ANNUAL REPORT & AUDITED STATEMENT OF ACCOUNTS 2022-23

Institute of Physics

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भौतिकी संस्थान
Institute of Physics

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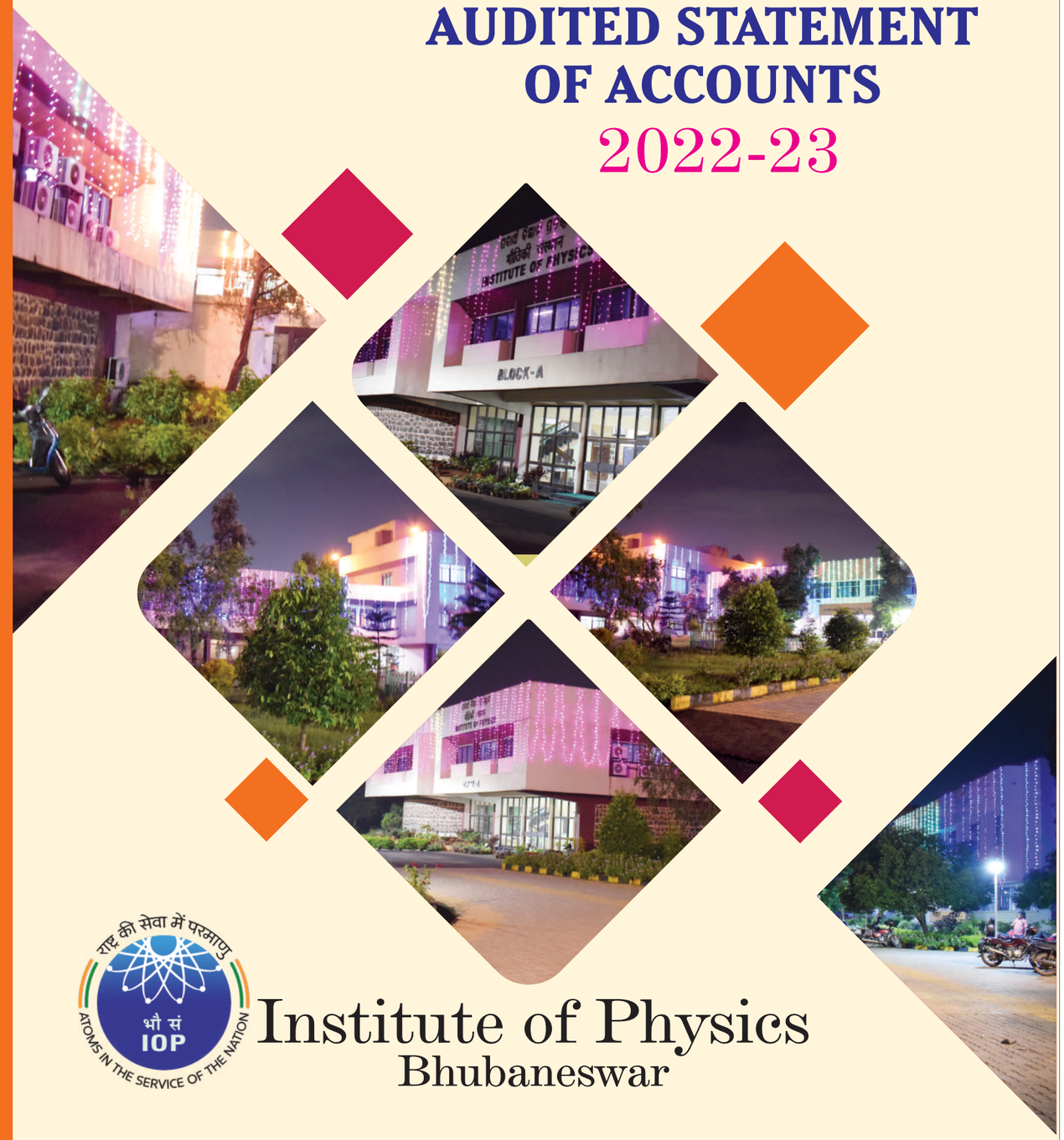

Institute of Physics
Bhubaneswar

Annual Report
&
Audited Statement of Accounts
2022-23

Institute of Physics

BHUBANESWAR

INSTITUTE OF PHYSICS

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About the Institute

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

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

The Institute offers Ph.D. programme in Physics. Selected students are required to successfully complete one-year course work at the Institute. The selection for the doctoral programme is through the Joint Entrance Screening Test (JEST). Candidates who have high CSIR-UGC NET or GATE scores are also eligible for admission to the doctoral program.

The Institute campus has housing facilities for the employees and hostels for the scholars and post-doctoral fellows. Compact efficiency apartments are available for post-doctoral fellows and visitors. Both indoor and outdoor games and sports facilities are also available in the campus. The Institute has a mini-gym in the New Hostel. The Institute also has a guest house, auditorium, and dispensary in the campus. The Foundation Day of the Institute is celebrated on 4th of September every year.

CHAIRMAN AND MEMBERS OF THE GOVERNING COUNCIL FOR THE YEAR 2022-23

1.	Dr. K. N. Vyas, Chairman, Atomic Energy Commission and Secretary to Govt. of India, Department of Atomic Energy, Anushakti Bhavan, C.S.M.Marg, Mumbai.	:	Chairman
2.	Prof. K. K. Nanda, Director, Institute of Physics, Bhubaneswar - 751005 (Since 16.06.2021).	:	Member
3.	Prof. Pinaki Majumdar, Director, Harish-Chandra Research Institute Chhatnag Road, Jhunsi, Allahabad-211019.	:	Member
4.	Prof. Gautam Bhattacharyya, Director, Saha Institute of Nuclear Physics, Sector-1, Block-A/F, Bidhan Nagar, Kolkata-700064.	:	Member
5.	Prof. Sudhakar Panda, Director, National Institute of Science Education and Research, Post. Bhimpur-Padanpur, Via. Jatni, Khurda - 752050.	:	Member
6.	Dr. Shashank Chaturvedi, Director, Institute for Plasma Research, Bhat Village, Near Indira Bridge, Gandhinagar-382428.	:	Member
7.	Smt. Sushma Taishete, Joint Secretary (R&D), Department of Atomic Energy, Anushakti Bhavan, C.S.M.Marg, Mumbai-400001.	:	Member
8.	Smt. Richa Bagla, IAS, Joint Secretary (Finance), Department of Atomic Energy Anushakti Bhavan, C. S. M. Marg, Mumbai-400 001.	:	Member
9.	Shri Bhaskar Jyoti Sharma Commissioner –cum-Secretary to Govt. of Odisha Science and Technology Department. Odisha Secretariat Bhubaneswar-751001 (From 17.09.2022).	:	Member
10.	Shri Manoj Kumar Mishra, IRTS, Science and Technology Department, Secretary to Govt. of Odisha, Odisha Secretariat, Bhubaneswar-751001 (Since 01.04.2021 to 16.09.2022)	:	Member
11.	Prof. Susmita Kar, Professor & Head, P.G. Department of Physics, Sriram Chandra Bhanjadeo University, Baripada (Since 05.08.2022)	:	Member
12.	Prof. Surya Narayan Nayak, Department of Physics, Sambalpur University, JyotiVihar, Burla, Sambalpur-768019. (till 04.08.2022)	:	Member
13.	Prof. Manas Ranjan Panigrahi, Department of Physics, Veer Surendra Sai University of Technology (VSSUT), Burla. (Since 05.08.2022)	:	Member
14.	Prof. Sukanta Kumar Tripathy, P. G. Department of Physics,` Berhampur University, Bhanja Bihar, Ganjam-760007. (till 04.08.2022)	:	Member

Secretary to the Governing Council

Shri R. K. Rath, Registrar, *(upto 31.07.2022)*, **Prof. P. K. Sahu,** (*from 01.08.2022)*
Institute of Physics, Bhubaneswar-751005

From the Director's Desk . . .

I am delighted to present before you the "Annual Report and Audited Statement of Accounts" of Institute of Physics (IoP), Bhubaneswar for the year 2022-23. This report provides a summary of our academic and research activities, as well as our accomplishments. IoP, Bhubaneswar is an autonomous research Institute funded by the Department of Atomic Energy (DAE), Government of India.It is one of the leading research institutes in India and its mission is to conduct high-quality research at the cutting edge of both experimental and theoretical physics. Research activities at IoP focus mainly on experimental and theoretical condensed matter physics, high energy physics and theoretical nuclear physics.

This year, IoP members have published around 110 research papers in high-quality international peer-reviewed journals, demonstrating the exceptional level of research being conducted by the faculty members. Further, IoP has published 96 research papers collectively through ALICE & CMS Collaboration. Members of IoP have also written several book chapters, popular articles, conference proceedings, etc.

Members of the Institute have received many accolades. Importantly, faculty members are associated with different reputed international scientific organizations. Scholars have also receivied awards for best oral as well as poster presentations in National and International conferences. Prof.Sanjib Kumar Agarwalla has been selected as an Associate Member of the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy and Membership of the world-class IceCube Neutrino Project through the University of Wisconsin, Madison, USA.Dr. Manimala Mitra has been awarded Institute for Particle Physics Phenomenology (IPPP) DIVA Award 2022-2023. Prof. Tapobrata Som continues as Executive Body Member

(Eastern India), Ion Beam Society of India. Prof. Debasish Chaudhuri has been nominated to continue as an Associate of ICTS-TIFR, Bangalore for three more years from January 2023 to December 2025.Prof. Aruna Kumar Nayak has been nominated to continue as an Associate of ICTS-TIFR, Bangalore.Prof. Shikha Varma has been elected as Endowment Chair Professor, Dr. K. C. Patel Research & Development Center (KRADLE). Ourscholars Sanu Varghese appointed as convener of the group on Strategy for Trigger Evolution and Monitoring (STEAM) by the CMS collaboration for two years. Dr. Joy Mukherjee was conferred with best oral presentation award in7th International Conference on Nanoscience and Nanotechnology (ICONN2023).

The Institute observed the 48th Foundation Day on 4th September 2022 in which Professor Ajit Kumar Mohanty, Director, BARC, Mumbai graced the occasion as Chief Guest and Prof. S. B. Krupanidhi, Emeritus Professor, IISc, Bangalore delivered Foundation Day Letcure. The Institute has observed AzadiKa Amrit Mahotsav and DAE ICONIC Week. Swachh Bharat and Outreach programs for communicating Science and scientific temper to school and college students, teachers and the public were organized. The team members from IOP visited different districts of Odisha to organize such activities. Similarly, students of different college and universities visited the Institute very frequently to acquire knowledge on sophisticated equipment of the Institute. Activities like night sky viewing with telescopes, popular science talks and talks on social issues are also being conducted. National and international conferences have been organized and National Science Day has been observed as “OPEN DAY” by demonstrating live experiments to motivate young minds towards Science.

In addition, emphasis has been given for implementation of the policy of the Government. Official Language Implementation in the Institute, Celebration of International Women’s Day, International Yoga Day and Observance of Vigilance Awareness Week, DAE Iconic Week etc. are some of them.

At last, I take this opportunity to acknowledge my sincere gratitude to all the stake holders of IOP community including the Governing Council members for their continuous support and advices. I would also like to thank all the faculty and staff for their relentless effort to take the Institue to a greater height including the committee members who have given such a shape to this Annual Report. I am confident that the Institute will continue to make significant contributions to both fundamental and applied physics research in the years to come.

Professor Karuna Kar Nanda

Director, IOP

Contribution of Institute of Physics (IoP) towards DAE Vision

Brief Summary of Annual Report 2022-2023

Institute of Physics (IOP), Bhubaneswar, is a premier research institute of the country, engaged in frontier research, both in experimental and theoretical physics. The major research programs are in the fields of theoretical and experimental condensed matter physics, theoretical and experimental high-energy physics and theoretical nuclear physics. During 2022-23, around 95 research papers were published in international peer-reviewed journals. Four students were awarded Ph. D through our intense doctoral programme during 2022-23.

The theoretical high energy group has made significant contributions to areas like; formal field theory, string theory, QCD, radiative corrections, neutrino physics, beyond the standard model scenarios and their phenomenology, ultra-relativistic heavy-ion collisions, astro-particle physics, cosmology and quantum information. The experimental high energy group is actively involved in the collider-based experiments at various international laboratories, such as CMS and ALICE experiments at CERN-LHC, STAR experiment at RHIC, BNL (USA), and the proposed CBM experiment at FAIR, GSI (Germany). The group has been playing a leading role in the development of tau lepton reconstruction and identification techniques in the CMS experiment at CERN as well as in the development of algorithms for the reconstruction of hadrons. Substantial contributions have also been made to various research activities related to the India-based Neutrino observatory.

The Condensed Matter Theory group has made well recognized contributions to the non-equilibrium aspects of a higher-order topological insulator, their superconducting phases hosting Majorana modes, their bulk boundary correspondence, quantum transport in Dirac/Weyl materials, twisted bilayer systems, quantum magnetism, strong correlations in a band topological insulators on the Lieb lattice, effect of interaction and disorder in strongly correlated systems in the presence of the magnetic field, aspect of quantum magnetism, organization of bacterial chromosomes, exact dynamical moments for trapped active Brownian particles showing a re-entrant non-equilibrium transition, the emergence of dynamical pattern formation and running waves on spherical membranes due to active cytoskeletal proteins.

The Theoretical Nuclear Physics Group worked mainly on the structure of neutron stars, especially their merger, to estimate the Gravitational Wave Strain. Lots of work is being done to understand the various modes of oscillation of neutron star, cooling of it and Supernovae and the Dark Matter effects. The Nuclear Reaction Dynamics and various exotic structures of finite nuclei are also being studied.

The experimental condensed matter group at IoP is actively involved in cutting-edge research that focuses on Brain-inspired computing, Resistive switching, ion beam-induced self-organized pattern formation and their nanoscale functionalization, photovoltaics, nano-bio glucose sensing, organic and DNA overlayers, novel electronic and magnetic phenomena in atomically engineered thin films/heterostructures, thermoelectric, electronic band structures of advanced materials and understanding of physical properties of atomically thin two dimensional layered materials. The low-energy 3 MV Pelletron accelerator of IOP has been used by different external users to carry out their research.

Institute of Physics, with its strong commitment towards science for social development, has undertaken many programmes under the 'Outreach' banner. A large number of school children visited IOP facilities and interacted with scientists. The Institute also has conducted several outreach programmes at various schools and colleges in remote parts of the state. Institute conducts regular sky-watch programmes for school children. February 28 is an 'Open Day' for the Institute to facilitate access and provide information about IOP facilities to the general public to celebrate National Science Day. The Rajbhasa wing of the Institute organised Hindi Diwas, four Hindi Workshops, and one Scientific Seminar.

ACADEMIC PROGRAMMES

1.1 PRE-DOCTORAL PROGRAM

One of the most important objectives of the Institute is to train and guide young scholars to do research in physics. Since 1975, IOP has a regular Pre-doctoral (Post M.Sc.) course, which is a very important academic program because it is designed to train the M.Sc. students for carrying out research activities. This programme is aimed at imparting a broad based training in advanced physics and research methodology to students. The course work is planned with the view that it should help the students not only in doctoral research, but also enable him/her to become a good physics teacher. The Institute participates in conducting the Joint Entrance Screening Test (JEST) to select students who are interested in pursuing Ph.D. in physics. The final selection of a student is based on the result of written test and an interview conducted at the institute. This year the Pre-doctoral course began in January 2022. On completion of the Pre-doctoral program, students are eligible to join research under the supervision of faculty members of the Institute, leading to the Ph.D. degree awarded by Homi Bhabha National Institute (HBNI).

The Institute has instituted Lalit Kumar Panda Memorial Endowment Fellowship (*L. K. Panda Memorial Fellowship)* to recognize the talent for themost outstanding pre-doctoral student. The fellowship consists of an award of Rs.5,000/- and a citation. Last year the awardee was Mr. Sayak Bhowmik.

A total of 72 students were called for written test and interview for admission to the pre doctoral course in August, 2022. This includes JEST qualifiers, UGC-CSIR qualifiers and valid GATE score holders. Following students enrolled to the doctoral course work program for the year 2022-2023:

1. Mr. Smruti Ranjan Senapaty
2. Ms. Ruma Khatun
3. Ms. Minakshi Subhadarshini
4. Mr. Raj Rajiv Upadhyay
5. Mr. Tarakeshwar Mondal
6. Mr. Subham Saha
7. Mr. Sambhav Antariksha
8. Mr. Debabrata Sahoo
9. Ms. Ankita Ghosh

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

Semester – I

Advanced Quantum Mechanics	:	Prof. Sudipta Mukherji
Quantum Field Theory - I	:	Dr. Manimala Mitra
Advanced Experimental Techniques	:	Prof. T. Som
Experimental Physics Lab	:	Prof. Satyaprakash Sahoo
Many Body Physics	:	Prof. Saptarshi Mandal

Semester – II

Mathematical Methods	: Prof. Goutam Tripathy/ Prof. Aruna Nayak
Quantum Field Theory – II	: Prof. Pankaj Agrawal/ Dr. Debottam Das
High Energy Physics	: Dr. Kirtiman Ghosh
Special Topics in Statistical Physics	: Prof. T. Som/Prof. A. Saha/ Prof. D. Topwal
Special topics in Condensed Matter Physics	: Prof. Satyaprakash Sahoo

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

1.2 DOCTORAL PROGRAM

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

1.3 POST-DOCTORAL FELLOWS

1. Dr. Abhijit Kumar Saha
2. Dr. Bhanu Sharma
3. Dr. Joy Mukherjee
4. Dr. Hemanta Kumar Sharma
5. Dr. Koushik Naskar
6. Dr. Sagarika Swain
7. Dr.Hanuma Kumar
8. Dr. Paramita Maiti
9. Dr. Akavoor Manu
10. Dr. Dr. Karan Singh (Upto 17.05.2022)
11. Dr. Anjan Kumar Jena (Upto 25.10.2022)
12. Dr. R. Bhattacharyya (Upto 20.04.2022)
13. Dr. Rakesh Kumar Sahoo (Upto 14.12.2022)
14. Dr. S. S. Khali (Upto 31.01.2023)
15. Dr. Siddharth Dwivedi (Upto 08.04.2022)

➢POST-DOCTORAL FELLOWS (P)-APEX

1. Dr. Arnab Chaudhuri (upto 20.08.2022)
2. Dr. Santanu De (upto 31.08.2022)
3. Dr. Pavan Kumar Yerra
4. Dr. Kaushik Mandal
5. Dr. Subrata Mondal (upto 24.01.2022)
6. Dr. Rajneesh Kumar
7. Dr. Deepak Kumar
8. Dr. Ashish Kumar
9. Dr. Paramita Maiti
10. Dr. Songshapatak De
11. Dr. Deepak
12. Dr. Lalit Kumar Saini
13. Dr. Ashish
14. Dr. Ramita Sarkar

1.4 (a) THESES (Submitted)

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

1. **Mr. Pranjal Pandey**
   Advisor: Prof. Shamik Banerjee
   Thesis Title: "spects of Flat Space Holography"

2. **Ms. Dilruba Hasina**
   Advisor: Prof. Tapobrata Som
   Thesis Title: "Nanoscale TiO_x-based memristive synaptic devices for neuromorphic computing applications: role of defect engineering"

3. **Mr. Alapan Dutta**
   Advisor: Prof. Tapobrata Som
   Thesis Title: "Optoelectronic optimization of thin films related to the metal oxide contact-based photovoltaic cell"

4. **Mr. Biswajit Das**
   Advisor: Prof. Pankaj Agrawal
   Thesis Title: "Probing Anomalous Higgs Boson Couplings at Colliders"

5. **Mr. Saiyad Ashanujjaman**
   Advisor: Prof. Kirtiman Ghosh
   Thesis Title*:* "Perusing some neutrino mass models at the LHC"

6. **Mr. Harish C. Das**
   Advisor: Prof. Suresh Kumar Patra
   Thesis Title: "Impacts of dark matter interaction on nuclear and neutron star matter within the relativistic mean-field model"

7. **Mr. Avnish**
   Advisor*:* Dr. Kirtiman Ghosh
   Thesis Title: "Exploring neutrino mass and dark matter motivated TeV scale scenarios at the collider experiments"

1.4 (b) THESES (Defended*)

1. **Dr. Debjyoti Majumdar***
   Advisor: Prof. Goutam Tripathy
   Thesis Title*:* "Rigidity and collapse of melting DNA"

2. **Dr. Atanu Maity ***
   Advisor: Prof. Saptarshi Mandal
   Thesis Title*:* "Classical Orders, VBS, QSL in Fisher Lattice & Spin Wave Analysis in Hollandite Lattice"

3. **Dr. Pranjal Pandey***
   Advisor: Prof. Shamik Banerjee
   Thesis Title*:* "Aspects of Flat Space Holography"

4. **Dr. Saiyad Ashanujjaman***
   Advisor: Dr. Kirtiman Ghosh
   Thesis Title*:* "Perusing some neutrino mass models at the LHC"

5. **Dr. Harish Chandra Das***
   Advisor: Prof. Suresh Kumar Patra
   Thesis Title*:* "Impacts of dark matter interaction on nuclear and neutron star matter within the relativistic mean-field model

1.5 Summer Student's Visiting Program (SSVP):

The motivation of the SSVP program is to expose young students to frontline research areas, especially in the areas of research work

Name of the Student	Topic of the Seminar	Advisor
Ms. Bhagya S Babu	Study of cosmic ray using plastic scintillator	Prof. P. K. Sahu
Ms. Aiswarya Rath	Density functional Theory	Dr. Aparajita Mandal
Mr. Harshal Kulkarni	5. all plus one loop amplitude in self-dual gravity	Prof. Shamik Banerjee
Mr. Gyanaranjan Swain	Growth and Characterization of Zinc Oxide (ZnO) thin film.	Prof. T. Som
Mr. Soumya Sweta Bhujabal	'Introduction to Superconductivity'	Prof. Saptarshi Mandal

pursuing at the Institute. This year the SSVP was held from 15th May to 30th June, 2022. Five students participated in the program. Round trip train fare, accommodation on campus, and a monthly stipend of Rs. 5000/- was provided to all the visiting students. Under this program, each student worked under the guidance of a faculty member of the Institute. At the end of the program, students presented their work in a seminar on the assigned topics.

1.6 Conferences / Workshops organized by IOP

1. Workshop on Beyond the Standard Model particle physics (30th August to 2nd September 2022)

This was a focused meeting on beyond-the-standard-model scenarios, in particular supersymmetry and large extra dimension based models. There were about 20 speakers, and a total of 40-50 participants. Apart from talks, there were intense discussion about the possible future directions. This meeting took place in hybrid mode and was organized by the HEP group.

2. Remembering Professor Trilochan Pradhan (15th to 16th December 2022)

A two-day meeting was organized to remember the legacy and contributions of Prof. Trilochan Pradhan. Prof. Pradhan was a visionary who not only made significant scientific contributions, but also developed and nurtured many institutions. In this meeting, some of his students, and some of those whose lives were touched by him gave scientific talks, paid tribute, and recalled their fond association with him. There were about ten scientific talks and about 15-2 associates paid tribute to him. This meeting was organized by Prof. K. K. Nanda and Pankaj Agrawal. Prof. Nanda announced that the main Lecture Hall of the Institute would be named as Prof. Trilochan Pradhan Lecture Hall.

3. International Meeting on High Energy Physics (IMHEP) (16th to 22nd February 2023)

A one-week conference on high energy physics was organized by the HEP group.Oneof the main objectives of this meeting is to review the status of our current understanding of beyond the Standard Model Physics and to make some definitive attempts in order tointerpret the observations at the LHC. There were plenary review talks in various areasof the standard model and beyond. There were also conference talks. In total, there wereabout fifty regular and review talks. In addition, there was a poster session and manyparallel sessions. This was second in a series of conferences to cover most areas of highenergy

physics. The number of speakers and participants was about one hundred and fifty.

4. Advances in Low-dimensional Materials for Optoelectronic and Nano Devices (ALMOND 2023)

The 1st National Conference on Advances in Low-dimensional Materials for Optoelectronic and Nano Devices (ALMOND 2023) was organized by the Institute of Physics (IoP), Bhubaneswar, during 3rd-5th March 2023 under the banner of *Azadi Ka Amrit Mahotsav*. Prof. Satyaprakash Sahoo, was the Convener and the conference was held under the guidance of Prof. Karuna Kar Nanda, Director, IoP. ALMOND-2023 was focused on the scientific advancement

in low-dimensional novel materials that includes 2D materials, Metal oxide, organic/inorganic thin films, and Nanowires, to meet the demands of state-of-the-art electronic and optoelectronic devices. Participants from different research institutes like IISc, IIT-Kgp, IISER-TVM, IISER-Bhopal, NISER, UGC-DAE, IIST-ISRO, JNCASR, IoP attended the conference. Prof. V. S. Ramamurthy, renowned nuclear scientist, was the Chief Guest of the event. Eminent Scientists/ Professors from different institutes delivered invited talks on broad areas from advanced materials growth to their applications in low-power miniaturized devices from experimental findings to theoretical aspects. There was a poster presentation session by students, and it was very interactive. The conference received overwhelming response from all the researchers and was concluded with a grand success.

1.7 Prestigious Fellows

Since its inception nearly 50 years ago, the Institute of Physics Bhubaneswar (IoPB) has cultivated an academic and cultural atmosphere that garners the interest of prestigious fellowship holders, who consider IoP an ideal host institute for their pioneering research. IoPB proudly accommodates four prestigious fellows: **Dr. B. K. Panigrahi, Dr. K. Bhattacharjee, Dr. A. Mandal and Dr. S. Koley.**

Dr. K. Bhattacharjee's research group is currently focused on three main areas: carbon nanotubes (CNTs) for thin film coatings in stray light control space applications, investigating the electrical properties of copper oxides and copper-oxygen-silicon hybrid films, and exploring the growth of two-dimensional tin (Sn) on WS2 substrates and studying their band structure and local density of states. Dr. K. Bhattacharjee, with her students, has successfully developed a low-cost technique to create thin film coatings using CNTs and carbon nanoscrolls (CNS) on aluminum substrates, which exhibit a low reflectance of around 2-3% in the visible and near-infrared spectral ranges. This development is significant for high absorber coatings in stray light control applications. In their study of Cu growth on a thick SiO2 dielectric on Si(111) substrates, the research group observed triangular voids and islands on the surface, indicating a void-filling mechanism. Through core-level X-ray photoelectron spectroscopy (XPS) measurements, they estimated different coordination states, oxidation numbers, and chemical compositions of the Cu-grown film. They found evidence of a mixed Cu-O-Si intermediate state at the interface, attributed to new chemical states of Cux+, Ox, and Six+. This highly catalytic intermediate state was present in a concentration of approximately 41%. The group also focuses on the growth of atomic Sn on WS2 substrates at room temperature under ultrahigh vacuum conditions. They investigate the surface morphology and local electronic properties of bare WS2 and Sn/WS2 surfaces using in-situ scanning tunneling microscopy (STM), scanning tunneling spectroscopy (STS) and density functional theory (DFT) studies.

Dr. A. Mandal, as a DST-INSPIRE Faculty Fellow, focused her research on developing passivating carrier-selective contacts for silicon-based heterojunction solar cells. They optimized the parameters of reactive RF sputtering to achieve high work function and optical transparency in vanadium oxide (VOx) thin films suitable for device fabrication. The optimized VOx films demonstrated excellent resistive switching (RS) characteristics and showed potential for neuromorphic functionalities, operating at remarkably low voltages. These findings highlight the suitability of VOx films for electronic synaptic devices. In a related field, Dr. A. Mandal conducted a detailed simulation using the open-source software SCAPS 1-D to study the roles of interfacial defects in a heterojunction solar cell based on antimony selenide (Sb2Se3) and tungsten oxide (WOx). The simulation aimed to understand the impact of interfacial defects on the performance of the solar cell. Overall, Dr. A. Mandal's research encompasses the exploration of metal oxides for applications in renewable energy, particularly solar cells, and their potential utilization in electronic memory technologies.

