200 MEV LINAC UPGRADE FOR FEL*

Yingui Zhou, Sai Dong, Duohui He, NSRL/USTC
Ge Li[#], Shanghai Jiao Tong University

Abstract

The present status of Hefei 200MeV RF linac are given. By upgrading its present thermal cathode system into the photo cathode system and implement RF phase locked system, using Hefei 200MeV RF linac as FEL driver is investigated.

INTRODUCTION

Due to its worse energy spread of thermal cathode as well as phase stability of its RF system etc for developing FEL, Hefei 200MeV linac is sometimes funny known as “tractor”. But now, it is going on the track to become “airplane” by upgrading all these subsystems.

Free Electron Laser (FEL) is the only light source with over 20 eV photo energy and GW peak power [1-3], which covers the spectrum from mm wave to x-ray and finds wide applications from physics, chemistry to life science. Linear accelerator (Linac) operation for a self-amplified spontaneous emission (SASE) or high-gain harmonic-generation (HGHG) FEL, the so-called 4th generation light source, requires state-of-the-art performance from all linac subsystems, especially RF power (within ±0.1% shot-to-shot) and phase (less than 1^{o} rms jitter shot-to-shot and 5^{o} rms long-term drift). To satisfy such tight criteria, both low-level and high-power RF systems are under evaluation together with development of a precision on-line phase detector system [4]. Earlier RF phase control implementation in APS RF linac [5-6], together with FEL component systems underpins nice environments for later successful APS SASE-FEL experiments [7] for the requirement of the phase stability for the APS SASE-FEL (LEUTL [8]) is less than 2^{0}.

In addition, the high accuracy RF Phase detector is essential to stabilize the emitted wavelength of FEL by controlling the beam energy of RF Linear accelerator. Further for X-ray SASE-FEL to produce femtosecond long pulses, properly choosing the RF accelerating phase, and controlling the wakefields effects, the electron energy chirping [9] is total controlled and thus of the frequency distribution along the radiation pulse.

SYSTEM DESCRIPTION

General Layout of HLS and its RF System

The layout of the Hefei Light Source (HLS) [10] is illustrated in Fig. 1. The HLS 800MeV electron storage ring is injected at 200MeV by a 200MeV electron linac and ramped up to 800MeV for synchrotron radiation use. By using storage ring itself as boost, the topology avoids the expensive construction of 800MeV energy boost and was the only economic possible way for HLS at 1980s, which was remained since then. The RF system to drive the 200MeV linac has no phase detector and feedback system presently, which needs upgrading for future FEL investigation based on linac.

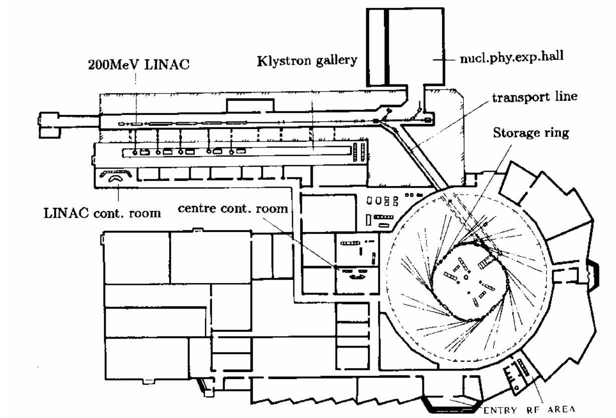

Figure 1: Layout of HLS and its 200MeV linac injector.

Basic Configuration of RF Phase Detector

The configuration of the RF phase detector is illustrated in Fig. 2. The RF upgrade of Hefei 200MeV linac with the developed RF phase detector is shown in Fig. 3. Successful implementation this RF system in HLS is essential for FEL research based on linac in HLS.

