The First Operation of Laser Electron Photon Facility in SPring-8

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Abstract

An intense photon beam from the laser-electron interaction was successfully produced in the first operation of LEP (Laser Electron Photon) beamline at SPring-8. Produced photons had the world-highest energy of 2.4 GeV at the maximum and the integrated intensity of 1.5×10^6/sec at the electron beam current of 100 mA. An expected effect of the LEP production was observed in the lifetime of the electron beam.

1 Introduction

High energy real photon produced by means of laser induced backward Compton scattering is expected to be very useful at synchrotron radiation (SR) facilities. Using a stored electron beam of energy more than 5 GeV, an intense γ ray in the GeV energy region is produced without domination of low energy photons and it is preferable for nuclear and hadron physics experiments. High tunableness of the photon polarization is another advantage of this method. ϕ meson photoproduction is one of the most interesting subject to study using the γ ray. The large $s\bar{s}$ content of ϕ makes it possible to study the mechanism of the strange quark production. To do this, energy of the photon must be considerably larger than 1 GeV. The maximum energy of LEP is approximately proportional to the square of energy of electron beam. SPring-8 has an 8 GeV electron storage ring which is the world highest energy among the SR sources and is the most adequate place to build a LEP facility.

The LEP beamline BL33LEP at SPring-8 is a contract beamline of the Research Center for Nuclear Physics (RCNP, Osaka University). A photon energy of 2.4 GeV is obtained at maximum with 351 nm laser. The LEP beam intensity is estimated to 10^7/sec at maximum with a highest power DC laser available. The plan of the beamline construction [1] have been carried out from the year 1997. With the completion of the modification of accelerator components in 1998 and the construction of a laser injection system in the first quarter in 1999, we were ready to obtain the first LEP beam to optimize the laser optic system and to check the effect of LEP production on the stored electron beam.

2 The BL33LEP beamline

The beamline is used to inject a laser light beam against the electron beam and to extract high energy photons produced via the electron-photon interaction

