Physics at Bose Institute

SANJAY K. GHOSH
DEPARTMENT OF PHYSICS, BOSE INSTITUTE, KOLKATA, INDIA

Main Campus.

Centenary Campus Campus.

INTRODUCTION

Bose Institute was founded on November 30, 1917, by Sir Jagadish Chandra Bose (1858 - 1937), the father of modern science in the Indian subcontinent. The Institute was founded as “not merely a laboratory but a temple”. In his foundation lecture “Voice of Life” he laid down the objectives of this Research Institute to be “advancement of knowledge with the widest possible civic and public diffusion of it, and this without any academic limitation, henceforth to all races and languages, to both men and women alike, and for all time coming” [1].

Bose Institute is Asia’s first modern research centre devoted to interdisciplinary research. Since inception, the Institute is pursuing research in different areas of Physics, Chemistry and Biology. In addition to the pioneering work of the founder in millimetre wave, Biophysics and Plant Physiology, the Institute can boast of many path breaking works in different areas of research.

Debendra Mohan Bose and his co-workers, made pioneering contributions in the field of Cosmic Ray research and on the susceptibility measurement of paramagnetic compounds [2-4].

Shyama Das Chatterjee pioneered the study of fission phenomena and the measurement of environmental radioactivity and radiocarbon dating [5,6].

Gopal Chandra Bhattacharya, an entomologist threw new light on the mechanism of how queens in insect societies produce other queens, workers or soldiers [7].

Furthering the legacy of our founder, most of the experiments were conducted with instruments designed and built internally, by researchers like Ananda Mohan Ghosh.

Prof. Shambhu Nath De made the pioneering discovery of Cholera Toxin and its role in the pathogenesis of Cholera. He was responsible for the breakthrough in the understanding of the molecular mechanism of toxin-receptor interaction in microbial pathogenesis [8]. For this,

Unified Campus.

Darjeeling Campus.

De was nominated by Joshua Lederberg for the Nobel Prize.

The multiplicity of RNAP from higher plant sources was demonstrated by Prof. B. B. Biswas and his group. They also discovered the inositol phosphate cycle in plants [9].

Bose Institute became an autonomous Institute funded by Department of Science & Technology, Govt. of India in 70's. Presently Institute has nine departments, namely, Bioinformatics, Biophysics, Biochemistry, Chemistry, Microbiology, Molecular Medicine, Plant Biology, Physics and Environmental Sciences. In addition, there are three Centres; Centre for Biotechnology Innovation, Centre of Excellence in Bioinformatics and Centre for Astroparticle Physics and Space Science.

Bose institute is presently spread over seven campuses, six in and around Kolkata and one in Darjeeling.

DEPARTMENT OF PHYSICS

Historical evolution:

Since its inception at the foundation of the Institute, Department of Physics has been an integral part of it and evolved along with the Institute. The founder himself had already won international recognition as an excellent physicist. He invented and fabricated the instruments needed for his millimetre wave experiments locally. Some of these are of common use today, such as, dielectric lenses, horn antenna ("funnel"), wave guides, and polarisers. In 1895, in Kolkata, India he gave first public demonstration of wireless signalling [10]. This demonstration preceded Marconi's famous Salisbury plain demonstration [11]. The work was presented at the Royal Institution in 1897, at the invitation of Lord Rayleigh. Bose's Galena detector was the first semiconductor device as noted by Sir Neville Mott and Walter Brattain. The feat is acknowledged by IEEE as a great milestone in the field of radio and wireless communication.

Though J. C. Bose himself was involved mainly in his biological experiments, the Physics Department was involved in both theoretical as well experimental studies of different aspects, such as, propagation of radio waves in the ionosphere, propagation of supersonic wave in different media, study of nuclear disintegration, radioactivity and Cosmic Rays.

The work on Cosmic Ray experiments became more intense after Debendra Mohan Bose took office as Director of the Institute after the demise of J. C. Bose. The Instrumentation remained an integral part of the work. A counter controlled Wilson Cloud Chamber, especially suited for the photography of Cosmic Ray shower was built. Subsequently two cloud chambers were built and were used for such studies at high altitude environment of Darjeeling (6700ft) and Sandakphu (11930ft). Photographic plates for the study of cosmic ray were also exposed at high altitudes of Darjeeling, Sandakphu and Pharijong (15000ft in Tibet). D. M. Bose and his co-workers made globally recognised contributions in cosmic rays. Ionisation chambers were built and used to


Madhyam Campus.


