

MAJOR ACHIEVEMENTS OF INSTITUTE OF PHYSICS, BHUBANESWAR

About the Institute

Institute of Physics (IOP) is an autonomous research institution within the Department of Atomic Energy (DAE), Government of India. The Institute was established in 1972 by Government of Orissa and continues to receive financial assistance from them. The Institute became an aided autonomous institution of Department of Atomic Energy (DAE) in 1985. It is a premier research institute of the country, engaged in frontline research, both in experimental and theoretical physics. The Institute has the distinction of having a very successful doctoral program and has produced a large number of highly trained and qualified scientists.

Mandate vis-à-vis relevance to DAE programs

The Institute engages in frontier research programs in the fields of theoretical and experimental condensed matter physics, theoretical high energy physics, theoretical nuclear physics, ultra-relativistic heavy-ion collisions, astro-particle physics and cosmology, quantum information, and experimental high-energy nuclear physics. One of the important research areas in the Institute is the field of Nanoscience and Nanotechnology in general and surface and interface studies in particular. The Institute has several advanced facilities for sample preparation and for the study of various physical and chemical properties of nanostructures and bulk condensed matter systems. The Institute is actively involved in the International Collaborations with CERN (Switzerland), BNL (USA), ANL (USA), GSI (Germany), and other laboratories abroad. The Institute is also participating in various research activities related to India-based Neutrino observatory. As per the press release dtd. 22th November, 2016 by DAE, India has become an Associate Member State of CERN. IOP plays a major role in this project.

The Institute has been contributing in a significant way towards quality human resource development in the form of a one year pre-doctoral course followed by a Ph.D. program, as well as its post-doctoral program. The Scholars of pre-doctoral program (the course work of the program) of the Institute are selected through JEST/NET/GATE/INSPIRE and interview, who will be pursuing their Ph.D after completion of the course work. By now, more than sixty eight students (out of a total of about 176 students) who have done their Ph.D. at the Institute, are occupying prestigious faculty positions (Sr. Scientist) in almost all the leading research Institutes, IITs, Central and State Universities in the country. The Institute has also been actively promoting interactions with colleges, universities, academic Institutions, and laboratories by means of visitor programs, workshops, symposia, and other academic events.

The library and the computer center of the institute are one of the most extensively utilized facilities, catering to a large number of outside users as well from academic

institutions of entire Odisha. Teachers from various colleges and Universities visit the Institute during vacation periods like summer holidays, Puja holidays, and winter break, to pursue their research works and projects using these facilities. The Institute also arranges a summer student visitor program where selected students from all over the country visit IOP to do projects and interact with students and scientists.

The Institute also regularly conducts various programs for Schools / College Students, Teachers of both Schools and Colleges viz. Science Day, SSVP, and refresher courses in order to enhance their knowledge about the modern physical sciences.

The Institute is actively involved in popularizing science through its 'Out Reach Program'. Every year in March, 'The National Science Day' is celebrated, along with the National Institute of Science Education and Research (NISER), where students from different schools across Bhubaneswar are invited for laboratory visits at IOP and demonstration experiments at NISER where they interact intimately with faculty members and research scholars. The students also attend popular science lectures given by eminent scientists. School and college students from all over Odisha also come to IOP for laboratory visits and popular science lectures at different times throughout the year. IOP members give popular lectures at various places, in particular at schools and colleges in Odisha. For school children, the Alumni association of the Institute arranges various programs such as debate competitions, science quiz, and science model contest. The Institute sponsors, and is actively involved in, a joint rural science education program with the Samanta Chandra Sekhar Amateur Astronomers Association (SCAAA) where members of SCAAA and IOP scientists visit villages of Odisha to give popular lectures on science and technology, and arrange sky viewing sessions at night with telescopes.

The Faculty members and scholars of the Institute have brought in activities on new research frontiers. Institute has provided them the necessary infrastructure required for their work. Many of these members work in collaboration with the various international groups as well as in-house.

Awards/Recognitions received in recent years

The Institute members have distinguished themselves with different recognitions and awards. A list of recent awards and recognitions is given below.

