4. Blum, M. S and Blum, N A, *Sexual Selection and Reproductive Competition in Insects*, Academic Press, New York, 1979, pp. 260.
5. Ananthakrishnan, T N., *Reproductive Biology of Thrips*, Indira Publishing House, Michigan, 1990, pp. 13–17.
6. Chauvin, R, *The World of an Insect*, World University Library, McGraw Hill, New York, 1967.
7. Beck, S D., *Insect Photoperiodism*, Academic Press, New York, 1980, pp 102–118.
8 Wehner, R., *Sci. Am.*, 1976, HPD, 1–11.
9 Blum, M. S., *Am. Entomol.*, 1992, **38**.
10. Lewis, T., *Insect Communication*, Academic Press, New York, 1989, pp 449
11. Evans. D. L. and Schmidt, J V., *Insect Defense*, State University of New York, 1990, pp. 289
12 Anthony, T. T., *Handbook of Natural Toxins*, Marcel Dekker, New York, 1984, vol. II, pp. 193–319.
13. Baker, T. C., *Chemical Control of Behaviour 14*, Pergamon Press, 1984, pp. 628
14. Ananthakrishnan, T N. and Senrayan, R., *Phytophaga*, 1992, 4, 87–94.

Received 20 November 1993; accepted 8 December 1993

Inter-University Consortium for Department of Atomic Energy Facilities

A. V. Pimpale and R. Srinivasan

The Inter-University Consortium for DAE Facilities was established to promote the use by university scientists of the major DAE facilities. This article summarizes the progress of various activities of IUC-DAEF in the last three years of its existence.

The Inter-University Consortium for the Department of Atomic Energy Facilities (IUC-DAEF for short) is a new concept in the academic structure of our country. Two main ideas contributed to its formation. First is the realization that research funding in Indian Universities is not keeping pace with the need for sophisticated equipment and infrastructural requirements for modern research. The ever-increasing costs of quality work make it extremely difficult for individual institutions or university departments to stake their claims for appropriate financial support. An equitable distribution of the available resources would spread it too thin for any meaningful use. The idea of multi-user institutions came to fore to address this situation and the University Grants Commission (UGC) opened the Centres like the Inter-University Centre for Astronomy and Astrophysics (IUCAA) at Pune and the Nuclear Science Centre (NSC) at Delhi. IUC-DAEF was conceived as a multi-user institution in the same spirit but with certain unique features stemming from the realization that the country has developed certain major facilities in the institutions of the Department of Atomic Energy (DAE) and a reserve of trained man-power in the universities. It was felt that making these major facilities in DAE institutions accessible to scientists from universities will be to mutual advantage. The decision to start the IUC-DAEF was thus taken after preliminary discussions between the then Chairman, Atomic Energy Commission, M. R. Srinivasan, and the Chairman of the University Grants Commission, Yash Pal. Although informal collaboration between scientists from universities and various DAE establishments had been going on for some time, the establishment of IUC-DAEF provided a formal mechanism for such co-operation between two different academic currents in the country – on the one side the research establishments of the Government of India such as DAE which have their own priorities for research and development and on the other the universities, which are autonomous institutions funded by different state governments and UGC. The memorandum of understanding signed between DAE and UGC provides for greater participation and involvement of the University system in the design, fabrication and particularly utilization of major (DAE) facilities leading to cross-fertilization of ideas, concepts, techniques and activities.

The Memorandum of Association of IUC-DAEF was formally registered on 31-7-1990. Even before it formally came into existence, IUC started functioning under the leadership of V. G. Bhide with co-operation of the Devi Ahilya Vishwa Vidyalaya, Indore, and its former Vice-chancellor, M. S. Sodha. Indore was chosen for the headquarters of IUC-DAEF since one of the major DAE facilities – an upcoming 450 MeV electron storage ring to be used as a dedicated synchrotron radiation source in the soft X-ray and VUV region of the electromagnetic spectrum – is being established at the Centre for Advanced Technology (CAT) at Indore.

