Raja Ramanna Centre for Advanced Technology, Indore

Foundation Day Function - February 19, 2013

A Warm Welcome from the Entire Staff of RRCAT

to

Dr. R. Chidambaram

Principal Scientific Advisor to Govt. of India & Former Chairman, AEC and Secretary DAE

" Scientific Accomplishments of the Last One Year "

Foundation Ceremony of Centre for Advanced Technology

Dr. Raja Ramanna
Chairman, Atomic Energy Commission

requests the pleasure of your company
at the ceremony to mark the commencement
of the project

CENTRE FOR ADVANCED TECHNOLOGY, INDORE
of the Department of Atomic Energy

on Sunday, February 19, 1984 at 4 p.m.
at Sukhnivas Site, Indore, Madhya Pradesh.

Giani Zail Singh
President of India
will unveil a plaque on the occasion

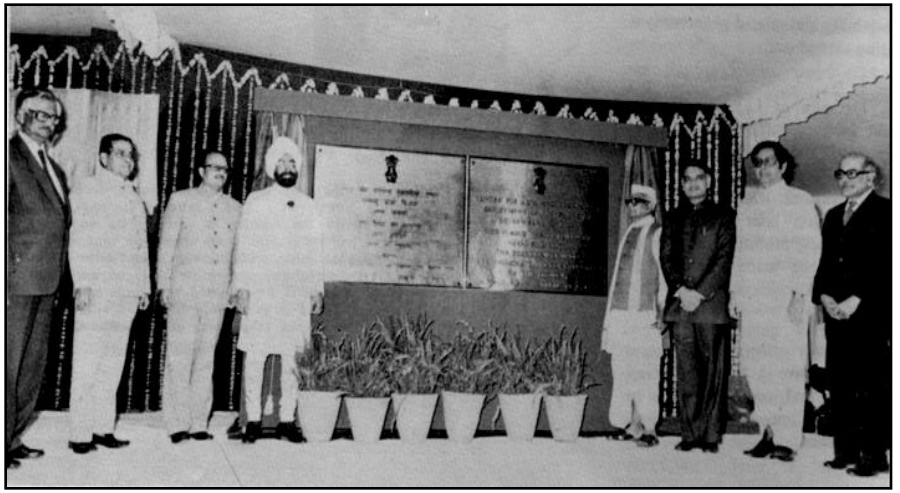
Shri Bhagwat Dayal Sharma
Governor of Madhya Pradesh
will preside.

RSVP :

Head, Publicity Divn.
Department of Atomic Energy
C. S. M. Marg, Bombay-400 039.
Tel : 202 - 2439, 202 - 6823

Engineer-in-charge, DAE
C/o. Collector, Indore.

February 19, 1984



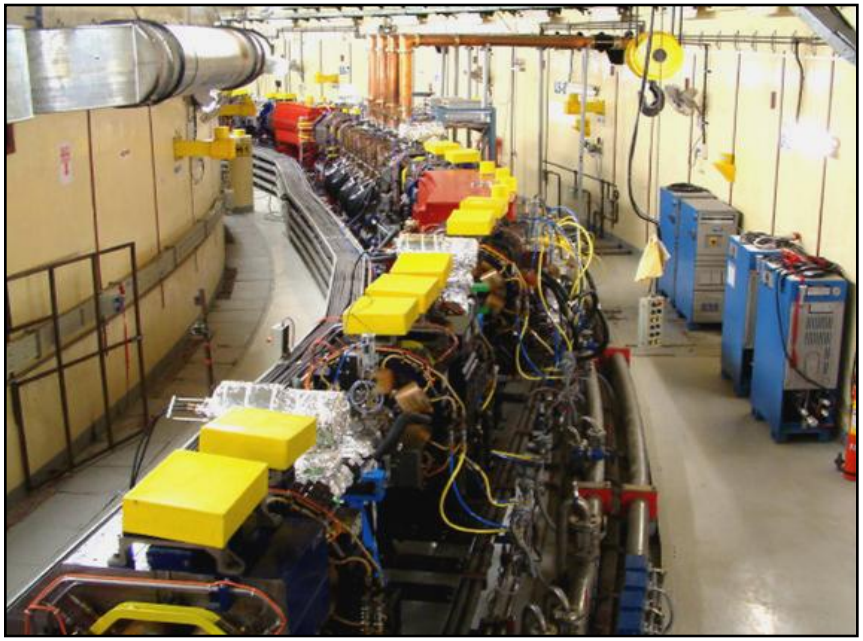
Indus-1 : Synchrotron Radiation Source

- Indus-1 regularly operated at 450 MeV, 100 mA in round-the-clock mode
- 5 beamlines are operational and made available to users

- Soft X-ray Reflectivity
- Angle Integrated Photoelectron Spectroscopy
- Angle Resolved Photoelectron Spectroscopy
- Photophysics
- High Resolution VUV

Indus-2 Synchrotron Radiation Source

Indus-2 SRS operating in three-shift mode at 2.5 GeV, 100 mA



A section of Indus-2 tunnel (172 m)

A section of experimental hall

- 9 beamlines commissioned and made available to researchers
- 8 beamlines under installation / commissioning

Indus-2 RF Power System

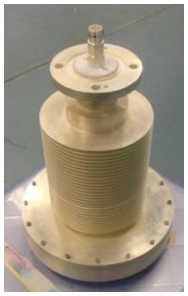
4 RF cavities of Indus-2

Klystron and control panel

- 4 RF cavities energized by a klystron each of 60 kW power at 505.8 MHz.
- Two klystrons failed, limiting operation of Indus-2 to 2 GeV,100 mA.
- Difficulties faced due to non-availability of replacement klystrons.
- Launched on the task of developing new technology of solid state amplifiers.
- Developed a 300 W module. During 2012 its power was enhanced to 500 W.

Development of RF Components

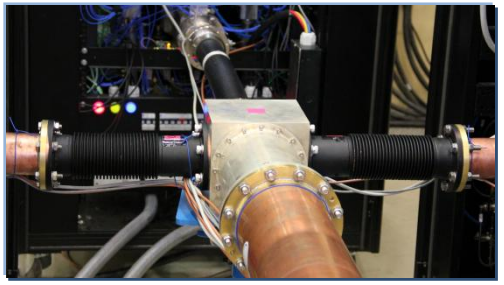
Several RF components such as power combiners, directional couplers, and dummy loads have been developed and used to build up tens of kW power amplifiers using 500 W modules.



16-way Power Combiner

2-way 20 kW Power Combiner

2-way 65 kW Power Combiners



3-way 45 kW Power Combiner

8 kW & 20 kW Coaxial Directional Couplers

30 kW, 75kW, 200 kW CW RF Load

High Power RF Amplifiers for Indus-2

Indus-2 RF station #1

Indus RF Station # 1 & 3 are now powered by solid state amplifiers

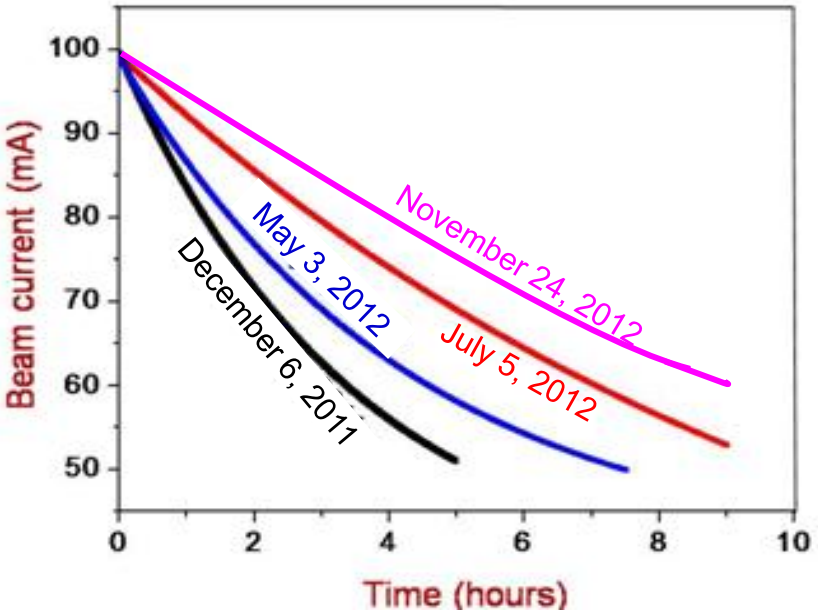
Indus-2 RF station #3

- Total RF power of solid state amplifiers = 175 kW.
- Highest power of solid state amplifiers operating at frequency > 500 MHz in round the clock mode.
- Capability to take up large accelerator projects.

Indus-2 Operation at 2.5 GeV, 100 mA

- 2.5 GeV, 100 mA operation was first achieved in December 2011.
- Synchrotron intensity enhancement by 20 X at photon energies > 15 keV.
- Regular operation of Indus-2 at 2.5 GeV, 100 mA from April 2012.

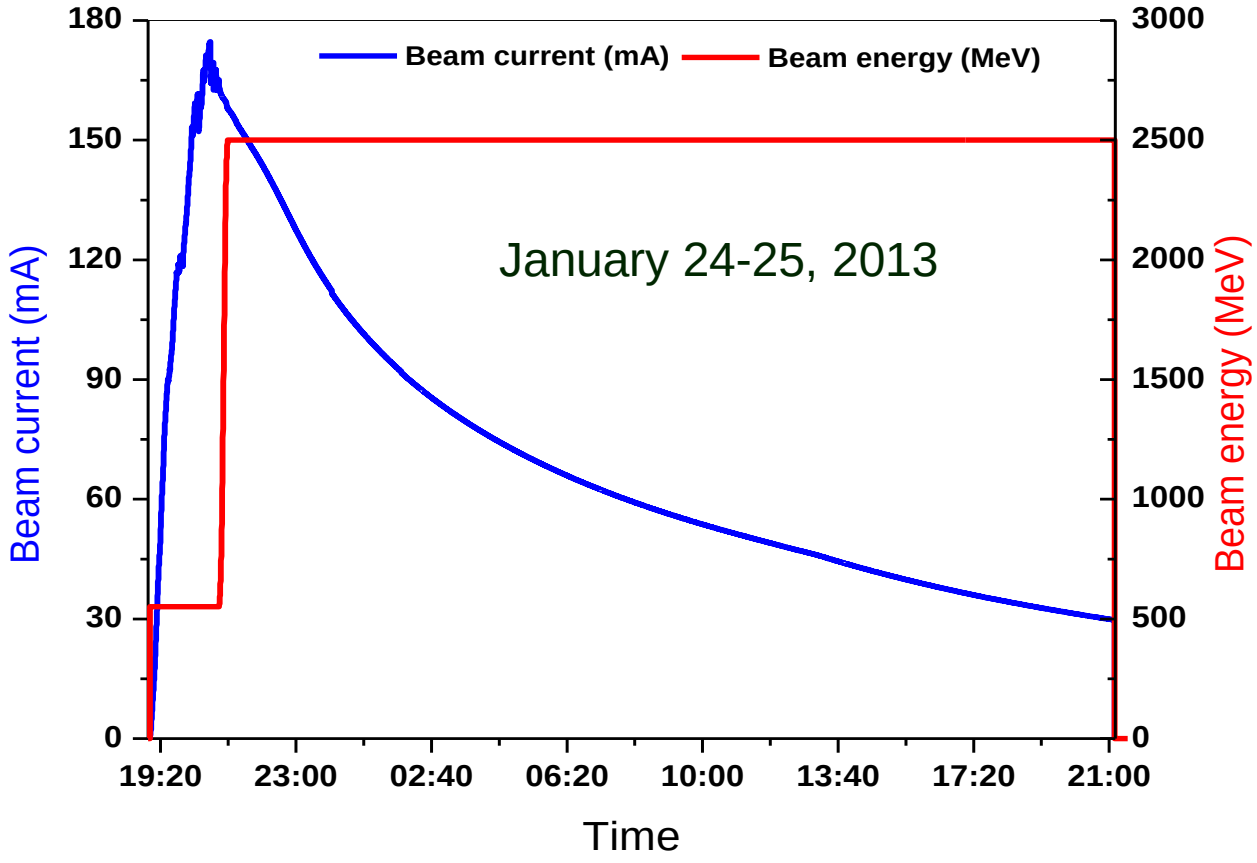
Improvement in Beam Lifetime



Date	Beam lifetime
06-12-2011	5 hrs
03-05-2012	6 hrs
05-07-2012	12 hrs
24-11-2012	16 hrs

