Five Decades of Department of Physics at IIT Kanpur : A Brief History

A new technological Institute has to begin by teaching physics, so did IIT Kanpur in 1960 in its transit campus at HBTI (Harcourt Butler Institute of Technology at Nawabganj, Kanpur). The first undergraduate class of the Institute appears to have been that 'of the first year introductory physics taught at a hurriedly spruced up class room by freshly recruited Senior Teaching Assistants, who with the support of the founder Director Prof P.K.Kelkar, worked hard to put up the first year first semester physics laboratory using essentially locally available materials.

However, one of the distinguishing features of contributions of IIT Kanpur to the Indian academic scenario was to believe in and actively build fully fledged strong science Departments in their own right actively interacting with engineers within a technological Institute. The evolution of the Department of Physics, by all accounts, did not happen along a pre-determined blue print, but was guided by the same key principles of equal and non-hierarchical participation of all disciplines. The spirit of IIT Kanpur in its formative years was to pioneer science-based education, and to make science and engineering education as interdisciplinary as possible with special emphasis given to foundations and fundamentals on the one hand and humanities and social sciences on the other. Physics and Chemistry (there was so much overlap in the interests of the faculty members that you could not tell one from the other in those days) had a clearly a significant role to play in the scheme of things right from the beginning. The foremost job for IITK was to find young band of faculty, modern in outlook, equally passionate about research and teaching, who would be willing to ignore the disadvantages of location ignited by the prospects of future and a new spirit of freedom from hierarchy.

It was realized that first class teaching could only be done by first class faculty who can be attracted and retained only if there were first class research facilities. Besides, the disadvantage of location would be minimize if there was a good school for children's education, a good health center and decent housing. All this was, therefore, built into the plans of IITK.

The First Decade: Initiating Research & Teaching Programmes

The enthusiasm of building a new Department with distinguishing features (' a new kind of place for academic excellence with freedom and flexibilities') started by hiring four bright young Ph.Ds. including Dr. Putcha Venkateswaralu, a renowned spectroscopist then working as a Reader in Aligarh Muslim University, being the senior most among them. Dr Venkateswarlu had an extremely impressive research record which included working with Prof Niels Bohr at Copenhagen and Profs. G. Herzberg and Robert Mulliken at Canada. Dr. Venkateswarlu, at that time was probably thinking of moving from Aligarh Muslim University. He visited Kanpur to find out more about the new upcoming IIT which was quite a bit in news in those days. The Director, Dr. Kelkar, in his usual very enthusiastic manner described to him the possibilities of building a vibrant and active Physics Department in a world class Institution and convinced him to think about IITK seriously. Subsequently, the first Faculty Selection Committee in August 1960, selected Drs Putcha Venkateswarlu, Arawind S. Parasnis (assistant professors), Ramesh C. Srivastava and Sunit C. Sen (lecturers). Drs

Parasnis and Sen joined almost immediately and started working on the undergraduate courses and setting up teaching laboratories in the make shift space made available by HBTI in their newly constructed extension. Drs Srivastava and Venkateswarlu joined later in January and April 1961 respectively.
The faculty selection was being done very carefully and consequently the faculty growth was slow. Even in 1964 there were only about two dozen faculty members in whole Institute with no associate professor or professor. Dr Venkateswarlu was among the first set of professors and was later on appointed Head of the Department. So, for almost the first 5 years the director was the only academic administrator and the Departments did not formally exist though informally there was one person in each discipline who was recognized like a leader.

The initial years brought the challenge of plunging head-on into the design and teaching of core courses and putting the doctoral programme in place for an active culture of research. Those were the heady days of developing the framework for a novel science-based engineering curriculum. It was also a deeply held shared commitment among the faculty members that the hallmark of the new Institute would be in that frontline researchers would be teaching courses right from the first year. This constant quest for the right blend of research and teaching efforts can probably be considered the single most unifying theme in the evolution of the Institute and the Department in particular. The two signature programmes of the Department came later - the M.Sc.(2 year) programme started in 1965 and the Five Year Integrated Masters Programme in
1971. The initial thrust in research centered around chemical physics through some seminal works on a range of EP R, NMR and optical spectroscopy of many molecular and solid state systems, crystal physics, crystal and molecular structure of novel compounds. Physics Department played the role of a leader in laser spectroscopy and technology in India and subsequently became the nucleus and initiator of the Center for Laser Technology. Internationally, this was also the period of tremendous growth in the study of solid state phenomena. This phase led ultimately to the formation of identifiable groups in theoretical and experimental condensed matter physics, optics and laser spectroscopy.

