UPDATE PLAN OF SPRING-8 LINAC

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Abstract

The SPring-8 linac was completed and the first beam was observed in August 1996. This Linac is used for injection of the SPring-8 storage ring and New SUBARU ring(VUV-soft X-ray ring, under construction) , and also used for some experiments like the slow positron facility and the parametric X-ray source. For the next stage, we are planning the reconstruction aimed at the single pass FEL (SASE : Self Amplified Spontaneous Emission). In the 1-D simulation, we get the 20 nm wavelength coherent light with 10-20 m length undulator. The gun system will be replaced from the thermonic HV cathode to the photocathode RF gun. And the magnetic bunch compress section will be installed in several areas.

Introduction

The SPring-8 linac was completed and the first beam was observed in August 1996 [1]. The layout of SPring-8 site is shown in Fig.1. And the present linac characteristic is shown in Table 1.

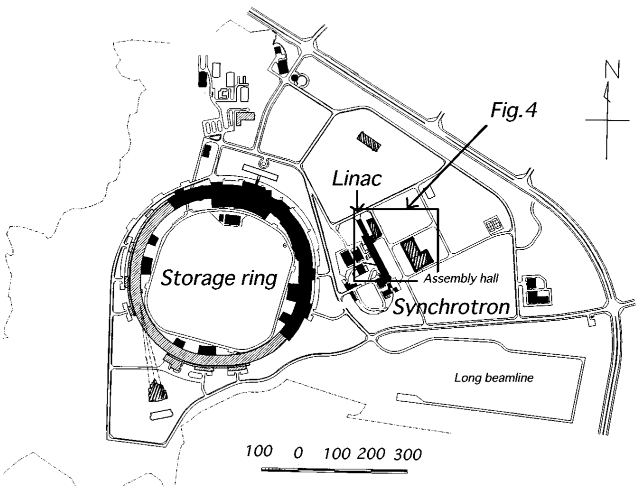

Fig.1 SPring-8 site layout

Table 1: Characteristic of present linac

Energy	1.15 GeV
Normalized Emittance	100 πmm•mrad
Bunch length	10~20 ps
Energy Dispersion	1%
Charge	3 nC/bunch
Electron Gun type	HV+, Thermal Cathode
Cathode	Disposed BaO (Y796)
Bunching	Pre Buncher + Buncher

The linac will be operated twice a day as the injector in the future and utilized for various applications in the rest of the time. For example, an inverse Compton scattering for nuclear excitation, a parametric X-ray and channeling X-ray generation, a slow positron generation are proposed. Especially a single pass FEL operating in the SASE mode is proposed as a VUV-soft X-ray coherent light source that is the most important and interesting application.

Future plan of SPring-8 Linac

This Linac is used to injection the SPring-8 storage ring and New SUBARU ring. And we have some plan to use some experiments like the slow positron facility, the parametric X-ray source and the single pass FEL. We report the study of the parametric X-ray and the single pass FEL.

Parametric X-ray

With the crystal is bombard by the electron beam, the X-ray of the energy which satisfies the Bragg condition at a Bragg angle is generated for the crystal plane is emitted. We call this electromagnetic radiated emission phenomena parametrics X-ray radiation (PXR). By choosing the crystal incidence angle of the electron beam, it is possible to take out the X-ray of hoping wavelength. Though the flux of coming out X-ray is also dependent on the electron energy a little, if we use the electron beam over 300 MeV, in the X-ray region of 14.4 keV, the conversion efficiency is about 10^{-5} photon/electron. At present, in the energy region under several hundred keV on the average flux, it is by far abounding of the synchrotron radiation of the storage ring. Recently, though we also examine that the strength is made to be the several score time by the technique with addition matching of X-ray and parametrics X-ray radiation by resonance transition radiation (RTR). It is very low flux than a synchrotron radiation of the storage ring yet. However, the electron of about 10^{10} is contained in the 1 bunch when the linac was operated at a single bunch. It is useful for the necessary experiment on the time resolution, because electron beam is bunched as 10 ps. This utilization is under preparation for the experiment, because it is corresponding by present linear accelerator.

Single pass FEL

The high brightness high-intense electron beam is bent by the undulator, and synchrotron spontaneous radiation light which arose that time is exponentially rapidly amplified by the interaction with the electron beam, and SASE is to generate the laser beam of high brightness and narrow spectral band width. Since the optical resonator which limits the wavelength shortening of the conventional free electron laser oscillation is not used, we notice the SASE radiation source as a high luminosity high brightness small wavelength coherent radiation light source. The photon flux at the peak surpasses by far the synchrotron radiation of the SPring-8 storage ring. In addition, we have the characteristic of that it is the light in the coherent pulse and that output itself is semi-monochromatic, and the burden for the spectroscope is also little.