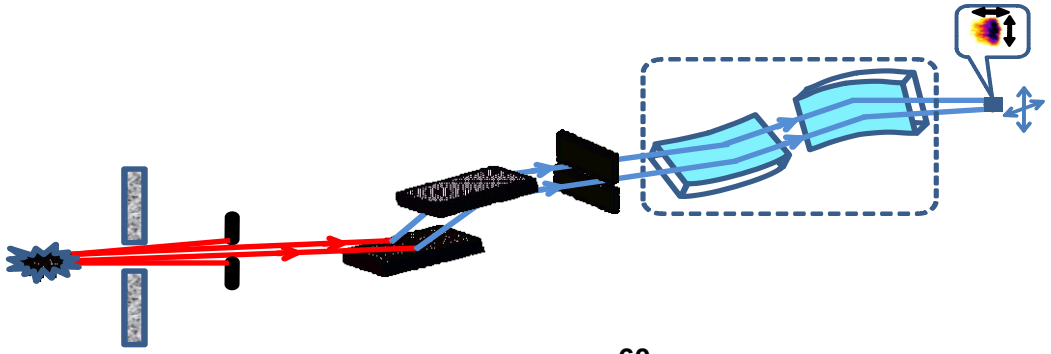
Indus-2 Operation at Higher Beam Current

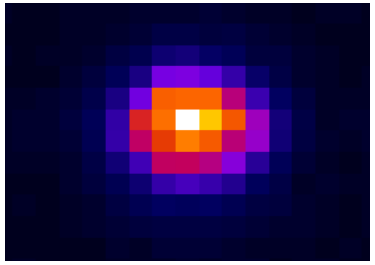
2.5 GeV energy, 158 mA operation

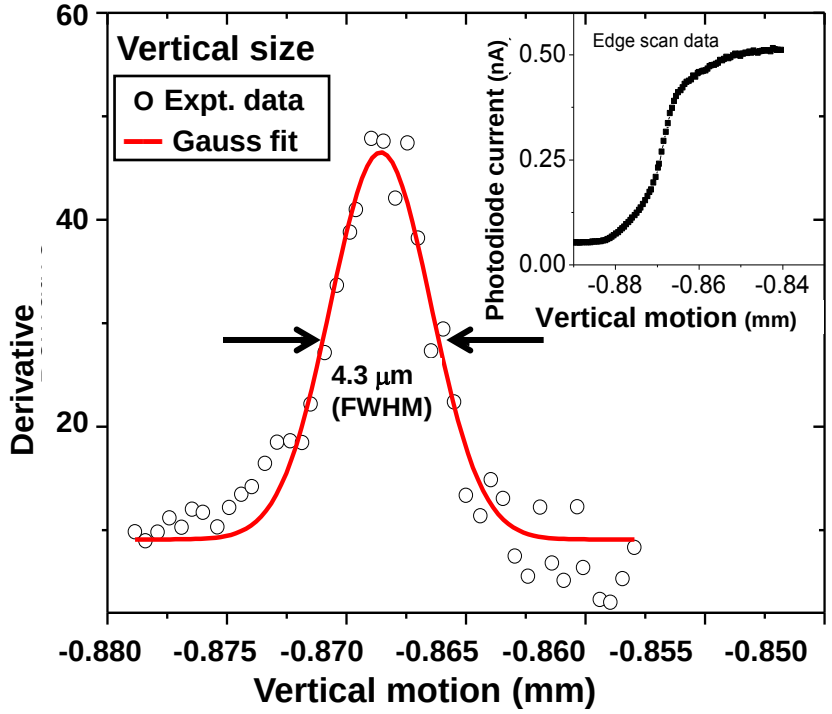


Photon Beam Focusability

- Wire/ edge scan measurements performed on focused photon beam in XRF microprobe beamline







- Measured focused beam size

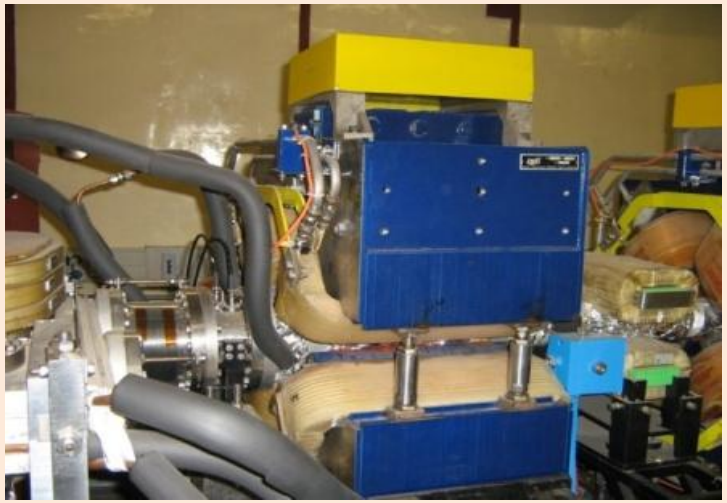
  7.5 μm (H) x 4.3 μm (V)

Improvements in Indus-2 Orbit Stability

Closed Orbit Correction

Closed Orbit correction has been carried out to keep the orbit distortion within 0.5 mm using 88 steering magnets and 56 beam position indicators.

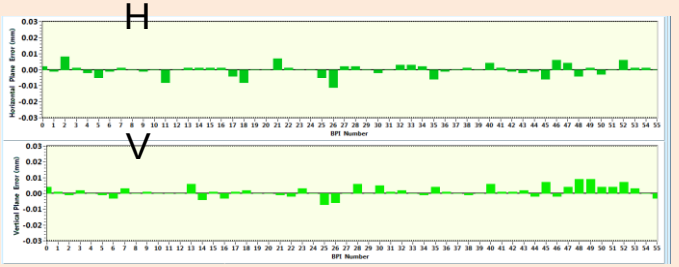
Beam Position Indicator



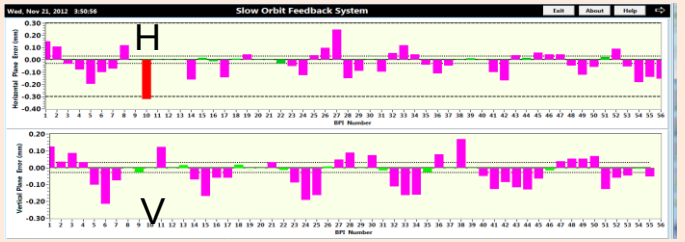
Slow Orbit Feedback Control

A multi-variable active feedback control system has been developed and installed to actively keep the electron orbit within ± 30 µm.

Feedback control ON



Feedback control OFF

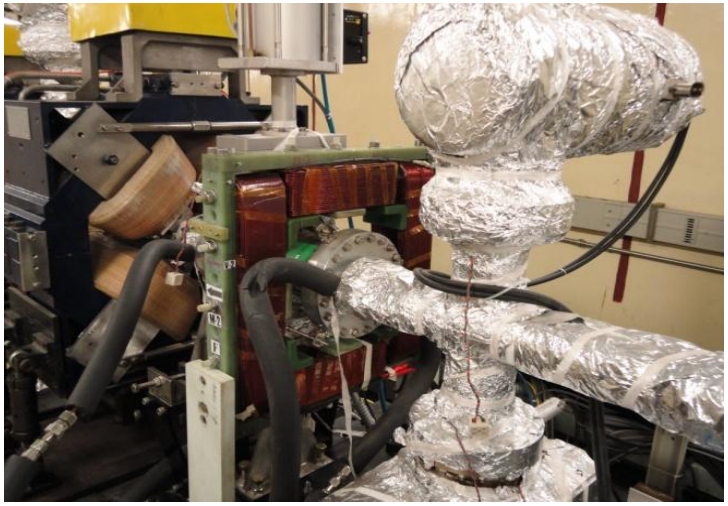


Development of Magnets for Fast Orbit Feedback System

High bandwidth, low inductance air core magnets have been developed for correction of high frequency perturbation of orbit in Indus-2.

4 corrector magnets have been installed in Indus-2 ring for local beam orbit correction for BL-8.

Magnet in measurement bench



Corrector magnets installed in Indus-2

Operational Beamlines on Indus-2

- Dispersive EXAFS (BL-8)
- Energy Dispersive XRD (BL-11)
- Angle Dispersive XRD (BL-12)
- X-Ray Fluorescence Microprobe (BL-16)
- X-ray Lithography (BL-7)
- X-Ray Photoelectron Spectroscopy (BL-14)

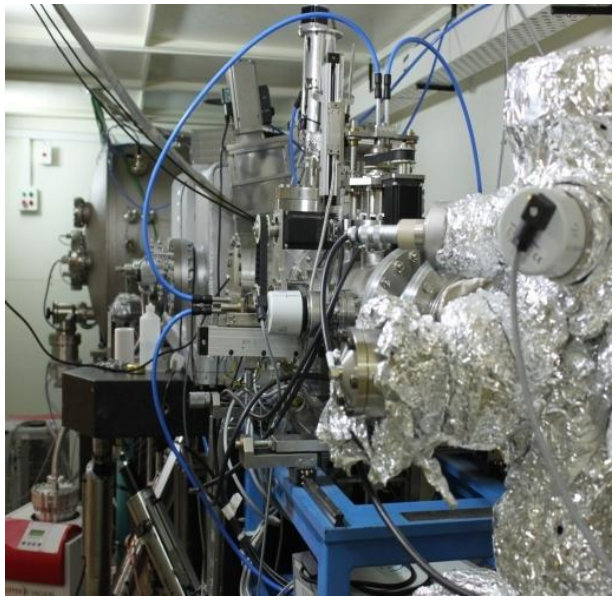
✓ Protein Crystallography (BL-21)

✓ Visible Diagnostics (BL-23)

✓ Scanning EXAFS (BL-9)

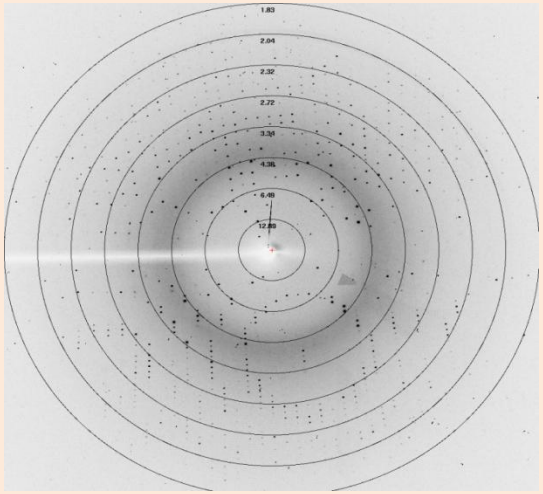
Commissioning of Protein Crystallography Beamline

(High Pressure Physics Division, BARC)

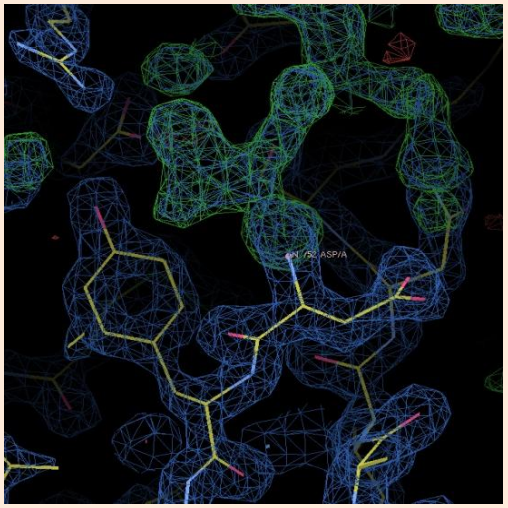


- Energy range : 5 - 20 keV
- Resolution $\Delta E/E$: 2.5×10^{-4}

Single crystal of Hen egg Lysozyme
Resolution : 1.4 Å



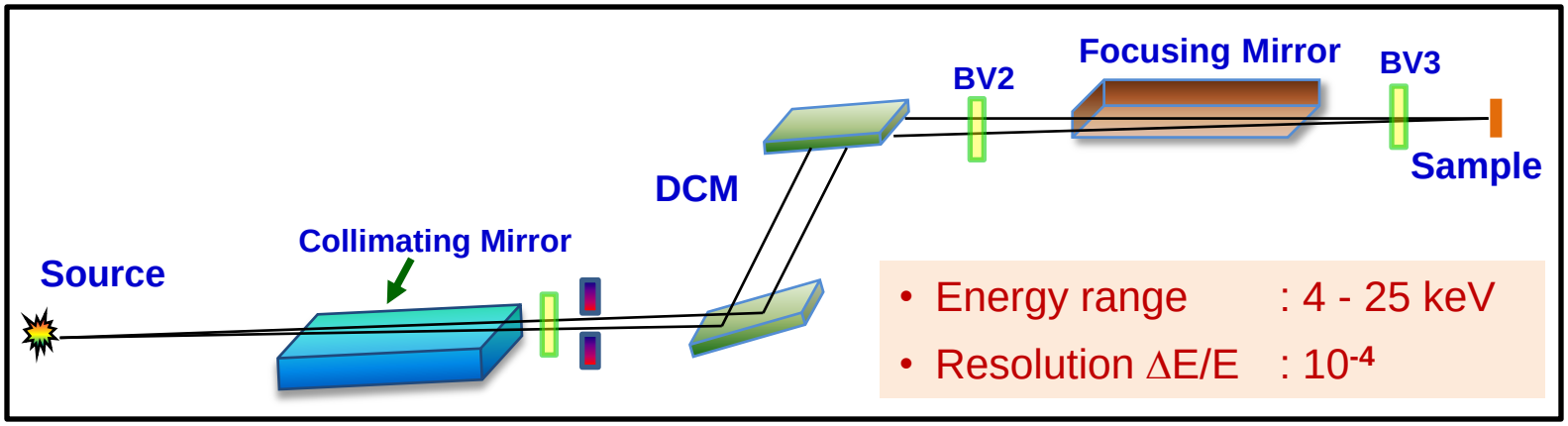
Data from single crystal acquired by X-Ray CCD