Falta Campus.

study the cosmic ray air shower and the effect of solar activity on cosmic ray flux.

Shyama Das Chatterjee pioneered the study of fission phenomena and the measurement of environmental radioactivity and radiocarbon dating. Large sized Pyrex glass proportional counters and neutron generator were designed for such studies.

The focus of the department shifted with time, more so during 80's to mid 90's, with induction of new faculties. Studies in the areas of Foundations of quantum mechanics, Astrophysics & Cosmology, High Energy Physics, Statistical Physics & Condensed Matter Physics, Radiation Physics and Material Science became the focus of research along with the continuation of research in Nuclear Physics.

D. Home and his collaborators proposed an experiment to show simultaneous wave and particle like behaviour in the same setup using single photon states of light [12]. This was subsequently verified at Hamamatsu Photonics laboratory, Japan [13].

Various aspects of electroweak probes of quark-gluon plasma were investigated by S. Raha and his collaborators. They also studied the primordial strange quark nuggets and obtained a baryon number limit above which strange nuggets would be stable on a cosmic time scale.

Works on strongly correlated systems and self-organized criticality were initiated by I. Bose and her group. They also started working on cross-disciplinary Physics and proposed a model to explain punctuated equilibrium behaviour observed for bacterial evolution.

Superheated liquid drop detector was conceptualized by S. C Roy, B. K. Chatterjee and collaborators which is now an integral part of PICASSO dark matter search experiments. Accelerator based Nuclear Physics research was also initiated around this time.

Present Scenario:

Research in complex systems and statistical physics at Bose Institute is currently being pursued in the areas of: (a) network science, and, (b) microbial interactions using theoretical and experimental methods. In the former area, the thrust is on finding new network measures, and, innovative use of networks in various domains like image processing, non-invasive diagnostics, structural optogenetics and evolutionary walks on fitness landscapes. In the latter area, the thrust is on antimicrobial resistance, phage therapy, and, phage resistance in mycobacteria. Of late, group is also exploring emerging realms like quantum games and quantum networks.

Design and synthesis of advanced materials (particularly perovskite oxides) with novel electronic properties is one of the active area of research. The structural, electrical, magnetic, vibrational and optical properties of these materials have been investigated by various experimental techniques. The understanding of these properties compliments the drive for technological applications of the materials. The density functional theory with generalized gradient approximation has been explored for physical understanding of these properties. The goal behind this work is to establish how the physical properties of materials are related to their structure and/or chemical composition and how these properties may be modified by varying the nature of the chemical bonds, the strength of the electron-electron interaction, the dopant concentration, etc.

Condensed matter group also actively pursues the studies on phonons and their couplings with various other quasiparticles (e.g., electrons, magnons, orbitons etc.) by means of Raman and photoluminescence spectroscopy at extreme conditions (e.g. Low / high temperatures, high pressures, magnetic field, and electric field) in semiconductor nanostructures, 2D materials and topological insulators/semimetals. Additional experimental activities are concerned with the study of light-matter interactions, development of 2D material based infrared photodetector, investigation of supercapacitor electrode materials and development of Surface Enhanced Raman Scattering (SERS) substrate for bio-molecule sensing. Presently, the group is equipped with Micro-Raman spectrometer with a liquid nitrogen-based cryostat which is capable of varying sample temperature from 77 K to 870K, a High-Pressure Diamond Anvil Cell (up to 100 GPa), micro-Photoluminescence measurement facility, UV-Vis spectrophotometer, High-temperature furnaces and Thin film coating unit.

Department is actively engaged in the research and development of detectors for high-energy physics experiments and detection of cosmic rays. This includes R&D of gaseous detectors such as Resistive Plate Chamber (RPC), Gas Electron Multiplier (GEM), Straw tube detector, Single Wire Chamber and Organic and Inorganic Scintillation detectors. The group is actively participating in the "A Large Ion Collider Experiment" (ALICE) at CERN, Geneva and Compressed Baryonic Matter (CBM) experiment of FAIR, Germany. One of the main research interests is the ageing study of gaseous detectors. This work is very much essential for both the ALICE-TPC upgrade and CBM Muon Chamber.

