TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Brief Annual Report: 1966-1967

The Tata Institute of Fundamental Research is the National Centre of the Government of India for Advanced Study and Fundamental Research in Nuclear Science and Mathematics. Both the Schools of Physics and Mathematics continued to make excellent progress, in the quality and quantity of research accomplished, during the year 1966-1967.

SCHOOL OF MATHEMATICS

A large number of research papers containing original results of fundamental importance have been written on a number of topics: differential geometry, moduli problem in algebraic geometry, Lie groups, algebraic topology and algebraic groups. These papers have been communicated to and many are already accepted by leading periodicals in America, England and Germany. Regular courses of lectures were given on different topics in mathematics: algebra, topology, harmonic analysis and number theory. In addition a number of seminars and colloquia were given. The Institute members also participated in the Bombay Mathematical Colloquium organized by the teachers of Bombay University in December 1966.

Six volumes of lecture notes were published: 1) 'Geodesics in Riemannian Geometry' by M. Berger, 2) 'Topics in Analysis' by Raghavan Narasimhan, 3) 'The Cauchy Problem' by Sigeru Mizohata, 4) 'Old and New Results on Algebraic Curves' by P. Samuel, 5) 'Minimal Models and Birational Transformations of two Dimensional Schemes' by I.R. Shafarevich and 6) 'Stratification of Complex Analytic Sets' by M-H. Schwartz.

Several mathematicians were in residence during the year 1966-67: Professor P. Gabriel (Strasbourg) for two months, Professor M.A. Kervaire (France) for two months, Professor M. Kneser (Göttingen) for two months, Professor S.N. Merguelian (Moscow) for two months, Professor A. Pfluger (Zürich) for two months, Professor C.L. Siegel (Göttingen) for two and half months and Professor J.R. Stallings (Princeton) for three months. All the Visiting Professors gave regular courses of lectures and also participated in the seminars and colloquia.

There were three guest lecturers during this year: Professor S.S. Abhyankar (Purdue University, Indiana) in September 1966, Professor L.D. Kudriavtsev (Steklov Mathematical Institute, Moscow) in May 1966 and Professor L. Sario (University of California, Los Angles) in August 1966.

S C H O O L O F P H Y S I C S

Research work in THEORETICAL PHYSICS was carried out in the following fields: (a) Particle Physics - the topics studied included the strong and weak interactions of elementary particles, their phenomenological symmetries, dynamical understanding of these symmetries especially through the bootstrap method, relations between bootstraps and strong coupling theory, analyticity properties in the complex angular momentum plane and their exploitation for the phenomenology of high energy interactions, and the application of the algebra of currents; (b) Low Energy Nuclear Physics - nuclear structure was studied on the basis of various nuclear models and in

terms of basic nucleon-nucleon interactions; these studies were carried out by using techniques of many-body theory as well as by an analysis of the statistical properties of nuclear levels; (c) Solid State Physics - research covered a study of the microscopic theory of superconductivity, of non-linear optics, of positron annihilation in solids, and phase transitions; (d) Magnetohydrodynamics - problems relating to hydromagnetic stability and hydromagnetic turbulence were studied; (e) Astrophysics - a theoretical study of carbon stars has been initiated; these stars are of interest because of their possible role as manifestations of later stages in stellar nucleo-synthesis and evolution.

In the area of COMPUTER DEVELOPMENT the design of the entire system of an on-line data processor (OLDAP), which will have versatile real-time facilities, has been completed. Individual circuit boards are ready to be wired. The central processor consisting of an arithmetic unit, a core memory and an input/output (I/O) interface will be ready for testing shortly. Peripheral units like paper tape reader and magnetic drum have already been assembled and are being tested. Development of software packages for OLDAP, using a simulator in the CDC 3600 Computer, have been initiated. Standardized circuit modules such as an operational amplifier, analog-digital (A/D) converter, multiplexor, clock sources, voltage comparators, digital display counters, etc. have now been designed on pluggable printed circuit cards; these modules can be produced in quantities for digital assemblies due to the availability of an

operational facility for printed circuit card fabrication. Samples of integrated sub-assemblies using one and two-sided printed circuit boards have already been made; a time analyzer using a novel technique is also nearing completion.