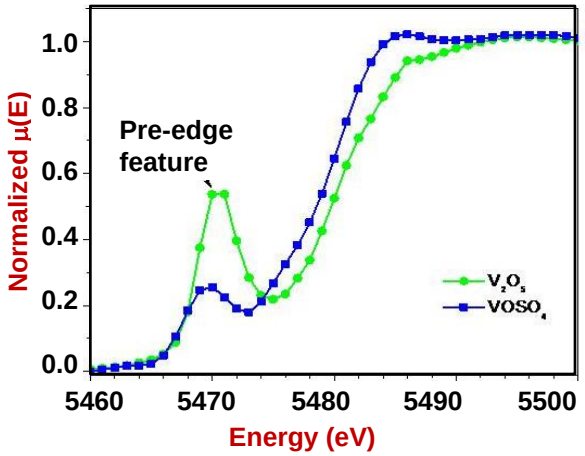
Electron density map computed from the data

Commissioning of Scanning EXAFS Beamline

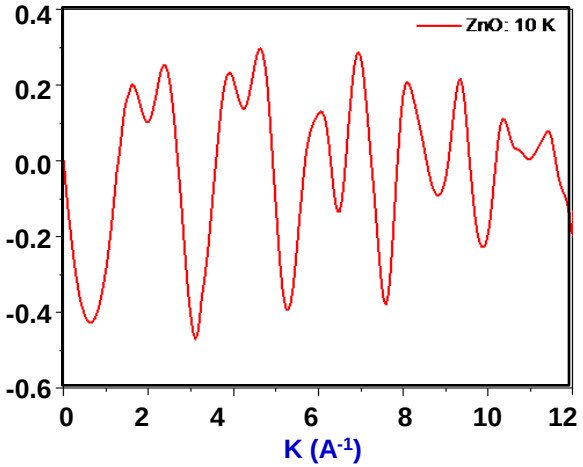
(Applied Spectroscopy Division, BARC)



Optics hutch of beamline

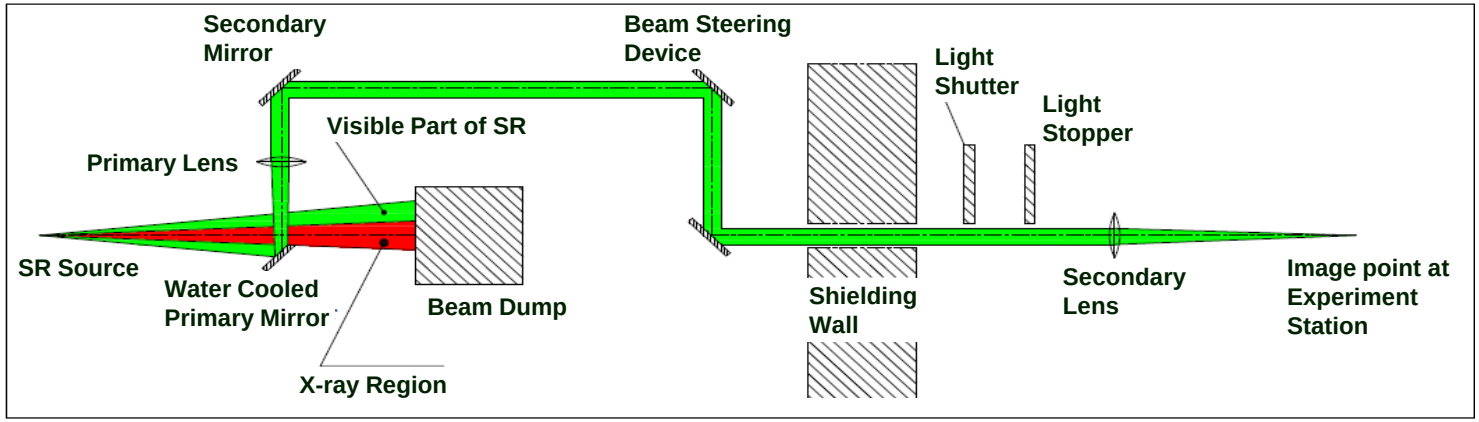


XANES data of $NaVO_3$ at V edge



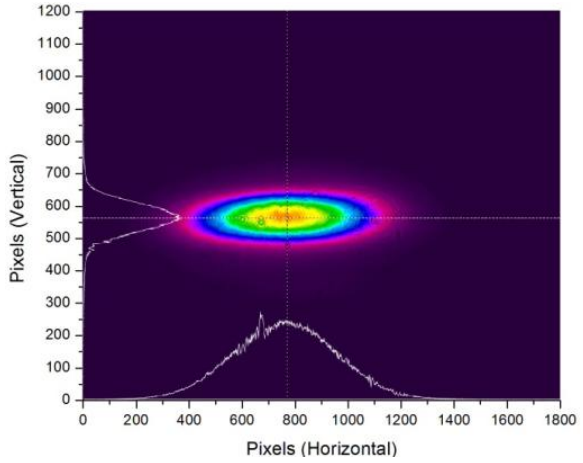
EXAFS data of ZnO at 10K

Commissioning of Visible Diagnostic Beamline

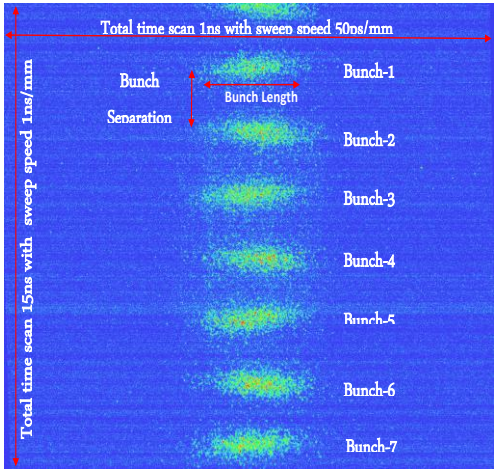


- Bunch length, Bunch filling pattern, Longitudinal instabilities

View of the Beamline

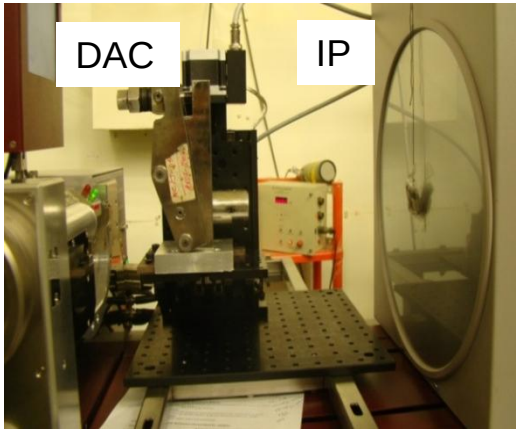


Beam profile of visible light

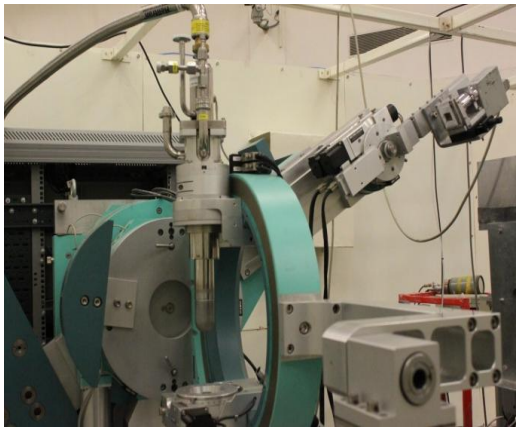


Consecutive bunches

Upgradation of Operational Beamlines

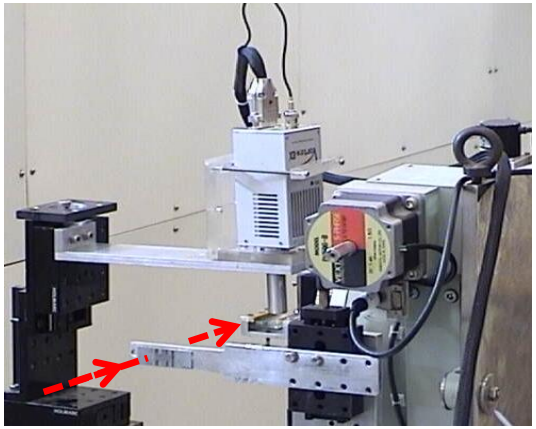


Diamond Anvil Cell
on ADXRD beamline



Liquid He cryostat on diffractometer
in ADXRD beamline

Low temperature facility
on EXAFS beamline

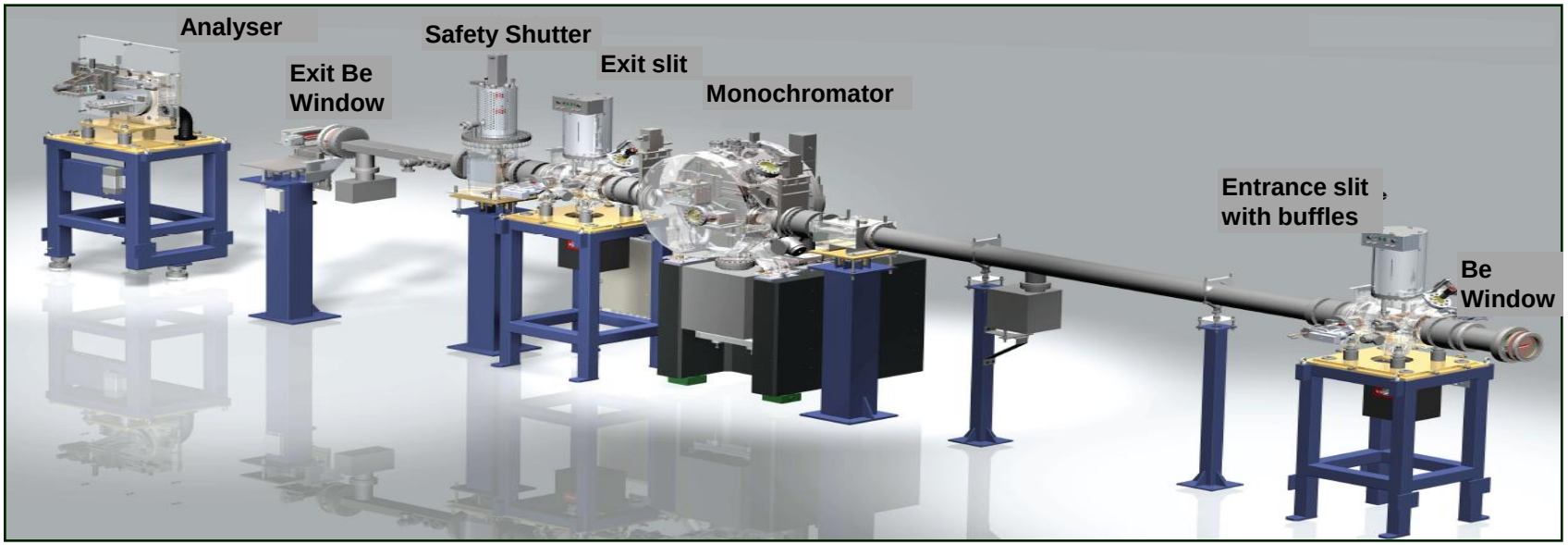


Total external reflection
facility on XRF Microprobe

X-ray Imaging Beamline BL-4

(Under Commissioning)

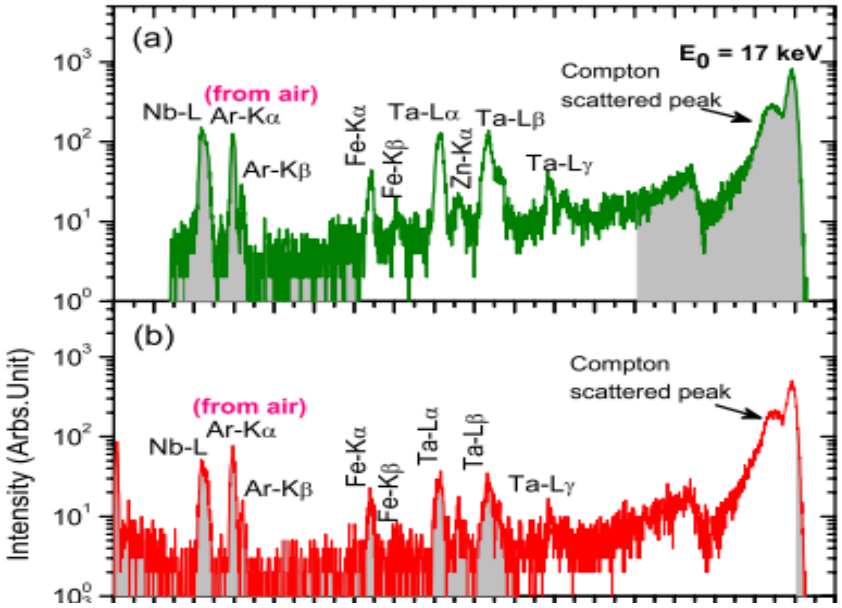
- Energy range : 8-30 keV
- X-ray absorption and phase contrast imaging



- Advanced materials for applications in defence, nuclear and space research.
- Absorption based micro-tomography, study of biological materials.

