one of the important high index Si surfaces. In all the above vicinal surfaces, the step edges are parallel to the $\langle 1\bar{1}0\rangle$ direction.

J. K. Dash, A. Rath, T. Bagarti, R. R. Juluri, A. Ghosh, A. Bhukta , and P.V. Satyam

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

In the growth of Ge nanostructures and microstructures on ultraclean, reconstructed high index Si(5 5 12) surfaces show that self-assembled growth at optimum thickness of the overlayer leads to interesting shape transformations, namely from nanoparticle to trapezoidal structures, at higher thickness values. The reconstruction has been confirmed with in-situ reflection high energy electron diffraction (RHEED). Thin films of Ge of varying thickness from 3 to 12 ML were grown under ultrahigh vacuum conditions on a Si(5 5 12) substrate while keeping the substrate at a temperature of 600°C. The substrate heating was achieved by two methods: (i) by heating a filament under the substrate (radiative heating, RH) and (ii) by passing direct current through the samples in three directions (perpendicular, parallel and at 45° to the step direction). The temperature was monitored with an infra-red pyrometer calibrated with a thermocouple attached to the sample holder. We found irregular, more spherical-like island structures under RH conditions. The shape transformations have been found under DC heating conditions and for Ge deposition more than 8 ML thick. The longer sides of the trapezoid structures are found to be along irrespective of the DC current direction. Also the absence of such a shape transformation in the case of Ge deposition on Si(111) substrates has been shown. Scanning transmission electron microscopy (STEM) measurements suggested the mixing of Ge and Si . This has been confirmed with a quantitative estimation of the intermixing using Rutherford backscattering spectrometry (RBS) measurements. A part of the thesis work is devoted to the theoretical modeling which complements the shape evolution mechanism. The theoretical model includes 2D kinematic Monte Carlo (kMC) simulation, which is a phenomenological model that was intended to explain the phenomena of shape transition observed in the experiments. In our model, we introduce anisotropy through binding energies of different types of bonds and the dependence of surface barrier on the direction of hopping. A deviation parameter (e) was introduced in the surface barrier term (E_D) to take the effect anisotropic diffusion , as one of the plausible mechanism.

We growth and shape evolution and compositional analysis of $Si_{1-x}Ge_x$ structures on three high index silicon surfaces Si(5 5 12), Si(5 5 7) and Si(5 5 3). A comparative analysis of these structures has been done under different growth conditions varying growth coverages, substrate temperature and mode of heating. A phenomenological theoretical modeling with 2D kinetic Monte Carlo Simulation compliments the experimental findings.

J. K. Dash, A. Rath, T. Bagarti, R. R. Juluri, A. Ghosh, A. Bhukta , and P.V. Satyam

Nanodot to nanowire: A strain-driven shape transition in self-organized endotaxial $CoSi_2$ on Si(100)

A phenomenon of strain-driven shape transition in the growth of nanoscale self-organized endotaxial CoSi2 islands on Si(100) substrates has been worked out. Nanodots of CoSi2 grow in the square shape following the four fold symmetry of the Si(100) substrate, up to a critical size of 67_67 nm2, where a shape transition takes place. Larger islands grow as nanowires with ever increasing length and the width decreasing to an asymptotic value of_25 nm. This produces long nanowires of nearly constant width. The endotaxial nanostructures grow into the Si substrate with a small extension above the surface.

J. C. Mahato, Debolina Das, R. R. Juluri, R. Batabyal, Anupam Roy, P. V. Satyam, and B. N. Dev, APL 2012.

Optimization of the preparation of GaN-based specimens with low-energy ion milling for (S)TEM

We report on optimization of electron transparent GaN based specimens for transmission electron microscopy (TEM) and scanning TEM (STEM) studies by combining focused ion beam thinning and low-energy (d"500 eV) Ar-ion milling. Energy dependent ion milling effects on GaN based structures are investigated and the quality of ion milled samples is compared with that of specimens prepared by wet chemical etching. Defects formed during ion milling lead to amorphization of the specimen. The experimental results are compared with Monte-Carlo simulations using the SRIM (stopping and range of ions in matter) software. Specimen thickness was deduced from high-angle annular dark field STEM images by normalization of measured intensities with respect to the intensity of the scanning electron probe and comparison with multislice simulations in the frozen lattice approach. The results show that the thickness of the amorphous surface layer can be successfully reduced below 1 nm by low energy ion milling, leading to a homogeneous image contrast in TEM and STEM, so that good conditions for quantitative analysis can be achieved. For an ion energy of 400 eV the thickness measurements resulted in an etching rate of about 6–8 nm/min, Micron 2012.

Thorsten Mehrtens, Stephanie Bley, P. V. Satyam, Andreas Rosenauer

Composition mapping in InGaN by scanning transmission electron microscopy

We suggest a method for chemical mapping that is based on scanning transmission electron microscopy (STEM) imaging with a high-angle annular dark field (HAADF) detector. The analysis method uses a comparison of intensity normalized with respect to the incident electron beam with intensity calculated employing the frozen lattice approximation. This procedure is validated with an In0.07Ga0.93N layer with homogeneous In concentration, where the STEM results were compared with energy filtered imaging, strain state analysis and energy dispersive X-ray analysis. Good agreement was obtained, if the frozen lattice simulations took into account static atomic displacements, caused by the different covalent radii of In and Ga atoms. Using a sample with higher In concentration and seriesof 32 imagestaken within 42 min scan time, we did not find any indication for formation of In rich regions due to electron beam irradiation, which is reported in literature to occur for the parallel illumination mode. Image simulation of an In0.15Ga0.85N layer that was elastically relaxed with empirical Stillinger– Weber potentials did not reveal significant impact of lattice plane bending on STEM images as well as on the evaluated In concentration profiles for specimen thicknesses of 5, 15 and 50nm. Image simulation of an abrupt interface between GaN and In0.15Ga0.85N for specimen thicknesses up to 200 nm showed that artificial blurring of interfaces is significantly smaller than expected from a simple geometrical model that is based on the beam convergence only. As an application of the method, we give evidence for the existence of In rich regions in an InGaN layer which shows signatures of quantum dot emission in micro-photoluminescence spectroscopy experiments ,tramicroscopy 2012,

A. Rosenauer, T. Mehrtensa, K. Muller, K. Gries, M. Schowalter, P. V. Satyam, S. Bley, C. Tessarek, D. Hommel, K. Sebald, M. Seyfried, J. Gutowski, A. Avramescu, K. Engl and S. Lutgen,

MeV Au $^{2+}$ ions induced surface patterning in silica

This paper reports the formation of self-organised surface morphological features on silica irradiated with MeV energy gold ions. Amorphous silica substrates were irradiated with 1.8 MeV gold ions at normal incidence at room temperature to various doses in the range of 5 × 10^{16} ions/cm^2 to 2 × 10^{17} ions/cm^2. The formation of a periodic surface pattern with a wavelength of 1.35 mm was observed at an irradiation dose of 1 × 10^{17} ions/cm^2. The observation of surface segregation of gold at around the same dose suggests possible role of surface stresses caused by the incorporation of metal atoms in the formation of the observed periodic surface morphology, Applied Surface Science 2012,

P. Santhana Raman, K.G.M. Nair, M. Kamruddin, A.K. Tyagi, A. Rath, P.V. Satyam, B.K. Panigrahi, V. Ravichandran

Structure of the occupied and un-occupied bands of Graphite - an ARPES study

Recent research activities on the two dimensional material graphene has given an impetus to the reinvestigation of some of the exotic and fundamentally important physical properties of carbon based materials. Like graphene, which shows a peculiar low energy electronic spectrum due to its sublattice structure, graphite also has a linear dispersion near the H point along with its quadratic band near the K point of its Brillouin zone. Many physical properties like the transport and magnetic behaviours, in single crystal graphite and in highly oriented pyrolytic graphite (HOPG) are not well understood and might be governed by the carrier dynamics near their Fermi energy (E_F). The near E_F electronic structure on both the occupied and the unoccupied sides are important for a consolidated understanding of the physics behind these properties. Although, there have been many experimental studies earlier on the electronic structure of the occupied states of graphite, recent works have shown many new results owing mainly to the improved experimental techniques. On the other hand, only a few studies have been reported recently on the electronic structure of the unoccupied states. We made a comparative study of the near fermi-level electronic structure of single crystal HOPG. Angle resolved photoelectron spectroscopy and angle resolved inverse photoelectron spectroscopy have been used to probe the occupied and unoccupied electronic states, respectively. The band dispersions showed by single crystal graphite along its G-K and G-M symmetry directions were found to be in agreement with calculated band structure of graphite. The p bands of single crystal graphite were found to have a splitting of 0:5 eV at the K-point. We also observe the presence of a quasiparticle peak below E_F at the K point at low temperature which indicates a strong electronâ€"phonon coupling in graphite. In HOPG, the M and K points like features were found to be present in the same radial direction due to the superposition of the G-M and G-K directions. Results from our angleresolved inverse photoemission spectroscopy present the dispersion of the conduction band states, particularly the lower pn band. We have also found the presence of some non-dispersive features in both the valence and the conduction bands.