Initially three major DAE facilities were specifically opened for utilization by the university personnel under the umbrella of IUC-DAEF. These were the various

The authors are in IUC-DAEF, Khandwa Road, Indore 452 001, India

neutron spectrometers on the Dhruva reactor at the Bhabha Atomic Research Centre, Bombay, the Variable Energy Cyclotron at Calcutta and the upcoming synchrotron sources Indus-1 and Indus-2 at CAT. For organizational ease it was planned to have three centres of IUC-DAEF at Bombay, Indore and Calcutta, with the head office in Indore. The centre at Bombay will look after the utilization of neutron spectrometers on the Dhruva reactor by university scientists and the centre at Calcutta will do likewise with the variable energy cyclotron. At Indore the IUC-DAEF had originally taken the responsibility of designing and erecting two beam lines on Indus-1. In addition IUC is to promote interaction with the low energy accelerator facilities at the Indira Gandhi Centre for Atomic Research in Kalpakkam and the laser facilities at CAT.

Right from the beginning IUC was envisaged not just as another funding organization to make grants available nor as only a liaison body between DAE and the various universities but as an active catalyst to bring about interaction between DAE scientists and university researchers. Moreover, since bulk of the research from universities needing neutron source or XUV spectroscopic work as well as VECC facilities fall under the broad areas of condensed matter physics and nuclear physics it was felt imperative to create some basic sample preparation, detector preparation and characterization facilities. The importance of a well-characterized clean sample and high quality detection systems cannot be exaggerated as interpretation of all experimental results is critically dependent on them. IUC thus developed a basic infrastructure both in terms of scientific personnel and research equipment to be made available to the scientific community of the country at large, and more particularly, for a better utilization of DAE facilities by university researchers.

In this article a brief description is given of the various activities of IUC-DAEF to promote university-DAE interaction, the major development activities undertaken so far and the facilities set up for the scientific community.

Organization of the IUC-DAEF

IUC-DAEF is a registered autonomous society located on the Takshasila campus of the Devi Ahilya Vishwavidyalaya, Indore. It has three centres at Bombay, Calcutta and Indore. Each will have a user committee to lay down guidelines for the use of the facilities.

IUC-Bombay centre

The activities of this Centre are primarily focussed on the neutron scattering facilities around the DHRUVA reactor in BARC, Bombay. The Solid State Physics Group of BARC provides local support for these activities. The following neutron spectrometers are available for research at the Dhruva reactor: profile analysis powder diffractometer, single crystal diffractometer, triple axis spectrometer for inelastic scattering studies, polarized neutron analysis spectrometer, high-Q diffractometer, filter detector spectrometer, double crystal inelastic spectrometer and high resolution quasi-elastic spectrometer. In addition the following facilities are available at CIRUS reactor: small angle spectrometer, neutron interferometer, rotating crystal spectrometer and triple axis spectrometer.

IUC in collaboration with the Solid State Physics Division of BARC conducts an annual course on various aspects of neutron scattering. Two weeks of this 3-week course are devoted to general lectures and tutorial session on neutron scattering and one aspect of neutron scattering is then dealt with in greater detail. The courses are attended by 25 to 30 participants consisting of young research scholars and faculty members likely to apply for projects on these neutron spectrometers. After the lecture course, the participants attend a practical demonstration of the neutron spectrometers.

Project proposals are then received from university scientists for use of these neutron spectrometers. These proposals are examined at BARC and the investigators invited to present their proposals. The funding for the accepted proposal is kept to a minimum and no funds are normally given for setting up capital equipment. There are at present 29 projects on the neutron spectrometers approved since January 1991. There are also a few chemists who have projects on the study of micelles, surfactants etc using the small angle neutron scattering facility.