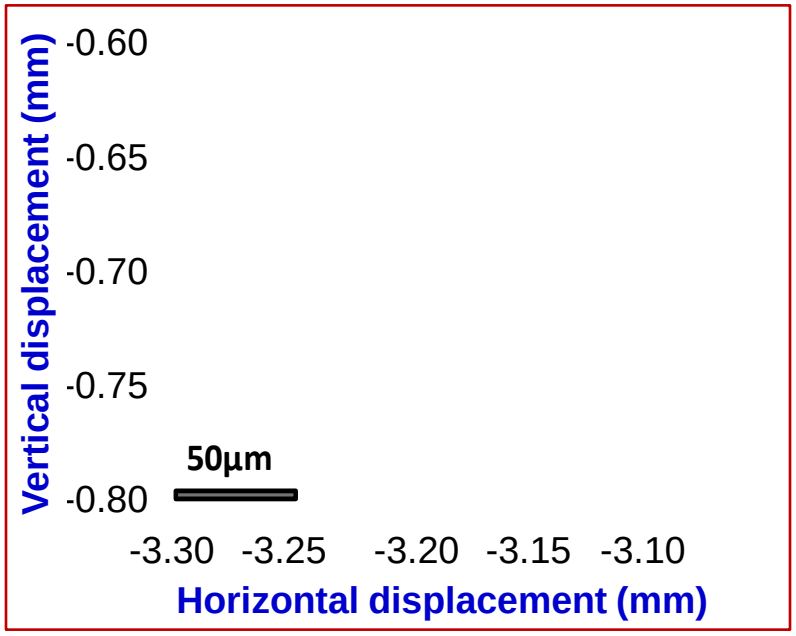
X-Ray Fluorescence Microprobe Beamline

Determining exact amount of Ta impurity in Nb for superconducting cavities



(Sample coupons from Jafferson Lab)

Spatial distribution of Pb in the broken tile paint sample from ASI



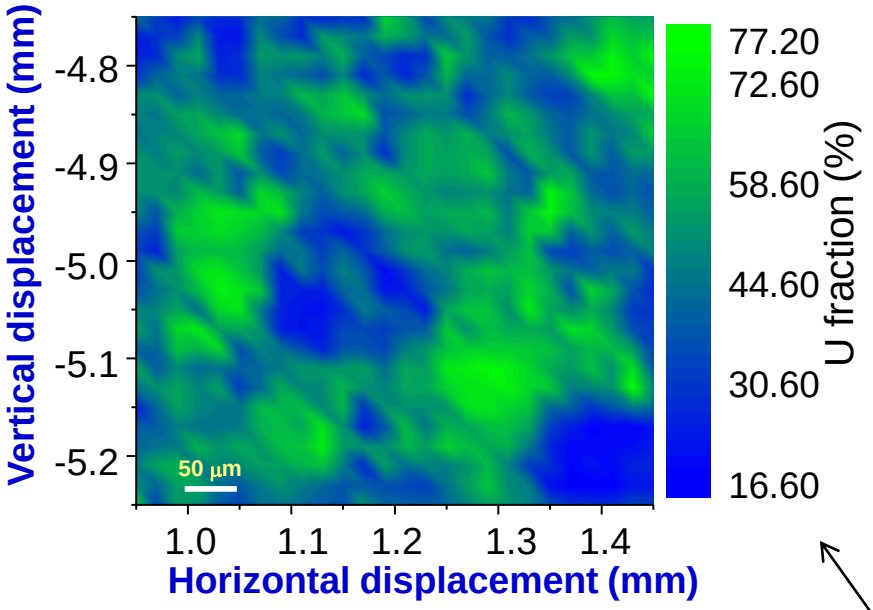
(Sample from St. Augustinian church, Goa)

Supercond. Sci. Tech. 25, 115020 (2012)

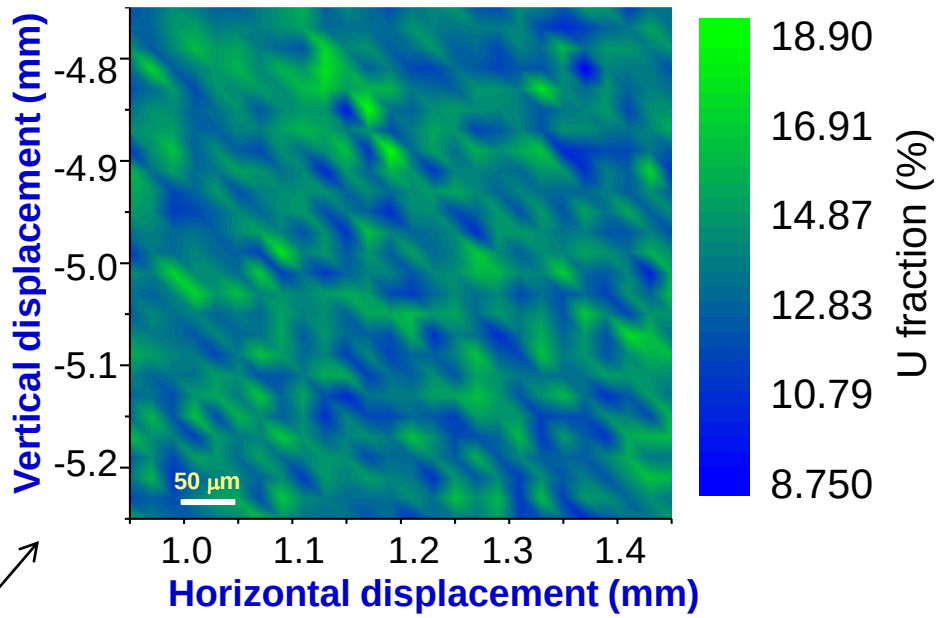
Application to Nuclear Power Programme

Composition distribution of uranium and thorium in fuel pellets prepared by two different methods for AHWR

CAP Process



PMC Process



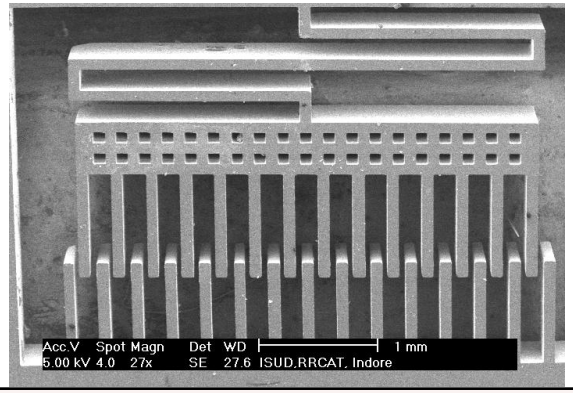
Uranium distribution

X-ray Spectrometry 42, 4 (2013)

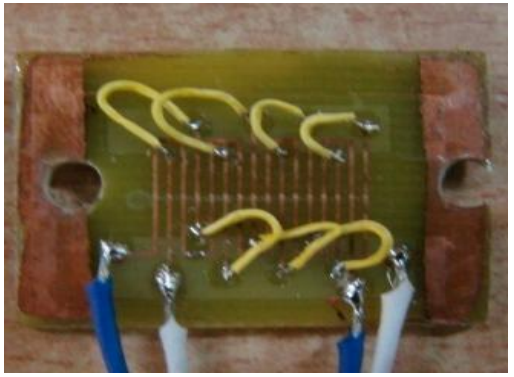
X-Ray Lithography Beamline : Applications

Fabrication of high aspect ratio micro-structures for a variety of applications

MEMS structure of a
High speed bearing



Comb fingers structure with
width 100 µm and depth 800 µm



Micro-fluidic channels

- MOU for collaborative work with University of Huyogo, Japan
- Shri Vithal Education & Research Institute, Pandharpur
- Users include CEERI-Pilani, IIT-Mumbai, TIFR, and many institutes of technology and engineering colleges

Synchrotron Radiation in Space Research

Far Ultravoilet Spectroscopy is of crucial importance in unraveling many mysteries of inter terrestrial matter.

International Space Missions like TWINS – LAD and Solar Orbiter Mission carried payloads which were characterized and calibrated at BESSY-II SRS.

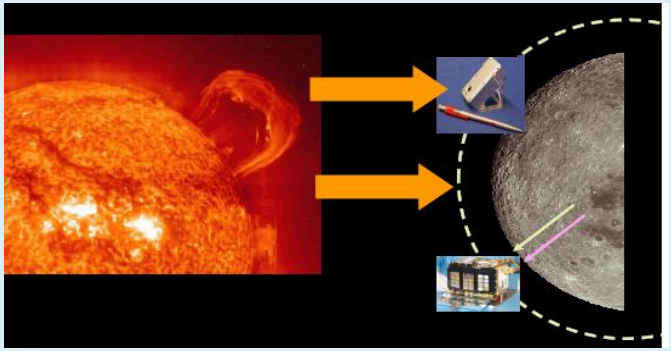
HRVUV Beamline

AMPD, BARC

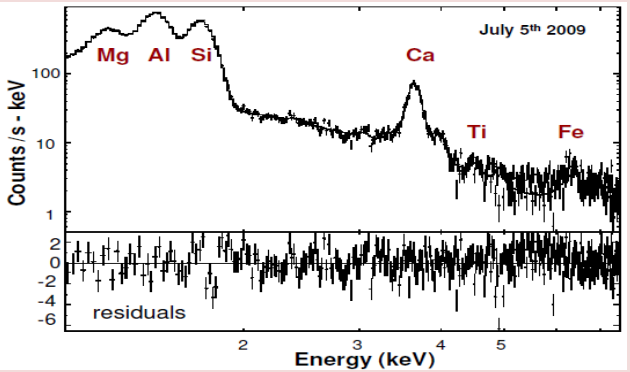
- ISRO is planning to launch a Mars Mission (Mangalyaan) in Oct-Nov 2013.
- ISRO scientists are with us this week to calibrate their ultraviolet spectroscopy payload using High Resolution Vacuum Ultra Violet Beamline on Indus-1.

Chandrayaan Mission : XRF Spectra of Lunar Material

Schematic of working of an X-ray spectrometer on Chandrayaan-1 mission

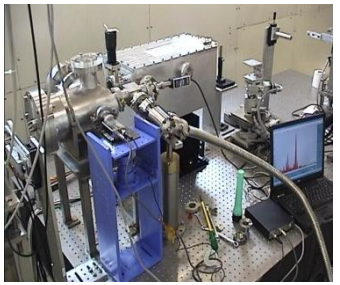


Typical XRF spectrum from a lunar sample due to solar excitation



- Quantitative analysis of the spectra of lunar material requires validation of the algorithm developed for this purpose by ISRO.
- Synchrotron X-ray radiation in vacuum environment is required to record XRF spectra of lunar simulant samples.

