Studies of Laser-Beam Interaction at the SPring-8 Linac

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Abstract

We are planning the studies of laser-beam interaction as the future plan of the SPring-8 Linac. Main subject of this studies is inverse Compton scattering. It is not for usage of the gamma-ray but for monitoring or investigation of beam physics using the inverse Compton scattering. For these studies, we expect the Linac characteristics such as short pulse, large density of the beam. In this proceeding, we present the outline of our plannings.

1 Introduction

The SPring-8 commissioning has finished and the operation for providing synchrotron radiation to users will be started in this October. In the future commercial operation period, the SPring-8 Linac will be drive twice a day to inject the electron beam to the Synchrotron.

Besides, the Linac has various capabilities to use their beams for another applications because of their current, beam energy or so on.

On the other hand, progress of the laser power is remarkable recently. 10^{12}W laser is already appeared. And also pulse length of the laser becomes shorter to several femto second.

So, as one of the future theme at the SPring-8 Linac, combination between laser and electron is considerable to be promising.

The inverse Compton scattering is one of application of this theme. It is useful as the source of gamma-ray, and also interesting as probe of the electron beam, or as beam physics. In our Linac, the former applications are severe because the electron beams are operated pulse mode so average current of electrons are lower compared with the ring type machine. But the latter is preferable. For example, SASE that is our another application [1] needs high density electrons to increase built up ratio. Therefore, bunch length must be shortened, emittance also must be reduced. Laser beam has possibility to be as the probe of that short bunch beam or as the sensor of reduced emittane.

2 Future beam lines of SPring-8 Linac

Fig.1 shows the layout of our Linac future beam lines. Nowadays, the Linac have only one beam transport line to the Synchrotron at the end of the Linac. But as shown in Fig.1, we have a future plan to have another two transportlines. One is named L4 beam transport line for the New Subaru ring, which is under construction by Himeji institute of technology, and the other is L3 beam transport line for our assembly hall. We are now starting the construction of these two lines, and the construction are expected to be finished by next September.

The L3 beam line is for our future beam experiments. It has an arc which forms triple bend achromatic optics. Straight section after the achromatic bending magnets is dispersion free area. And the wall thickness of this tunnel is designed to stand against the high current of 12 μA average, that is maximum beam specification of the present Linac. So various experiments can be done in this area. The beam characteristics of the present Linac are shown in Table.1.

After the straight section, beam dump is temporally mounted. In the future plan, this beam dump will be removed and long undulator for SASE experiment [1] will be set up at downstream of this line.

As the laser-beam interaction experiments, two ports for laser injection are prepared in the L3 line. One is at the chamber of the bending magnet to the beam dump. The beam dump be will set under ground so this port protrudes in the direction of downstream of the beam line. At this port, studies of head on collision will be able to done. The other is at the chamber of the last bending magnet of the achromatic section. This port protrudes in the opposite direction of the beam line. In this section, the laser can be injected from behind the beam. And after this port, the long straight section can be used as interaction area. 90° interaction experiments will be able to done at the middle area of the straight section.

Measurements of the gamma-ray will be able to done at the area after the beam dump.

Table 1
SPring-8 Linac performance

Energy		1.2GeV
Pulse Length	2μs	10ns
Current	100mA	1A
Repetition Rate		60 pps
Absolute Emittance		1πmm·mrad at 1GeV

3 Applications

Fig.2 shows the concept of the inverse Compton scattering. Distribution of gamma-ray energy, or differential cross section are clearly calculated as follows.

$$h\nu_o = \frac{h\nu_i\left(1+\beta_i\cos\theta_i\right)}{1-\beta_i\cos\theta+\frac{h\nu_i}{\gamma_i m_o C^2}\left(1+\cos\left(\theta+\theta_i\right)\right)} \quad (1)$$