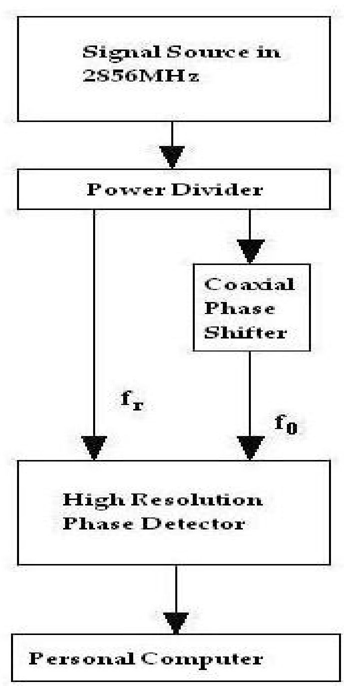

Figure 2: Configuration of precise phase detector.

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#lige@sjtu.edu.cn

RF System of Two-Frequency Photocathode Gun

Nearly all successful FEL researches are based on photocathode RF guns [11-12] for its exceptional performance of high brightness and low emittance. The FEL system can be further optimized by implementing two-frequency photocathode RF gun, which can reduce the beam emittances from 0.6 to 0.3 microns or less over the main body of the electron bunch [13-14]. Then, the FEL saturation length can be significantly decreased. As illustrated in Fig. 4, the RF system in photo-cathode RF gun is implemented with precise phase detector; the cavity is excited by both fundamental and third harmonic RF sources matched with suitable amplitudes and phases. The phase detector in 3x2856MHz together with frequency multiplier must be developed in the system. It is well-known facts that the implemented high power klystron in 3x2856MHz is the present available technology [15-16].

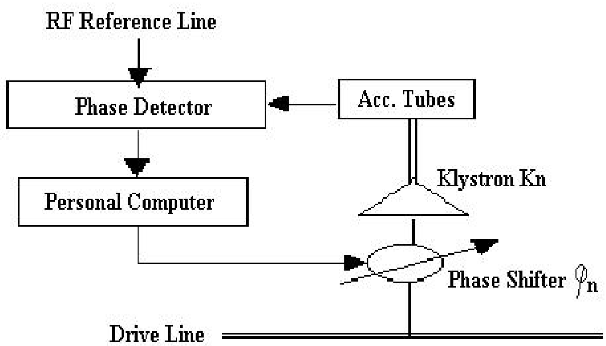

Figure 3: RF upgrade for Hefei 200MeV linac.

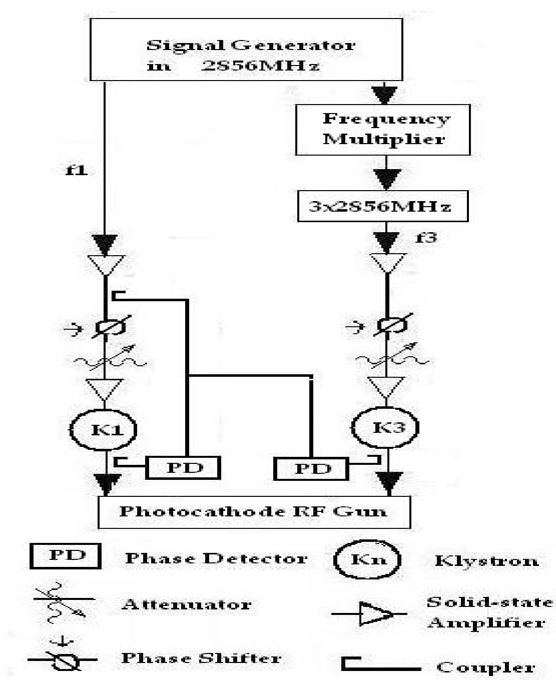

Figure 4: Configuration of RF system for a two frequency RF photocathode gun.

PRIMARY IN-SITU EXPERIMENTS

Fig. 5 illustrates the desktop test of the 2856MHz RF phase detector. In order to test its in-situ electromagnetic compatibility in the strong electromagnetic environment of klystron corridor, it is measured in Hefei 200MeV RF Linac, which is shown in Fig. 6. The signals in the downstream of klystron 5 and the main drive line are coupled out for measuring. The results are listed in table 1. The phase detector detects different phases within 2.6 degrees in the same phase shifter position at different time within a period of half hour. So, the RF system of Hefei 200MeV Linac is slowly shifting while in normal operation, that agrees well with the measured results of APS linac [7].