In the general area of COMPUTER RESEARCH there has been considerable development. A metatheoretic model has been developed which can cope with programming languages and computers within a uniform framework. Some preliminary applications of this model have been made to artificial intelligence studies. A speech spectrum analyzer incorporating 15 channels and capable of analysing steady-state spectra of vowels, etc. has been built, tested and calibrated. Further, a programme has been developed for the CDC 3600 for speech synthesis, given the speech spectrograms; the generated speech can be either played on-line or recorded on an audiotape. Work is being undertaken on designing an adequate specification language to allow synthesis of prosodic features like intonation, stress etc. COMPAX, a specially designed picture processing language was used to simulate a hand printed English letter generator, and a language called COMPANION, with very powerful generative and editing features, was developed to generate animated picture sequences; cartoon movies of considerable sophistication can be produced using the latter language. A specially designed interface enables these movies to be displayed under computer control on a Tektronix oscilloscope. COMPANION is also being made available as a research tool for generating dynamic visual displays of physical processes.

The NATIONAL COMPUTATION CENTRE based on a CDC 3600-160A computer system completed its second year of operation in October 1966. This facility was used by over sixty scientific and engineering research and educational organisations, government and private agencies. The computer system is now being operated for 5 shifts twice-a-week and two shifts over the rest of the days (excluding holidays); on an average, 2500 job decks are processed monthly.

In the field of EXPERIMENTAL LOW ENERGY NUCLEAR PHYSICS angular correlation studies using some short-lived radioactive nuclei were carried out near the Apsara Reactor at Trombay. At the Van de Graaff machine, also at Trombay, nuclear energy levels excited by Coulomb excitation were studied. Measurements of magnetic moments and g-factors for excited vibrational states of some radioactive nuclei and investigations on the core polarisation effect on the magnetic moments were continued. The spin-parity of Ac^{228} was established as 3^- by beta-gamma directional and circular polarisation measurements. Construction of a 256-channel pulse amplitude analyser is nearing completion. Single-gap and single-lens beta ray spectrometers are being assembled to investigate penetration matrix-elements in magnetic dipole conversion processes by means of electron-electron and electron-gamma correlation studies. A new project for studying Mössbauer spectra, at liquid helium temperatures in isotopes produced by nuclear reactions with the Van de Graaff machine has been undertaken. Some of the other investigations carried out in this field are: (a) a study of positron annihilation effects in some compounds with 7-member and 8-member ring structures, (b) a study of

quenching of triplet state positronium in condensed materials, solid polymers, co-valent crystals and liquids and (c) measurements of g-factors for levels in some Cerium isotopes.

Work has been continued on the wideline NUCLEAR MAGNETIC RESONANCE (NMR) studies of liquid metals, semi-conductors, and rare earth alloys to get an insight into their electronic structure and magnetic properties. Solvent-solute interactions in several organic compounds were studied using high resolution NMR, and their aromaticities estimated from dilution shifts. The Mössbauer effect of Sn^{119} was observed in platinum-tin and rare-earth-tin alloys. Further, from the relaxation effects observed in Mössbauer spectra of Gd Sn_3 and Eu Sn_3 intermetallic compounds, the conduction electron polarisation due to localised rare earth magnetic moments has been studied. The magnetic susceptibilities of a number of nickel and ferric complexes were measured at several temperatures to understand their structure. Interesting results from the point of view of physics, chemistry and biology have been obtained from electron spin resonance (ESR) investigations. A new interpretation has been given for the alternating line width phenomenon in the ESR spectra of semiquinone radicals which occur in many biological systems. Investigations carried out in collaboration with the Indian Agricultural Research Institute, New Delhi, on different samples of soil humic acids, give strong evidence for a microbial origin of the humic acids in soil. Other areas of work in which progress has been made are: contact shifts in proton resonance in paramagnetic complexes; studies on single crystals using rare-earth impurities; the

measurement of relaxation times of paramagnetic species; the investigations on transition metal complexes and on free radicals produced by radiation damage in organic solids. A spin-echo equipment and a pure quadrupole resonance spectrometer have also been fabricated to probe the nature of solids.

Investigations on primary galactic and solar COSMIC RADIATION were carried out by sending electronic detectors and nuclear photographic emulsions to high altitudes by means of plastic balloons manufactured at the Institute. 8 successful balloon flights were made from Hyderabad during 1966, using balloons of volume 56,640 cubic metres. For the first time, positive evidence for the emission of neutrons from the sun was obtained with a specially designed scintillator-spark chamber telescope; a proposal for a satellite experiment to detect solar neutrons, incorporating the basic principle and design of this instrument, has been submitted to the National Aeronautics and Space Administration (NASA) of United States for consideration. The intensities of protons and helium nuclei of the galactic cosmic radiation were measured over Hyderabad in 1966 using an improved and standardised detector system; experimental data on the high energy (> 16 GeV) primary electron component of cosmic rays is being rapidly increased, and used to probe the physical conditions existing in interstellar and intergalactic space. Considerable work has been carried out in the interpretation of the recent data on the low energy component of cosmic radiation. A number of experiments were conducted with plastics and meteorites, mainly to