Dr. Somnath Koley, another DST-INSPIRE Faculty Fellow, is actively researching devices based on colloidal quantum dots (CQDs). Colloidal quantum dots (CQDs) are semiconductor nanocrystals (SCNCs) with a typical diameter of 2 to 10 nm and possess size tuneable optoelectronic properties due to the quantum confinement of charges. Altering these defined electronic states via systematic and pre-designed electronic-functionalization remains the central of CQD-based devices. The ultimate applicability of the SCNCs towards optoelectronic devices relies on (i) the Development of high - quality building blocks, (ii) How two neighboring particles interact with each other, and (iii) the device aspect.

1.8 (A) Awards / Honours/ Rcognitions/ External funding for Faculty Members

Prof. Shikha Varma

- Endowment Chair Professor, Dr. K. C. Patel Research & Development Center (KRADLE), CHARUSAT, Gujarat : Since 2021

Prof. Pankaj Agrawal

- Funding: I am part of a continuing DST funded cluster project – Quantum Information Technologies with photonic devices.
- Organized workshop on Beyond Standard Model Particle Physics, from Aug 30 - Sep 2, 2022. This meeting was organized with the other HEP group members.
- Organized meeting "Remembering Professor Trilochan Pradhan", from Dec 15-16, 2022. This meeting was co-organized with Prof. K. K. Nanda.
- Organized International Meeting on High Energy Physics (IMHEP-2023), from Feb 16-22, 2023. This meeting was organized with the other HEP group members.

Prof. S. K. Patra

- Funding: Structural properties of Neutron-Rich Exotic Nuclei (No. CRG/2019/002691)
- Funding: Explore the internal composition of the Neutron Star (No. CRG/2022/005378)
- Funding: Effect of nuclear density approximation and shell closure in the dynamics of heavy-ion induced reaction (58/14/12/2019-BRNS)
- Funding: Nuclear Structure and reaction dynamics within effective field theory motivated relativistic mean field approach (FOSTECT.2019B.04)

Prof. T. Som

- Funding: Two sub-projects in the on-going DAE Apex Project of IoP.
- "Elastic Recoil Detection Analysis" in High End Workshop on Scattering Methods (Electron, X-ray and Ion) for Materials Characterization, organized by IIT Bhubaneswar (June 15, 2022).
- "Atomic Force Microscopy: A tool for micro-to-nanoscale science" in International Conferenceon Advanced Materialsand Applications (ICAMA-2022), organizedby S'O'A University, Bhubaneswar (December15, 2022).
- "Atomic Force Microscopy: An Amazing Tool for Micro-to-nanoscale Science" in International Symposiumon Semiconductor Materialsand Devices (ISSMD-2022), organized by KIIT University, Bhubaneswar (December16, 2022).
- "Memristive Materials: Some perspectives" in National Conferenceon Advancesin Low-dimensional Materials for Optoelectronics and Nano Devices (ALMOND 2023), organized byInstittueof Physics BhubaneswaratToshali Sands, Puri (March 5,2023).
- "Memristive Materials: Fundamentalsto Applications" in 7th International Conferenceon Nanoscience and Nanotechnology (ICONN 2023), organized by SRM Institute of Science andTechnology, Chennai (March 27, 2023).
- High End Workshop on Scattering Methods (Electron, X-rayandIon) for Materials

Characterization", organized by IITBhubaneswar (June, 2022).

- "International Conference on Advanced Materials and Applications (ICAMA-2022)", organizedby S'O'A University, Bhubaneswar(December, 2022).
- "International Symposium on Semiconductor Materials and Devices (ISSMD-2022)", organizedby KIIT University, Bhubaneswar (December, 2022).
- "National Conference on Advances in Low-dimensional Materials for Optoelectronics and Nano Devices (ALMOND2023)", organized by Instituteof Physics Bhubaneswarat Toshali Sands, Puri (March,2023).
- "7th International Conference on Nanoscience and Nanotechnology (ICONN 2023), organized by SRM Institute of Scienceand Technology, Chennai (March 27, 2023).

Prof. P. K. Sahu

- Funding: BI/IFCC, DST project for CBM at FAIR, GSI, Germany.
- Officiating Registrar at IOP since 1st August 2022.
- Evaluation of Ph.D. thesis in r/o Mr. Pritam Chakraborty, IIT, Bombay (12/2022)
- Evaluation of Ph. D thesis submitted by Mr Bidhan Khirali, NIT, Jamsedpur(8/2022)
- Evaluation of Ph.D. thesis in r/o Mr. Baidyanath Sahoo, IIT, BombayBombay (6/2022)
- Invitation to review for Physica Scripta (3/2022)
- The Fund for Scientific Research – FNRS; Brussels, Belgium F.R.S.-FNRS invitation to review (2/2022)
- India-ALICE-STAR Collaboration online Meeting: 25th -28th April 2022
- Popular talk 21st May 2022 at SCS (A) College, Puri.
- Course taught and School conducted in ALICE-STAR School, 1st -12th November 2022.
- Outreach events13-14th November 2022 at Model Degree College Boudh and JNV Boudh
- Outreach events 24-25th December, 2022 Berhampur University, and Mathura Village, Ganjam
- Outreach events 28-29th January 2023, CUTM, Bolangir campus and Govt. Women's College, Bolangir.
- Outreach events 31st March 2023, JNV, Konark, Puri.

Prof. D. Topwal

- Funding: DST project: CRG/2020/003108
- Funding: UGC-DAE CSR project: CSR/2021-22/01/362

Prof. Sanjib K Agarwalla

Externally funded Projects (India + Foreign sponsorships)

- **Funding:** DST-SERB Swarnajayanti Project (SB/SJF/2020-21/21)
  Project Title: Landscape of Beyond the Standard Model Physics at Neutrino Experiments.
  Total cost of Project: Rs. 1,00,27,040/-
- Awarded The Prestigious Fulbright-Nehru Academic and Professional Excellence Fellowship (FNAPE) to perform cutting-

edge research on the fundamental properties of massive neutrinos at the University of Wisconsin-Madison, Madison, USA.

- Appointed as an Honorary Fellow of the Physics Department, University of Wisconsin-Madison, Madison, USA.
- Full Membership of the world-class IceCube Neutrino Project through the University of Wisconsin-Madison, Madison, USA.
- Multi-messenger Tomography of Earth – (MMTE 2022) Workshop

I organized the above workshop during 30th to 31st July, 2022 at Salt Lake City, Utah, USA. The main aim of this workshop was to bring together leading experts from the neutrino and geoscience communities to discuss in depth the present status of the field and its future developments.

https://indico.fnal.gov/event/53004/page/2944-multi-messenger-tomography-of-earth-mmte-2022-workshop

- Organized Institute Online Colloquium by Prof. Livia Ludhova on "Geoneutrinos - A New Tool to Study the Earth", 22nd November, 2022.

Prof. Saptarshi Mandal

- Funding: Continuing SERB funded project "Exploring Multiferrocity in Hollandite type Mn-based Oxide Materials through Experimental and Theoretical studies" FILE no CRG/2021/006934

Prof. Aruna Kumar Nayak

- Organized IMHEP 2023, 16 – 22 February, 2023, Institute of Physics, Bhubaneswar

Prof. Debasish Chaudhuri

- Funding: SERB MATRICS (Mathematical Research Impact Centric Support) grant under project number MTR/2019/000750
- I have been nominated to continue as an Associate of ICTS-TIFR, Bangalore for three more years, from January 2023 to December 2025
- I have been invited with a Visiting Professorship of CY Cergy Paris University, Paris, France, from 26 September to 7 October 2022.
- Visited LPTM CY Cergy Paris University, Paris, France, with a Visiting Professorship from 26 September to 7 October 2022. This visit helped to start a collaboration with Professor Fernando Peruani of CY Cergy Paris University.
- Visited ICTS-TIFR Bangalore as an Associate of that institute from 23 May to 24 June 2022 to continue collaboration with Prof. Abhishek Dhar of ICTS-TIFR.
- Visited S N Bose National Centre for Basic Sciences from 4-6 July 2022 to present seminars and to start collaborative discussions with Prof. Urna Basu.
- Visited IISER-Mohali from 6-13 April **2022** to continue research collaboration with Prof. Abhishek Chaudhuri and Prof. Dipanjan Chakraborty.
- Invited lecture on "Pattern formation, localized and running pulsation on active spherical membranes" at the 8th Indian Statistical Physics community meeting (ISPCM) at ICTS- TIFR, Bangalore (01 February 2023)
- Invited lecture on "Motor Protein Drive: Filaments and Membranes" at the international conference on "Statistical Biological Physics: From single molecule

to Cell" at ICTS-TIFR, Bangalore (20 October 2022)

- Invited colloquium on "Stochastic thermodynamics and entropy production in the active matter" at LPTM, CY Cergy Paris University, Paris, France on 29 September 2022.
- Invited lecture on "Active particles: from single particle to collective motion" at LPTM, CY Cergy Paris University, Paris, France on 5th October 2022.
- Invited lecture at S N Bose National Centre for Basic Sciences on "Active matter: from single particle trajectory to collective behavior" on 5 July 2022.
- Invited lecture at IISER-Mohali on "Active matter: role of persistence, fluctuations, alignment, and trapping," delivered on 7th April 2022.

Prof. Debakanta Samal

- Funding: SERB,India (research grantNo.CRG/Z019/005144) (continuing)
- Funding:Max Planck Partner group funded by Max Planck Society, Germany (continuing)

Dr. Debottam Das

- Organized Workshop on the Beyond the SM Particle Physics(Aug 30 – Sep 2, 2022)
- Organized International Meeting on the High Energy Physics (Feb 16 – 22, 2023)

Dr. Manimala Mitra

- Funding: Indo-French CEFIPRA project - 6304-2
- Organized IMHEP-II 2023, IOP, Bhubaneswar

Dr. Kirtiman Ghosh

- MATRICS (Mathematical Research Impact Centric Support) grant funded by the Science and Engineering Research Board (SERB) for the theoretical research and development of some specific new variants of the Extra-Dimensional Model. [MTR/2022/000989]

1.8 (B) AWARDS / HONOURS AND RECOGNITIONS SCHOLARS

- Sanu Varghese (student) appointed as convener of the group on Strategy for Trigger Evolution and Monitoring (STEAM) by the CMS collaboration for two years (September 2022 to August 2024). This is a Level-2 convener position under CMS Trigger Coordination.
- Best oral presentation award was conferred to my group PDF (Institute PDF), Dr. Joy Mukherjee in 7th International Conferenceon Nanoscienceand Nanotechnology (ICONN2023), organized by SRM Instituteof Scienceand Technology, Chennai (March27, 2023).

RESEARCH

2.1. Theoretical High Energy Physics

(A.M. Srivastava, P. Agrawal, S. Mukherji, S. K. Agarwalla, S. Banerjee, D. Das, M. Mitra, K. Ghosh)

The faculty members of the Theoretical High Energy Physics group at IoP (THEP@IoP) are actively researching advanced topics such as string theory, cosmology, astrophysics, Quark-Gluon Plasma, Relativistic Heavy-Ion Collisions, neutrino oscillation, and experiments related to dark matter. Additionally, they are investigating collider phenomenology within various scenarios that go beyond the Standard Model. This research is being conducted in relation to both the ongoing Large Hadron Collider (LHC) and planned experiments involving electron-positron colliders. The notable research outcomes achieved by THEP@IoP in the academic year 2021–22 are as follows:

Throughout the academic year 2021–22, Professor Ajit M. Srivastava and his fellow researchers examined modifications in pulsar pulses, attributing these changes to density fluctuations caused by phase transitions affecting the pulsar's moment of inertia. They also explored the concept of acoustic black holes within the hydrodynamic flow of electrons. Furthermore, Professor Srivastava participated in a project involving the utilization of liquid crystal textures in the liquid crystal laboratory to investigate the shapes of microorganisms.

Professor Pankaj Agrawal, in collaboration with his students, performed calculations pertaining to the electroweak corrections to the decay of the Higgs boson (H) into a pair of vector bosons (V), either a W or a Z boson. This intricate process involves one-loop diagrams featuring the VVHH coupling. Consequently, this decay procedure presents an opportunity to establish constraints on this coupling. The team conducted an in-depth analysis of the implications stemming from alterations to the HHH and VVHH couplings, mainly focusing on the influence of such modifications on the decay width.

Professor Sudipta Mukherji commenced a groundbreaking exploration by employing holography to analyze a field theory existing on a time-dependent background with a conical defect. The focal point was the Milne spacetime, wherein the Milne vacuum was represented by the adiabatic one. Within this context, the researchers successfully calculated the two-point correlators of operators that correspond to massive scalars within the AdS-Milne bulk background with the conical defect. In a separate research endeavor, Professor Mukherji and his collaborators undertook a computation involving the topological charge of the Hawking-Page transition point for black holes within the AdS space. Their approach involved utilizing the Bragg-Williams construction to determine off-shell free energy.

Professor S.K. Agarwalla and a team of collaborators conducted a comprehensive investigation concerning the capabilities of the Deep Underground Neutrino Experiment (DUNE). Their research delved into the potential for detecting deviations from maximal mixing in the second-third (23) generation neutrinos and the ability to determine the octant. This analysis was conducted in light of the currently available data. Furthermore, the researchers explored the implications of possible non-unitary neutrino mixing (NUNM) within the context of upcoming long-baseline experiments, specifically DUNE and the T2HKK/JD+KD experiments. The latter involves a configuration with one detector located in Japan (T2HK/JD) and a second detector situated in Korea (KD). This work aimed to assess the impact of NUNM on the outcomes of these next-generation experiments. They estimated the sensitivities of these setups to place direct, model-independent, and competitive constraints on various NUNM parameters.

Dr. Debottam Das and his collaborators have calculated a few observables connecting beyond the Standard Model of particle physics where the importance of radiative corrections

can help to identify the NEW physics signatures at the LHC. While gluon-initiated processes have traditionally been regarded as the primary source of di-Higgs production at the LHC experiment, the group has shown that light-quark-initiated processes can also yield significant contributions, particularly in the presence of new resonances. The team also developed a technique to calculate the two-loop corrections in the context of quantum field theory. In a definite example, focusing on an SM singlet scalar with a small leading order result, they computed the dominant next-to-leading (NLO) order corrections to produce such a scalar at the LHC. Additionally, in an ongoing collaboration, Dr. Das and his collaborators have been working on the rare decays of the Z-boson in the SM.

Dr. Manimala Mitra played a pivotal role in two intersecting areas of research: Dark Matter and collider phenomenology. Collaborating with fellow researchers, Dr. Mitra delved into the intricacies of dark matter phenomenology, specifically focusing on Weakly Interacting Massive Particles (WIMPs) and Feebly Interacting Massive Particles (FIMPs). The team's work involved an extension of the Standard Model incorporating three triplet fermions, one triplet scalar, and one singlet fermion. This extended model had the potential to simultaneously account for neutrino masses and dark matter. Moreover, the researchers delved into the possibility of the next-to-lightest odd particle within the triplet becoming long-lived. This aspect opened avenues for probing this particle using the proposed MATHUSLA detector. The combined efforts of Dr. Mitra and her collaborators significantly contributed to advancing our understanding of both dark matter and collider physics, uncovering potential complementarity between these two fascinating realms.

Dr. Kirtiman Ghosh's research group is dedicated to investigating the underlying nature of Beyond the Standard Model (BSM) scenarios. Their primary mission revolves around comprehending the phenomenology of various BSM scenarios, particularly within the context of collider experiments, as well as other experimental domains, including neutrino scattering and oscillation, Dark Matter direct/indirect detection, and lepton flavor violation. A central focus of their work is to discern the interconnectedness and mutual benefits between these diverse experimental approaches. Dr. Ghosh's group has substantially contributed to advancing our understanding of BSM physics. These scenarios include the incorporation of exotic leptons within large gauge multiplets, the investigation of triplet-like Higgs bosons, the analysis of Scalar Leptoquarks, and the exploration of doubly-charged Higgs bosons.

Research Contribution by Prof. A.M. Srivastava Group

1 (a) Modulation of pulse profile as a probe for density fluctuations in a pulsar

(Partha Bagchi, Biswanath Layek, Anjishnu Sarkar, and Ajit M. Srivastava)

We calculate detailed modification of pulses from a pulsar arising from the effects of phase transition induced density fluctuations on the pulsar moment of inertia using a simple model where the initial moment of inertia tensor of the pulsar is assumed to get random additional contributions for each of its component which are taken to be Gaussian distributed with certain width characterized by the strength of density fluctuations. In ongoing work, we use this technique for the case when an asteroid collides with the pulsar. Such collisions have been proposed as explanation of certain gamma ray bursts. We propose that one should look for pulse modifications in correlation with such gamma ray bursts.

(b) Hawking radiation from acoustic black holes in hydrodynamic flow of electrons

(Shreyansh S. Dave, Oindrila Ganguly, Saumia P.S., and Ajit M. Srivastava)

Acoustic black holes are formed when a fluid flowing with subsonic velocities, accelerates and becomes supersonic. The surface

on which the normal component of fluid velocity equals the local speed of sound acts as an acoustic horizon. We investigate this possibility in the hydrodynamic flow of electrons. Resulting Hawking radiation in this case should be observable in terms of current fluctuations. Further, current fluctuations on both sides of the acoustic horizon should show correlations expected for pairs of Hawking particle. In the ongoing work, we are calculating resulting current-current correlations on the two sides of the sonic horizon as expected from the correlated Hawking particle pairs.

(c) Probing shapes of microbes using liquid crystal textures

(Ajit M. Srivastava)

Topological defects in nematic liquid crystals are routinely investigated using a cross-polarizer set-up in optical microscopes. Characteristic signature of topology and structure of the defect is contained in the structure of dark brushes emanating from the core of topological defects.

We carry out numerical simulations to show that this property can be used to identify shapes of microbes embedded in a nematic liquid crystal (NLC) sample. In ongoing work, we are working on experimental verification of these predictions with the use of nanorods and nanodots (representing cylindrical and spherical shapes of bacteria and viruses), in the liquid crystal lab.

(d) Relativistic QGP flow, Hawking radiation and non-stationary black hole horizon

(Oindrila Ganguly, Saumia P.S., and Ajit M. Srivastava)

Our earlier work on Hawking radiation from acoustic black holes in relativistic heavy-ion collisions considered non-relativistic QGP flow velocities appropriate for high baryon density QGP expected to be formed in heavy-ion collisions. In the present work we are extending it to ultra-relativistic fluid flow case as appropriate for LHC energies. This leads to non-stationary event horizon of acoustic black hole and conceptual issues associated with that have to be handled. The work is in progress.

(e) QCD, Gravitational Waves, and Pulsars

(Partha Bagchi, Oindrila Ganguly, Biswanath Layek, Anjishnu Sarkar, and Ajit M. Srivastava)
Invited review article for Modern Physics Letters A

This review discusses specific aspects of a pulsar relating to the extreme accuracy of observation of pulsar timings which provide a very sensitive probe of any minute deformations of the pulsar configuration. Specifically, the focus will be on the type of physics which can be probed by utilizing the effect of changes in the MI tensor of the pulsar on pulse properties, such as phase transitions to exotic QCD phases as well as the possibility of using pulsars as Weber detectors of gravitational waves.

Research Contribution by Prof. Pankaj Agrawal Group

2. (a) Electroweak Corrections to H → V V four leptons

(Pankaj Agrawal with Biswajit Das)

We have computed the electroweak corrections to the decay process H V V , where V boson can be a W or a Z boson. Here the vector bosons can decay into four neutrinos or four charged leptons. The one-loop diagrams have the V V HH coupling. So this process can be used to put a bound on this coupling. There are large numbers of complicated diagrams. In the case of neutrinos and charged leptons, one has to do renormalization, while in the case of charged leptons, there is additional complication of infrared diver-gences. In-house codes have been developed to carry out the computation. We have studied the effect of modifying HHH and V V HH coupling on the decay width. This can help in determining these couplings. We have found significant dependence on the HHH coupling, while the dependence on the V V HH coupling is quite mild.

(b) Inferred Uncertainty Relations

(Pankaj Agrawal with Chandan datta and Shrobona Bagchi)

Uncertainty relations play a significant role in drawing a line between classical physics and quantum physics. Since the introduction by Heisenberg, these relations have been considerably explored. However, the effect of quantum entanglement on uncertainty relations was not probed. Berta et al. removed this gap by deriving a conditional-entropic uncertainty relation in the presence of quantum entanglement. In the same spirit, using inferred-variance, we formulate uncertainty relations in the presence of entanglement for general two-qubit systems and arbitrary observables. We derive lower bounds for the sum and product inferred-variance uncertainty relations. Strikingly, we can write the lower bounds of these inferred-variance uncertainty relations in terms of measures of entanglement of two-qubit states, as characterized by concurrence, or G function. The presence of entanglement in the lower bound of inferred-variance uncertainty relation is quite distinctive. We also explore the violation of local uncertainty relations in this context and an interference experiment. Furthermore, we discuss possible applications of these uncertainty relations.

(c) Correlations in multipartite and bipartite qudit systems

(Pankaj Agrawal)

With many collaborators, I have been studying properties of quantum correlations in multipartite, bipartite qudit systems, and bipartite qubit systems in mixed states. In particular we are examining cryptography protocols, Bell inequalities, and communication protocols. Characterization of the entanglement for such systems is also a challenge. We are working on a different classification of the multipartite states. This classification is from the point of view of quantum communication. We are also working on characterizing the correlations a two-qubit mixed states. In the case of two-qubit mixed states, one needs to use a set of measures to fully characterize its correlations and its nonlocal features.

Research Contribution by Prof. Sudipta Mukherji Group

3. (a). (Sudipta Mukherji with S. Mishra and Y. Srivastava)

We initiate a holographic study of field theory on time dependent background with conical defect. We focus on the Milne space-time to which, in the absence of cosmological constant, at late time any hyperbolic Friedmann-Robertson-Walker metric flows to. When the Milne vacuum is represented by the adiabatic one, we are able to compute the two point correlators of operators which are dual to the massive scalars in the bulk AdS-Milne background with defect. We find, for both twisted and untwisted operators, the correlators can be represented as the sum over images. This sum can be carried out explicitly to write the results in compact form.

(b) (Sudipta Mukherji with P.K. Yerra and C. Bhamidipati)

Using the Bragg-Williams construction of an off-shell free energy we compute the topological charge of the Hawking-Page transition point for black holes in AdS. A computation following from a related off-shell effective potential in the boundary gauge dual matches the value of topological charge obtained in the bulk. We also compute the topological charges of the equilibrium phases of these systems, which follow from the saddle points of the appropriate free energy. The locally stable and unstable phases turn out to have topological charges opposite to each other, with the total being zero, in agreement with the result obtained from a related construction.

4. Research Contribution by Prof. S. K. Agarwalla Group

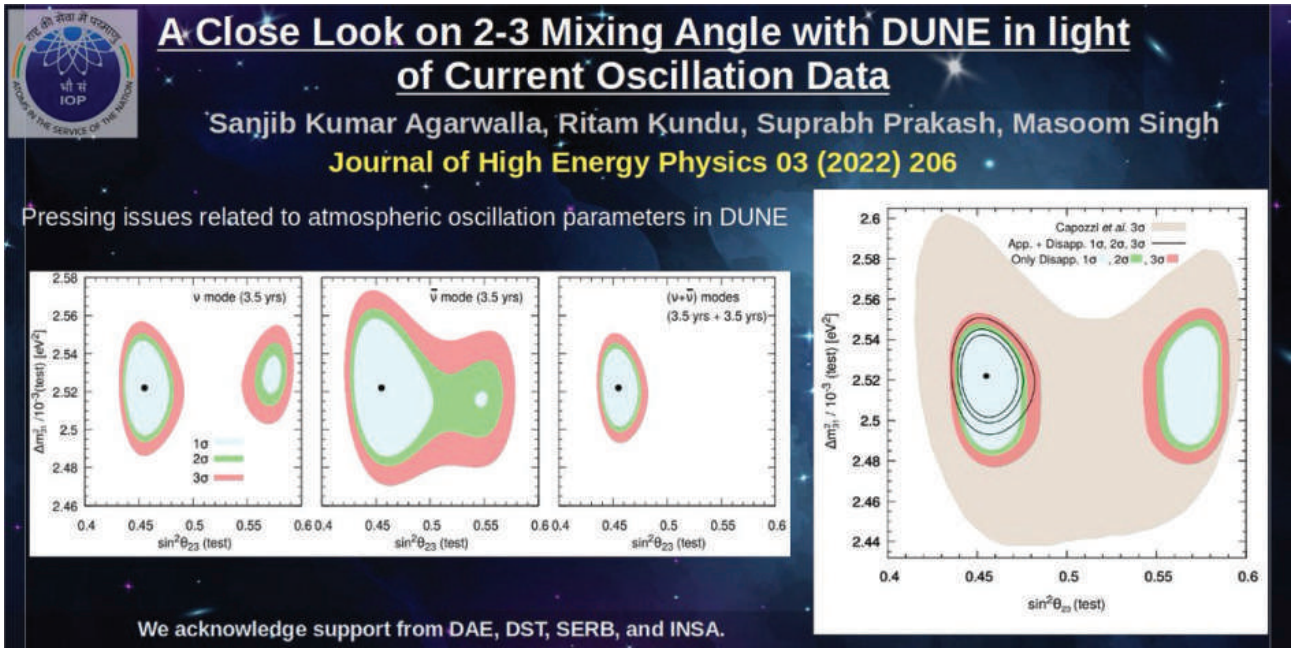
(S.K Agarwalla)

Recent global fit analyses of 3n oscillation data show a preference for normal mass ordering (NMO) at 2.5s and provide 1.6s indications for lower q_{23} octant ($\sin^2 q_{23} < 0.5$) and leptonic CP violation ($\sin d_{CP} < 0$). In this work, we study in detail the capabilities of DUNE to establish the deviation from maximal q_{23} and to resolve its octant in light of the current data. Introducing for the first time, a bi-events plot in the plane of total neutrino and antineutrino disappearance events, we discuss the impact of $\sin^2_{23}$ - "m^2_{31} degeneracy in establishing non-maximal q_{23} and show how this degeneracy can be resolved with the help of spectral analysis. We study the role of appearance and disappearance channels, systematic uncertainties, marginalization over oscillation parameters, and the importance of spectral analysis in establishing non-maximal q_{23}. The paper got published in the international refereed journal JHEP 03 (2022) 206.

Our knowledge on the active 3í mixing angles ($è_{12}$, $è_{13}$, and $è_{23}$) and the CP phase d_{CP} is becoming accurate day-by-day enabling us to test the unitarity of the leptonic mixing matrix with utmost precision. Future high-precision long-baseline experiments are going to play an important role in this direction. Under this project, we study the impact of possible non-unitary neutrino mixing (NUNM) in the context of next-generation long-baseline experiments DUNE and T2HKK/JD+KD having one detector in Japan (T2HK/JD) and a second detector in Korea (KD). We estimate the sensitivities of these setups to place direct, model-independent, and competitive constraints on various NUNM parameters. We demonstrate the possible correlations between the NUNM parameters, $è_{23}$ and d_{CP}. The paper got published in the international refereed journal JHEP 07 (2022) 121.

