Energy Stabilities of 200 MeV Electron LINAC

Yuan Ji Pei, Mei Bai, Gui Rong Huang

National Synchrotron Radiation Laboratory
University of Science and Technology of China
Hefei, Anhui 230029, P.R.China

Abstract

The electron LINAC of 200MeV is an injector of the 800MeV electron storage ring at NSRL. The beam energy stabilities of the LINAC is briefly discussed in this paper. An energy stabilization system is described. After installing the energy stabilizer, the energy stability of the LINAC is improved. The central energy change rate is less than 0.4%.

Introduction

Hefei Synchrotron Radiation light source (HLS) is mainly composed of an electron LINAC of 200MeV, an 800MeV electron storage ring and their transport line of 88m in length. The 200MeV LINAC is not only an injector for the storage ring at National Synchrotron Radiation Laboratory (NSRL), but an electron accelerator used for nuclear physics, Radio biology, Radio chemistry, material science and other research field. The LINAC includes mainly an accelerator structure (preinjector, four accelerator units), which is a travelling wave, constant impedance disk-loaded waveguide and is located in tunnel, RF system (master Oscillator, booster amplifier, five Klystrons and modulators etc.), vacuum system, focusing system, beam diagnostic system and control system, and so *on*[1]. The layout of the LINAC is shown in Fig.1.

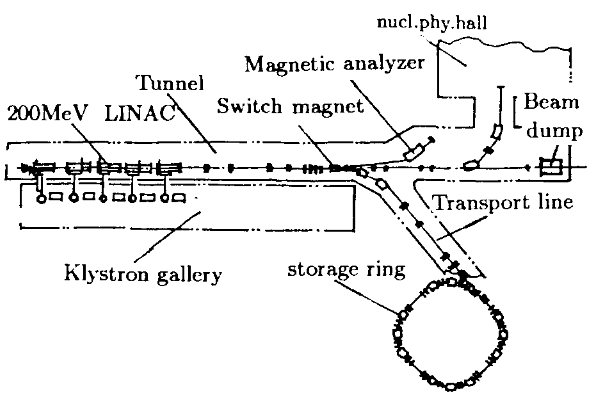


Fig.1 Layout of 200MeV LINAC

Since commissioning LINAC was successful in Nov. 1987, the 200 MeV LINAC has run for 28,000 hours. The LINAC is running for both injecting the beam into the storage ring and the beam to be used for producing the short lifetime isotope, irradiation biology effects etc. The typical operation parameters are summarized in table 1.

Table 1. Operation parameters of LINAC

Energy (MeV)	200.5
Current(pulse)(mA)	70
frequency (MHz)	2856.04
cavities' temperature (°C)	42
output power of Klystron (MW)	
1# Klystron	9.7
2# Klystron	16.2
3# Klystron	15.7
4# Klystron	16.8
5# Klystron	9.3
Current of the gun filament (A)	1.19
Beam current of the gun (mA)	100 ~ 150
beam pulse length (μs)	0.2 ~ 1.0
Energy spread(FWHM)	0.8%
Vacuum (mb) (without beam)	$<1 \times 10^{-8}$
(with beam)	$< 1 \times 10^{-7}$

In the beginning of operating the LINAC, the LINAC energy was not so stable, sometime the unstable energy made the injecting the beam into the storage ring to be difficult. After that we did some machine studies and adopted some measures. The energy stability has been improved so that the injection became easy. In the end of 1991, more than 300 mA stored in the storage ring was got. Since that the LINAC was routinized to operate.

Energy stabilizing measures

The LINAC is a complicated system that consists of many parts. The electron beam from the electron gun will experience all sorts of effects during accelerating process. In a nutshell, the beam performances and energy stability of the LINAC are mainly caused by following factors:

- Machining tolerance of the accelerating structure

- Operation temperature and its stability
- Frequency stability of RF system
- Beam loading
- stabilities of output of Klystron
- Phase stability

These factors as mentioned above have two effects. First, they reduce the amplitude of the accelerating field and shift its phase, leading to a change in the energy of the electrons accelerated. Second, they broaden energy spectrum of the electrons. These are summarized in table 2[2].

