LLRF SYSTEM IMPROVEMENT FOR HLS LINAC UPGRADE*

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Abstract

The linac beam energy will be upgraded from 200MeV to 800MeV, in order to realize the full-energy injection of storage ring at Hefei Light Source. This paper introduces the improvement of linac LLRF system, which is composed of phase reference and driver signal transmission and distribution, phase stability system, phase reversal device for SLED. The LLRF prototype has been constructed, and the test results are described in the paper.

800MEV LINAC INTRODUCTION

The layout of 800MeV linac is shown in Figure 1, and the parameters in Table 1.

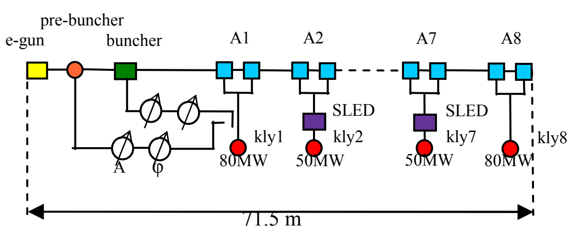

Figure 1: 800MeV Linac layout

Table 1: Linac parameters

	200 MeV	800 MeV
Beam current	50mA	1 A
Beam pulse	0.1-1µs	1 ns
Repetition /Hz	0.5	1
Energy spread	0.8%	0.5%
RF freq. / MHz	2856	2856
Acc. section	4	8
klystron	5 (20MW)	6 (50MW) +2 (80MW)
SLED	0	6

The 800MeV Linac is composed of injector (prebuncher, buncher) and eight accelerating sections. the prebuncher is a single resonant cavity, and the buncher is a 1-meter travelling wave accelerating construct. Each accelerating section contains two 3-meter constant gradient travelling wave accelerators. The design energy of linac is 1GeV, one accelerating section may stand by when linac beam energy is 800MeV.

PHASE REVERSAL DEVICE FOR SLED

Six SLEDs will be installed in RF stations from the 2nd to 7th. The SLED parameters are listed in table 2, and the test result of the SLED prototype is shown in Figure 2.

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Table 2: Parameters of SLED

Freq. /MHz	2856
Q_0	~100000
β	5
Insert Loss /dB	0.2
Tuning range /kHz	± 500
Pulse time /µs	4
Power Gain /dB	7
VSWR	1.05

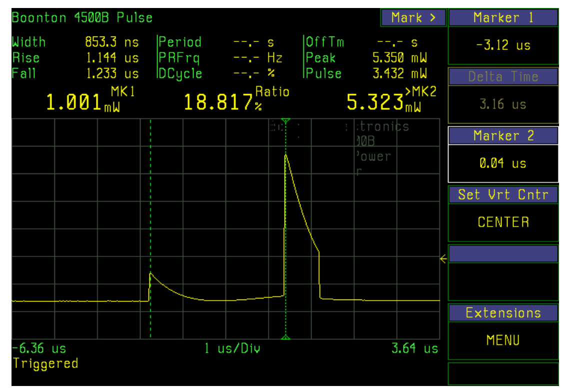

Figure 2: SLED RF output profile

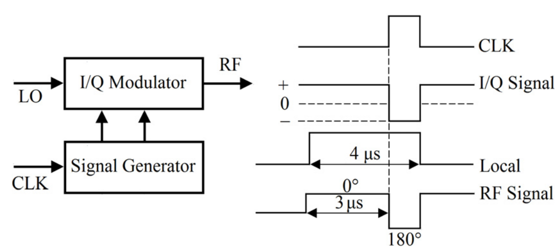

Figure 3: Schematics of the 180° phase reversal system

Table 3: Parameters of IDOH-01-45

Carrier (LO) Freq. /MHz	2000–4000
RF Freq. /MHz	LO ± 100
I & Q Freq. /MHz	DC-100
Conv. Loss /dB	10
Amplitude Balance /dB	1.0
Max. Phase Balance /°	8.0
Isolation /dB	30
VSWR min.	1.5:1

The phase reversal device for SLED showed in figure 3 is consist of fast pulse signal generator and I/Q modulator. The I/Q Modulator is the IDOH-01-45 manufactured by Pulsar Microwave company, and the parameters are

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shown in table 3. The I/Q pulse voltage signals is generated by Agilent 33250A , which voltage resolution is 0.1 mV. The voltage applied to the I/Q port of Modulator is about ±500 mV, so the voltage accuracy could be 0.02%.