1986

- Prof. S. N. Sahu : Honored with International WELCH Award from International Union for Vacuum Science and Technology and Applications (IUVSTA), USA

1988

- Prof. S. P. Misra : Honored with Samanta Chandrasekhar Award for Physical Sciences, By Orissa Bigyan Academy

1989

- Prof. A. M. Jayannavar Honored with Alexander von Humboldt Fellow
- Prof. L. Satapathy : Honored with Samanta Chandrasekhar Award for Physical Sciences by Orissa Bigyan Academy

1990

- **Prof. Trilochan Pradhan : Received the Padma Bhushan Award from President of India**
- 1991
- Prof. S. N. Behera : Honored with Samanta Chandrasekhar Award for Physical Sciences by Orissa Bigyan Academy.
- 1992
- Prof. J. Maharana : Honored with Samanta Chandrasekhar Award for Physical Sciences by Orissa Bigyan Academy.
 - Prof. Alok Kumar : Honored with Regular Associateship of Abdus Salam ICTP, Trieste, Italy for seven year.
- 1993
- Prof. Alok Kumar : Received Associateship of the Indian Academy of Sciences, Bangalore and Received INSA Medal for Young Scientist by Indian National Science Academy, New Delhi
- 1994
- Prof. S. M. Bhattacharjee : Honored with Regular Associate of Abdus Salam ICTP, Trieste, Italy.
- 1995
- Prof. A. V. Khare : Elected as Fellow of Indian National Science Academy (INSA).
- 1996
- Prof. Laxmidhar Satapathy : Awarded with
 - Kamal Kumari National Award for Science & Technology by the Kamal Kumari Foundation, Mahatma Gandhi Road, Jorhat, Assam.
 - Prof. A. M. Jayannavar : Received the Fellow of Indian Academy of Sciences, Bangalore
 - Prof. A. M. Jayannavar : ICTP Prize (UNESCO Centre) in honour of Sir Nevill Mott in the field of Solid State Physics
- 1998
- Padma Bhushan Prof. Trilochan Pradhan : Honored with Senior Scientist Award felicitated by Orissa Bigyan Academy
 - Dr. B. B. Dhal : Honored with Young Asian Scholar Award by the Australian Research Council
 - Dr. A. M. Jayannavar : Honored with Shanti Swarup Bhatnagar (SSB) Prize for Physical Sciences
 - Ms. Soma Dey received the Young Research Award in recognition of her paper presented during the 5th IUMRS International Conference in Asia held at IISc., Bangalore during 13-16 October, 1998.
 - Prof. Avinash V. Khare : Received the Meghnad Shah Award of the Hari Om Ashram Trust Awards instituted by the University Grants Commission
- 1999
- Prof. A. M. Jayannavar : Honored with Associate Member of Abdus Salam ICTP, Trieste, Italy.
 - Dr. S. N. Sahu : Samanta Chandrasekhar Award for Physical Sciences by Orissa Bigyan Academy.
 - Shri Bibhudutta Rout : Young Scientist Award for Physical Sciences by Orissa Bigyan Academy.

- 2000
- Prof. S.M.Bhattacharjee : Fellow of Indian Academy of Sciences, Bangalore
- 2002
- Prof. A. M. Jayannavar : Fellow of Indian National Science Academy, New Delhi
- 2003
- Prof. A. M. Jayannavar : Fellow of the National Academy of Sciences and Senior Associate member of Abdus Salam ICTP, Trieste, Italy.
- 2004
- Prof. A. M. Jayannavar G.D.Birla Awar for Scientific Research
 - Prof. R. K. Choudhury : Samanta Chandrasekhar Award for Physical Sciences by Orissa Bigyan Academy
- 2005
- Prof. S. N. Sahu : Rajiv Gandhi Akshaya Urja Award by DST, Govt. of Orissa
- 2006
- Prof. B. N. Dev : Elected for Fellow of Indian Academy of Sciences, Bangalore
 - Dr. Goutam Tripathy : Received ICTP Junior Associateship from 2005.
- 2007
- Prof. Y. P. Viyogi : Received Helmholtz-Humboldt Research Award for 2006
 - Ms. Binata Panda (Scholar) : Received Marie Curie (Theoretical Physics) Early Stage Fellowship to work at CERN for the year 2007
 - Mr. Dipak Paramanik (Scholar) : Received Graduate Student Silver Award from Material Research Society, USA for the year 2007
- 2008
- Prof. Y. P. Viyogi : Elected Fellow of National Academy of Science, Allahabad.
 - Prof. S. M. Bhattacharjee : Elected Fellow of Indian National Science Academy, New Delhi.
 - Prof. S. N. Sahu : Elected for President of Materials Science Section, 95th Indian Science Congress 2007 – 2008.
 - Ms. P. S. Saumia (Scholar) : Received Best poster presentation award at the Quark Matter – 2008 Conference at Jaipur in Feb 2008.
 - Ms. Binata Panda (Scholar) : Received “Giulio Racah Diploma” at the International School for Sub – Nuclear Physics, Erice, Italy, September 2007.
 - Dr. S. N. Sarangi (IOP-Staff) : Received Best Poster Award at 95th Indian Science Congress Meeting, Andhra University, in January 2008.
- 2009
- Prof. A. M. Jayannavar : Awarded with J. C. Bose National Fellowship by DST, Government of India
 - Prof. Y. P. Viyogi : Elected Fellow of Indian National Science Academy, New Delhi, India
- 2010
- Prof. S. M. Bhattacharjee : Awarded with J. C. Bose Fellowship by DST, Government of India
 - Prof. A. K. Pati : Awarded Samanta Chandrasekhar Award from Odisha Bigyan Academy.
- 2011
- Prof. A. Khare : Awarded with Raja Ramanna Fellow by DAE.
 - Prof. J. Maharana : Awarded with Raja Ramanna Fellow by DAE.

