BL33LEP
(Laser-Electron Photon)

1. Introduction

BL33LEP (LEPS) uses a polarized photon beam produced by laser-induced backward Compton scattering from 8-GeV electrons to study quark–nuclear physics. This photon beam has a large polarization of nearly 100% at the maximum energy (2.4 GeV with 355-nm laser or 2.9 GeV with 266-nm laser), which is a great advantage in elucidating the photoproduction mechanism. Photon energies above 1.5 GeV are tagged by detecting recoiled electrons. The wavelength of such a high-energy photon is shorter than the typical size of a hadron (~1 fm), which consists of quarks. This beam can be used to investigate the substructure of hadrons (*i.e.,* the quark world). We photoproduced hadrons by irradiating the Laser-Electron Photon (LEP) beam mainly to liquid hydrogen and liquid deuterium targets. Then forward-going reaction products are detected with a high-resolution magnetic spectrometer. Many important results have been obtained, including a hint of existence of the pentaquark Θ^+, baryon resonances, and threshold enhancement of the ϕ meson photoproduction. On the other hand, photoproduced charged pions or converted electrons/positrons in the GeV energy region are suitable tools to test and calibrate prototype detectors. BL33LEP has also been used for test experiments as international joint usage. The result of the test for an aerogel Cherenkov detector, which will be used in a J-PARC experiment, has recently been published [1].

In FY2018, we stopped the physics run at BL33LEP. Instead we conducted test experiments to evaluate the performance of new detectors for the LEPS2 spectrometer of BL31LEP and developed two kinds of advanced equipment for future LEPS experiments. These activities are described below.

2. Preparation for double-polarization experiments

To date, photoproductions of mesons and baryons have been measured only by using unpolarized targets with a linearly polarized beam. However, double-polarization measurements for photoreactions with a polarized target and circularly polarized photon beam are sensitive means to investigate small and exotic amplitudes such as a ϕ-meson photoproduction by a knockout of a possible strange-quark pair in the nucleon. To realize the double-polarization measurements, we developed a frozen-spin polarized HD (hydride deuterium) target at the Research Center for Nuclear Physics (RCNP), Osaka University.

The polarization method for the HD target is static. According to the Boltzmann law, the polarizations of a proton and deuteron reach 85% and 25%, respectively, under the conditions of 17 T and 14 mK. An important element for the fast growth of polarization and a long relaxation time is a small mixture of the ortho-H_2 gas. Hence, we developed a dedicated gas analyzer system to adjust its concentration. After a long aging time of a few months at this low temperature, the polarization is frozen. Then we can move the HD target from RCNP to SPring-8 under a relatively high temperature (< 4 K) and low magnetic field (1 T) while keeping its polarization. The whole system (a dilution refrigerator with a 17-T magnet, storage cryostat, in-beam cryostat, and two transfer cryostats) was constructed. The operation tests of each cryostat are almost complete [2]. To date, a HD target with a polarization of 40% and a relaxation time of 240 days has been realized.

A circularly polarized beam is another important component in double-polarization experiments. In principle, circular polarization can be obtained by linearly polarized laser light passing through a quarter wavelength (λ/4) plate. (The laser light itself is almost 100% linearly polarized.) However, the reflection rate depends on the angle between the reflection plane at the mirror and the axis of linear polarization. Four mirrors are used to inject laser light to the electron storage ring.

To produce a circularly polarized beam, we investigated these effects at BL33LEP for two different sets of third and fourth mirrors (*i.e.,* quartz and Al-evaporated mirrors). In both cases, about 36% linear polarization remained at the optimum rotation angle of the λ/4 plate, which was placed between the fourth mirror and laser. Next we combined the λ/2 plate with the λ/4 plate (Fig. 1). Figure 2 plots the linear polarizations of the laser lights measured at the storage ring tunnel against the rotation angle of the λ/2 plate when the λ/4 plate is set to a fixed angle. Under the optimal condition, the linear polarization almost disappears. In FY2019, we will insert another λ/4 plate at the laser beam end and measure the linear polarization downstream of this λ/4 plate to determine the direction of circular polarization.

3. Intensity upgrade by a pulse laser synchronized with the electron bunch

We used continuous-wave (CW) or pseudo-CW (80 MHz) lasers at BL33LEP. We replaced the laser with that of newly available higher output power to increase the photon beam intensity every few years. However, increasing the output power not only distorted the optical components but also induced a faster deterioration. Since the efficiency of the LEP beam production is reduced, we are investigating ways to increase the beam intensity while suppressing the output power.