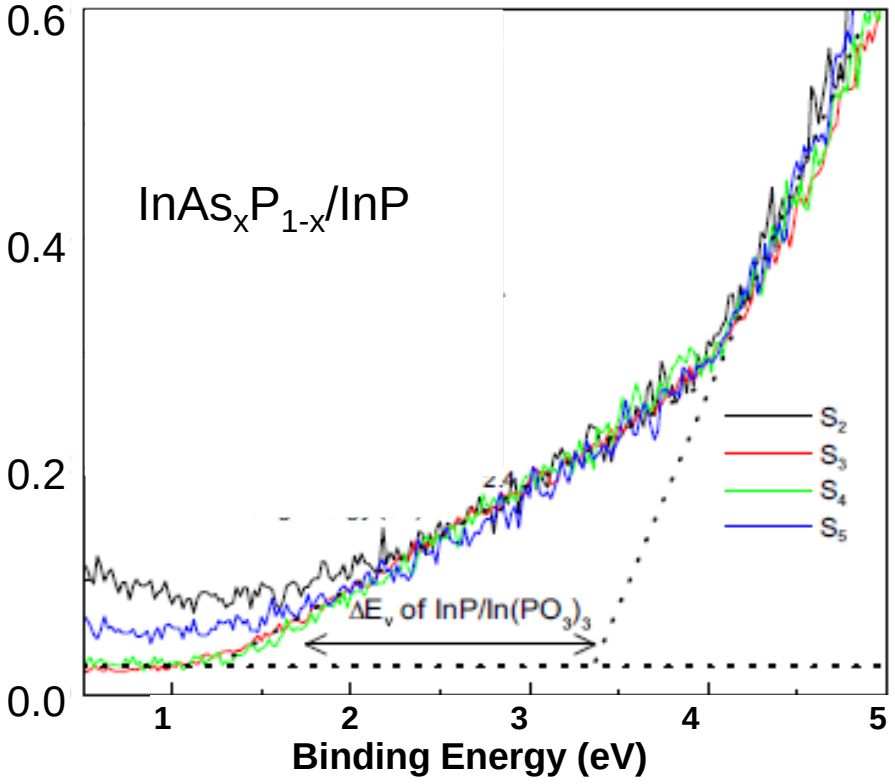
Vacuum assisted XRF experimental station



Basic and Applied Research using Indus-1 SRS

Band alignment in strained surface quantum wells for opto-electronic devices

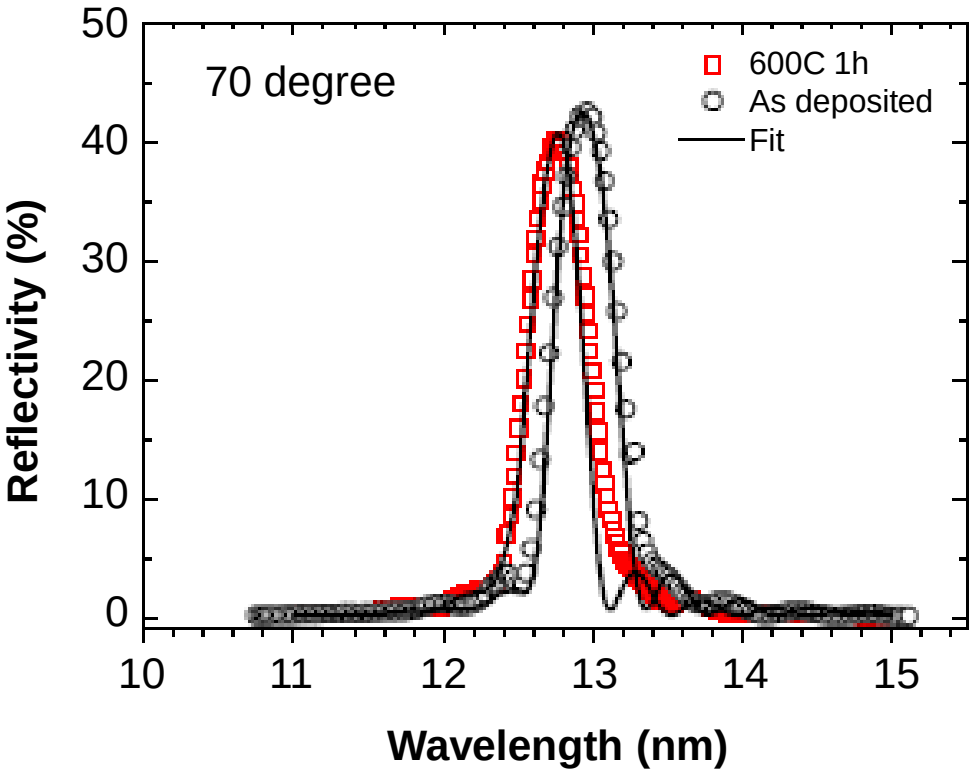
Angle Integrated PES Beamline



Materials Letters 87, 69 (2012)

Soft x-ray reflectivity of metal carbide multi-layers for use in free electron lasers

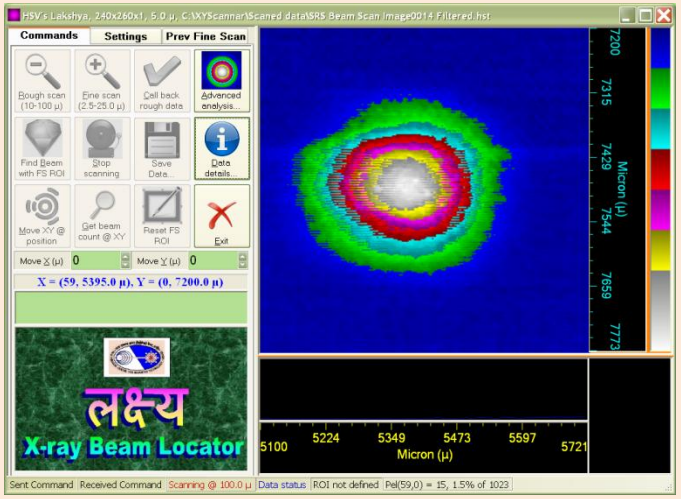
Soft X-ray Reflectivity Beamline



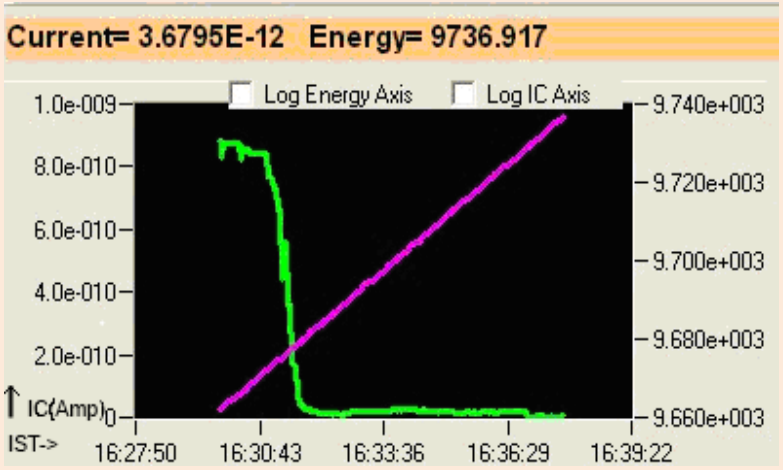
Optics Express 20,15114 (2012)

Instrumentation and Software Support for Indus Beamlines

A high precision (2.5 μm) synchrotron beam locator system is developed and deployed at ADXRD beamline for aligning diamond anvil cell.



An automated energy scan for the double crystal monochromator has been developed and deployed at XRF Microprobe beamline.



Indus Synchrotrons Users

Universities

- Vikram University, Ujjain
- Goa University
- Mumbai University
- Univ. of Allahabad
- DAVV, Indore
- RGTU, Bhopal
- Andhra University
- Panjab University, Chandigarh
- MS University, Baroda
- Punjabi University, Patiala
- University of Pune, Pune
- M.L.S. University, Udaipur
- Barkatullah University, Bhopal
- SOA University, Bhubneshwar
- Banasthali University, Jaipur

Research / Educational Institutes

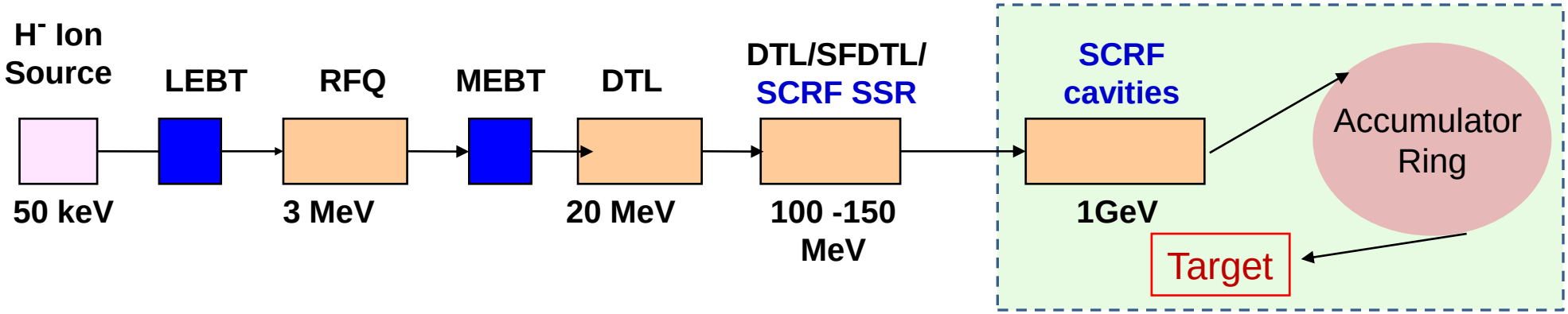
- IIT, Mumbai
- IIT, Kanpur
- IIT, Delhi
- IIT, Madras
- CEERI, Pilani
- IISc, Bangalore
- JNCASR, Bangalore
- ISM, Dhanbad
- ISRO Satellite Centre, Bangalore
- TIFR, Mumbai
- BARC, Mumbai
- IGCAR, Kalpakkam
- RRCAT, Indore
- UGC-DAE-CSR
- PRL, Ahemdabad
- IISER, Pune
- IISER, Bhopal
- DIAT, Pune

66 publications in international journals and conference proceedings during 2012

High Energy Proton Linac for Spallation Neutron Source

- Pulsed proton linac of 1 GeV energy, 1 mA average current for SNS is an intermediate step towards a CW proton accelerator required for ADS.

Schematic of 1 GeV proton accelerator for ISNS



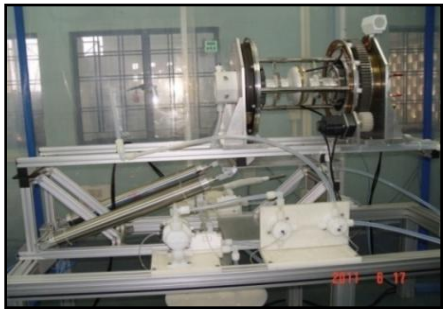
- Linac to be housed in an underground 1.5 km long tunnel
- Key role of SCRF science and technology

SCRF Science and Technology Program

- A comprehensive program for design, development, manufacturing and testing of superconducting cavities and cryomodules is under implementation.
  - ❖ Superconducting materials
  - ❖ SCRF cavity development
  - ❖ Cryogenic engineering
  - ❖ RF technology development
  - ❖ Infrastructure being set up

Infrastructure for SCRF Cavity Fabrication and Characterization

Cavity forming facility



Electro-polishing setup

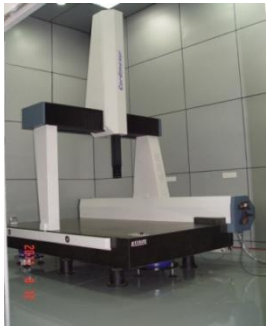
Centrifugal barrel polishing machine

High pressure rinsing Set up

SIMS setup installed

Laser scanning confocal microscope installed

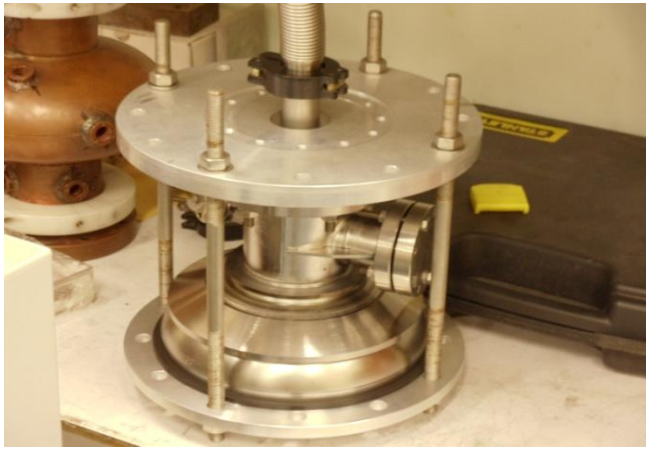
Optical bench developed



3D CMM installed

Multi-cell SCRF Cavity and End Groups

- Earlier two single-cell 1.3 GHz cavities were fabricated at RRCAT which had given acceleration gradient of 37.5 MV/m with Q > 10^{10} at 2K.
- During 2012, a 5-cell 1.3 GHz Niobium cavity has been fabricated.
- End groups have also been fabricated.

