Reviving experimental physics in the universities – The IUC initiative

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*There is widespread concern about the state and future of science in the universities – witness the recent presentation and discussion of the National Science University (NSU) proposal in these pages. One of the measures taken by the University Grants Commission (UGC) to provide improved opportunities for research level work in the university sector is the creation of several Inter-University Centres where unique facilities are shared by workers from all over the country. The Inter-University Centre for Astronomy and Astrophysics (IUCAA) is an example and a brief report by J. V. Narlikar appeared in Current Science some time ago (1993, **65**, 730). The author of this article recently visited the Inter-University Centre for DAE facilities (IUC-DAEF) located on the university campus in Indore and was struck, as many others before him have been, by the many unique features of this institution, where a serious effort is being made to revive first-rate experimental condensed-matter physics in the universities, in a quiet, low-key, low-publicity style. The following sections on the origin of this institution and its facilities and activities have been compiled based on detailed information kindly provided by the staff at IUC-DAEF.*

Origin of IUC-DAEF

It is undeniable that experimental research in physics in universities in India, barring a few notable exceptions, is in very dire straits today. Condensed-matter physics is an area in which experimental work of reasonable quality can be pursued by small teams with not too expensive equipment. Though the majority of the existing universities do pursue research in condensed-matter physics, facilities for characterization of the materials prepared and for carrying out a reasonably complete range of experiments on materials at different temperatures are very often not available to most researchers. This means that the standard of the research as well as the stimulation that it offers to students and faculty at the university both suffer.

On the other hand, first-rate experimental facilities are often established outside the university system. For example, DAE has built a variety of neutron spectrometers on the Dhruva reactor. Protons, deuterons and alpha particles can be accelerated to several MeV energies with the Variable-Energy Cyclotron in Calcutta (VECC). There are plans to build a superconducting cyclotron. The Centre for Advanced Technology (CAT) in Indore is developing synchrotron radiation sources Indus 1 and Indus 2. It was felt both in the DAE and outside that these frontline research facilities must be available to university scientists. University scientists must be slowly inducted to work with scientists from DAE in developing different types of accelerators, beam-lines, etc. One can add that elsewhere in the world this kind of university participation is a rule rather than an exception. The Very Large Array Telescope, which in many senses the world's most powerful radio telescope, is even run by an association of universities, and many accelerators like CERN have large teams of university researchers building and using giant detectors.

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Aims

To improve the quality of experimental research in physics in universities and to provide access to the major DAE facilities to the researchers from universities, the UGC set up the Inter-University Consortium for DAE Facilities (IUC-DAEF) in 1990. This is an autonomous society fully funded by UGC. IUC-DAEF has three centres, at Bombay, Calcutta and Indore, the last one being the headquarters.

The IUC-DAEF supports projects from university researchers to use the major national DAE facilities at BARC and VECC and also the upcoming DAE facilities at CAT. To make the best use of these expensive facilities, it is necessary to work with well-prepared and characterized materials and to carry out other experiments which will be complementary to those obtained with the major DAE facilities such as the neutron spectrometers at BARC or cyclotron at VECC. Therefore, the IUC-DAEF has the task of setting up supporting facilities. The IUC-DAEF also participates in certain development projects of DAE. Periodic workshops on current topics of research for the benefit of young faculty and research scholars of universities are another important activity.

Utilization of DAE facilities

In the last four years the number of university projects on the Dhruva reactor at BARC has increased to 30. There is a steady stream of university scientists visiting BARC for carrying out experiments with the neutron spectrometers. The majority of the projects use the profile analysis powder diffractometer, the small-angle neutron scattering spectrometer, the high-Q diffractometer for the study of amorphous materials and the neutron spectrometers for magnetic studies, in that order. The SANS (small-angle neutron scattering) spectrometer is being used by chemists from different universities. The IUC-Bombay centre conducts each year in association with BARC scientists a three-week workshop in which about 20–25 scientists from universities and other institutions participate. Two weeks are devoted to lectures on various aspects of neutron scattering and diffraction. In each workshop one aspect of neutron scattering is emphasized. During the discussions that follow the lectures and tutorials, the participants are encouraged to come out with ideas for projects. In the third week of the workshop the participants are taken to BARC so that they can see actual demonstrations of the different spectrometers. This method of generating proposals has proved effective. The proposals are often prepared after a detailed discussion between the investigator from the university and the scientists from BARC. Every year the progress in a project is reviewed at a Project review meeting at which all project investigators and scientists from the Solid-State Division of BARC are present. From 1992–1994 ten papers have been published in journals on results obtained in these projects. The number of presentations at the annual DAE symposium on solid-state physics is 20. Till recently K. R. Rao and P. R. Vijayaraghavan, with the cooperation of their colleagues in the Solid-State Physics Division of BARC, were looking after the administrative and scientific aspects of these projects. Dhananjai Pandey joined as the Centre Director of the IUC-Bombay Centre in the middle of 1994.