Precision measurements of neutrino oscillation parameters have provided a tremendous boost to the search for sub- leading effects due to several beyond the Standard Model scenarios in neutrino oscillation experiments. Among these, two of the well-studied scenarios are Lorentz violation (LV) and non-standard interactions (NSI), both of which can affect neutrino oscillations significantly. We point out that, at a long-baseline experiment where the neutrino oscillation probabilities can be well-approximated by using the line-averaged constant matter density, the effects of these two scenarios can mimic each other. This would allow the limits obtained at such an experiment on one of the above scenarios to be directly translated to the limits on the other scenario. However, for the same reason, it would be difficult to distinguish between LV and NSI at a long-baseline experiment. The paper got published in the international refereed journal Physics Letters B 841 (2023) 137949.

Atmospheric neutrinos provide a unique avenue to explore the internal structure of Earth based on weak interactions, which is complementary to seismic studies and gravitational measurements. In this work, we demonstrate that the atmospheric neutrino oscillations in the presence of Earth matter can serve as an important tool to locate the core-mantle boundary (CMB). An atmospheric neutrino detector like the proposed 50 kt magnetized ICAL at INO can observe the core-passing neutrinos efficiently. These neutrinos would have experienced the MSW resonance and the parametric or neutrino oscillation length resonance. The net effect of these resonances on neutrino flavor conversions depends upon the location of CMB and the density jump at that radius. We quantify the capability of ICAL to measure the location of CMB in the context of multiple three-layered models of Earth. The paper got published in the international referred journal JHEP 04 (2023) 068.



Research Contribution by Dr. Debottam Das Group

5. (a) Leptoquark-assisted Singlet-mediated Di-Higgs Production at the LHC

(Arvind Bhaskar, Debottam Das, Bibhabasu De, Subhadip Mitra, Aruna Kumar Nayak, Cyrin Neeraj)

Ref: e-Print: 2205.12210 (Phys.Lett.B 833 (2022) 137341, Phys.Lett.B C 833 (2022) 137341

At the LHC, the gluon-initiated processes are considered to be the primary source of di-Higgs production. However, in the presence of a new resonance, the light-quark initiated processes can also contribute signi cantly. In this letter, we look at the di-Higgs production mediated by a new singlet scalar. The singlet is produced in both quark-antiquark and gluon fusion processes through loops involving a scalar leptoquark and right-handed neutrinos. With benchmark parameters inspired from the recent resonant di-Higgs searches by the ATLAS collaboration, we examine the prospects of such a resonance in the TeV-range at the High-Luminosity LHC (HL-LHC) in the 2b2tau mode with a multivariate analysis. We obtain the 5sigma and 2sigma contours and find that a significant part of the parameter space is within the reach of the HL-LHC.

(b) Production of singlet dominated scalar(s) at the LHC

(Subhadip Bisal, Debottam Das, Swapan Majhi, Subhadip Mitra)

Ref: e-Print:2207.01358 [hep-ph], Phys.Lett.B 839 (2023) 137806

The leading order production of an SM singlet-like scalar has primarily been realized through the gluon fusion process by mixing with the $SU(2)_L$ scalar doublet of the model. The dominant part of the physical state, i.e., the singlet component, does not have any role in its direct production. Focusing on such a state with a mass smaller than the SM-like Higgs scalar, we calculate the dominant next-to-leading (NLO) order corrections to its production cross-section. With these improved cross-sections, the present and future LHC limits may become somewhat more stringent.

(c) The rare decays of Z boson (ongoing work):

(Subhadip Bisal, Debottam Das)

We study the rare decay process of Z boson into photon, accompanied by a CP-even or CP-odd scalar. We present the analytical delineation of the processes through the model-independent parametrizations of the new physics couplings

and, finally, consider the Next-to-Minimal Supersymmetric Standard Model to mark out the parameter space where the branching fraction can have the maximum value. As a part of the necessary phenomenological and experimental cross-checks, we aim to fit the anomalous magnetic moment of the muon and W boson mass anomaly through the supersymmetric contributions. We also find that the rare Z decay can serve as an excellent complementary test to the rare Higgs boson decay. Future proposals such as ILC, CEPC, and FCC-ee are anticipated to operate for multiple years, focusing on center-of-mass energy near the Z pole. Consequently, these projects will be capable of conducting experiments at the Giga-Z and Tera Z levels, which may probe the aforesaid rare decay processes, thus, the model as well. These unconventional yet complementary searches offer different routes to explore the supersymmetric with extended Higgs sector models like NMSSM.

Research Contribution by Dr. Manimala Mitra Group

6. Dark Matter Phenomenology:

In JHEP 11 (2022) 133, we explored dark matter phenomenology for WIMP and FIMPS arising from a singlet-triplet sermonic model. We present an extension of the SM involving three triplet fermions, one triplet scalar and one singlet fermion, which can explain both neutrino masses and dark matter. One triplet of fermions and the singlet are odd under a Z2 symmetry, thus the model features two possible dark matter candidates. The two remaining Z2-even triplet fermions can reproduce the neutrino masses and oscillation parameters consistent with observations. We consider the case where the singlet has feeble couplings while the triplet is weakly interacting and investigate the different possibilities for reproducing the observed dark matter relic density. This includes production of the triplet WIMP from freeze-out and from decay of the singlet as well as freeze-in production of the singlet from decay of particles that belong to the thermal bath or are thermally decoupled. While freeze-in production is usually dominated by decay processes, we also show cases where the annihilation of bath particles give substantial contribution to the final relic density. This occurs when the new scalars are below the TeV scale, thus in the reach of the LHC. The next-to-lightest odd particle can be long-lived and can alter the successful BBN predictions for the abundance of light elements, these constraints are relevant in both the scenarios where the singlet or the triplet are the long-lived particle. In the case where the triplet is the DM, the model is subject to constraints from ongoing direct, indirect and collider experiments. When the singlet is the DM, the triplet which is the next-to-lightest odd particle can be long-lived and can be probed at the proposed MATHUSLA detector. Finally we also address the detection prospects of triplet fermions and scalars at the LHC. In other work, JHEP 05 (2022) 182, we considered a secluded dark sector and explored DM phenomenology.

Effective field theory: The gauge singlet right-handed neutrinos (RHNs) are essential fields in several neutrino mass models that explain the observed eV scale neutrino mass. In Phys.Rev.D 106 (2022) 11, 11 , we assume RHN field to be present in the vicinity of the electroweak scale and all the other possible beyond the standard model (BSM) fields arise at high energy scale $> \Lambda$. In this scenario, the BSM physics can be described using effective field theory (EFT) where the set of canonical degrees of freedoms consists of both RHN and SM fields. EFT of this kind is usually dubbed as NR-EFT. We systematically construct relevant operators that can arise at dimension five and six while respecting underlying symmetry. To quantify the phenomenological implication of these EFT operators we calculate different couplings that involve RHN fields. We discuss the constraints on these EFT operators coming from different energy and precision frontier experiments. For pp, ep, and e+e- colliders, we identify various channels which crucially depends on these operators. We analytically evaluate the decay

widths of RHN considering all relevant operators and highlight the differences that arise because of the EFT framework. Based upon the signal cross-section we propose different multi-lepton channels to search for the RHN at 14 TeV LHC as well as future particle colliders.

The other works on collider phenomenology of seesaw models are JHEP 06 (2022) 168 and Eur. Phys. J.C 82 (2022) 10, 858.

In other works, which are under review process, in e-Print: 2304.08732 [hep-ph], we have explored doubly charged Higgs discovery potential in a. Muon collider; in e-Print: 2303.02681 [hep-ph] we explored dark matter phenomenology in a dynamic scotogenic model, in e-Print: 2211.09675 [hep-ph], we have explored an alternate version of the Left-Right symmetric model.

Research Contribution by Dr. Kirtiman Ghosh Group

7. (Kirtiman Ghosh)

The primary mission of our research group is to study the phenomenology of different BSM scenarios in the context of collider and other (neutrino scattering and oscillation, Dark Matter direct/indirect detection, lepton flavor violation, etc.) experiments and understand the complementarity between then. We have contributed to the development and phenomenology of different BSM scenarios during 2022-23. A brief account of the important outcomes of our research is given in the following.

(a) Search for exotic leptons in final states with two or three leptons and fat-jets at 13 TeV LHC:

Exotic leptons in large gauge multiplets, appearing in many scenarios beyond the Standard Model (SM), can be produced at the LHC in pairs or association. Owing to their large masses, their eventual decay products—SM leptons and bosons—tend to be highly boosted, with the jets stemming from the SM bosons more likely to manifest themselves as a single fat-jet rather than two resolved ones. With the corresponding SM backgrounds being suppressed, final states with two or three leptons and one or two fat-jets are expected to be sensitive in probing exotic fermions much heavier than 1 TeV, and we propose and investigate an appropriate search strategy.

(b) Type-II see-saw: searching the LHC elusive low-mass triplet-like Higgses at electron-positron colliders: While the triplet-like Higgses up to a few hundred GeV masses are already excluded for a vast region of the model parameter space from the LHC searches, strikingly, there is a region of this parameter space that is beyond the reach of the existing LHC searches, and doubly/singly-charged and neutral Higgses as light as 200 GeV or even lighter are still allowed by the LHC data. We study several search strategies targeting different parts of this LHC elusive parameter space at two configurations of electron-positron colliders—500 GeV and 1 TeV centre of mass energies.

(c) Phenomenology of Scalar Leptoquarks at the LHC in Explaining the Radiative Neutrino Mass, Muon g " 2 and Lepton Flavour Violating Observables: We study the phenomenology of a particular leptoquark extension of the Standard Model (SM), namely the doublet-singlet scalar leptoquark extension of the SM (DSL-SM). Besides generating Majorana mass for neutrinos, these leptoquarks contribute to muon and electron (g " 2) and various lepton flavour violating processes. Collider signatures of the benchmark points (BPs), consistent with the neutrino oscillation data, anomalous muon/electron magnetic moments, experimental bounds on the charged lepton flavour violation observables, etc., are studied at the LHC/FCC with centre-of-mass energies of 14, 27 and 100 TeV.

(d) Low-mass doubly-charged Higgs bosons at LHC: Search for light (within the mass

range 84–200 GeV) doubly-charged Higgs bosons decaying into a pair of W-bosons has been deemed challenging using the conventional LHC searches with leptons, jets and missing transverse momentum in the final state. Such Higgses, together with slightly heavier singly-charged and neutral Higgses, when arranged in an SU(2)L triplet as in the type-II see-saw model, are later shown to accommodate the recent measurement of the W-boson mass by the CDF collaboration. When produced in a highly Lorentz-boosted regime, these tend to manifest as a single fat-jet or a pair of adjacent same-sign leptons plus missing transverse momentum. First, we perform a multivariate analysis to discern such exotic jets from the SM jets. Then, we present a novel search in the final state with an exotic jet and two same-sign leptons plus missing transverse momentum. We find that such low-mass doubly-charged Higgsses could be directly probed with the already the already collected Run 2 LHC data.

2.2. Theoretical Nuclear Physics

(S. K. Patra, P. K. Sahu)

We have worked on different areas of nuclear physics, such as finite nuclei, nuclear matter, and neutron stars. Starting from the finite nuclei, we mainly explore the properties such as nuclear structure and reaction dynamics of different atomic nuclei. Some of the structural properties, such as binding energy, charge radius, magic numbers, two-neutron separation energy, symmetry energy, etc., in detail, have been calculated. Nuclear reactions, including alpha and beta decays, clusterization, fissions, etc., were determined with the help of relativistic to non-relativistic energy density functionals.

The nuclear matter properties such as binding energy per particle, energy density, pressure, effective mass, symmetry energy, and its different coefficients, etc., in different environments, either in the presence of dark matter or temperature from very low density to high density. The nuclear matter, finite nuclei, and neutron star equation of states are calculated with the well-known relativistic mean-field (RMF) model. We have developed our two functionals such as G3 and IOPB-I and applied them from finite nuclei to the neutron star. Our extended RMF model well reproduced the properties of different systems, such as finite nuclei to the neutron star.

Recently, we have extended our domain and explored the neutron star properties by adding dark matter. Some of these neutron star properties, such as its equation of states, mass, radius, tidal deformability, the moment of inertia, cooling scenario, inspiral properties of the binary neutron star, oscillations properties, different curvature parameters, etc. are calculated. Also, we have added temperature to see its effects on the thermal conductivity, emissivity, specific heat, thermal index, etc. are computed with different fractions of dark matter inside it.

The gravitational wave properties are also explored using the post-Newtonian method for different masses of the binary neutron star. In the inspiral stage, some well-known properties such as frequency, polarisability, phases of the two binary, etc., have been calculated for dark matter admixed neutron stars.

Another method known as Coherent Density Fluctuation Model (CDFM) is applied by our group to calculate the surface properties of finite nuclei as well as of Neutron Star. Here, we evaluate the symmetry energy, neutron pressure and there surface properties.

Research Contribution by Prof. S.K. Patra Group

1. I have an extensive research background in the field of Nuclear Physics and Nuclear Astrophysics theory, with a strong publication record. Over the years, my research has covered a wide range of topics such as nuclear reaction studies, the construction of both relativistic and non-relativistic nucleon-nucleon interactions, and the study of surface properties using the Coherent Density Fluctuation Model. I have also conducted

research on nuclear giant resonances for both stable and unstable nuclei, structures of exotic and super heavy nuclei, and nuclear fission for neutron-rich nuclei. Additionally, I have investigated nuclear high spin states (nuclear spectroscopy), nuclear structure and cluster radioactive-decay, and the nuclear equation of states. Currently, we are delving into the intriguing area of dark matter and the quarkyonic model. We are specifically interested in exploring their signature in the gravitational waves produced in the merger of binary neutron stars.

(S. K. Patra)

Research Contribution by Prof. P. K. Sahu Group

2. (a) Relativistic interacting Hadron-Resonance Gas model.

The meson exchange interaction based on relativistic mean-field (RMF) theory has been introduced in the hadron resonance gas (HRG) model, called the interacting HRG (iHRG) model. This model can explain the experimental data at finite temperature (T) with finite chemical potential (ìB) and finite temperature at vanishing chemical potential. The nuclear matter equation of state also can be explained at zero temperature with finite baryon density (finite chemical potential) due to attractive and repulsive interactions between the hadrons in the iHRG model. This study's results are compared with those from other heavy-ion transport models and experimental data.

(b) The Fermionic dark matter inside the neutron star.

We study the Fermionic dark matter inside the neutron star, which couples to nucleons through Higgs field via effective Yukawa coupling. The neutron star matter consists of leptons, nucleons, and hyperons in the relativistic chiral sigma model. If the dark matter composition is increased, then the neutron star gets more compact, and hence the size and mass reduce significantly.

(P. K. Sahu)

2.3. Experimental High Energy Physics

(P. K. Sahu, A. K. Nayak)

Contributions to the CMS experiment at CERN-LHC:

The CMS group at IOP made major contributions to the measurement of Higgs boson CP properties in its decay to a pair of tau leptons. The angle between the decay planes of the two tau leptons is exploited to probe the CP nature of the Higgs boson. The analysis with full Run-2 data at 13 TeV provided a measured value of the CP mixing angle to be (-1 +/- 19) degree at 68% confidence level and excludes a pure CP-odd state by 3 standard deviations. The results are published in JHEP.

In addition, we are leading an analysis for the search of a charged Higgs boson decaying to a charm and a strange quark, where the charged Higgs originates from the decay of a top quark. The analysis involves kinematic fitting to fully reconstruct the top quark pair and multivariate methods to discriminate signal from backgrounds. The analysis with full Run-2 data is in advance stage and expects significant improvement with respect to previous bound. We are also involved in the analysis for the search for a pseudo-scalar Higgs boson that can decay to a Z boson and the Standard Model like Higgs boson. The final state consists of two leptons (electron/muon) from Z decay and two tau leptons from Higgs decay. The analysis is being performed with full available 13 TeV data. Furthermore, we are starting to work on an analysis for the search of a Lepto-Quark decaying to a top quark and a tau lepton.

Our group plays leading role in the development of CMS high-level trigger system for LHC Run-3, which started from 2022. We are involved in leading the STEAM group under Trigger Coordination for last three years. Sanu Varghese (student) was appointed as STEAM group convener from Sep 2022 to Aug 2024. We have been consistently performing trigger rate studies for last two years using high

instantaneous luminosity data in order to validate menus and prepare trigger pre-scales for the trigger menus being developed and deployed for data taking for the last two years. Also, we have developed various analysis frameworks for these purposes. We have also been leading the development of tau reconstruction and identification at the HLT level and development of tau HLT paths for Run-3 data taking and their performance measurement in Run-3 data. Vinaya Krishnan (student) is a convener of the tau-trigger group for last two years. We are contributing to the upgrade of the CMS silicon-strip tracker detector, for CMS phase-II upgrade. We have assembled a DAQ set up for the functional test of a single silicon-strip tracker detector module. Currently, in collaboration with other institutes, we are trying to set up a multi-module testing facilities.

We have studied and developed, using Monte-Carlo simulated data, machine learning techniques to reconstruct the invariant mass of the heavy gauge bosons (Z' and W'), where these heavy particles decay to final states with tau leptons. It is difficult to reconstruct full invariant mass from decay products in these final states because of the missing neutrinos. However, our ML studies show promising results in reconstructing the invariant mass as well as improving the mass resolution.

Research Contribution by Prof. P. K. Sahu Group

1(a) Characterizations of GEM detector prototype

Gas Electron Multipliers (GEM) detectors possess high rate capability and resolution compared to the detector based on the wire chamber or tracking drift chamber principle.

A systematic study of the absolute gain of a prototype GEM detector at different gas flow rates is carried out. The gain uniformity across the detectors, which is important for a quantitative understanding of the functioning of different areas of the detector, is also examined. The active surface area (10 cm × 10 cm) of the detector is divided into 16 zones of equal area (2.5 cm × 2.5 cm), and each zone is irradiated with a collimated Fe^{55} X-ray source. Absolute gain is calculated using the measured anode current from the detectors. For this purpose, a pre-mixed gas mixture of Ar: CO_2 in the ratio of 80:20 is used in the range of 5–27 SCCM flow rate. In addition, for a fixed flow rate of 21 SCCM, the dependency of gain uniformity on gas flow is investigated by reversing the gas flow direction inside the gas chamber.

(b) Detectors Simulation

We have done an investigation for GEM signal and Time resolution using a numerical analysis method. The Garfield++ simulation package is used here with a known field solver, ANSYS. To examine the impacts of gas mixture and electron transport characteristics inside the detectors, two other software, Magboltz, and Heed, are utilized. By exploring the impacts of detector geometry, electric fields, incoming particle energy, and gas mixture characteristics, we tried improving GEM detectors for higher temporal resolution. A single GEM detector is investigated with two radiation sources, i.e., a 5.9 KeV Fe^{55} X-ray photon and cosmic muons with energies ranging from 1 MeV -1 TeV. For Ar:CO_2 gas mixture for a particular set-up, a minimum temporal resolution up to around 4 ns is recorded. By examining the various detector geometries and field settings, this number can be reduced even more. A significant result in lowering the temporal resolution is achieved by the change of drift field and percentage of the ionization component in the gas mixture. The admixture of O_2 and N_2 in the gas medium also improves the detector time performance. It is also observed that, the initial particle energy has little effect on the timing accuracy of the detector.

(P.K. Sahu)

Research Contribution by Prof. Aruna K Nayak Group

1.(a) Physics analyses using pp collision data recorded by the CMS experiment at CERN- LHC

The IOP-CMS group made major contributions to the measurement of Higgs boson CP properties in its decay to a pair of tau leptons. The Higgs boson in the SM is expected to have a CP quantum number of +1 (CP even state). However, various BSM models predict additional Higgs bosons, including the ones that can be CP odd (CP=-1) or a mixture of the two (not a CP eigen state). The angle between the decay planes of the two tau leptons is a suitable observable to discriminate between the CP odd and CP even states as well as between CP eigen and CP mixture states. The analysis with full Run-2 data at 13 TeV provided a measured value of the CP mixing angle to be (-1 +/- 19) degree at 68% confidence level and excludes a pure CP-odd state by 3 standard deviations. The results are published in JHEP.

In addition, we are leading an analysis for the search of a charged Higgs boson decaying to a charm and a strange quark, where the charged Higgs originates from the decay of a top quark. The analysis involves kinematic fitting to fully reconstruct the top quark pair and multivariate methods to discriminate signal from backgrounds. The analysis with full Run-2 data is in advance stage and expects significant improvement with respect to previous bound. We are also involved in the analysis for the search for a pseudo-scalar Higgs boson that can decay to a Z boson and the Standard Model like Higgs boson. The final state consists of two leptons (electron/muon) from Z decay and two tau leptons from Higgs decay. The analysis is being performed with full available 13 TeV data. Furthermore, we are starting to work on an analysis for the search of a Lepto-Quark decaying to a top quark and a tau lepton.

(b) Contributions to the development of high-level trigger and detector upgrade in the CMS experiment

We are involved in the development of CMS high-level trigger system for LHC Run-3, which is starting from 2022. We are involved in leading the STEAM group under Trigger Coordination for last three years. Sanu Varghese (student) was appointed as STEAM group convener from Sep 2022 to Aug 2024. We have been consistently performing trigger rate studies for last two years using high instantaneous luminosity data in order to validate menus and prepare trigger pre-scales for the trigger menus being developed and deployed for data taking for the last two years. Also, we have developed various analysis frameworks for these purposes. We have also been leading the development of tau reconstruction and identification at the HLT level and development of tau HLT paths for Run-3 data taking and their performance measurement in Run-3 data. Vinaya Krishnan (student) is a convener of the tau-trigger group for last two years. India-CMS will be contributing significantly to the phase-II upgrade of the CMS detector for HL-LHC. Towards this effort, we are contributing to the upgrade of the CMS silicon-strip tracker detector. We have assembled a DAQ set up for the functional test of a single silicon-strip tracker detector module. Currently, in collaboration with NISER, we are trying to set up a multi-module functional test system, with cold burn-in functionality, which will be used to test modules during the assembly.

(c) Phenomenological studies:

We have studied and developed, using Monte-Carlo simulated data, machine learning techniques to reconstruct the invariant mass of the heavy gauge bosons (Z' and W'), where these heavy particles decay to final states with tau leptons. It is difficult to reconstruct full invariant mass from decay products in these final states because of the missing neutrinos. However, our ML studies show promising results in reconstructing the invariant

mass as well as improving the mass resolution. We have also contributed to another study on leptoquark-assisted singlet-mediated di-Higgs production at LHC.

(A. K. Nayak)

2.4 Quantum Information

(P. Agrawal)

The quantum information group has been working in the area of Quantum Correlations, Quantum Nonlocality and Contextuality, Quantum Communication protocols, and Quantum Cryptography. In 2022, the Nobel Prize in physics was awarded in this area. The Nobel Prize recognized efforts to take quantum weirdness out of philosophical discussions and to experimental demonstration and some practical applications. The award recognized work in testing Bell inequalities and implementation of several quantum communication protocols.

The group has proposed new Bell inequalities and suggested a new way to test the securities of quantum cryptographic protocols. The proposed Bell inequalities are minimal-scenario multipartite Bell inequalities and require minimal resources to test the nonlocality of a pure multipartite state. The group has also proposed new uncertainty relations that are suitable for entangled systems. These relations depend on the measures of entanglement. These relations for a pure entangled state also give a new way to test security of the Eckert type quantum cryptographic protocols.

Research Contribution by Prof. Pankaj Agrawal Group

1. Inferred Uncertainty Relations

(Prof. Pankaj Agrawal with Chandan datta and Shrobona Bagchi)

Uncertainty relations play a significant role in drawing a line between classical physics and quantum physics. Since the introduction by Heisenberg, these relations have been considerably explored. However, the effect of quantum entanglement on uncertainty relations was not probed. Berta et al. removed this gap by deriving a conditional-entropic uncertainty relation in the presence of quantum entanglement. In the same spirit, using inferred-variance, we formulate uncertainty relations in the presence of entanglement for general two-qubit systems and arbitrary observables. We derive lower bounds for the sum and product inferred-variance uncertainty relations. Strikingly, we can write the lower bounds of these inferred-variance uncertainty relations in terms of measures of entanglement of two-qubit states, as characterized by concurrence, or G function. The presence of entanglement in the lower bound of inferred-variance uncertainty relation is quite distinctive. We also explore the violation of local uncertainty relations in this con-text and an interference experiment. Furthermore, we discuss possible applications of these uncertainty relations.

2. Correlations in multipartite and bipartite qudit systems

(Prof. Pankaj Agrawal)

With many collaborators, I have been studying properties of quantum correlations in multipartite, bipartite qudit systems, and bipartite qubit systems in mixed states. In particular we are examining cryptography protocols, Bell inequalities, and communication protocols. Characterization of the entanglement for such systems is also a challenge. We are working on a different classification of the multipartite states. This classification is from the point of view of quantum communication. We are also working on characterizing the correlations a two-qubit mixed states. In the case of two-qubit mixed states, one needs to use a set of measures to fully characterize its correlations and its nonlocal features.

2.5 Experimental Condensed Matter Physics

(S. Varma, T. Som, B. R. Sekhar, D. Topwal, S. Sahoo, D. Samal)

IoP Experimental Condensed Matter Physics Group is pursuing several research programmes which are based on ion accelerators, thin films, surface and interface science, highly correlated electron systems, two-dimensional materials, quantum materials. Some of the major research areas include energy research, resistive switching and its use to emulate bio-synaptic behavior for in-memory computing, etc. Our main goal is to investigate and understand the structure-property correlation of solids. Different techniques are employed for synthesis and modification of solids such as ion implantation, pulsed laser deposition, sputter deposition, molecular beam epitaxy, high temperature solid state reaction, and chemical route. Different physic-chemical properties of materials are investigated using advanced characterization techniques, viz. high resolution x-ray diffraction, field emission gun-based scanning electron microscope, atomic force microscope, SQUID-VSM, physical properties measurement system, high-resolution Raman spectrometer, current-voltage spectroscopy, optical spectroscopy etc.

Research Contribution by Prof. Shikha Varma Group

1. (a) Resistive switching properties of ion implanted ZnO thin films

(Shikha Varma with Ashis Manna, A. Kanjilal, Shiv Nadar Univ., S.K. Srivastava- IIT Kgp, D. Kanjilal- IUAC)

Resistive switching behavior of ion implanted ZnO thin films has been explored. For the films implanted at the highest fluence, an asymmetric Resistive Switching behavior is observed. A Switching behavior, from a high resistance state to a low resistance state, is demonstrated under positive bias conditions. Migration of oxygen vacancies contribute to the formation of conducting filament which may be crucial for the observation of switching phenomenon at the highest fluence.

(b) Ion Irradiation of Nanostructures for Catalysis Applications

(Shikha Varma with Rakesh Sahoo, K.K. Nanda)

CuSe nanostructures have been fabricated and the effect of ion fluence on their morphological and electronic structure evolution has been investigated. Ion irradiation enhances the overall absorption in UV- Vis range, as well as changes the bandgap properties. These materials are being investigated for their catalytic and sensing applications.

(c) XPS studies of the interaction of DNA with metals and metal ions

(Shikha Varma with Prof. Peter Dowben Univ. of Nebraska, Lincoln, USA)

X-ray Photoelectron Spectroscopy has been used to study the interactions of heavy metal ions with DNA. Surface sensitivity and selectivity of XPS are advantageous for identifying and characterizing the chemical and elemental structure of the DNA to metal interaction. It is seen that metal interaction with DNA results in conformational changes in the DNA structure.

(d) Phase transition in TiO2 films with ion implantation

(Shikha Varma with Ashis Manna, S.K. Srivastava- IIT Khargpur, D. Kanjilal- IUAC)

Role of Ti ion implantation has been explored for structural phase transition in TiO2 thin films. GIXRD and Raman results reflect presence of a critical fluence where the initial phase transformation, from Anatase to Rutile, is observed. The role of Oxygen vacancies, in this transformation, has been explored here by XPS. Modifications in UV–Vis and Bandgap results show rich behavior which also reflects phase transformation at the critical fluence.