Table 2. Parameters of effecting energy

Factor change or relative change		relative change of energy ΔE/E
Inner diameter 2b change 1 μm		-0.47%
Temperature change $\Delta T = \pm 0.5$		-0.24%
Frequency change $\Delta f/f = 1 \times 10^{-6}$		-0.0032%
Beam current change $\Delta i(mA)$		
(i=100mA)		-0.048 Δi%
(i=50 mA)		-0.044 Δi%
voltage change of modulator		
for boosteer amplifier	$\frac{\Delta V_{bo}}{V_{bo}} = 1\%$	-9.3%
	0.2%	-0.37%
Voltage change of klystron		
modulater	$\frac{\Delta V_k}{V_k} = 1\%$	-1.6%
	0.5%	-0.67%

In accordance with above table the energy change is dominantly caused by the change of modulator voltage. As to other effect factors, they can be controlled and reduced. After improving voltage stability of power network and reducing jitter time of the trigger for modulator etc., the energy stability was improved, but it was not good enough to make the injection easier. In order to overcome these instabilities further more, an automatic energy stabilization equipment for the LINAC was developed.

For simplicity, the electron energy gained in the accelerating process is given by

$$W = eV\cos\phi \qquad (1)$$

where V is an equivalent accelerating voltage in the accelerating path, ϕ is accelerating phase and W is electron energy gained.

From the equation we see that W will vary with V and ϕ. We assume that energy of an equilibrium electron is W_s. It is a design value and given by

$$W_s = eV_s\cos\phi_s \qquad (2)$$

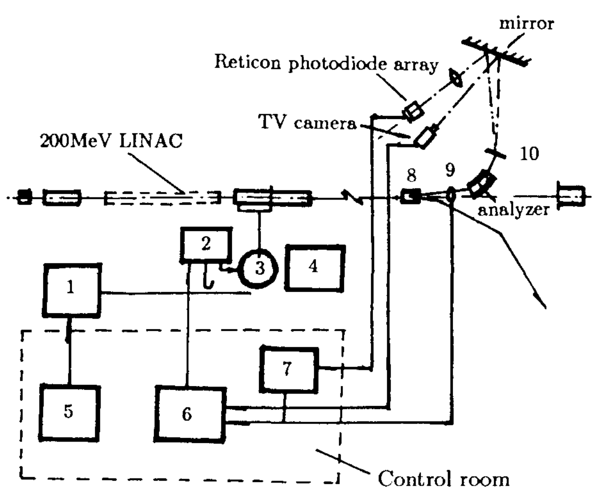
It is obvious that variety of V and ϕ will make W change and deviating from Ws. We regulate the accelerating phase, so that the following equation is satisfied.

$$eV\cos\phi = eV_s\cos\phi_s = W_s \qquad (3)$$

Therefore the energy change has been compensated, although V and ϕ were not equal to V_s and ϕ_s respectively. According to this idea, we developed an automatic energy stabilization system(AESS).

Automatic energy stabilization system

AESS mainly consists of an energy measuring equipment for measuring beam energy and its energy spread that is located at the end of the LINAC, a phase shifter between the fifth klystron and booster amplifier, and a computer control system. The AESS is schematically shown as Fig.2



1-booster amplifier	2-shifter
3-5#klystron	4-5#modulator
5-master oscillator	6-computer
7-oscilloscope	8-switch magnet
9-toriode	10-ceramic plat(AF955R)

Fig.2 Layout of the automatic energy stabilizer

The energy measuring equipment is composed of a switch magnet of 6°, a magnetic analyzer of 60°, a fluorecent ceramic plat located at the focusing point of the electron beam bent by the magnetic analyzer, and the screen emits red light. Because the intensity of the light is proportional to the beam intensity, The light intensity distribution on the screen represents the energy spectrum.

See Fig.3.

