A.7: First signature of coherence in the CUTE-FEL setup

The **C**ompact **U**ltrafast **Te**rahertz **F**ree **E**lectron **L**aser (CUTE-FEL) at RRCAT is designed to lase in the 80 – 150 μm wavelength band using a 10 – 7 MeV electron beam and a 2.5m long, pure-permanent magnet undulator. Recently, the first signature of build-up of coherence in THz radiation output has been observed in experiments on the CUTE-FEL setup with the measured THz power output being more than 100 times higher than the expected spontaneous power output for the charge transmitted through the undulator. This has been made possible by the installation and successful commissioning of a fundamental frequency pre-buncher (FPB) in place of the sub-harmonic pre-buncher (SPB) installed earlier, but which could not be powered on since the high power RF source ordered from an outside vendor was not delivered. Consequently, peak electron beam current in earlier experiments was limited to < 5 A, which is very much lower than the threshold current of ~ 17A required for initiation of coherence build-up as revealed by FEL simulations. It needs ~ 30A of peak current for the FEL instability to saturate, or for the FEL to lase.

The first measurement of THz radiation from the CUTE-FEL setup with the optical cavity installed was made in February 2011 using a liquid helium cooled bolometer [QMC, QGeB/2]. Due to the low available peak current in those experiments (< 5A) on account of the SPB cavity being un-powered, no further increase in THz radiation output was possible. The feasibility of incorporating a fundamental frequency pre-buncher (FPB) at S-band was studied through beam dynamics and RF simulations. A new FPB design based on modified photocathode RF gun geometry was finalized and a 1.6 cell, S-band photocathode RF gun built earlier for another application was re-machined into a single-cell FPB. Beam dynamics simulations were fine-tuned to determine a parameter regime enabling the FPB to be installed at the same location as that of the SPB causing minimum disturbance in the CUTE-FEL beam transport line. With ~ 250W power fed to the FPB, the 1 ns FWHM bunches at 90 keV from the thermionic electron gun can be bunched to ~ 30 ps at the entry to the linac, which further bunches and accelerates the beam to rated energy with a significantly higher total charge transmission through the injector linac system as compared to earlier experiments without any pre-buncher. Figure A.7.1 shows a picture of the FPB structure undergoing cold-test before installation in the CUTE-FEL setup.

Experiments with the FPB were performed after optimization of the transport line parameters and the phase of RF in the FPB and the PWT linac to obtain maximum accelerated charge transmission through the linac. Fig. A.7.2(i) shows the ICT trace for the input 90 keV electron beam at the entrance of the PWT linac. Fig. A.7.2(ii) shows the ICT trace for the accelerated electron beam from the PWT linac with the FPB powered off, and fig. A.7.2(iii) shows the ICT trace with the FPB powered on and after optimization of RF phase. The measured doubling of charge transmission agrees very well with predictions of PARMELA simulations for the total accelerated charge from the linac. Out of this total accelerated charge, the bending magnet selects a fraction with the right mean energy and with an energy spread falling within the acceptance of the beam transport line. PARMELA simulations determine the fraction of charge in these experiments with the 0.5% relative energy spread required for the CUTE-FEL to be ~ 15 A, which is close to the threshold current of ~ 17A for coherence build-up to be initiated. The beam energy used in these experiments was ~ 5.5 MeV with an expected photon wavelength of ~ 250 μm. The measured out-coupled CW average THz power of 570 pW at 2 Hz operation translates to a photon flux of ~ 6.6×10^{11} photons/s, which is more than hundred times larger than the expected spontaneous emission power indicating a nonlinear dependence on the charge due to a build-up of coherence

Efforts are presently underway to install a copper plated SPB cavity and a 750 W RF source developed by PHPMS, RRCAT for experiments on further enhancement of peak current, which is expected to further increase the THz output from the CUTE-FEL setup.

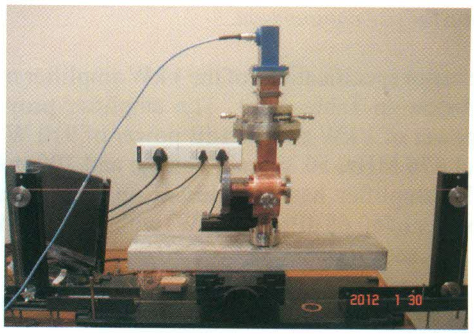

Fig. A.7.1: FPB structure undergoing final cold-test.

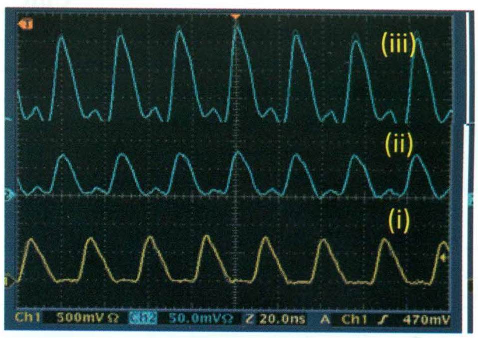

Fig. A.7.2: ICT signals (i) at linac input, (ii) accelerated beam with FPB off, and (iii) with FPB on.

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