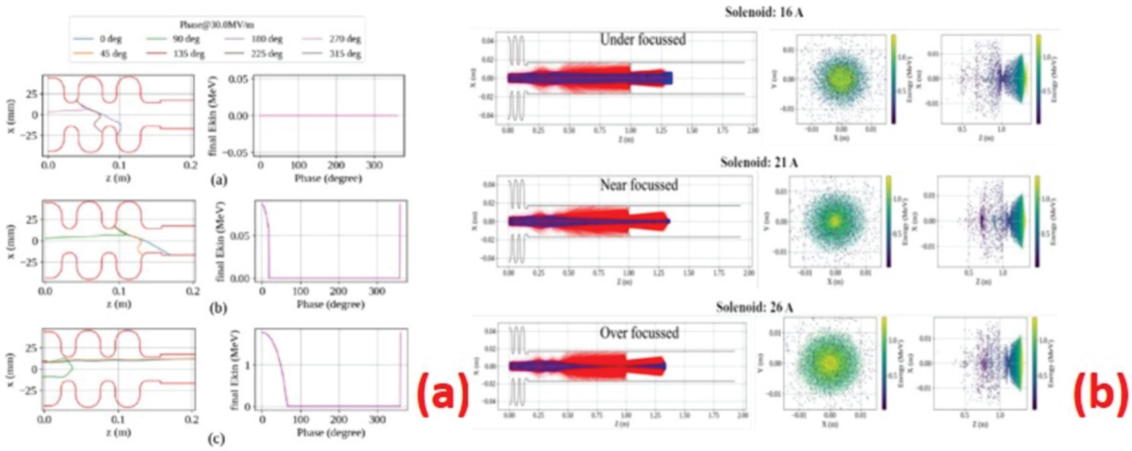

Figure 2. (a) Simulation for production of dark current (b) Electron beam trajectory plot illustrating focusing point along with transverse and longitudinal distribution at screen for the focused beam.

2.2.2.3 Status of the Photocathode Deposition System at IUAC

The production of electron beam has already been demonstrated by striking laser beam on the Cu photocathode. It is being planned subsequently to enhance the electron beam production using Cs_2Te photocathode. Last year we have reported the testing of photocathode deposition system at Brookhaven National Laboratory (BNL), USA. The complete system along with all its accessories was shipped from BNL in summer 2021 and arrived at IUAC in Sept. 2021. After careful inspection and unpacking, the deposition system is being installed at IUAC after making necessary space arrangement and mounting of the supporting fixtures [6]. The existing photocathode insertion chamber is being integrated with the deposition system. The installation is in its final stage and functionality of the system will be tested soon with XHV vacuum. Figure 3 shows the 3-D design of the deposition system consisting of four chambers along with the chambers installed in the beam line.

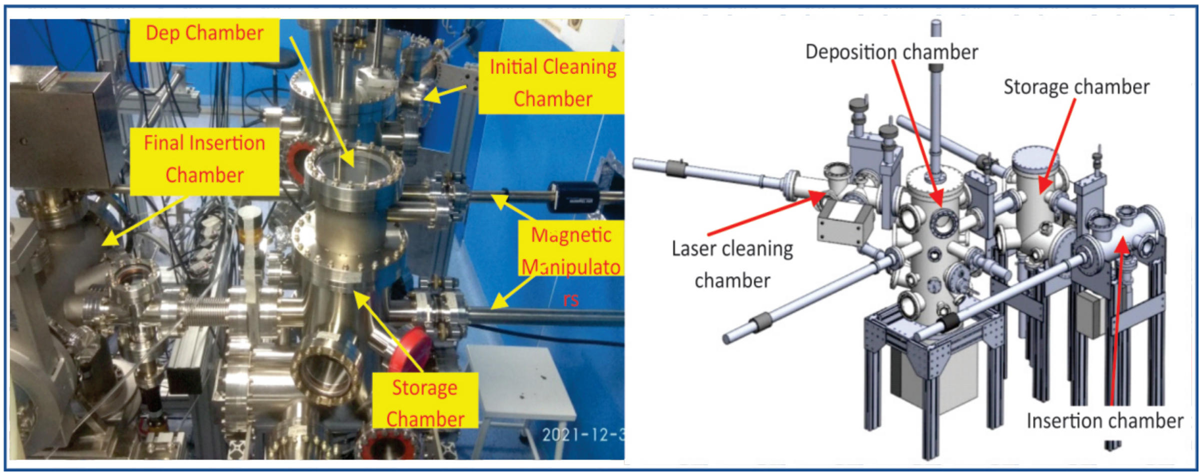

Figure 3. Photograph (left) and schematic (right) of the photocathode deposition system installed at IUAC.