This was also the decade of the involvement of Consortium of US Universities through the Kanpur Indo- American Programme (KIAP) and brought some key benefits which were instrumental in shaping the future of the Department. The dollar account turned out to be a generous source of equipping the Department with spectrometers of all manner, and the library became one of the best stocked in the country. The faculty from the US universities played a role broadening the vision of the Department. The initial thinking that to be able to make a mark one needed to focus in few areas gave way to the idea that a fully-fledged physics department needs to have groups on all major and emerging frontier areas of research. A broad spectrum of research areas was compatible and even necessary for mounting a sustainable world-class Postgraduate Programmes. The visits of the faculty members to the Consortium Universities also became a rich source of motivating bright young Ph.D.s from India and abroad students interested in career at IIT Kanpur. The notable among the KIAP participants were Profs. Jon Matthews and Burton J Moyer from Berkeley, Peter Mason from Caltech, Arthur. H Benade from case Western and J G. Fox from Carnegie Mellon. Dr

returned later on to as the last Programme Director who ahd the task of winding up the Kanpur Indo-American programme. Dr. Benade took keen interest in the development of Core Physics Laboratories.

Professor Jagadishwar Mahanty, a well known solid state theoretical physicist, had moved from Punjab University to IITK and subsequently became the Head after Prof P. Venkateswarlu. The academic landscape of the Department in terms of discernible broad areas of research interests got consolidated into groups such as condensed matter theory with emphasis on electronic calculations, nolinear dynamics and statistical mechanics, low temperature experimental condensed matter physics with emphasis on magnetism, magnetic and optical spectroscopy , particle physics theory. In order to strengthen particle physics theory group Dr Mahanty succeeded in convincing Prof Gyan Mohan to join IITK. In order to do this an offer of Senior Professors position had to be made to him as BHU had offered him the same. This position is now extinct but it was given to only very senior people and was almost never offered to a new comer. However, after coming to IITK, Dr. Mohan started working on monsoon dynamics and converted some other theoreticians into atmospheric physics. The group remained active until Dr. Mohan retired and the other active member Prof Vijay. K. Deshpande very unexpectedly died.

The culture of academic freedom fostered the growth of individual research programmes and never gave rise to hierarchal structures within the subgroups. It was the teaching programmes which brought close interaction among faculty members with diverse interests and, in part, was responsible for cross-fertilization of ideas on the research front as well.

The formative years of 60's, as Professor T.V. Ramakrishnan now remembers, *"were magical.. ..! had stumbled on to a strange and exhilarating place, where even the Professors were mostly young, and everything seemed possible"*. With the phase of expansion and consolidation in the next decade, many things changed as they were bound to, but fortunately, in the words of Prof. Ramakrishnan, *" ... the values of academic freedom, democracy and room for growth continued quietly and firmly to be a part of institutional ethos .... it was the freedom and democracy of IITIK that has gone so deep that I cannot think of an outstanding, empowered institution being any other way. "*

Towards Top Teaching Programmes: Years of Consolidation

The design and teaching of physics core courses in the first and second year became a fertile field of pedagogical innovation, both in content and style. Large lectures, smaller tutorials, emphasis on uniform grading with expected accuracy up to fractional marks, openness to students' feedback formed the backbone of the teaching culture. Among the first things noticed by a new faculty member joining the Department or fresh students is the intensity of rigour and thoroughness in the teaching experience - be it the colloquium quality preparation of the main lectures or the discussion on deep conceptual underpinnings of seemingly innocent looking problems outside the class room.