In Calcutta, activities started from February 1992, when S. N. Chintalpudi was appointed the Centre Director. There are now 32 projects on the Variable-Energy Cyclotron, including projects in nuclear physics, materials science, chemistry and biology. These projects are also reviewed each year. Seven publications have appeared in international journals and eleven papers have been presented at national symposia so far. Discussion meetings on pre-equilibrium phenomena and in-beam γ-ray spectroscopy have been held to evolve group projects.

Starting from 1993, seven projects were sanctioned on the low-energy accelerators at IGCAR, Kalpakkam. This was done after holding a workshop on the type of experiments that can be done with low-energy accelerators. The projects were reviewed in November 1994. Students from different universities have stayed for extended periods in Kalpakkam and have helped in setting up the various beamlines on the accelerators, and it is expected that useful scientific results will soon be forthcoming.

IUC Indore

The Indore Centre started in July 1990 with V. G. Bhide in charge and R. Srinivasan took over the Directorship in December 1990. This Centre, which is also the headquarters, has independent materials preparation and characterization facilities as well as supporting facilities of EXAFS, ESCA, soft-X-ray spectroscopy, transport properties and AC susceptibility measurements, etc. The centre is involved in developing beamlines for synchrotron radiation for users from universities. One current project is to build a beamline for photoelectron spectroscopy (PES) on Indus 1. The wavelength range in which this PES beamline will work is from 60 to 1600 Å. After an evaluation of the various types of gratings, mountings, etc., it was decided to use a toroidal grating monochromator with three interchangeable gratings to cover this wavelength range. To get adequate resolution for PES work the TGM 2600 design of Bessy has been chosen. The toroidal grating monochromator has been purchased from Jobin Yvon in France and the turbo and sputter ion pumps were attached to it, and ultra high vacuum achieved. The grating has been aligned and the expected resolution checked with He I and He II sources. The design for the mirror chambers, the laser alignment chambers, etc., have been made by scientists from IUC. These are under fabrication. It is expected that the entire beamline, which will be 12.1 m in length, will be assembled and tested by December 1995 in conformity with the expected time schedule of completion of Indus 1. To carry out some basic photoelectron spectroscopy experiments the IUC-DAEF has given a project to D. D. Sarma and M. S. Hegde of IISc, Bangalore, to construct a set-up consisting of a sample preparation chamber, sample analysis chamber, and analyser with provision for putting a twin X-ray anode and a He UV source. This spectrometer has been constructed and is being assembled.

With this beamline one can study the core level spectroscopy of K levels of light elements, L levels of elements of medium atomic weight and M levels of heavy elements. A discussion meeting on the type of projects to be undertaken has been held in Indore.

The second major project is to build a complete soft-X-ray system to study transmission and reflection of thin films at different angles of incidence. This is of interest from the point of view of mirror coatings for the synchrotron radiation source. This project is partially supported by DST. In this project the rotating magnetic seal with an aluminium anode has been imported from Rigaku and the filament assembly, the vacuum chamber and the power supply have been built locally. It is designed to operate at 3 kW. The soft-X-ray continuous radiation coming out of the rotating anode source will be monochromatized with a double crystal monochromator with a fixed entrance and exit slit. Such a monochromator operated by a single screw driven by a DC motor has been designed and fabricated with a positioning accuracy of 5 μm. The large *d* spacing crystals have been imported. The channeltron detector has been imported and successfully tested. The experimental chamber with $\theta - 2\theta$ mount is currently being fabricated. The whole system will be operational by October 1995.

Materials preparation and characterization

The IUC-Indore centre has set up materials preparation, characterization and measurement facilities listed below:

1. An EXAFS (extended X-ray absorption fine structure) spectrometer with the mechanical movements designed in Pune University and built by a company there. This is a bent-crystal Johansson-type spectrometer using a Si crystal. This spectrometer is mounted on one window of a 12 kW rotating anode X-ray generator. Since the generator has Cu and Co anodes, EXAFS for elements whose absorption edges fall in the appropriate wavelength range can be carried out. This instrument has been used to study the EXAFS of copper-containing organic complexes, copper-containing chalcogenide glasses, As–Se glasses and glassy bismuth copper oxide materials. Users are from universities, IITs and the IISc.

2. A powder diffractometer mounted on the second window of the Rigaku rotating-anode generator. This is equipped for use at temperatures varying from 80 to 1000 K and allows grain size determination, strain determination, etc. This has been widely used by several university groups to characterize their samples. Last year nearly 500 diffractograms at different temperatures were taken for university users.

