EUROPEAN
PLASMA RESEARCH
ACCELERATOR
WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA
Preparatory Phase

Opportunities for collaboration : India

Rajeev Pattathil

Head, Novel Accelerator Science and Applications,

CLF, Rutherford Appleton Laboratory

This project has received funding from the European Union Horizon Europe research and innovation programme under grant agreement
No. 101079773

Outline

- Laser Plasma Accelerator Programs and Recent Works
- Large Scientific Infrastructures
- Partnerships in Mega Science Projects
- Our partnership with India

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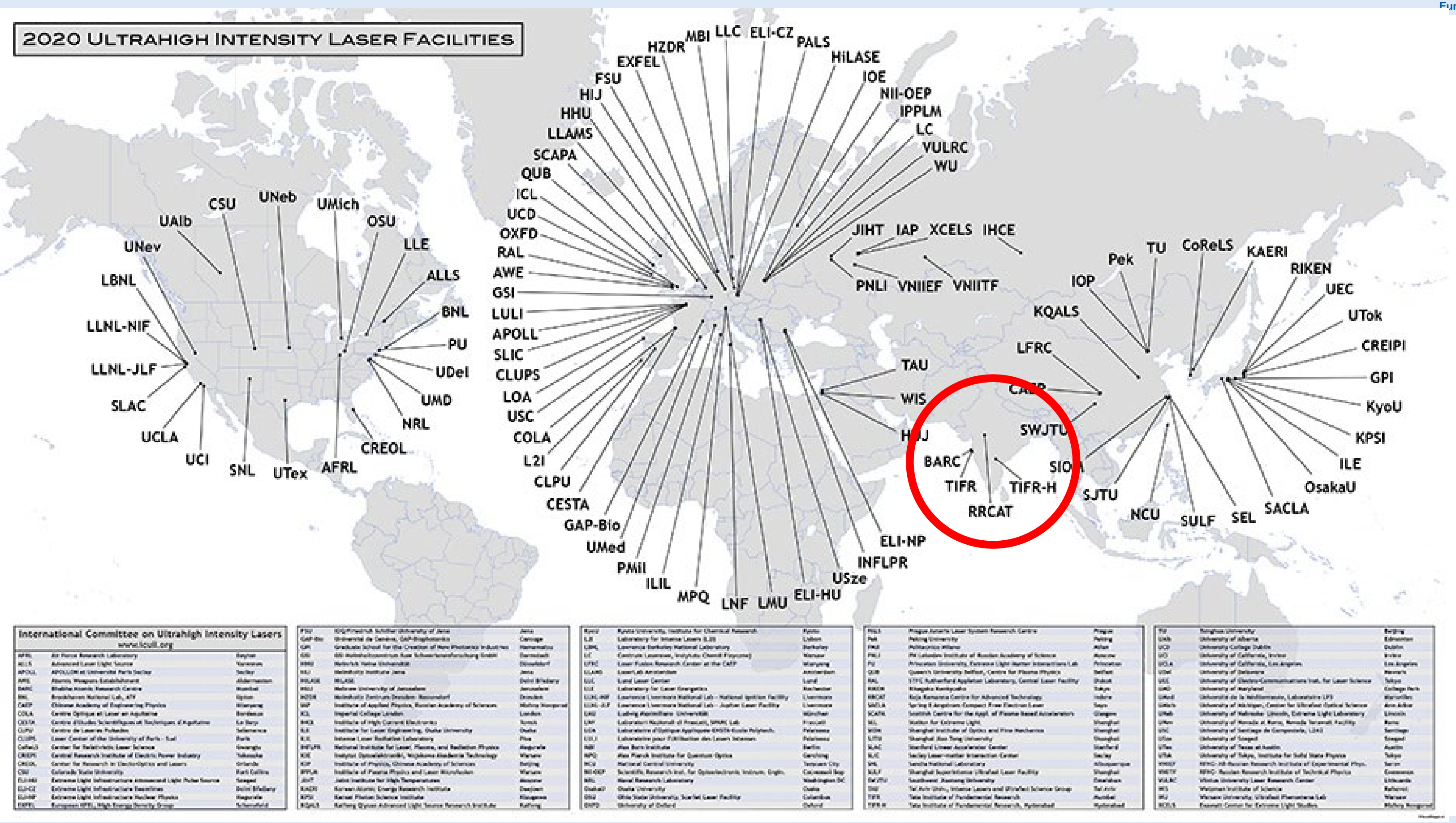
A High-Intensity Laser View of the World

Funded by the European Union



TIFR: world-class research centre

India's premier scientific institute for fundamental research in all areas

Very good partner for Intense laser physics research

Attracts some of the best talents in the country

https://www.tifr.res.in/dnap/ultrashort-pulse-high-intensity-laser-laboratory.html

