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High Power RF Test of the Digital Feedback Control System for the PEFP Accelerator

Kim Han-Sung, Kwon Hyeok-Jung, Seol Kyung Tae, Kim Dae-Il and Cho Yong-Sub
PEFP, KAERI, 150, Deokjin-dong,Yousung-gu, TaeJeon, 350-353, Korea
kimhs@kaeri.re.kr

1. Introduction

To control the RF field in the accelerating cavity for the PEFP (Proton Engineering Frontier Project) proton accelerator, a digital feedback control system has been developed [1][2]. The stability requirements of the RF field are ±1% in amplitude and ±1˚in phase. The digital feedback control system is based on the commercial FPGA PMC board hosted in VME board. The analog front-end was also developed which contains the IQ modulator, RF mixer, attenuators etc. To check the performance of the digital feedback control system, low power test with a dummy cavity has been performed with an intentional perturbation and shown that the feedback system rejected the perturbation as expected. High power RF test with a klystron has been performed and an accelerating field profile was measured. In addition, the pulse-to-pulse stability was checked by pulse operation with 0.1 Hz repetition rate. The detailed high power test results will be given in this paper.

2. Experimental Set-up

The overall control system and experimental set-up is shown in Figure 1. The sampled signal in the RF cavity is mixed with 340 MHz LO (local oscillator) signal and down-converted to 10 MHz IF signal which contains the RF amplitude and phase information. The IF signal is digitized in the ADC with a sampling frequency of 40 MHz, which results in IQ decomposition of IF signal [3]. The digitized signal is fed into the FPGA which performed the control logic and the control signal is applied to the IQ modulator through DAC. The proportional-integral control algorithm has been adopted.

3. Results and Discussion

3.1 Perturbation rejection performance

By using a dummy cavity the basic performance test was conducted. We compared the RF amplitude profile in the dummy in an open loop case with a closed loop case. The result is shown in Figure 2. As can be seen in the figure, the perturbation was almost completely rejected in a closed loop operation.

3.2 Field and Phase Profile within a single pulse

Figure 3 shows the field and phase profile in the DTL

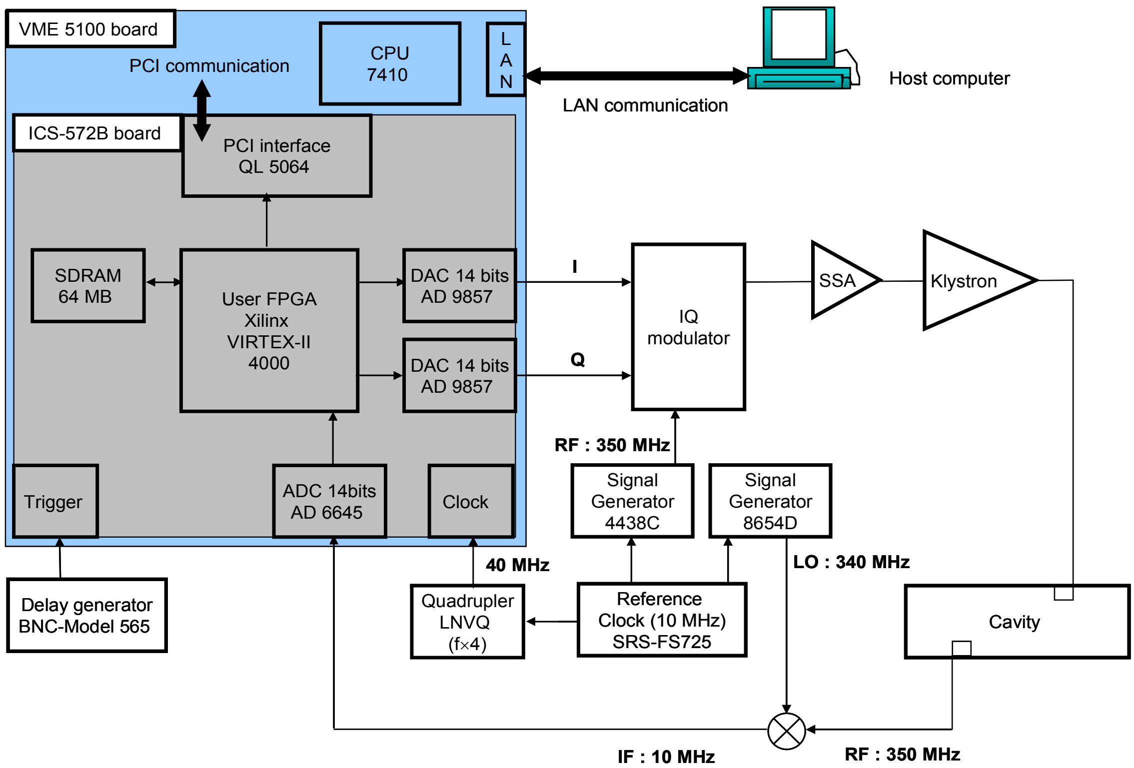

Figure 1. Schematic of the overall control system and experimental set-up.