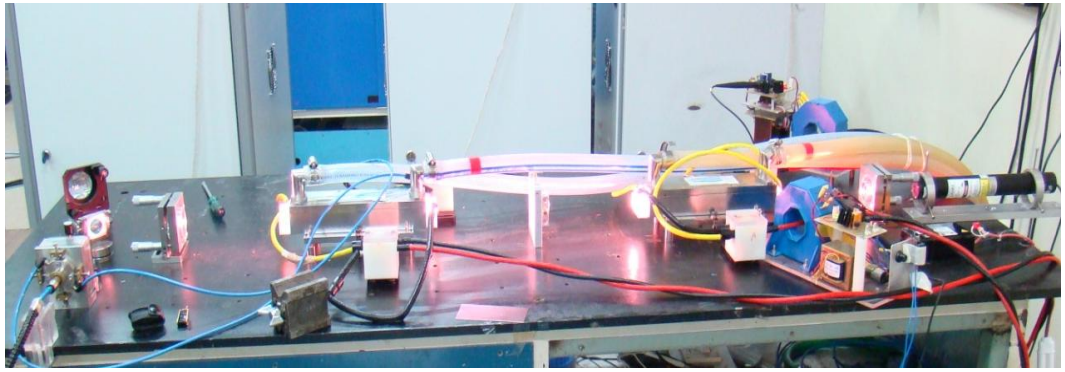


- This cavity is being sent to Fermilab for processing and testing of performance.

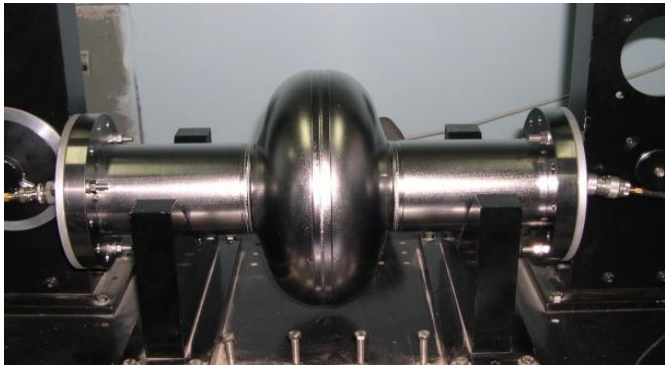
Laser Welding of Niobium Superconducting RF Cavity

- RRCAT has made a technological innovation of fabricating superconducting cavities using laser welding. (International patent applied)
- During 2012, a single-cell 1.3 GHz Niobium cavity has been fabricated using a fiber-coupled Nd:YAG laser.

20 kW Nd:YAG fiber-coupled laser



First laser-welded Nb cavity



Advantages of laser welding over e-beam welding

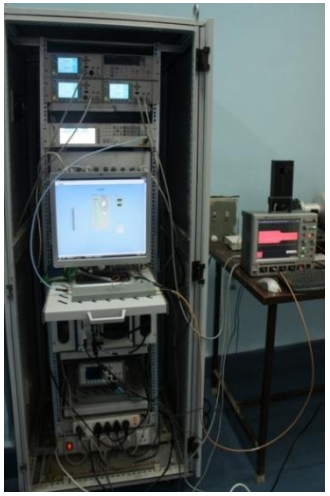
- Smaller energy deposition : Less shrinkage and less distortion
- Not necessary to use vacuum
- Less cleaning requirement

Development of Vertical Test Stand for Superconducting Cavities

- Design of 2K cryostat done together with Fermilab.
- Cryostat has been fabricated, tested and after its assembly with magnetic shields installed in the pit.
- RF system for operation of VTS also developed.

Assembly of external shield

Installation of Cryostat in pit

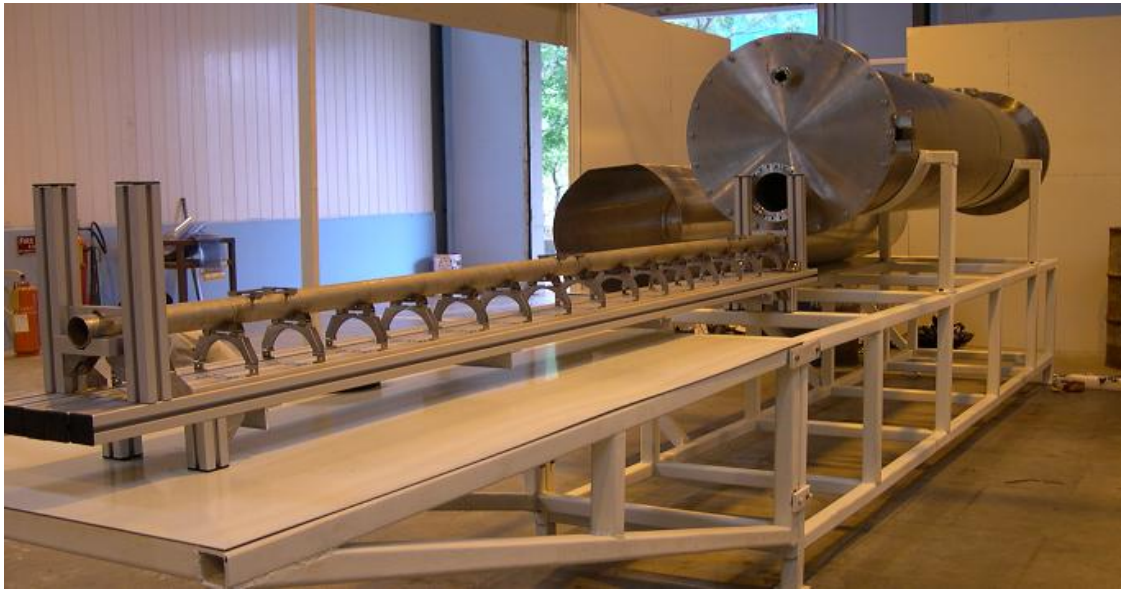


Automated RF instrumentation

1.3 GHz 500W solid state RF amplifier

Cryomodule Component Test Rig

- A cryomodule component test rig has been installed to validate design calculations of different subsystems of Cryomodule and Horizontal Test Stand.



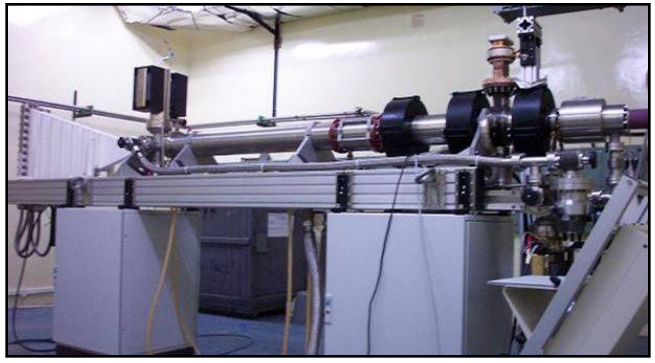
- This rig will also be used to validate some value engineering concepts proposed by RRCAT in existing cryomodule designs (DESY/JLab).

Agricultural Radiation Processing Facility (ARPF)

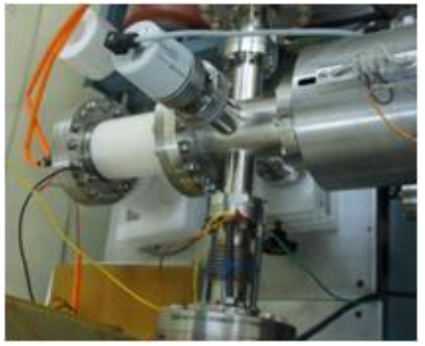
Under Construction near Sabzi Mandi, Indore

Exposing food to controlled levels of ionizing radiation for beneficial effects.

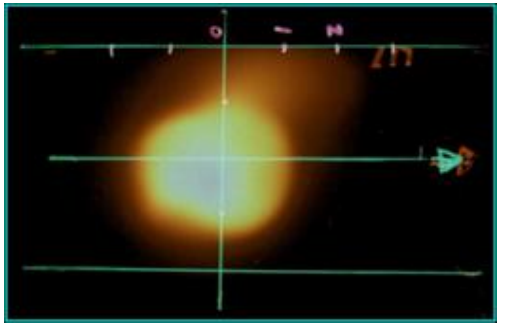
- Food preservation and hygienisation
- Quarantine of agricultural products
- Mutation breeding



10 MeV, 5 kW Linac



Triode electron gun



Electron beam spot

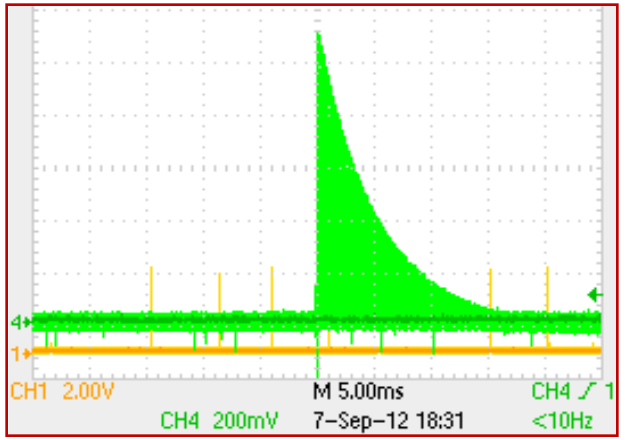
Compact Ultrafast Tera Hertz Free Electron Laser (CUTE-FEL)

Signature of build-up of coherence

- A fundamental frequency (S-band) pre-buncher has been designed, developed and commissioned in the CUTE-FEL setup.
- This has increased the peak accelerated electron beam current to 15 A.

CUTE-FEL Laboratory

S-band pre-buncher



Bolometer trace for the THz output

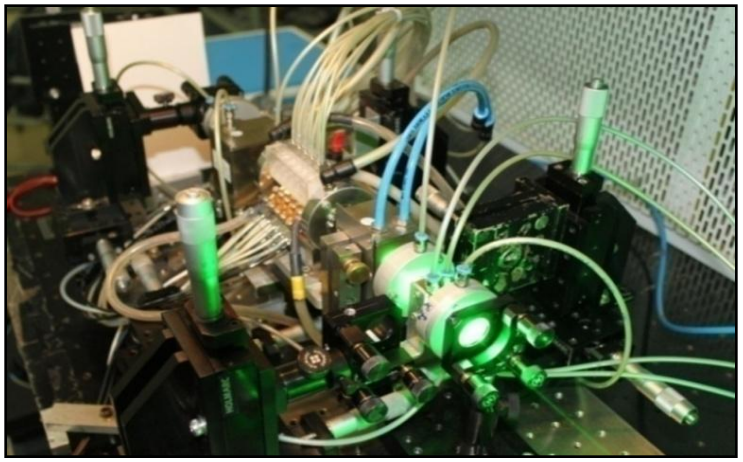
- Measured bolometer signal corresponds to a photon flux of ~ 6.6 x 10^{11} photons/s, which is more than 100 times the expected spontaneous emission.

Development of MOPA chain of Copper Bromide Lasers

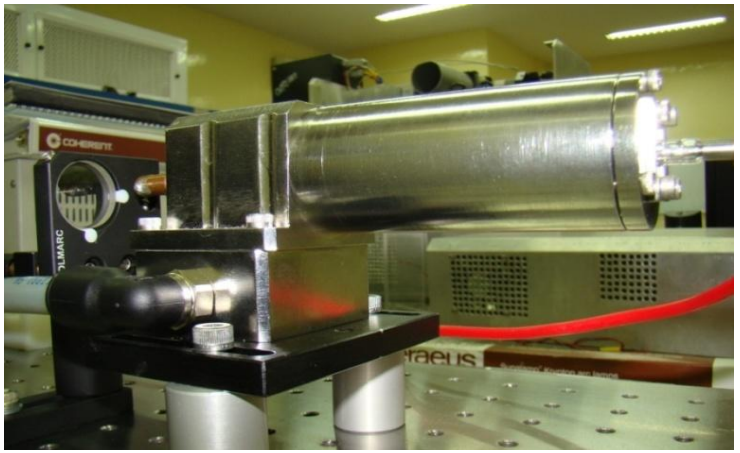
- Copper bromide laser has several advantages over copper vapour laser in terms of lower temperature of operation, higher efficiency and better beam quality.
- A Master Oscillator Power Amplifier (MOPA) setup of the 3 copper bromide lasers has been developed and average laser power of 110 W is obtained.

Laser Systems for Defense Applications

- A pulsed high beam quality Nd:YAG green laser (avg. power 100 W) has been developed for dazzler application.
- A 14W CW Nd:YAG laser has been developed for indigenization of laser radiator of missile firing system of T-90 tank. The laser has been tested at Opto-Electronics Factory, Dehradun and it meets military standards.