2.2.2.4 Status of the Undulator

The elctron beam emitted from the phootcathode and focused by the solenoid will be injected into the undulator to produce the radiation in the desired frequency range (0.18-3 THz). A spare undulator supplied by Helmholtz Zentrum Berlin (HZB), Germany underwent some refurbishment and magnetic field measurement at Deutches Electronen Synchrotron (DESY), Germany. The undulator was subsequently shipped to IUAC and installed in the beam line during April-May, 2021. The stretched wire measurements for the field integrals of the device, which are important to understand the steering effect on the electron beam due to end fringe field and the ambient magnetic field, have been performed at IUAC [7]. The control rack of the undulator has been installed and the gap movement was successfully accompolished with all the safety measures in place. The field integral measurements for the permanent magnets of the undulator and the long ambient field correction coils have been completed. The measurments for the end kick coils are in progress. The long coils and the end-kick coils together will be used for the mitigation of the residual field integral of the device. This will be followed by the final installation of the undulator along with its vacuum chamber.

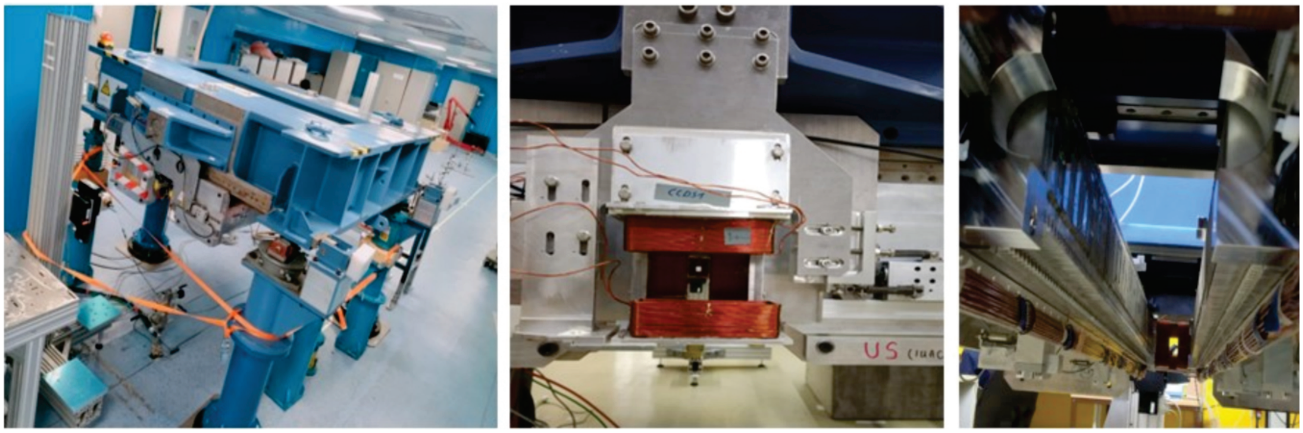

Figure 4. Installed undulator (left) with the end correction coils (middle) and long coils (right).

2.2.2.5 Commissioning status of the beam line

The complete beam line design and its 3-D drawing were made and the beam line has been commissioned upto the entrance of the undulator along with the Solenoid magnet, beam position monitor, integrated current transformer, beam viewer with digital camera. A modification in the beam line has been incorporated to install a diagnostic chamber with a YAG screen at the entrance of the electron gun to visually verify the laser beam ensuring that it will strike on the photocathode placed inside the electron gun. The undulator has been shifted inside the clean room and positioned in the FEL beam line. The THz extraction chamber is also getting ready for installation. The photograph of the installed beam line is shown in figure 5.