IUC-Indore centre

The activities of IUC-DAEF started in 1990. A summary of the activities is given below:

Synchrotron beam line work

Indus-1, the synchrotron electron storage ring at CAT would give synchrotron radiation primarily in the XUV region of the electromagnetic spectrum. The critical wavelength λ_c is 61 Å. The actual use of the radiation for carrying out experimental work is done in an experimental chamber. The storage ring has an electron current in ultra-high vacuum of the order of 10^{-10} torr and the ring is highly shielded. The radiation comes out of a port in the shield and is highly collimated both in vertical and horizontal planes. For Indus-1 most of the intensity is in the horizontal plane with a divergence of about 10 mrad. The intensity of radiation declines sharply on the low wavelength side of λ_c and gradually on the longer wavelength side. The beamline is essentially an interface between the radiation source and the experimental system to be investigated using this radiation. Usually a number of beam lines operate simultaneously on the storage ring and their characteristics differ according to applications. IUC is involved in developing two different beam lines for carrying out experiments of interest to university scientists. One is meant for photoelectron spectroscopy and the other for X-ray spectroscopic EXAFS work in the soft X-ray region. The main aspects of synchrotron radiation source influencing the beam lines include the immobility of the source, the wide spectral range available, the vertical and horizontal angular divergences, the polarization character and the large distance between the source and the experimental chamber. The other factors include radiation safety considerations, sizes of bending magnets, acoustic delay line, the fast closing gate valve near the source, intensity of radiation and the consequent thermal load and the required resolution. Also, the experimental system comprising the sample chamber, detecting systems etc. is usually bulky and difficult to move in UHV conditions necessitating a fixed exit slit for radiation.

The beam-line essentially comprises of various optical elements and their spatial arrangements and housings subject to various constraints like vacuum requirements and necessary dynamical motions of optical elements. For INDUS-1, since the radiation used is in the vacuum ultraviolet soft X-ray region of the electromagnetic spectrum one has to employ grazing incidence reflection optics. Also in this region carbon contamination of optical elements can drastically reduce the reflectivities of the optical elements. There is therefore a need for clean vacuum. There are also stringent restrictions on the acceptable surface roughness and tangent errors of optical elements. These elements have to be positioned with high precision. Ideally one can have a separate beam line for each of the experiments using synchrotron radiation. However, to minimize the expenditure in establishing beam lines the experimental requirements of a large number of users are combined.

Photo-electron spectroscopy beam line

This beam line covers the spectral range of 60–1600 Å i.e. photon energy varying from 200 down to 7 eV. The optical design of the beam line was worked out depending on the experiments planned on the beam line, the resolution necessary, the optimization of the optical system for various aberrations and image quality considerations.