2014

- Dr. Sanjib Kumar Agarwalla : INSA Medal for Young Scientist for 2014
- Dr. Sanjib Kumar Agarwalla : Young Scientist Platinum Jubilee Award by National Academy of Sciences, India (NASI)
- Shri Raghavendra Rao : Juluri Best Micrograph Award-2014 in EMSI Conference, 2014.
- Ms. Sabita Das : Best Experimental Poster presentation at XLIV International Symposium on Multi-Particle Dynamics (ISMD), during 8-12 September, 2014.
- Dr. Sanjib Kumar Agarwalla : Young Scientist Platinum Jubilee Award by National Academy of Sciences, India (NASI)
- Prof. Sudhakar Panda : Elected as Fellow of Indian National Science Academy (INSA)
- Dr. Sanjib Kumar Agarwalla : Appointed as Simons Associate of Abdus Salam ICTP, Trieste, Italy for the period 1.1.2015 to 31.12.2020.

2015

- Prof. A.M.Jayannavar : 10 years of excellence Distinguished Faculty Award from HBNI, Mumbai.
- Dr. Dipak Paramanik : Outstanding Doctoral Thesis Award by HBNI
- Ms. Saumia P.S. : Outstanding Doctoral Thesis Award by HBNI
- Prof. J. Maharana : S.N.Bose Medal, 2015 from INSA, New Delhi.
- Prof. Trilochan Pradhan : Kalinga Samman Award for popularization of science
- Dr. Arua Kumar Nayak : Ramanujan Fellowship awarded by the SERB of DST, Govt. of India.

2016

- Dr. Sanjib Kumar Agarwalla : NASI SCOPUS Award for 2016- Physics Category.

Major Experimental Facilities

I. Accelerator Based Experimental Research

The experimental research work at IOP is primarily based around the 3 MV tandem Pelletron accelerator which started functioning since 1992. It has proved to be an invaluable tool for modification and analysis of thin films and bulk samples to understand the phenomena occurring at surfaces and interfaces. Energetic ion beam from the accelerator is also capable of analyzing the presence of trace elements in materials which is otherwise very difficult to obtain (by other techniques). Over the



ION BEAM ACCELERATOR

years, several beam lines have been developed for ion beam analysis of materials including Rutherford backscattering spectrometry (RBS), elastic recoil detection analysis (ERDA), RBS-Channeling, proton induced X-ray emission (PIXE) etc. All these facilities have a large number of external users from India and collaborative works from abroad.

II. Advanced Material Processing Laboratory (AMPL)

The laboratory houses equipment for conducting research in several frontier areas on thin films and nanomaterials. Using the facilities existing here, samples can be prepared under sensitive and controlled conditions and can be investigated for their morphological, magnetic, optical, vibrational properties.

III. Facility for Investigation of Photoluminescence and Raman Spectroscopic Properties:

CMPF system was installed in May 2014 and is equipped with water cooled Argon laser. The Micro Raman facility is operated in backscattering geometry. Confocal mapping capabilities with sub-micron spatial resolution are possible. A wide range of excitation wavelengths, using laser, is possible allowing control of the penetration depth into the material, and thus, control of the volume sampled. By combining these techniques it is possible to characterize both the vibrational and electronic properties of materials. The system will be utilized to understand the properties of many semiconductor systems including oxide semiconductors. Our group, in general, is involved in investigating the electronic structure as well as physical, optical, magnetic and chemical properties of surfaces, thin films and nanostructures, grown by a variety of techniques involving Ion sputtering, thermal deposition, vapor deposition. The interaction of DNA and polymers with surfaces and nanostructures is also being actively pursued in the group. Oxide semiconductors are energy storage materials displaying excellent UV and Visible light absorption properties when suitably patterned with nanostructures. Interaction of DNA with oxide surfaces can demonstrate many exciting properties which have technological implications for sensors and bio- implants. Our group has shown that DNA can also act as a tiny sensor of Mercury. These systems will be investigated for their vibrational properties.