The FEL characteristics and the electron beam parameters are shown in Table 2. And calculation result is shown in Fig. 2. At the first phase, for proof of principle, the 20 nm FEL will be challenged. However the linac was optimized only for the injector to the booster synchrotron, its beam characteristics are not adequate for the FEL without improvement.

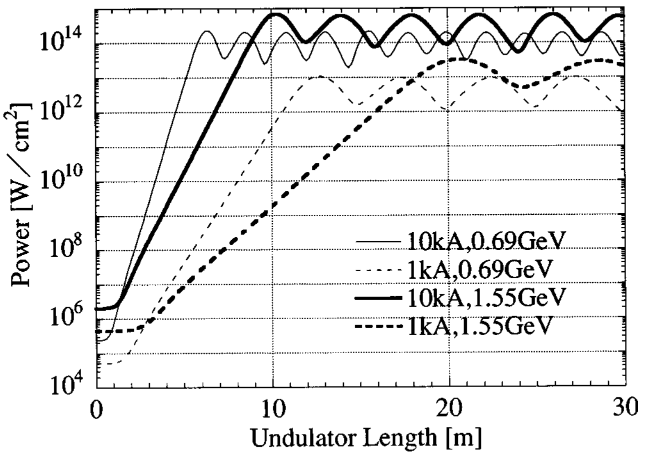

Fig. 2 Power growth in undulator

There are several key issues to realize the FEL, for example an RF photocathode gun system, a beam transport system and an undulator system. After these issues will be fixed, the 20 nm FEL will be realized. Then the shorter wavelength FEL, 4 nm at 1.55 GeV, will be challenged. The FEL parameter r, the power gain length and so on are obtained by 1-D calculation [2].

Table 2: FEL characteristics and beam parameter

Wavelength [nm]	20	4
Beam energy [GeV]	0.69	1.55
Undulator period [cm]	3.2	3.2
Undulator parameter K	1.62	1.62
Peak current [kA]	1-10	1-10
Normalized Emittance [πmm•mrad]	1	1
Betatron wavelength [m]	10	10
FEL parameter r	2.7-5.7x10^{-3}	1.6-3.4x10^{-3}
Field gain length [m]	0.55-0.26	0.94-0.44
Saturation length [m]	10.4-5.2	16.8-8.5
Undulator length [m]	20-10	30-15
Peak power [GW]	1.9-40	2.4-52
Peak brilliance [phs./sec. /mm^2/mrad^2/0.1%B.W.]	5.2-5.4x10^{27}	2.5-2.6x10^{28}

At first we determine the undulator parameters, the period of 3.2 cm and K=1.62, so as to minimize the field gain length. The beam energy of 0.69 GeV is realized without any improvement of the linac. However 1.55 GeV will be achieved by addition of extra accelerator tubes or energy doubler (SLED) system.

We will realize this value by means of attaching the focusing element with the undulator. We are now developing the 3-D calculation code which includes the element of external quadruple field.

R&D status of the single pass FEL

Some R&D studies were started already for SASE. We introduce R&D of the electron gun for low emittance beam and beam transport simulation.

Photocathode RF gun

In order to obtain a small emittance beam an RF photocathode system is required. In the SPring-8 single cell RF photocathode gun is developed. In case of 2cell or multicell, it is possible to raise achievement energy in the cavity exit. However, in that structure for suppressing the effect of adjustment mechanism and 0 modes of the resonant frequency, the coupler structure is required. Therefore, we raise that it may become a factor of the break down in the high field generation and that the field intensity of the disk tip rises further than the field intensity of the cathode surface as a defect. And, in usual accelerating cavity, by doing the association of one combination hole, the RF power from the waveguide supplies the cavity. However, the center of the electromagnetic-field distribution is displaced from the central axis of the cavity, since the electromagnetic field in the cavity is distorted by the combination hole. Therefore, the coupler structure suppresses the increase in the emittance by the higher mode component as a double feed coupler structure. The layout of test stand of photocathode RF gun is shown Fig.3.

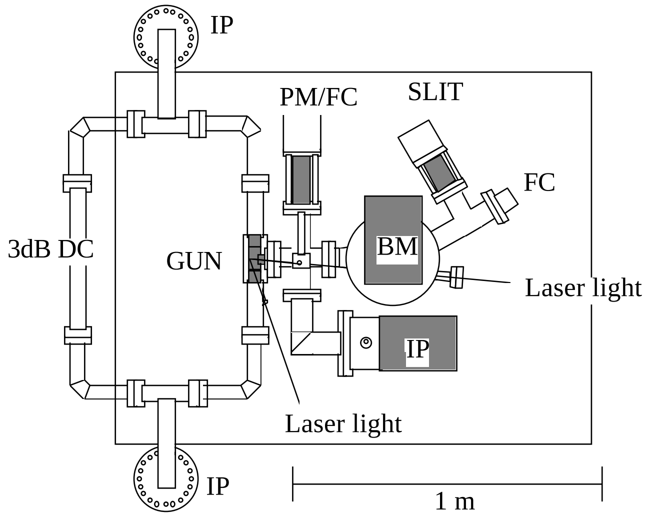

Fig 3. Layout of test stand of photocathode RF gun
PM : profile monitor, FC : faraday cup