Funded by the

nature physics

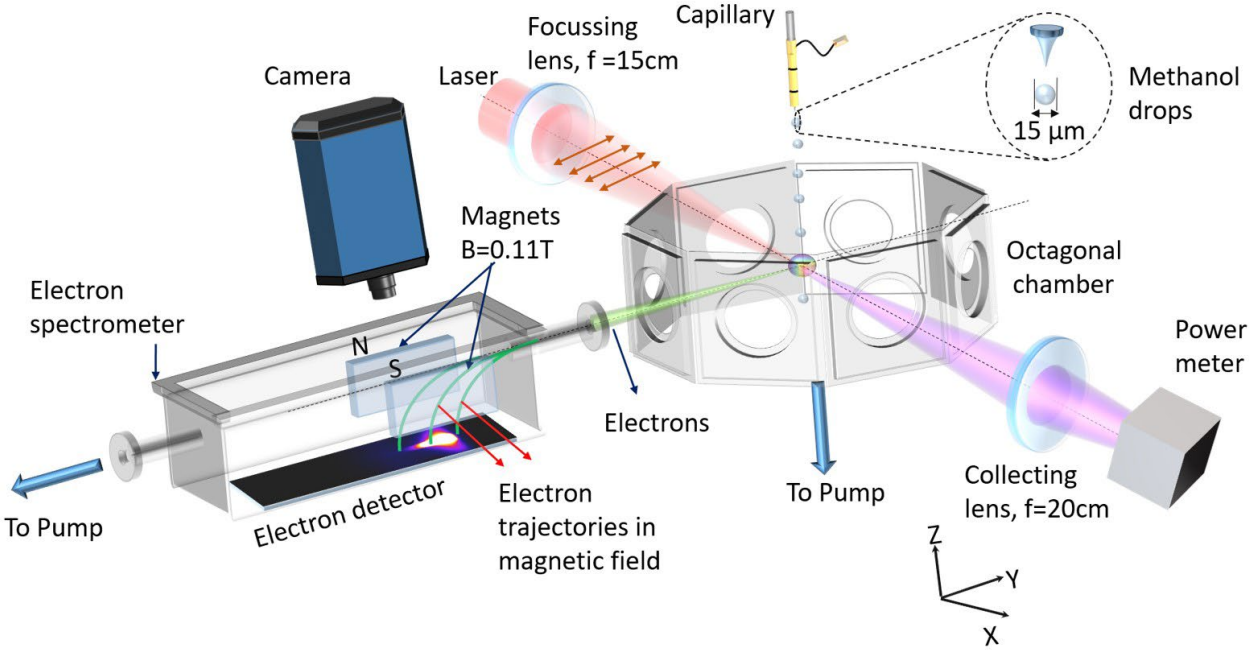
ARTICLES

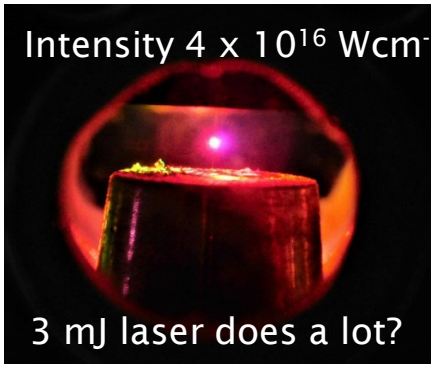
PUBLISHED ONLINE: 27 JANUARY 2013 | DOI: 10.1038/NPHYS2526

A compact laser-driven plasma accelerator for megaelectronvolt-energy neutral atoms

R. Rajeev, T. Madhu Trivikram, K. P. M. Rishad, V. Narayanan, E. Krishnakumar and M. Krishnamurthy*

Micro-accelerators with liquid drops

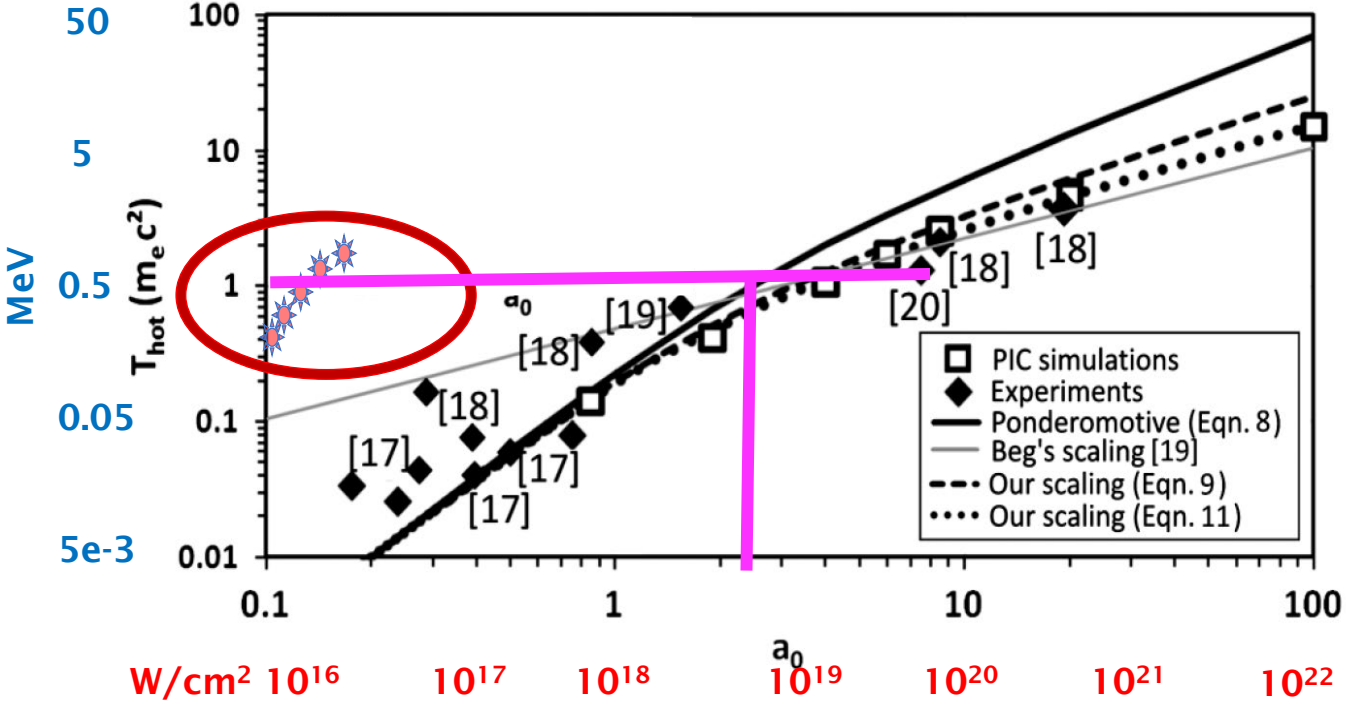




Communications Physics 7, 85 (2024)

