Study of Linac Based Single Pass FEL

Kenichi YANAGIDA, Hiroshi ABE, Takao ASAKA, Toshihiko HORI, Toshiaki KOBAYASHI, Akihiko MIZUNO, Hironao SAKAKI, Shinsuke SUZUKI, Tustomu TANIUCHI, Hideaki YOKOMIZO and Hiroshi YOSHIKAWA

Japan Synchrotron Radiation Research Institute
Kamigori Ako-gun, Hyogo 678-1298, Japan

1. Introduction

The construction of the SPring-8 linac was completed in August 1996 as an injector for this large synchrotron radiation facility. Presently, this linac provides an electron beam to the booster synchrotron twice a day. In the future, it will also provide an electron or positron beam for various applications. For example, beam injection will be started in September 1998 for the New SUBARU storage ring. Additionally, plan is currently being made on achieving inverse Compton scattering for nuclear excitation. The building for both applications is now under construction. Of particular note is that a single pass FEL operating in the Self Amplified Spontaneous Emission (SASE) mode is proposed as a VUV $\sim$ soft X-ray coherent light source, perhaps the most important and interesting application.

First, for the proof of the principle, challenge will be on achieving a 500nm FEL at an electron beam energy of 140MeV, because the characteristics of FEL light are easily observed at this energy. After the 500nm FEL is achieved, shorter wavelength FELs, e.g., 20nm at 690MeV and 4nm at 1.55GeV, will be challenged.

2. FEL Characteristics

The FEL parameters are shown in Table 1. The Pierce parameter, the field gain length, and so on, were obtained by 1-D calculation [1]. First, we determined the undulator type and its parameters [2]. A hybrid planner undulator was found to be most suitable in this case because of its short periodicity.

The period and K parameter were determined as 3.2cm and 1.62, respectively, so as to minimize the field gain and saturation length in the shorter wavelength region. The K parameter was determined at the minimum undulator gap of 13mm. Consequently, the beam energy was derived as 140MeV for a 500nm FEL, 690MeV for a 20nm FEL and 1550MeV for a 4nm FEL.

The beam energy of 1550MeV should be achieved by adding extra accelerator tubes or energy doublers (SLEDs). The betatron wavelength and normalized emittance in the undulator section are assumed as 10m and 1πmm*mrad, respectively. Both values are slightly atypical because the large coulomb force enlarges them. Figure 1 shows the exponential growth of 500nm FEL power computed by 1-D simulation. We estimate expect the peak current to be 1-10kA.

Table. 1: FEL parameters obtained by 1-D calculation

Wavelength [nm]	500	20	4
Beam Energy [MeV]	140	690	1550
Undulator			
Period [cm]	3.2	3.2	3.2
K Parameter	1.62	1.62	1.62
Peak Current [kA]	1-10	1-10	1-10
Pierce Parameter or			
Energy Deviation [%]	0.5-1.1	0.27-0.57	0.16-0.34
Field Gain			
Length [cm]	30-14	55-26	94-44
Peak Power [GW]	0.68-15	1.9-40	2.4-52
Saturation			
Length [m]	6.4-3.2	10.4-5.2	16.8-8.5

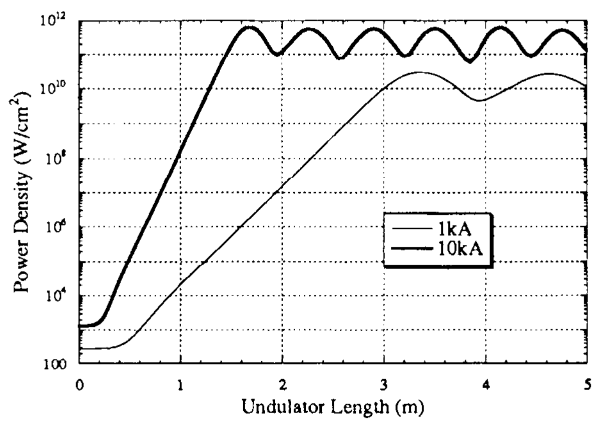

Fig. 1 Exponential growth of 500nm FEL power

3. RF Photocathode Gun System

In order to obtain a small emittance beam, an RF photocathode gun system is indispensable. For R&D purposes, a test bench for a single cell RF photocathode gun is now under construction. RF gun experiments are expected to be started soon.