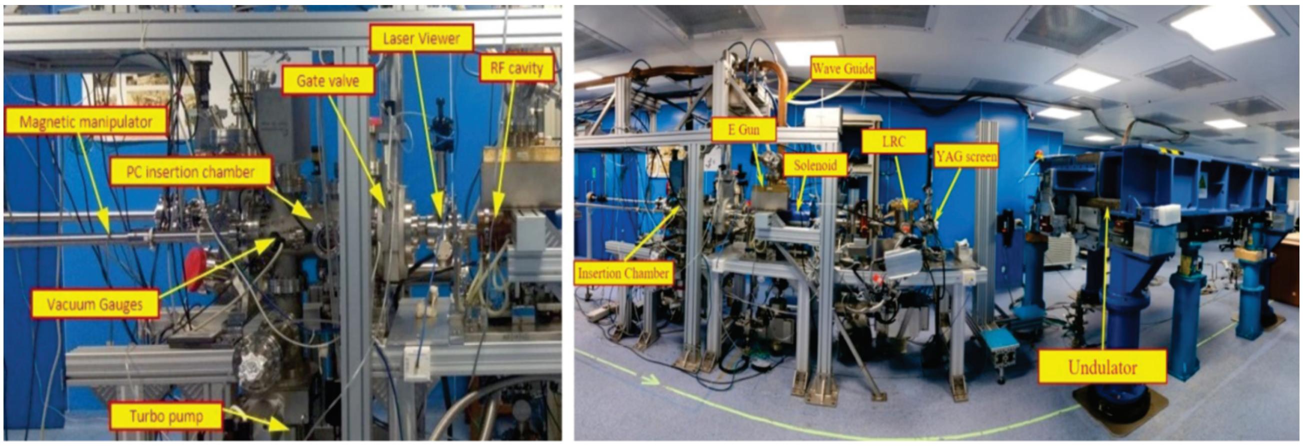

Figure 5. The complete beam line for pre and post Undulator section along with modifications for laser viewer.

2.2.2.6 Testing and calibration of strip line Beam Profile Monitors and associated electronics

The strip line BPM from Instrumentation Technologies has been procured for diagnosing the electron beam in the Delhi Light Source (DLS) facility. The BPM has four electrodes with SMA feedthroughs which receive corresponding signals depending on the beam position. For testing the device and the associated electronics, stretched wire setup was used as shown in the block diagram of figure 6 (a). A stretched copper- beryllium wire is made to pass through the BPM. Pulses of specified duration as per the specification of DLS electron beam with known amplitude are passed through the stretched wire and the signal from the four electrodes of the BPM are measured. The four signals are then recorded by the dedicated Libera Single pass electronics module and processed. These signals are seen on the graphical user interface (GUI) terminal developed with EPICS based control and X/ Y positions are calculated [8]. Subsequently, the wire was moved in a 10 mm x 10 mm mesh with 1 mm step size and calibration of the measurement of X and Y is carried out as shown in figure 6 (b). It is observed that the linear region of the BPM lies in the range of X values from -2 mm to +2 mm and, Y values from -3 mm to +3 mm so the electron beam passing within this boundary will have negligible error in the measurement of its position. The BPM and its support electronics have been installed in the beam line after successfully testing and calibrating. The beam position data from the BPM has been acquired and analyzed during the recent test of producing photo-electrons by the electron gun. In all the future operations of the electron gun, the BPM will be routinely used to measure the beam position.

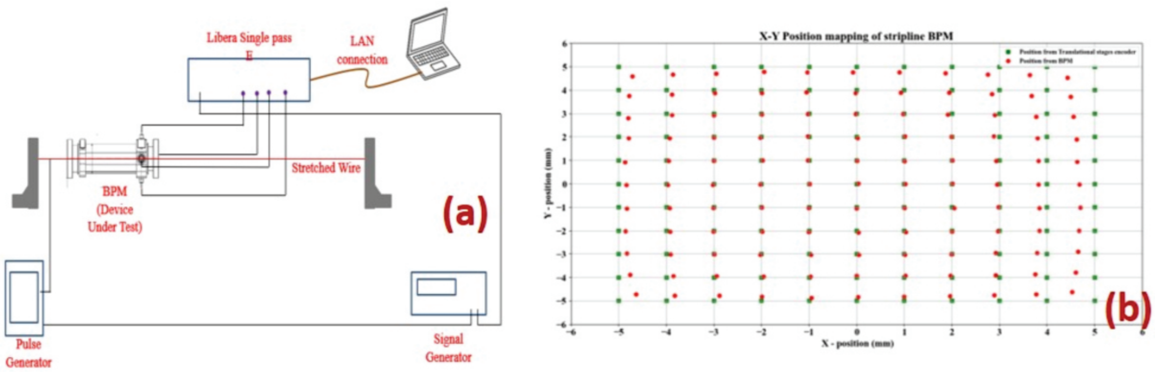

Figure 6. (a) The stretch wire set up for testing of BPM (b) Calibration of BPM using X-Y position mapping.