Micro-accelerators with liquid drops

Liquid drops enable ~ 100-fold enhancement in effective intensity



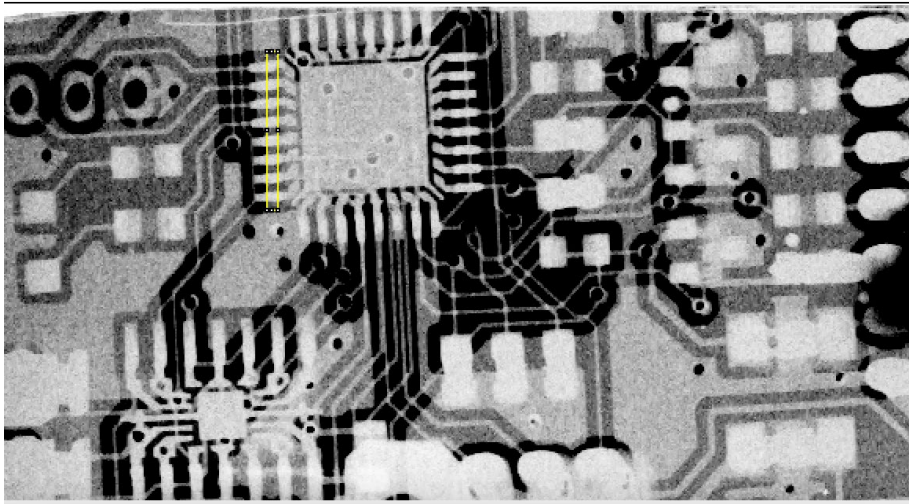
Threshold for keV electron generation: 80 μJ @ 30fs

Physics of this involves two-plasmon decay

4 papers now published on this now

Communications Physics 7, 85 (2024)

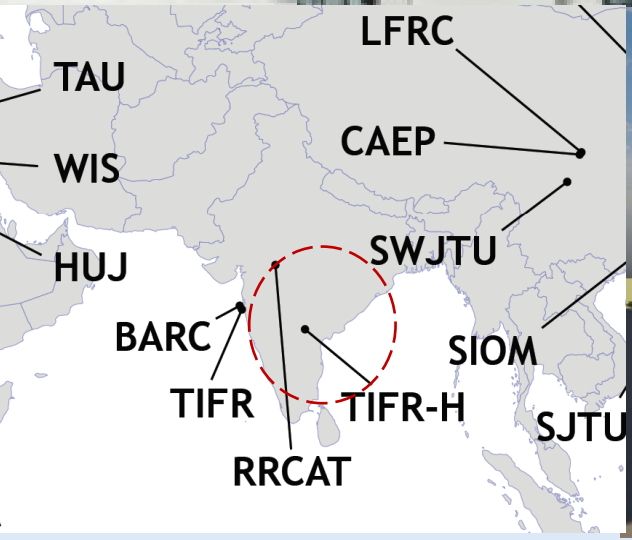
Truly Table-top Accelerators



190 fs
2 mJ @ 10 kHz

Upcoming PW facility in TIFR-Hyderabad

Funded by the European Union



Upcoming PW facility in TIFR-Hyderabad

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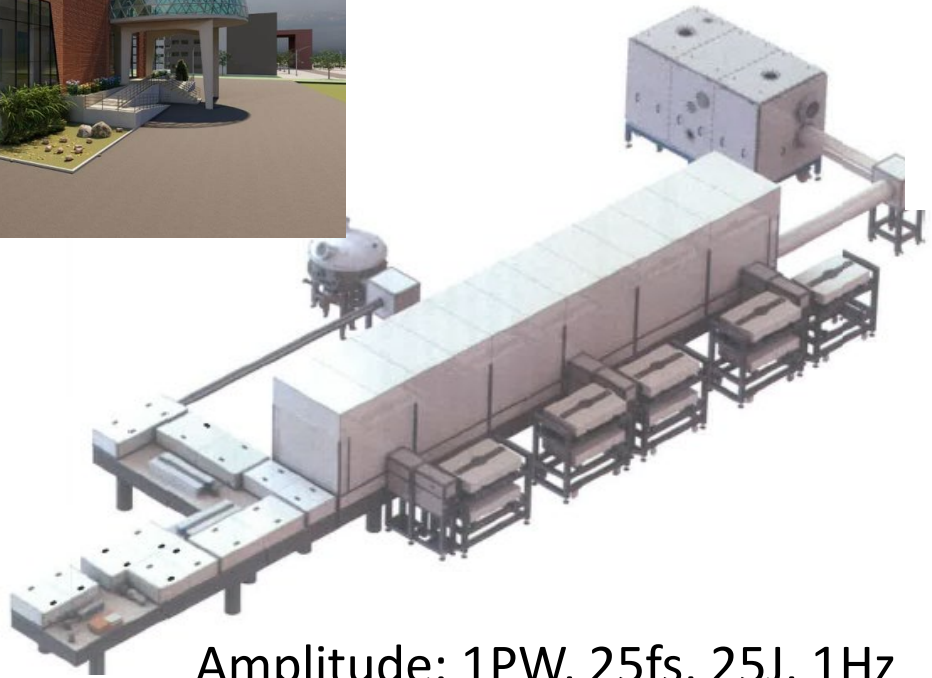
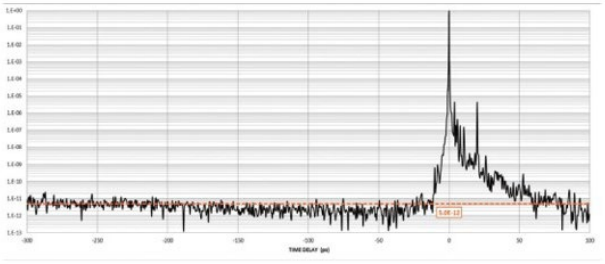
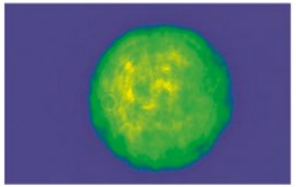