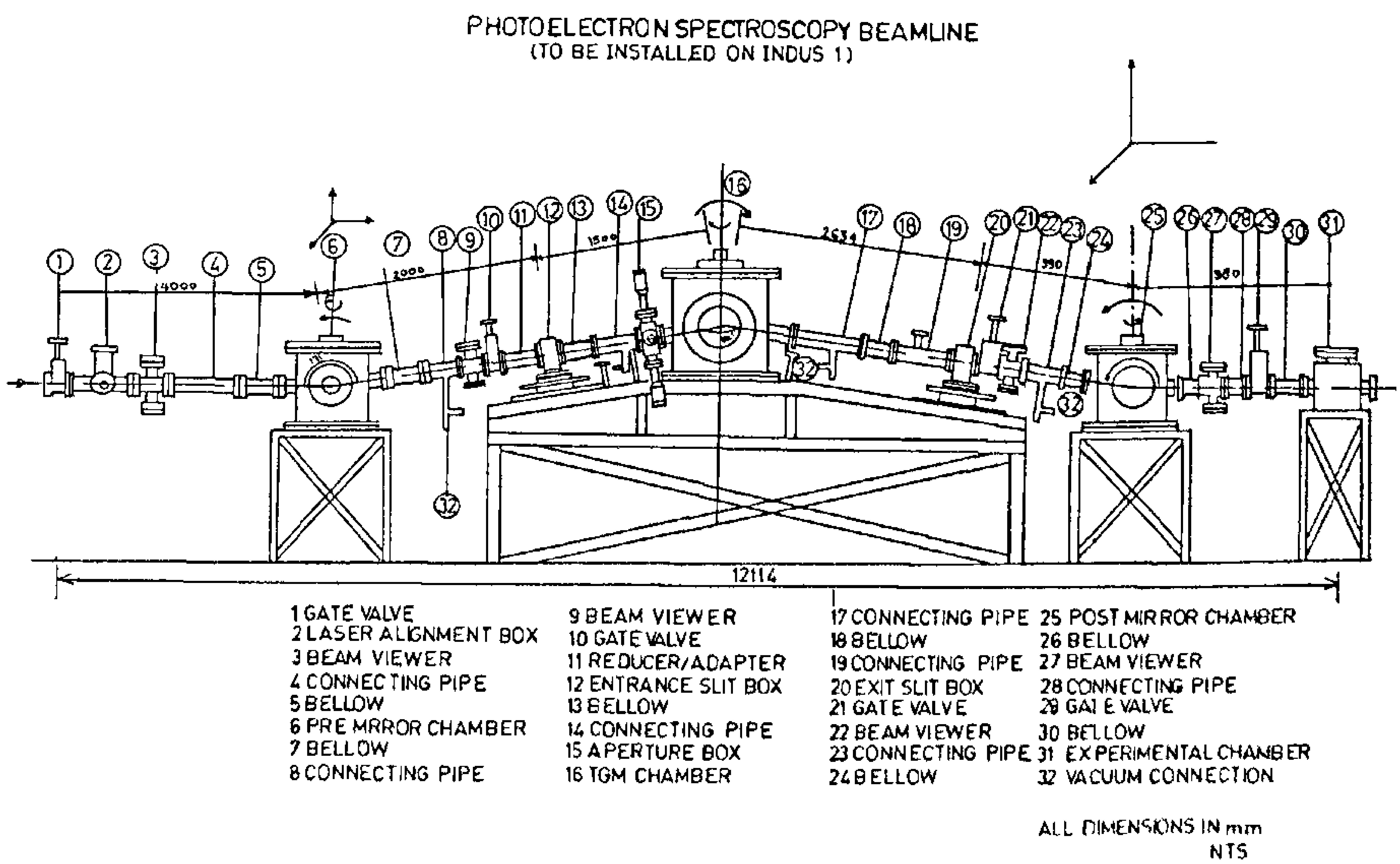

Figure 1. Photoelectron spectroscopy beam line to be installed by IUC on INDUS-1 at CAT, Indore

The optical layout of the beam line (Figure 1) consists of three modules, a pre-mirror, a monochromator and a post-mirror followed by an experimental chamber. The crucial component is the monochromator. A toroidal grating monochromator (TGM) is chosen as it focuses both in the horizontal and vertical planes and gives an acceptable resolution with substantially improved flux. Also, in TGM the angle between the incident and diffracted directions is the same for all wavelengths and different wavelengths are obtained at the exit slit of TGM by simply rotating the toroidal grating and thereby changing the angle of incidence and diffraction. For TGM to be used in PES beam line the angle between the incident and diffracted directions is 18°. Three gratings are required with different line spacings to cover the entire wavelength range of interest: grating I with 1800 lines/mm to cover the range from 60 to 180 Å, grating II with 600 lines/mm to cover the range from 180 to 540 Å and grating III with 200 lines/mm to cover the range from 540 to 1600 Å. Typical achievable resolutions are about 0.02 eV at a photon energy of 10 eV (using grating III), 0.075 eV at 35 eV (grating II) and 0.25 eV at 100 eV (grating I). The parameters for the toroidal grating monochromator which give the above resolution were worked out by S. K. Kulkarni of Poona University under the guidance of V. G. Bhide using a program obtained from BESSY. A mechanical arrangement allows one to change the gratings in the UHV condition without breaking vacuum to enable one to span the entire spectral range.

The pre-mirror brings the radiation from the storage ring exit slit to the entrance slit of the monochromator. An ellipsoidal pre-mirror with a demagnification ratio of 2:1 has been chosen. A complete ray tracing programme for the entire beam line has been indigenously developed by A. V. Pimpale and Geeta Iyengar of IUC. This program considers the reflectivity of various optical surfaces, surface roughness and tangent errors in the calculation. This program does not necessitate the post-mirror to be ellipsoidal and a toroidal post-mirror is used cutting down the costs. For alignment it is necessary to have precision x-, y- and z-motions for both mirrors and rotation around the three axes. The linear motions should have an accuracy in microns and the angular motions in millidegrees. The design of the chambers for housing the pre- and post-mirrors along with requisite motions in UHV has been worked out and a trial fabrication of one chamber will be taken up soon.

