A.9: Development of an infra-red free electron laser (IR-FEL) at RRCAT

The Infra-red Free Electron Laser being built at RRCAT is designed to lase in the 15 – 50 μm wavelength band using a 15 – 25 MeV electron beam and a 2.5m long, pure-permanent magnet undulator. In stage-1, the FEL will deliver pico-second pulses of 1.5 MW peak power output at a repetition rate of 29.75 MHz for a macro-pulse duration of ~ 5 μs and a pulse repetition rate of 1 – 10 Hz. In stage-2, the micro-pulse repetition rate as well as the macro-pulse repetition rate will be doubled to increase the continuous wave (CW) average power output from the IR-FEL.

The injector system for the IR-FEL comprises a pulsed thermionic electron gun, a 476 MHz sub-harmonic pre-buncher (SHPB) and two 12-cell Plane Wave Transformer (PWT) linac structures resonating at 2856 MHz. The gun generates 90 keV, 1 ns pulses of ~ 1 nC charge at a repetition rate of 29.75 MHz for a macro-pulse duration of 1 – 10 μs and a pulse repetition rate of 1 – 10 Hz. The ns pulses are bunched in the SHPB before injection into the linac for further bunching to 10 ps and acceleration to rated energy of 15 – 25 MeV. The SHPB and the PWT linac structures have been RF conditioned at rated power levels before integration in the IR-FEL setup. The RF systems for the the SHPB and the S-band linac structures have been developed by RFSD and PHPMD respectively. Figure A.9.1 shows a picture of the IR-FEL injector system.

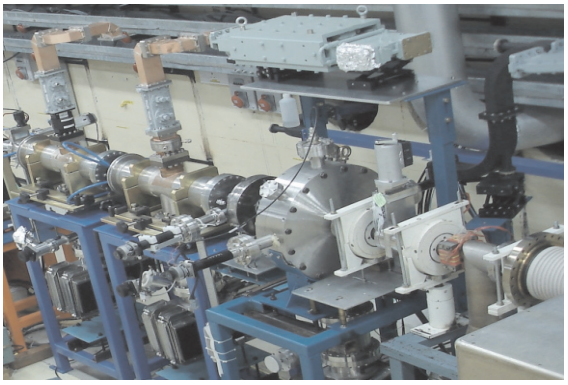

Fig. A.9.1: IR-FEL injector system

Electron bunches from the injector system shall be transported to the IR-FEL undulator by employing a transport line with a 'dog-leg' bend. All transport line magnets built in-house by Accelerator Magnet Technology Division (AMTD) were characterized and fiducialized before installation in the IR-FEL setup. All electromagnet power supplies built by the Power Supplies & Industrial Accelerator Division (PSIAD) have been tested and commissioned in the IR-FEL setup. Figure A.9.2 shows a part of the IR-FEL electron beam transport line.

Fig. A.9.2: IR-FEL electron beam transport line

The IR-FEL employs a 2.5 m long pure permanent magnet undulator with a 5 cm period and tunable K_{rms} from 0.5 to 1.2. This variable gap undulator has undergone detailed field mapping to ensure compliance to design specifications of RMS field error ≤ 0.5% before being installed in the IR-FEL setup. The vacuum beam pipe for the undulator section has been fabricated by Ultra High Vacuum Technology Section (UHVTS) using Aluminum alloy with a race-track internal cross section of 17 mm height and 81 mm width. Figure A.9.3 shows the undulator at the design operation gap of 31.6 mm with the vacuum pipe installed in the gap.

Fig. A.9.3: IR-FEL undulator with vacuum chamber

Installation of all sub-systems of the IR-FEL inside its 60 m long shielded area is complete and the setup has been pumped down to rated vacuum levels by UHVTS. A Supervisory Control And Data Acquisition System (SCADA) has been developed by LESD and all sub-systems have been individually tested for remote operation. Testing and commissioning of individual sub-systems of the IR-FEL has been completed and preparations are underway to start trial operations. After an initial period of RF conditioning of the two linac structures at rated power levels, beam trials will be done initially with low electron beam currents to transport the accelerated electron beam from the exit of the linac to the electron beam dump with minimum loss of charge. The next stage of experiments would involve increase of electron beam current to rated values for generation of IR radiation from the FEL.

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