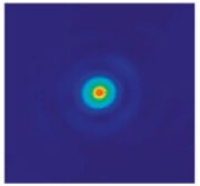
Pulsar 500 HR Sequoia
HD contrast measurement

Pulsar PW

Ultra intense ultrafast laser



Pulsar 500 HR typical
Near Field beam profile



Pulsar 1000 HR typical
Far Field beam profile

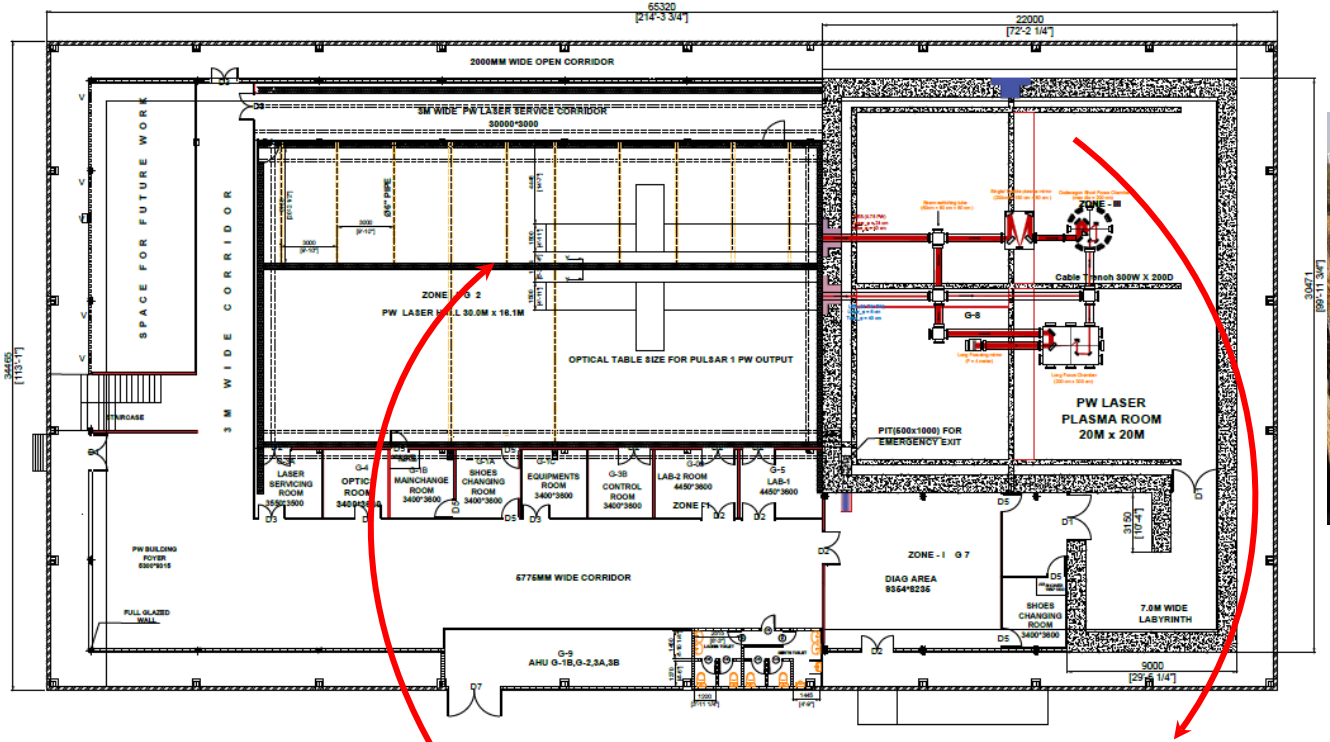
Amplitude

Amplitude: 1PW, 25fs, 25J, 1Hz

Key Features

- > Up to 25 J
- > Highest contrast ratio better than 10^{10} : 1
- > Up to 5 Hz repetition rate
- > Ultra-short sub-20 fs pulses
- > Advanced Monitoring System