Figure 4 shows the stability and accuracy test for phase reversal device. In 2700 seconds, the average reversal phase is 180.5°, phase error (rms) is less than 1°, and maximum phase deviation is 1.5°.

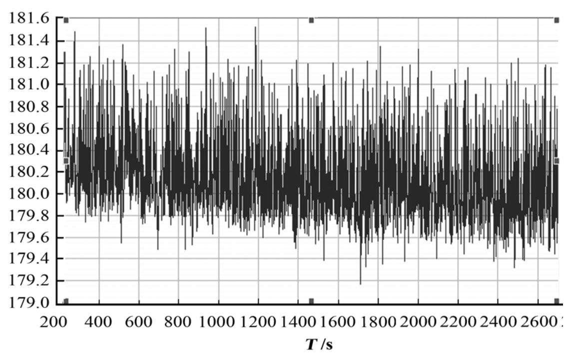

Figure 4: Phase reversal system test results

LINAC RF PHASE STABILITY

The most of new accelerator and upgrade of old one tend to select the digital LLRF system for phase stability [1-4]. But limited by budget, a simple analogy LLRF system is used for HLS 800MeV linac phase measure and control [5]. The analogy system is good enough if the linac is only used as an injector. The design requirements for stability of accelerating phase is ± 1°.

The RF phase stability system contains I/Q demodulator, data acquisition equipment, electronic phase shifter (EPS). The data acquisition equipment is Pico4424 virtual oscilloscope, I/Q demodulator is IDOH-01-458, the type of electronic phase shifter is S7-H67-444A (Pulsar Microwave Company), whose voltage set range is 0-10 V, corresponding phase shift is 360°. The control voltage comes from one 16 bits DAC PCI board.

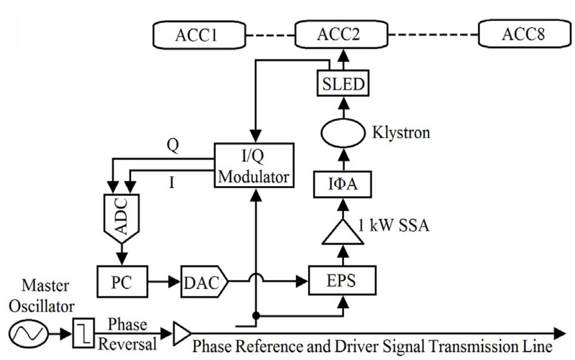

Figure 5: Diagram of phase stability system

The resolution of Pico4424 virtual oscilloscope is 16 bit， and the minimum resolution voltage is 0.03 mV under the voltage range set at 500 mV. When the LO signal of IDOH-01-458 set to 10 dBmW, RF signal is about 0 dBmW, the voltage rang of I/Q output signal is about ± 200 mV. The phase of RF signal changes 0.1°, I/Q voltage vary at least 0.2 mV, which is larger than Pico4424 resolution. Therefore the phase measuring resolution can reach 0.1°.

In the laboratory environment (room temperature stable, no external noise interference), we made a phase stability system prototype on the table test, test device is shown in Figure 7. The RF output of EPS connects to the RF signal input of I/Q modulator, to form the feedback loop. Figure 8 is open loop phase measuring results. The test lasted 2100 second, the rms error of phase measurement is less than 0.1°, which shows that the phase measurement resolution is ±0.1°. The maximum phase deviation is ±0.15 °, it means the measuring precision can reach ± 0.2°. Figure 9 shows the phase closed loop test, the phase feedback control accuracy is set to ± 0.5°. In order to avoid feedback overshoot even or self-excited, each feedback turn adjusts 30 ~ 90% of phase deviation. Setting up different target phase by control program, the loop response to different phase deviation 1°, 2°, 5°, 10°, and 20° has been examined. The loop feedback is stable without overshoot under any phase deviation.