B. R. Sekhar

Electronic structure of Electron Doped CMR Materials

Strong interplay of charge, spin, and lattice degrees of freedom of electrons form the basis of the phenomena of colossal magnetoresistance (CMR) shown by manganites. To a large extent, the traditional models employing the charge-spin coupling, have been able to explain the CMR in many of the hole-doped compositions ($R_{1-x}A_xMnO_3$ with $x \ll 1/2$, where R is a trivalent lanthanide and A is a divalent alkaline-earth element). But, much less is known about the electron-doped versions of these materials with $x \rightarrow 1$. The charge, orbital and spin ordering add complexity to the ferromagnetic double exchange and the superexchange interactions in these materials. These Mn(IV) rich compositions exhibit marked differences from their Mn(III) rich counterparts in their electronic and magnetic properties. For example, their electrical conductivity behavior in the range of 150 - 300 K was found to be distinctly different from the hole-doped materials. Further, earlier studies have shown the existence of dynamic ferromagnetic spin correlations at high temperatures and antiferromagnetic correlations at low temperatures in these electron-doped systems. Recent studies on thin film and nanoparticle forms of different CMRcompositions have highlighted the role of dimensionality in such phase coexistence. The coexisting magnetic phases in these materials are the focus of new models proposed to explain the metal-insulator transitions in doped 3d metal oxide compounds. We have studied the temperature-dependent changes in the near E_F electronic structure of the electron-doped, phase separated colossal magnetoresistance (CMR) compound, $Ca_{0.86}Pr_{0.14}MnO_3$ using photoemission and x-ray absorption studies. At low temperatures, this compound shows a high e_g electron density near the E_F though the compound is insulating. Photoemission measurements further showed a temperature dependence of the e_g electron occupation and localization while the complementary results of XAS showed corresponding changes in the number of unoccupied states. Our results indicate a transfer of charges from the t_{2g} states to the e_g band, probably due to a decrease in the crystal field splitting in the ferromagnetic metallic (FMM) phase following the structural changes of the MnO_6 octahedra at low temperatures. We have interpreted our results from a FMM-antiferromagnetic insulating (AFMI) phase separation scenario.

B. R. Sekhar

Electronic structure of $Bi_{1-x}Pb_xFeO_3$

Multiferroic materials have been attracting a lot of interest due to the complex spin coupling between their co-existing magnetic and ferroelectric (FE) orders. Technologically, these materials are important for the construction of multifunctional devices in the field of spintronics and sensors. Most studied among them, the $BiFeO_3$, has its antiferromagnetic (AFM) and FE orders originating from the $6s^2$ lone pair electrons of the off-center located Bi ions and the partially filled d orbitals of the Fe ions respectively. The large spontaneous FE polarization shown by this material was initially thought to be due to the heteroepitaxial constraint on its crystal structure. But, recent measurements on thin films and single crystals have shown that this FE polarization arises from the structural modifications or the different FE paths. These studies have further shown that the FE polarization is intrinsic to the $BiFeO_3$ and depends strongly on the topology of the oxygen octahedra in its structure. We have studied the valence band electronic structure of the $Bi_{1-x}Pb_xFeO_3$ (x = 0.02 - 0.15) system by using X-ray and ultra-violet photoelectron spectroscopy. As this system undergoes a R3c to cubic phase transition with Pb doping, the near Fermi level states show an enhanced oxygen 2p character due to the weakening of the Fe 3d - O 2p - Bi 6p hybridization strength. The valence bands of compositions with the R3c structure were found to be qualitatively similar to the LSDA calculations except for their estimates of the band width and band gap. Reasons for this could be the higher value of the effective Coulomb interaction (U_{eff}). These results could be of importance to the understanding of the electronelectron correlation in multiferroic materials.

B. R. Sekhar

Energetic Ion Based Materials Science : Ion beam induced surface nanostructuring of semiconductors

Self-organization during low-to-medium-energy ion induced erosion of semiconductor surfaces has started showing its efficacy as a cost-effective technique for generation of large area nanostructured semiconductor surfaces. It is a single step processing route to create sub-hundred nm features at a much faster rate compared to the conventional lithographic techniques. Recently, several reports have demonstrated the formation of ripples and nanodots on various semiconductor surfaces by ion sputtering. It is possible 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 nanostructures on semiconductor surfaces (e.g. Si, Ge, InP, GaAs, and GaN) by using intermediate ion energy (50-60 keV) and to understand the underlying physics in terms of various experimental parameters and the existing theories.

S.K. Garg, T. Basu, J.R. Mohanty, M. Kumar, Shiv Poojan Patel, V. Venugopal, O.P. Sinha, S.R. Tripathy, S.R. Bhattacharyya, D. Kanjilal, and T. Som

Thin film / nanoscale magnetism

We are studying ion beam induced interface modification of magnetic multilayer thin films to tune their magnetic properties. Co-Pt and Co-Cr-Pt systems are used as magnetic recording media and ion irradiation is known to provide a unique way to tailor their magnetic properties with a high spatial selectivity. In case of magnetic multilayers, using keV ion irradiation, one can lead to controlled mixing (by varying the ion fluence) across the interfaces. Such interface modification leads to bring changes in their magnetic and structural properties. We have performed molecular dynamics simulation to understand the processes responsible for interface mixing which results such changes in structural and magnetic properties of the multilayer samples.

We are also working on growth of nanostructured Co films on rippled substrates to study morphological anisotropy driven magnetic anisotropy. This is a totally new area of research in terms of use of patterned substrates for growth of functional materials.

In another study, we made an attempt to achieve room temperature ferromagnetism in GaN:Cr system which was predicted by a recent theoretical study. In this process, we implanted Cr-ions in GaN at elevated temperature and at various fluences. Based on a detailed analysis of the magnetometry data, we demonstrate that the magnetic interactions between Cr moments in GaN are antiferromagnetic (AFM). Increasing the Cr fractional concentration up to 0.35, we observe that strong nearest cation neighbor AFM coupling results in the reduction of the effective moment per Cr atom. The uncompensated Cr moments exhibit paramagnetic behavior perturbed by AFM interactions in an anisotropic crystal field. We discuss the observed changes in magnetic and structural properties induced by thermal annealing in terms of defect annealing and Cr agglomeration. Our results support the view that the high-temperature ferromagnetism often observed in transition-metal doped GaN may be non-intrinsic.

J.K. Tripathi, Shiv Poojan Patel, T. Basu, M. Kumar, M.O. Liedke, A. Gupta, L.M.C. Pereira, K. Temst, A. Vantomme, and T. Som

Growth and characterization of thin films for photovoltaic applications

We are studying growth of oxide thin films, viz. In_2O_3:SnO_2 (ITO) and ZnO:Al_2O_3 (AZO) on glass, silicon, and polymer substrates which are useful for photovoltaic applications. The main objective is to study three-dimensional growth of these materials by glancing angle deposition technique which is an integral part of the sputtering set-up. We are studying their structural, optical, and electronic properties. It is observed that room temperature (RT) grown ITO films, deposited by pulsed DC sputtering, show a very high transmittance and low resistance upon annealing in air. We are in the process of comparing the film properties grown by RF magnetron sputtering. Detail electrical- and photo-conductivity studies are also underway. On the other hand, RT grown AZO films also show very low resistance and high optical transmittance. Photo-conductivity studies provide the relevant information on defect states and the nature of doping of Al in these films.

M. Kumar, T. Basu,, S. Nandy, R. Siva Kumar, S. Chatterjee, C. Sanjeevi Raja, P. Ayyub, and T. Som

Ion beam induced epitaxial crystallization of materials

Ion beam induced epitaxial crystallization of amorphous layers offers a few advantages: i) low temperature recrystallization, ii) high spatial selectivity, and iii) dynamic defect annealing. For quite some time, we are working on swift heavy ion induced recrystallization of self ion-induced amorphized germanium layers at different temperatures. Recrystallization was realized by micro-Raman, cross-sectional transmission electron microscopy (XTEM), and selected area diffraction pattern studies. We have attributed these results to the consequence of higher electronic energy loss to nuclear energy loss (S_e/S_n) ratio. More experiments are underway to address the individual role of nuclear and electronic energy loss in case of SHI induced recrystallization process at temperatures much lower compared to the solid phase epitaxial growth of the respective system.

Recently, we started working on SHI induced recrystallization study of thermally grown SiO_2 on Si. Usually, recrystallization of SiO_2 is a complex process albeit with the help of SHI we have achieved recrystallization of thin SiO_2 layers at low processing temperatures.

T. Som, T. Basu, S.K. Garg, P.K. Sahoo, A. Benyagoub, M. Toulemonde, and D. Kanjilal

Patterning of Oxide semiconductor Single Crystal Surfaces by Ion irradiation

Nanodots have been fabricated on rutile TiO_2 (110) single crystals using Ar ion beam. Ion beam sputtering creates oxygen vacancies, leading to a 45 nm thick Ti rich layer, on the surface. Post-sputtering, rutile TiO_2 also exhibits a decrease in the inter planar separation along [110] direction. Additionally, blueshift in the E_g Raman mode, representing the vibrations of oxygen atoms along c-axis, is also observed. Both these results suggest the development of a compressive stress along c-axis upon sputtering. Enhancement in intensity of A_{1g} raman mode also indicates modification in Ti-O vibrational influence. Raman Scattering Investigations display formation of strains in the system.