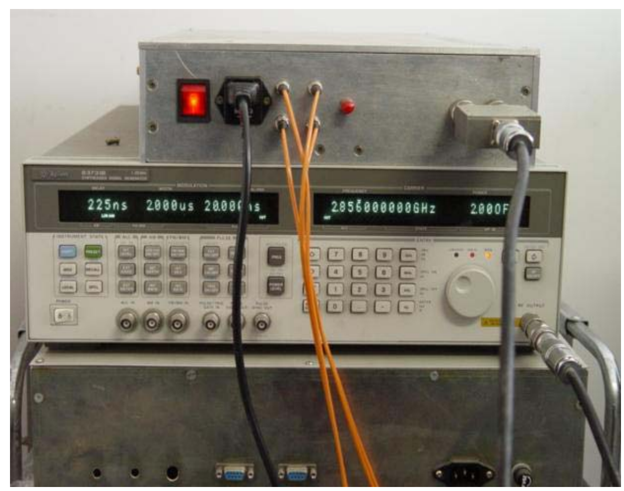

Figure 5: The desktop test of precise phase detector.

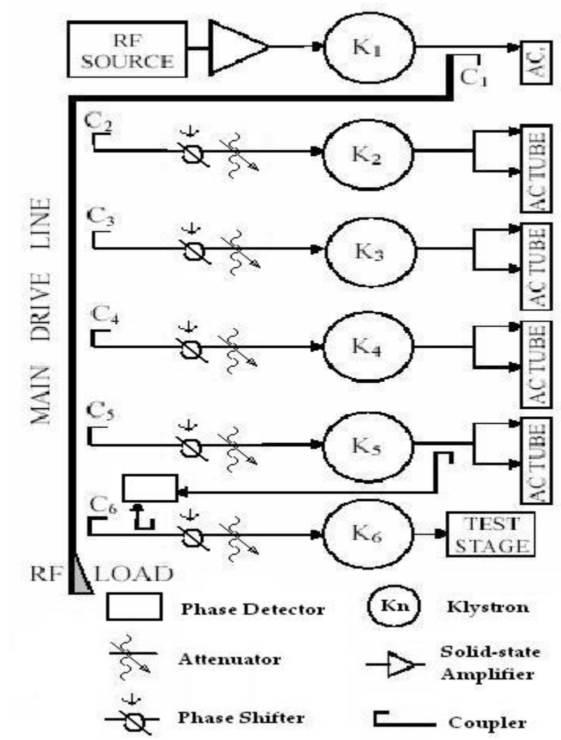

Figure 6: In-situ experiments of precise phase detector.

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Table 1: The in-situ measured phases dated on 27-4-2004.

Phase Shifter Position	The Measured Phase/degree	Time
189	-82.0	11:23
170	-56.0	11:27
170	-56.2	11:31
180	-67.7	11:34
180	-65.1	11:35
189	-81.4	11:40
189	-82.6	11:41

SUMMARY

The RF system of Hefei 200MeV Linac is slowly shifting while in normal operation, which must be upgraded with phase-locked system if it is intended to be FEL driver, for linac based FEL requires the phase stability is less than 2^0, such as APS SASE-FEL (LEUTL [10]). The developed high accuracy RF Phase detector in 2856MHz satisfy the urgent needs of upgrading Hefei 200MeV RF linac for development of linac based FEL in HLS.

The phase detector is essential in a two frequency photo-cathode RF gun, where the cavity is excited by combined fundamental and third harmonic RF sources matched with suitable amplitudes and phases. The beam emittances are reduced from 0.6 to 0.3 microns or less over the main body of the bunch [15-16]. Therefore, the saturation length of the FEL system can then be significant decreased, especially in the process of developing short wavelength FEL [13-14].

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