Figure A.2.1 below shows the CUTE-FEL setup used to generate terahertz radiation. A 0.5 µs, 90 keV beam of electrons from a pulsed thermionic electron gun was transported through an un-energized 476 MHz (1/6 harmonic) pre-buncher cavity into the 8-cell, S-band PWT linac structure for acceleration to rated beam energy of 7 - 10 MeV. The pre-buncher was not energized since the RF power source for the same is still awaited. A low energy beam transport line comprising solenoids and rotatable saddle dipole coils was used to optimize transmission of the 90 keV beam from the gun to the 8-cell PWT linac structure. Accelerated beam from the linac was transported to the optical cavity of the CUTE-FEL using a beam transport line comprising a quadrupole triplet and an achromatic double bend. The beamline has provision for steering the electron beam, if needed. Diagnostic elements are provided in the beamline for measurement of beam current and beam profile at different points for optimizing beam transport

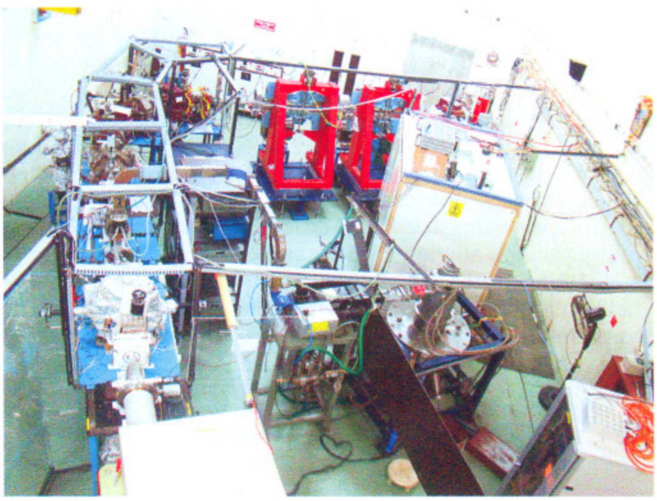

Fig. A.2.1: CUTE-FEL setup

The optical cavity for the CUTE-FEL is 4.1 m long with out-coupling of radiation through a hole in the downstream mirror. The first set of experiments were aimed at optimization of transmission of beam through the undulator for generation of spontaneous terahertz radiation. Hence, the downstream mirror was not installed, as it would have severely curtailed the out-coupled power, making measurements with the bolometer difficult due to low expected power levels.

Figure A.2.2 shows traces of the beam current, measured using fast current transformers, at the entrance and exit points of the linac and the undulator. Figure A.2.3 shows the bolometer trace corresponding to the beam current shown in Fig. A.2.2. The measured signal of 11.2 V corresponds to a CW average power of 6.5 nW and a macropulse power of ~ 15 mW in the 0.2 µ s pulses.

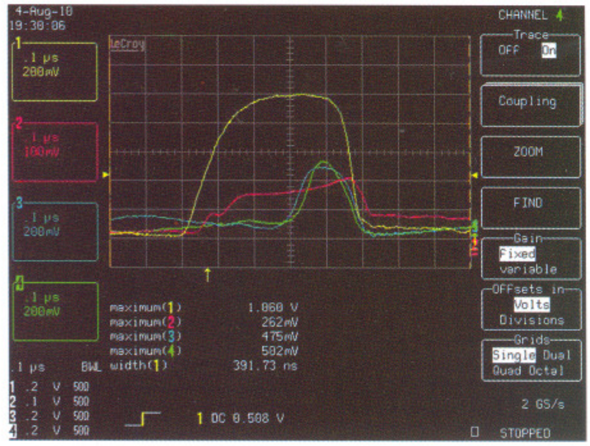

Fig. A.2.2: CRO traces of FCT signals before linac (yellow, 1A), after linac (red, 262 mA), before undulator (blue, 31.7 mA) and after undulator (green, 25.1 mA)

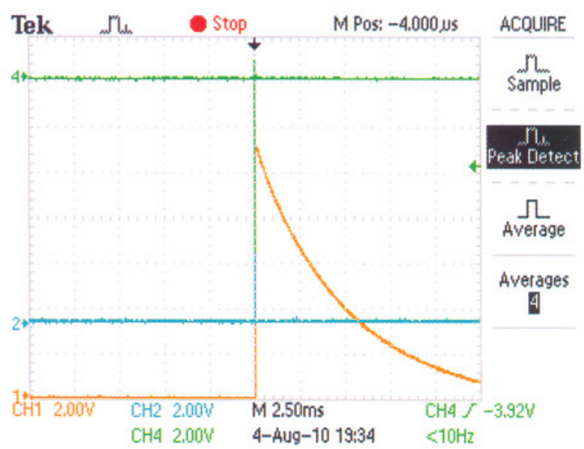

Fig. A.2.3: CRO trace of signal from Bolometer

In near future, it is proposed to use fast pulsing of the electron beam with pulse spacing matching the round trip time of optical radiation in the optical cavity of the CUTE-FEL. This will give the micro-pulse peak current required for amplification of spontaneous emission with small beam loading in the linac.