S. Varma, Subrata Majumder, V. Solanki, I. Mishra, S.R. Joshi (from IOP) and D.K. Avasthi, D. Kanjilal (IUAC) N. Delhi

Making polymer PDMS and semiconductor surfaces biocompatible

XPS studies are being carried out on the Polymer surfaces irradiated by Plasma treatment. Contact angle Measurement studies indicate an increase of Hydrophilicity suggesting an increased biocompatibility.The effect of plasma treatment on biocompatibility was understood from cell adhesion and proliferation tests. We are also investigating the effect of plasma treatment and UV irradiation on semiconductor surfaces with the motivation of making them biocompatible.

S. Varma, N. Gomathi (IIST, Trivendrum), S. Majumder, Indrani Mishra

Interaction of Plasmid DNA and Lambda DNA with Mica surfaces and semiconductor surfaces

Lambda DNA and Plasmid DNA are being used to understand the interaction of biomolecules with Mica surface and semiconductor surfaces. Patterned surfaces have also been interacted with these DNA. The DNA molecules undergo severe perturbation on their interaction with these surfaces. These perturbations are also reflected in the geometry as seen by AFM and electronic properties. CV measurements, AFM and XPS studies indicate several conformal changes.

S. Varma, S. Majumdar, Indrani Mishra

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57) L.M.C. Pereira, T. Som, J. Demeulemeester, M.J. Van Bael, K. Temst, and A. Vantomme : "Paramagnetism and antiferromagnetic interactions in Cr-doped GaN" – J. Phys.: Condens Matter 21 (2011) 346004.

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4.2. PRE-PRINTS / SUBMITTED / ACCEPTED FOR PUBLICATION

1) S. Ghosh, G. Gopal Khan, K. Mandal, S. Varma : Effect of nitrogen/fluorine in the defect driven intrinsic room-temperature ferromagnetism of Li-N/F co- doped ZnO nanowires Submitted.

2) V. Venugopal, T. Basu, S. Garg, J. K. Tripathi, S. Chandramohan, P. Das, T. K. Chini, S. R. Bhattacharyya, D. Kanjilal, and T. Som : "Ion erosion induced nanostructured semiconductor surfaces: Potential templates for magnetic thin films"–*Int. J. Nanotechnology* (In Press).

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

4) R. Sivakumar, Mohit Kumar, C. Sanjeevi Raja, and T. Som : "Enhancement in optical transmittance of indium tin oxide thin films grown by pulsed dc magnetron sputtering: Effects of pulsing frequency and annealing"–*J. Vac. Sci. Technol. A*.

5) T. Basu, J. R. Mohanty, and T. Som : "Unusual pattern formation on Si(100) due to low energy ion bombardment"–*Appl. Surf. Sci*.

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

7) JK Dash, A Rath, RR Juluri, PV Satyam : Shape evolution of MBE grown $Si_{1-x}Ge_x$ structures on high index Si (5 5 12) surfaces: A temperature dependent study -Arxiv preprint arXiv:1205.6039, under review, 2012

8) A Rath, JK Dash, RR Juluri, PV Satyam : Structural modification in Au/Si (100) system: Role of surface oxide and vacuum level-Arxiv preprint arXiv:1204.5370, under review, 2012

9) A Rath, RR Juluri, PV Satyam : Dynamic and Static Transmission Electron Microscopy Studies on Structural Evaluation of Au nano islands on Si (100) Surface-Arxiv preprint arXiv:1204.4618, under review, 2012

10) JK Dash, T Bagarti, A Rath, RR Juluri, PV Satyam : Universality in Shape Evolution of $Si_{1-x}Ge_x$ Structures on High Index Silicon Surfaces-Arxiv preprint arXiv:1204.0578; under review 2012

11) R.K. Mohapatra, P.S. Saumia, and A.M. Srivastava : " *Probing the anisotropic expansion history of the universe with cosmic microwave background*", arXiv:1111.2722.

12) U. S. Gupta, R. K. Mohapatra, A. M. Srivastava, and V. K. Tiwari : " *Effects of quarks on the formation and evolution of Z(3) walls and strings in relativistic heavy-ion collisions*", arXiv:1111.5402.

13) R. K. Mohapatra, P. S. Saumia, and A. M. Srivastava, : " *Analyzing flow anisotropies with excursion sets in relativistic heavy-ion collisions*", arXiv:1112.1177.

14) Shakeb Ahmad, M. Bhuyan and S. K. Patra : Properties of $Z = 120$ nuclei and the

α-decay chains of the $^{292,304}120$ isotopes using relativistic and nonrelativistic formalisms, Communicated to Phys. Rev. C.

15) S. K. Ghorui, Z. Naik and S. K. Patra, Int. J. Mod. : Rotational bands and electromagnetic transitions of some even-even Neodymium nuclei in PHF model, International Journal of Physics. E (In Press).

16) R.C. Nayak and L. Satpathy, *Mass Predictions of Atomic Nuclei in the Infinite Nuclear Matter Model" (in press).*

17) Subrata Majumder, D. Paramanik, V. Solanki, I. Mishra, D.K. Avasthi, D. Kanjilal and ShikhaVarma : Ion Irradiation induced Nano Pattern Formation on TiO_2 single Crystal-Appl. Surf. Sci. (2012) in press.

4.3. ARTICLES IN PROCEEDINGS

1) Ambresh Shivaji and Pankaj Agrawal : Multi vector boson production via gluon fusion at LHC, in proceedings of "10th International Symposium on Radiative Corrections" PoS(RADCOR2011)010.

2) Subhadip Mitra, Ambresh Shivaji, and Pankaj Agrawal : Production of KK-gravitons in association with a boson via gluon fusion in the LHC, in proceedings of "10th International Symposium on Radiative Corrections" PoS(RADCOR2011)045.

3) B Sundaravel, S Kalavathi, P SanthanaRaman, PV Satyam, KGM Nair, R Mittal, AK Chauhan, R Mukhopadhyay : Formation of NiSi2 nanoclusters by Ni ion implantation into Si (100) and the effect of preinjection of Si^{2+} ions-*AIP Conference Proceedings-American Institute of Physics V 1447 (2012) 285*

4) A Rosenauer, T Mehrtens, K Müller, K Gries, M Schowalter, S Bley, PV Satyam : 2D-composition mapping in InGaN without electron beam induced clustering of indium by STEM HAADF Z-contrast imaging, *Journal of Physics: Conference Series 326, 012040*

5) B. B. Sahu and S. K. Patra : Microscopic nucleon-nucleon interaction obtained from relativistic mean field theory and its application to nuclear decay, National Conference on Recent Advances in Science and Technology (RAST-2012) Feb. 27-28, 2012.

6) B. B. Sahu and S. K. Patra, : Microscopic study of proton emission from heavy nuclei, Proceeding of DAE Symp. On Nucl. Phys. 56, 516 (2011).

7) B. B. Singh, B. B. Sahu and S. K. Patra : Study of the fusion phenomena in heavy ion collisions and the $\alpha-$decay using nucleon-nucleon interaction derived from relativistic mean field theory. Proceeding of DAE Symp. On Nucl. Phys. 56, 546 (2011).

8) B. B. Sahu, S. K. Singh, M. Bhuyan, S. K. Ghorui, Z. Naik, S. K. Patra and C. R. Praharaj : Band Structure study of ^{161}Er nucleus, Proceeding of DAE Symp. On Nucl. Phys. 56, 308 (2011).

9) M. Bhuyan and S. K. Patra : Journey to superheavy valley, Proceeding of DAE Symp. On Nucl. Phys. 56, 148 (2011).

10) M. Bhuyan and S. K. Patra : The Structure and Stability of superheavy nuclei, Proceeding of DAE Symp. On Nucl. Phys. 56, 192 (2011).

11) A. Shukla, A. Aberg and S. K. Patra : Shape and structure of N=Z nuclei in A=80 mass region, Proceeding of DAE Symp. On Nucl. Phys. 56, 274 (2011).

12) A. Shukla, A. Aberg and S. K. Patra : Bubble nuclei in relativistic mean field theory, Proceeding of DAE Symp. On Nucl. Phys. 56, 276 (2011).

13) A. Shakeb, M. Bhuyan and S. K. Patra :

Superdeformed ground state in Z=120 nuclei and the $\alpha-$decay chain of the $^{292,304}120$ isotopes, Proceeding of DAE Symp. On Nucl. Phys. 56, 294 (2011).

14) B B Singh, M. Bhuyan, S. K. Patra and R. K. Gupta : The RMF based R3Y vs the M3Y NN interaction for the cluster radioactive decay studies, Proceeding of DAE Symp. On Nucl. Phys. 56, 304 (2011).

15) S. K. Ghorui, Z. Naik, S. K. Patra. A. K. Singh, P. K. Raina, P. K. Rath and C. R. Praharaj : K-isomeric bands of highly deformed neutron-rich Nd nuclei in PHF model, Proceeding of DAE Symp. On Nucl. Phys. 56, 338 (2011).