(e) Topological non-hexagonal rings and

Stone Wale defects in 2D layered Graphene

(Shikha Varma with Ashis Manna, S. R. Joshi-Ajou Univ., S. Korea, T. Komesu, Univ. of Nebraska, Lincoln, USA)

Topological non-hexagonal rings and Stone Wale defects have been explored by Raman experiments in both single and multi-layer graphene after they are ion irradiated. Variations in the SW/NHR related Raman mode intensities demonstrate the annihilation of these topological defects at higher energies. The direct observation of SW/NHR defects by Raman spectroscopy could be important in promoting exploration of rich topological aspects of Graphene in various fields

Research Contribution by Prof. T. Som Group

2. (a) On-going research Projects:

(i) Ion-induced nanoscale patterning of materials and their functionalization

(ii) Growth of thin films for applications in optoelectronics

(iii) Emulation of bio-synaptic behavior at nanoscale using memristors for potential applications in neuromorphic computing

(i) Ion-induced nanoscale patterning of materials and their functionalization

Ion induced self-organized pattern evolution and their functionalization

We have worked on the evolution of self-organized patterned surfaces using energetic (0.25-60 keV) ion beams. These patterns include ripples to facets to nanowire-like extreme regular patterns over wide areas. Differently patterned surfaces offer useful applications through their nanoscale functionalization. Presently, we are working on patterning elemental and compound semiconductors as well as oxide layers. These surfaces offer immense potential in several frontline research areas.

(a) Impurity-free ripple formation on GaSb by 500 eV Kr^+ ion irradiation

In this work, we have studied the formation of impurity-free perpendicular-mode ripple formation on GaSb by 500 eV Kr^+-ion irradiation at room temperature. Atomic force microscopy (AFM) exhibits the presence of nanoscale ripples which are highly ordered in the angular window of 30° to 72° of ion incidence. In contrast, at near grazing ion incidence (80°), the transformation of well-defined ripples to faceted structures takes place. The observed results are attributed to an interplay between mass redistribution and ion-induced sputtering and are compared by estimating the curvature-dependent parameters using SDTrimSP code.

(b) Performance optimization of versatile, microwave-based, ultra-low energy electron cyclotron resonance plasma-based ion source for silicon nanopatterning

This work illustrates the optimization of various parameters required for microwave coupled plasma-based ultra-low energy (50 eV – 2 keV) electron cyclotron resonance (ECR)-based ion source. The extraction of inert Ar^+-ion beam from a magnetron coupled plasma cup by three grid ion optics is widely studied for ion induced nanopatterning on silicon. The dependence of ion current on two major parameters (viz. working pressure and magnetron power) is studied at different ion extraction energies. In addition, the dependence of beam current on extraction voltage (applied on the grid) is also investigated for different ion energies.

(ii) Growth of thin films for applications in optoelectronics

Thin film growth using radio-frequency magnetron sputtering

Our continuous effort on studying the growth and characterization of oxide thin films (e.g. carrier selective contacts, transparent conducting oxide layers, and other important

optoelectronic layers) to fabricate multi- junction carrier selective contact-based photovoltaic cells, photodetectors, and resistive switching devices was intensely pursued. We employ both bulk and local probe-based studies for optimizing each layer.

(a) Growth angle-dependent tunable physical properties of Sb2Se3 thin films

We have studied the importance of varying the growth angle on structural, optical, and electrical properties of Sb2Se3 films grown by radio frequency (rf) magnetron sputtering technique. As a matter of fact, we have studied growth angle (èg)-dependent (in the range of 0°-87°) change in physical properties of Sb2Se3 films. It is observed that the band-gap of all Sb2Se3 films increases upon increasing the èg. Due to post-growth annealing, a phase transition (structural) takes place in all Sb2Se3 films, leading to changes in the band-gap as well. The present study will be useful for the growth of Sb2Se3 films with optimized physical properties towards fabricating Sb2Se3 absorber layer-based efficient solar cells.

(b) Thickness-dependent tunable optoelectronic properties of Al-doped (4 wt.%) ZnO thin films

Room temperature diode characteristics of ZnO: Al (4 wt.%) (AZO)/p-Si heterostructures are investigated by current-voltage measurements. In this study, a systematic decreasing trend in the film stress and turn- on potential is observed with increasing AZO film thickness. Likewise, band-gap and the surface potential for all the films show a decreasing trend as well with increasing film thickness. Our observations can be well described in the framework of AZO thickness-dependent variation in grain size and in turn trap density at the grain boundaries which control the carrier transport across the adjacent grains.

(c) Carrier selective contact: WO_X thin films

In this study, we have explored the thickness- and growth angle-dependent optoelectronic properties of WO_X/p-Si heterojunctions fabricated by radio frequency magnetron sputtering setup. Amorphous nature of as-deposited WO_X thin films was revealed by x-ray diffraction studies, while through current-voltage spectroscopy studies we observe that all WO_X/p-Si heterojunctions are quasi-ohmic in nature. Kelvin probe force microscopy was employed to measure the work function of WO_X films. The present results demonstrate that 6 nm-thick WO_X films grown under an obliquely incident flux (87?) can be considered as the optimal one suitable for constructing a carrier selective contact-based Sb2Se3 absorber layer photovoltaic cell.

(d) Growth angle-dependent tunable work function and optoelectronic properties of WO_X thin films

This study is on the influence of growth angle on the structural, electrical, and optical properties of radio- frequency magnetron sputter deposited WO_X films on p-Si substrates. X-ray diffraction studies confirm all the films are amorphous in nature. It is noticed that the average grain size increases with increasing growth angle (from 0° to 87°) and the sharp absorption edges are blue shifted with increasing growth angle up to 87°. To figure out the work function of WO_X film, Kelvin probe force microscopy technique is utilized. In addition, rectifying behaviour of the WO_X/Si junctions is studied by current-voltage characteristics. The growth dynamics of WO_X films with varying growth angles is attributed to be responsible for tunable physical properties of the films.

(e) Optimization of growth parameters for VO_X thin films for photovoltaic applications

We have studied the process parameter-dependent optoelectronic properties of vanadium oxide thin films prepared by reactive rf sputtering at room temperature over a wide range of growth angles. The morphological evolution of the films

as a function of O2 flow rate and growth angle were examined by atomic force microscopy, whereas the work functions are measured using Kelvin probe force microscopy. A 1 eV increase in work function is achieved by optimizing the Ar:O2 flow ratio during deposition at normal incidence. Oxygen vacancies act as donors in the films, leading to an upward shift in the Fermi level. XPS analysis reveals nearly stoichiometric V2O5 phase formation in the optimized films. The adopted film growth conditions (viz. oblique angle deposition using low deposition power) would be promising for solar photovoltaic technology.

(iii) Emulation of bio-synaptic behavior at nanoscale using memristors for potential applications in neuromorphic computing

Importance of local probe-based studies on memristors for emulating bio-brain features

Two-terminal memristors have aroused immense research interest due to their potential applications in future non-volatile memory and artificial synapses in brain-inspired neuromorphic computing systems. Neuromorphic computing (or brain-inspired computing) is a promising concept for processing enormous information even at low-power, energy-efficient spiking networks with the capability of self-learning, cognitive adaptation, and recognition of speech, gesture, and objects. These human-brain-like features can be realized using artificial synapse network. We are addressing these issues using atomic force microscopy- based =local probe techniques.

(a) Site-specific emulation of neuronal synaptic behaviour in Au nanoparticle-decorated self- organization of TiO_X surface

Neuromorphic computing is a potential approach for imitating massive parallel processing capabilities of a biological synapse. Till date, memristors have emerged as the most appropriate device for designing artificial synapses for this purpose due to their excellent analog switching capacities with high enduranceand retention. However, to build an operational neuromorphic platform capable of processing high-density information, memristive synapses with nanoscale footprint is important, albeit with device size scaled down, retaining analog plasticity and low power requirement often become a challenge. Here, we demonstrate site-selective introduction of gold (Au) nanodots on a patterned TiO_X layer formed as a result of ion-induced self-organization, resulting in site-specific resistive switching and emulation of bio-synaptic behaviour (e.g. potentiation, depression, spike rate-dependent, and spike timing-dependent plasticity, paired pulse facilitation and post tetanic potentiation) at nanoscale. The observed results are attributed to the defect migration and self-assembly of implanted Au atoms on self-organized TiO_X surfaces. By leveraging the site-selective decoration of gold-nanostructures, the functionalized TiO_X surface holds significant potential in a multitude of fields for developing cutting-edge neuromorphic computing platforms and Au-based biosensors with high-density integration.

(b) A highly stable nanoscale artificial nociceptor on Au-ion implanted TiO_X ($x<2$) films

In this work, we report the nociceptor behaviour in a simple two-terminal Au ion-implanted TiO_X/p^{++}-Si memristor. The current-voltage characteristics of $Pt/TiO_X/p^{++}$-Si device characterized by conducting atomic force microscope show a prominent and highly stable hysteresis loop, which is ascribed to the electric field-induced migration of oxygen vacancies in TiO_X layers. Further, the electrical-stimuli-induced fundamental nociceptive phenomenon such as a “threshold”, “no-adaptation”, “relaxation”, “overlapping”, “allodynia”, and “hyperalgesia” are found from this TiO_X device under a self-biased condition in the nanoscale range using cAFM technique in the first time to our knowledge, which provide an interesting

pathway towards neuromorphic computing. Hence, this present study imparts an important and unique platform to design highly stable and reproducible nanoscale electronic artificial nociceptors for artificial intelligence systems like humanoid robots.

(c) Linear synaptic potentiation and experience-dependent learning in WO3 memristors

Our work demonstrates synaptic plasticity behaviours in WO3 memristor-based electronic synapses using conductive atomic force microscopy. The device reveals gradual conductance modulation (analogous to synaptic plasticity) under consecutive DC voltage sweeps and shows multi-level resistance switching in the current-voltage hysteresis curves. The device emulates diverse essential synaptic functions. The linearly potentiated synaptic weight modulation for the identical pulses is observed for different amplitude, width, and interval of the input voltage pulses and is presented as an invariant feature of the nanoscale artificial synapse. More importantly, the device exhibits the fascinating "experience-dependent plasticity" behaviour where synaptic plasticity is highly dependent on the frequency of the previous pulse train.

(d) An artificial nociceptor with neuromorphic capabilities

In this work, we demonstrate multiple neuromorphic functions in Cu-doped ZnO (CZO) memristor at nanoscale using local-probe microscopy-based techniques. CZO memristor-based electronic synapse exhibits basic nociceptive functions like threshold, relaxation, allodynia, and hyperalgesia. Simultaneously, the device successfully simulates essential synaptic functions such as potentiation/depression, spike rate-dependent plasticity, and paired-pulse facilitation. Most importantly, the memristor shows linear and symmetric potentiation/depression under suitable pulse voltages, which is crucial for high accuracy and learning of neuromorphic devices. The demonstrated multifunctional capabilities therefore, make CZO-based memristors a highly suitable candidate for designing sensor-computing-integrated AI platforms.

(e) Bipolar resistive switching-based synaptic memory in mixed-phase transparent vanadium oxide thin films: Role of stoichiometry

We are investigating the role of stoichiometry of vanadium oxide (VO_X) thin films in determining their resistive switching properties and neuromorphic functionalities. Stoichiometry-controlled VO_X films were achieved by reactive rf-sputtering through the alteration of growth angle. The VO_X films containing dominant V^{5+} oxidation state exhibit excellent switching stability and synaptic functionalities under very low operating voltages. In contrary, VO_X films, in which mixed-phase components exist, are relatively less stable and devoid of any synaptic capabilities. Results will be of great interest for transparent Mott-insulator-based power efficient memory devices targeting neuromorphic platforms.

(f) Nanoscale resistive switching in pulsed laser deposited TiO_X films: A parametric investigation

This study investigates the resistive switching behavior of TiO_X films at nanoscale by systematically varying pulsed laser deposition (PLD) growth parameters. The influence of oxygen pressure, growth temperature, and laser energy density on the RS stability and SET/RESET voltages of TiO_X /p^{++}-Si structures is examined. This investigation reveals that TiO_X films grown at a temperature of 1023 Kexhibit memristive behaviour with the lowest operating voltages within ±1.2 V, along with a respectable ON/OFF ratio and high repeatability. The parametric phase diagrams developed based on various spectroscopic and microscopic evidences, provide insights into the influence of growth parameters and phases, highlighting

the importance of an optimum stoichiometric configuration in achieving low-power operation and stable device performance.

(g) Nanoscale resistive switching in functionalized MoS_2 nanosheets for next generation neuromorphic computing applications

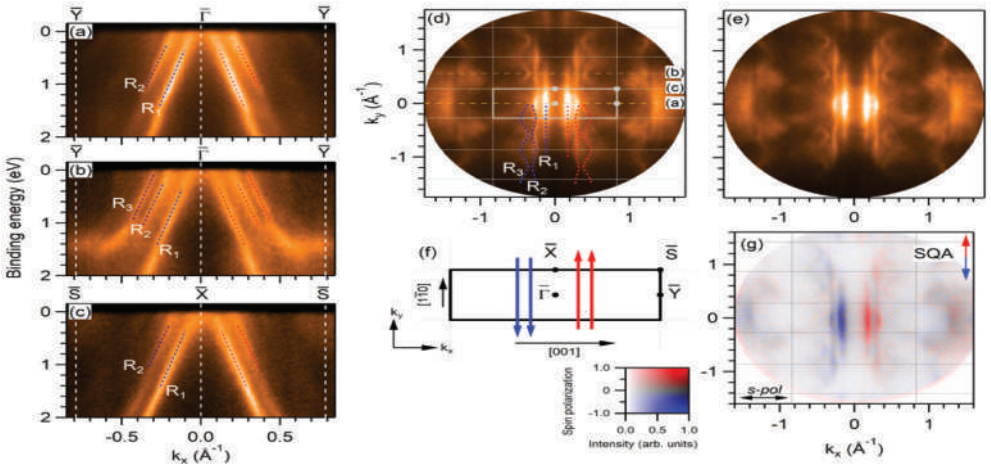
In this project, we report the resistive switching and neuromorphic functionalities of 2-D MoS2 nanosheets prepared on ITO-coated glass substrates. The nanosheets were prepared using nonpolar organic solvent, which enables a high yield with stable dispersion for more than six months. During exfoliation, oleylamine gets immediately absorbed at surface vacancy sites on the basal plane and edges of the exfoliated nanosheets, which provides the stability of MoS_2 nanosheet dispersion. The functionalized MoS_2 nanosheets appear to enable a unique way to modulate switching characteristics through surface modification. The MoS2-based device exhibits stable threshold resistive switching behaviour and demonstrates diverse functionalities of biological synapses such as potentiation and paired-pulse facilitation. The Schottky emission is found to be the dominant charge conduction mechanism in the present device under external electrical bias. The present study paves the way to optimize the performance of functionalized 2D-TMDC-based resistive memory devices for future neuromorphic applications.

(T. Som)

Research Contribution by Prof. Dinesh Topwal Group

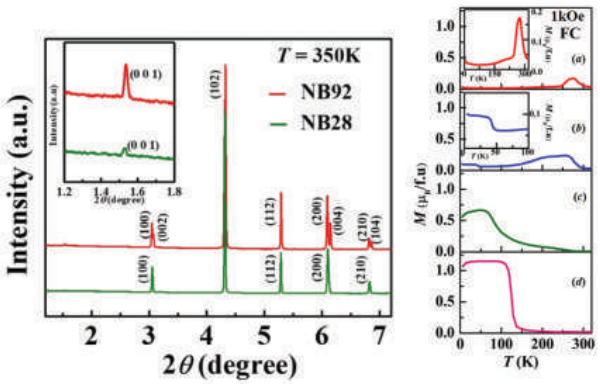
3. (a) Spin-polarized electrons confined in low-dimensional structures are of high interest for spintronics applications. We investigated the electronic structure of an ordered array of Bi monomer and dimer chains on the Ag(110) surface. By means of spin- resolved photoemission spectroscopy, we find Rashba-Bychkov split bands crossing the Fermi level with one-dimensional constant energy contours. These bands are up- spin polarized for positive wave vectors and down-spin polarized for negative wave vectors, at variance with the Rashba-Bychkov model that predicts a pair of states with opposite spin in each half of the surface Brillouin zone. Density functional theory shows that spin-selective hybridization with the Ag bulk bands originates this unconventional spin texture.

Energy momentum dispersion of Bi/Ag(110) p(4×1) along: (a) Ã”Y of the first SBZ; (b) Ã”Y of the second SBZ; (c) along X”S; the corresponding ky positions of the cuts are indicated in (d). (d)–(e) 2D momentum maps taken at 0.55 eV binding energy with and without SBZ on top. Blue and red dashed lines indicate R1–R3 pair of RB states. Solid grey lines indicate the SBZ. (f) SBZ of Bi/Ag(110) p(4×1). The sketch of blue and red arrows show the spin texture at the Fermi surface from this work. (g) Spin-resolved photoemission intensities for the data shown in panel (e). Red and blue intensities



correspond to spin-up and spin-down electronic states as shown in the legend. All measurements were taken at 120 eV of photon energy with s-polarized light. The directions of the light polarization and of the SQA are shown in panel (g).

(b) We investigated the effect of A-site cationic ordering on structural, transport and magnetic properties of mixed-valent perovskite manganite $NdBaMn_2O_6$. Temperature (T) dependent x-ray diffraction data reveals that different types of phase transitions seen in this compound explicitly depend on the degree of ordering of the A-site cations Nd^{3+} and Ba^{2+}. For example, the ordered compound undergoes multiple structural phase transitions with decreasing T, whereas the disordered compound



retains the high-T crystal structure. Resistivity measurements show that although both the compounds are insulating, the mechanism of charge transport is different for the two compounds. Similarly, the magnetic properties and colossal magnetoresistance also depend on the degree of ordering. Cationic disorder suppresses the long-range antiferromagnetic order and enhances ferromagnetic correlations at lower temperature; which (ferromagnetic correlation) is accompanied with larger value of saturation magnetic moment while ferromagnetic T_C too shifts to higher temperature with increasing disorder. Disordered system also exhibits a larger value of magnetoresistance at low temperature compared to the ordered counterpart. Comparison of XRD data of A-site ordered (NB92) and disordered (NB28) $NdBaMn_2O_6$ at temperature 350K. Collected at wavelength of 0.20736Å. Temperature dependence of magnetization of $NdBaMn_2O_6$ compounds in a magnetic field 1kOe of (a) NB92, (b) NB60, (c) NB28, (d) NB00, with different degree of A site ordering.

(D. Topwal)

Research Contribution by Prof. Satyaprakash Sahoo Group

4. 1. 2 D materials and novel metal oxides for optoelectronics and memory applications 2D materials

(a) Phonon renormalization in twisted moiré structures:

(S. Sahoo)

The ability to control the atomic-scale behavior in quasi-two-dimensional crystals via twisting the vicinal layers and generating patterned moirei potentials provides an additional degree of freedom to study correlated physics. Under the existence of macroscopic external parameters such as strain, we study the high-frequency Raman active vibrational modes of chemical vapor deposition (CVD)-grown monolayer, stacked (AA2 and AB), and twisted bilayer MoS_2. The polarized Raman scattering, being an efficient characterization tool for these moirei structures, is employed to investigate the effects of strain on the different phonon modes. The recently discovered moirei phonons (FA_{1g}), i.e., zone center phonons in a twisted bilayer MoS_2, stem from the folding of the off-center phonons of its monolayer constituents and are found to be Raman polarized. Moreover, the Raman shift impressions of these moirei phonons in twist angle in the range between 0 and 30° are reproduced, showing the strain-coupled modifications of the previously reported sinusoidal behavior. Our findings establish an effective method to probe the strain–induced anisotropy in twisted van der Waals systems using polarized Raman spectroscopy showing future directions to moirei-related physics.[i]

Mallik, S. K. et al. Polarized Moiré Phonon and Strain-Coupled Phonon Renormalization in

Twisted Bilayer MoS_2. Journal of Physical Chemistry C 126, 15788–15794 (2022).

(b) High performance Photo detectors applications:

Two-dimensional transition metal dichalcogenides have garnered much attention in potential advances in optoelectronic devices because of the enhanced photoresponsivity and tunable band gap for broadband photodetection. The photogating effect is responsible for high responsivity, which inherently includes the electrical bias stress contributing to the carrier trapping and degrades the device performance. Herein, we report a facile and effective approach to control carrier trapping, resulting in a high-responsive low-power photodetection considering monolayer MoS_2 as the photoactive material. Implementing the gate bias as a stream of pulses, the photogating and photoconductive effects become simultaneously enhanced, which could provide an opportunity for obtaining high responsivity in optoelectronic devices. In consequence, this approach results in a large photoresponsivity of <"4.2 × 10^3 A/W and a high photo gain of <"11.3 × 10^3 with the positive gate bias stress even in the low-power illumination. Additionally, the photoresponsivity and photo gain of <"0.7 10^3 A/W and <"1.92 10^3, respectively, with the negative gate bias stress demonstrate the gate-tunable photoresponse. Our findings show the potential for future development of a highly responsive low-power photodetector.[ii]

Sahoo, S. et al. High Responsivity in Monolayer MoS_2 Photodetector via Controlled Interfacial Carrier Trapping. ACS Appl Electron Mater 5, 1077–1087 (2023).

(c) Optoelectronics artificial synapse for Logic and Neuromorphic Computing applications

The hardware implementation of advanced artificial intelligence (AI) technology based on complex deep learning and machine learning algorithms is constricted by the limitation of conventional Von–Neuman architecture. Emerging neuromorphic computing architecture based on the human brain with in-memory computing capability could instigate unprecedented breakthroughs in AI technology. In this pursuit, 2D MoS_2 optoelectronic artificial synapse imitating complex biological neuromorphic behavior such as short/ long-term memory, paired-pulse facilitation, and long-term depression-potentiation is proposed and demonstrated. Furthermore, the broadband sensitivity of the device can be utilized to emulate Pavlov's classical conditioning for associative learning of the biological brain. More importantly, reconfigurable Boolean AND and OR logic gate operation is demonstrated within the same device by synergistically modulating the device conductance via the persistent photoconductivity and electrical gate stress. The linear response of the photocurrent to the optical stimulus can perform arithmetic operations such as counting, addition, and subtraction within a single device. This novel integration of memory, synaptic behavior, and processing within a single monolayer MoS_2 device is believed to put forth a new horizon for the Non- Von–Neuman type in-memory computing architecture for highly advanced AI applications based on 2D materials.[iii]

Sahu, M. C., Sahoo, S., Mallik, S. K., Jena, A. K. & Sahoo, S. Multifunctional 2D MoS_2 Optoelectronic Artificial Synapse with Integrated Arithmetic and Reconfigurable Logic Operations for In-Memory Neuromorphic Computing Applications. Adv Mater Technol 8, 2201125 (2023).

(d) Transition metal substituted MoS_2/ WS_2 van der Waals heterostructure for realization of dilute magnetic semiconductors

With the implementation of extensive first principles calculations, we demonstrate the MS_2(M = Mo, W) monolayers, as well as their van der Waals (vdW) hetero-bilayers as promising

candidates for the successful realization of 2D dilute magnetic semiconductors with the incorporation of Mn and Co dopants. Under various pairwise doping configurations at different host atom sites, we report the electronic properties modifications induced change in magnetic exchange interactions. The magnetic coupling among the dopant pairs can be tuned between FM and AFM orderings via suitable doping adjustments. The developed interlayer exchange coupling between the vdW layers leads to strong and long-ranged ferromagnetic interactions which unleash robust magnetic moments with stable doping configurations. Our findings address the novel magnetic behavior of the layered vdW heterostructures and may further guide the future experimental efforts for the possible applications in modern electronics and nanoscalemagnetic storage devices.[iv]

J. Magnetism and Magnetic Materials, 560 (2022) 169567

2. Resistive switching in Novel metal oxides for Neuromorphic computing applications

Memristive devices are among the most emerging electronic elements to realize artificial synapses for neuromorphic computing (NC) applications and have potential to replace the traditional von-Neumann computing architecture in recent times. In this work, pulsed laser deposition-manufactured Ag/TiO_2/Pt memristor devices exhibiting digital and analog switching behavior are considered for NC. The TiO_2 memristor shows excellent performance of digital resistive switching with a memory window of order <"10^3. Furthermore, the analog resistive switching offers multiple conductance levels supporting the development of the bioinspired synapse. A possible mechanism for digital and analog switching behavior in our device is proposed. Remarkably, essential synaptic functions such as pair-pulse facilitation, long term potentiation (LTP), and long-term depression (LTD) are successfully realized based on the change in conductance through analog memory characteristics. Based on the LTP-LTD, a neural network simulation for the pattern recognition task using the MNIST data set is investigated, which shows a high recognition accuracy of 95.98%. Furthermore, more complex synaptic behavior such as spike-time-dependent plasticity and Pavlovian classical conditioning is successfully emulated for associative learning of the biological brain. This work enriches the TiO_2-based resistive random-access memory, which provides information about the simultaneous existence of digital and analog behavior, thereby facilitating the further implementation of memristors in low-power NC.[v]

Jena, A. K. et al. Bipolar Resistive Switching in TiO_2 Artificial Synapse Mimicking Pavlov's Associative Learning. ACS Appl Mater Interfaces 15, 3585 (2022).

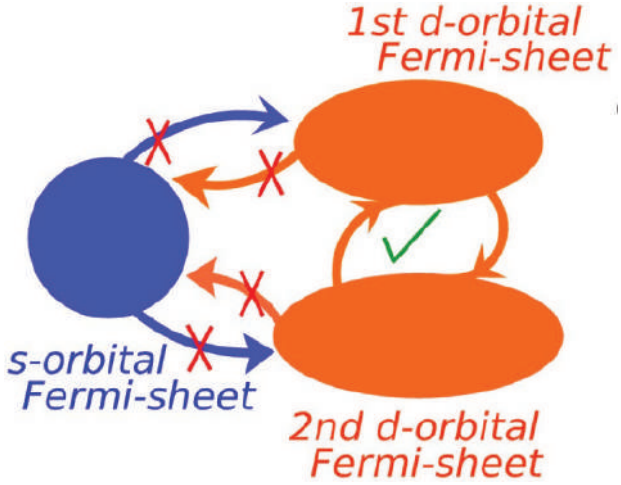
(S. Sahoo)

Research Contribution by Prof. Debakanta Samal Group

5.(a) Revealing multiband character from weak antilocalization effect in platinum thin films

Platinum (Pt) has been very much used for spin-charge conversion in spintronics research due to its large intrinsic spin-orbit interaction. Magnetoconductance originating from weak antilocalization in the quantum interference regime is used as a powerful tool to obtain the microscopic information of spin-orbit interaction and the coherence phase breaking scattering process among itinerant electrons. We have performed a magnetoconductance study on Pt thin films which manifests multiband (multichannel) conduction. An extensive analysis of quantum-interference-originated weak antilocalization reveals the existence of strong (weak) interband scattering between two similar (different) orbitals. Coherence phase breaking lengths ($l_{ö}$) and their temperature dependence are found to be significantly different for these two conducting

bands. The observed effects are consistent with the theoretical prediction that there exist three Fermi sheets with one s and two d orbital character. This study provides the evidence of two independent non-similar conducting channels and the presence of anisotropic spin-orbit interaction



along with e-e correlation in Pt thin films.