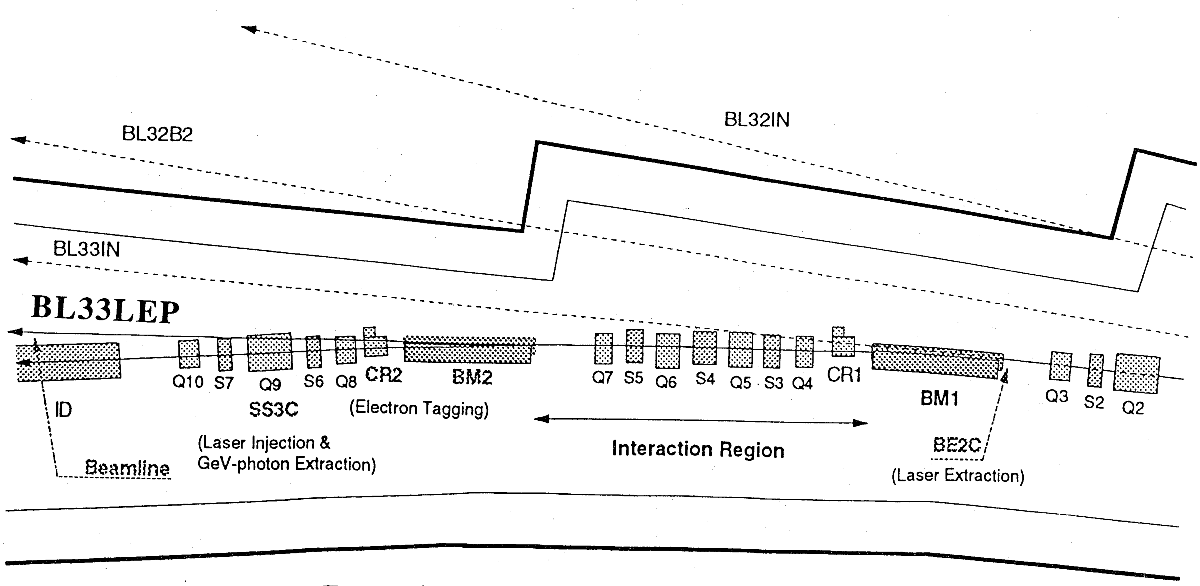

Fig. 1 Accelerator components on BL33LEP

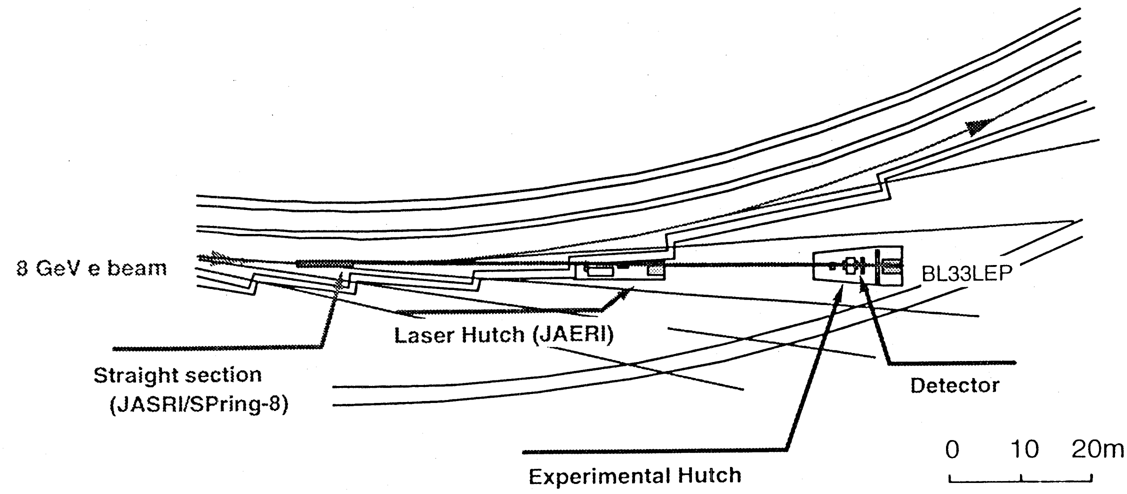

Fig. 2 LEP is extracted out from the accelerator tunnel to the laser hutch. The experimental hutch was not used in this time.

in a 7.8 m long straight segment. Fig. 1 shows the interaction region between two bending magnets BM1 at upstream and BM2 at downstream of the cell 33 of the storage ring. The high energy photons are produced in the direction of the electron beam. As the storage ring components on this beamline were originally designed to extract SR from BM2 to a direction which was shifted by 4 mrad towards the center of the ring when compared with the current one, we replaced two of them, a crotch absorber CR2 placed at downstream of BM2 for absorbing unnecessary SR outside a photon extraction aperture and a straight chamber SS3C which had a duct to extract photons out from the ring.

Since high energy photons are produced inside a narrow cone with an opening half angle of about 60μrad centered at the electron beam direction, a conventional collimation technique can not be used to separate energies of the photons. Instead, we use a tagging method by detecting horizontal deviations of recoil electrons from the beam axis after they pass through BM2, which works as a spectrometer magnet. A slot for the deviated electrons was inlaid in a modified vacuum chamber BM2C between BM2 poles. Electrons which transferred more than 1.5 GeV and less than 3.5 GeV of their energies into photons travel in the slot and they are extracted through a 3 mm thick Al window of a modified crotch chamber CR2C. After the window there is a space prepared to put tagging detectors. The lower limit of the photon energy to be tagged is determined by the minimum distance of the detectors from the electron beam axis. Inner wall of the electron duct in the modified CR2C is narrowed from the side of detector space by 7 mm down to 18 mm from the beam axis. A further approach to the beam axis was not done for avoiding influences on the electron beam. The narrowed duct has a length of 17.5 cm and it is continued to the normal ones at the both sides by tapers inside the CR2C.

Injected laser light passed through the interaction region proceeds through a chamber between BM1 poles, bellows chamber BE2C and is extracted through a port on a flange at the end of BE2C to a monitoring system.

High energy photons extracted from the ring are delivered through a pathway called frontend, where unnecessary SR is cut by a Cu mask and a Pb collimetor, toward experimental hall outside the beam tunnel as shown in Fig. 2. An opening window on the wall of the tunnel had been shifted according to the shift of the beamline direction.

In the experimental hall, there are two hutches along the beamline. The first one just outside the beam tunnel is a laser hutch for containing a laser optic system, an 1 m long 0.5 T sweep magnet, a gamma beam monitor and a movable beam dump which makes it possible to use this hutch independently by disconnecting the following part of the beamline. The second one is equipped with experimental apparatus such as a spectrometer dipole magnet, drift chambers and an array of TOF counters and the beam line ends at a beam dump in this hutch. The first and second hutches are connected by a beam transport pipe.

The second experimental hutch and the transport pipe is under construction at present and the first operation of the laser beam injection had been done only with the laser hutch.

