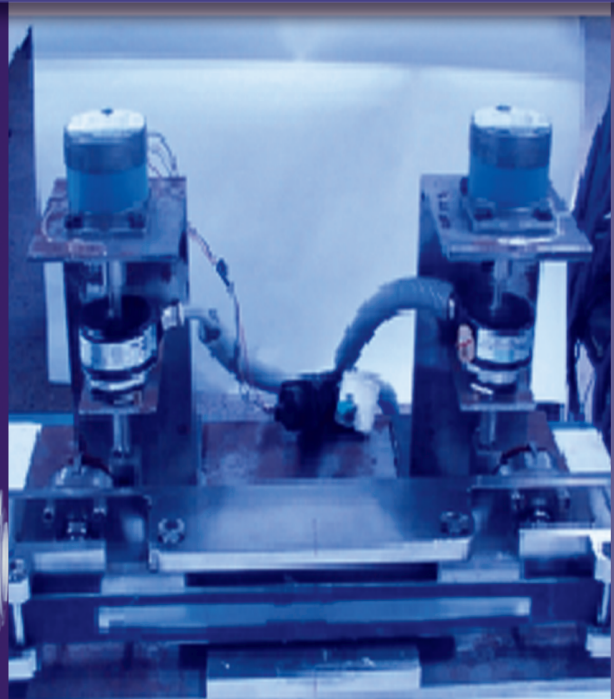
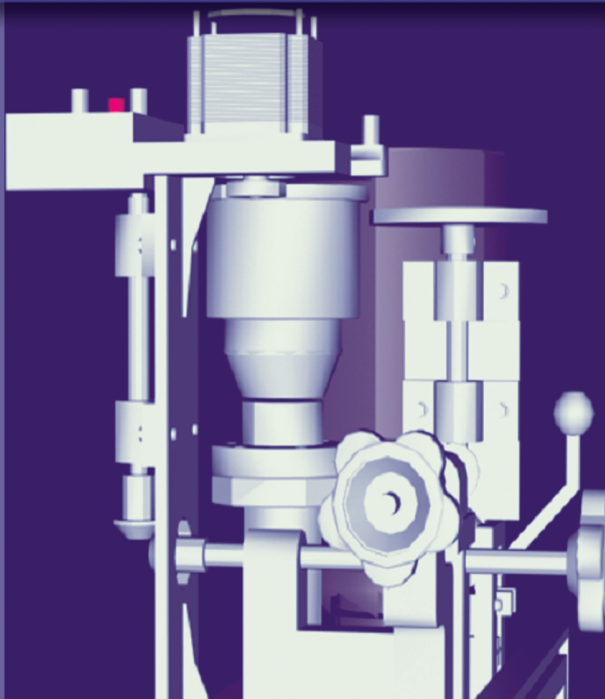


# BARC

## HIGHLIGHTS



PHYSICAL  
SCIENCES

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HIGHLIGHTS

**PHYSICAL  
SCIENCES**



भारत सरकार  
Government of India

**भाभा परमाणु अनुसंधान केंद्र**  
**BHABHA ATOMIC RESEARCH CENTRE**

स्वर्ण जयंती वर्ष  
GOLDEN JUBILEE YEAR  
2006-2007

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## FOREWORD

Bhabha Atomic Research Centre (BARC) is celebrating its golden jubilee year during 2006-07. On 20<sup>th</sup> January, 1956, Pandit Jawaharlal Nehru formally inaugurated the Atomic Energy Establishment Trombay (AEET), which was renamed as Bhabha Atomic Research Centre (BARC) on January 22, 1967. As a premier R & D centre of the Department of Atomic Energy (DAE), BARC has a mandate to provide R & D support to the nuclear power programme, to pursue all activities related to nuclear fuel cycle, to operate research reactors for supporting neutron beam research and supplying radioisotopes for various applications, to conduct frontline basic research in physical, chemical, biological and engineering sciences all of which leading towards improving the quality of life of our people. The achievements BARC has made over the last 50 years are well known not only to the scientific community in the country but also to our people at large. Scientific achievements made by this premier research centre are well documented in various publications of DAE including the series "BARC Highlights". During this golden jubilee year, we have made an effort to bring out some glimpses of recent research and development accomplishments in the form of 8 volumes, highlighting the following areas:

1. Nuclear Fuel Cycle
2. Physical Sciences
3. Chemical Science and Engineering
4. Materials Science and Engineering
5. Life Sciences
6. Reactor Technology and Engineering
7. Electronics, Instrumentation and Computers
8. Environmental Science and Engineering

These volumes will showcase the latest work in the aforementioned areas and will demonstrate how each of these is directed towards achieving the overall goal of using nuclear energy for the benefit of our people.

Nuclear energy programme in India has now reached a level of maturity. Today, India is self-sufficient in building nuclear power stations of 540 MWe capacities and has gained mastery over the entire fuel cycle. We are at the threshold of entering the second stage of nuclear power programme, in which a rapid growth in installed capacity is expected through the fast reactor programme. In the area of basic research in science and engineering, BARC has been maintaining a lead position both in national and international scenario. One of the strongest points of basic research in BARC lies in its capability in building sophisticated research facilities in-house. The core competence of the scientists and engineers in our centre covers a very wide range as is reflected in the 8 companion volumes getting released on the occasion of the golden jubilee year.