16) M. S. Mehta and S.K. Patra : Shell closure at N=32, 34 in drip-line nuclei, Proceeding of DAE Symp. On Nucl. Phys. 56, 450 (2011).

17) R. N. Panda, M. Bhuyan and S. K. Patra : Fission energy from neutron rich U and Th isotopes, Proceeding of DAE Symp. On Nucl. Phys. 56, 504 (2011).

18) M. K. Sharma, M. S. Mehta and S. K. Patra : Nuclear reaction cross-section of ^{22}C using Glauber model and relativistic mean field formalism, Proceeding of DAE Symp. On Nucl. Phys. 56, 578 (2011).

(19) Microscopic nucleon-nucleon interaction obtained from relativistic mean field theory and its application to nuclear decay, B. B. Sahu and S. K. Patra, National Conference on Recent Advances in Science and Technology (RAST-2012) Feb. 27-28, 2012.

(20) *Microscopic study of proton emission from heavy nuclei*, B. B. Sahu and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 516 (2011).

(21) *Study of the fusion phenomena in heavy ion collisions and the $\alpha-$decay using nucleon-nucleon interaction derived from relativistic mean field theory*, B. B. Singh, B. B. Sahu and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 546 (2011).

(22) *Band Structure study of ^{161}Er nucleus*, B. B. Sahu, S. K. Singh, M. Bhuyan, S. K. Ghorui, Z. Naik, S. K. Patra and C. R. Praharaj, Proceeding of DAE Symp. On Nucl. Phys. 56, 308 (2011).

(23) *Journey to superheavy valley*, M. Bhuyan and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 148 (2011).
(6) *The Structure and Stability of superheavy nuclei*, M. Bhuyan and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 192 (2011).

(24) Shape and structure of N=Z nuclei in A=80 mass region, A. Shukla, A. Aberg and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 274 (2011).

(25) Bubble nuclei in relativistic mean field theory, A. Shukla, A. Aberg and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 276 (2011).

(26) Superdeformed ground state in Z=120 nuclei and the $\alpha-$decay chain of the $^{292,304}120$ isotopes, A. Shakeb, M. Bhuyan and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 294 (2011).

(27) The RMF based R3Y vs the M3Y NN interaction for the cluster radioactive decay studies, B B Singh, M. Bhuyan, S. K. Patra and R. K. Gupta, Proceeding of DAE Symp. On Nucl. Phys. 56, 304 (2011).

(28) K-isomeric bands of highly deformed neutron-rich Nd nuclei in PHF model, S. K. Ghorui, Z. Naik, S. K. Patra. A. K. Singh, P. K. Raina, P. K. Rath and C. R. Praharaj, Proceeding of DAE Symp. On Nucl. Phys. 56, 338 (2011).

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(30) Fission energy from neutron rich U and Th isotopes, R. N. Panda, M. Bhuyan and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 504 (2011).

(31) Nuclear reaction cross-section of ^{22}C using Glauber model and relativistic mean field formalism, M. K. Sharma, M. S. Mehta and S. K. Patra, Proceeding of DAE Symp. On Nucl. Phys. 56, 578 (2011).

4.4. BOOKS / SPECIAL ISSUE

Proceedings of IINM - 2011 in Applied Surface Science as a special issue (Vol 258, 2012) : Edited by T. Som and S. Varma.

5 SEMINARS AND COLLOQUIA

5.1. COLLOQUIA

1) **Dr. Kousik Dutta**, DESY : Models of Inflation : New developments, April 04, 2011.

2) **Prof. Kalobaran Maiti**,*Department of Condensed Matter Physics and Materials Science,TIFR, Mumbai* : Novel non-magnetic phase in magnetic materials - universality of Kondo effect, April 18, 2011.

3) **Prof. Krishnendu Sengupta**, *IACS* : Bosons in Optical Lattice : Gauge Field, Tilt and Dynamics, August 01, 2011.

4) **Prof. Sourendu Gupta**, *TIFR, Mumbai* : Phases of QCD, August 08, 2011.

5) **Prof. D.P.Roy**, *Homi Bhabha Centre for Science Education,Tata Institute of Fundamental Research, Mumbai* : Standard Model and Beyond, September 30, 2011.

6) **Prof. Peter A. Dowben,** *University of Nebraska-Lincoln, USA* : Graphene/ substrate initial state charge transfer and final state effects characterized by electron spectroscopies, December 09, 2011.

7) **Prof. Subhendra Mohanty**, *Physical Research Laboratory, Ahmedabad* : Cosmological Consequences of Higgs Mass Measurement at Atlas and CMS, February 08, 2012.

8) **Dr. S. Triambak**, *Department of Physics & Astrophysics University of Delhi, Delhi* : Precision nuclear physics measurements : Their Context and importance, February 09, 2012.

9) **Prof. Jayanta Bhatacharjee**, *SN Bose Centre, Kolkata* : Oscillators : Old and New, February 27, 2012.

10) **Prof. Ignatios Antoniadis**, *CERN* : Finding Strings at LHC ?, March 03, 2012.

5.2. SEMINARS

1) **Swapan Mahji**, *Saha Institute of Nuclear Physics, Kolkata* : Higher order Radiative Corrections in Collider Physics, May 05, 2011.

2) **Dr. Tae-Hun Lee**, *S.N.Bose Centre, Kolkata* : A Particle Carrying Non-Abelian Charge, May 27, 2011.

3) **Prof.M.K.Parida**, *HRI, Allahabad* : Predictive Unification, Dark Matter and Neutrino Masses, June 03, 2011.

4) **Dr. Navinder Singh**, *PRL, Ahmedabad* : Explaining the long coherence effects in photosynthetic exciton energy transfer as observed by 2D photon echo spectroscopy: TCPS model, June 09, 2011.

5) **Dr. Pallav Basu**, *Kentucky University* : An Excursion in Holographic Condensed Matter Systems, June 30, 2011.

6) **Dr. Sarira Sahu**, *Instituto de Ciencias Nucleares Universidad Nacional Autonoma de Mexico Mexico City* : Very High Energy Cosmic Ray and Neutrino Events from Centaurus A, July 15, 2011.

7) **Prof. Sumit R. Das**, *University of Kentucky* : Quantum Quench and Holography, July 25, 2011.

8) **Dr. Jagjit Nanda**, *OakRidge National Lab., OakRidge, USA* : Energy Storage R&D: From Fundamental Science to Application, August 02, 2011.

9) **Dr. Sadhan Dash**, *(for the ALICE Collaboration) Universita and INFN di Torino, ITALY* : Open Charm

Reconstruction in ALICE Experiment at LHC, August 18, 2011.

10) **Dr. R. Sivakumar**, *Alagappa University :* Studies on ITO thin films by pulsed dc sputtering technique, August 29, 2011.

11) **Dr.S. Dhara**, *Indira Gandhi Centre for Atomic Research, Kalpakkam :* Physical Properties of GaN, September 09, 2011.

12) **Dr. Dinesh Topwal**, *Scientist , Sincrotrone Trieste S.C.p.A.(ELETTRA) ,Trieste, ITALY :* Spectroscopy of self assembled networks and nanosystems, September 12, 2011.

13) **Dr. Manju Unnikrishnan**, *Sincrotrone Trieste S.C.P.A.(ELETTRA) ,Trieste, ITALY :* Spectroscopy of self assembled networks and nanosystems, September 13, 2011.

14) **Dr. Mahesh Kumar** *Surface Physics and Nanostructures Group, National Physical Laboratory, New Delhi :* Hetero-epitaxial growth by surface modifications of semiconductor and insulator substrates, September 16, 2011.

15) **Prof. C.S. Unnikrishnan**, *TIFR, Mumbai :* Matter Wave Interferometry with Ultra-cold Atoms: Fundamental Physics and Applications, September 20, 2011.

16) **Prof. M.K.Parida**, *HRI, Allahabad :* Radiative see saw for neutrino mass with dark matter in Grand Unified Theory, September 22, 2011.

17) **Dr. S M Yusuf,** *Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai :* Functional Magnetic Materials: Fundamental and Technological Aspects, October 11, 2011.

18) **Dr. Satadeep Bhattacharjee**, *Division of Materials Theory, Uppsala University, Sweden :* Electronic structure, vibrational properties and spin dynamics of some selected magnetic systems, October 11, 2011.

19) **Prof. Jogesh Pati** , *Physics Dept., Universityi of Maryland, USA :* Grand Unification: Issues of Proton Decay, Neutrino Oscillations and the Early Universe, October 14, 2011.

20) **Debakanta Samal**, IISc., Bangalore: *Emergence of exotic phenomena in superconductor ferromagnet Hetero-structures*, November 2, 2010.

21) **Dr. Apoorva Nagar**, *IIT, Hyderabad :* Effect of mutators on evolution, October 31, 2011.

22) **Dr.A.K.Arora**, *IGCAR, Kalpakkam :* Raman spectroscopy of nanostructures, November 01, 2011.

23) **Dr. Deepshikha Jaiswal Nagar**, *Hyderabad University :* Magnetocaloric effect and magnetic cooling near a field-induced quantum-critical point, November 01, 2011.

24) **Dr.A. Shukla**, *RGIPT, Raeborali :* Double Beta Decay: Present Status & Future Prospects, November 14 2011.