To maintain the reputation of its class room teaching in 21st century it is necessary to introduce more technology and use more interactive teaching & lecturing which so as to enhance learning efficiency. Lecture demonstrations which have been variously used by faculty need to be

strengthened. Mention must be made of excellent demonstrations developed by Prof. Parasnis for teaching wave optics. The colourful effects that are produced using quarter wave and half wave plates will, probably, never be forgotten by the students who have seen them. These have also been demonstrated by him in some International Conferences.

The Department has since the middle of 60's honed the two Masters programmes to make them arguably the finest in the country and kept up their relevance with periodic changes, thanks to the continuous debate within the faculty. Since 1967, the M.Sc. (2 year) programme has graduated about 559 students by 2009, and the list of alumni consists of virtually who's who of physicists active in the premier Institutes and Universities of India. The Department has about 268 graduates till date from the Five year M.Sc. Integrated Programme, which makes the best use of blending science and engineering courses in the Institute to produce a wider range of career options from being a hybrid engineer-scientist to a pure theoretical physicist of particular specialization. This Programme attracted some of the best minds coming through the JEE to opt for Physics, in spite of other more market-wise lucrative options. This trend has all but vanished in the last decade though the quality of motivated students continues to be inspiring. The intake to M.Sc (2-Yr) programme nearly doubled after common entrance tests across all IITs were introduced in 2003. The importance of Laboratory based courses throughout the programme structures including open ended two semester long experimental projects, and the flexibility of choice of elective courses have been some of the central features. With changes in the educational scene in the country (including the advent of large number of new Institutes for such Programmes), there is currently discussions to completely remodel our Programems to be able to meet the new challenges.

The Department owes its success in teaching programems to the deeply held conviction that the quality of the teaching programme is organically linked to the quality of research programme. The mainstay of the research environment of the Department has been the Ph.D. programme in which about 300 students have so far completed their doctoral programme. The number of students registered in the programme showed a decline around the end of 90's reflecting the worldwide trends. In 2001, the Physics was the only Department in the Institute to pioneer M.Sc-Ph.D. Dual Degree Programme in which students time saving features for motivated B.Sc. students were introduced combining the best of the M.Sc. programme and smooth transition to doctoral work starting from the M.Sc. level Project. The strength of the Ph.D. programme doubled within five years of the introduction of the programme with the first batch of students beginning to graduate by the end of 2007. The programme has been further fine-tuned recently after operation of seven years to make it more integrated research programme and allowing students to be awarded an interim M. Sc. degree at the end of three years. The current strength of the Ph.D. programme is about 100. This is being matched with resurgent efforts to create a more vibrant atmosphere for an active graduate school. Currently, this task is on the top of the priorities list of the Department.

The Physics Department can boast of several physicists of great international repute among its alumni who are our best brand ambassadors. Apart from their intrinsic brightness we believe the quality of education and scientific environment they found at lIT Kanpur and the Department of Physics in their formative years has contributed to their success in some measure. It is tempting to mention an illustrative list of our alumni even at the certainty of leaving out many more worthy names : reputed *string theorists* include Prof. Ashoke Sen, Prof. K.S. Narain, Prof. Rajesh Gopakumar, Prof. Spenta Wadia, Prof. Shiraz Minawala, Prof. lnan Maharana; *experimentalists:* Prof. D.D. Sharma, Prof. Arup K Raychaudhury, Prof. T. (Venky)

Venkatasan, Prof. R.S: Nigam, Prof. G. Ravindra Kumar; *condensed matter theorists* as Prof. Jainendra Jain, Prof. H.R. Krishnamurthy, Prof. K. Senthil; Prof. Deepak Dhar, Prof. Onuttam Narayan, Prof. S.N. Behera; and astro-physciscists, Prof. Arnab Ray Chaudhury, Prof. D. Balsara. Alumni who are currently on the faculty of the Department are Dr. Anjan K Gupta, Dr. Rajeev G u p t a , Dr. S.A. Ramakrishna, Prof. M.K. Harbola, Prof. H.C. Verma, Prof. D. Chowdhury.