study the composition of heavy nuclei in the primary radiation during modern and prehistoric times. Experiments to study nuclei heavier than iron in the primary cosmic radiation are now in progress.. A magnetic-emulsion chamber, (to extend the measurements of the energies of primary cosmic ray nuclei beyond 10 GeV), and a number of detector systems to detect heavy nuclei, X-rays and gamma-rays of cosmic origin have been developed. On the interpretative side a number of calculations have been initiated which interconnect cosmic ray and astrophysical parameters.

50,000 showers recorded with the EXTENSIVE AIR SHOWER array at Ootacamund were analysed on the CDC 3600 computer system to determine, as a function of shower size, the lateral structure of the nuclear active component, (with energy greater than 5×10^{10} eV), in showers of primary energy greater than 3×10^{14} eV; a total absorption spectrometer was used to measure the energy in the nuclear active particles. Interesting results have been obtained which have a bearing on air shower phenomenology at shower energies greater than 10^{13} eV. In the air shower array operated on the surface at Kolar Gold Fields, in coincidence with muon detectors placed underground at depths between 300 and 600 metres, 8000 showers associated with high energy muons were recorded; underground scintillators and cerenkov counters detected muons of energy exceeding 10^{11} eV. Attempts are being made to understand, with minimum speculative assumptions, the different observed features of the electron, muon and nuclear active particles in air showers, in terms of the composition of primary cosmic radiation, their energy spectrum, and

characteristics of ultra high energy nuclear interactions.

In the NEUTRINO EXPERIMENT, which is being carried out deep underground in the Kolar Gold Fields there has been considerable increase in the area of the detector array as well as in sophistication. Three new telescopes were installed during 1963, doubling the area. In these new telescopes additional neon flash tube arrays, to determine azimuth angles accurately, have been incorporated. It is estimated that about 11 neutrino induced events have been detected so far. To enable a more refined analysis, two magnet spectrometers are being installed at present. This programme is being undertaken by the Institute in collaboration with the Osaka University (Japan) and the Durham University (U.K.).

GEOPHYSICS RESEARCH

Experiments are being carried out to study the disequilibrium amongst the radioactive members of the uranium and thorium series in natural waters and sediments; the geochemical implications of the results already obtained are under examination. Calculations are being made to study the interaction between the ocean and the atmosphere, and its association with climatic changes in the past and their influence on the atmospheric inventory of radiocarbon; the conclusions will be verified experimentally by measuring the dissemination in the oceans of radiocarbon produced in nuclear explosions. Experiments are being conducted to test the feasibility of using radon to trace the flow of the SW monsoon air. Exploratory measurements made over the Arabian Sea and the Indian Ocean have given encouraging results. Attempts are being made to observe the decay of long-lived radionuclides Ca^{48} and V^{50}. Suitable counting techniques and chemical procedures required for this

purpose have been developed; half-life periods in the region of 10^{20} years can be detected with these techniques.

In the HYDROLOGY LABORATORY, besides tritium, (H^3), two other cosmic ray produced radioisotopes Si^{32} and C^{14} have been used to determine the age of ground waters in Rajasthan, Gujarat, Punjab and Neyveli. The results indicate that in the arid regions the waters are old enough with respect to tritium (half life~12 years) but not too antique with respect to Si^{32} and C^{14}, (half lives~600 years and~5600 years respectively). The measured ages provide a fair estimate of the 'recharge rates' of the aquifers and are consequently valuable in water management.

In the RADIO CARBON LABORATORY, work on the dating of archaeological samples has continued. It has been found that neolithic culture existed in Southern India from 2300-1000 B.C. i.e. showing a slow pace of development for a long period of about 1300 years; this is in contrast to the highly urbanised Harappan civilization of short (~ 600 years) duration which emerged in the NW and W of this subcontinent. The overlap phase of neolithic and megalithic cultures has also been dated. Both in Northern and Southern India the advent of the iron-age can broadly be placed in the beginning of the first millenium B.C. In Eastern India, however, the iron-age came much later, but was definitely pre-Mauryan. These findings have implications with respect to proto-historic migrations in India.

In the area of ROCK MAGNETISM, the magnetic properties of various types of rocks in different physical environments were studied.