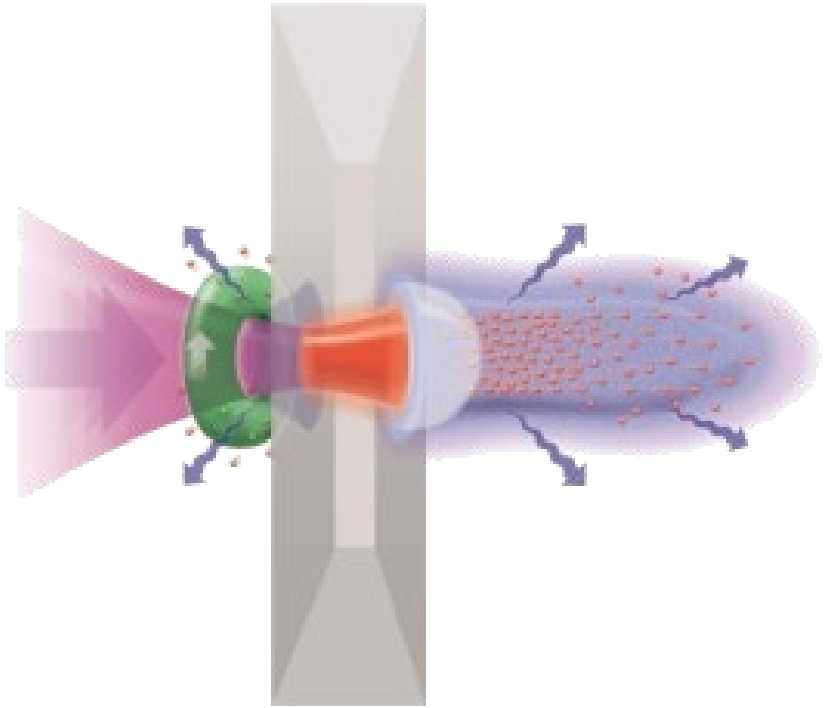
Upcoming PW facility in TIFR-Hyderabad



100's of m extension capacity

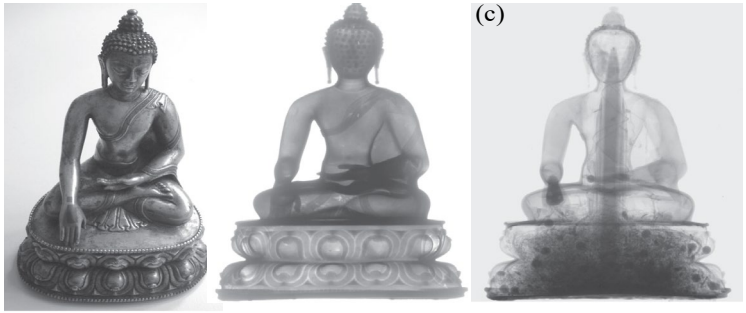
- $30m \times 16\ m$ *Laser Hall*
- $20m \times 20\ m$ *experimental Hall*

PW laser opens-up more science avenues



Experimental area designs are being developed for research in

- LWFA research and applications
- Proton/ion acceleration & radio therapy applications
- Multi-modal imaging

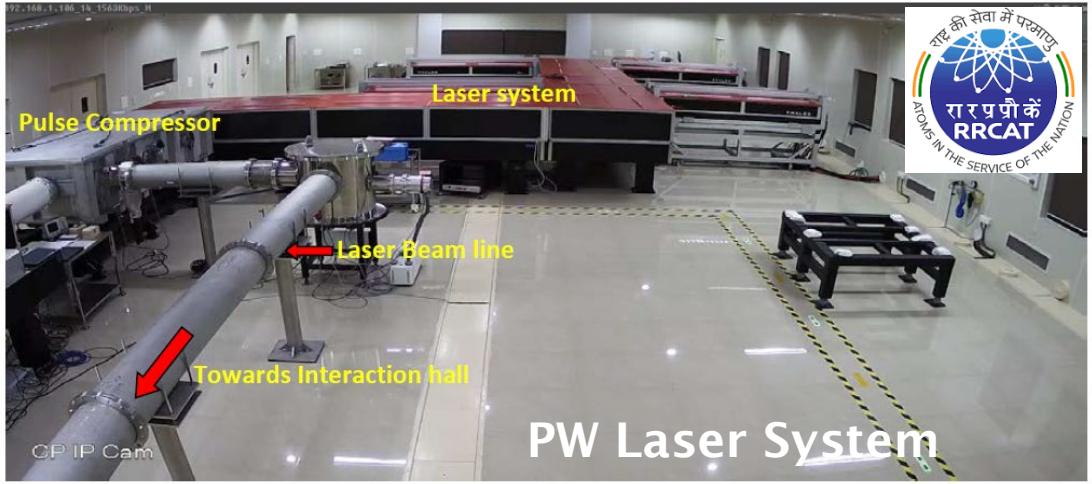


© *Paul Scherrer Institut* (PSI), Switzerland.

There is a strong interest in embarking on plasma-based FEL research activities

RRCAT, Indore (Raja Ramanna Centre for Advanced Technology)

Funded by the European



RRCAT is a National R & D Institute,

under Department of Atomic Energy, India.

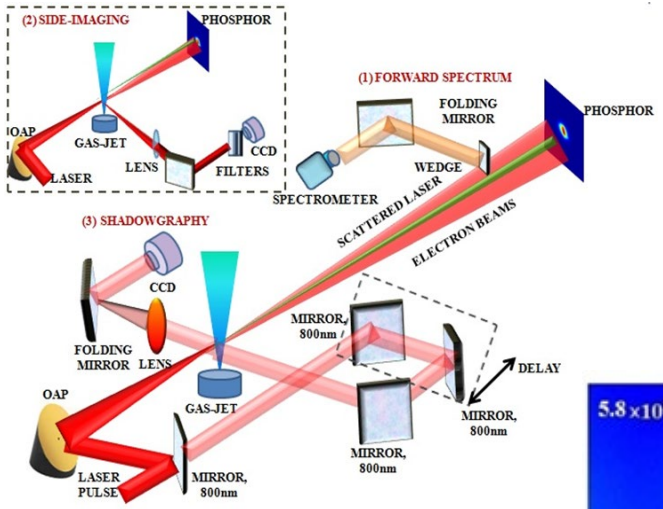
R & D in Accelerators and Synchrotrons:
Indus-I: 450 MeV; Indus-II: 2.5 GeV

R & D in Laser Development and Utilisation:
Solid state and fiber laser development,
Semiconductor laser, Crystal growth etc.