3. An ESCA unit from VSW, UK, has been functioning for the last three years. This has provision for XPS with a twin-anode source, UPS (ultraviolet photoemission spectroscopy) with He I and II light source and an electron gun for Auger spectroscopy. There were several problems with this instrument, but all the problems have been solved with the expertise available in Indore. This facility has been availed of by nearly 15 university users so far, mainly for core-level spectroscopy work. It is planned to improve the facility by providing a scraper unit, a variable-temperature attachment and a high-energy Argon ion gun for depth profiling.

Facilities developed in-house

4. A fully automated AC susceptibility set-up with variable temperature in the range 80–300 K and with provision for recording the in-phase and 90° out-of-phase components up to the seventh harmonic. With this, studies have been made on the AC susceptibility of sintered pellets of high-T_c materials. The set-up can be used to study magnetic ordering and the growth of harmonics close to the ordering temperature.

5. An automated low-frequency AC conductivity set-up with a precision of 1 part in 10^5 with temperature control to 0.1 K in the range 80–300 K.

6. A dielectric constant and loss set-up to work in the temperature range 80–600 K and in the frequency range 10–13 MHz. This is being automated.

7. A low-temperature resistivity set-up built on a closed-circuit refrigerator. The resistivity of three (metallic or semiconducting) samples can be measured at the same time with temperature controlled to 10 mK in the range 15–300 K.

8. A low-temperature thermopower set-up mounted on a closed-circuit refrigerator and automated to operate between 15 and 300 K. The thermo-emf can be measured to a precision of 0.1 μV. A set-up for high-temperature thermo-emf measurement is available. A provision for evacuating the sample chamber and filling it with an inert gas needs to be made.

9. A vibrating-reed set-up for measuring internal friction and elastic constant is working and has been automated.

10. An adiabatic pulse calorimeter has been set up and automated to work in the range 80–300 K. This requires samples of 0.5 g to set a good accuracy.

Very soon the temperature range in which the above facilities will be operational will be extended to 4.2 K with cryostats fabricated by a Madras firm.

In addition, there is a ball mill, temperature-controlled resistive furnaces, and an arc furnace for preparation of samples. A thin-film coating unit is also available.

Nearly 60 groups from various universities, IITs and IISc have used the facilities in the last two years.

Low-temperature facility

The entire low-temperature facility for production of cryogens has been set up using second-hand machines obtained as gift from IIT, Madras, the Free University, Berlin, and the Max-Planck Institute for Solid-State Research in Stuttgart. A 25-year-old nitrogen plant obtained as a gift from IIT, Madras, has been installed and has produced in the last two years 8000 l of LN_2. An old helium plant obtained from Free University, Berlin, was commissioned in May 1994 and is working satisfactorily. The IUC has supplied liquid helium to NCL, Pune, twice (60 + 70 l).

In Calcutta facilities have been set up for making targets for users of the cyclotron and many university groups have used these facilities. Temperature-controlled diffusion furnaces for making Si(Li) detectors have been set up and some detectors made. Their performance is being evaluated. Several NIM electronic modules are made available for users of the VECC. A Mössbauer spectrometer has been commissioned and is being regularly used by scientists from different institutions around Calcutta. A positron annihilation set-up and a time differential perturbed angular correlation set-up are being established with the help of several university groups. Laboratories for radiochemistry, general chemistry and toxic chemistry have been set up. Attempts to prepare Mössbauer and positron sources are underway.

The three centres together have conducted nearly 30 workshops/discussion meetings/national symposia in the last four years. More than 700 research scholars and scientists from universities and other research institutions drawn from most of the states of the country have participated in these workshops.

Some special features

Even the rather bald factual account of IUC-DAEF activities given above is impressive, given the short time that it has been in existence. But visitors to the Indore Centre quickly learnt that this is only a part of the story. The way in which the centre was built up and is being run has some special features which may be of wider interest. One important aspect was that even before the main building was complete, the first laboratory activities had started. The recruitment was carried out in a phased manner, so that everyone who joined had plenty of work to do. This situation prevails even at present, and is in healthy contrast to others, alas not uncommon in our country, when a large building and recruitment programme precedes active research. It also appears that the administration is small in size, uses modern means of communication, and is charged with helping the scientists procure what they need with the minimum possible delay. The scientists themselves can devote up to 30% of the time to their own research, which is of course a good incentive to keep the equipment in good condition. This is a lesson for those who would set up pure 'facilities' and appoint people to do only routine work. At the same time, the opposite situation of the facilities being all used in-house, with only lip service to outside users, can also arise! There seems to be no risk of this at IUC at present – if anything, it was clear that enormous effort was being put in to see that the university users went away with the data they wanted. Another important point is the presence of IUC's own research students, who, like the staff, are enthusiastic about their work and spend long hours in the laboratories. Many years ago, C. V. Raman described some of our laboratories as 'graveyards of scientific equipment'. The sight of so much equipment well maintained *and fully utilized* would have warmed his heart. It should be mentioned that there is a strong emphasis on the workshop and on fabrication of many things in-house. *The entire low-temperature facility is based on equipment which had been discarded elsewhere.* By making it work, the staff at IUC have earned the right to ask for new equipment in a manner which is again not common elsewhere!