Commercially available transparency sheets, identified as Polyethylene Terephthalate (PET), have been standardized as solid state nuclear track detector (SSNTD). PET has much higher detection threshold and hence can be used for the detection of rare events. A calibration curve for PET has been proposed. Array of PET detectors has been deployed in high altitude stations such as Darjeeling and Hanley. One of the objectives is to search for strangelets in Cosmic Ray air showers. In addition, active detector array has also been installed at Darjeeling for air shower studies. The effect of cosmic ray on atmospheric electric field is an important input for atmospheric studies.

Phenomenological studies on the physics and astrophysics of quark-gluon plasma is being pursued by the high energy physics group for last few years. Presently the group is working for a better understanding of thermodynamic properties of strongly interacting matter with simple models like Nambu--Jona-Lasinio model, Polyakov loop model, Hadron Resonance Gas model etc.

Research in nuclear physics involving rare isotope beams is of paramount importance. Recently, nuclear physics group has carried out an experiment at CERN, Geneva, Switzerland; to study the cosmological lithium problem, where there is a serious anomaly between the observed and Big Bang Nucleosynthesis predicted abundance of 7Li. In the theoretical front, a robust framework has been developed, with excellent results, to study resonance states and wave functions of unstable/unbound nuclei using supersymmetric quantum mechanics.

The Quantum Information and Foundations group at Bose Institute works on a wide range of problems in Entanglement theory, Quantum state discrimination, Quantum channels and ontological models. The focus is on solving basic problems with significant applications in quantum technology. For example, in a very recent work a new kind of quantum nonlocality exhibited by product states of a composite quantum system has been discovered. These results demonstrate the existence of locally hidden information without entanglement.

Interested readers are requested to visit our websites http://www.jcbose.ac.in/physics and http://www.jcbose.ac.in/basic-and-applied-problems-in-physical-and-environmental-sciences for more details.

TEACHING

Bose Institute conducts Integrated M.Sc. - Ph.D. courses for both Physical as well as Life sciences. All the faculties of the Physics department participate in the Physical Science course. The degree is awarded jointly by Bose Institute and University of Calcutta. More detailed information of the course can be found in http://www.jcbose.ac.in/integrated-phd.

References

[1] www.jcbose.ac.in

[2] Bose, D M, Chowdhury, B. Origin and nature of heavy ionization particles detected on photographic plates exposed to cosmic rays, Nature 147: 240 (1941).

[3] Bose, D M, Chowdhury B. A photographic method of estimating the mass of mesotron, Nature 148: 259 (1941); Nature 149: 302 (1942).

[4] Bose, D M, Chowdhury, B. Photographic plates as detector of mesotron showers, Nature, 145 :894-89 (1940).

[5] Baliga B. B.,Physics Teacher, Vol.37, No.3, 1995.

[6]Chatterjee S. D., Transactions of Bose Institute, Vol.XVI,pp.65-71, 1946.

[7] Bhattacharya G. C., Trans. Bose Res. Inst. Vol. XV, 137-156,(1943).

[8] De, S. N. Cholera: its pathology and pathogenesis, Published by Oliver and Boyd, London, 1961.

[9] Mondal H, Mandal R. K., Biswas B. B., RNA Stimulated by Indole Acetic Acid, Nature New Biology. 240: 111–113 (1972).

[10] Mitra A. P., Bose J. C.; At the Dawn of Radio Science, Sci. Cult. 63:6-8 (1997).

[11] Birch C., Biology and the Riddle of Life, UNSW Press, Sydney,1999.

[12] Ghose P., Home D., Agarwal G. S., An experiment to throw more light on light, Physics Letters A 153, 403 (1991).

[13] Yutaka Mizobuchi, Yoshiyuki Ohtaké, An "experiment to throw more light on light", Physics Letters A 168, 1 (1992).

Sanjay K. Ghosh is the current Chairman of the Department of Physics of Bose Institute, Kolkata. He completed his PhD from Institute of Physics, Bhubeneswar, India. He completed his research Associateship first at Bose Institute and then at TRIUMF, Vancouver, Canada and then joined the faculty of Bose institute in 2002 and became a Professor in 2015. His research fields are high energy physics and atmopheric physics.