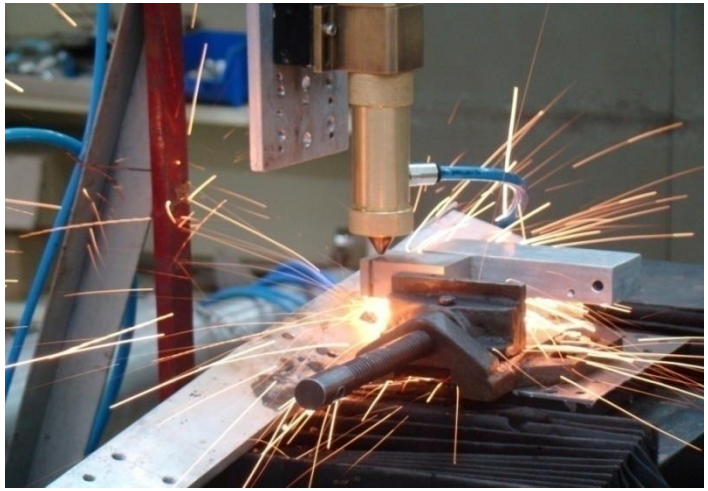
Nd:YAG green laser for dazzler

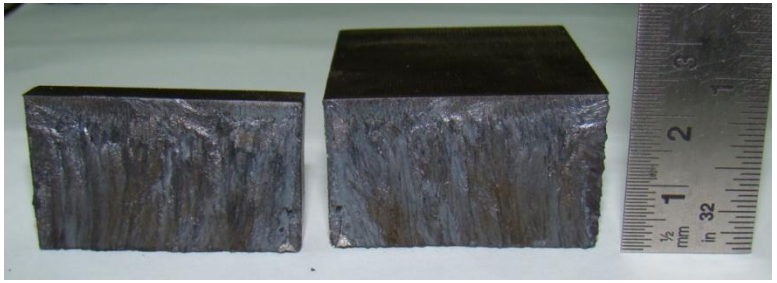


Indigenized laser radiator for T90 tank

Laser Cutting of 23 mm Thick Stainless Steel by Nd:YAG Laser

Industrial Nd:YAG laser of 10 kW peak power (500 W average power)





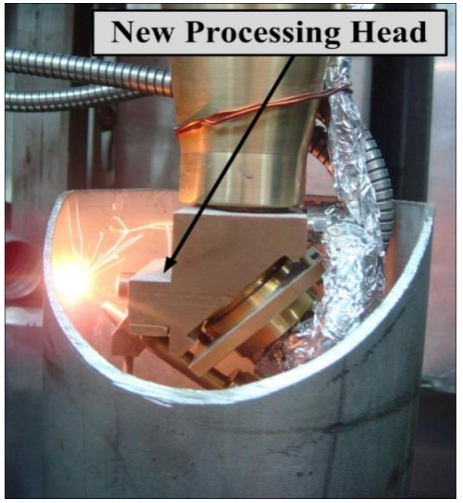
Laser cut surface in air
Heat affected zone : 370μm

Laser cut surface underwater
Heat affected zone : 210 μm

This development will be useful in maintenance operations and decommissioning of nuclear power plants and for many other industrial applications.

Laser Rapid Manufacturing and Cladding

A processing head for the deposition of material on inner vertical surfaces of pipes is developed.



Erosion resistance of laser deposited Ni-based alloy T 700 was found to be 3 times better than conventionally used material SS 440 C.

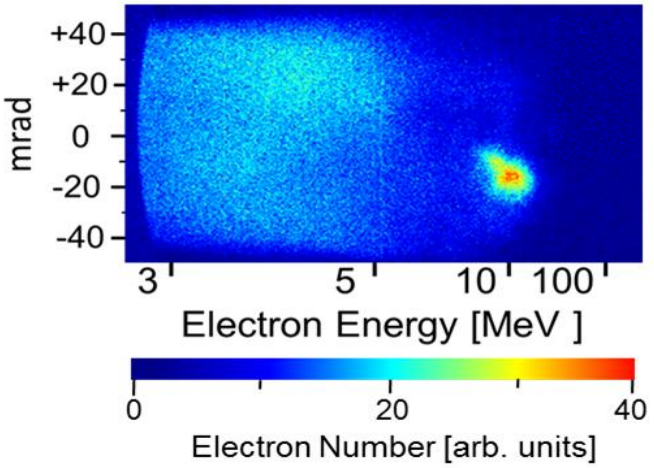
This alloy was successfully deposited on the Spools of Hydraulic Valves for Refueling Technology Division, BARC.

Laser Driven Electron Acceleration

- Laser wakefield electron acceleration can provide very high accelerating fields of 300 GV/m as compared to only 20-30 MV/m by using standard RF technology.
- Mono-energetic electron beam has been generated in pre-formed plasma plumes (instead of conventional gas jets) using laser wakefield acceleration.

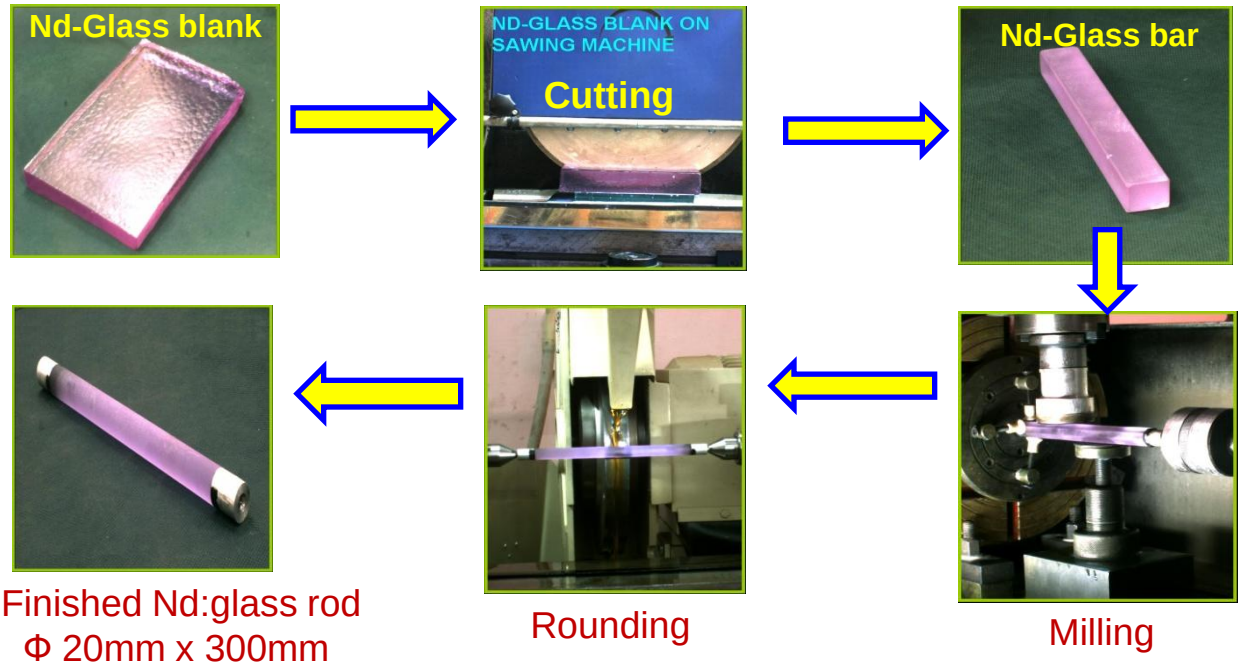
Ti-Sapphire Laser Plasma Lab

Laser Accelerated Electron Beam



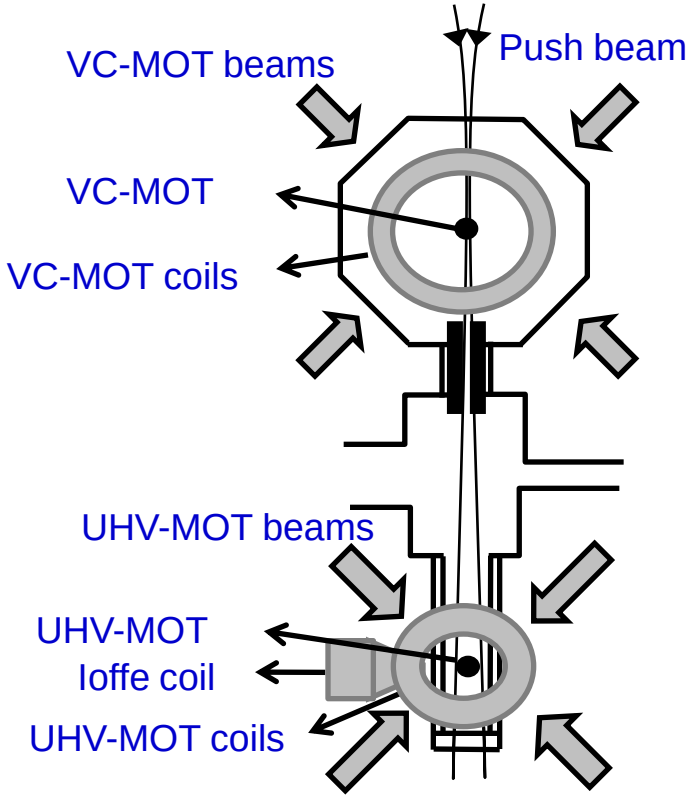
Indigenous Development of Nd:Phosphate Laser Glass

- Indigenous development of laser glass is necessary for achieving self-reliance in the area of high power lasers for studies in High Energy Density Regime of strategic importance.
- CGCRI and RRCAT are jointly developing this technology.
- Nd:glass rods of 20 mm diameter and 300 mm length have been made and work to produce larger size rods and discs is in progress.

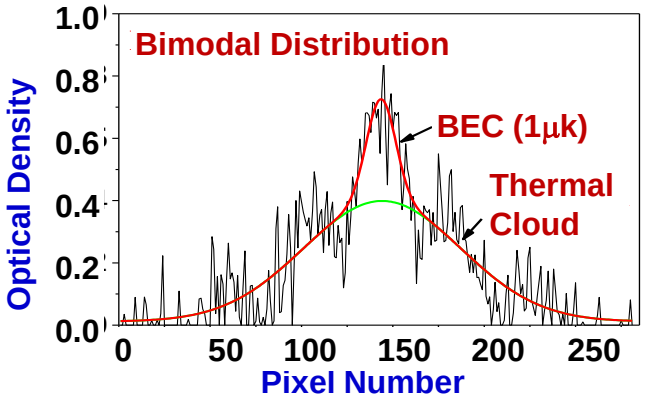


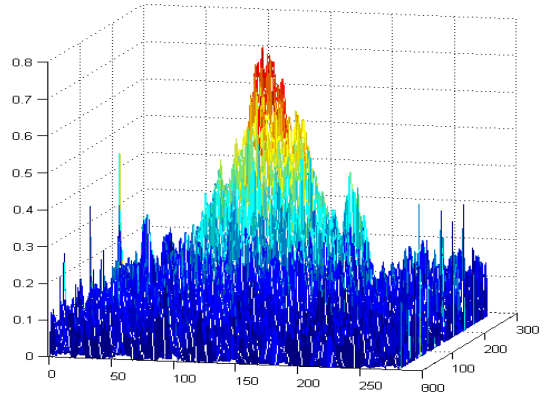
Cold Atoms and Bose-Einstein Condensation

Bose-Einstein condensation in Rb^{87} atoms achieved in a double magneto optic trap setup at T = 1 μK, n = 10^{13}/cc and N=10^{6} atoms with a life time of 14 sec.



Schematic of double-MOT setup



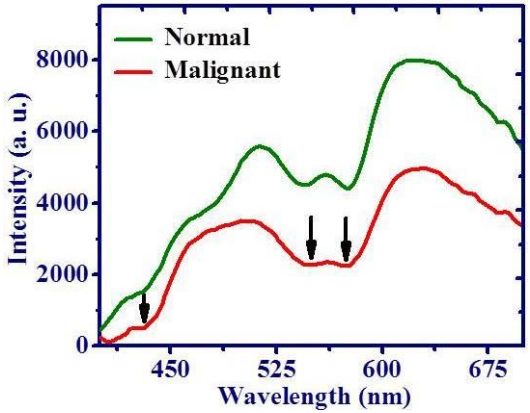


Sharp peak in the centre is signature of Bose-Einstein condensate.

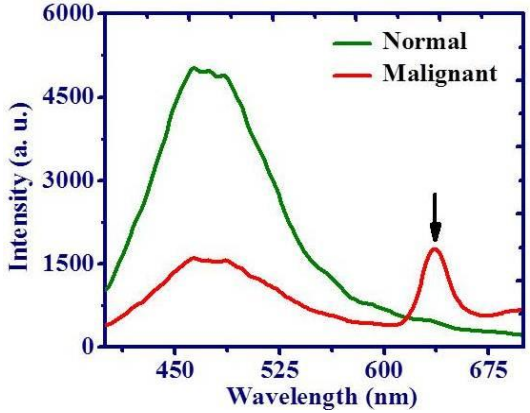
LED based Diagnosis of Oral Cancer

- An LED-based diagnostic system has been developed for detection of oral cavity cancer.
- Both reflectance and fluorescence spectra are recorded from the same tissue site.