Laser Plasma Interaction
Particle acceleration and x-ray generation

CPA Based Ti:Sapphire Laser Systems
150TW, 25fs, 5Hz, (Amplitude)
1PW, 25fs, 0.1Hz (Thales)
Recently Installed
Trial and Commissioning under Progress

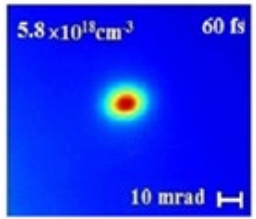
LWFA studies with 150TW

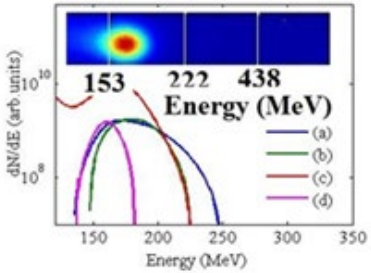


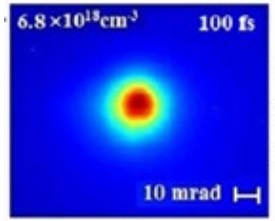
Energy gain from Wakefield (WF) and Direct Laser Acceleration (DLA)

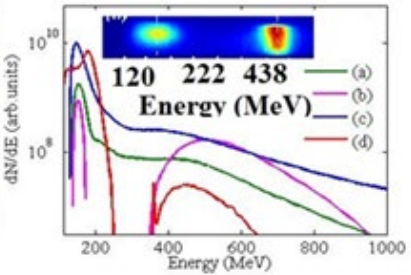
- Longer pulse duration DLA
- Intermediate pulse duration: Hybrid (WF+DLA)

4mm He plasma: Hybrid Acceleration WF + DLA







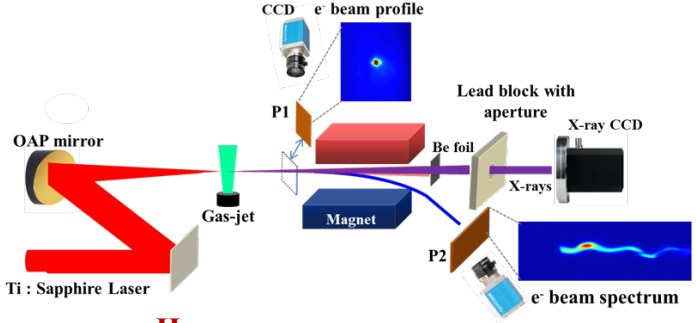


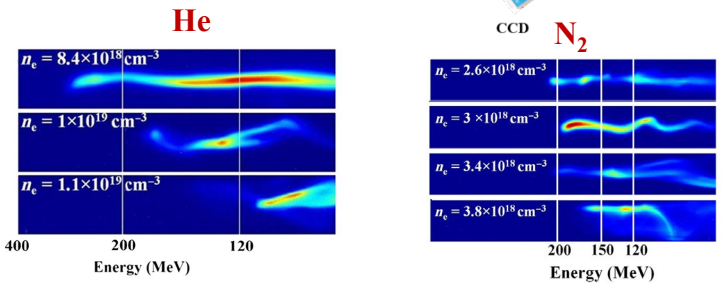
Plasma Phys. Controlled Fusion 60, 085015 (2018); ibid 61, 125016 (2019) Phys. Rev. Accelerator and Beams 22 , 074701 (2019);

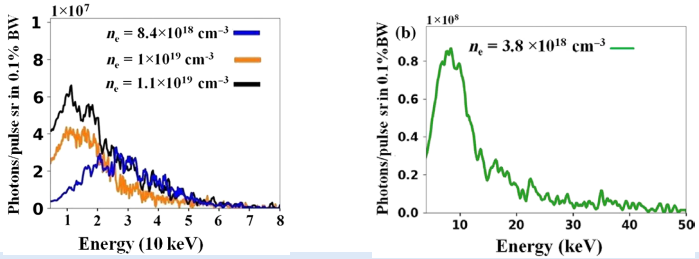
D. Hazra D, Ph. D. Thesis, 2020, HBNI, DAE, Mumbai, http://hbni.ac.in/thesis.html

Betatron generation and applications

Funded by the European Union





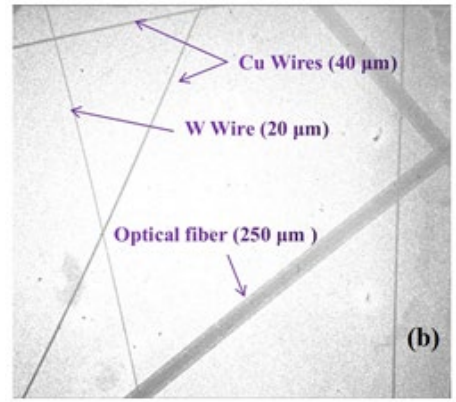


Effect of electron density: He, N_2

Effect of Chirp: Positive chirp higher collective oscillation and hence larger x-ray flux.

Role of Pulse Front Tilt (PFT)

X-ray Imaging



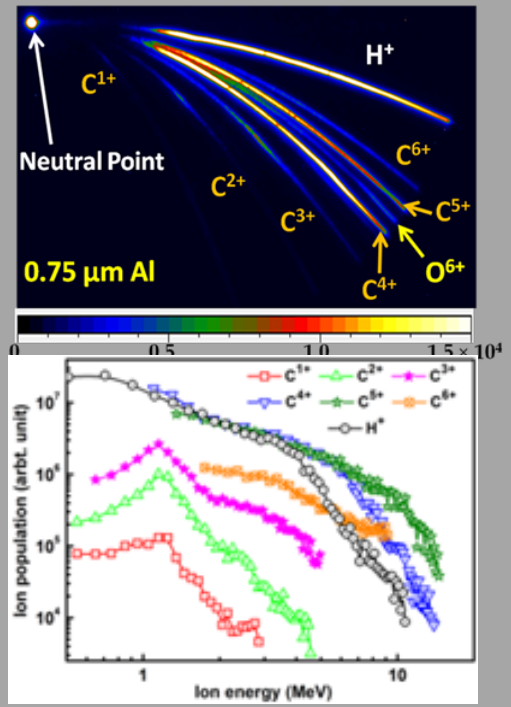
Phys. Rev. Acc. And Beams 25, 090703 (2022)

Phys. of Plasmas, Accepted.