The different chambers such as pre-mirror, TGM, and the post-mirror will be connected by bellows, pipes and appropriate slits. Viewports and laser alignment systems will also be inserted. Vacuum ports will be provided at different intervals and pumping done using turbo-molecular and ion pumps. Some turbo- and ion-pumps have been procured. The completed beam line will be 12 I m long. A scaled-down model of the beam line has been made for visualization.

The experimental chamber will be essentially a photoelectron spectrometer with a sample preparation chamber, spectrometer chamber and an analyser chamber connected to the spectrometer by a lens. The hemispherical electron analyser has a mean diameter of 180 mm and is expected to give 0.7% energy resolution with 2 mm slit width. This system is being developed at the Indian Institute of Science, Bangalore, by M. S. Hegde and D. D. Sarma on a project funded by IUC-DAEF.

Beam line for X-ray spectroscopic studies

For this beam line spectral purity and high resolution are more important than PES beam line. A plane grating is therefore more suitable as a dispersing element compared to toroidal grating. To have a fixed entrance and exit slits it is necessary to precede the plane grating with a plane mirror. An analytic theory of the kinetic principle involved in the plane mirror-plane grating combination has been worked out by A. V. Pimpale, S. K. Deshpande and V. G. Bhide in an earlier publication. This theory enables one to work out the positions of the plane mirror and plane grating and the necessary motions for the monochromatization of this beam line. An elliptical post-mirror takes the monochromatized radiation to the experimental chamber. An addition of elliptical pre-mirror to the orthogonal plane decouples vertical and horizontal focussing to achieve a better quality image with enough flux. The completed optical design of the beam line is shown in Figure 2. A ray tracing program has been developed by A. V. Pimpale and V. S. Edlabadkar in IUC and the tolerances in the positions of the optical elements as well as their surface conditioning, the precision requirements for the angular motions involved in scanning etc. have been worked out. In view of the cost involved, the advisability of building a single beam line with IUC and BARC sharing the work and the cost is now being considered.

EXAFS spectrometer and soft X-ray system

Even before the formal registration of IUC-DAEF as an autonomous society, the task of developing a mechanical design of an EXAFS spectrometer was given to A. V. Pimpale and S. M. Chaudhari at Poona. This spectrometer is of the Johansson type using bent and ground focussing and dispersing crystals. The source slit, the crystal and the detector are on a Rowland circle of 400 mm diameter. Two linear motions are sufficient to achieve wavelength scanning. These are achieved through software-controlled DC motors. Optical encoders are placed in the two arms along which linear motions take place so that the crystal and detector can be positioned with an accuracy of 5 μm. The sample whose EXAFS is to be determined is alternately