Diffuse reflectance



Fluorescence



- This system is more compact, rugged and maintenance-free compared to the N_2 laser based systems used earlier.
- Should prove particularly useful for screening of populations at potential risk.

Laser Uranium Fluorimeter

Uranium exploration and environmental survey

- Photon counting version of uranium fluorimeter has been developed.

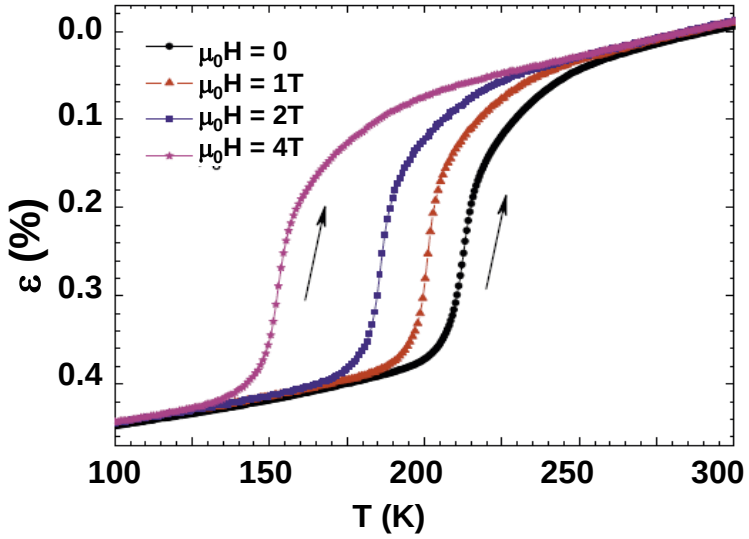
- Detection limit 0.02 ppb
- Measurement range of up to 50 ppb
- Instrument has been given to EAD, BARC for field evaluation

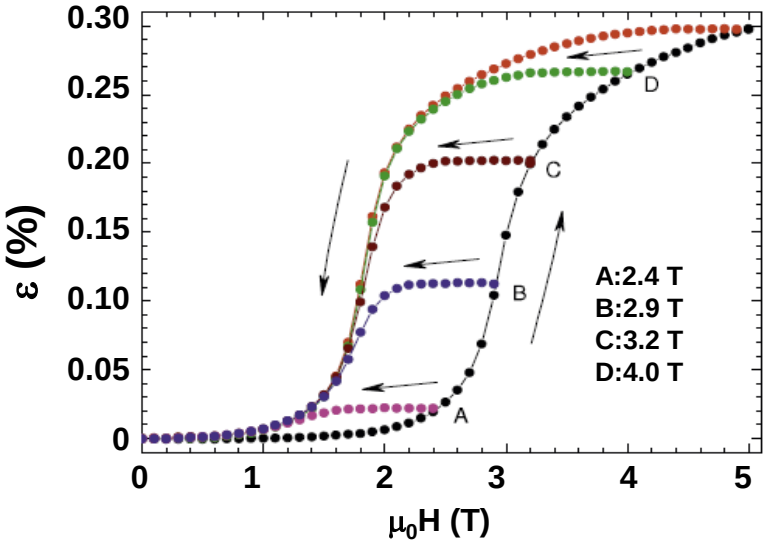
Development of Gated Grid S-20 Optical Streak Camera

- A gated grid S-20 optical streak camera has been developed for measurement of a single pulse selected from a train of pulses.
- It has been tested in Indus-1 SRS by the electron bunch length measurement.

Large Magneto-strictive Effect in FeRh Alloys

- Large magneto-striction of about 0.3% is observed, which is reproducible under multiple temperature and magnetic field cycle.
- This alloy system also shows large magneto-caloric effect.
- These arise due to a first order magneto-structural phase transition.





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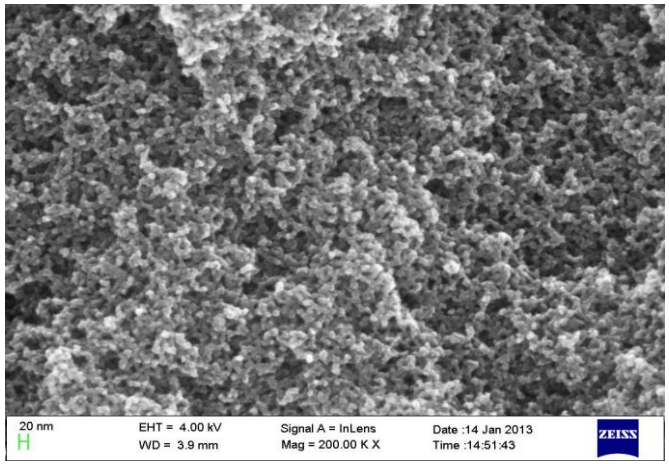
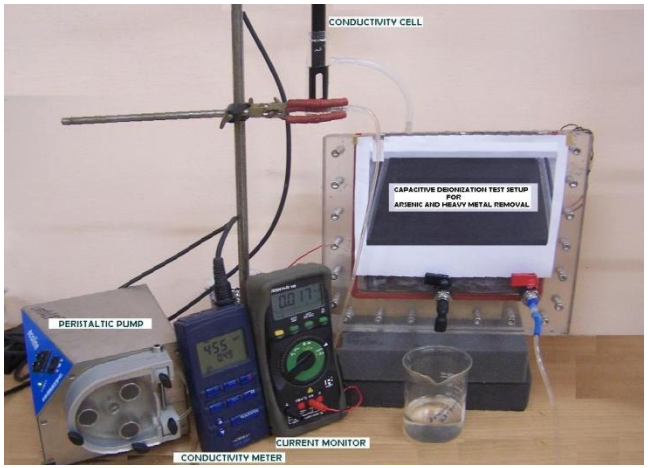
Capacitive De-ionization for Desalination and Arsenic Removal

- Electrodes have been developed using carbon aerogels activated with CO_2, having surface area ~ 1100 m^2 and specific capacitance of 102 F/g.
- In a single capacitive de-ionization cell, salt removal from 800 ppm to 410 ppm and arsenic removal from 500 ppb to 140 ppb has been achieved.



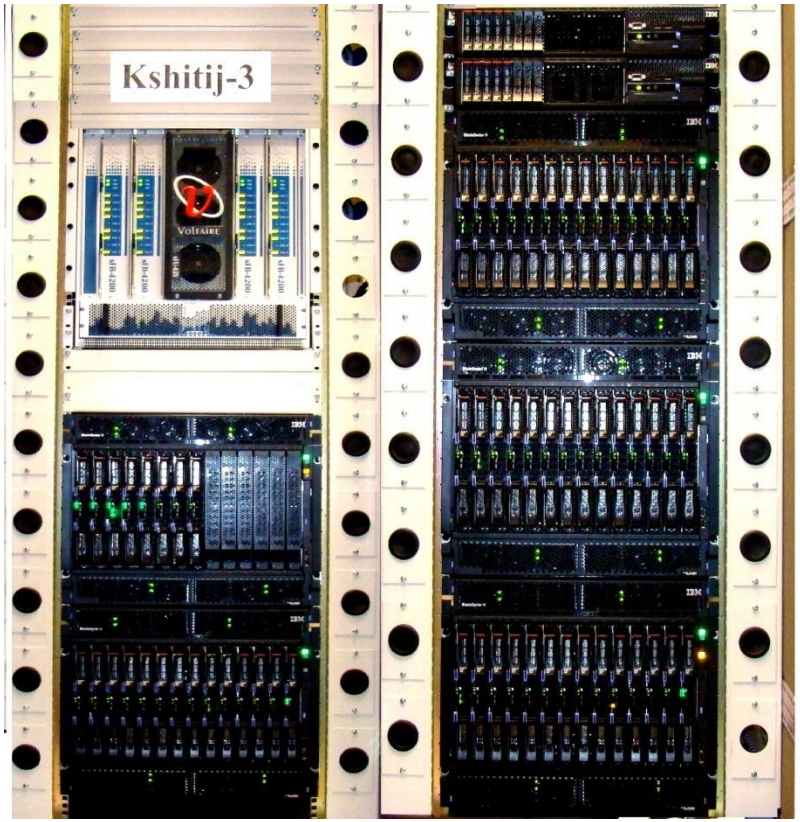
SEM of carbon aerogel with pores of ~ 20-30 nm.



Test setup for salt and arsenic removal

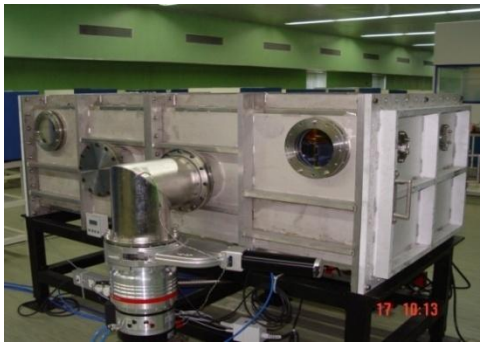
- Arsenic concentration can be brought down to < 20 ppb from 500 ppb in four stage setup.

Computing and Communication Systems

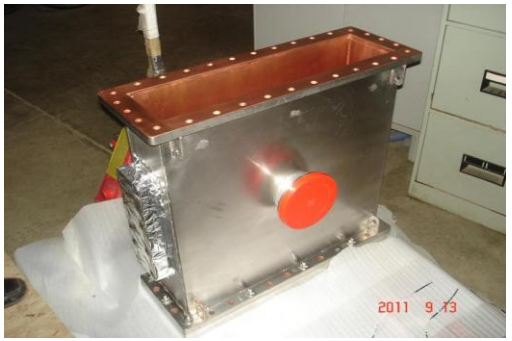


- A high performance computing cluster (Kshitij-3, क्षितिज-3) has been commissioned.
- It delivers peak computing power of 9 teraflops.
- Commissioned high resolution tile display for resource monitoring and visualization applications.

Precision Manufacturing and Chemical Treatement of Accelerator & Laser Components



Pulsed compressor for 150TW Ti sapphire laser

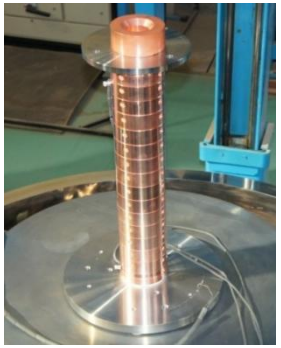


Wave guide coupler (CERN)

Components for soft x-ray laser

Copper plating of DTL Tank of LEHIPA

Electroplating of RFQ chamber (IUAC)

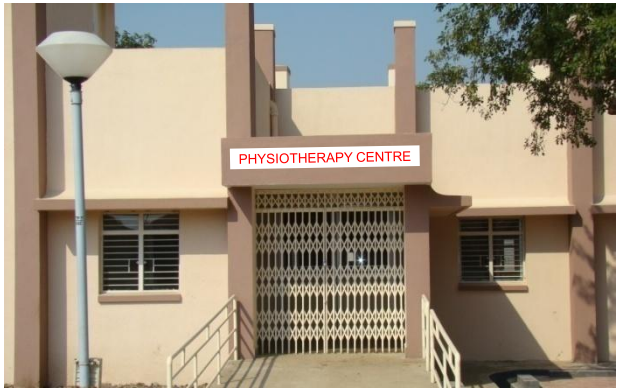


Vacuum brazing of LINAC

RF coupling for Pre-buncher

Infrastructural Works

Physiotherapy Unit



Fire Station operates round the clock

Central Complex Sub-Station

Guest House Extension (Dinning Hall)

A number of laboratory buildings for Indus Synchrotron Users, Laser Materials, Laser Biomedical Applications, Semi-conductor laser, SCRF cavity, ARPF etc. have been completed.

Human Resource Development

- BARC Training School at RRCAT - 13th batch (Physics, Electronics) : 14 TSOs

- HBNI PhD Registrations : 97 (External students : 33, Staff members : 64)
- HBNI M.Tech Programme : 67 Registered, 51 Completed
- About 40 external M.Tech students carry out 1-year project work every year.

Other Activities & Photo Gallery

- National Science Day : Feb 25, 2012
- YSRP during May - June 2012 for 8 weeks
- Training School Graduation Function : July 26, 2012
- Visit of Sh. S. Basu, Director BARC : Sept 5-6, 2012
- Hindi Diwas Celebration : Sept 14, 2012
- International Linear Collider School :Nov.27-Dec.8, 2012
- Visit of Dr.T. Ramasami, Secretary DST :Nov. 3, 2012
- DAE-CERN Co-ordination Meeting : Nov. 19, 2012
- LIGO-India Interaction Meeting : Jan. 24, 2013

Thank You