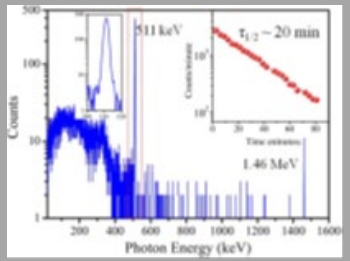
Proton and ion acceleration

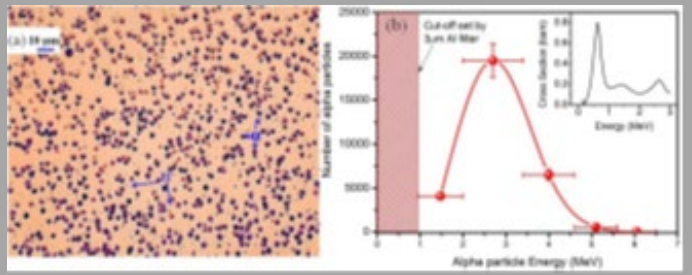
Funded by the European Union

Proton (few MeV to >10 MeV)
and Carbon ion acceleration



Production of ^{11}C radio-isotope:
^{11}B (p, n)^{11}C and ^{10}B (d, n)^{11}C
Proton-boron fusion reaction: $p + {}_5B^{11} \Rightarrow 3\alpha + 8.7$ MeV





Phys. Rev. E 90, 023103 (2014)

Phys. Rev. E 92, 051103 ® (2015)

Phys. of Plasmas 25, 083113 (2018)

Plasma Phys. Controll. Fusion. 61,-115007 (2019)

M. Tayyab, Ph. D. Thesis, 2019, HBNI, DAE, Mumbai,

http://hbni.ac.in/thesis.html

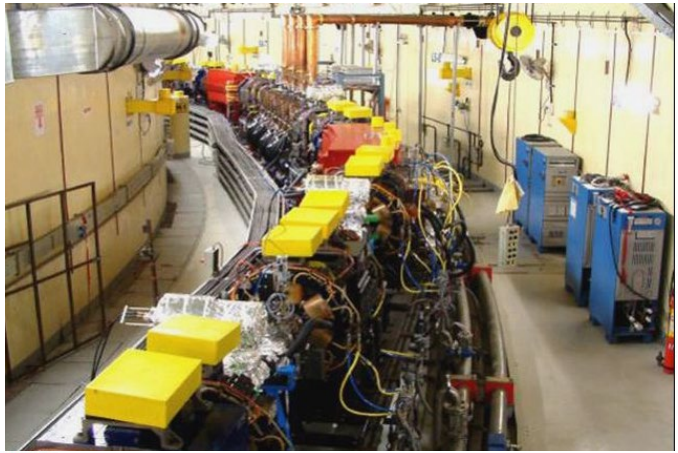
राष्ट्र की सेवा में परमाणु
रा र प्रौ कें
RRCAT
ATOMS IN THE SERVICE OF THE NATION

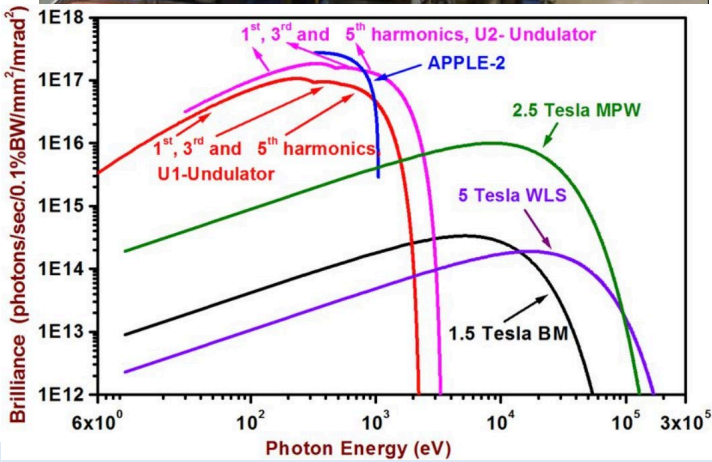
Outline

- Laser Plasma Accelerator Programs and Recent Works
- Large Scientific Infrastructures
- Partnerships in Mega Science Projects
- Our partnership with India