2.2.2.7 Setting up new control room for the FEL facility

A dedicated control room for the FEL operation is getting ready along with a separate entry from control room to the FEL facility. The control modules along with distribution racks are finalised and the instrumentation racks are placed at appropriate locations. The modules for vacuum system control and read-back are being developed in house. The networking along with wiring of interlock and control signals are completed. EPICS based control scheme is being implemented for all the control devices. The magnet power supplies are integrated with RS 232 based control scheme in an Orange Pi machine running EPICS server. Control and interlock requirements for high power RF system, LLRF system, beam diagnostics devices and undulator are being taken care by the independent standalone control modules. Team viewer and AnyDesk software are used for remote control and monitoring. EPICS based client server architecture is being implemented for LLRF, BPM, and Gigabit Ethernet based camera for beam viewing. IP based CCTV cameras are installed in the facility along with remote monitoring facility in the control room. Two remote control clients made operational in the control room for routine operation and the first production of electron beam was demonstrated. Development of client GUI interface is being worked out taking care of the operational requirements of the facility. The scheme of the control architecture along with control room is shown in figure 7.

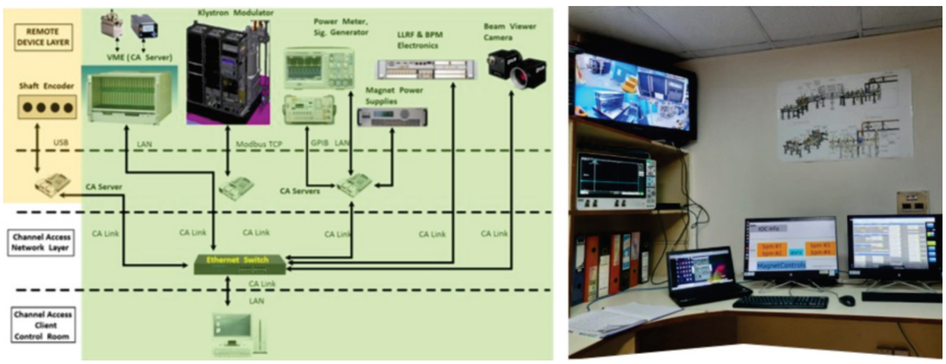

Figure 7. EPICS based control scheme for FEL along with view of control room.

2.2.2.8 Simulation studies for production of THz radiation

Simulations were carried out to optimize the multi bunch dynamics inside the undulator [9] for two frequencies, viz. 0.5 THz and 2 THz, with emphasis on optimizing the bunching factor at the required frequency. The bunching factor spectrum, its variation and the bunch longitudinal distribution at the entrance, middle and exit of the undulator is shown in the figure 8 for the two frequencies. The corresponding radiation spectrum is also analyzed. The calculated peak power is ~ 50 kW and 1 MW respectively for the two frequencies. The simulation results are shown in Figure 8.

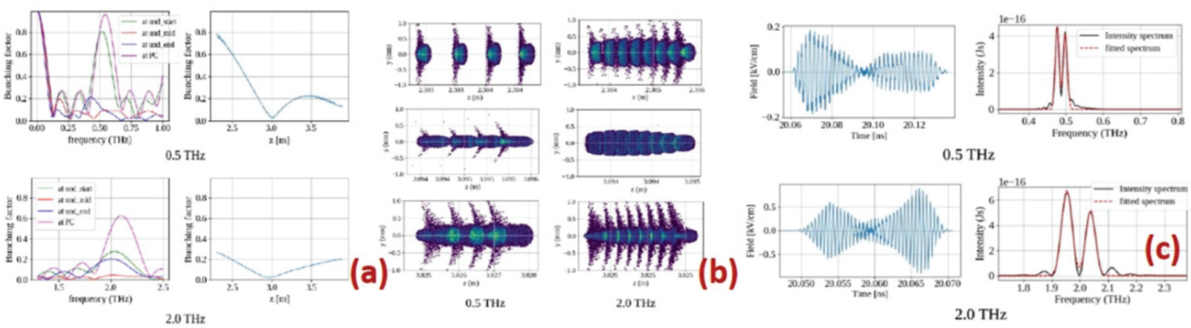

Figure 8: (a) Bunching factor spectrum and its variation through undulator at 0.5 and 2 THz respectively. (b) The bunch longitudinal distribution for the two frequencies at the entrance, middle and exit of the undulator. (c) Radiation field and the corresponding spectrum for the two frequencies.

2.2.3 CONCLUSION

Significant progress has been made in the commissioning of the compact Free Electron Laser at IUAC for the production of THz beam. The RF conditioning of the electron gun has been accomplished up to 1 MW of peak RF power and the first signature of electron beam from the RF photo cathode gun using a ns UV laser has been demonstrated recently. High power RF circulator is being planned to be installed in summer '2022 and then the RF gun can be conditioned up to the desired power level of 24 MW. The fiber laser system is also in the final stage of development and is expected to be commissioned by the end of 2022. A workshop to discuss the experimental proposals using THz radiation and electron beam has been arranged. It is expected that the first signature of THz radiation can be demonstrated in the next academic year.

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