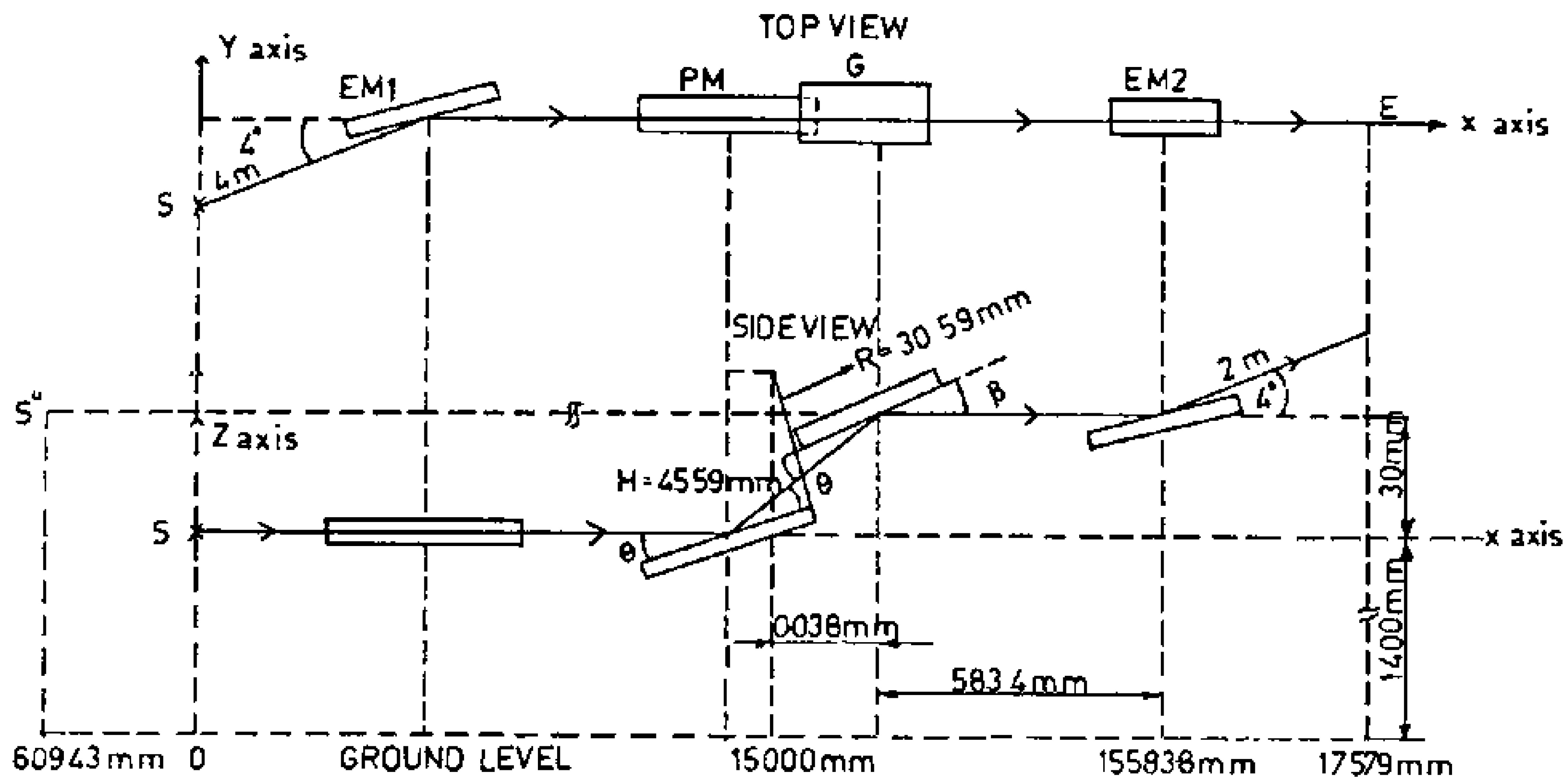

Figure 2. Schematic arrangement of the plane grating monochromator beam-line planned on INDUS-1 at CAT.

introduced and removed from the path of the beam to get the transmitted intensity with and without the sample. A resolution of 8 eV is obtained using a Si (311) reflection at the Copper K_α energy. This spectrometer, manufactured and marketed by Inconix of Poona, is installed on the 12 kW rotating anode X-ray generator at IUC-DAEF and has provided service to a number of users so far.

As stated earlier the radiation from INDUS-1 will be mainly in the soft X-ray-ultraviolet region of the electromagnetic spectrum. It is therefore necessary to develop expertise in the country to work in spectroscopy. It will also be of considerable interest to study the reflectivity properties of optical materials in this wavelength region. Work has therefore been undertaken to develop a laboratory soft X-ray source, a monochromator to disperse this radiation and an experimental system to study the traditional absorption spectroscopy as well as reflection properties. This work is supported by the Department of Science and Technology through a research project.