25) **Mr. Amit Sharma**, *National Centre for Biological Sciences, (NCBS – TIFR) Bangalore :* Structure and function of DNA replicating machinery – Perspective to multi drug resistance in TB, November 05, 2011.

26) **Dr. Sudhanwa Patra**, *PDF, IOP :* Superluminal neutrino and Lorentz violation, November 8, 2011.

27) **Dr. Chandra Sekhar Rout**, *Birck Nanotechnology Center, Purdue University, USA :* Optical properties of ZnO nanorods and SERS substrates based on metal nanoparticles

decorated rapheme petal arrays, November 11, 2011.

28) **Dr. Jyoti Ranjan Mohanty,** *Technical University Berlin, Germany :* Magnetism at nanoscale: Nano-small meets Ultra-fast, November 30, 2011.

29) **Prof. M.P. Das**, *Australian National University, Canberra :* Some issues on meso/nanoscopic system, December 13, 2011.

30) **Mr. M.Bhuyan**, *Sambalpur University :* Journey from light to superheavy nuclei, December 15, 2011.

31) **Prof. X.Vinas**, *University of Barcelona :* SEMICLASSICAL APPROXINATION TO PAIRING IN THE WEAK COUPLING REGIME: NUCLEI, COLD ATOMS AND NEUTRON STARS, December 26, 2011.

32) **Prof. A.Abbas,** *Aligarh Muslim University :* A = 3 Clustering in Nuclei, January 2, 2012.

33) **Dr.T.N.Sairam**, *IGCAR, Kalpakkam :* High Pressure Investigations of Zinc Cyanide Using Synchrotron Infrared Absorption Spectroscopy, February 01, 2012.

34) **Prof. Subhendra Mohanty**, *PRL, Ahmedabad :* Superluminal Neutrino, February 09, 2012.

35) **Dr. Satyajit Sahu**, *National Institute for Materials Science, Advanced Nano Characterization Unit,Tsukuba :* Synchrony based evolution of microtubule and its applications, *February 15, 2012.*

36) **Dr.Tapan Nayak**, *VECC, Kolkata:* Heavy Ion Frontier of the Large Hadron Collider, March 06, 2012

37) **Dr. Kuntala Bhattacharjee, *PDF, IOP :*** General Discussion on Different STS Techniques and Atom Manipulation, March 12, 2012.

38) **Prof. Abhijit Bhattacharya,** *Department of Physics, University of Calcutta :* The thermodynamic properties of strongly interacting matter, March 19, 2012.

39) **Dr. Sukanta De**, *School of Physics and CRANN Trinity College Dublin, Ireland :* Next Generation of Transparent Electrode Materials for Flexible Devices, May 04, 2011.

40) **Dr. Priti Sundar Mohanty** , *Lund University, Sweden :* Escaping the squeeze: Soft particles at high effective volume fractions, July 08, 2011.

41) **P. K. Mohanty**, *SINP, Kolkata :* An elegant way of Multiplying Matrices, September 02, 2011.

42) **Prof. B. P. Das**, *IIA, Bangalore :* The Role of Relativistic Many-Body Theory in Probing the Standard Model of Particle Physics, June 14, 2011.

43) **Dr. Sankar Dhar**, *NUSNNI- NanoCore, National University of Singapore, Singapore :* Unusual material properties induced by irradiation, doping and alloying, October 13, 2011.

44) **Samrat Bhowmick, *IOP :*** Anisotropic Inflation in Rolling Tachyon Models, June 16, 2011.

45) **Dr. Payal Mohanty**, *VECC, Kolkata :* Lepton-pair interferometry : a tool to characterize different phases of matter produced in heavy ion collisions, July 08, 2011.

46) **Dr.Sarmistha Banik**, *SINP, Kolkata :* Equation of state for core collapse supernova simulation and neutron star core, November 21, 2011.

47) **Dr. Anurag Sahay, *IOP* :** Thermodynamic geometry, phase transitions and the Widom line, July 12, 2011.

48) **Dr. Swarnendu Sarkar**, *Delhi University :* Strong Coupling BCS Superconductivity and Holography, July 25, 2011.

49) **Dr. Dileep Jatkar**, *HRI, Allahabad :* New Massive Gravity from AdS_4 Counter Terms, October 20, 2011.

50) **Ambresh Shivaji, *IOP* :** KK-gravition production in association with a vector Boson via Gluon Fusion in ADD models, November 23, 2011.

51) **Dr. Sachin Jain, *IOP* :** Action Principle for Hydrodynamics, February 17, 2012.

52) **Dr. Binata Panda**, *HRI :* Heat Kernal Expansion and Extremal Black Hole in Einstein Maxwell Theory, February 28, 2012.

53) **Mr. Souvik Banerjee, *IOP* :** Holographic Spectral Functions in Non-equilibrium states, March 16, 2012.

54) **Prof. J. Maharana,** *IOP :* T-Duality of NSR Superstring : A Worldsheet Perspective, March 23, 2012.

55) **Dr. Maheswar Nayak,** *RRCAT, Indore :* Physics of Nano-scaled X-ray Multilayer and novelty of resonant x-ray scattering for basic surface/interface science, September 19, 2011.

56) **Prof. J.C. Pati**, *Universityof Maryland, USA :* Grand Unification: A Historical Perspective and Current Status, October 12, 2011.

57) **Dr. Bhaskar Chandra Mohanty**, *Department of Mat. Sci. and Engg., Yonsei University Seoul, South Koria :* Growth dynamics of ZnO thin films for photovoltaic applications, November 08, 2011.

58) **Dr. Rajdeep Sensarma,** *Univ. of Maryland, USA :* Dynamics with cold atoms near and far from equilibrium, December 01, 2011.

59) **Dr. Swarup Kumar Majee**, *National Taiwan University,* Universal Extra-Dimension at LHC, December 05, 2011.

60) **Dr. Ramesh Chandra Nath**, *Indian Institute of Science Education and Research,Thiruvananthapuram :* Interesting Ground State Properties of Frustrated Low-dimensional Spin Systems, December 05, 2012.

61) **Dr. Santosh K. Rai**, *Oklahoma State University* : Reading the LHC Data with Leptonic Spectacles, December 07, 2011

62) **Dr. Sanjib Kumar Agarwalla,** *Universitat de Valencia :* Neutrino Oscillation Parameters: Current Knowledge and Future Goals, December 07, 2011.

63) **Dr. Tanumoy Pramanik**, *SNBCBS :* Fine-grained uncertainty relation and nonlocality of tripartite systems, December 09, 2012.

64) **Arnab Das, *IOP* :** Dynamical Freezing, December 29, 2012.

65) **Dr. Sourin Das,** *Delhi University:* Looking for neutral modes in non-abelian quantum hall states via thermoelectric effect, February 13, 2012.

66) **Dr.P.Sanyal**, *S.N.Bose Center, Kolkata :* "Double exchange in double perousbites : normal magnetic phase transitions", February 17, 2012.

67) **Dr. Rajdeep Sensarma,** *Univ. of Maryland, USA :* Dynamics with cold atoms near and far from equilibrium, December 01, 2011.

68) **Dr. Ramesh Chandra Nath**, *Indian Institute of Science Education and Research,Thiruvananthapuram* : Interesting Ground State Properties of Frustrated Low-dimensional Spin Systems, December 05, 2011.

69) **Dr. Swarup Kumar Majee**, *National Taiwan University :* Universal Extra-Dimension at LHC, December 05, 2011.

70) **Dr. Santosh K. Rai**, *Oklahoma State University :* Reading the LHC Data with Leptonic Spectacles, December 07, 2011.

71) **Dr. Sanjib Kumar Agarwalla,** *Universitat de Valencia :* Neutrino Oscillation Parameters: Current Knowledge and Future Goals, December 07, 2011.

72) **Dr. Tanumoy Pramanik**, *SNBCBS :* Fine-grained uncertainty relation and nonlocality of tripartite systems, December 09, 2011.

73) **Prof. Hiranmaya Mishra,** *Physical Research Laboratory,Ahmedabad :* Chiral symmetry breaking in strong magnetic fields, December 27, 2011.

74) **Arnab Das, *IOP* :** Dynamical Freezing, December 29, 2011.

75) **Dr. Sai Vinjanampathy**, *University of Massachusetts Boston :* Quantum Correlations in Photosynthesis, January 20, 2012.

<u>**76) Dr.Aswini K. Rath Memorial Lecture**</u>

Prof. M.K.Pal, *Former Director, SINP :* Subrahmanyan Chandrasekhar and cosmology, January 30, 2012

77) **Dr. Kuntala Bhattacharjee**, *PDF, IOP :* Self-assembly of various 1D chains: atomic structure & spatially resolved electronic properties, February 10, 2012.

78) **Prof. Andres Reyes Lega**, *Universidad de Los Andes Bogota, Columbia :* Some uses of fiber bundles and topology in physics, February 02, 2012.

79) **Dr. Sourin Das,** *Delhi University :* Looking for neutral modes in non-abelian quantum hall states via thermoelectric effect, February 13, 2012.

