National Institute of Physics Research Agenda

The NIP currently has six research groups namely: Condensed Matter Physics Laboratory, Gravity, Astronomy, Nuclear and Particle Physics, Instrumentation Physics Laboratory, Photonics Research Laboratory, Structure and Dynamics, and Theoretical Physics Group.

The National Institute of Physics research agenda is to strengthen these six existing research groups by engaging on topics that are aligned and relevant to the field of concentration of these research groups.

Specifically, these will include topics/areas on the following:

Instrumentation Physics

- Instrumentation physics is a branch of applied physics that deals with the application of proven physical principles and theories to achieve a deeper exploration of novel physical phenomena through the research and development of advanced measurement techniques offering better accuracy and precision as well as efficiency of signal sampling and data gathering, information processing, and signal recovery. Cutting-edge scientific discoveries are not possible without access to such techniques.

- The spectrum of physical systems that are of interest to instrumentation physicists in NIP ranges from the micrometer-scale (e.g., biological cells, neuronal networks, Brownian particles), the intermediate (granular system) and to the very large (e.g., power distribution networks, vehicular traffic and queues) and the different techniques that are developed to characterize them are hybrid platforms of hardware and software integrations. Over time, IPL researchers have formulated and tested novel techniques in optical microscopy, interferometry and video imaging as well as pioneering applications of neural networks, machine learning and complex system analysis.

- Keywords: Instrumentation physics, Complex systems modeling and analysis, granular media, epidemiological systems, remote sensing and mapping, Wave dynamics and particle motion control, 3D imaging, optical microscopy and interferometry.

Condensed Matter Physics Laboratory (CMPL)

- Fundamental and applied studies on solid state and condensed matter.
- Synthesis of materials and device fabrication.
- Optical, electrical, and magnetic properties of materials and their use.
- Nanotechnology
- Semiconductor device fabrication and testing.
- Ultra-high vacuum deposition and processing.
- Spectroscopy
- Metrology
- Computational studies on the material and device properties

Photonics

Photonics encompasses the generation, transmission, modulation, amplification and frequency conversion, detection, and the use of light. It has found ever-increasing applications, such as in optical communications, signal processing, computing, sensing, and material synthesis and characterization.

Our current research areas are:

- Astrophotonics
- Beam shifts for Material Characterization
- Catastrophe Optics
- Cloaking
- Digital Holography
- Fringe Processing
- Imaging Techniques such as Single Pixel Imaging and Fluorescence Imaging
- Intense Magnetic Field Generation
- lon Acceleration
- Laser Ablation and Plasma Dynamics
- Laser-Driven Plasma Compression
- Optical Angular Momentum
- Optical Information Storage
- Optical Spectroscopy
- Pulsed Laser Deposition
- Relativistic Laser-Plasma Interactions
- Speckle Interferometry
- Structured Light Generation and Detection
- Tailored Polarization and Polarization measurements
- Use and control of Partially Coherent Light Sources

Structure and Dynamics

- Fundamental studies relating to the structure and dynamics of condensed matter systems using numerical, computational and analytical approaches. Topics include atomic and electronic transport, topological features, thermodynamics and transport, magnetism, and others that are crucial to materials discovery and design.

- Simulations of complex systems and data analysis. Systems of interest include biophysical systems, large data sets, fields, molecular systems, and other models where computer simulations can provide predictive modelling.

- Quantum correlations and entanglement in low temperature systems. Fundamental studies on how entanglement arises in condensed matter as a resource for quantum information technologies and how algorithms can be built for quantum computing.

Gravity, Astronomy, Nuclear and Particle Physics

Basic and fundamental studies in physics covering:

- Gravitational physics
- Relativistic astrophysics and cosmology
- Nonlinear dynamics and chaos
- Applications of geometry in physics
- Hadron physics
- Nuclear structure
- Application of deep learning in Nuclear and Hadron physics
- Amplitude analysis
- High energy physics
- Particle physics phenomenology
- Data-driven astrophysics and cosmology
- Application of machine learning in astrophysics
- Application of white noise analysis in astrophysics
- Collider physics
- Physics beyond the Standard Model

Theoretical Physics Group

Condensed Matter Physics

- Fundamental and applied studies on solid state and condensed matter.
- Optical, electrical and magnetic properties of materials and their use.

Theoretical physics - basic and fundamental studies in physics covering:

- High-energy physics
- Quantum mechanics
- Statistical physics
- Astrophysics
- Condensed matter physics
- Mathematical physics
- Classical mechanics