3 Laser injection and LEP detection systems

The laser optic system in the laser hutch is composed of a continuous 20W Ar laser generator, mirrors and a beam expander to tune the focal point of the laser beam. Those components are settled on an optics table. At the end of this table there are two movable mirrors to tune the position and direction of the laser beam for the injection. The mirror angle is tunable by a step of 7 μrad which corresponds to 0.3 mm for the position of the focal point at the center of the interaction region.

The designed focussing radius is 1 mm. The laser light is injected into the beam pipe through two in-vacuum fixed mirrors in a mirror chamber which has a quartz window at 400 mm apart from the beamline. This two mirror method avoids the radiation hazards of the injection window.

Operation of the laser beam tuning was simulated during the accelerator shutdown by measuring photon distributions with the laser monitor system at the upstream end of the beamline.

Production of LEPs were detected by two means, namely, a calorimetric and a tagging methods.

A calorimeter composed of 9 rectangular PWO crystal cells was placed in between the sweep magnet and the beam stopper. Energy calibration of PWOs had been done with gas Bremsstrahlung at a beam current of 1 mA.[2] Measured energy spectra for beam exposures centered at each crystal was fitted by convolutions of a known radiation spectrum and resolution functions of the crystals. The highest energy channel for each crystal was identified as the maximum energy deposit calculated by EGS4.

The tagging counter system is composed of plastic scintillators and arrays of Si strip detectors to measure the positions of electrons.

4 The first production of LEP

The first LEP production was obtained on 28 June, 1999 by the collision between a 351 nm low intensity laser beam and a 100 mA electron beam. The intensity of laser was tuned to obtain a LEP production rate of 10^4/s. Our purpose was to perform radiation survey and to establish a laser tuning method. A low intensity laser was focussed at the center of the interaction region and the laser beam axis was changed to obtain the maximum yield.

On July 1, 1999, the laser beam with its full power was incident on the 1 mA electron beam at the beginning and on 100 mA later. The laser-electron overlap was tuned with the 1 mA run. Figure 3 shows the energy spectrum of LEP at this run showing the maximum energy was 2.4 GeV as expected.

The production rate was counted by the tagging counter at the 100 mA run. Using the energy acceptance of the tagging counter obtained from the 1 mA run, counts in the 100 mA run were translated to the production rate. It was turned out that the rate of the LEP production was 1.5×10^6/s at maximum. This was about 20% of the expected maximum rate. The reason of the reduction is now under study.

5 Effect of LEP production on electron beam

The LEP production with a rate $\dot{N}_\gamma = 1 \times 10^7$/s at 100 mA is expected to reduce the beam lifetime by contributing an additional decay rate of $1/\tau_{LEP} = 1/87(\mathrm{hr}^{-1})$. When the natural lifetime is 54 hours and $\dot{N}_\gamma = 1.5 \times 10^6$/s, the expected rate of the reduction is 8.3%. The observed reduction was consistent with this expectation.

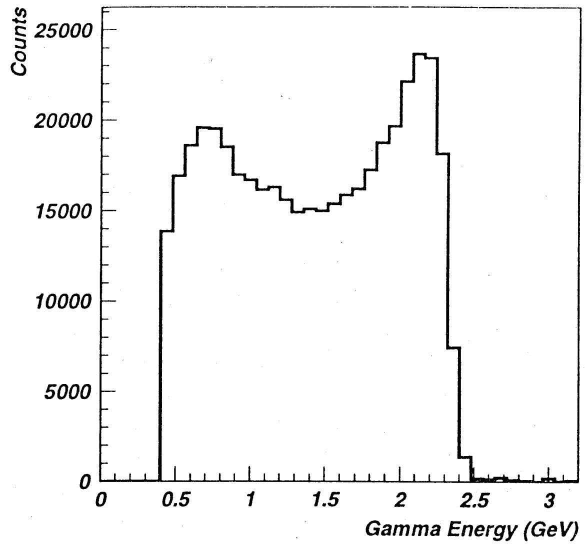

Fig. 3 Energy distribution of the first LEP measured by PWO calorimeter.

Someone may wonder if scattered electrons cause a deformation of the structure of the beam. This has, however, no place to take a part in our case for damping times of the longitudinal and transverse beam oscillations multiplied by $\dot{N}_\gamma$ are negligibly small compared with the total number of stored electrons.

6 Conclusion

A LEP beamline BL33LEP have been constructed. The first laser injection was successfully performed to produce LEP with the maximum energy of 2.4 GeV and an intensity $\dot{N}_\gamma = 1.5 \times 10^6$/s under the condition of the electron beam of 100 mA. The effect of the LEP production on the electron beam lifetime was consistent with the expectation.

With having those successful results, physics runs are scheduled to start before the end of this year.

References

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[2] A. Asano, in preperation.