Fig.1 The schematic diagram for theoretically predicated three Fermi sheets, one derived from s orbital (blue color) and the other two derived from d orbital (orange color). The possible interaction among them is denoted by arrows (allowed and forbidden interactions are marked by ×, –′, respectively). Interconnected two d orbitals leads to one effective conducting channel and the other one is from s orbital.

(b) Emergent quantum transport due to quenched magnetic impurity scattering by antiferromagnetic proximity in $SrCuO_2/SrIrO_3$

Gaining control over electron scattering in complex materials is a critical step to advance the understanding that can have technological implication. Through an antiferromagnetic proximity effect, we demonstrate the evidence for quenched magnetic impurity scattering in a spin-orbit coupled semimetal $SrIrO_3$ (which is predicted to host 3D Dirac quasiparticles near the Fermi energy) proximitized with an antiferromagnetic $SrCuO_2$ layer from quantum interference originated magnetoconductance study. The quenching of magnetic impurity scattering is discussed in the framework of antiferromagnetic proximity effect which originates from spin Andreev reflection at the $SrCuO_2/SrIrO_3$ interface. More importantly, we observe chiral anomaly induced topological response in longitudinal magnetoconductance (B E) for the $SrCuO_2/SrIrO_3$ bilayer which is absent in bare $SrIrO_3$ film. Compared to the results on bare $SrIrO_3$ film, antiferromagnetic proximity effect in $SrCuO_2/SrIrO_3$ unfolds a practical means to circumvent the detrimental effect of unintended magnetic impurity scattering and preserve topological electron transport in $SrIrO_3$.

(D. Samal)

2.6. Theoretical Condensed Matter Physics

(G. Tripathy, S. Mandal, A. Saha, D. Chaudhuri)

At IOP, the condensed matter theory group is involved in cutting-edge research in various aspects of quantum condensed matter physics and studies of complex systems, including statistical physics, active matter physics, and the physics of life.

Quantum Condensed Matter Physics

In this field, the activity of the group involves the exploration of emergent electronic and magnetic properties of various quantum materials. This includes a special emphasis on studies of high-temperature superconductors, iron-pnictides, frustrated magnetism, topological insulators, dynamical construction of higher-order topological superconductors, Floquet Majorana modes in Rashba nanowires, and topological superconductivity in magnetic spin chains.

Complex systems

In complex systems research, the main current emphasis is on the development of understanding in various aspects of the physics of life and active matter. Studies were performed proposing and exploring a simple model of ant-

trail formation, the dynamics of cytoskeletal filaments driven by molecular motors and related active polymers, exact calculation of transport properties of dynamical or shape anisotropic active Brownian particles, studies of stop-and-go motion in animals and bacteria, exploring properties of scalar active baths, and the impact of reciprocity and its absence on active nematics.

Research Contribution by Prof. Saptarshi Mandall Group

1. The research summary from my group is as follows. We mainly worked on some aspect of high temperature superconductor, iron-pnictide, aspects of frustrated magnetism and topological insulators.

In iron-pnictide superconductor we consider a Cooper pair beam splitter for an iron-pnic and calculate the entangled electron-hole current. We investigate the interplay of various physical parameters such as doping at electron and hole pockets as well as non-zero nesting between the electron and hole pocket. We find that in the absence of magnetic order, the currents due to hole pocket and electron pocket add up ordinarily. However, in the presence of magnetic ordering, the two currents take part in characteristic interference effect to modify the resultant current significantly. This interference effect manifests itself in the non-monotonous and oscillatory nature of a beam splitter current. We investigate in detail this non-monotonicity with the chemical potential as well as nesting vectror -5Ø*Ü-. We also investigate the evolution of density of states with system parameters and correlate it with the beam-splitter current. Furthermore, we enumerate the relevant parameter space where the efficiency of such a beam splitter setup is enhanced. Our finding can be useful in experimental determination or verification of a coexistence phase in iron-pnictide superconductors and has potential applications in realizing quantum gates or switches.

In the area of frustrated magnetism, we perform a projective symmetry group (PSG) classification of symmetric quantum spin liquids with different gauge groups on the square-octagon lattice. Employing the Abrikosov fermion representation for spin 12, we obtain 32SU(2), 1808U(1), and 384Z2 algebraic PSGs. Constraining ourselves to mean-field parton ansätze with short-range amplitudes, the classification reduces to a limited number, with 4 SU(2), 24 U(1), and 36 Z2, distinct phases. We discuss their ground-state properties and spinon dispersions within a self-consistent treatment of the Heisenberg Hamiltonian with frustrating couplings.

In the area of higher-order topological (HOTI) insulator we study emergent phases in the extended Haldane model without C3 symmetry. For inversion symmetric case, the QSHI and QAHI phases can embed the HOTI phases while remaining QASHI phase does not yields any HOTI phases. Remarkably, four-fold degeneracy of zero-energy corner states can be reduced to two-fold under the application (withdrawn) of sub-lattice mass (Zeeman field) term. The sub-lattice mass and Zeeman eld terms compete with each other to pin down the two mid-gap states at zero-energy. Interestingly, the bulk-polarization can topologically characterize the second-order topological insulator phase with the mid-gap corner modes irrespective of their energies as long as inversion symmetry is preserved. Our study indicates that a hybrid symmetry can in principle protect the second-order topological insulator phases, however, spin-spectrum gap has to be essentially there.

(S. Mandal)

Research Contribution by Prof. Arijit Saha Group

2. **(a) "Dynamical construction of Higher-Order Topological Superconductors"**

Non-equilibrium aspects of topological phases have attracted a great deal of attention in the community as the driven topological systems exhibit non-trivial properties which are absent in

the corresponding static phase. In this direction, we have further proposed a three-step periodic drive protocol to engineer two-dimensional (2D) Floquet quadrupole superconductors and three-dimensional (3D) Floquet octupole superconductors hosting zero-dimensional Majorana corner modes (MCMs), based on unconventional d-wave superconductivity. Remarkably, the driven system conceives four phases with only zero MCMs, no MCMs, only anomalous ð MCMs, and both regular zero and anomalous ð MCMs. To circumvent the subtle issue of characterizing zero and ð MCMs separately, we employ the periodized evolution operator to architect the dynamical invariants, namely quadrupole and octupole motion in 2D and 3D, respectively that can distinguish different higher-order topological phases unambiguously. Given the experimental challenge to engineer step-drive protocol, we also propose a practically feasible time-periodic sinusoidal drive protocol in an on-site mass term to generate the 2D Floquet second-order topological superconductor, hosting both the regular 0- and anomalous ð- MCMs while starting from a static 2D topological insulator/ d-wave superconductor heterostructure setup. We also investigate the time evolution of dynamical MCMs in the presence of such drive.

(b) "Floquet Majorana modes in Rashba nanowire"

We investigate the emergence of Floquet Majorana modes in an experimentally realizable model based on a one-dimensional (1D) Rashba nanowire and proximity-induced s-wave superconductivity in the presence of a Zeeman field. The driven system hosts regular 0-Majorana end modes and anomalous ð-Majorana end modes (MEMs). By tuning the chemical potential and the frequency of the drive, we illustrate the generation of multiple MEMs in our setup. We utilize the chiral symmetry operator to topologically characterize these MEMs via a dynamical winding number constructed out of the periodized evolution operator. Interestingly, the robustness of the 0- and ð -MEMs is established in the presence of on-site random disorder potential. We employ the twisted boundary condition to define the dynamical topological invariant for this translational-symmetry broken system. The interplay between the Floquet driving and the weak disorder can stabilize the MEMs, giving rise to a quantized value of the dynamical winding number for a finite range of drive parameters. This observation might be experimentally helpful in scrutinizing the topological nature of the Floquet MEMs.

(c) "Topological superconductivity in magnetic spin chain"

We investigate the phase transition from a nontrivial topological p-wave superconductor to a trivial s-wave-like superconductor through a gapless phase, driven by different magnetic textures as a 1D spin-chain impurities, e.g., Bloch-type, in-plane, and out-of-plane Neèel-type spin chains, etc. In our proposal, the chain of magnetic impurities is placed on a spin-triplet p-wave superconductor where we obtain numerically as well as analytically an effective s-wave-like pairing due to spin rotation, resulting in gradual destruction of the Majorana zero modes (MZMs) present in the topological superconducting phase. The Shiba bands, on the other hand, formed due to the overlapping of Yu-Shiba-Rusinov states play a crucial role in this topological to trivial superconductor phase transition, confirmed by the sign change in the minigap within the Shiba bands. We also characterize this topological phase transition via gap closing and winding number analysis. We also analyse the case of 2D p-wave superconductor hosting 1D Majorana edge modes [MEdMs] (in absence of any magnetic chain) and show that initially MZMs (in presence of 1D magnetic chain) can hybridize with such MEdMs. Interestingly, in the topological regime with a fixed impurity spin orientation, the MZMs survive at the ends of the magnetic chain even when the MEdMs disappear at some critical value of the chemical potential and exchange coupling strength.

(A. Saha)

Research Contribution by Prof. Debasish Chaudhuri Group

3. Our main research interest revolves around the Physics of Life and active matter. At the heart of both areas is non-equilibrium stochastic processes. In Physics of Life, we focused on cytoskeletal dynamics, ant trail formation. In active matter we considered transport and collective properties.

- **Model of ant trail formation**

We recently proposed an active walker model to investigate ant-trail formation. Within this model, a random walker modifies its local environment, to which a walker passing by later can respond. In certain parameter regimes of pheromone deposition and evaporation, the extension of trails displays a re-entrant coil-globule transition extracted from explicit numerical simulations and explained by our mean-field theory.

- **Motion of cytockeletal filament under motor protein drive**

In the cell's cytoskeleton, active motion and stress generation by molecular motors utilizing chemical fuel ATP play a crucial role in maintaining cell shape, size, and locomotion. We proposed a detailed model of molecular motors driving cytoskeletal filaments to study the emergent dynamics. With the help of detailed numerical simulations and careful analysis of the results using mean field theory, we developed an effective active polymer model of the filament. The impact of motor protein dynamics leads to a directed force and an exponentially correlated force fluctuation determined by the attachment-detachment rates and elastic constant characterizing motor extension.

- **Transport properties of anisotropic active colloids**

We studied active particle dynamics in the presence of fluctuation in the active speed, translational noise, and angular diffusion incorporating anisotropy. For this, we proposed and used a fully analytic method to calculate all dynamical moments in arbitrary dimensions. The probability distribution of particle displacement shows two crossovers between compact and extended trajectories via two bimodal distributions at intervening times. While the speed fluctuation dominates the first crossover, the second crossover is controlled by persistence.

- **Active bath**

Active baths are characterized by a non-Gaussian velocity distribution and a quadratic dependence with active velocity of the kinetic temperature and diffusion coefficient. While these results hold in over-damped active systems, inertial effects lead to normal velocity distributions, with kinetic temperature and diffusion coefficient increasing with active velocity with an exponent smaller than 2. Remarkably, the late-time diffusivity and mobility decrease with mass. Moreover, we show that the equilibrium Einstein relation is asymptotically recovered with inertia. In summary, the inertial mass restores an equilibrium-like behavior.

- **Active stop-and-go motion**

We consider active Brownian particles switching between run and stop states. Such intermittent dynamics are ubiquitous at all scales, from bacteria to animals and in artificial active systems. We provide exact solutions for their transport properties, e.g., velocity autocorrelations and diffusion coefficients. The spread of particles depends on minute details, such as if the memory of active orientation is retained across a stop event. We predict dynamic schemes maximizing the effective diffusivity, potentially utilized by active agents for better access to distributed food.

- **Impact of reciprocity on active nematics**

Active nematics undergo spontaneous symmetry breaking and show phase separation instability. Within the prevailing notion that macroscopic properties depend only on symmetries and conservation laws, different microscopic models

are used out of convenience. We tested this notion carefully by analyzing three different microscopic models of apolar active nematics. They share the same symmetry but differ in implementing reciprocal or non-reciprocal interactions, including a Vicsek-like implementation. We showed how such subtle differences in microscopic realization determine if the ordering transition is continuous or first order and whether the associated phase separation is fluctuation-dominated or displays sharp interfaces.

(D. Chaudhuri)

2.7 Research Contribution from Long Term Visitors

Research Contribution by Dr. Kuntala Bhattacharjee Group

1. Current research of my group is focussed on three main streams namely carbon nanotubes (CNTs based thin film coatings for stray light control space application, electrical nature of Cu oxides and Cu-O-Si hybrid films, and growth of two dimensional (2D) Sn on the WS2 substrate and probing the band structure and hybridized local density of states.

Thin films of carbon materials with low light reflectance has received significant attention for the development of high absorber coatings for stray light control applications. We have developed a successful technique to fabricate low cost thin film coatings comprised of CNTs and carbon nanoscrolls (CNS) on aluminium (Al) substrate that exhibit low reflectance of the order of 2–3% in the visible and near-infrared (NIR) spectral bands. Spectroscopy, microscopy and microstructural studies demonstrate emergence of CNS via curling and folding of graphene sheets (GS) and merging of HiPCO single-walled carbon nanotubes (SWCNTs) to multiwalled carbon nanotubes (MWCNTs) via diameter enlargement as a result of the sequential chemical processing of as-prepared SWCNT bundles. These blended films of CNTs, CNS show high stability in adverse space conditions after performing the fundamental space environmental simulation tests (SEST) by exhibiting similar reflectance in the visible and NIR range.

Growth of Cu on a thick SiO^2 (270 nm) dielectric on the Si(111) substrate shows evidence of triangular voids and formation of triangular islands on the surface via a void-filling mechanism. Different coordination states, oxidation numbers, and chemical compositions of the Cu-grown film are estimated from the core level X-ray photoelectron spectroscopy (XPS) measurements. We find evidence of different compound phases including an intermediate mixed-state of Cu"O"Si at the interface. Emergence of a mixed Cu"O"Si intermediate state is attributed to the new chemical states of Cu^{x+}, O^x, and Si^{x+}. This intermediate state, which is supposed to be highly catalytic, is found in the sample with a concentration as high as <"41%. Within the Cu"O"Si phase, the atomic percentages of Cu, O, and Si are <"1, <"86, and <"13 % respectively. This intermediate state, as high as <"41%, dominates the film composition followed by Cu oxides (<"37%) and Si oxides (<"22%). The formation of all these phases can be associated with the temperature of annealing, thickness of the SiO^2 barrier, amount of the deposited Cu, diffusion and reactivity of Cu in the SiO^2/Si system, and migration of Si toward the surface. Two probe electrical measurements carried out on the Cu-grown film exhibit different current channels across the film with resistance varying from 10^3 to 10^7 Ù indicating evidence of different phase domains that exist in the film. Hall measurements performed using vdP geometry confirm an n type semiconducting nature of the grown film with an overall sheet resistance of the order of 10^6 Ù.

Two dimensional (2D) derivatives of atomic tin (Sn), mainly planar or buckled hexagonal lattice called stanene has received enormous research interest presently due to their atomically thin structure, quantum properties and

hybridization with the substrates. Owing to large core size of Sn that prefers sp^3 hybridization over sp^2, an appropriate choice of substrate is very crucial to realize 2D growth of Sn. Transition metal dichalcogenides (TMDs) like MoS_2 or WS_2 with honeycomb lattice structure predicted to be promising substrate candidates in this regard. We report here room temperature (RT) growth of atomic Sn under ultrahigh vacuum (UHV) conditions on the mechanically cleaved WS_2 surface and investigate the surface morphology and local electronic properties of bare WS_2, as well as, Sn/WS_2 surfaces by performing in-situ scanning tunneling microscopy (STM), scanning tunneling spectroscopy (STS) and first principles density functional theory (DFT) studies. Our investigations reveal an atomically flat WS_2 surface with valence band (VB) maxima at the Ã point and conduction band (CB) minima between the K-Ã points with the band edges lying at -0.2 eV and 1.19 eV respectively. Thus, an indirect band gap of 1.39 eV is demonstrated theoretically for the pristine bulk WS_2 when defects or vacancies are not considered. Upon considering 'S' vacancies in the calculations, that are evident on the WS_2 surface in the STM investigations, we find signature of in-gap electronic states directly corroborating the STS results obtained from bare WS_2 with 'S' vacancies. STM studies on RT growth of Sn indicate commensurate or nearly commensurate adsorption of Sn at the 'S' sites with a buckling height of 40 10 pm, whereas, emergence of modulated in-gap states are detected in the measured local density of states (LDOS) by STS upon Sn adsorption. These experimental observations are quantified by the DFT calculations considering substitutional doping of Sn atoms at the 'S' sites that exhibit a buckling height of 80 pm. The calculations also reveal Sn p and W d hybridized in-gap LDOS as are observed in the STS measurements. Substrate induced stabilization of low buckled structures via synergistically governed effects of lattice stretching, orbital modifications can cause various quantum effects in the system like opening of strong SOC generated bandgap, topologically derived in-gap edge states and so on. Our theoretical results are in good agreement with the STM and STS investigations providing in-depth knowledge on the hybridized local surface and interface states and their electronic nature.

PUBLICATIONS

3.1. Papers Published in Refereed Journal

Condensed Matter Physics (Experiment)

1. **Photocurrent Polarity Switching and Enhanced Photoresponse in Silver Nanoparticles Decorated a GaN-Based Photodetector,**

   D. K. Singh, P. Prajapat, J. Saroha, R. K Pant, SN Sharma, KK Nanda, SB Krupanidhi, and G Gupta, ACS Appl. Electron. Mater. 2023**, 5,** 1394"1400.

2. **Intrinsic stability of perovskite materials and their operational stability in light-emitting diodes,**

   KL Kumawat, KK Nanda and P Rajamalli, **J. Mater. Chem. C**, 2023,**11**, 7159-7182.

3. **Reduced-graphene oxide decorated ã-In_2Se_3/Si heterostructure-based broadband photodetectors with enhanced figures-of-merit,**

   B Roul, AM Chowdhury, M Kumari, KL Kumawat, S Das, KK Nanda and SB Krupanidhi, Mater. Adv., 2023**, 4,** 596-606.

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S. Mishra, S. Beura and B. Mallick, the Pharma Innovation Journal **11**(12), 3557-3559, 2022.

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3.2 Conference proceedings:

Nuclear Physics

1. **Correlations among the surface properties of finite nuclei within the Coherent Density Fluctuation Model,**

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2. **Decay properties of newly synthesized 207,208Th isotopes,**

   Jeet Amrit Pattnaik, RN Panda,Mrutunjaya Bhuyan, S K Patra, Proceedings of the DAE Symp. on Nucl. Phys, V. **66** (2022).

3. **Fusion cross-section using density-dependent relativistic R3Y effective nucleon-nucleon interaction,**

   Shilpa Rana, Raj Kumar, S K Patra, BV Carlson, Mrutunjaya Bhuyan,Proceedings of the DAE Symp. on Nucl. Phys, V. **66** (2022).

4. **Role of symmetry energy on the inner crust composition of neutron star,**

   Vishal Parmar,Manoj K Sharma, S K Patra, Proceedings of the DAE Symp. on Nucl. Phys, V. **66** (2022).

5. **Effect of pairing coefficient in 12,13C+12C reactions within collective clusterization mechanism,**

   Sarbjeet Kaur, Rupinder Kaur, Navjot Kaur, BirBikram Singh, S K Patra,Proceedings of the DAE Symp. on Nucl. Phys, V. **66** (2022).

6. **Spectra and E2-M1 transition properties for the Ground band and K = 6+ isomers of 172Er,**

   CR Praharaj, BB Sahu, S K Patra, Z Naik, Proceedings of the DAE Symp. on Nucl. Phys, V. **66**(2022).

7. **Dynamical aspects of decay of exotic nuclear systems,**

Sarbjeet Kaur, BirBikram Singh, S KPatra, Proceedings of the DAE Symp. on Nucl. Phys, V. **66** (2022).

8. **Decay analysis of compound nuclei 194Hg, 200Pb, 203Bi and 207At within dynamical clusterdecay model,**

   Sarbjeet Kaur, BirBikram Singh, S K Patra, Proceedings of the DAE Symp. onNucl. Phys, V. **66** (2022).

9. Role of cationic size mismatch and effect of disorder in mixed valent manganites

   Aisha Khatun, Payel Aich and D. Topwal AIP Advances 13, 025125 (2023)

High Energy Physics (Theory)

10. **Establishing non-maximal 2-3 mixing with DUNE in light of current neutrino oscillation data**

    Sanjib Kumar Agarwalla, Ritam Kundu, Suprabh Prakash, Masoom Singh Zenodo link: https://zenodo.org/record/6784883 Contribution to proceedings of the 30th International Symposium on Lepton Photon Interactions at High Energies (LP-2021)

Others

11. **Low dimensional structural derivatives of Carbon from HiPCO SWCNTs,**

    S. Saini, G. M. Gouda and Kuntala Bhattacharjee Proceeding of 66th DAE Solid State Physics Symposium.

Book Published/Book Chapter Published:

1. **Symmetry Energy of Finite Nuclei Using Relativistic Mean Field Densities within Coherent Density Fluctuation Model**

   Manpreet Kaur, Ankit Kumar, Abdul Quddus, M. Bhuyan, and S. K. Patra

   Multifragmentation in Heavy-Ion Reactions: Theory and Experiments,

   Jenny Stanford Publishing Pte. Ltd., 2023,

   Editors: Prof. Rajeev K. Puri, Dr. Arun Sharma, and Prof. Yu-Gang Ma

OTHER ACTIVITIES

4.1. Foundation Day

Institute of Physics, Bhubaneswar, celebrated its 48th Foundation Day in its premises on 4thSeptember 2022.Prof. Ajit Kumar Mohanty, Director, Bhabha Atomic Research Centre (BARC), Mumbai,graced the occasion as Chief Guest and delivered the Foundation Day Talk.Prof. Mohanty explained how IoP is an iconic place for pursuing research and how he is an IoPian in many aspects. He also explained the peaceful use of nuclear energy in the energy sector, particularly sustainable nuclear power for society. Prof. Mohanty emphasized the research of the Neutrino, the use of materials for thermoelectricity, supercomputer applications etc. He also addressed the audience by citing the brief story of HomiBhaba and Sir C. V. Raman.

The session was chaired by Prof. K. K. Nanda, Director, Institute of Physics, Bhubaneswar, in the presence of Prof. T. Som, Chairman of the Foundation Day Celebration Committee, Prof. P. K. Sahu, Registrar and Dr Basudev Mohanty, Convener at the Institute's Auditorium. The meeting ended with a vote of thanks by Prof. P. K. Sahu, Registrar, Institute of Physics, Bhubaneswar, followed by a Cultural Programme.

Apart from these, eminent Professors in Physics delivered two Foundation Day Colloquia on different domains of Physics in the morning sessions. In the first session, Prof. S. B. Krupanidhi, Materials Research Centre (MRC), Indian Institute of Science (IISc.), Bangalore, talked on "*Heterojunctions based on 2D/III-Nitrides hybrids*", emphasising various applications of photo-detectors such as environmental monitoring, space research and optical communication. In the second session, Prof. D. Kanjilal, Inter-University Accelerator Centre (IUAC), New Delhi, talked about "*Ion Accelerators and their Applications in Research and Industry*". It covered the design and development aspects of various ion accelerators and associated technology, especially in the country. The use of various ion beams at different energies is also explained by Prof. Kanjilal.

4.2. Outreach Programme

i) National Science Day

Each year on 28th February, Institute of Physics (IoP) observes National Science Day in its premises. As a part of this year's celebration, IoP organized an "OPEN DAY" event to showcase its

diversified research activities, and demonstrate various live experiments. The main objective of this observation was to awaken the scientific spirit and temper in the minds of the budding talents and create more scientific and technological awareness among the students, teachers, parents, technology enthusiasts and the general public in the day-to-day life. During the "OPEN DAY" event, the students and scientists of IoP demonstrated live demo experiments, organized Laboratory visits, and presented scientific posters. Some of the exciting live demo experiments included Plasma Generation from Grapes in Microwave, Light Emission from Quantum Dot, Demonstration and application of Eddy current, Conservation of angular momentum, Non-Newtonian fluid, Laser bottle, Mobius strip, Cyclotron, Gyroscope, Superconducting Levitation, Health monitoring system , Demonstration of Solar energy , 3D Hologram , Refractive index and densities, Neutrino as a tool for societal benefits, Solar photovoltaic: An amazing source of green energy, Liquid Nitrogen, Radiation and Liquid Crystal. Various laboratories/ experimental set up suchas Ion Beam Laboratory, Advance Material Growth Laboratory, Laboratory for Low-Dimensional Materials, X-ray Photoelectron Spectroscopy (XPS) Laboratory, Transmission Electron Microscopy (TEM) Laboratory, Surface Nano structuring and Growth Laboratory, Raman spectrometer, SQUID-Magnetometer, Pulsed laser deposition (PLD), HEP Detector Laboratory, and Liquid crystal laboratory werethe main attractions

ii) Popular Science Talk in the Wissenaire'22 program at IIT Bhubaneswar on April, 3, 2022.

Prof. A.M. Srivastava gave a popular science talk on "The Universe. Elementary particles, and Dark energy" at the Annual Techno - Management fest of IIT Bhubaneswar. Wissenaire'22 on April 3, 2022. A star gazing session (with telescopes taken from IOP) was also planned at IIT, but in the end due to clouds it could not be done.

iii) The study tour of S.C.S. (Autonomous) College, Puri students and teachers to Institute of Physics, Bhubaneswar on 13.04.2022

The study visit of students and teachers of S.C.S. (Autonomous) College, Puri to Institute of Physics, Bhubaneswar was held on 13.04.2022. Director Prof. K. K. Nanda, enlightened the students about the carrier in basic science and the research activity carried out at IOP. Dr. S. N. Sarangi, scientific officer, Institute of Physics coordinated the program and the students interacted with the members of IOP and visited different laboratories of IOP. Doctoral Scholars and scientific staffs of different labs volunteered for the smooth visits of the students to different Laboratory.

A group photograph of the students who visited IOP on 13.04.2022

iv) ***Popular Science Talk on "Black Holes for General Public" in the SOAFAL Series on 15th June, 2022***

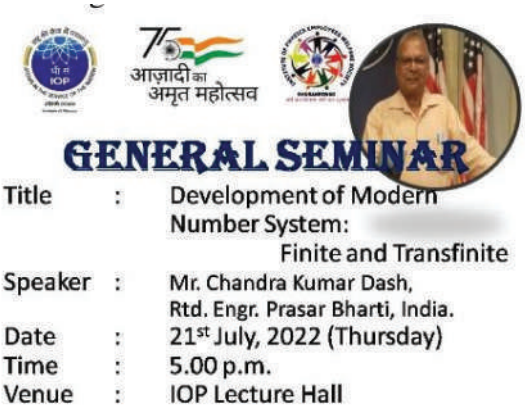
Prof. A.M. Srivastava gave a popular talk on "Black Holes for General Public" in the SOAFAL (Siksha O Anusandhan Fortnightly Academic Lecture) Series of SOA University, Bhubaneswar on 15th June, 2022. The talk was attended by about 75 students, faculty members and audience from general public.