The design of the cavity is reported in a previous paper [3].

One cw seed laser and two different laser amplifier systems are employed for beam emission. The former is the Lightwave 131, whose frequency is 178.5MHz. This frequency corresponds to a value 1/16 the acceleration frequency. The latter are switched by a retractable mirror. One amplifier system is a high-power "regenerative" amplifier that generates a single pulse (bunch) for the experiment of the first phase. In this case, a copper cathode is utilized. The electron charge is 1-10nC/bunch. The other amplifier system is a six-pass "cascade" amplifier that generates a multiple-pulse (bunch) train to obtain a higher FEL average power. In this case, an alkali cathode is used, for example, Ce_2Te. The electron charge is 1nC/bunch. Table 2 shows the characteristics of the RF photocathode gun.

Table. 2 RF photocathode gun characteristics

Laser Amplifier Type	Regenerative	Cascade
Number of Laser Pulses	1	200
Laser Pulse Width [ps]	10	10
Maximum Fundamental (1047nm) Laser Power [MW]	2000	5.6
Maximum Fourth Harmonic (262nm) Laser Power [MW]	200	0.22
Maximum Fifth Harmonic (209nm) Laser Power [MW]	40	—
Photocathode Material	Cu	Ce_2Te
Charge/Bunch [nC]	1-10	1
Beam Energy [MeV]	~3.4	~3.4
Repetition [Hz]	1-10	1-10

4. Beam Transport

A schematic drawing of the layout is shown in Fig. 2. The electron beam from the RF photocathode gun, whose pulse width is 10ps, is accelerated to the energy of 100-150MeV. Then, the pulse width is compressed to ~1ps. After this compression, the beam is accelerated to the final energy.

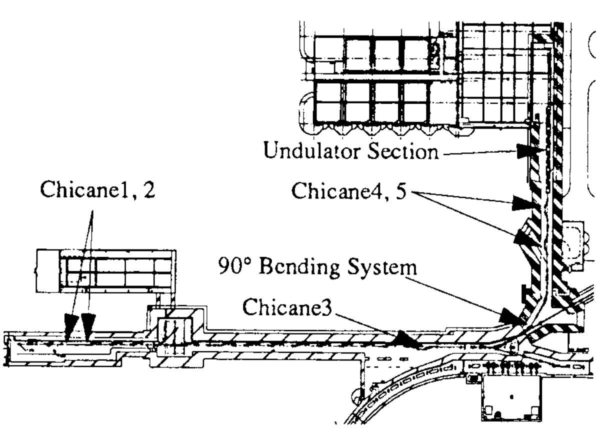

Fig. 2: Layout of the SPring-8 linac. The entire building is scheduled to be completed in 1998.

The location of the building is on the left side, where the linac beam can be introduced. In order to transport the beam to the building, a 90-degree isochronous bending system will be installed. When the high-current electron beam passes through the dispersive section, the emittance will grow.

Therefore, in order to preserve the emittance, an energy compression system will be installed before the bending system to enlarge the beam pulse width to ~10ps. After the beam is bent by 90 degrees, the beam will be re-compressed to a pulse width of 0.1-1ps by two compressors.

The first-order calculation for the beam transport system is introduced in previous papers [4][5]. The layout and beam transport system for a 500nm FEL are to be designed.

5. Conclusion

We have designed an FEL system and have developed an RF photocathode gun system these past several years. To go further, we must find ways to ensure the start up and exponential growth of FELs as soon as possible. We think 500nm FELs are most suitable for this purpose.

References

[1] K. -J. Kim and M. Xie, Nucl. Instr. and Meth. **A331**, 359 (1993).

[2] K. Yanagida et al., Proc. of the 21st Linear Accel. Meeting in Japan, Tokyo, Japan, p. 260 (1996).

[3] T. Taniuchi et al., Proc. of the 11th Sympo. on Accel. Sci. and Tech., Harima Sci. Garden City, Japan, p. 203 (1997).

[4] K. Yanagida et al., AIP Conf. Proc. **413**, p. 299 (1997).

[5] K. Yanagida et al., Proc. of the 11th Sympo. on Accel. Sci. and Tech., Harima Sci. Garden City, Japan, p. 528 (1997).