6 - 3 Progress of LLRF Control System for CiADS Injector

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The demo injector is designed to accelerate proton beam to 25 MeV with beam current up to 10 mA. It includes a proton ECR ion source, LEBT, a 2.1 MeV room-temperature RFQ, MEBT and superconducting RF linac system[1]. It's operated in continuous-wave(CW) mode.

The LLRF control system is the key component to keep RF field in cavity, used as a closed loop controller which maintains cavity field gradient and phase stability when operating the cavity with beam. The great progress of LLRF control system has been achieved since the end of 2014. With the increase of the control system scale, the number of LLRF control system was increased from 3 to 21. The overall framework of LLRF control system for CiADS injector was shown in Fig. 1(a) and the LLRF controller chassis installed in field rack was shown in Fig. 1(b). Not shown is the LLRF control system which is used to control the room-temperature RFQ.

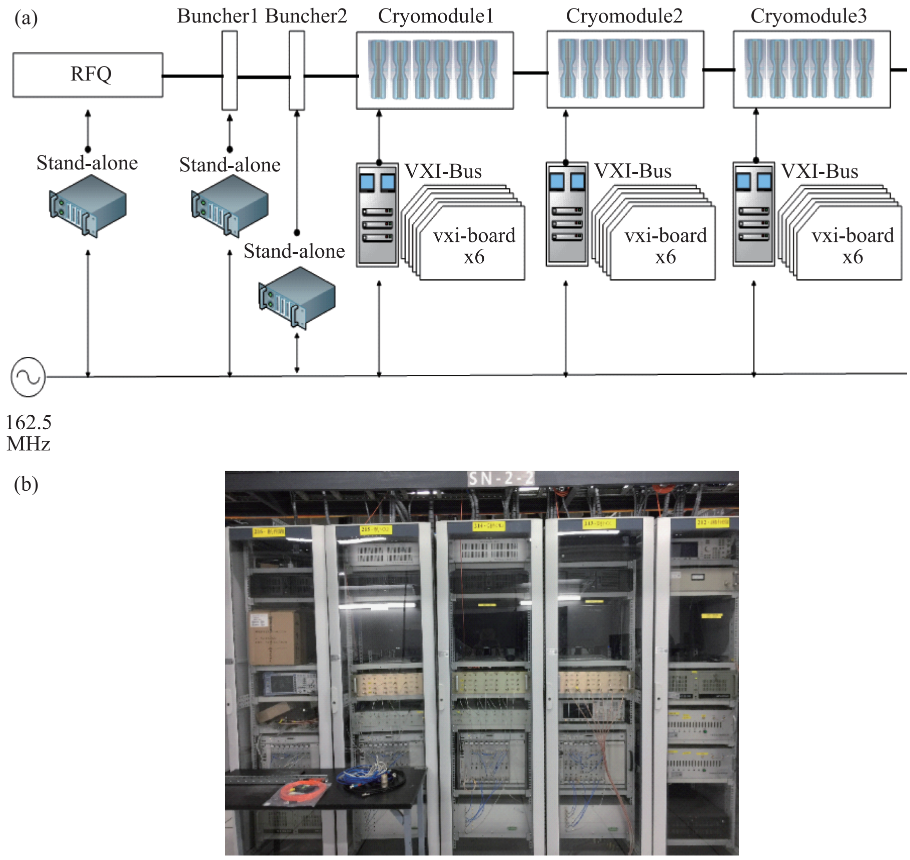
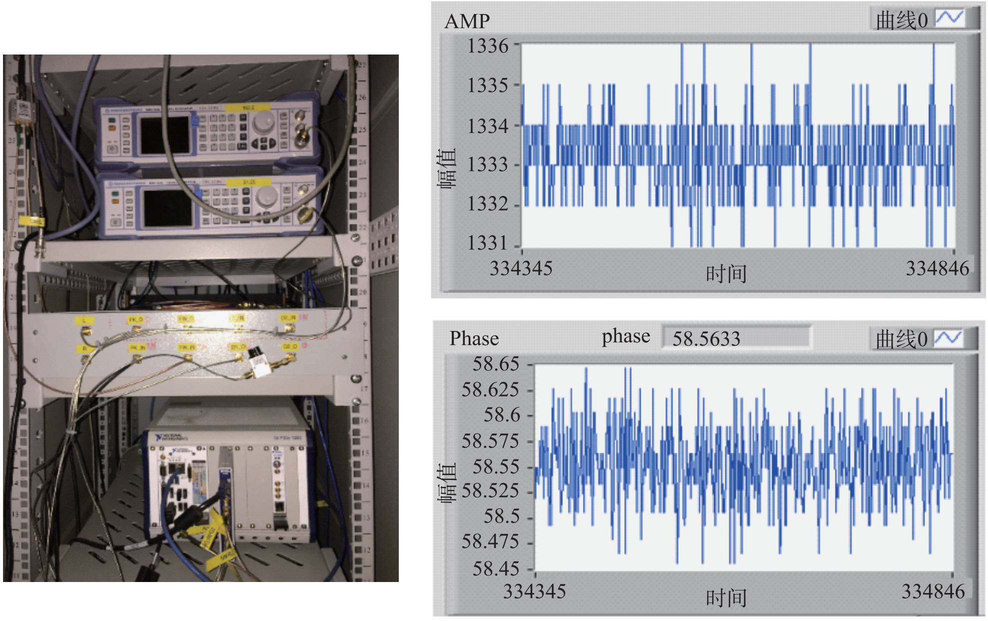