YouTube Link:

https://www.youtube.com/watch?v=hJDIqNXWJr8&list=PLBZfl5tRid2v7FQiJokHu1_ftc_h1Kwcr&index=6

v) ***Motivational Seminar of IPEWS "Modern Number System : Finite and Transfinite" on 21st July, 2022***

A motivational talk was arranged on 21st July, 2022 in the Lecture Hall of the Institute. The title of the talk was "Modern Number System: Finite and Transfinite". The talk was delivered by Mr. Chandra Kumar Das. Mr. C. K. Dash, Associated Member of "Institute of Electronics & Telecommunication Engineers, new Delhi. Around 110 audience including research scholars and PDFs were gathered in the said talk.



vi) ***Celebration of DAE Iconic Week from 22nd August, 2022 to 28th August, 2022 as a part of AzadiKaAmritMahotsav.***

Institute of Physics, Bhubaneswar observed the "DAE Iconic Week"

As part of "Azadi Ka Amrit Mahotsav" the department of Atomic Energy (DAE) observed "DAE Iconic Week" from 22nd to 28th August 2022. To bring Science to the forefront and awaken the scientific spirit, various programs are being organized at the Institute of Physics (IoP), Bhubaneswar, namely: Seminars, Lab visits & Quiz competitions (for School & Junior College & Senior College students), Orientation Programme & Art of Living, Physics Open discussion, Skywatch Program etc.

vii) DAE Iconic Week dated22.08.2022: Plantation

The Institute of Physics, Bhubaneswar celebrates the DAE Iconic Week as a part of the AzadiKaAmritMahotsav. The inaugural meeting of the proposed week was observed today i.e. on 22.08.2022 in the conference hall of the Institute. Around 100 staff members of Institute including research scholars are participated the inaugural function. As a part of the DAE Iconic Week, the Institute decided to start the activity with tree plantation programme. The Tree Plantation Program (Bano Mahotsav) by the Institute members was organized and 200 of saplings collected from the Forest Department, Govt. of Odisha such as Neem, Pista, Kanchan, Jammu, Ashok etc. were planted inside the Institute campus. Prof. KarunaKar Nanda, Director, Prof. P.K. Sahu, Registrar and Dr. S. N. Sarangi, Convener, AKAM deliver their speeches on Celebration of DAE Iconic Week at inaugural meeting. All the staff members participated in the tree plantation and the program completed successfully.

(Prof. K. K. Nanda, Director, Institute of Physics delivering the Inaugural Speech at Inaugural function)

(All staff members at Tree Plantation ground and Prof. K. K. Nanda planting a tree)

(Prof. P. K. Sahu and Prof. S. Varma planting tree)

(Blood Donation Banner and a Group Photos of IOP staff members and Director, IOP)

Staff members and donors in Blood Donation camp

Registrar, IOP and Staff members donating Blood

viii) DAE Iconic Week Dated24.08.2022: (Science AwarenessProgram for School and Jr. college Students)

Institute of Physics, Bhubaneswar organizes a Science Awareness program for school and junior college students on 24.08.2022. Around 120 students from different schools and colleges of Odisha participated in the program. The students visited all the experimental laboratories of Institute and interacted with faculty members and scientific officers of the Institute. The program ended with an interesting quiz program among the students and the prize distribution was made during the competition.

(Director, Registrar delivering their Inaugural Talk)

Group Photo of participants

Some winner receiving Prizes during Quiz program

ix) DAE iconic week dated 25.08.2022: (Academic Program for Sr. College & University students)

As a part of the DAE Iconic week, the Institute organized one day academic science awareness program for senior college students. Around 200 students from various colleges and universities of Odisha have participated in the program. Prof. A.K. Tyagi, Director, Chemistry Group, BARC, Mumbai delivered a popular lecture on the "Career in Science" and had a close interaction with the students. Mr. Manish Patel and Ms. Aisha Khatun, Research Scholars of IOP also gave scintillating academic

talk in the morning session. In the afternoon session, Prof. K.K.Nanda, Director, IOP delivered a popular talk on "Photoluminescent materials for societal applications". Dr. S. N. Sarangi, SO/D of the Institute demonstrated an experiment on Light Emission. The session concluded with National Anthem. By the support of all staff members of IOP, the program was completed successfully.

Prof. A. K. Tyagi, BARC on interaction session with participants

Mr. Manish Patel and Ms. Aisa Khatun, IOP research scholars delivering talk

Prof. K. K. Nanda, Director, IOP on Question-Answer Session with the participants

(Demonstration of Light Emission by Dr. S. N. Sarangi, IOP)

x) DAE iconic week dated 26.08.2022 : [program for Ankur children (children resides in nearby basti) and yoga program]

The Institute dedicated the 5th day of the DAE Iconic Week to ANKUR (Children lives in the nearby Basti/Slum area). Volunteers from the research scholars of the Institute picked up about 35 children of Standard-III to Standard-VIII from Biswaswar Basti in two slots. There are various scientific awareness activities, explanatory film on Chandrayaan, Trigonometry, scientific recreational activities and many other magical scientific experiments. IOP researchers help children to draw various trigonometric figures. Prof. A.M. Srivastava explained the basic principles of lens and magnet. Prof. Srivastava also advised the kids about the childhood life of prominent scientists like Einstein. Dr. B. Mallick explained the kids on various magical scientific experiments like rainbow production and vacuum pump etc. In the evening session, the Institute organized a Yoga camp with the help of "Art of Living" group. Around 100 participants from the Institute attended the program. With the support of all staff members of IOP, the program was concluded successfully.

Prof. K. K. Nanda, Director, Prof. P. K. Sahu, Prof. A. M. Srivastava and others interacting with the ANKUR Children

(Research Scholars of the Institute helping the ANKUR Children to draw different geometrical shapes)

(YOGA Progam, Prof. K. K, Nanda and Prof. P. K. Sahu in Yoga Camp)

xi) Dae iconic week dated 27.08.2022: [health camp program for Iop members]

A health camp on Cardio, Ortho and Diet subjects on 6th day of Iconic week. The camp was organized with the professional doctors from local well-known Kalinga Hospital, Bhubaneswar. Approximately 100 members from the Institute campus along with their family members attended the session. Mrs. AnjanaTripathy elaborated the importance of balanced diet. Prof. &DrRanjitPanigrahi gave a popular talk on Orthopedics (Arthritis) and Dr. SusantSaila has given a seminar on Cardiology. Both the doctors have also clarify the questions asked by the audience. Dr. Panigrahi and Dr. Tripathy attended the patient from the audience/ members from IOP after the seminar session. By the support of all staff members of IOP, the program was completed successfully.

(Banner of Health Camp, and a group photograph with Director)

(Prof. K. K. Nanda, Director felicitating Dr. Ranjit Sr. Orthopedics and Dr. Sushant, Sr. Cardiologist of Kalinga Hospital, Bhubaneswar)

(Director felicitating the Dietician and Volunteers from Kalinga Hospital, Bhubaneswar)

Dr. Saila (Cardiologist) and Dr. Tripathy(Orthopedics) attending the normal checkup camp with Institute campus members)

xii) Dae iconic week dated 28.08.2022:[program on scientific presentation by campus children and drawing competition on AzadikaAmritMahotsav]

As a part of the DAE Iconic week, on the 7th day of the week, Institute of Physics, with the aim of inculcating scientific temper in the campus children as well as patriotism among the little ones, it was decided to have a drawing competition program among the children on the theme "AzadiKaAmritMahotsav". About 40 children participated in this program. All the winners of the drawing competitions were awarded by the Director, Prof. K. K. Nanda. Later a scientific presentation was given by the children of the campus. Among them, two children were selected to get prize, Mr. Sarfaraz Khan and Ms. Subhrangi. In order to encourage all the little children for their activity, they were given the "AzadiKaAmritMahotsav" Seal. The program ended with the national anthem with the participants. Before the conclusion of the session, there was a group discussion on future planning for the outreach program at IOP. The evening's Skywatch program was canceled due to the bad weather. The program was successfully completed with the support of all the staff members of IOP.

(Banner and Group Photos of the drawing competition)

(Program for ANKUR Children)

(Practical Mathematics for ANKUR Children)

(Yoga Program and the Concluding Session of the AKAM)

xiii) Sonepur College, Subarnapur (12.11.2022, Saturday)

1. The tour of the outreach members started on 12th November, 2022 at 8.00 am from Boudh district towards Sonpur College, Subarnapur.

2. Our outreach team was given a grand welcome by the Principal, HOD, students and other faculty members of Sonpur College, Subarnapur.

3. Sonepur College had an inaugural session in their auditorium where the Director, along with all the academic members of that college were welcomed by the Principal of Sonepur College, Formally after lighting the lamp and all were facilitated with memento. A grand opening talk was given by Prof. R.L Acharya, Principal, Dr. (Mrs.) Rath, HOD, Dept. Physics of Sonepur College and our Director Prof. K. K. Nanda and Chief guest from BARC Dr. S. Kar. Outreach coordinator Dr. S.N. Sarangi proposed the vote of thanks.

4. The technical session of the above program started after a short tea break.

5. Inauguration of technical session by Prof. K.K. Nanda, Director, Institute of Physics, as listed below.

TECHNICAL SESSION		
S.N.	**Name of the Speaker**	**Topic of Presentation**
1.	Prof. K. K.Nanda, Director	Career in Science
2.	Dr. S. Kar, SO-G, BARC	Water Treatment
3.	Dr. S. N. Sarangi	Nano Science and Nano Structure
4.	Dr. B. Mallick	Practical application of Liquid Nitrogen

xiv) Collector Office, Boudh (12.11.2022)

1. The Academic member of IOP outreach team and Dr. S. Kar, Scientist, BARC held a meeting with District Collector, Boudh regarding the installation of water treatmentplant in Boudh District. The meeting was held at Circuit House Boudh around 10.30 pm. The meeting lasted till late-night 12.20 am.

2. 2. The team explained in detail the details of the water treatment plant of DAE (figure) in front of the District Collector, Boudh, Panchayat Officer and Tehsildar.

3. The meeting was very successful and the Collector, Boudh immediately showed interest in setting up 5 water treatment plants and later he agreed to set up about 100 more water treatment plants in Boudh district. The team also collected water samples from 5 locations where treatment plants are going to be set up soon.

4. The meeting ended with a vote of thanks to each and every member.

xv) Jawahar Navodaya Vidyalaya, Boudh (13.11.2022, Sunday)

1. As per the invitation from Jawahar Navodaya Vidyalaya (JNV), Boudh, the outreach members started the tour on 13th November, 2022 at 5.00 PM to visit JNV, Boudh for an academically inspirational program. There was a gathering of around 400 students from classes VI to XII. Their teachers were also thronged with eagerness for the academic programme.

2. The troop was grand welcomed by JNV.

3. The academic program commenced at around 7.30 pm after a formal introductory meeting and introduction of the dignitaries before the gatherings.

4. Academic Inspirational Sessions from the Academic Group of Outreach Team listed below.

TECHNICAL SESSION		
S.N.	**Name of the Speaker**	**Topic of Presentation**
1.	Prof. K. K.Nanda, Director	Grow with Science
2.	Prof. P. K. Sahu	Facilities available at Institute of Physics and their Utilities in Research
3.	Dr. S. N. Sarangi	Light and Nano Structure
4.	Dr. B. Mallick	Magic in Science with Liquid Nitrogen

xvi) Model Degree College, Boudh (14.11.2022, Monday)

1. As per schedule, visiting outreach members reached the venue at around 9.00 am. The inaugural session began after due registration of a gathering of around 300 students from five nearby colleges.

2. Principal Model Public College Boudh introduced the guests present in the meeting. Prof. P.K. Sahu, Registrar, IOP delivered the inaugural address, Prof. K.K. Nanda, Director, IOP delivered the chief guest address. The session concluded with the inauguration of the AKAM Bulletin followed by the vote of thanks by Dr. P.C. Behera, The Nodal Officer of the program and the Principal of Boudh Panchayat College.

3. The academic and technical session of the above program started after a short tea break with snack for the students.

4. Inauguration of technical session by Prof. K.K. Nanda, Director, Institute of Physics, as listed below.

5. The program ended around 2.30p.m. with a grand lunch for the gathering students and teachers.

TECHNICAL SESSION		
S.N.	**Name of the Speaker**	**Topic of Presentation**
1.	Prof. K. K.Nanda, Director	Career in Science
2.	Prof. P. K. Sahu, Registrar	Facilities in Institute of Physics
3.	Dr. S. N. Sarangi	Nano Science, Nano Structure & its application
4.	Dr. B. Mallick	Application of Liquid Nitrogen

xvii) Report onOutreach Programme conducted on 24.12.2022 at Ganjam District

Institute of Physics (IOP), Bhubaneswar has been regularly organizing seminars and other public awareness & outreach programs time-to-time with the objective of creating awareness among students, teachers, public representatives, government officials and member of public.

Public Outreach program on 'Outreach Programme for Science Students' was organized at Berhampur Universtiy (BU), BhanjaVihar, Berhampur, Ganjam, Odisha on dated 24.12..2022 for the M. Sc students of Department of Physics, Department of Chemestry, Department of Electronics, Department of Electronics of Berhampur Universtiy. Students from NIST College and Khalicote college also joined in the meeting. Around 200 Nos. of students participated in the programme. The aim of the program was to draw the attention of the young minds towards carrier in science, the societal application of Nuclear Science and activities of DAE and IOP, Frontier research in materials science etc.

The inaugural meeting was chaired by Prof. Geetanjali Dash, Vice-Chancellor, Berhampur University, Prof. KarunaKar Nanda, Director, IOP, Prof. P. K. Mohanty, Chairman, P.G. Council, BU, Prof. P. K. Sahu, Registrar, IOP, Prof. S. K. Tripathy, Department of Physics, BU and Dr. S. Panda, Head, Deptt. Of Physics, BU. Dr. SachindraNathSarangi, Convener, AKAM Committee, IOP introduced the aim of the meeting and welcomed the gathering. All the chaired dignitaries addressed the students and faculties present in the meeting. Prof. Geetanjali Dash, Vice-Chancellor thanked the IOP team for organizing such a wonderful &knowledgeable programme at Berhampur University. She appreciated the knowhow and the use of Nuclear Energy to produce nuclear power as a safe, eco-friendly and economically viable source of electrical energy to meet the increasing energy demands of the country. The inaugural meeting was ended with vote of thanks Dr. S. Panda, Head, Deptt. Of Physics, Berhampur University, Berhampur.

After inaugural meeting, the technical session began at around 10:30 hrs where Prof. K. K. Nanda talked about eh recent advances in the topic 'Resistive Sensor'. Prof. P. K. Sahu delivered a talk on "Atomic Energy and its Applications to Society". The aim of the presentation was to enhance the awareness about nuclear energy, on-going project activities and to provide the information about the measure being taken to make nuclear energy safe & environmental friendly. Dr. S. N. Sarangi addressed the gathering on the topic of "Nanoscience and Nanotechnology". Dr. Mallick, SO, IOP delivered a talk on "Research Facilities at Institute of Physics, Bhubaneswar".

(Guests on the Dias during the inaugural function and a group photograph of the participants, speakers and delegates)

(Participants in the Hall, and Prof. Nanda delivering the talk)

xviii) Report on Outreach Programme conducted on 25.12.2022 at Mathura, Khallikote, Ganjam, Odisha

Public Outreach program on 'Atomic Energy in the service of Mankind' was organized at Mathura, Khallikote, Ganjam, Odisha on dated 25.12.2022 for the general public of the Khallikote Block. Around 300 Nos. of general public from different Panchayats including ANM, Anganwadi staff, SSG people, NGO people etc. were participated in the programme. The aim of the program was to awareness the general public about the activity of Department of Atomic Energy and Institute of Physics and to draw the attention towards the safe use of Nuclear power and societal applications using nuclear energy. Sri Pratap Ch. Pal. Bhairabi Club welcomed the guests as well as participants.

(Guest and speakers on the Dias , Left -Sri Pratap Ch. Pal, Bhairabi Club, Prof. K. K. Nanda, Director, Prof. P. K. Sahu, Registrar and Dr. S. N. Sarangi, Scientific Officer, Institute of Physics, Bhubaneswar)

(Dr. S. N. Sarangi speaking to audience and a photograph of the delegates and guests)

xix) Out reach programs at Centurion University of Technology and Management (CUTM) Balangir during 27th January 2023

Institute of physics has conducted Public Outreach program on 'Outreach Programme for Science Students' at Centurion University of Technology and Management (CUTM), Balangir as a part of the celebration of AzadikiAmritMohotsav on 27th January 2023. Shri P. Sarangi (Director) CUTM and Prof. Biswal,CUTM) and all faculty members of Centurion University of Technology and Management co-ordinated to organize the program on the behalf of the CUTM, Balangir campus. Around 220 numbers of students were participated in the program. The program was inaugurated by Prof. K. K. Nanda. Prof. Nanda inspired the students by a popular science talks, Prof P. K. Sahu talks about how the Atomic energy and the Nuclear energy can be used for benefit of mankind and Dr. S. N. Sarangi talks about NanoScience and Nanotechnology and experimental facilities available at IOP, Bhubaneswar and how the students and researchers utilise these facilities. At the end Dr. Sarangi, organised few fun science experiments along with Sri B. K. Dash for the students.

xx) Outreach programs at Women's College, Balangir during 28th January 2023

Institute of physics has conducted Public Outreach program on 'Outreach Programme for Science Students' at Govt. Women's College, Balangir as a part of the celebration of AzadikiAmritMohotsav on 27 th January 2023. Prof. Manoranjan Mishra, Principal and all teaching staffs of Govt. Women's College, Balangirco-ordinated with IOP members for arranging the program in the college. Science students of Rajendra University also took part in the program. 200 numbers of students participated in

the program. The program was inaugurated by Prof. K. K. Nanda. Prof. Nanda inspired the students by a popular science talks. Prof P. K. Sahu talks about how the Atomic energy and the Nuclear energy can be used for benefit of mankind. Dr. S. N. Sarangi talks about Nanotechnology and experimental facilities available at IOP, Bhubaneswar. It was a very successful program.

xxi) "Outreach Programme for Science Students" organized at Jawahar Navodaya Vidyalaya (JNV), Konark, Dist. Puri on 31st March, 2023

Public Outreach program on 'Outreach Programme for Science Students' was organized at at Jawahar Navodaya Vidyalaya (JNV), Konark, Dist. Puri, Odisha on dated 31.12..2022 for the students of JNV, Konark. Around 400 Nos. of students participated in the programme. Inauguration meeting started with the welcome address by the Principal, JNV Konark and Dr. Sachindra Nath Sarangi, Convener, AKAM Committee, IOP introduced the aim of the meeting and welcomed the gathering. All the chaired dignitaries addressed the students and faculties present in the meeting. Prof. K. K. Nanda talked about the recent advances in the topic material Science. Prof. P. K. Sahu delivered a talk on "Atomic Energy and its Applications to Society". Dr. S. N. Sarangi addressed the gathering on the topic of "Nanoscience and Nanotechnology". The aim of the program was to draw the attention of the young minds towards carrier in science, the societal application of Nuclear Science and activities of DAE and IOP, Frontier research in materials science etc.


xxii) Physics Open Discussions (POD) and POD-Online for students:

Prof. A. M. Srivastava

Physics Open Discussions (POD) was arranged earlier, once a month, for school children at the Institute of Physics where students could ask any question in physics and engage in free discussions. This program is now being conducted online regularly on 3rd Saturday of every month in coordination with Pathani Samanta Planetarium, Bhubaneswar. This is an ongoing program. Following are the details of sessions conducted during period 1st April, 2022- 31st Aug. 2022.

Session 8: 16th April2022

Youtube Link: https://www.youtube.com/watch?v=tNQ-sm0qa9I&t=2399s

Session 9: 21st May 2022

Youtube Link: https://www.youtube.com/watch?v=PDeMJ3Fg_sc&t=7s

Session 10: 18th June 2022

Youtube Link: https://www.youtube.com/watch?v=6D6OAAcMaXc&t=850s

Session 11: 23rd July 2022

Youtube Link: https://www.youtube.com/watch?v=jIUg2rslZ88&t=67s

Session 12: 27th August, 2022

(Special 12th Session of Physics Open Discussion (POD) on the occasion of "Azadika AmritMahotsav" at IOP Bhubaneswar)

Youtube Link: https://www.youtube.com/watch?v=WfZy1yQGiXo&t=423s

xxiii) International Women's Day -2023 celebrated at Institute of Physics

Prof. Shikha Varma as a chairperson of Women cell- IOP, arranged online talk on the occasion of the Women's day on 1st March 2023. This year the theme for International Women's Day focuses on Women and Girls in the development of transformational technology and digital education: DigitALL: INNOVATION AND TECHNOLOGY FOR GENDER EQUALTY". The talk was given by Ms. Rama Sarode, Socio legal Trainer. In her talk on "Embrace Equality Don't let the Gender Measure their Potential" she discussed issues related to the safety of women at work place. The meeting was held in

hybrid mode, with speakers and some IOP members present online and some members present in the lecture hall.

xxiv) Popular Talks

Prof.Shikha Varma

a) Applications with Surfaces and Nanostructures: Sensors and Catalysis "From Surfaces to Nanotechnology to "Nano Bio" at VigyanVidushiPogram organized by HomiBhabha Science Center (HBSC) and TIFR (July 2022)

b) 'Exciting Functional Materials & Applications of Nanoscience' at Indian Association of Nuclear Chemists and Allied Scientists-Eastern Regional Center (IANCAS- ERC) program on 'Wonder Materials, Energy and Radiation' at Rama Devi (RD) University, Bhubaneswar (July 2022)

Prof. Debasish Chaudhuri

a) Presented an online talk on "Soft matter, living system, and active matter" in a symposium IMPACT-22 on 28 May 2022, organized by S N Bose National Center for Basic Science, Kolkata, as a part of the AzadiKaAmritMahotsav celebration.

4.3. OFFICIAL LANGUAGE

During the period 2022-23 (April-2022 to March, 2023), the following items of the important work relating to the progressive use of Hindi were undertaken by the Official Language Section-

i. Implementation of the Official Language Policy and the Annual Programme of the Govt. of India: All Sections of the Institute were advised to comply with the provisions of the Official Lanugae Act, Rules and instructions issued thereunder for achieving the targets fixed by the Ministry of Home Affairs, Department of Official Lanugage, in the Annual Programme for the year of 2022-23. Various check-points were also devised for the effective implementation of the Official Language Policy of the Union.

ii. The Official Language Section acts as a co-ordinator in the event of Official Language inspection of various Sections.

iii. The Official Language Section also processes nominations of officials for various training courses conducted under Hinid Teaching Scheme by the Department of Official Languge, Ministry of Home Affairs. During the period under report, 03 officials were nominated for Praveen Course and 02 officials were nominated for Parangat Course.

iv. Meeting of the Official Language Implementation Committee: Quarterly meeting of the Official Lanugage Implementation Committee (OLIC) of the Institute are held as per provisions, wherein progress relating to the use of Hindi in official work in the Institute is reviewed and based on discussions therein, effective strategy is worked out for the improvement of progressive use of Hindi and implementation of the official language policy. During the period of three meetings wer held regular basis and one meeting could not held due to unavoidable reasons.

v. During the period under report, apart from the regula translation of routine materials, a number of important and time-bound translation of materials/doucments specified in Section 3 (3) of the Official Languge Act, 1963 and other parliamentary activities were carried out.

vi. In consonance with effective implementation of the Official Language Policy and creating awareness of using Hindi in day-to-day official work, "Hindi Pakhwara" was organised from 14.09.2022 to 29.09.2022 in the Insttitue. During the Pakhwara 05 Hindi competitions were held. Cash Prizes were distributed to the winner employees. Certificate to the winners were also awarded in a "Certificate Award Ceremony" organised in the Insttitue on 29.09.2022.

(Prof. K. K. Nanda, Director and Prof. P. K. Sahu, Registrar are dais during the Hindi Day Celebration on 14.09.2022)

(Prof. P. K. Sahu, Registrar and Prof. S. Varma, Director (I/c) on dais during "Prize & Certificate Award Ceremony" held on 29.09.2022)

vii. Hindi Workshop organised: Institute organised 03 Hindi Workshops during the period under report. On 21.09.2022 a workshop was organised on the title "Labour Laws and Govt. Accounts Police". Sri S. Sampat Kumar, Dy Chief Labour Commissioner (Central)), Sri P. K. Rana, Regional Labour Commissioner and Sri Harmanjit Kaur, Asst. Labour Commissioner (Central) were delivered the talks on this topic. On 05.12.2022, a workshop was organised on "Guidance of the parents for academic developmen t of students". Sri A. K. Panda, Principal, KV No.-1, Bhubaneswar and Dr. R. K. Dubey, PGT (Hindi) were delivered on the above cited subject. On the occasion of the World Hindi Day Celebration, a Hindi Workshop was organised on 10.01.2023 at IREL (India) Ltd. OSCOM jointly.

(Delegtes during the Hindi Workshop organised on 21.09.2022)

(Prof. K. K. Nanda, Director felicitating the Guests duirng Hindi Workshop held on 05.12.2022)

(Prof. K. K. Nanda, Director during the meeting of Town Official Language Implementation Committee (Central) held on 29.08.2022 in the Institute)

(Delegates on dais during the World Hindi Day Ceremony held on 10.01.2023

4.4. AZADI KA AMRIT MAHOTSAV (AKAM) PROGRAM

DAE Iconic week under "AzadiKaAmritMahotsav" program

As a part of the DAE Iconic week, the Institute of Physics, Bhubaneswar organized a weeklong 7 days various activities starting for, school students, college students, Institute stu senior college students. Around 200 students from various colleges, and universities in Odisha have participated in the program. Bark Prof. A.K. Tyagi, Chemistry division, BARC, Mumbai delivered a popular speech on Career in Science and had an interesting interaction with the students. Prof. Tyagi cleared various doubts asked by students. Ms. Manish Patel and Ms. Aisa Khatoon, IOP research scholars also gave a scintillating academic speech in the morning session. In the afternoon session, Prof. K.K.Nanda, Director, IOP delivered a popular talk on Photoluminescent materials for societal applications, Dr. S. N. Sarangi demonstrated an experiment on Light emission. The session

concluded with RashtraGana. By the support of all staff members of IOP, the program was completed successfully.

i) DAE ICONIC WEEK DATED 24.08.2022 : (Science awareness program for school and jr. college students)

Institute of Physics, Bhubaneswar organizes a Science Awareness program for school and junior college students on 24.08.2022. Around 120 students from different schools and colleges of Odisha participated in the program. The students visited all the experimental laboratories of Institute and interacted with faculty members and scientific officers of the Institute. The program ended with an interesting quiz program among the students and the prize distribution was made during the competition.

(Director, Registrar delivering their Inaugural Talk)

(Student Session and lab Visit)

Group Photo of Participants

ii) DAE ICONIC WEEK DATED 25.08.2022: (academic program for sr. college & university students)

As a part of the DAE Iconic week, the Institute organized one day academic science awareness program for senior college students. Around 200 students from various colleges and universities of Odisha have participated in the program. Prof. A.K. Tyagi, Director, Chemistry Group, BARC, Mumbai delivered a popular lecture on the "Career in Science" and had a close interaction with the students. Mr. Manish Patel and Ms. Aisha Khatun, Research Scholars of IOP also gave scintillating academic talk in the morning session. In the afternoon session, Prof. K.K.Nanda, Director, IOP delivered a popular talk on "Photoluminescent materials for societal applications". Dr. S. N. Sarangi, SO/D of the Institute demonstrated an experiment on Light Emission. The session concluded with National Anthem. By the support of all staff members of IOP, the program was completed successfully.

4.5. Sports and Cultural Activities

Along with the research activities, the sports and cultural activities have been promoted through different sports and cultural programs to keep all the members physically fit. To carryout different sports and cultural activities a committee was formed. Also IOP Employees Welfare Society support the committee in organizing different

Followings are the different activities conducted during the year 2022-23:

1. A Football match was conducted on 15th August, 2022. This was a friendly match between Team A (Faculties andDoctoral scholars) and Team B (Staffs of the Institute). The match was tie. Around 110 spectators were there to enjoy the football match. It was organized by IOPEWS.

2. Also a friendly Cricket match was conducted on the occasion of 26th January, 2023. This match was played betweenTeam A (Faculties andDoctoral scholars) and Team B (Staffs of the Institute). It was a very interesting match. Team Awon the match. Around 80-viewers joined and made the event successful.