80) **Dr.P.Sanyal**, *S.N.Bose Center, Kolkata :* Double exchange in double perousbites : normal magnetic phase transitions, February 17, 2012.

5.3. LECTURES GIVEN ELSEWHERE BY IOP MEMBERS

Dr. P. Agrawal :

(1)*Discord, Quantumness and Generalization*', Quantum Discord Workshop, CQT, Singapore, January 9-13, 2012.

(2) *More Communication with Less Entanglement*', International Workshop on Quantum Information, HRI, Allahabad, February 20-26, 2012.

Dr. S. M. Bhattacharjee :

(1) *Entanglement entropy*, UGC Conf on cond mat physics, Sushil Kar College, Sept 2011 2.

(2) *DNA unzipping and melting*, National conf on cond mat physics, Bishnupur College, Nov 2011 3.

(3) *Helicase activity on DNA*, International conference on mathematical biology, IISER, Pune, Jan 2012 4.

(4) *DNA unzipping and melting*, National conf on cond matt physics, BITS Pilani, Feb 2012

A. M. Srivastava :

(1) Invited talk on *Probing the anisotropic expansion history of the universe with cosmic microwave background*, Indo-UK seminar "Confronting particle-cosmology with PLANCK and LHC", at IUCAA, Pune, Aug. 2011.

(2) "*Universe and the dark energy*", at the Physics Dept., BITS, Pilani, Oct. 2011.

(3) Seminar on "Dark energy and our Universe" in the Physics Dept. Ravinshaw University, Cuttack, Oct. 2011.

(4) "*Dark energy in the Universe*" at the Physics Dept., Berhampur University, on 28th Feb. 2012.

Dr. S. Varma :

(1) *Enhanced Photo-absorption and Photoluminescence Properties of TiO2 via nanostructures created by Ion sputtering* at 'Nanostructures by Ion Beams' organised by IUAC at Allahabad (Oct 2011).
(2) *Can DNA be used as a Sensor,* National workshop on Advanced Materials and Technology (NWAMT)' organised by ITER at Bhubaneswar (Apr 2011).

(3) *Investigations of Rutile TiO_2 Nanodots Formed by Low energy Ion beam Sputtering* ,'National Workshop on New and Nanomaterials' organised by Institute of Materials Science and Science and Technology Department, Govt. of Odisha, at Bhubaneswar (Jan 2012).

Dr. Anupama Chanda :

"Highly conductive PEDOT:PSS films for flexible and transparent electronics", International Conference and Workshop on Nanostructured Ceramics and other Nanomaterials (ICWNCN), 13-16 March 2012, University of Delhi, Delhi, India.

Saumia P. S. :

(1)CMBR anisotropies and flow fluctuations: Some similarities , Invited talk at WHEPP Satellite Meeting, VECC, Kolkata, January, 2012.

(2) *Using CMBR tools for flow anisotropies in relativistic heavy-ion collisions* Working Group talk at WHEPP 2012, Mahabaleswar, January, 2012.

(3) *Probing the anisotropic expansion history of the universe with cosmic microwave background,* International Conference on Gravitation and Cosmology, Goa, India, December, 2011.

Abhishek Atreya :

Baryon Homogeneities due to CP violating QCD Z(3) walls, International Conference on Gravitation and Cosmology (ICGC) 2011, Goa, 16 December 2011,

Dr. Sachin Sarangi, SO-B :

(1) "*Electrical characterization studies of nanocrystalline CdSe/Au Schottky junction interface*", University of Electrocommunication,Tokyo, Japan on 1st March 2011

2) "*Electrochemical growth of PN ZnO nanorod diodes for UV LED Application*", Seminar for ORIENTATION FOR JSPS POSTDOCTORAL FELLOWS held at Hanzomon, Tokyo on Feb, 27-29, 2012

3) *Oxide semiconductor anostructures: ZnO and NiO* ", University of Electrocommunication, Tokyo, Japan on 11 June 2012.

Dr. T. Som : (1) "*Ion beam induced processing of nanostructured materials*", National Workshop on Advanced Materials And Technology (NWAMT), ITER, Bhubaneswar on 23.04.2011.

(2) *"Nanoscale fabrication of ion induced self-organized nanostructures"* International Conference on Materials for Advanced Technologies, National university of Singapore, Singapore , on 27.06.2011.

(3) *"Sputter erosion induced nanoscale pattern formation on semiconductor surfaces", International Workshop on Nanoscale Pattern Formation at Surfaces, El Escorial, Madrid, Spain* , on 20.09.2011.

(4) *"Ion induced nanopattern formation on semiconductor surfaces",* National Workshop on Plasma Processing For Thermonuclear Fusion and Industrial Applications (PPTFIA-2011), KIIT University, Bhubaneswar , on 10.11.2011.

(5) *"Large area nanoscale pattern formation on semiconductor surfaces by sputter erosion"* at International Conference on NanoScience, Technology and Societal Implications (NSTSI 2011), C.V. Raman College of Engineering, Bhubaneswar , 08.12.2011.

(6) *"Ion induced nanopattern formation on semiconductor surfaces"*, National Workshop on Nanocoatings, KIIT University, Bhubaneswar , 20.03.2012 .

(7) *"Experimental Condensed Matter Physics Research at Institute of Physics",* Awareness Workshop on The Facilities of UGC-DAE Consortium for Scientific Research, Utkal University, Bhubaneswar , 24.03.2012.

(8) *"Low Energy Pelletron Accelerator: Avenues in Materials Research",* National Workshop cum Theme Meeting on Accelerator Based Interdisciplinary Research in Basic Sciences, Guru Ghasidas Vishvavidyalaya, Bilaspur , 29.03.2012.

(9) *Summary and Recommendation Talk,* National Workshop cum Theme Meeting on Accelerator Based Interdisciplinary Research in Basic Sciences, Guru Ghasidas Vishvavidyalaya, Bilaspur , 29.03.2012.

5.4. LECTURES GIVEN AT THE INSTITUTE BY IOP MEMBERS

Dr. S. Varma : (1) *Interaction of DNA with Hg clusters: tiny Mercury Sensor* at 'workshop on Photoemission Studies of Advanced Materials (PSAM)' organised at IOP Bhubaneswar (Dec 2011).

(2) Presented an Invited talk on *Tiny Mercury Sensors using DNA* at conference on 'Advanced Functional Materials' organised at IOP Bhubaneswar (July 2011).

(3) Presented an invited talk on *X-ray photoelectron spectroscopy (XPS) and its Applications for Nanostructures, Biology, Pollution,* at 'workshop on Electron Microscopy (WEM)' organised at IOP Bhubaneswar (Nov 2011).

Dr. T. Som : (1) *"Synthesis of self-organized nanostructures by ion beams" Advanced Functional Materials, Institute of Physics, Bhubaneswar*, 29.07.2011.

(2) *"Large area nanopatterning of semiconductor surfaces by ion induced sputter erosion",* Workshop on electron Microscopy *(WEM2011), Institute of Physics, Bhubaneswar* , 24.11.2011 .

(3) *"Ion erosion induced nanopatterned semiconductor surfaces",* Workshop on Photoemission Studies of Advanced Materials (PSAM 2011), Institute of Physics, Bhubaneswar 12.12.2011 .

5.5. POPULAR LECTURES GIVEN BY IOP MEMBERS

Dr. A. M. Srivastava

1. Popular talk and telescope show for "looking at moon and Jupiter" for class IX students at IMA, BBSR, Jan, 2012.

2. Two talks on "Dark Energy" at the meetings of Samanta Chandra Sekhar Amateur Astronomers' Association, Bhubanerswar, in Nov. and Dec. 2011.

3. Popular talk on "Inspiration and motivation in Science" in the Science Day celebrations of the Physics Dept., Berhampur University, on 28th Feb. 2012.

Dr. S. M. Bhattacharjee

Lectures on Polymers, RRI School on stat phys, Mar 2012.

6 CONFERENCES AND OTHER EVENTS

6.1. ALUMNI DAY

The 31st Alumni Day was celebrated on September 3, 2011. The programme 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 Allumni members of IOP, Prof. Pradeep Kumar Mohanty, Saha Institute of Nuclear Physics, Kolkata; Prof. Sanjay Swain, National Institute of Science Education and Research, Bhubaneswar; Prof. S. Rath, Indian Institute of Technology, Bhubaneswar.

The colloquium was given by distinguished scientist, Prof. Deepak Dhar, Tata institute of Fundamental Research, Mumbai.

The evening programme started with prize distribution to the winners of various competitions in the year-long programmes. It was followed by a talk by International Indian Hockey player Mr. Dilip Tirkey, Chief Guest of the evening. This was followed by Excellent Bharatnatyam Dance by Miss. Medha Hari and her group from Chennai.

Following were the office bearers

Secretary	:	Tanmoy Pal
Assistant Secretary	:	Shubhashis Rana
Treasurer	:	Partha Bagchi
Faculty Advisor	:	Dr. P. V. Satyam

6.2. FOUNDATION DAY

The 37th Foundation day of the Institute was celebrated on September 4, 2011. 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. R. Rajaraman, Jawaharlal Nehru University, New Delhi.