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A.3: Development of 1.3 GHz Single cell SCRF cavities

Two numbers of 1.3 GHz prototype Single cell Superconducting Radio frequency (SCRF) cavities have been successfully developed by a team of members from Power Supply and Industrial Accelerator Division (PSIAD), Accelerator Components Design and Fabrication Section

(ACDFS), Pulsed High Power Microwave Section (PHPMS) and Proton Linac and Superconducting Cavities Division (PLSCD). These first prototype cavities have been successfully tested recently at Fermi National Accelerator Laboratory, USA. Electron beam welding (EBW) of high RRR niobium parts of cavity were carried out at Inter University Accelerator Centre (IUAC), New Delhi in collaboration. The cavity processing and testing at 2K has been carried out at Fermi National Accelerator Laboratory (FNAL), USA under Indian Institution-Fermilab Collaboration (IIFC).

RRCAT has done development of forming tooling for half cells, machining and validation of cavity components, design and development of welding fixture, and testing for vacuum integrity and RF parameters. The present report is on development and testing of first two prototype SCRF cavities at 2K. *(Development of Metal Forming Tooling for 1.3GHz SRF cavity has been reported in RRCAT Newsletter - article A.8, vol.2, issue2, 2009).*

Development of SCRF cavities was carried out with a study of the required cavity geometry, control of mechanical tolerances on cavity parts, quality of weld joints and end flanges, and sealing requirements. Dedicated precision beam pipe rolling setup and necessary EBW fixtures were designed and developed. Manufacturing process was developed to make the SCRF cavity with desired length and frequency at 2K. The cavity has to attain vacuum leak tightness and surface quality to produce a desirable accelerating gradient at 2K. The manufacturing process was initially validated by making a few number of prototype aluminum cavities.

Experienced gained during prototype cavity development process in aluminum helped in manufacturing single cell cavity in Niobium (Nb). EBW process requires a good quality of weld joint preparation. The weld edges at iris and equator were prepared and pre-weld etched for getting a uniform weld bead. Welding parameter were established using coupons of Nb-Nb and Nb-Ti. Experimentally verified allowances were provided in cavity joints to accommodate welding shrinkage. Welding at equator was most critical, which required full penetration weld from outside to control the under bead for desired RF performance.

To control cavity frequency during stage machining of half cells, length to frequency sensitivity was analyzed by measuring frequency after successive trimming from equator and also compared with calculated values.

Both the cavities were subjected to various testing and qualification process upon completion that included mechanical measurement, vacuum leak testing, frequency and quality factor (Q) measurements at 300 K and 77 K (Fig. A.3.1). Bead pull measurements were also done to measure the electric field profile. Effect of cool down from 300 K to 77K on cavity frequency was measured. A good agreement of RF measurement data was observed between RRCAT and FNAL before processing of the cavities.

Fig. A.3.1: Prototype cavities undergoing inspection before dispatch to FNAL for processing and performance evaluation

The processing of these cavities were done using facilities of FNAL that included centrifugal barrel polishing (CBP), ultrasonic cleaning, electro-polishing (EP), high pressure rinsing (HPR), low temperature baking at 120°C for 48 Hrs and testing at 2 K in Vertical Test Stand (VTS). These first prototype single cell SC cavities achieved accelerating gradient (E_{acc}) of 19.3 MV/m and 21 MV/m with no sign of field emissions (Fig. A.3.2). Both the cavities were also free from significant Q drop before the onset of quench.

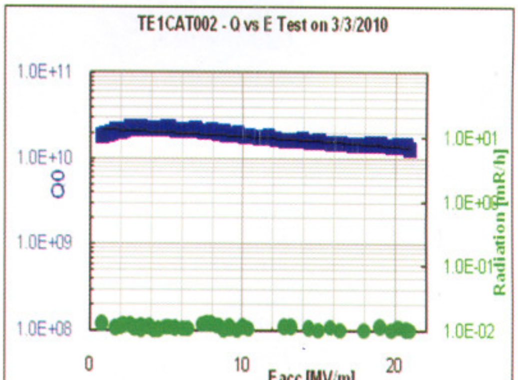

Fig. A.3.2: Q vs Eacc plot for the first Indian SCRF Cavity TE1CAT002

The results of prototype cavities are quite encouraging. Important learning lessons have been learnt during these prototype activities that will help for further improvement.

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