Evolving Contours of Research Programmes:

Condensed Matter Physics

In the formative days, the studies of the experimental groups centered around investigations of dislocations and colour centers in crystals, crystal structure and phase transitions using X-ray diffraction, electron paramagnetic resonance, nuclear magnetic resonance and optical spectroscopy. From the early days of optical spectroscopy, crystallography and crystal physics, the Department emerged as a major centre in condensed matter physics and was involved in development of the material science programme and establishing Advanced Centre for Material Science. The establishment of the Liquid Helium Facility in 1992 made possible research on superconductivity, metallic alloys, Kondo systems, spin glasses, leading to present day emphasis on laser ablation of oxides and structures for spintronics, low dimensional electronic systems and imaging of electronic properties of importance to superconductivity and magnetism. The establishment SQUID and PPMS, and scanning tunneling microscopy in the last decade has added cutting edge quality to this area. In parallel to the studies at low-temperature, studies of semiconductors with a strong emphasis on amorphous silicon started in the late seventies with experimentalists closely working with theorists interested in disorder in solids, especially in semiconductors and their alloys. These studies emphasized on the physics of defects in alloy semiconductors, properties of porous silicon and compound semiconductors such as AlGaAs and its related compounds. By the end of
90's emphasis on research in organic semiconductors emerged with the establishment of a co-ordinated effort on a large scale to bring engineers and scientists on a technology platform for industry through establishment of Samtel Centre for Display Technologies. This has given rise to an active group on physics of large area displays, thin film transistors and solar cells. The research of experimental condensed matter group has always enjoyed a thriving and symbiotic collaboration with the material science programme and center for laser technology of the institute.

Theoretical condensed matter physics developed along two different flavours, of which can be loosely termed as electronic calculations and the other as statistical mechanics and non-linear dynamics of complex systems. The electronic variety thrived on phase transitions and critical point of phenomena, electronic band structure calculations, disordered systems and also computational materials science. This has led to the current emphasis on correlated systems and nanoclusters. The importance of computational physics increased keeping pace with the availability of supercomputers in the 90's to the present high performance computing through clusters.

Members of the IITK Physics faculty and ex-faculty have earned many honours and recognition at various times. However, we must make a mention of Prof T V Ramakrishnan who was elected Fellow of the Royal Society, London. Among his many important contributions is the celebrated paper on "Scaling Theory of Localization" which was co-authored with E. Abrahams, P. W Anderson and D. C. Licciardello. These four physicists are some times

referred to as "the gang of four" in condensed matter theory circles! Mention may also be made of the Ramakrishnan-Yussouff "Theoryof Freezing" which truly opened up a new frontier of research not only in hard condensed matter but also for soft condensed matter where it has been used successfully for predicting structure of colloidal systems. Commenting perceptively on his days at IIT Kanpur TVR (as he is popularly called) says, *'Trying to grow as a research physicist was a specially lonely activity in those days when one asked for reprints on postcards and Xeroxing was an unusual thing. It was the protected side road of IIT Kanpur, well laid out and away from the major highways scientific doings, though connected with them, that allowed one to develop my muse.'*

The department also pioneered research on non-linear dynamics and chaos theory in the country, and made seminal contributions to the study of fluid dynamics and instabilities, especially magneto-hydrodynamic instabilities. From 90's onwards, the shift of emphasis to the statistical physics of soft matters, disordered systems, vehicular traffic, and traffic-like motion in cells have been widely acknowledged. Members of condensed matter theory group in tandem with members from high energy groups have been contributing substantially to the fascinating area of quantum phase transitions and dynamics, quantum entanglement, information, computation and decoherence.