6.3 WEM2011: November 23 – 25.

The workshop on Electron Microscopy (WEM2011) was jointly organized by Institute of Physics (IOP), Bhubaneswar and Indian Institute of Technology Bhubaneswar (IIT-BBSR), Bhubaneswar from November 23 - 25 , 2011 and was held at the Institute of Physics (main lecture hall), Bhubaneswar. The main objective of the workshop on Electron Microscopy was to bring many young researchers from the Eastern part of India and provide a platform to have interaction with eminent microscopists. The topics include both Physical Sciences and Life Sciences. There were 32 invited lectures from eminent scientists (including Prof. A. Rosenauer from Germany) and a poster session. One of the main aspect of this workshop was practical training/ exposure on "Demonstrative TEM and SEM experiments, and Sample Preparation methods" during the evening hours. We had a total about 120 participants, including about 50 students/postdoctoral fellows/young faculties from Odisha state (mainly from IOP, IITBBSR, NISER, IMMT). Besides the IOP as main contributor, DRDO (Delhi), many private firms have supported financially. Prof. M. Chakraborty, Director, IIT-Bhubaneswar was the Chairman and Prof. P. V. Satyam, IOP, was the convener of the WEM2011 workshop.

6.4 Lectures on Photoemission (LOP)

Institute of Physics, Bhubaneswar, organized a short course 'Lectures on Photoemission (LOP)' during 8 to 11 and 13 December. The course was given by Prof. Peter A. Dowben of University of Nebraska – Lincoln, USA. Prof. Peter A. Dowben gave nine lectures on the topics of The principles and instrumentation behind photoemission, Determining surface composition from angle-resolved XPS, Symmetry selection rules in photoemission, Inverse photoemission, Band mapping, Band Structure, Experimental band structure of molecular overlayers, Elemental contributions to specific conduction and valence bands, Photoemission for determination of semiconductor properties, XMCD and EXAFS.

Many faculty members, research scholars, Postdoctoral fellows and scientists from IOP as well as other Institutes in Bhubaneswar like NISER, Utkal University, Institute of Metals and Materials, Institute of Material Science, ITER as well as from institutes outside Bhubaneswar like IUAC Delhi, NIT Roulkela attended LOP. The total number of registered participants (students, post docs, scientists, faculty) was 48.

6.5 Workshop on Photoemission Studies of Advanced Materials (PSAM)

One day Workshop on 'Photoemission Studies of Advanced Materials (PSAM)' was held on 12 Dec. 2011 to discuss the frontier research areas in the field of Photoemission techniques. There were several speakers from India as well as from one from outside. The topics included: The Surface Science of Adsorption on Crystalline Ferroelectric Polymer Surfaces, Photoelectron Spectroscopy of Nanoscale Materials, Core level spectra of disordered metallic alloys, Ion Erosion Induced Nanostructured Semiconductor Surfaces, Photoemission study of collective electronic excitations in metals, Applications of TEM – EELS, Electronic Structure Studies Using Various Techniques , Photoemission studies of DNA .

Many faculty members, research scholars, Postdoctoral fellows and scientists from Institutes in Bhubaneswar and outside attended PSAM-2012.

6.6 International School and Conference on Quantum Information - 2011

At the Institute of physics, a second school-cum-conference of the series ISCQI, ISCQI-2011, was organized from December 13-22, 2011. School was organized from Dec 13-17, 2011. Conference took place from Dec 19-22, 2011. It was organized by Pankaj Agrawal, Arun Pati, HRI, Allahabad, I. Chakrabarty, and S. Adhikari. The topics covered in the school and conference included quantum computation and algorithms, quantum error-correction and decoherence, quantum cryptography, quantum information theory, quantum entanglement, quantum games, relativistic aspects of quantum information, quantum correlations in a many-body system, and quantum foundation. Eight speakers gave lectures in the school. The list included Prof. T. Sudbery, S. Chaturvedi, G. P. Kar, I. Fuentes, S. Ghosh, U. Sen, P. Rungta, and G. Chappell. A total of 51 students, including 46 students from outside Odisha, paricipated in the school. In the conference, there were 35 invited speakers. There were about 90 overall participants.

6.7 All India DAE Official Language Conference

Institute of Physics, Bhubaneswar organized the All India DAE Official Language Conference on 2-3 November, 2011 jointly with NISER. Padmabibhushan Shri Sitakanta Mohapatra, Eminent Odiya poet was the chief guest for this meeting. In addition, Dr. C.B.S. Venkataramana, Joint Secretary (I&M) and Chairman, DAE Official Language Implementation Committee, Sri Bijaya Bhushan Pathak, Joint Secretary, Branch Secretariat, DAE, Sri S.K. Malhotra, Head, Public Awareness Division, DAE were also present as guests of this function. All the Official Language officials of the DAE and their Research and Development Sectors, Power Sectors, Industries and Mineral Sectors, Public Undertakings, Service Organisations and Aided Institutions and other organization of DAE were also present during this two days conference. Various activities related to Official Language (Hindi) were carried out in this conference.

Prof. Shikha Varma delivering the welcome address of LOP-PSAM

Prof. Peter. A. Dowben giving the inaugural lecture on Photoemission (LOP-PSAM 2011)

Inaugural function of WEM-2011 :
(L) Prof. M. Chakraborty, Director, IIT, Bhubaneswar; (R) Prof. P. V. Satyam, IOP

A view of participants attending the WEM-2011 meeting

Inaugural function of ISCQI - 2011

Group photograph of participants for ISCQI - 2011

Inaugural function of All Indian DAE official language conference

Predoctoral scholars of 2010 - 11 batch.

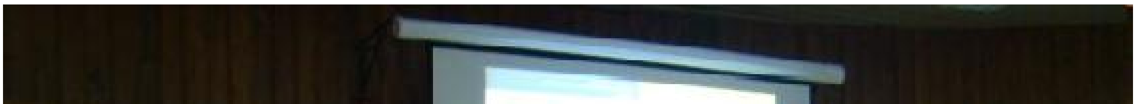
Snaps from 37th Foundation day programme

Falicitation of Professor S. N. Sahu upon his superannuation

Falicitation of Shri J. N. Dash upon his superannuation

7 OUTREACH

Science Modelling co-ordinated by Alumini Association



Lecture by Prof. D. Dhar, TIFR, Mumbai
on the eve of Alumini Day celebration, 3rd September, 2011.

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. Under the outreach program, the following programs were carried out during the past year.

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 during March (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 150 school students from Bhubaneswar (both English medium and Oriya medium schools). About 10 students from the local Basti participated in the program. The program started at 10:00 a.m. with following popular level talks at the Institute Auditorium.

1. Talk on "Chemistry creates a new world", (in English/Oriya) by Prof. C.S. Panda, Prof. of Chemistry (Retd.), NISER.

2. Talk on "Hormones: Magic molecules of the body", (in English/Oriya) by Prof. G.B. Chainy, Executive Dir. IMGENEX India Pvt. Ltd., and former Head of Biotechnology Dept., Utkal Univ.

Following this, student visits were arranged, in small groups, to IOP experimental facilities, as well as Demonstration Experiments at NISER Labs. There was enthusiastic participation of NISER students in arranging these demonstrations (for Physics, Chemistry, Mathematics, and Biology), and by IOP research scholars and scientific assistants in explaining various experimental facilities to school students. The program ended at 5:30 p.m.

7.2 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 visits were arranged:

1) About 76 students (class XII) from Delhi Public School Kalinga visited IOP for Laboratory visits on 8th Sept. 2011.

2) About 40 students from Godavaris Mahavidyalaya, Banpur, Odisha, visited IOP for Laboratory visits on 17th Jan,2012.

Activities related to the Official Language implementation in the institute

The Hindi Day was observed on 14.09.2011 at the institute. On this occasion, a report on various activities, related to official language was prepared by this Institute during the year 2010-11 which was presented to the employees. The message issued by Dr. Srikumar Banerjee, Chairman, AEC was read out and circulated. Institute celebrated the Hindi fortnight from 14.09.2011 to 28.09.2011 with various competitions among the employees. On the valedictory function of Hindi fortnight, all winners of the competitions were awarded. Prof. A. M. Jayannavar, Director, Shri C. B. Mishra, Registrar & Chairman, OLIC and all OLIC members were present in the occasion. Sri Braja Nath Mishra, A.D. (OL), O/o the Employees Provident Fund Commissioner, Odisha Region, Bbhubaneswar was invited as the Chief Speaker.

In addition, "The World Hindi Day" was also celebrated on 10.01.2012. Capt. K. S. Noor, Principal, Sainik School, Bhubaneswar was invited as the Chief Speaker for this function.