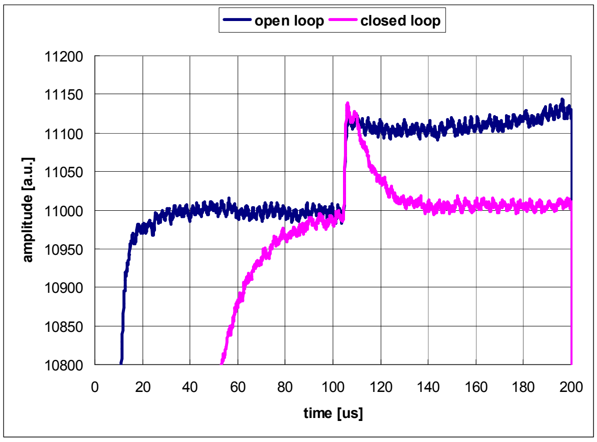

Figure 2. Perturbation rejection test results

cavity from 150 μs to 200 μs after applying the RF power to the cavity. The amplitude variation is less than 0.2% and phase variation is less than 0.3˚, which meet the requirements of the RF control system. For DTL cavity, it takes about 100 μs to fill and stabilize the RF power in the cavity, therefore, the proton beam will be injected after about 150 μs.

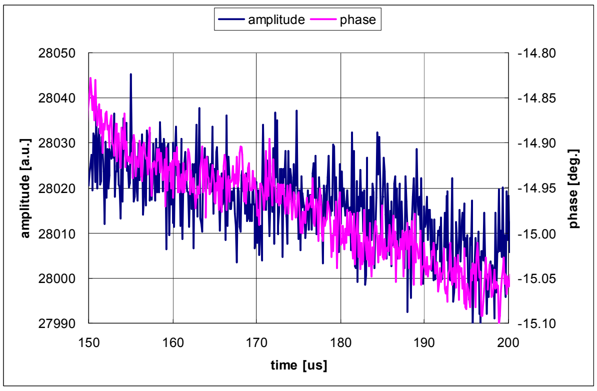

Figure 3. RF amplitude and phase in DTL cavity

3.3 Pulse-to-pulse Stability Measurements

To check the pulse-to-pulse stability, the RF system was operated in pulse mode with pulse duration of 200 μs and repetition rate of 0.1 Hz. The RF amplitude and phase of the DTL cavity for 600 shots are shown in Figure 4 and the results are summarized in Table 1. For 600 shots, the RF amplitude and phase were kept within ±0.7% and ±0.9˚ respectively, which meet the requirements of the RF control system. The standard deviation was 0.43% in amplitude and 0.3˚ in phase.

4. Conclusion

The digital feedback system for the RF amplitude and phase control has been developed and tested. The stability requirements of the RF field are ±1% in amplitude and ±1˚in phase and the high power test showed that the digital feedback system with PI control algorithm meets the requirements. For future work, the performance of the digital feedback control system under beam loading should be confirmed with beam acceleration experiments.

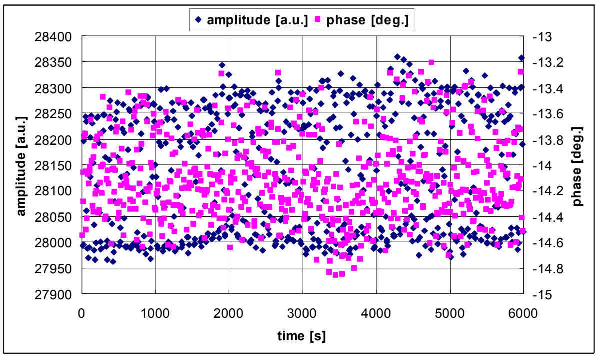

Figure 4. Pulse-to-pulse stability measurement results

Table 1. Statistics for 600 shots measurements results

	amplitude	phase [deg.]
average	28139.1	-14.109
sigma	121.2	0.323
max error	0.79%	0.904
min error	-0.63%	-0.744

5. Acknowledgements

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