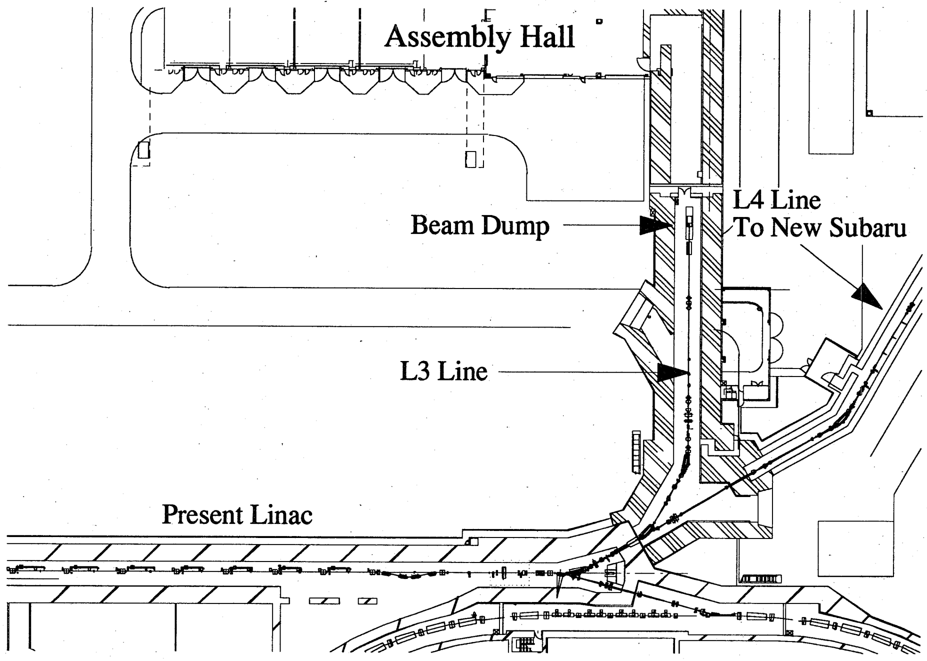

Fig. 1 Future layout of SPring-8 Linac beam lines. L3 and L4 beam lines will be start construction from this fall.

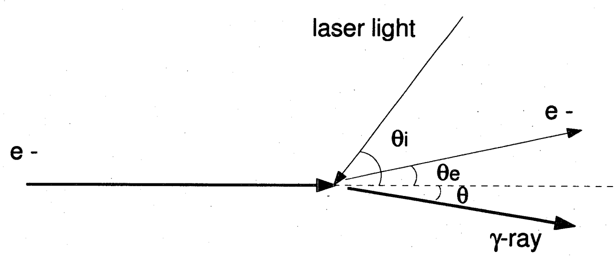

Fig. 2 Concept of inverse Compton scattering

$$\frac{d\sigma}{r_0^2 d\Omega} = \frac{4\left(\gamma_i^4\theta^4 + 1\right)\gamma_i^2}{\left(\gamma_i^2\theta^2 + 1\right)^4} \quad (2)$$

where, β_i and γ_i are relativistic factors of the electron beam, θ_i is incident angle of laser light and θ is scattered angle of gamma-ray. r_0 is classical electron radius. The eq.1 is strictly derived. As the eq.2, the effect of the quantum theory is not considered. And we assume that the factor of β_i is very close to 1. In the region of under 1 GeV as the electron energy, quantum effects is negligible.

Fig.3 shows energy of the observable gamma-ray depends on electron beam energy at our Linac. In this calculation, laser wave length of $1\mu m$ or $0.6\mu m$ and θ_i of zero are assumed.

It is clear from these above equations, we can strictly predict characteristics of the observed gamma-ray, and also predict various beam qualities by monitoring the gamma-ray. So several experiments of the monitoring of the beam can be considered.

Our study planing of the laser-beam interactions are mainly separated to three steps.