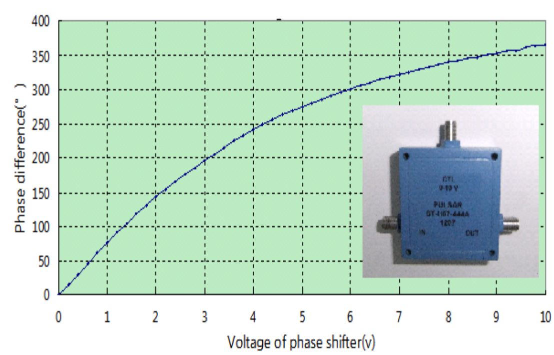

Figure 6: Phase shift *vs* control voltage

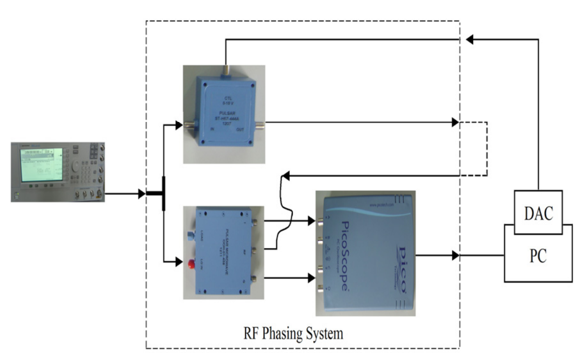

Figure 7: Self-test for RF phase stability system

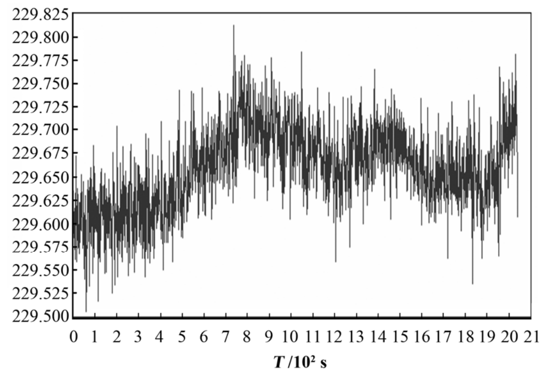

Figure 8: Phase measurement resolution

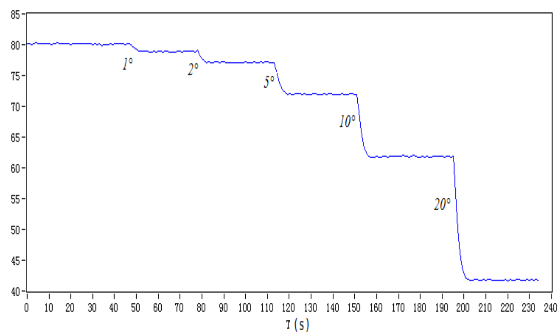

Figure 9: Loop response to different phase deviation

We tested the phase stability system in the No.1 RF station of 200MeV Linac. As shown in Figure 10, the loop is set to open before 1700 second, the RF phase drifted 1.3°. After then the loop is closed, the stable phase set at 87°, and the closed-loop control accuracy is ± 0.5° in the first 3000s, after that is ± 0.3 °. The result shows that the phase error can be controlled in ± 0.5°, but failed in ± 0.3°, since the online phase noise is ± 0.3° (Figure 11). Therefore the online closed-loop phase stability is ± 0.5 °.

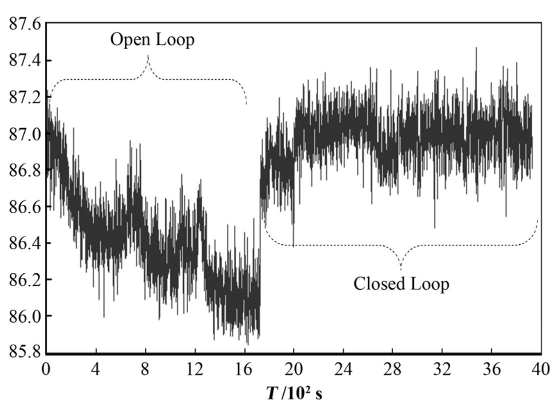

Figure 10: RF stability system online experiment

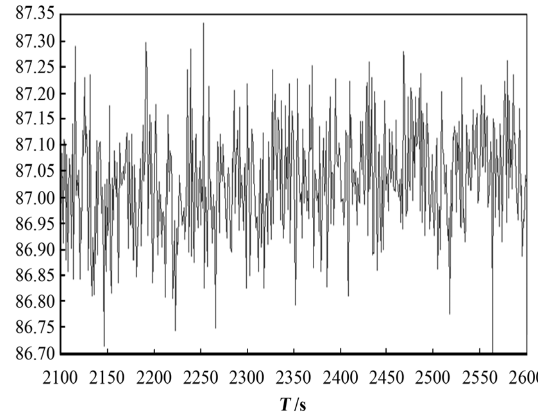

Figure 11: Background noise of online measurement

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