II. Major Condensed Matter Experimental Research facilities

An active program has been developed in the interdisciplinary experimental research areas of condensed matter physics. This has been possible by establishing state-of-the-art facilities for pursuing cutting edge research. These facilities cater to the needs of a very large number of institutions, universities and colleges across the country. Institute of Physics has also become a hub of energetic ion beam based materials research in the south-eastern part of the country. Several advanced experimental facilities like Atomic Force Microscope (AFM), Transmission Electron Microscope (TEM) , X-ray photoelectron spectroscopy and Angle Resolved UV photoelectron spectroscopy (XPS and ARUPS),

Focused ion beam (FIB) facility with a high-resolution field emission gun based scanning electron microscope (FEGSEM), Molecular Beam Epitaxial (MBE), superconducting quantum interference device with-vibrating sample magnetometer (SQUID- VSM), UHV electron beam evaporation, DC/RF magnetron sputtering and Pulsed Laser Deposition (PLD) facilities are extensively utilized by the users from all over the country. Using these facilities scientists can fabricate (e.g. thin films, nanostructures, patterns, biomolecule-interfaces), manipulate these structures (e.g. anneal, modify with ion beams, interact with gasses, dope, implant) understand their composition, structural, optical magnetic and electronic properties.

Research Achievements

The research output of the Institute in various areas of theoretical and experimental physics has been very impressive as evident from publication record. There are on average about 80 publications in refereed journals every year. Faculty members, scholars and post-doctoral fellows of the Institute are invited for talks at various conferences and different institutes within the country and abroad. Specific research achievements in various areas are as follows.

I. Condensed Matter Theory

Research areas in condensed matter physics theory span mesoscopic systems, statistical mechanics for non equilibrium systems and biophysics, dynamic phase transition in DNA, fluctuation theorems, phase transitions in driven lattice systems, understanding models of growth and pattern formation. Various phenomena relating to structural phase transition, charge density waves, high temperature superconductivity and strongly correlated electron systems have also been investigated. Several new effects in mesoscopic have been predicted. Theoretical treatments of machines/engines at nanoscales have been developed from microscopic considerations. Cellular Automata inspired models have been studied to understand traffic jams which are rather ubiquitous in various situations from traffic flow to data transmission in a network, phase separation in a granular material etc. The effect of random forces on a double stranded DNA in unzipping the two strands, which is analogous to the problem of an adsorbed polymer under a random force, has been studied and it is shown that the unzipping phase diagram is drastically different from the pure case.

II. Condensed matter Experimental Research

A cutting edge research program in the frontier areas research are being undertaken in the interdisciplinary experimental research areas of nanostructures, pattern formation, ion beam interactions with matter, clusters, and nano-bio physics. Enhanced mass transport under MeV ion impact is being studied for better understanding of ion-matter interaction in space and nuclear materials. Studies are being conducted to show that TiO_2

semiconductor surfaces are able to absorb visible spectrum more strongly after nanostructures are created on their surfaces by ion beams. Studies are also being conducted on optoelectronic materials in order to modify their band gap and optical properties. Analysis of valence band electronic structure and band mapping of transition metal-oxide compounds using photoelectron spectroscopy has been undertaken. Quantum structures of ultra-clean systems on clean/reconstructed surfaces of *Si (111)*, *Si (100)* and *Si (110)* have been studied. Besides, it has been demonstrated that circular plasmid DNA can be used as mercury sensor.

III. High Energy Theory

The high energy physics group is actively involved in pursuing research in string theory, astro-particle physics, cosmology and particle physics phenomenology. Some of the topics of recent interest are gauge / gravity duality, black hole physics, anisotropic power law inflation, different aspects of relativistic heavy ion collisions such as flow fluctuations and their connection with fluctuations in the cosmic microwave background radiation, topological objects in the quark-gluon plasma phase, and dual superconductor model of hadronization. Connections between phase transition in cosmology and condensed matter system such as liquid crystal are also being investigated. Investigations of gluon fusion processes have been carried out at hadron colliders, such as production of Kaluza-Klein graviton in association with a Higgs boson in extensions of the standard model.