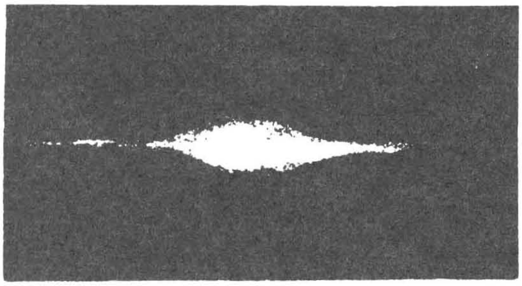


Fig.3 Photograph of light spot

A mirror reflects the light through a lens of f=50mm, and focus the light spot on a Reticon linear photodiode array. In order to focus the image of the spot on the Reticon, the mirror is driven by a motor to change the reflect angle remotely. The start signal and clock signal for the Reticon are synchronized with the beam current signal between the switch magnet and analyzer. The Reticon gives a clear energy spectrum as the picture shown in Fig.4.

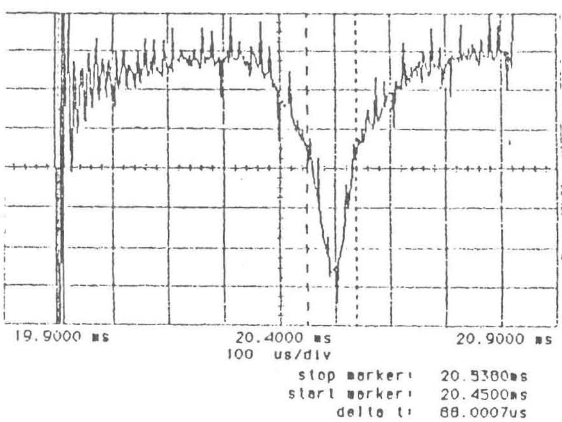


Fig.4 Waveform of energy spectrum

The image of light spot is taken by a TV camera. The video signal is sent to LINAC control room and then converted into digital signal.

The computer pocesses these digital signals which represent the energy spectrum and the position of the central energy, then sends a signal to drive a stepping motor to regulate the shifter so that the accelerating phase in last accelater unit is located at a necessary position.

Test result

The energy stabilizing system was successful in stabilizing the energy in 1992. Typical running results are as following. Before the AESS was turn on, the central energy change rate $\frac{\Delta E_o}{E_o}$ was more than 0.8%. It is shown in Fig.5. Sometimes the energy deviated much more and it made the injection difficult.

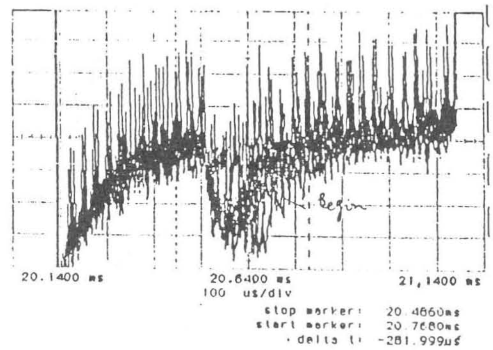


Fig.5 Energy spectrum without AESS

When the AESS was on, not only the rate $\frac{\Delta E_o}{E_o}$ was reduced to 0.4%, but also the energy spread was lowered. See Fig.6. Since then the LINAC has been running stably.

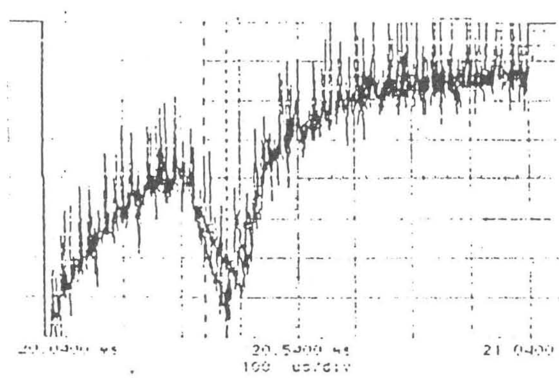


Fig.6 Energy spectrum with AESS

Reference

[1] Y.J.Pei, An injector – 200MeV electron LINAC for HESYRL storage ring, Rev. of Sci. Instr., Vol. 60, No. 7, 1701(1991).

[2] Y.J.Pei, A problem on energy stabilities of electron LINAC of 200MeV, (NSRL report)(1991).