What of the future?

While the achievements of IUC are laudable, one should also utter a word of caution. By providing such ready-made facilities, one may be depriving the researcher from learning to do good experiments himself. In such a case the IUC will not be promoting the growth of expertise in experimental physics. Perhaps the IUC should think of organizing experimental courses for two to three weeks whereby young scientists are made to handle equipment and do their experiments themselves. This may not be easy because it would mean setting up a duplicate set of less expensive facilities for handling by the students and may cost money. But if the culture of doing good experiments is to grow, the UGC *must* find money for such a programme.

The IUC with its expertise must try to involve young students in designing equipment and, if such designs are successful, it must find a way of involving small-scale industry in fabricating and selling such equipment. Unless we try to make our own equipment, Indian science will be captive.

The workshops organized by IUC have generally been well received. IUC pays for the travel and boarding of the participants. Possibly due to financial constraints, too much is attempted to be covered in too short a time and enough reading material is not given to the participants. Also, due to lack of guest house facilities it has not been possible to put the participants and speakers together. This can hinder the development of interactive participation. A guest-house with a sufficient number of rooms seems to be an essential requirement. If IUC could restrict the topics to be covered and make the lectures truly pedagogical, the purpose of organizing such workshops will be served better.

IUC should put some effort in improving the laboratory curriculum of B Sc and M Sc classes. It is involved in one such education project which is restricted to five colleges of Madhya Pradesh. The project has just started. It will be interesting to watch how this project succeeds.

Finally, it may not be inappropriate to caution IUC about the dangers of doing too many things in too short a time. IUC must now consolidate the gains it has achieved so far. The experiment of getting university people to work together is alien to our prevailing culture. Hence, one must wait for sufficient time for the idea to take root. Sometimes pushing an idea too fast may generate an adverse reaction!

The success of any venture depends on the initiative and dedication of the leadership. IUC has been lucky in that the first two directors have shown qualities of dedication and purposeful action. To nurture IUC, which is a young plant today, into a spreading tree tomorrow with well-entrenched roots, great care must be taken in selecting the next Director of IUC-DAEF. He must be an experimental physicist of repute and must command the respect of the physics community as a whole. He must be deeply committed to the cause of providing service to the university community and to strengthening the bonds between the scientists of DAE and the universities. He must have administrative competence and should keep in check the universal, ever-present tendency for the growth of red-tapism in any organization. It is to be hoped that the IUC-DAEF will be fortunate in having a succession of such leaders.

Modern science and technology: The public perception

V. Govindarajulu

Positive public perception and attitude towards modern science and technology (S&T) is a vital link in the all-round economic, industrial and cultural development of a nation. Public hostility and/or indifference towards modern S&T, on the other hand, is a drag on the growth of economic productivity of any nation. Public policy options, as derivatives of public perceptions, can be the basis for formulating effective and productive development programmes. The results of this DELPHI study, conducted in the State of Kerala, highlights the public perceptions and attitudes towards modern S&T, productivity and industrial development. The public in the State of Kerala possesses a positive and desirable perception that modern S&T is the key to productivity and national development. The results are comparable to the studies done elsewhere and, therefore, universally valid. This study provides a broad spectrum of philosophical and sociological foundations of modern S&T and industrial development. In-depth areawise, sectorwise and disciplinewise impact assessment studies are required before initiating large-scale investment-oriented S&T projects in the states and in the country.

SCIENCE and technology (S&T), nowadays, plays a vital role in the daily routines of our lives. Industrial development, economic productivity and thus national prosperity depend much on the vital role played by S&T. Efficiency and productivity of our nation's economy are functions of social technology of the people. Social technology is the level of knowledge base, entrepreneurship and social consciousness acquired by the people, that continuously helps them to raise the quality output of goods and services per given quantum of resources as input. The gross domestic product (GDP) per capita or per capita income at any given time is the index of the level of social technology of the people and their economic productivity attained. Thus, per capita income of some Asian countries – in 1993, for example, Japan

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