IV. Nuclear Physics

In nuclear physics, research has focused on nuclear structure and nuclear reaction. The mechanism for the formation of superheavy elements in astrophysical objects, nucleon-nucleus and nucleus-nucleus reaction, study of cluster decay properties have been pursued. Recently discovered superheavy nuclei and a new mode of fission decay for neutron-rich heavy nuclei are being studied in details. In addition, international collaborative research is being pursued at ALICE at CERN in search for quark-gluon plasma phase.

Further, Institute is pursuing a new area of research in the form of quantum computation and information.

Societal Impact:

The most important contribution of the institute towards society is in developing high quality scientific manpower through its pre-doctoral course work, doctoral program, and its post-doctoral program. By now, more than sixty eight students (out of a total of about 176 students) who have done their Ph.D. at the Institute, are occupying faculty positions in almost all the leading research centers, IITs, Central and State Universities in

the country. The Institute provides a center for top class scientific facilities, including its computer and library facility for users, in particular for teachers and researchers across the state of Odisha. The Institute has a vibrant outreach program through which scientific awareness and scientific thinking is propagated to remote areas, in particular in villages, as well as to school children across Odisha.

The scientific programs of the institute on one hand relate to basic research, so essential towards higher level of scientific awareness and scientific learning of the society. At the same time, the Institute also engages in research with reasonably direct technological implications, such as in the area of nano-technology, solar cells, bio-nano device applications, etc.

ACHIEVEMENTS IN LAST THREE YEARS (2013-2016)

*Institute of Physics,
Bhubaneswar*

Institute of Physics, Bhubaneswar (IOP) has been making substantial contributions to the scientific research in the field of theoretical and experimental research in the areas of condensed matter physics, nuclear physics, high energy physics and interdisciplinary areas such as quantum computation, biological physics, complex systems, nano-science and material science. Institute is actively involved in international collaborations with CERN (Switzerland) (ALICE, CMS), BNL (USA), ANL (USA), GSI (Germany). Institute is also participating in various research activities related to India-based Neutrino Observatory (INO). IOP has around 24 faculty members, 3 more to join soon 45 Ph. D students and 22 Post-doctoral fellows. During last three years institute has published around 330 papers in high impact international peer reviewed journals. Many of these publications have made significant advancements to research in frontier areas of physics internationally. Further during the three years IOP has produced around 25 Ph.Ds. IOP also has many state of art experimental facilities like, 3MV pelletron particle accelerator, electron cyclotron resonance based accelerator, high resolution transmission electron microscope, atomic force microscope, molecular beam epitaxy systems, Raman spectrometers, photoemission spectrometers etc. In last three years these facilities have been extensively used by around 80 external users from various Universities, IITs and National Institutes. Following are some of the applauded research highlights from IOP in last three years.

1. Important contributions to the detector simulation studies related to the Iron Calorimeter (ICAL) detector at the INO.
2. Important contributions in identifying methods to determine the neutrino mass ordering, mixing angles, and CP-violation in the lepton sector in India-based Neutrino Observatory (INO).
3. Development of 4-GEM prototype detector of India ALICE at CERN, Geneva.
4. Usage of $GdAlO_3$ as magnetic refrigerant for liquefying hydrogen.
5. Development of organometallic halides solar cells with 16.4% of efficiency.
6. Observations on holographic c-function and black hole singularity.
7. Studies on RG-flow and thermodynamics of causal horizons in higher derivative AdS gravity.
8. Established a DST Max Planck Partner group titled ``Quantum Black Holes" at the IOP tied with the Albert-Einstein-Institute in Potsdam, Germany.
9. Detailed exploration of the classical and quantum properties of black holes.
10. Theoretical prediction of DNA mimicking the strange quantum phenomena of Efimov effect.
11. Theoretical studies of microscopic single particle stochastic heat engines and refrigerators.

Out-Reach Programme

IOP has a very strong out-reach programme committed to the society. This programme is targeted mainly to school and college students, Teachers and children of local 'Basti'.

1. Seminar on 'Generating public awareness about Nuclear Power'
2. Regular Night Sky viewing sessions.
3. Teaching children of local Basti and helping them to enrol in schools.
4. School teachers training programme.
5. Science modelling, quiz and telescope making sessions for school children.
6. Awareness-cum-Seminar on Atomic Energy and nuclear Power in Service of mankind.