The soft X-ray source is designed to be of a rotating anode type with a flange-mounted rotating aluminium target (Rigaku, Japan) and an X-ray source chamber built around it. The power supply, control system, water cooling arrangements, cathode assembly, and filament mounting etc. are now complete. Vacuum is achieved using a turbo molecular pumping system backed by a rotary pump. The work of commissioning the source will start shortly. X-ray dispersion is achieved using a double crystal monochromator and high lattice spacing crystals such as KDP. A vacuum-compatible monochromator including a Soller slit collimating system has been designed and fabrication is in progress. Work on the design of an experimental chamber is also in progress.

Infrastructural facilities

Experimental facilities (see box) have been set up in IUC-DAEF, Indore and made available to university users.

Infrastructure facilities of IUC-DAEF

* EXAFS facility on one window of the 12 kW rotating anode X-ray generator.
* Powder diffractometer with attachments to go up to 1200 K and down to 90 K on the other window of the rotating anode generator.
* ESCA instrument for XPS, UPS and Auger electron spectroscopy.
* AC magnetic susceptibility set-up (operating at room temperature and 77 K) with provision for measuring real and imaginary susceptibilities up to seventh harmonic.
* Automated resistivity set-up to measure resistivity from room temperature to 15 K. This is a home-made set-up on a closed circuit refrigerator capable of measuring resistivity of three samples at a time.
* Automated thermopower set-up in the above temperature suitable for semiconducting samples.

- A planetary ball mill with agate cup and balls, two resistive furnaces going upto 1000°C and a small arc furnace for preparing materials are available.

Liquid nitrogen is produced from an old nitrogen plant. A second hand liquid helium plant will soon operate so that work at 4.2 K can be done.

Workshops/short-term courses

IUC also conducts workshops and discussion meetings on topics of interest and relevance.

Projects at IGCAR, Kalpakkam

Proposals have been received from several university groups. This includes one to carry out ion beam channeling studies and another to develop RBS and NRA facilities.

IUC-Calcutta centre

The IUC-Calcutta centre started functioning from February 1992 in Bidhan Nagar and works in association with VECC. There are 19 research projects going on in VECC. These were mostly continuation of projects which the UGC was sponsoring before IUC was formed. A thin film coating unit with a digital thickness monitor has been commissioned. A microbalance with a sensitivity of 10 μg has been procured for precise determination of the films deposited. A 100 ton press has been set up to prepare pellets. The detector laboratory has two thin film-coating units, one for gold and aluminium contact layers and the other for lithium coating. Some Si (Li)-charged particle detectors and a 300 mm Si (Sb) barrier detectors in transmission mounts have been procured. Also available are equipment such as HP Ge GMK detectors, RCA 8575 photomultiplier tubes and an Si (Li) X-ray detector. The electronics laboratory consists of NIM electronic covering bins, amplifiers, CFDs, pre-amplifiers, power supplies, timing single channel pulse shape analysers. A Mössbauer spectrometer is being used by scientists from universities and other institutions in the eastern region. A positron annihilation and angular correlation equipment is now being set up. The Centre has successfully prepared a ^{57}Co isotope using the reaction ^{56}Fe (d, n)^{57}Co. In collaboration with the chemistry group at Andhra university, a radiochemical separation of the carrier-free ^{57}Co isotope from the target using ion exchange chemical process has been carried out. The first open source sample prepared on mylar compares favourably with the Amersham standard source. Diffusion of the source in non-magnetic matrix like Cu or Rh is presently in progress. A CEMS detector has been fabricated and is ready for testing. ^{22}Na positron activity has been produced. Carrier-free chemical separation is in progress.

The IUC, Calcutta also conducts discussion meetings on accelerator-based chemical and biological studies. Project proposals are considered for funding.

Conclusion

If this institution succeeds in bringing together scientists from universities and DAE in the pursuit of a common goal it can serve as a model for future consortia for collaboration between different streams of scientists in the country.

ACKNOWLEDGEMENTS We thank Prof S Ramaseshan for encouraging us to write this article. Thanks are also due to all our colleagues in all the centres of IUC-DAEF and in BARC, CAT and VECC for their encouragement and support

Received 6 October 1993, accepted 27 October 1993