High Energy and Nuclear Physics

The development of Nuclear theory group and High Energy Physics (HEP) groups took place towards the end of the first decade. During 1967-69, four HEP faculty and one new nuclear theory faculty joined. The combined strength remained at seven for a decade. During this period of 40 years since, there was a global shift in the emphasis: Low energy nuclear theory research was phased out and medium energy nuclear research was replaced more and more by that at the nuclear-particle interface: Heavy ion collisions, quark-gluon plasma, QCD-related topics, nuclear astro-particle physics. The HEP-nuclear group has kept pace with this global trend. The total strength has remained at nine or below for 40 years. The initial emphasis of HEP theory group was evenly balanced between field theory and phenomenology. In keeping with the global emphasis in HEP, that of the group has also. drastically shifted in the initial days from SU(3), current algebras, Regge pole theory, dual models on one hand and newly discovered resonances, scaling experiments on the other. With the advent of gauge theory, standard model, and discovery of neutral currents and charmed quark , the emphasis shifted to electroweak and perturbative QCD calculations in 70's and later shifted to supersymmetry and string theory in 80's and later. Keeping in view the global shift in the emphasis, the group has been successful in recruiting faculty working in developing areas. In nuclear theory, there was a recruitment in 1978. There were additions and depletions in faculty in the period 1996-2002, and it had changed the picture of the department and also of HEP and Nuclear group. During this period and following this, faculty was recruited more rapidly in subsequent years. HEP group started newer activities: General relativity and cosmology in 1990, quark-gluon plasma and astrophysics around 1995, string activity in 1998, Foundations of Quantum Mechanics 1996, Quantum Information theory 2003 and has kept up with the diverse areas that HEP globally supports. HEP group members have contributed also to research in condensed matter theory, quantum information theory and atmospheric physics. At present, strength of HEP group stands at eight, not very different from HEP and Nuclear group in early years (1970). At present, the group has varied and diverse expertise: Quantum Field Theory, Particle phenomenology, string theory, astrophysics, General relativity and cosmology, QCD, Quark-gluon Plasma, Neutrino

Physics, Quantum Information theory. It is ready to meet the challenge of new experimental revelations from LHC, expected to start from this year.

Accelerator and Ion Beam Physics

In 1968, a 2 MY van de Graff accelerator was acquired and constituted the heart of the Central Nuclear Facilities at the Institute. The installation of this facility was no less a dramatic an event in its details compared to the commissioning of IBM-1620 in the computer centre in 1963. The facility turned out to be a unique source of P-neutrons in the country and became a national facility in its own right. Eventually the energy proved to be too low for cutting-edge nuclear physics experiments in the long run. However, studies using Rutherford Back Scattering (RES) spectroscopy, channeling and accelerator related material diagnostics kept the facility busy. In the 90s, the accelerator was used extensively for material modification and preparation of technologically significant metastable materials through ion-beam mixing. In parallel, techniques such as Mossbauer spectroscopy, and positron annihilation were used to investigate the properties of solid state materials and phase transitions, and nanocrystals of minerals. Since 2000, a need was felt to completely revamp the facilities' based on the strength of our expertise in ion beams to explore new frontiers of manufacturing nano-structures and devices using focused ion beams. Prof. Girijesh K. Mehta, who had played an instrumental role in building nuclear physics laboratories during the first two decades, played again a catalytic role in the Department's efforts to establish a modern facility for ion beam based interdisciplinary science and engineering. A modern 5 MY tandem accelerator, and facilities for focused ion beams which are being used for manufacturing nano-systems is beginning to take on the shape of a centre for excellence in the form of Ion Beam Complex to take unique advantages that charged particles provide in processing and manufacturing of structures. The group is also pioneering the development of multi-element focused ion beams by using innovative microwave plasma as the source of ions.

Prof. Girijesh K Mehta recounts his reconstruction of what he calls one of the biggest missed opportunities for the Department. The KIAP offered to provide the dollar resources for collaboration with Atomic Energy Establishment for acquisition of a 12-15MV Tandem accelerator and a Variable Energy Cyclotron to be built indigenously with US$3 million dollars at that time. A proposal for national facility consisting of the Tandem accelerator for front-ranking research at IITK was widely discussed among nuclear physicists here and in the US. Dr. Homi Bhabha visited IIT Kanpur in 1965 in this connection leading to a round of discussions with AEE in which IIT Kanpur was represented by Prof. B. J. Moyer. However, the surprising reaction of AEE was that the Tandem should be acquired at Trombay and IIT Kanpur should build the Cyclotron. IITK was looking forward to kickstart its frontline nuclear research with already available expertise rather than get bogged down with machine development with a large gestation period and without the requisite expertise. The project therefore did not materialize and a great opportunity for enabling world class research was lost.