8 PERSONNEL

8.1. 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**
   Associate Professor
   Condensed Matter Phyiscs (Theory)

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

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

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

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

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

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

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

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

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

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

15. **Pradip Kumar Sahu**
    Reader-F
    Nuclear Physics (Theory)

B. Post-Doctoral Fellows

1. Birbikram Singh
2. Indranil Chakrabarty
3. Pallavi Debnath
4. Sudipto Muhuri
5. Subhadip Mitra
6. Satyabrata Adhikari
7. Bidhu Bhusan Sahu
9. Samrat Bhowmick
10. N. Revathi

C. Doctoral Scholars

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

D. Pre-doctoral Scholars

1. Arpan Das
2. Subrata Kumar Biswal
3. Soumyabrata Chatterjee
4. Sumit Nandi

E. Administration

1 Sri C.B. Mishra, Registrar.

(i) Director's Office:

1 Sk Kefaytulla
2 Raja Kumari Patra
3 Rajesh Mohapatra
4 Bramhananda 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 Pramod Kumar Senapati
7 Daitary Das

(iv) EPABX

1 Srikanta Rout
2 Dullabha Hembram

(v) Despatch

1 Krushna Chandra Sahoo

(vi) Transport

1 Sadananda Pradhan
2 Binjaban Digal
3 Sanatan Jena
4 Sarat Chandra Pradhan
5 Umesh Chandra Pradhan

(vii) Stores

1 Judhistira Senapati
2 Sanatan Das

(viii) Accounts

1 Ranjan Kumar Biswal
2 Ambuja Kanta Biswal
3 Pravat Kumar Bal
4 Kali Charan Tudu
5 Jitendra Kumar Mishra
6 Bhaskar Misra
7 Chandramani Naik
8 Banshidhar Panigrahi
9 Bijaya Kumar Swain

(ix) Maintenance

1 Pravakar Acharya
2 Baikuntha Nath Barik
3 Purna Chandra Maharana
4 Patita Sahu
5 Sajendra Muduli
6 Pabani Bastia
7 Rabi Narayan Mishra
8 Debaraj Bhuyan
9 Gangadhar Behera
10 Biswa Ranjan Behera
11 Kapilendra Pradhan

(x) Estate Management

1 Sahadev Jena
2 Purasttam 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 Chandra Dash
11 Bijaya Kumar Das
12 Babuli Naik
13 Pradip Kumar Naik
14 Meena Dei
15 Sanatan Pradhan
16 Bhaskara Mallick
17 Kulamani Ojha
18 Pitabas Barik
19 Sudhakar Pradhan
20 Dhoba Naik
21 Kailash Chandra Jena
22 Charana Bhoi
23 Jatindra Nath Bastia

24 Martin Pradhan
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

(xii) Computer Centre

1 Bishnu Charan Parija
2 Nageswari Majhi

(xiii) Laboratory

1 Sanjiv Kumar Sahu
2 Anup Kumar Behera
3 Sachindra Nath Sarangi
4 Khirod Kumar Patra
5 Madhusudan Majhi
6 Ramarani Dash
7 Santosh Kumar Choudhury
8 Arun Kanta Dash
9 Biswajit Mallick
10 Pratap Kumar Biswal
11 Arakhita Sahoo
12 Bala Krushna Dash
13 Soumya Ranjan Mohanty
14 Kshyama Sagar Jena
15 Maheswar Bailarsingh
16 Nityananda Behera
17 Purna Chandra Marandi
18 Deba Prasad Nanda
19 Srikanta Mishra
20 Rama Chandra Murmu
21 Brundaban Mohanty
22 Ranjan Kumar Sahoo
23 Naba Kishore Jhankar

(xiv) Workshop

1 Ramesh Chandra Nayak
2 Subhabrata Tripathy
3 Rama Kanta Nayak
4 Rabi Narayan Naik

8.3. RETIREMENT

(1) Prof. S. N. Sahu

Date of Retirement : **31.07.2011**
Date of Joining : **16.04.1991**
Last post held : **Professor**

(2) Shri. J. N. Dash

Date of Retirement : **30.06.2011**
Date of Joining : **10.04.1975**
Last post held : **Administrative Officer (E)**

(3) Mr. Basanta K. Mekap

Date of Retirement : **29.02.2012**
Date of Joining : **09.04.1975**
Last post held : **Trade-Man-C**

(4) Mr. B.ijaya K. Biswal

Date of Retirement : **30.04.2011**
Date of Joining : **21.08.1981**
Last post held : **Helper - D**

9 AUDITED STATEMENT OF ACCOUNTS

INSTITUTE OF PHYSICS, BHUBANESWAR

BALANCE SHEET AS AT 31ST MARCH 2011

(Amount - Rs.)

CORPUS/ CAPITAL FUND AND LIABILITIES	Schedule	Current Year	Previous Year
CORPUS/ CAPITAL FUND	1	552,143,721	573,939,700
EARMARKED/ ENDOWMENT FUNDS	2	254,370	181,551
CURRENT LIABILITIES AND PROVISIONS	3	155,873,929	153,680,316
TOTAL		708,272,020	727,801,567
ASSETS			
FIXED ASSETS	4	578,154,227	538,802,420
CURRENT ASSETS, LOANS, ADVANCES ETC.	5	130,117,793	188,999,147
TOTAL		708,272,020	727,801,567
SIGNIFICANT ACCOUNTING POLICIES	21		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS			

In terms of our report of even date annexed

Place : Bhubaneswar
Date : 01-09-2011

INSTITUTE OF PHYSICS, BHUBANESWAR

INCOME AND EXPENDITURE ACCOUNT FOR THE PERIOD/YEAR ENDED 31ST MARCH 2011

(Amount - Rs.)

INCOME	Schedule	Current Year	Previous Year
Grants/ Subsidies	6	105,834,211	126,724,130
Interest Earned	7	4,338,724	3,667,209
Other Income	8	693,100	757,973
Prior period Income		-	-
TOTAL (A)		110,866,035	131,149,312
EXPENDITURE			
Establishment Expenses	9	96,750,253	95,695,060
Other Administrative Expenses etc.	10	42,693,869	35,807,175
Depreciation	4	67,788,397	61,021,760
Loss of Assets		31,857	-
TOTAL (B)		207,264,376	192,523,995
Balance being excess of Expenditure over Income (B-A)		(96,598,341)	(61,374,683)
BALANCE BEING SURPLUS/(DEFICIT) CARRIED TO CORPUS/CAPITAL FUND		(96,598,341)	(61,374,683)
SIGNIFICANT ACCOUNTING POLICIES	21		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS			

In terms of our report of even date annexed

Place : Bhubaneswar
Date : 01-09-2011

INSTITUTE OF PHYSICS, BHUBANESWAR
RECEIPTS & PAYMENTS FOR THE FINANCIAL YEAR 2010-11

(Figure in Rs.)

	RECEIPTS	SCH	Current Year	Previous Year		PAYMENTS	SCH	Current Year	Previous Year
I.	Opening Balance				I.	Expenses			
	a) Cash in hand		18,476	32,402		a) Establishment Expenses	13	96,877,354	95,144,382
	b) Bank balances					b) Administrative Expenses	14	24,132,520	21,066,203
	i) In current accounts SBI		4,430,999	664,299		c) Maintenance Expenses	15	13,270,182	10,552,518
	ii) In deposit accounts				II.	Payments made against funds for various projects			
	LK Panda (SBI Term Deposit)		100,000	100,000		TPSc		25,106	96,071
	iii) Savings accounts					LK panda Scholarship		5,000	5,000
	Indian Overseas Bank		36,534,803	49,054,874					
	Union Bank		57,731,407	39,073,934	III.	Expenditure on Fixed Assets & Capital W.I.P			
	SBI (LK Panda)		57,415	57,751		a) Purchase of Fixed Assets	16	74,720,919	149,606,158
	Union Bank (TPSC)		24,136	38,659					
II.	Grants Received				IV.	Interest Receivable		-	-
	a) From Govt. of India - Plan		124,700,000	140,000,000					
	Non-Plan		54,922,000	145,400,000	V.	Project Revenue Expenses	17	3,091,814	4,149,592
	b) From State Government		700,000	700,000	VI.	Travel Advance	18	-	-
	c) Raja Ramana Fellowship		1,410,000	-	VII.	STAFF LOAN	19	329,693	362,370
III.	Receipts against Sponsored Projects				VIII.	Other Advance	20	-	-
	TPSC		100,000	80,000					
IV.	Income on Investments from				IX.	Security Deposit with CESU		741,704	-
	LK Panda A/c		1,981	4,664					
	TPSC A/c		944	1,548	X.	Closing Balance			
V.	Interest Received	11	4,315,778	3,514,982		a) Cash in hand		9,787	18,476
VI.	Other Income (Specify)					b) Bank balances			
	Misc Receipts		5,438	5,656		i) In current accounts SBI		38,231,501	4,430,999
	Sale of Tender paper		14,100	16,500		ii) In deposit accounts			
	House/Guest House Rent		673,162	733,791		LK Panda (SBI Term Deposit)		100,000	100,000
	Advance from NISER		-	33,060		iii) Savings accounts			
	Sale of Asset		165,750	85,900		Indian Overseas Bank		29,310,014	36,534,803
VII.	Other Receipts					Union Bank		5,197,608	57,731,407
	Earnest Money Deposit		48,646	43,069		SBI (LK Panda)		54,386	57,415
	Security Deposit		(310,420)	(932,199)		Union Bank (TPSC)		99,974	24,136
	Security Deposit BSNL		10,500	-					
	Caution Money		2,000	1,600					
	RECOVERY OF STAFF LOAN	12	540,258	1,168,040					
	TOTAL		286,197,372	379,878,530		TOTAL		286,197,372	379,878,530

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