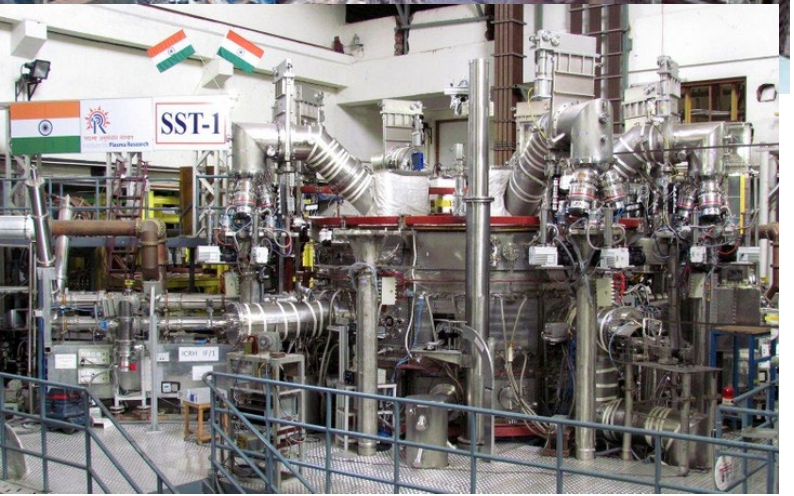
Indus I & II: India's Synchtrotron

Beamline	Insertion Device	Energy range	Radiation type	Applications
Atomic, Molecular and Optical Science	Pure permanent magnet undulator	6eV to 250eV	Soft X-ray	UV and Vacuum UV Photo ionization, photo dissociation dynamics and energetic of atoms, molecules, clusters
Energy Dispersive X-ray Diffraction	Superconducting wavelength shifter	5 keV to 80 keV	Hard X-ray	High pressure X-ray diffraction, High Q x-ray diffraction .
Protein Crystallography	Superconducting multipole wiggler	5 keV to 20keV	Hard X-ray	Single and multiple wavelength anomalous diffraction from proteins.
Angle Resolved Photoelectron spectroscopy	Pure permanent magnet undulator	30eV to 900 eV	Soft X-ray	Electron density of states, and band structure mapping of materials
X-ray Magnetic Circular Dichroism	Pure permanent magnet helical undulator APPLE II	300eV to 1500eV (including higher order harmonics)	Circularly and linearly polarized soft X-ray	Magnetic properties of materials.





Tokamaks: Aditya and SST-I



Institute for Plasma Research (IPR) - Ahmedabad

- Plasma physics
- High Energy Density Physics
- Fusion studies (MCF)
- Simulations

Major partner in ITER

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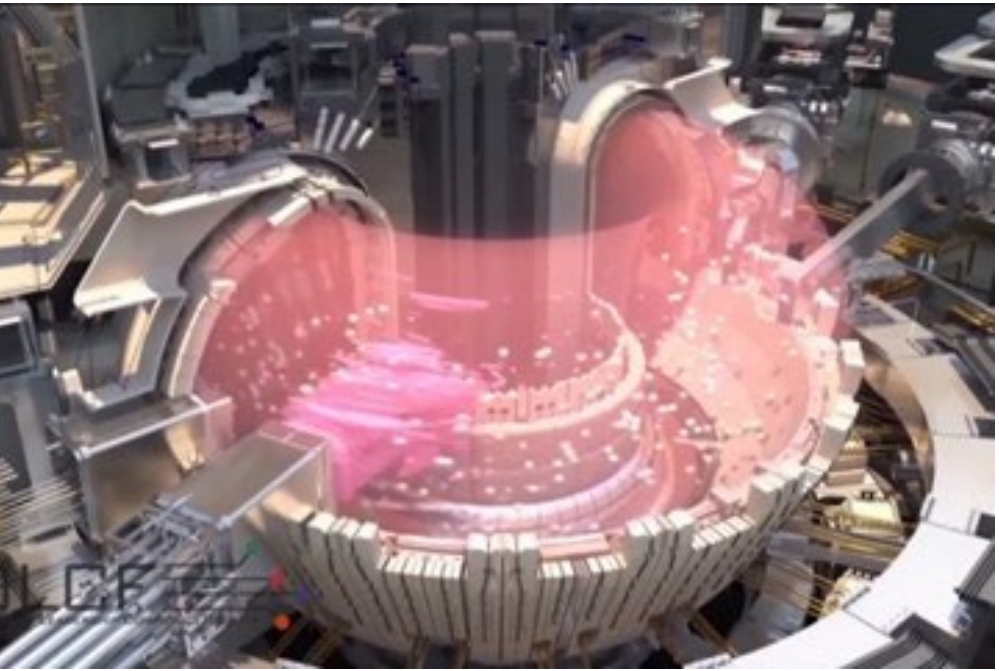
Mega projects: ITER



https://www.iterindia.in

Strong partner of ITER

Supplier of

- Entire cryo-system, including 30mx 30m cryostat
- In-wall shielding
- Cooling water and Heat Rejection System
- ICRF source system and power supplies

Mega projects: FAIR, SKA and LIGO

FAIR — Facility for Antiproton and Ion Research in Europe

Partner in building FAIR – co-owner

- Supplying some of the accelerator components
- Test and proof-of-principle experiments in Indian labs
- Monetary and in-kind contribution

Strong partner of SKA from beginning

Developing and delivering:

- Telescope Manager (TM) System and Observatory Management System
- Pulsar Search System (PSS) and the Signal and Data Transport System

Mega projects: CERN

Contributes to

- CMS
- ALICE
- LHC
- Computing Grid (Tier 2 Centres in TIFR and VECC

http://india.web.cern.ch/#

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Long-standing collaborations with India

- Funded through Newton-Bhabha programme, involving UK and Indian universities since 2015
- Workshops held in India, exploring the potential of laser-driven sources for therapy, diagnosis and biomedical imaging
- A strong interest to establish a joint centre for translational research
- A *pilot programme* in 2017: UK Science minister announces a joint innovation project between CLF and Tata Institute of Fundamental Research (TIFR)
- Joint development of control systems for next-generation high power lasers
- This led to a unique joint innovation centre with India

Extreme Photonics Innovation Centre (EPIC)

- A £5.5M Centre established in Hyderabad, India in partnership with TIFR and wider DAE
- Funded by UKRI FIC & ISPF
- Employs over 30 people who work on various aspects of plasma accelerator technology – from TIFR, IIT's and universities
- Design and manufacture of key components for laser-driven accelerators, inc. control systems, high volume data analysis & processing, targetry and detectors.
- Now expanding to include bioimaging for cancer, assisted with Machine Learning (with TMC and TIFR)
- Opportunities to expand the collaboration further

EPIC
Extreme Photonics Innovation Centre

(Partnerships) Make Photons Great Again