3. During the year 2022-23, Sri Jyoti Ranjan Behera had selected for Odisha to play National Cricket Championship for Deaf against Bengal Team It was a pride moment for Institute.

4. In this year, many members of IoP had selected to play in the various events of Zonal selection matches of the XXXVII Annual DAE Sports and cultural meet. Among them Sri Jyoti Ranjan Behera selected to play in the final of the DAE Annual Sports and Cultural meet for Table Tennis, organized by BARC, Visakhapatnam and got fifth position.

FACILITIES

5.1 MAJOR EXPERIMENTAL FACILITIES

ION BEAM FACILITIES

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

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

The electron cyclotron resonance (ECR) ion source for ion implantation, nanoscale patterning, ion-beam induced epitaxial crystallization, ion beam mixing, ion-beam shaping and synthesis of embedded nanostructures and so on. At Surface Nano structuring and Growth (SUNAG) Laboratory, we have facilitated a low energy (50eV-2 keV), broad beam (I in. diameter) electron cyclotron resonance (ECR) source based ion beam etching facility for creating self-organized surface nanostructures.

MICROSCOPY FACILITIES

The High Resolution Transmission Electron Microscope (HRTEM) facility consists of two components: Jeol 2010 (UHR) TEM and Associated Specimen Preparation system. High-Resolution Transmission Electron Microscopy (HRTEM) with an ultra-high resolution pole-piece

(URP22) working at 200 keV electrons from LaB_6 filament assures a high quality lattice imaging with a point-point to resolution of 0.19 nm.

ARUPS FACILITIES

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. The angle resolved studies are possible on single crystals.

PULSED LASER DEPOSITION (PLD) SYSTEM

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

MAGNETIC PROPERTY MEASUREMENT FACILITY

The SQUID-VSM lab consists of the Quantum Design MPMS SQUID-VSM EVERCOOL system. The magnetic property measurement system (MPMS) is a family of analytical instruments configured to study the magnetic properties of samples over a broad range of temperatures and magnetic fields. Extremely sensitive magnetic measurements are performed with superconducting pickup coils and a Superconducting Quantum Interference Device (SQUID).

OPTICAL PROPERTY MEASUREMENT FACILITY

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.

5.2 COMPUTER CENTRE

The computer centre facilitates the scientific community dedicatedly in terms of scientific computation and In-House IT facilities. The centre is responsible for managing information and communication technology infrastructure in the Institute. The centres activity ranges from administration (server, network, etc.), hosting various services to laptop/desktop & user support. The Centre provide support in a hybrid environment consisting of different operating systems such as Unix-based (Cent OS, Redhat, Fedora, Ubuntu), MS Windows and MAC OS. Our Data centre activities has a state-of-art mechanism to handle system administration which includes mail services, centralized storage solution with backup facility and in-House development of web and intranet and gigabit network connectivity. In order to accomplish our Data centre activities, we have installed high end servers, core, distribution, access layer network switches, Firewall (UTM) and load balancer. Wireless network is available across all the buildings in campus. Internet facility is extended to residence area through Asynchronous Data Subscriber Line (ADSL).

The centre manages over 200 Desktops, Laptops, Software and License (Mathematica, Matlab, Origin etc.), Closed Circuit Television (CCTV) based surveillance systems installed at several offices and laboratories. A number of heavy duty printers are installed at different locations of academic building for general printing over LAN using terminal and through Web using online printing facility.

Institute has leased line Internet connectivity from one Internet Service Provider (ISPs) of 100 Mbps and 1 Gbps network connectivity by National Knowledge Network (NKN). The Institute operates over its own IP addresses from Indian Registry for Internet Names and Numbers (IRINN). Institute is a part of EDUROAM facility.

The centre provide technical support for administrative work, such as accounting, personnel management, stores management. Several software packages such as MSOffice, Wings 200 Net, Tally and multilingual software are in use.

The center conducts training, workshop and awareness programs in relevant areas time to time.

5.3 SAMKHYA (सांख्य):High Performance Computing Facility

SAMKHYA (सांख्य) - High Performance Computing (HPC) Facility at Institute is a hybrid environment which consists Sixty (60) Compute Nodes, two (2) Master Nodes, Four (4) I/O nodes (OSS & MDS) and 50 TB of object storage, QDR Infiniband interconnect and 1 Gbps Local Area Network. The infrastructure is of two (2) precision AC (10 ton of refrigeration each) and uninterrupted supply through three (3) 40KVA & one (1) 60 KVA UPS to facilitate the system. The facility consists of 1440 CPU cores, 40 NVIDIA Tesla K80 cards and 40 Intel Xeon Phi 7120P.

This facility has been ranked in the list of top supercomputers in India by CDAC, Bengaluru (January 2018 report at http://topsc.in). The facility is acknowledged in various publications by the user community.

5.4. ANUNET FACILITY

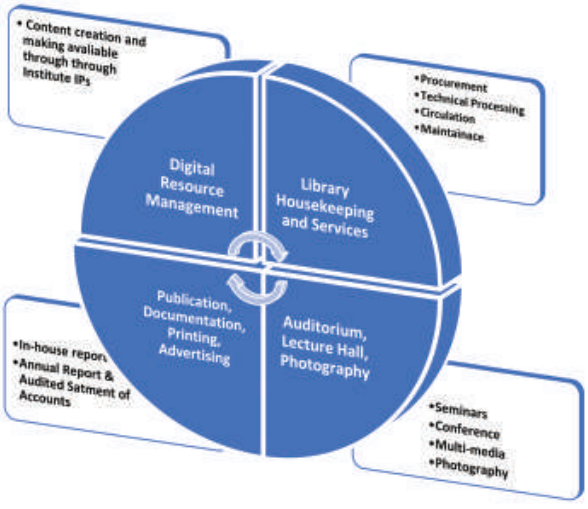
Institute of Physics is a node on ANUNET with the provision to connect other units of DAE directly by VSAT link for voice and data communication. Seismic monitoring equipment

has been installed in the Institute and seismic data is being continuously transmitted to Bhabha Atomic Research Centre (BARC) for analysis using ANUNET. The link is also used to connect with DAE and other institute on ANUNET through video conferencing setup.

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

5.5. LIBRARY

The primary objective of the IOP Resource Center is to carefully select, acquire, process, and disseminate scientific and technical resources in print and electronic/digital formats to the research community and other visiting users. In contrast, the IOP General Library focuses on meeting the needs of the IOP community and promoting a culture of readinghabit. In addition to its regular library services, the IOP Library also offers various supplementary services, including reprography, printing, publishing, advertising, photography, videography, document delivery, and an auditorium with lecture hall services. Moreover, the IOP Library actively engages in outreach programs, along with hosting conferences and seminars. A visual representation of the IOP Library's operations can be seen in the accompanying figure.



The Library facility is open to both members of the Institute and individuals from other academic institutions, particularly DAE members and those affiliated with the Department of Higher Education of the Government of Odisha. For a comprehensive overview of the Library's holdings, users can visit the Library Portal at http://www.iopb.res.in/~library.

The Library offers a diverse collection that includes over 17,500+print books, 6,000+ e-books, and 23,643 bound Journals. Subscriptions are maintained for 135 e-journals, along with selected print Journals, Magazines, and Newspapers. Additionally, the Library has obtained perpetual access rights to electronic archives of publications such as IOP (UK), John Wiley, Springer Physics and Astronomy, Scientific American, World Scientific, and Annual Reviews Archives (OJA), encompassing articles published since Volume 1. Furthermore, the Library provides access to e-books in the Lecture Notes in Mathematics and Physics series, ensuring perpetual access to back-files. As a core member of the Department of Atomic Energy (DAE) Consortium with M/s Elsevier, the Library also have electronic access to specific Elsevier journals dating back to 1995.

The Library has subscribed to iThenticate, an Anti-Plagiarism Web Tool, to uphold the academic integrity of the Institute. This tool is accessible through the library portal at http://www.iopb.res.in/~library/plagiarism.php and can be utilized within the Institute's IP ranges. Additionally, the Library has also subscribed to Grammarly Tool, a cloud-based software service provided by Grammarly Inc., USA, which assists researchers in writing and citation auditing.

As part of the resource sharing program, the Library assists users in obtaining articles from other libraries. Users can also request articles for academic purposes through Digital Inter-Library Loan. Notably, the IOP Library was the first library in Odisha to be automated using the Integrated Library Management System (ILMS).

It has then migrated to an RFID-based Smart Library Solution powered by the KOHA (an widely used Open-source ILMS) in the year 2028. This system supports various library housekeeping activities, including acquisition, cataloguing, circulation, and serial control, with automated check-in and check-out functionalities.To search for books and journals, users can utilize the Library's WEB-OPAC, accessible at https://www.iopb.res.in/~library/ or http://10.0.1.16/.

The Library is manages the publication, printing, and advertisement (PRD) division of the Institute, as well as providing reprographic services. To ensure that scientists and the research community at IOP are well-informed about the efficient utilization of electronic resources and technology-enabled services, the Library organizes training-cum-demo sessions at regular intervals. Additionally, the Library offers various extension services, including facilitating study tours for Library and Information Science (LIS) students and supporting their projects and dissertations.

5.6 AUDITORIUM

IOP boasts a splendid auditorium within its campus, purposefully designed for hosting a wide range of events such as Colloquiums, Seminars, Workshops, Conferences, Cultural activities, and Social programs on a regular basis. The auditorium is equipped with top-notch facilities, ensuring a high-quality experience for attendees. It has a seating capacity of over 330 people, providing ample space for gatherings and events.

PERSONNEL

PERSONNEL

Prof. Karuna Kar Nanda, Director
Institute of Physics

6.1. List of Faculty members and their research specialization

1. **Prof. Ajit Mohan Srivastava**
(Up to 31.08.2022)
Professor
High Energy Physics (Theory)

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

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

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

5. **Prof. Sudipta Mukherji**
Professor
High Energy Physics (Theory)

6. **Prof. Suresh Kumar Patra**
Professor
Nuclear Physics (Theory)

7. **Prof. Tapobrata Som**
Professor
Condensed Matter Physics (Experiment)

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

9. **Prof. Pradip Kumar Sahu**
Professor
Nuclear Physics (Theory)

10. **Prof. Dinesh Topwal**
Associate Prof.
Condensed Matter Physics (Experiment)

11. **Prof. Sanjib Kumar Agarwalla**
Associate Professor
High Energy Physics (Theory)

12. **Prof. Arijit Saha**
Associate Prof.
Condensed Matter Physics (Theory)

13. **Prof. Saptarshi Mandal**
Associate Prof.
Condensed Matter Physics (Theory)

14. **Prof. Satyaprakash Sahoo**
Associate Prof.
Condensed Matter Physics (Experiment)

15. **Prof. Aruna Kumar Nayak**
Associate Prof.
High Energy Physics (Experiment)

16. **Prof. Debashis Chaudhuri**
Associate Prof.
Condensed Matter Physics (Theory)

17. **Prof. Shamik Banerjee**
(Up to 29.06.2022)
Associate Prof.
High Energy Physics (Theory)

18. **Prof. Debakanta Samal**
Associate Prof.
Condensed Matter Physics (Experiment)

19. **Dr. Debottam Das**
Reader - F
High Energy Physics (Theory)

20. **Dr. Manimala Mitra**
Reader - F
High Energy Physics (Theory)

21. **Dr. Kirtiman Ghosh**
Reader - F
High Energy Physics (Theory)

6.2. Inspire/ Visiting Faculty

1. Dr. Kuntala Bhattacharjee
2. Dr. Aparajita Mandal
3. Dr. B. K. Panigrahi
4. Dr. Chhatrasal Shalikram Gayner (up to

18.07.2022)
5. Dr. Somnath Koley

6.3. Post-Doctoral Fellows

1. Dr. Abhijit Kumar Saha
2. Dr. Bhanu Sharma
3. Dr. Joy Mukherjee
4. Dr. Hemanta Kumar Sharma
5. Dr. Koushik Naskar
6. Dr. Sagarika Swain
7. Dr.Hanuma Kumar
8. Dr. Paramita Maiti
9. Dr. Akavoor Manu
10. Dr. Dr. Karan Singh (Upto 17.05.2022)
11. Dr. Anjan Kumar Jena (Upto 25.10.2022)
12. Dr. R. Bhattacharyya (Upto 20.04.2022)
13. Dr. Rakesh Kumar Sahoo (Upto 14.12.2022)
14. Dr. S. S. Khali(Upto 31.01.2023)
15. Dr. Siddharth Dwivedi (Upto 08.04.2022)

6.4. Doctoral Scholars

1. Alok Kumar
2. Sayari Ghatak
3. Ashish Kumar Panigrahi
4. Rahul Puri
5. Sayak Bhowmik
6. Debabrata Dey
7. Nevin Noble
8. Subhalaxmi Rout
9. Nabendu Mondal
10. Subhransu Sekhar Mishra
11. Aditya Mehta
12. Suman Roy
13. Raju Mandal
14. Sharmistha Chattopadhyay
15. Manish Patel
16. Aswin Kumar Burma
17. Pujalin Biswal
18. Kamalesh Bera
19. Amartya Pal
20. Ithineni Sairam
21. Rameswar Sahu
22. Sanu Varghese
23. Sheikh Moonsun Pervez
24. Subhadip Bisal,
25. Debasish Mondal
26. Dipak Maity
27. Digbijaya Palai,
28. Abhishek Roy
29. Aisha Khatun
30. Ankit Kumar
31. Arnob Kumar Ghosh
32. Arpan Sinha
33. Chitrak Karan
34. Harish Chandra Das
35. Mousam Charan Sahu
36. Pragyanprasu Swain
37. Ritam Kundu
38. Sameer Kumar Mallik
39. Sandhyarani Sahoo
40. Siddharth Prasad Maharathy
41. Sudipta Das
42. Bibhabasu De
43. Diwakar
44. Pranjal Pandey
45. Rupam Mandal
46. Saiyad Ashanujjaman
47. Rojalin Padhan
48. Gupteswar Sabat,
49 Abhisek Bag
50. Avnish
51. Debjyoti Majumdar
52. Subhadip Jana
53. Vinaykrishnan M.B.
54. Sudarshan Saha
55. Alapan Dutta
56. Dilruba Hasina

57. Biswajit Das

6.5. Project Doctoral Fellows

1. Anil Kumar (INO Proj. Student)
2. Sadashiv Sahoo (INO Proj. Student)

6.6. ADMINISTRATIVE PERSONNEL

Prof. Pradip Kumar Sahu, Registrar
(From 01 .08.2022)

Shri R. K. Rath, Registrar
(Up to 31.07.2022)

(i) Director's Office:

1. Bira Kishore Mishra
2. Saubhagyalaxmi Das
3. Lipika Sahoo
4. Rajan Biswal
5. Sudhakar Pradhan

(ii) Registrar's Office

1. Abhishek Mahraik
2. Abhimanyu Behera

(iii) Establishment

1. M.V. Vanjeeswaran
2. Bhagaban Behera
3. Baula Tudu
4. Rajesh Mohapatra
5. Pramod Kumar Senapati
6. Ranjit Pradhan
7. Samarendra Das
8. Pradip Kumar Naik
9. Gandharba Behera

(iv) Stores & Transport

1. Purabi Paramita
2. Keshab Chandra Dakua
3. Sanatan Jena (Up to 30.09.2022)
4. Sarat Chandra Pradhan
5. Jahangir Khan

(v) EPABX

1. Arakhita Sahoo
2. Daitari Das

(vi) Accounts

1. Debendranath Sahoo
2. Priyabrata Patra
3. Raj Kumar Sahoo
4. Purabi Paramita
5. Prativa Choudhury
6. Bijaya Kumar Swain

(vii) Maintenance

1. Arun Kanta Dash
2. Debaraj Bhuyan
3. Brundaban Mohanty
4. Deba Prasad Nanda
5. Naba Kishore Jhankar
6. Martin Pradhan
7. Chandra Mohan Hansdah

(viii) Estate Management

1. Saroj Kumar Jena.
2. Tikan Kumar Parida
3. Biswanath Swain(Up to 31.01.2023)
4. Bijaya Kumar Das
5. Sanatan Pradhan
6. Bhaskara Mallick
7. Kulamani Ojha(Up to 30.09.2022)
8. Pitabas Barik
9. Kapila Pradhan
10. Dhoba Naik
11. Charan Bhoi
12. Jatindra Nath Bastia
13. Basanta Kumar Naik
14. Ramakanta Nayak
15. Ramesh Kumar Patnaik

(ix) Library

1. Dr. Basudev Mohanty
2. Ajita Kumari Kujur
3. Rama Chandra Hansdah(Up to 30.04.2022)
4. Kisan Kumar Sahoo
5. Kailash Chandra Jena

(x) Computer Centre

1. Makrand Siddhabhatti
2. Nageswari Majhi
3. Jyoti Ranjan Behera

(xi) Laboratory

1. Sanjib Kumar Sahu
2. Dr. Sachindra Nath Sarangi
3. Khirod Chandra Patra
4. Madhusudan Majhi
5. Ramarani Dash
6. Santosh Kumar Choudhury
7. Dr. Biswajit Mallick
8. Pratap Kumar Biswal
9. BalaKrushna Dash
10. Soumya Ranjan Mohanty
11. Purna Chandra Marndi
12. Srikanta Mishra
13. Ranjan Kumar Sahoo

(xii) Workshop

1. Subhabrata Tripathy

(xii) Purchase Section

1. Aviram Sahoo
2. Ghanashyam Pradhan

6.7. LIST OF RETIRED MEMBERS

Name: Shri Ram Chandra Hansdah
Designation: Scientific Assistant-C
DoJ: 14.05.1982 - DoR: 30.04.2022

Name: Shri Rushi Kumar Rath
Designation: Registrar
DoJ: 30.10.2016 - DoR: 31.07.2022

Name: Prof. A. M. Srivastava
Designation: Senior Professor
DoJ: 15.04.1991 - DoR: 31.08.2022

Name: Shri Sanatan Jena
Designation: Driver cum Supervisor
DoJ: 16.04.1982 - DoR: 30.09.2022

Name: Shri Kulamani Ojha
Designation: MTS-C
DoJ: 24.11.1992 - DoR: 30.09.2022

Name: Shri Biswanath Swain
Designation: MTS-B
DoJ: 11.07.2001 - DoR: 31.01.2023

परीक्षित लेखा विवरण
AUDIT STATEMENT OF ACCOUNTS
2022 - 23

भौतिकी संस्थान
INSTITUTE OF PHYSICS
भुवनेश्वर, ओडिशा
BHUBANESWAR, ODISHA

जीआरसी एंड एसोसिएट्स / GRC & Associates
सनदी लेखाकार / Chartered Accountants
एन् -6/432, पहली मंजिल, आईआरसी गांव, नयापल्ली
N-6/432, 1st Floor, IRC Village, Nayapalli
भुवनेश्वर, ओडिशा, पिन – 751015
Bhubaneswar, Odisha, Pin - 751015

Contents

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GRC & ASSOCIATES
Chartered Accountants

INDEPENDENT AUDITORS' REPORT

To

The Director,

Institute of Physics,

Bhubaneswar.

Report on the audit of the financial statements

We have audited the accompanying financial statements **of INSTITUTE OF PHYSICS** ("the Society"), which comprise the balance sheet as at March 31, 2023, and the Statement of Income and Expenditure and the statement Receipt and Payment for the year ended as on that date.

Management's Responsibility for the Financial Statements

Management is responsible for the preparation of the financial statements that give a true and fair view of the financial position, financial performance of the Society in accordance with the applicable Accounting Standards and Societies Registration Act 1860. This responsibility includes the design, implementation and maintenance of the internal control relevant to the preparation of the financial statements that are free from material misstatement, whether due to fraud or error.

Auditor's responsibility

Our responsibility is to express an opinion on these financial statements based on audit. We conducted our audit in accordance with the standards on auditing issued by the Institute of Chartered Accountants of India. Those standards require that we comply with ethical requirements and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing producing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risk of material misstatement of the financial statements, whether due to fraud or error. In making preparation and fair representation of the financial statements in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting polices used and the reasonableness of the accounting estimates made by the management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

GRC & Associates Bhubaneswar Chartered Accountants

Qualified opinion

Basis of Qualification:

1.

a) The Society has not followed IAS 10 for accounting of Fixed assets and AS 6 for provision of depreciation. The society has not maintained fixed assets register to verify the individual asset residual value. Depreciation has been charged on gross block at the end of the year on SLM method irrespective of the fact that individual old assets may have been depreciated in full. The depreciation on assets purchased during the year was also charged for the whole year instead of proportionate basis from date to use.

b) The Fixed Assets of the Society were not physically verified in full during the year under audit.

c) None of the Fixed Assets of the Society were tested for impairment in accordance with IAS 28 and no provision has been made for impairment if any.

2. IAS 12 on accounting of Government grants has not been followed. The grants have been recognized on realization basis. Capital grants have been recognized as capital fund and shown as Liability.

3. The Capital Fund of the Institute is decreased to the tune of Rs71.10 lakhs to due recognition of unutilised Government grant as current liabilities at the end of the year.

Emphasis of Matter:

Attention of the management is also drawn on the following matter:

1. Balances of advances and liabilities to/from third parties are subjects to confirmation.
2. GST paid on Fixed Assets Purchased during the year has been capitalised in the books of accounts. Also GST paid on Expenses has been included with expenses. However, input for ineligible GST credit amounting to Rs 2238159/-has been claimed in GST portal.

Based on the above, in our opinion and to the best of our information and according to the explanations given to us, the financial statement read with the Accounting policies and note on accounts gives the information required by the Act in the manner so required and give a True and Fairview in conformity with the Accounting Principles Generally Accepted in India.

a. In the case of Balance sheet of the state of affairs of the Society as at March 31 2023
b. In the case of the statement of income and expenditure, of the deficit of the institute for the year ended on that date.

c. In case of statement of receipt and payments, the receipts and payment for the year ended on the date.

Report on other legal and regulatory requirements

(a) We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit and have found them to be satisfactory.

(b) In our opinion proper books of account as required by law have been kept by the Institute, so far as it appears from our examination of those books.

(c) The Balance Sheet, the Statement of income and Expenditure and Receipts and payment dealt with by this report are in agreement with the books of accounts.

For GRC & Associates
Chartered Accountants
Firm Registration No.02437S

CA A Mohapatra
Partner
MembershipNo.055285
UDIN: 23055285BGWKOL5636

Place: Bhubaneswar
Date: The 29th Day of August 2023

GRC & Associates * Bhubaneswar * Chartered Accountants

INSTITUTE OF PHYSICS
Sachivalaya Marg, Bhubaneswar

Balance Sheet as at 31st March 2023

(Amount in Rupees)

SOURCES OF FUNDS	Schedule	Current Year	Previous Year
CORPUS/ CAPITAL FUND AND LIABILITIES			
CORPUS/ CAPITAL FUND	1	53,19,82,590	48,25,21,728
RESERVES AND SURPLUS	2	0	0
EARMARKED/ENDOWMENT FUNDS	3	1,24,40,771	2,11,40,209
SECURED LOANS AND BORROWINGS	4	0	0
UNSECURED LOANS AND BORROWINGS	5	0	0
DEFFERED CREDIT LIABILITIES	6	0	0
CURRENT LIABILITIES AND PROVISIONS	7	20,38,93,435	19,14,35,912
TOTAL		**74,83,16,795**	**69,50,97,849**

APPLICATION OF FUNDS	Schedule	Current Year	Previous Year
ASSETS			
PROPERTY,PLANT & EQUIPMENTS	8	70,36,16,667	65,48,82,707
INVESTMENTS FROM EARMARKED/ ENDOWMENT FUNDS	9	0	0
INVESTMENTS OTHERS	10	0	0
CURRENT ASSETS, LOANS, ADVANCES ETC.	11	4,47,00,128	4,02,15,142
TOTAL		**74,83,16,795**	**69,50,97,849**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

As per our attached report of even date

For and on behalf of
GRC & Associates
Chartered Accountants
FRN-002437S

CA A Mohapatra
Partner
M.No. 055285
UDIN: 23055285BGWKOL5636
Place: Bhubaneswar
Date: The 29th Day of August 2023

GRC & Associates * Chartered * Bhubaneswar

For and on behalf of
Institute of Physics, Bubaneswar

29/8/23
(Mr. D. N. Sahoo)
Jr. Accounts Officer
कनिष्ठ लेखा अधिकारी/JUNIOR ACCOUNTS OFFICER
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

29/08/2023
(Dr. S N. Sarangi)
Registrar
रेजिस्ट्रार/REGISTRAR
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

29/8/23
(Prof. K. K. Nanda)
Director
निदेशक/DIRECTOR
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

INSTITUTE OF PHYSICS
Sachivalaya Marg, Bhubaneswar

STATEMENT OF INCOME AND EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2023

(Amount in Rupees)

Particulars	Schedule	Current Year (2021-22)	Previous Year (2020-21)
INCOME			
Income from sale or services	12		
Grants/ Subsidies	13	37,84,01,164	31,31,00,000
Fees/ Subscriptions	14	0	0
Income from investments	15	0	0
Income from royalty, Publication etc	16	0	0
Interest Earned	17	2,34,731	2,18,469
Other Income	18	13,45,454	6,67,236
Increase decrease in stock of finised goods/ WIP	19	0	0
TOTAL (A)		**37,99,81,349**	**31,39,85,705**
EXPENDITURE			
Establishment Expenses	20	27,01,41,379	25,00,98,281
Other Administrative Expenses etc.	21	9,40,35,188	9,48,79,204
Expenditure on grants Subsidies etc (Plan grant Surrendered)	22	0	0
Interest Paid	23	0	0
Depreciation (Corresponding to Schedule 8)		7,49,63,894	5,42,45,400
TOTAL (B)		**43,91,40,461**	**39,92,22,885**
Balance being excess of Expenditure over Income (A-B)		(5,91,59,112)	(8,52,37,180)
Unspent Grant at year end		71,10,000	1,32,22,000
BALANCE BEING SURPLUS/(DEFICIT) CARRIED TO CORPUS/ CAPITAL FUND		**(6,62,69,112)**	**(9,84,59,180)**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

As per our attached report of even date

For and on behalf of
GRC & Associates
Chartered Accountants
FRN-002437S

CA A Mohapatra
Partner
M.No. 055285
UDIN: 23055285BGWKOL5636
Place: Bhubaneswar
Date: The 29th Day of August 2023

GRC & Associates Bhubaneswar Chartered Accountants

For and on behalf of
Institute of Physics, Bubaneswar

29/8/23
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Jr. Accounts Officer
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INSTITUTE OF PHYSICS, BHUBANESWAR
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2023

SCHEDULE 1 -CORPUS/CAPITAL FUND

(Amount in Rupees)

Particulars	Current Year (2022-23)		Previous Year (2021-22)	
Balances as at the beginning of the year		48,25,21,728		57,99,14,871
Add : Contributions towards Corpus/Capital Fund	11,57,29,973		10,66,038	
Add/(Deduct) : Balance of Income/(Expenditure) transferred from Income & expenditure Account	-6,62,69,112.00	4,94,60,861	-9,84,59,180	-9,73,93,142
Balances as at the year end		53,19,82,590		48,25,21,728

29/8/23
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GRC & Associates * Chartered Accountants * Bhubaneswar

INSTITUTE OF PHYSICS, BHUBANESWAR
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2023

SCHEDULE 3 - EARMARKED/ENDOWMENT FUNDS

(Amount in Rupees)

