A.19: Design and development of 476 MHz pulsed RF system for Free Electron Laser (FEL)

Free Electron Laser (FEL) being developed at RRCAT uses a 476 MHz Sub Harmonic Pre Buncher (SHPB) for proper bunching of the electron beam. To feed SHPB RF cavity a 10 kW Pulsed 476 MHz, RF power amplifier with Digital Low Level RF (DLLRF) system has been designed and developed. This system, shown in Fig. A.19.1, consists of a 476 MHz pulsed high power RF power amplifier along with a PXI based pulsed Digital LLRF system and associated components.

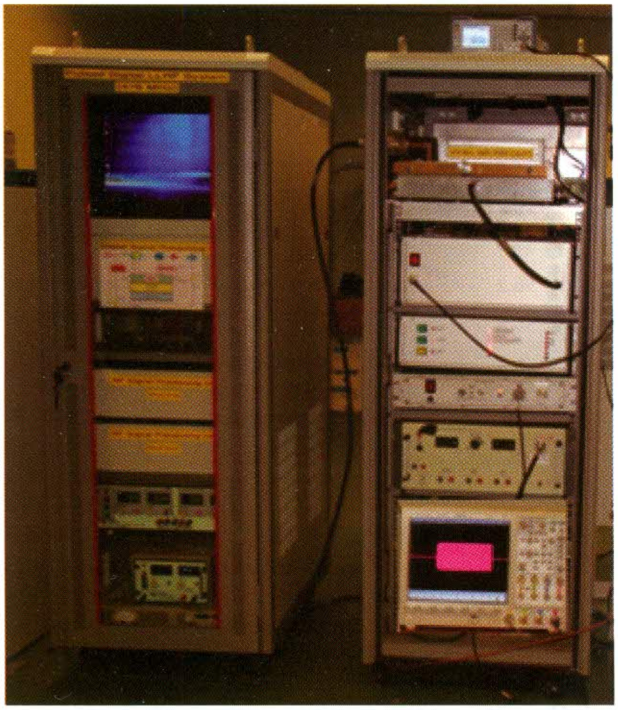

Fig. A.19.1: 476 MHz Pulsed RF system with Digital LLRF System

The RF power amplifier at 476 MHz is designed and developed using planar triode tube. The amplifier assembled in 19" rack, consists of output cavity assembly, input circuit assembly, RF socket for mounting the tube, output coupler, anode bias assembly, cathode bias assembly. The rectangular waveguide output cavity form the output matching, which has a tuning range of ±50 MHz.Input matching and tuning network is realized using strip line based network with required frequency tuning range. The amplifier is having 8.0 kV modulator DC power supply for anode and -90 volts grid power supply. Siemens make PLC based control, interlock and monitoring system is realized for monitoring various parameters and facilitate proper start-up & shutdown of the amplifier system. This system also detects malfunctions during operation and brings the system in a safe stage, thereby assuring reliable operation of the amplifier system. Siemens make S7-CPU-315-2DP CPU and OP277 6" human machine interface (HMI) device is used for this system. To measure peak pulse RF power sampled from directional coupler a detector board using RF detector (ZX-47), Sample & hold (LF398) and monostale IC (CD4538) has been developed. The RF signal is converted to pulse signal by RF detector & given to Sample & Hold. This hold signal is interfaced to PLC through its A/I. Suitable algorithm has been written in PLC to display peak power in HMI.

Constant gap voltage in SHPB cavity of FEL is very critical as any variation in gap voltage could lead to change in velocity modulation imparted to electron consequently affecting the bunching of the beam at the entry of LINAC. In such situation bunch will not reach the LINAC on the ideal RF phase resulting in poor phase stability of the accelerated electron beam for the LINAC. To achieve highly stable RF gap voltage and phase in SHPB cavity a PXI based Pulsed Digital LLRF system is developed. Digital LLRF (DLLRF) control system in addition to inherent feature of flexibility, adaptability, reduced long time drift errors provides better accuracy of the RF cavity field control with higher dynamic range.

The system has been developed in-house using XILINX make FPFA based digital electronics. Digital I/Q detection is used for amplitude and phase detection and controller is implemented in Virtex-5 FPGA. A GUI is developed for operation of RF system and measurement of various parameters. Real time simulator for the SHPB cavity was also developed to test the DLLRF system in absence of SHPB RF cavity. RF signal processing unit is developed for RF signal conditioning and making the front end RF signal compatible with the digital hardware. This unit also generates proper drive signal for high power amplifier. A RF switch with a gating pulse is used at the output of DLLRF to ensure safe operation of the RF system. In case of any parameter going beyond range this RF switch cuts off the drive to the high power amplifier. The DLLRF system and pulsed RF amplifier were integrated and tested with SHPB RF cavity. Initially in open loop operation measurement and calibration of RF cavity gap voltage RF phase and RF power at different stages was done. Then parameters of the digital feedback controller were optimized in close loop operation to achieve required field stability. With optimized parameters 476 MHz pulsed RF system was tested at full power of 10 kW having 50 microsecond RF pulse width at repletion rate of 50 Hz with SHPB cavity. The required stability of ±0.1% in amplitude and ±0.1 degree in phase was achieved for RF field within SHPB cavity.

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