M.1: Operation of the IR-FEL facility in the 'User Mode'

The Infra-red Free Electron Laser (IR-FEL) based user facility, which is the first of its kind in the country, was formally inaugurated in December 2024 for outside users by Dr. A. K. Mohanty, Secretary, DAE and Chairman, AEC. The light from the IR-FEL is regularly delivered at the user facility for experiments. Two experimental stations are presently available for the users: (i) Frequency domain spectroscopy in low temperature and high magnetic field environment, and (ii) wavelength selective scanning, imaging and absorption studies at room temperature using pyro-electric detectors and a home-built Michelson interferometer. A third user port has been commissioned for FEL Physics experiments, which is also available for users to set up experimental stations for studies in Chemistry, Biology or other areas. More user stations will be available in the near future.

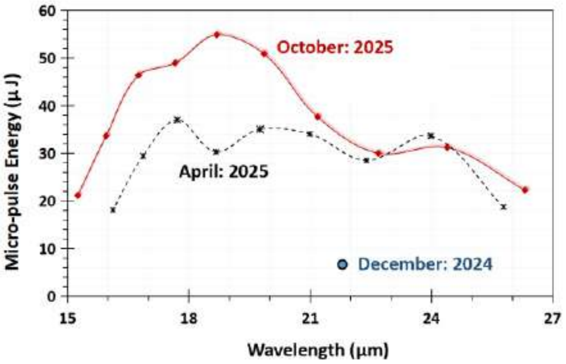

Fig. M.1.1: Improvement in peak micro-pulse energy at a user station through machine optimization.

The IR-FEL provides continuously tunable radiation from 12.5 - 50 micron wavelength with a CW average photon flux ~10^{14} photons/s and a peak photon flux of ~10^{18} photons/s over 10 ps micropulses at the user stations. The facility has been operated in the 'User Mode' for more than 750 hours in the year 2025. Repeatable and stable (5%) operation of the machine over typical user cycles of 8 hours, with machine start-up time ~15 minutes after initial conditioning, have been established. At the request of users from TIFR and IIT Bombay for their proposed studies of nonlinear phenomena using IR-FEL light, the energy per micropulse at the user stations has been enhanced from ~7 μJ/micropulse in December 2024 to more than 30 μJ/pulse at present over the wavelength range from 16- 26 microns, with a peak of >50 μJ/micropulse at 19.12 microns (Fig. M.1.1).

Using the IR-FEL light, user experiments have been performed to study the wavelength dependencies of photo-currents in bulk narrow gap semiconductor and absorption in a silver black sample received from CEERI Pilani. Wavelength dependent absorption spectroscopy and imaging studies in both transmission and reflection modes (see Fig. M.1.2) were performed on two Ti-V alloy thin film based superconducting radiation detector structure samples (consisting of a meander structure and inter-digitated capacitor) designed and developed in-house. The experimentally obtained absorption characteristics matched reasonably well with the results of electromagnetic (CST) simulation. The first results of this study were presented at the Low Temperature Detectors Conference LTD-2025, New Mexico, and the sharp tunability of IR-FEL is crucial for these studies.

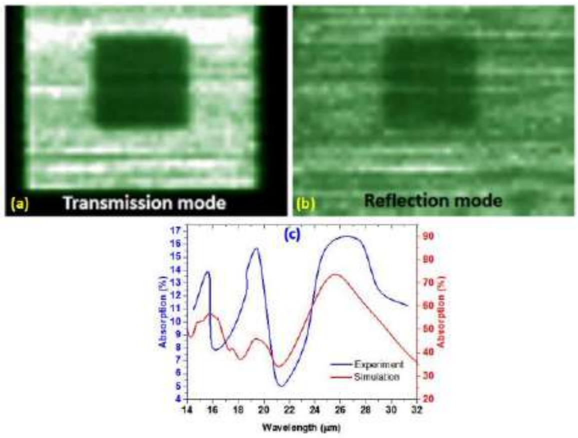

Fig. M.1.2: Scanning measurements using IR-FEL light on superconducting Ti-V thin film radiation detector structure, and comparison with CST simulation.

Utilizing the fact that pure AlN has an absorption band between 11 and 18 micron wavelengths, the IR-FEL light was used to locate the sites of inhomogeneities in an AlN thin film (see Fig. M.1.3) through scanning-imaging experiments. The IR-FEL light was sequentially tuned at wavelengths within and outside the absorption band of pure AlN, and the disorder sites were located by scaling the measured reflectivities.

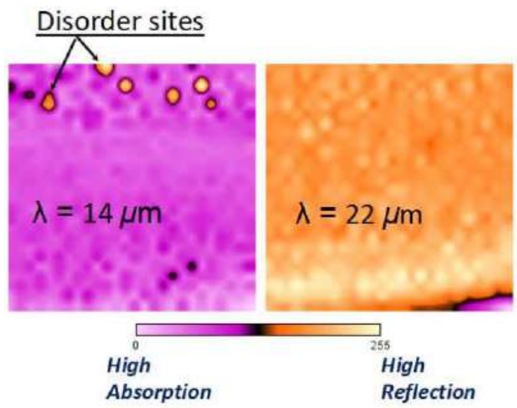

Fig. M.1.3: Wavelength selective scanning-imaging of AlN thin film using IR-FEL light revealing sample inhomogeneities.

For the non-destructive characterization technique presented above (Fig. M.1.3) the tunability and power of the IR-FEL are essential, and a spatial resolution of 300 microns is achieved.

Reported by:
M. K. Chattopadhyay (maulindu@rrcat.gov.in)