	Particulars	Current Year (2022-23)				Previous Year
		OB	Receipt	Payment	CB	(2021-22)
1	L.K.Panda Memorial Fellowship SB A/C No.10164207776	1,29,886	3,542	-	1,33,428	1,29,886
2	TPSC Account SB A/C No. 450502010004886	1,07,711	3,060	-	1,10,771	1,07,711
3	JC Bose of Prof. A.M.Jayannavar SB A/C No.15987	14,50,955	59,753	-	15,10,708	14,50,955
4	JC Bose of Prof. S.M.Bhattacharjee SB A/C No.16376	3,042	85	94	3,032	3,042
6	CSIR Pool Scientist Programme SB A/C No.18179	8,072	226	94	8,204	8,072
7	UGC-DAE CSR Grant SB A/C No.18489	2,09,439	7,872	-	2,17,311	2,09,439
8	RAMANUJAN FELLOWSHIP DR. A.K. NAYAK SB A/C No.18511	24	-	-	24	24
9	INSA PROF. J MOHARANA SB A/C No.18532	1,01,640	2,664	87,900	16,404	1,01,640
10	BI IFCC Grant of Dr. P.K. Sahu SB A/C No.18597	7,00,017	2,26,906	2,94,695	6,32,228	7,00,017
11	Inspire Grant of Dr. Manimala Mitra SB A/C No.18695	1,22,132	4,209	-	1,26,341	1,22,132
13	DST Grant of Prof. S. Verma SB A/C No.18704	31			31	31
15	MAX PLANCK GROUP DR. DEBAKANTA SAMAL SB A/C No. 18738	42,61,093	4,31,278	5,37,836	41,54,535	42,61,093
16	INSA YOUNG SCIENTIST SCHEME BY DR. SK AGRAWAL SB A/C No. 18952	1,62,900	3,294	1,62,999	3,195	1,62,900
17	NALCO Project - Prof. P.V. Satyam SB A/C No.19051	2,85,607	94,494	3,06,016	74,085	2,85,607
18	DST PROJECT OF PROF PANKAJ AGRAWAL SB A/C No. 19123	13,59,453	4,79,749	7,04,892	11,34,310	13,59,453
19	PMFS SB A/C No.19143	3,31,464	1,07,91,515	1,08,13,984	3,08,995	3,31,464
20	DST PJ TO DR. K BHATTACHARJEE,IIST SB A/C No. 19182	25,10,505	1,64,201	25,87,505	87,201	25,10,505
21	DST PROJECT OF DR. SHAMIK BANERJEE SB A/C No.19296	56,425	1,680	-	58,105	56,425
22	IOP PROJECT PRENMM&CE-SERB DR.K. GHOSH SB A/C No. 19314	6,02,342	14,352	3,56,729	2,59,965	6,02,342
23	IOP PJ SAP"&F-SERB DR. DEBASISH CHOUDHURI SB A/C No.19315	1,12,932	1,84,089	2,89,126	7,895	1,12,932
24	IOP SERB PROJECT DR SOUMYA C SB A/C No. 19316	5,149	617	5,766	-	5,149
25	SERB PROJECT OF DR. DEBAKANTA SAMAL SB A/C No.19348	20,88,092	58,799	10,821	21,36,070	20,88,092
26	SWARNAJAYANTI FELLOWSHIP DR. SK AGARWALLA SB A/C No.19387	11,295	333	11,628	-	11,295
27	IOP INSPIRE FACULTY FELLOWSHIP OF A MANDAL SB A/C No. 19497	21,00,827	1,02,610	17,46,725	4,56,712	21,00,827
28	IOP SERB PROJECT OF DR. DINESH TOPWAL SB A/C No.19498	5,94,524	10,920	3,36,954	2,68,490	5,94,524
29	SERB PROJECT OF DR. SATYAPRAKASH SAHOO SB A/C No.19506	6,78,618	15,327	4,82,206	2,11,739	6,78,618
30	IOP SERB-LBSMPNE PROJECT OF DR. SK AGARWALLA SB A/C No.19539	11,52,010	35,193	11,63,971	23,232	11,52,010
31	CEFIPRA PROJECT OF DR. MANIMALA MITRA SB A/C No. 19540	4,79,485	4,87,328	6,39,429	3,27,384	4,79,485
32	IOP PJ SJF-SAFPH DR.SHAMIK BANERJEE SB A/C No.20244	15,14,540	23,268	15,37,808	-	15,14,540
	IOP PJ-EMHMBOMEST-SAPTARSHI MANDAL SB A/C No.202360	-	49,447		49,447	-
	IOP-PJ-RRF-BINAYA KUMAR PANIGRAHI SB A/C No.20361	-	13,62,433	12,41,503.04	1,20,930	-
TOTAL		2,11,40,209	1,46,19,244	2,33,18,682	1,24,40,771	2,11,40,209

GRC & Associates Chartered Accountants Bhubaneswar

29/8/23
कनिष्ठ लेखा अधिकारी/JUNIOR ACCOUNTS OFFICER
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

29/08/2023
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29/8/23
निदेशक/DIRECTOR
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2023

SCHEDULE 7 -CURRENT LIABILITIES AND PROVISIONS:

(Amount in Rupees)

Particulars	Current Year (2022-23)		Previous Year (2021-22)	
A CURRENT LIABILITIES				
1 Statutory Liabilities:		-		1,19,758
GST Recovery Payable		-	89,776	
NPS Recovery Payable		-	29982	
2 Other Liabilities:		4,21,56,256		3,53,20,125
Earnest money Deposit	99,865		68,000	
Caution money from Scholars	19,600		15,400	
Audit Fee Payable	59,000		59,000	
Project Grant Payable	90,000		-	
Provision for Expenses	2,01,60,069		2,08,22,316	
Payable to NALCO Project	49,875		49,875	
Fellowship Payable	85,160			
Gratuity Payable	6,96,078		3,82,603	
Security Deposit contractors	4,19,479		4,91,421	
Transferable Receipt			10,400	
Unspent Grant	2,03,32,000		1,32,22,000	
Incometax Payable	1,45,130		1,99,110	
TOTAL(A)		**4,21,56,256**		**3,54,39,883**
B PROVISIONS		16,17,37,179		15,59,96,029
1 Gratuity	8,00,64,547		7,75,37,741	
2 Accumulated Leave Encashment	8,16,72,632		7,84,58,288	
3 Others (Specify)	0		0	
TOTAL(B)		**16,17,37,179**		**15,59,96,029**
TOTAL(A+B)		**20,38,93,435**		**19,14,35,912**

29/8/23
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भुवनेश्वर/BHUBANESWAR

GRC & Associates Chartered Accountants Bhubaneswar

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2023

SCHEDULE 8- PROPERTY, PLANT & EQUIPMENTS

(Amount in Rs.)

DESCRIPTION	Rate of Depreciation	GROSS BLOCK				Residual Value	DEPRECIATION				NET BLOCK	
		Cost/valuation As on 01.04.2022	Additions	Deduction	Cost/ valuation as on 31.03.2023		Opening Balance as on 01.04.2022	For the Year	On Deduction	Closing Balance as on 31.03.2023	As on 31.03.2023	As on 01.04.2022
A. PROPERTY,PLANT & EQUIPMENTS (PLAN)												
1 LAND		-		-	-		-	-	-	-	-	-
a) Leasehold		50,00,000.00		-	50,00,000		-	-	-	-	50,00,000	50,00,000
2 BUILDINGS		-		-	-		-	-	-	-	-	-
a) On leasehold Land	1.63%	21,09,86,379.00		-	21,09,86,379	1,05,49,319	6,05,58,769	34,39,078	-	6,39,97,847	14,69,88,532	15,04,27,610
3 ROADS	1.90%	65,48,158.00		-	65,48,158	3,27,408	62,20,750	-	-	62,20,750	3,27,408	3,27,408
4 PLANT MACHINERY & EQUIPMENT	5.28%	90,07,69,483.70	19,00,717	-	90,26,70,201	4,51,33,510	55,05,47,837	4,76,60,987	-	59,82,08,824	30,44,61,377	35,02,21,647
5 COMPUTER/PERIPHERALS	16.21%	15,11,78,313.00	2,93,032	-	15,14,71,345	75,73,567	14,24,45,238	47,500	-	14,24,92,738	89,78,607	87,33,075
6 Capital Work In Progress		7,79,53,160.23	10,00,00,000	-	17,79,53,160	17,79,53,160	-	-	-	-	17,79,53,160	7,79,53,160
7 Advance for capital Goods		2,28,702.00	-		2,28,702	2,28,702	-			-	2,28,702	2,28,702
TOTAL(A)		1,35,26,64,196	10,21,93,749	-	1,45,48,57,945	24,17,65,666	75,97,72,594	5,11,47,565	-	81,09,20,159	64,39,37,786	59,28,91,602
B. PROPERTY,PLANT & EQUIPMENTS (NON-PLAN)												
1 VEHICLES	9.50%	28,70,817.00	-	-	28,70,817	1,43,541	27,50,321	-	-	27,50,321	1,20,496	1,20,496
2 FURNITURE, FIXTURES	9.50%	2,39,92,893.00	25,494	-	2,40,18,387	12,00,919	2,22,51,200	2,422	-	2,22,53,622	17,64,765	17,41,693
3 OFFICE EQUIPMENT	9.50%	13,03,22,115.00	5,73,618	-	13,08,95,733	65,44,787	12,30,64,511	54,494	-	12,31,19,005	77,76,728	72,57,604
4 ELECTRIC INSTALLATIONS	6.33%	5,09,20,593.00	2,59,195	-	5,11,79,788	25,58,989	2,14,09,357	32,39,681	-	2,46,49,038	2,65,30,750	2,95,11,236
5 LIBRARY BOOKS	9.50%	46,47,17,195.00	1,39,299		46,48,56,494	2,32,42,825	44,13,57,119	13,233	-	44,13,70,352	2,34,86,142	2,33,60,076
6 Online Journal Subscription	100.00%	-	2,05,06,499		2,05,06,499	-	-	2,05,06,499	-	2,05,06,499	-	-
TOTAL(B)		67,28,23,613	2,15,04,105	-	69,43,27,718	3,36,91,061	61,08,32,508	2,38,16,329	-	63,46,48,837	5,96,78,881	6,19,91,105
TOTAL OF CURRENT YEAR (A+B)		**2,02,54,87,809**	**12,36,97,854**	-	**2,14,91,85,663**	**27,54,56,727**	**1,37,06,05,102**	**7,49,63,894**	-	**1,44,55,68,996**	**70,36,16,667**	**65,48,82,707**
PREVIOUS YEAR		**2,01,83,48,490**	**71,39,319**	-	**2,02,54,87,809**	**17,52,97,161**	**1,31,63,59,702**	**5,42,45,400**	-	**1,37,06,05,102**	**65,48,82,707**	**70,19,88,788**

29/8/23
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INSTITUTE OF PHYSICS, BHUBANESWAR
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2023

SCHEDULE 11-CURRENT ASSETS, LOANS, ADVANCES ETC.

(Amount in Rupees)

Particulars	Current Year (2022-23)		Previous Year (2021-22)	
A CURRENT ASSETS:				
1 Inventories:		17,20,752		17,75,466
a) Electrical Fittings Stock	10,14,363		10,47,102	
b) Office Stationery	3,61,110		58,804	
c) Computer Stationery	87,651		2,03,112	
d) Diesel Stock	40,396		1,29,917	
e) Carpentry Material Stock	33,389		78,595	
f) Workshop Spares	1,64,955		1,77,268	
g) PH Material Stock	18,888		80,668	
2 Cash balances in hand (including cheques/ drafts and imprest)				
3 Bank Balances:		3,45,21,361		3,53,26,657
a) With Scheduled Banks:				
i) In current accounts SBI	9,10,862		26,39,770	
b) Savings accounts				
i) IOB CS Pur (SB 10917)	23,27,371		13,09,841	
ii) IOB CS Pur (SB-16916)	1,67,25,761		87,66,526	
iii) IOP Corpus Fund (SB-19339)	21,16,596		14,70,310	
iv) Project Bank Account (Sch.3)	1,24,40,771		2,11,40,209	
TOTAL(A)		**3,62,42,113**		**3,71,02,123**
B LOANS, ADVANCES AND OTHER ASSETS				
1 Loans (Interest bearing):		56,700		1,21,150
a) Computer Advance	56,700		1,21,150	
2 Interest Accrued but not due on Loans		4,027		17,053
a) Motor Car Advance	-		-	
b) House Buildings Advance	4,027		16,135	
c) Computer Advance	-		918	
3 Loans (Non-Interest bearing):		1,27,057		1,87,295
a) Staff Advance	54,757		1,65,080	
b) Festival Advance	-		-	
c) Travel Advance	33,800		22,215	
d) Contingency Advance(ALICE)	38,500			
4 Advances and other amounts recoverable in cash or in kind or for value to be received:		82,70,231		27,87,521
a) On Capital Account				
b) TDS (IT) Receivable	-		49,875	
c) Receivable from NALCO project	-		89,776	
d) Security deposit With CESCO	26,21,944		26,21,944	
e) Franking machine deposit	2,976		2,976	
f) Security Deposit with BSNL	2,000		2,000	
g) Security Deposit for GAS	20,950		20,950	
h) STDR against LC	55,84,861		-	
i) AKRUTI Fund Receivable	37,500		-	
TOTAL(B)		**84,58,015**		**31,13,019**
TOTAL(A+B)		**4,47,00,128**		**4,02,15,142**

GRC & Associates Bhubaneswar Chartered Accountants

29/8/23
कनिष्ठ लेखा अधिकारी/JUNIOR ACCOUNTS OFFICER
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

29/08/2023
रेजिस्ट्रार/REGISTRAR
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भुवनेश्वर/BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2023

SCHEDULE 13 -GRANTS/ SUBSIDIES

(Amount in Rupees)

Particulars	Current Year (2022-23)		Previous Year (2021-22)	
1 DAE - Government of India		37,84,01,164		31,31,00,000
a) Non-Plan (Salary)	26,81,00,000		22,51,00,000	
b) Non-Plan (General)	6,83,30,992		8,80,00,000	
c) Plan	4,19,70,172		-	
2 Government Of Orissa (Non-Plan Revenue)	-		-	
TOTAL		**37,84,01,164**		**31,31,00,000**

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SCHEDULE 17 - INTEREST EARNED

(Amount in Rupees)

Particulars	Current Year (2022-23)		Previous Year (2021-22)	
1 On Term Deposits:		2,24,927		1,97,784
a) With Scheduled Banks				
b) Others (LC & Security Deposit)	2,24,927		1,97,784	
2 On Savings Accounts:		-		-
a) With Scheduled Banks				
3 On Loans:		9,804		20,685
a) Computer Advance	9,677		20,685	
b) Motor Car Advance	127		-	
TOTAL		**2,34,731**		**2,18,469**

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SCHEDULE 18- OTHER INCOME

(Amount in Rupees)

Particulars	Current Year (2022-23)		Previous Year (2021-22)	
Other Income				
1 Miscellaneous Income		99,475		324
a) Project Overhead	-		-	
b) I-Card Charge				
c) RTI Fee	330		20	
d) Auditorium Charges	88,000		-	
e) Miscellaneous Income	7,040		304	
f) Interest on IT Refund	4,105			
2 Sale of Tender paper		10,500		-
3 Rent				
a) Bank Rent	3,60,000	12,35,479	3,60,000	6,66,912
b) Guest House Rent	5,52,790		1,73,680	
c) Hostel Room Rent	3,22,689		1,33,232	
TOTAL		13,45,454		6,67,236

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SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2023

SCHEDULE 20 - ESTABLISHMENT EXPENSES

(Amount in Rupees)

Particulars	Current Year (2022-23)		Previous Year (2021-22)	
1 Salaries and Wages		15,93,46,997		16,09,98,910
a) Staff Salary	12,77,22,309		13,10,56,414	
b) NPS Contribution	65,78,643		61,00,771	
c) Honorarium	3,48,283		9,78,401	
d) Fellowship	2,41,68,031		2,23,19,949	
e) Remuneration to Medical Officer	5,29,731		5,43,375	
2 Allowances and Bonus		2,91,36,650		11,24,303
a) PRIS	2,56,01,061		15,240	
b) Update Allowance	33,95,589		8,09,063	
c) Uniform Allowance	1,40,000		3,00,000	
3 Staff Welfare Expenses		34,19,010		30,55,919
a) Reimbursement of Medical Expenses	17,58,947		9,25,833	
b) Canteen Expense	1,52,591		3,01,999	
c) Recreation & Welfare Expenses	1,28,982		3,67,705	
d) Children Education Allowance	13,77,000		14,51,048	
e) Medical Aid Centre Expenses	1,490		9,334	
4 Retirement and Terminal Benefits		7,61,41,924		8,30,72,385
a) Leave salary	1,03,01,005		1,54,05,495	
b) Pension	5,67,25,465		4,98,45,433	
c) Gratuity	91,15,454		1,78,21,457	
5 Others		20,96,798		18,46,764
a) Contigency Grant to Scholars	20,96,798		18,46,764	
TOTAL		27,01,41,379		25,00,98,281

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SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2023

SCHEDULE 21 -OTHER ADMINISTRATIVE EXPENSES ETC.

(Amount in Rupees)

Particulars	Current Year (2022-23)		Previous Year (2021-22)	
1 Repair & Maintenance		1,82,60,888		2,46,39,010
a) Civil	83,20,348		85,59,770	
b) Vehicle	5,80,410		2,61,148	
c) Library	7,32,758		6,75,283	
d) Workshop	24,467		5,718	
e) Furniture	55,674		43,226	
f) Electrical	6,78,568		8,69,780	
g) AC Plant	10,56,645		31,70,286	
h) Computer	39,71,370		43,35,257	
i) Laboratory	24,88,589		62,93,219	
j) Garden	1,58,005		1,53,731	
k) Telephone	-		74,670	
l) Office Equipment	1,94,054		1,96,922	
2 Electricity and power		2,06,12,314		2,27,17,545
3 Water charges		3,41,230		3,28,942
4 Conference & Symposia		4,73,409		82,305
5 Science Outreach Activities		10,72,527		3,11,260
6 Postage & Telegram		45,655		66,504
7 Telephone & Telex		8,45,826		5,67,592
8 Printing and Stationery		3,37,328		6,93,206
9 Travelling Expenses		18,05,827		8,86,642
a) Conference TA	2,15,067		15,033	
b) Foreign Travel	5,300		-	
c) Visiting scientist TA	1,17,542		1,00,354	
d) Domestic Travel	3,25,917		6,60,502	
e) Leave Travel concession	11,25,773		90,964	
f) Hire Charge	16,228		19,789	
10 Auditors Remuneration		59,000		59,000
11 Entertainment Expenses		4,79,451		2,80,827
12 Security Charges		66,70,820		59,02,069
13 Professional Charges		1,02,030		4,14,600
14 Project Revenue Expenses		4,22,40,477		22,80,106
a) ALICE Utilisation and CBM Participation	2,86,732		-	
b) Investigating Spin Structure	2,69,780		8,15,607	
c) Vigyan Prativa	525		14,64,499	
d) CMS_Revenue Expenses	10,532		-	
e) Supporting Scientific Infr. (RIO 4003)	2,95,82,457		-	
f) Theoretical and Experimental Physics	1,20,90,451		-	
15 Advertisement and Publicity		2,81,885		2,02,754
16 AKRUTI Expenditure		-		73,719
17 Books & Journal		-		3,45,15,045
a) Books	-		-	
b) Online Journal Subscription	-		3,45,15,045	
18 Lease Rent	-	-	1,909	1,909
19 Priorperiod Expenses	-	-	86,676	86,676
20 Interest on Income Tax	-	-	1,12,434	1,12,434
21 Others		4,06,521		6,57,058
a) Miscellaneous Expenses	4,06,521		6,57,058	
TOTAL		**9,40,35,188**		**9,48,79,204**

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SCHEDULES FORMING PART OF THE ACCOUNTS

FOR THE YEAR ENDED ON 31.03.2023

SCHEDULE 24 - SIGNIFICANT ACCOUNTING POLICIES

1. ACCOUNTING CONVENTION

The financial statements have been prepared under accrual basis under historical cost convention with Generally Accepted Accounting Principles in India except for Government Grants.

2 PROPERTY, PLANT & EQUIPMENTS

2.1 Freehold: Property, Plant & Equipment are stated at Historical cost less accumulated Depreciation. The cost of acquisition includes the cost of Carriage Inward, duties & taxes and other incidental direct expenses incurred in relation to such particular fixed assets.

2.2 Leasehold: Out of acquired leasehold land of Ac. 56.130 dec., the institute is in possession of title of land of Ac.6.130 dec. . The Lease rent has been paid on A6.130 dec land upto 31.03.2023. Rest of the land is in the name of Higher Education Department, Govt. of Odisha, alienated in favour of the Institute and hence for this part, no rent is due to the State Government.

3. INVESTMENT

Noncurrent Investments are carried individually at cost less Provision for diminution. Current Investments are carried at lower of Cost of fair value.

However, the Institute has no long-term Investment of any nature. Moreover, there are short-term investments in shape of STDR with bank.

4. VALUATION OF INVENTORIES

Stock of Office Stationery, Computer Stationery, Cleaning Material Stock, Hardware and Electrical items etc. are valued at cost.

5. BANK BALANCE

Earmarked/ Endowment Fund (As per Sch-3) Bank balances of ₹ 1.24 Crore shown under the total Bank balances.

6. DEPRECIATION

6.1 Depreciation is provided on straight-line method at the rates specified in the Company Act, 1956. However, the amendment of 2013 has not been taken into account. Depreciation has been charged on those assets whose WDV are exceeding the residual value of 5% of Gross Block as per the fixed assets schedule. However incase of addition of Fixed Assets, depreciation has not been calculated on the basis of number days put to use.

6.2 Assets costing ₹ 5000/- or less are fully provided.

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7. **GOVERNMENT GRANTS / SUBSIDIES**

The grants are accounted for on realisation basis.

7.1. Plan grants to be utilised for capital expenditure is treated as Capital Fund otherwise has been taken into Income & Expenditure A/c.

7.2. Non-Plan grants to be utilised for revenue expenditure has been taken into Income & Expenditure A/c.

7.3. The Grants received, unutilized at the yearend has been considered as current Liability.

8. **FOREIGN CURRENCY TRANSACTIONS**

Transactions involving foreign currency are accounted at the exchange rate prevailing on the date of the transactions.

9. **RETIREMENT BENEFITS**

9.1 Liability in respect of Gratuity on retirement payable as on 31.03.2023 has been provided in accounts on actual basis. Provision for liability towards accumulated leave encashment benefit to the employees as on 31.03.2023 has been provided for in accounts on actual valuation.

9.2 Provision for liability payable towards Pension to the employees has been provided in the Accounts.

9.3 No Pension fund has been created by the Institute.

9.4 Contribution to newly defined pension scheme has been made regularly by the Institute for those employees who have joined the Institute after 01-01-2004.

9.5 The Institute has its own Provident Fund Trust which manages the Provident Fund of the employees who have joined the Institute on or before 31.12.2003. The Accounts of the Trust for the year ending 31.03.2023 has been audited by a firm of Chartered Accountants.

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SCHEDULES FORMING PART OF THE ACCOUNTS

FOR THE YEAR ENDED ON 31.03.2023

SCHEDULE 25 – CONTIGENT LIABILITIES AND NOTES ON ACCOUNTS

1. CONTIGENT LIABILITIES

1.1.	Bank Guarantee given by / on behalf of the Institute	NIL
1.2.	Bills discounted with Bank	NIL
1.3.	Letter of Credit	Nill
1.4.	Disputed demand in respect of	
	Income Tax	NIL
	Sales Tax/GST (IDS)	NIL
	Municipal Taxes	NIL
1.5.	In respect of claims from parties for non-execution of orders	NIL

2. NOTES ON ACCOUNTS

2.1. **CURRENT ASSETS. LOANS AND ADVANCES**

The current assets, loans and advances have a value on realization in the ordinary course of business, equal at least to the aggregate amount shown in the Balance Sheet.

2.2. **CURRENT LIABILITIES & PROVISIONS**

All known liabilities have been provided in the accounts of the Institute.

2.3. **TAXATION**

The Institute is a research-oriented organization founded by Government of India, Department of Atomic Energy jointly with Government of Odisha. The income of the Institute is exempted under Income-tax Act 1961 and hence no provision for Income tax has been made during the year.

2.4. External Grants from DST & other funding agencies for specific projects/fellowship have been taken into account in the year under Earmarked Fund.

2.5. Figures in the Balance Sheet and Income & Expenditure Account have been rounded off to nearest rupee.

2.6. Previous year's comparative figures have been regrouped/ rearranged, wherever necessary. Figures in the brackets indicate (-ve).

2.7. Income recognition on interest on staff Loan is accounted after the repayment of principal as per practice adopted. Interest on saving bank is accounted on receipt basis.

2.8. Schedule 1 to 25 are annexed to and form an integral part of the Balance Sheet as at 31.03.2023 and Income & Expenditure Account for the year ended on that date.

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3 FOREIGN CURRENCY TRANSACTIONS

Value of Imports calculated on C.I.F/Ex-works & FOB basis	31.03.2023 (₹)	31.03.2022 (₹)
a) Purchase of Lab. Equipment	Nil	5,99,70,646
b) Stores, Spares and Consumables	55,84,861	5,99,833
c) Journal subscription	3,94,55,846	2,79,52,280
Expenditure in foreign currency		
a) Travel	Nil	Nil
b) Other expenditure (Honorarium)	1,33,197	1,24,466
Earnings		
Value of Exports on FOB basis	Nil	Nil

4 Remuneration to Auditors

As Audit Fees	50,000	50,000

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ACTION TAKEN REPORT ON THE COMMENTS OF STATUTORY AUDITORS ON THE ANNUAL ACCOUNTS OF INSTITUTE OF PHYSICS, BHUBANESWAR FOR THE FINANCIAL YEAR 2022-23

Sl. No.	AUDITOR'S OBSERVATION	INSTITUTE'S REPLY
Qualified opinion		
Basis of qualification		
1	a) The Society has not followed IAS 10 for accounting of Fixed Assets and AS 6 for provision of depreciation. The society has not maintained fixed assets register to verify the individual asset residual value. Depreciation has been charged on gross block at the end of the year on SLM method irrespective of the fact that individual old assets may have been depreciated in full. The depreciation on assets purchased during the year was also charged for the whole year instead of proportionate basis from date to use.	Noted for corrective measures. The Institute has engaged M/s. Laldash& Co., CAs vide W.O. No. 793 dt.25.06.2018 for preparation of Asset Register from 2011-12 onwards and they have submitted their report year wise up to 2020-21. The current year Assets Register has been prepared by the Institute.
	b) The Fixed Assets of the Society were not physically verified in full during the year under audit.	The institute is doing the physical verification of Fixed Assets on yearly basis. The assignment of physical verification is in full swing by M/s. Laldash & Co., CAs. along with the internal team to be completed soon
	c) None of the Fixed Assets of the Society were tested for impairment in accordance with AS 28 and no provision has been made for impairment if any.	Point has been noted for future compliance.
2	IAS 12 on accounting of Government grants has not been followed. The grants have been recognized on realization basis. Capital grants have been recognized as capital fund and shown as Liability.	The Institute has been receiving full grant from DAE (Govt. of India) under GIA (General) and GIA (Creation of Capital Assets) which is treated as Capital Fund as per the provision of Accounting Standard 12.
3	The Capital Fund of the Institute is decreased to the tune of Rs71.10 lakhs to due recognition of unutilised Government grant as current liabilities at the end of the year.	No comments
Matter of emphasis		
1	Balances of advances and liabilities to/from third parties are subjects to confirmation.	Point has been noted for future compliance.
2	GST paid on Fixed Assets Purchased during the year has been capitalised in the books of accounts. Also GST paid on Expenses has been included with expenses. However, input for ineligible GST credit amounting to Rs 2238159/- has been claimed in GST portal.	The input credit which has been claimed, will reversed in the next quarterly GST return.

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