From this fact, we manufacture the test equipment of the simple cavity by the double feed coupler structure, and we do the emission testing of the photocathode RF gun. It will be made to be metal cathode which is more integrated than the viewpoint of the break down prevention with the cavity in the cathode.

There are one CW seed laser and two different laser amplifier systems for photocathode. The seed laser is the Lightwave 131 whose frequency is 178.5 MHz. This frequency corresponds to 1/16 of acceleration frequency. The amplifier system is switched by retractable mirror.

The high power "Regenerative" amplifier which generates a single pulse (bunch) will be used at the proof of principle mode. In this case metal cathode, for example Cu or Al, is used. The electron charge will be expected as 10 nC/bunch. The other is 6 pass "Cascade" amplifier which generates multiple pulse (bunch) train is used for higher average power FEL. In this case the alkali cathode will be used, for example Ce2Te. The electron charge will be expected as 1 nC/bunch.

Beam transport

The schematic drawing of layout for SASE is shown in Fig.4. The electron beam from the RF photocathode gun, whose pulse width is expected as that of laser system 10 ps, is accelerated to 100~150 MeV. Then the beam is compressed to 1 ps. After compression the beam is accelerated to final energy.

The building for general purpose use is now under construction. This building is located at the left side where the linac beam can be introduced. To transport the beam the isochronous 90 degree bending system will be installed. It is easily expect if the high current beam passes through the large despersive section the emittance growth occurs. In order to preserve the emittance the energy compression system is installed in front of the bending section. After the bending section the beam is re-compressed to the pulse width of 0.1-1 ps by means of two compressors.

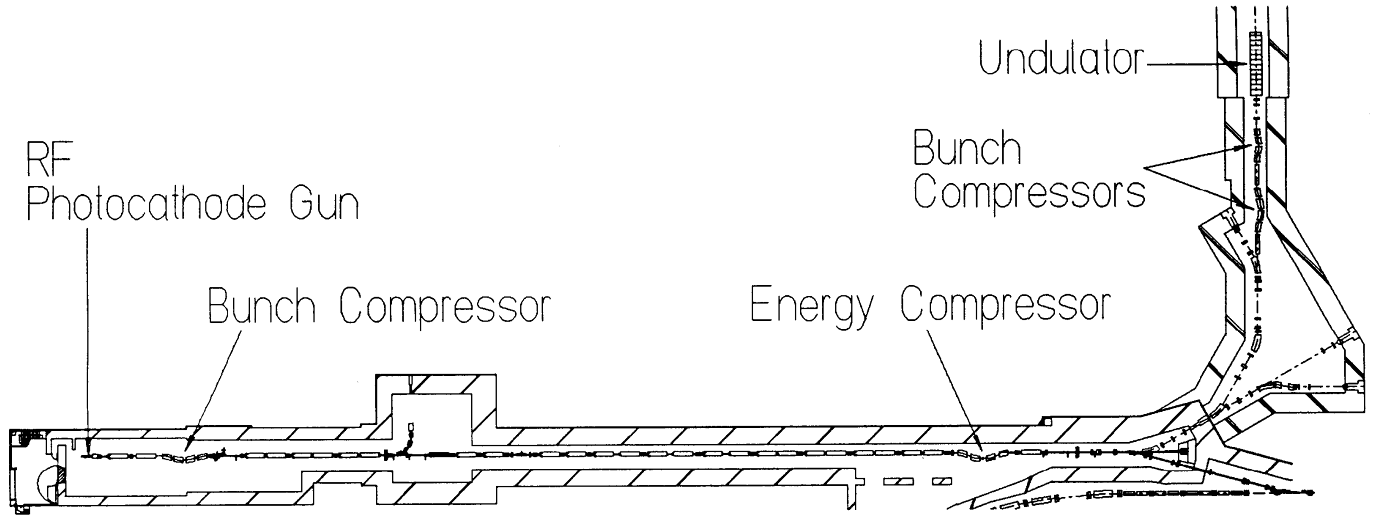

Fig.4 Schematic drawing of layout for SASE

Conclusion

The construction of SPring-8 linac will be completed soon. We reported some plan of the linac next stage. Various technological development is necessary for the SASE. These are important for the activity of the linac members.

Acknowledgment

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