Fig. 1 (color online) The block diagram of the LLRF control system and in-situ photo.

The LLRF control system which appears as a single chassis was developed by IMP[2]. The digital feedback functions of this LLRF control system are based on the synchronous in phase and quadrature demodulation techniques, and the digital signal processing is implemented using field programmable gate array (FPGA). The transient beam loading compensation method which made use of a combination of PI feedback and feedforward control algorithm was implemented in this independent R&D LLRF system. The repetitive error in the RF control loop caused by the pulsed proton beam was successfully suppressed. In order to quickly track the frequency of superconducting cavity during cavity commissioning and recover from trip to operational gradient, the digital self-excited loop mode was also developed and successfully tested on HWR superconducting cavity.

The LLRF control system for RFQ was developed by IMP. The core of this LLRF controller is mainly digitally implemented using a PXIe platform provided by National Instruments. The signal generator, RF front end box and PXIe chassis installed in rack was show in Fig. 2(a).

The RFQ LLRF control system adopts an FPGA for digital signal processing and real-time control. The signal acquisition is performed in digitizers following the FlexRIO reconfigurable I/O (RIO) architecture. The system is programmed using the LabVIEW environment. The amplitude stability of $<1‰$, and phase stability of $<0.1°$ was achieved.



(a) (b)

Fig. 2 (color online) The in-situ photo of the LLRF control system for RFQ and performance data curve.

The LLRF controllers installed in VXI chassis were ordered from TRIUMF, CA. They are used for RF control of HWR010 superconducting cavities. These LLRF controllers were designed based on self-excited feedback loop, with the self-excited frequency stabilized by an internal analogue Phase-Locked Loop, capable of operating in both CW and pulse mode[3]. The system consists of two main parts, the first is RF Module, the second is DSP Module. The RF signal are processed and converted into baseband in RF module, the baseband signal is converted into digital form and processed by DSP module

The CiADS demo injector successfully accelerated 12 mA (@ 26 MeV) pulse beam and 170 μA (@ 25 MeV) CW beam on July 6th, these beam commissioning results also demonstrated that the LLRF control system can maintain stable operation. Work will continue to further improve the algorithm with a goal of more stable cavity gradient and phase.

References

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[3] K. Fong, RF control system for ISAC II superconducting cavity test stand, in: Proceedings of LINAC, (2002).

6 - 4 Beam Commissioning Activities of High Power Superconducting Linac for China ADS

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The CIADS accelerator will be developed by the collaborations between Institute of Modern Physics (IMP) and Institute of High Energy Physics (IHEP). The demonstrative project is divided into three stages. Firstly, a research facility including a superconducting 500 MeV 5 mA CW proton linac with a test reactor will be built with a reactor power of 10 MW by the year 2 022. At this stage, the critical technologies will be tested and the prove principle system will be synthesized. At stage 2, most of the challenges will hopefully be resolved and the energy of the linac will be increased to 1 GeV at 10 mA with a reactor power of 100 MW for an operational demonstration ADS system. Finally, a 1.5 GeV CW accelerator with beam current of 10 to 25 mA plus a 1 GW reactor commercial prototype system will be built for the performance studies of the daily operation.

To reach the goal of the first stage, a 25 MeV 10 mA CW superconducting proton linac has been built to study the accelerator technologies. It consists of ion source, low energy beam transport line (LEBT), a 162.5 MHz radio frequency quadrupole accelerator (RFQ), medium energy beam transport line (MEBT), superconducting accelerator section and HEBT. The layout is shown in Fig. 1.