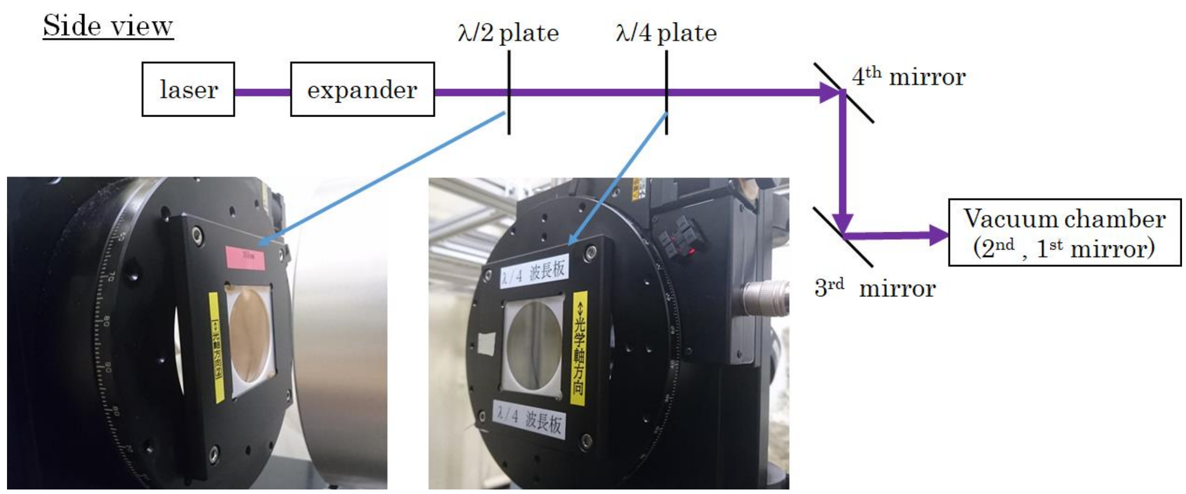

Fig. 1. Setup to inject circularly polarized laser light to the SPring-8 storage ring.

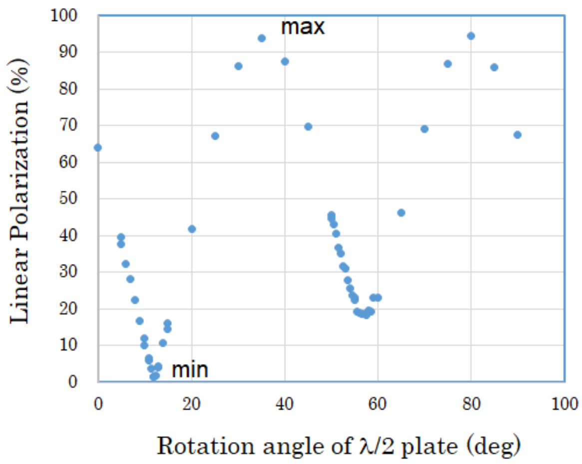

Fig. 2. Variation of the linear polarization at the laser-beam end in the SR tunnel against the rotation angle of the λ/2 plate. Axis of the λ/4 plate is fixed in this measurement.

The first test experiments in FY2017 demonstrated that the use of a pulse laser synchronized with the electron bunch can give a higher-intensity photon beam. Figure 3 depicts a conceptual drawing. In the case of a synchronized pulse laser, there is ideally no empty shot at the collision point. Because the test was conducted with a very low output power and low frequency, we were unable to evaluate whether it could be used in an actual experiment. This test was conducted in FY2018. We selected the F-mode (1/14 filling + 12 bunches) because a single bunch interval of 342.1 ns is suitable for the prepared pulse laser. The output pattern of the pulse laser was controlled by the function generator. The RF signal obtained from the SPring-8 storage ring was pre-scaled and used as the external trigger of the function generator.

When the trigger signal reaches the function generator, it sends an arbitrary waveform to the pulse laser. By adjusting the delay of the output of the function generator, the synchronized point can be investigated. We initially set the output power and frequency to 0.1 W and 208.8 kHz, respectively, and tuned the delay timing. Changing the delay timing produced 12 sharp peaks in the intensity of the tagging counter, which correspond to the 12 single bunches. The timing can be adjusted so that the laser photons hit any electron bunch at the focus point. Increasing the output power and frequency achieved a beam intensity of 1 MHz. The present pulse laser is very promising to realize an upgraded laser system at both the BL33LEP and BL31LEP beamlines.

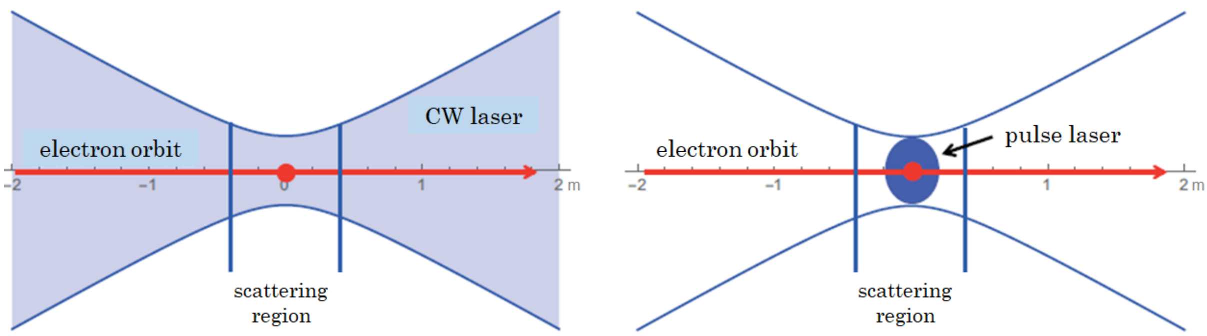

Fig. 3. Schematics of the laser Compton scattering near the collision point for (left) a CW laser and (right) a pulse laser synchronized with a beam bunch.

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References:

[1] M.H. Kim et al., *Nucl. Instrum. Methods Phys. Res. A* **923**, 38 (2019).
[2] Y. Yanai et al., *Proceedings of Science*, PSTP 2017, 003 (2018).