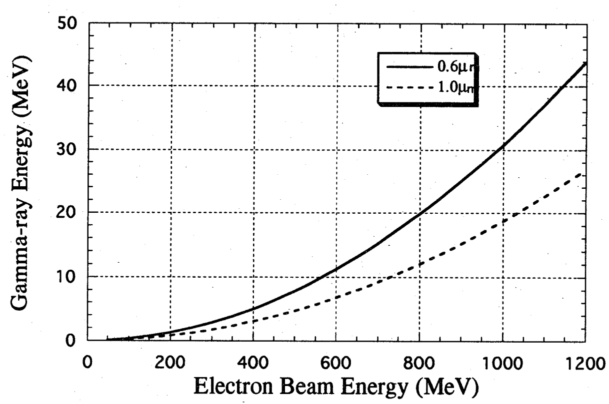

Fig. 3 Observed gamma-ray energy which is depend on electron beam energy.

One is head on collision. laser is injected towards the electron beam. In this case, interaction region between electron beam and laser became larger, so yield of observed gamma-ray is large and timing system is easier than another cases. So, these studies are considered to be first step. In this step, the experiments which is considered are following.

- Electron beam energy measurement by observing Compton edge.
- Measurement of transverse beam structure.
- Measurement of transverse time structure.
- Measurement of beam emittance.

Each data which are expected to be observed can be calculated in advance. So we can monitor beam characteristics by comparing with calculation. For instance, as Compton edge, differential cross section which depends on observed gamma-ray energy can be derived from eq.1 and 2.

$$\frac{d\sigma}{d(h\nu_o)} = \frac{8}{3}\pi r_0^2 \frac{6\left(\gamma_i^4\theta^4+1\right)\gamma_i^2}{\left(\gamma_i^2\theta^2+1\right)^4}\frac{h\nu_i}{\left(h\nu_o\right)^2} \tag{3}$$

where, $\gamma_i^2\theta^2 = 4\gamma_i h\nu_i\left(\frac{\gamma_i}{h\nu_o} - \frac{1}{m_0 C^2}\right) - 1$

We are planning to start the first step experiment from the beginning of FY 1999.

Other two steps are 90° and 180° scatterings. In 90° scattering experiment, incident laser beam is perpendicular to the electron beam. In this case, interaction region becomes smaller compared with 0° and 180° experiment. So, timing jitter is sever, and yield of gamma is smaller. But this study is suitable for micro pulse investigation. The experiment of this step are considered to be following.

- Measurement of longitudinal beam structure.
- Measurement of transverse beam structure.
- Measurement of bunch length.
- Production of femto second gamma-ray. ,etc.

The third applications are 180° scattering experiments. In this case, basically gamma-ray is not observed. because if θ_i is π in the eq.1, a numerator of eq.1 becomes to zero. So this scattering can not be used for beam investigations. But momentum direction of each electron in the beam is not same because of beam emittance. So θ_i is not always π. Thus, various applications are considered following.

- Emittance reduction of electron beam.
- Production of femto second beam. ,etc.

Upper applications are based on beam energy modulation by 180° scattering. Energy modulation technique is considered to be hopeful on other applications.

These second and third experiments are expected to start from FY 2000. They are considered to be useful to investigate the low emittance and short pulse beam which will be produced by RF gun [2] that is studying now. So in the future, inverse Compton scattering, the RF gun and the SASE are expected to be combined systematically.

4 Summary

In this proceeding, we describe the laser-beam interaction study for future plan of the SPring-8 Linac. These studies are one of the theme of our Linac, but they are important for future theme of short current and high density beam studies.

We do not describe about the detector and laser in this time. They are very important but now detail study have not started. We must start examination soon. Collaboration with other institute can be also considered.

The budget for the L3 and L4 beam transport line is very sever now. But we believe we can experiment at L3 line in the near future.

References

[1] K.Yanagida et al.,"Beam Transport for SPring-8 Linac Future Plan", Proc. of the 11th Sympo. on Accel. Sci. and Tech., Harima Sci. Garden City,(1997) to be published.

[2] T.Taniuchi et al.,"Photo Cathode RF Gun Study for SPring-8 Linac", Proc. of the 11th Sympo. on Accel. Sci. and Tech., Harima Sci. Garden City,(1997) to be published.