Nuclear Physics research is focussed on nuclear collisions at high energies and formation of hot and dense nuclear matter, study of nuclei with large spins and deformations and underlying symmetries and investigation of nuclei away from the line of stability and formation of super-heavy nuclei. The experimental programmes have been pursued at the Pelletron accelerator facilities at Mumbai and Delhi. Current research in astronomy and astrophysics are directed towards gaining an in-sight into the non-thermal processes in the Universe and also to understand the sources of high energy cosmic radiation and the processes which enable charged particles to be accelerated to energies of upto 1020 eV and beyond. Research activities in the emerging areas in atomic and molecular spectroscopy include cluster physics using supersonic molecular beam, laser spectroscopy, spectroscopy of trapped ions, single molecule spectroscopy, mass spectrometry of bio-molecules and spectroscopy of quantum solids. R & D efforts in the development of specialized optical components, devices, data acquisition and control system and instruments were also continued.

Significant contributions have been made in the development of various beamlines on synchrotron radiation sources at Raja Ramanna Center for Advanced Technology, Indore. Recently, three beamlines namely, the High Resolution Vacuum Ultra Violet (HRVUV), Photo Physics (PP), Angle Resolved Photo Electron Spectroscopy (ARPES) were established at synchrotron sources at Indus-I. The Angle

Resolved Photoelectron Spectroscopy (ARPES) beamline has been used to study photo-emission spectroscopy for probing electronic states in atoms, molecules and solid surfaces and High resolution VUV beamline, has been employed in high resolution studies in the range 700–2000 Å. The Photoabsorption Spectroscopy Study beamline is under installation and will be used for near-to-absorption edge (17–225 Å) spectrum analysis in terms of local electronic structure. Photo Electron Spectroscopy (PES) beamline will use X-rays in the energy range from 0.8 keV to 15 keV. The heart of the beamline is an indigenously developed double crystal monochromator.

BARC has developed multi-channel Raman spectrometer for analysis of microparticles, scanning monochromator for isotopic analysis and electron spectrometers meet some of the increasing demands for improved analysis of materials. An optical periscope has been specially designed for video recording of objects with a resolution of 0.7 mm in the core of Fast Breeder Test Reactor. A notable development were the room temperature operating sensors based on Te and conducting polymer thin films. BARC has made significant contributions to the development of mass spectrometric techniques in nuclear areas and has expertise in areas like HV/UHV technology, precision mechanical engineering and fabrication, magnet technology, ion optics, sensitive and stable analog and digital electronics, data systems that are important to develop sophisticated mass spectrometers such as Isotopic Ratio Mass Spectrometers (IRMS), Inductively Coupled Plasma source Mass Spectrometer (ICPMS), Quadrupole Mass Spectrometer (QMS) and double focusing mass spectrometer.

New radiation detectors and imaging systems such as X-ray diffraction, tomography, EXFAS, X-ray holography are developed at BARC for nuclear, defence and space technology applications. BARC continues research in advanced functional materials for nuclear reactors, synchrotron sources, lasers and other applications. Cylinders of high temperature superconductors have been fabricated for application in superconducting motors. Thin films and multilayer coatings have been prepared for laser resonators, optical components for synchrotrons and analytical instruments. Single crystals, glasses and glass-ceramics for nuclear particle detectors, lasers, hermetic seals and vacuum components are routinely prepared and fundamental studies on superconducting and colossal magnetoresistive materials have been carried out.

In the area of electron beam technology, with a view of its wide ranging industrial applications for radiation processing like modification of bulk polymers, cross linking of plastic films, foam and cables, sterilization of medical products and food preservation, BARC has developed 500 keV to 10 MeV particle energy and 10 to 30 kW beam power Electron accelerators (DC and RF) and a 10 MeV RF *linac*. Gigawatt single and multi-pulse systems in strategic applications for high power microwave generation and pulsed high magnetic fields for EM welding of metal to ceramic joints are other accomplishments. Shock wave studies using ultra short lasers, development of tunable dye lasers, laser cooling of atoms in traps in 100 micro Kelvin and laser produced plasmas by resonant ionization are some of the areas intensely pursued in BARC. Besides, development of laser-based instrumentation for applications in nuclear fuel cycle and plasma torches with long lives are the other highlights in this area.

In this volume accomplishments of the last few years in the front line areas of physical sciences have been discussed.

Srikumar Banerjee  
Director

## PREFACE

Fundamental research in different branches of Physics, such as condensed matter, lasers, accelerators, neutron scattering, protein crystallography, high pressure physics and nuclear physics employing sophisticated techniques is carried out with zeal at BARC. Simultaneously, there have been consistent attempts to apply the expertise gained towards indigenous development of high-tech instruments/systems and processing of new functional materials and fabrication of devices. Notable accomplishments include the development of particle accelerators, high power gas-gun, radiation detection and imaging systems, high power fast lasers, high-resolution mass spectrometers, neutron diffractometers, beamlines on synchrotron radiation sources Indus-1 and Indus-2. State-of-the-art facilities and expertise have been developed to prepare/process and characterize different materials such as ceramics, glasses, oxide semiconductors, high-  $T_c$  superconductor, etc. in the form of polycrystalline bulk, multilayer thin films and single crystals for basic as well as applied research and for device applications. The Centre also has a strong base to carry out theoretical studies and simulation work in basic as well as applied physics.

This volume of Highlights provides a summary of some of the activities in many areas of research and development in Physics at BARC, conducted during recent years. Physics-based activity is spread over many Divisions/Sections of BARC. The account of work presented here is by no means complete but only representative of the current activities. These activities are briefly described in fourteen sections. References to only a few representative publications are made at the end of each write-up so as to provide information about the contact persons to enable the prospective readers easy access to further details of the work. The write-ups have been kept brief to convey the essence of the activity and it is hoped that the contents will be useful to readers. It may also be mentioned here that the present volume primarily covers the basic research aspects of Physics-based programmes at BARC and technological spin-offs have been presented in related parallel volumes of the current series.

J.V. Yakhmi



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