An apparatus was built to display the low field hysteresis loops of rocks directly on the oscilloscope; and some time-dependent hysteresis behaviour, (memory phenomenon), has been observed in some of the basalts which had been critically studied earlier for palaeomagnetism.

In RADIO ASTRONOMY, there has been considerable progress in the construction of the large cylindrical radio telescope at Ootacamund; the telescope is expected to be in full operation during 1968. It will be used for lunar occultation studies of radio sources, for observations of flare stars, long base line interferometry etc. Observations on the sun are being made daily with the multi-element high resolution solar radio telescope built at Kalyan, near Bombay. All three components of solar radio emission from the quiet sun, the slowly varying component, and radiation from solar bursts are being studied. The brightness distribution observed from the quiet sun is in accordance with the theoretical predictions; the sources of the slowly varying component are thermal in nature and have diameters approximately 8 minutes of arc and brightness temperatures of the order of 0.5×10^6 °K. A few solar bursts have already been recorded, and the present receiving system is being slightly modified to get more detailed information about these. Studies are also being made of extended sources in our galaxy such as W 44, W 51, Cygnus loops, etc. using data from the 300 ft. diameter radio telescope at Puerto Rico.

In the field of MOLECULAR BIOLOGY, studies have been continued on the synthesis and role of macromolecules in the regulation of metabolic processes. Following the demonstration that several biochemical

reactions in the cell are oscillatory, several glycolytic mutants of yeast have been isolated. Variations in the level of enzymes and metabolites, and their significance in the regulation of energy yielding reactions are being investigated. A detailed analysis of the synthesis of ribonucleic acid during primary and secondary immune response has been carried out. Studies on nuclear-cytoplasmic interaction during sea urchin embryogenesis have indicated a distinct shift in the pattern of RNA metabolism following gastrulation. Other work in progress include a study of recombination following bacterial centrifugation, an experiment on transformation and genetic mapping of B subtilis, and an investigation on genetically altered enzymes. A method based on zonal centrifugation for the enrichment of competent cells has been developed; and an amino acid analyser has been set up as a part of a programme to investigate the chemistry and structure of proteins.

There has been considerable development work in the areas of SOLID STATE ELECTRONICS and MICROWAVE ENGINEERING. Extensive facilities have been set up for developing microelectronic circuits for computer applications. Steps have been taken to duplicate capacity type welders and micropositioners from imported samples. Test equipment such as S-band signal generator, power measuring equipment, frequency meters and standing wave ratio detectors have been developed. Transmitting and receiving (TR) cells required in large quantities for use in radar systems are being developed.

A Summar School on "Coding Theory and Graph Theory" was organised at the Institute from May 30 to June 17, 1966. The principal

lecturers were Professor R.C. Bose, North Carolina University (U.S.A.), and Professor C. Berge, Director of the International Computation Centre at Rome (Italy). Two other Summer Schools were held in Bangalore during June - July, 1966. In the first Summer School on "Mössbauer Effect and its Applications to Chemical and Solid State Physics", Professor K.S. Singwi, Argonne National Laboratory, (U.S.A.), Professor J.F. Duncan, Victoria University, Wellington (New Zealand), and Professor V.G. Bhide, Institute of Science, Bombay (India) delivered the lectures. In the second Summer School On "Relativistic Astrophysics and Cosmology", Professor G.R. Burbidge and Professor (Mrs.) E.M. Burbidge, F.R.S., both of the University of California, (U.S.A.), and Professor D.W. Sciama, University of Cambridge (U.K.) lectured.

A Tutorial Seminar on "Implementation of Microelectronics Technology" was organised at the Tata Institute of Fundamental Research from December 5-12, 1966. The Seminar included both lectures and laboratory demonstration sessions. These were given by Dr. L.P. Retzinger and Mr. A. Egger of TRW systems; Dr. A. Stevenson, Litton systems; and Dr. W. Lindemann, Control Data Corporation, all from U.S.A. Some thirty scientists actively engaged in this field in India from the Institute and other institutions participated in this Seminar.

Five volumes of lecture notes were published: 1) 'Nonelementary Particles' by R.H. Capps, 2) 'Bootstraps' by L.A.P. Balázs, 3) 'Reactions with Strongly Absorbed Particles' by J.S. Blair, 4) 'Formal Reaction Theories and Their Physical Consequences' by C.F. Clement, 5) 'Stripping and Pick Up Reactions and Their Application to Nuclear Spectroscopy' by Shiro Yoshida.