Towards Photonics

The initial studies on spectroscopy eventually paved the way for the formation of research group devoted to laser Raman spectroscopy, nonlinear optics, and laser interactions with plasma. In the 70's and 80's include some of the largest Laser laboratories were set up for academic research in India,(many lasers were actually built at IITK) training large number of Ph.D students in laser research and interactions with R&D laboratories such as Central Electronics Ltd, New Delhi, and

Bharat Heavy Electricals, Hyderabad for laser technology based instrumentation. In the 90'steh emphasis turned to plasma diagnostics of importance to laser ablation of technologically important thin films such as ZnO, simulation of astrophysical phenomena, bio-medical applications of lasers, coherent control of lasers, and the exploration of the exciting properties and applications of metamaterials and materials with negative refractive index.

Breeding Ground of Interdisciplinary Programmes

The Department participated in building interdisciplinary programmes of Materials Science and Laser Technology Progamme through joint appointment of faculty who contribute to both teaching and research in these programmes. The Department has the responsibility of two central facilities such as Central Nuclear Facility (which is developing more as an Ion Beam Complex over the recent years), and facilities to make available Liquid Nitrogen and Liquid Helium. The first liquid nitrogen plant commissioned in 1981 by IOL was surprisingly an industrial type unit housed in a large hall needing workers in shifts for continuous operation. It was replaced by a more efficient bench top model only in 1998 and is being able to barely provide for the current demand which has seen a steep rise in the last couple of years. The first liquid helium plant, which truly gave a fillip to condensed mater research, was installed in 1992 and is being replaced by a new one this year in July 2009.

Physics Everywhere

In its spatial extent within the campus the Department has facilities and Laboratories strewn over 3rd, 4th and 6th floor of the Faculty Building, with Nuclear Laboratories in the North, Condensed Matter and Laser Labs in the Southern block, and materials labs in ACMS. The Core Laboratories are shifting to a brand new Core Lab Building occupying seven large halls this summer. There is a growing hope that activities of the Department will get consolidated into an Integrated Science Building in the newly expanding part of the academic campus towards north.

Foundation of Five Decades

Due to the vision of the founders of the Institute, the Department has always remained in the mainstream of Institute affairs and provided more than its fair share of academic administrators. It is a tribute to the spirit of IITK that a theoretical particle physicist, Professor H.S. Mani headed the Undergraduate Review Committee (UGRC) which brings in major revision in Institute-wide Undergraduate Curriculum. The Department has been a constant source of Directors and Vice-Chancellors for Institutes and Universities of repute in the country.

Over the last five decades, starting from the transit campus at HBTI, the Department has grown to be a major seat of Physics teaching and research in the country with a present faculty strength of 36 (close to its original sanctioned strength of 38), 150 undergraduate students in its Masters Programmes and close to 100 Ph.D. students. One of the unsung achievements not obvious to outsiders is the strong and deep roots that democratic functioning and hierarchy-less spirit of academic freedom has taken. The Department is keenly aware of the challenges that the changes in academic environment in the country has brought and hopes to able to creatively respond by reinventing a new blend of research and teaching commitments. The biggest challenge would be to launch internationally visible high impact research programmes by creating interdisciplinary and interdependences without affecting the spirit of academic freedom and space for individual growth. It is important to ensure that best young minds continue to come to our Programmes, and young

faculty members choose to make it the preferred destination for their creativity to take tangible shapes. The need of the time is to use history of the last five decades as a candid and critical guide to chart out new directions for the coming decades.

(*by Y. N. Mohapatra with input from many including Prof. R C Srivastav, Prof. G.K. Mehta, Prof. S D Joglekar* on the occasion of Golden Jubilee year of the Institute 2009.)