POLARIZED HIGH-ENERGY PHOTON BEAM PRODUCTION WITH LASER-COMPTON BACKSCATTERING

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Abstract

We have produced a beam of high-energy gamma-rays by Compton backscattering of 1064 nm laser photons from 1 GeV electrons circulating in NewSUBARU storage ring. The detected photon yields were measured at about 3×10^4 photons $s^{-1}mA^{-1}W^{-1}$ for the 20 mmΦ collimator. The photon energy width from the collimator corresponds to 6.6-17.6 MeV. The fundamental characteristics well agree with the theoretical ones. We have tried to measure the polarization of the produced gamma-rays using a nuclear fluorescence experiment. The preliminary results are described in this paper.

1 BACKSCATTERIG FACILITY

In order to carry out photonuclear experiments on the electromagnetic interaction in the energy range of several MeV to tens of MeV, a laser-Compton backscattering facility has been installed at NewSUBARU[1] storage ring. The angle-energy correlation method is used in that system. These gamma-rays can be used also for electron beam diagnoses at the storage ring. An 11-m long straight line (BL1), was used for the laser-Compton backscattering experiment. Fig.1 shows a schematic overview of the laser-Compton backscattering facility.

The laser source used is a CW Nd:YVO4 laser (λ =1064 nm, EL=1.168 eV) and both the horizontal and the vertical waist diameters of the laser source are 0.42 mm and both the full divergences are 3.4 mrad. The laser photons are injected into the interaction area with four mirrors and a lens. The laser beam waist is located at the center of the interaction area

2 PRODUCTION OF PHOTON BEAM

We conducted experiments at an electron energy of 1 GeV, a current of 5-20 mA and laser power of 0.5-1.0 W. The backscattering photon beam was collimated in one of 0.67 mrad(20 mmΦ), 0.335 mrad (10 mmΦ) or 0.067 mrad (2 mmΦ) 10 cm long lead collimators. The photon energy widths correspond to 6.6-17.6 MeV, 12.4-17.6 MeV, 17.3-17.6 MeV for 20, 10 and 2 mmΦ collimators, respectively. The collimator was placed on the gamma-ray beam axis approximately 14 m from the center of the interaction region.

We monitored the produced photon flux with a 180 cm^3 coaxial-type HPGe or 3”×3” NaI detector. The detector shielded by lead blocks was placed on photon beam axis approximately 20 m from the center of the collision area and about 1 m behind the lead collimator. The gamma-ray energies were calibrated with the 1.461 MeV gamma-rays from the ^{40}K and several standard gamma-ray sources.

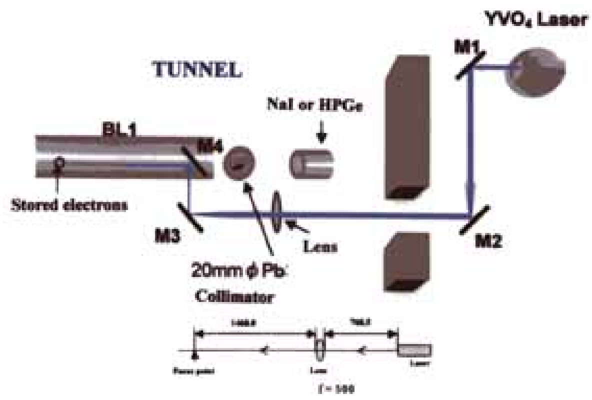

Figure 1: Schematic overview of laser-Compton back-scattering facility

The energy spectra of the backscattered photons were measured at an electron energy of 1 GeV. The solid lines in Fig. 2 show the energy spectra of the backscattering photons measured with the various collimators. The Bremsstrahlung photons have been subtracted from the original spectra. When using the 2mmΦ collimator, the photo peak and single escape peak can be seen as shown in Fig. 2, though the peaks are very small due to the volume of the detector.

We compared the obtained energy spectra with the simulated model calculations using the Monte-Carlo electron-gamma shower simulation code, EGS4[2]. The calculated energy spectra are shown with the dotted lines in Fig. 2. The shapes of the calculated energy spectra are reproduce the measured ones. The photon yield can be estimated from the normalization between the measured and calculated spectra. The detected photons are about 3×10^4, 5×10^3 and 5×10^2 $s^{-1}mA^{-1}W^{-1}$ for the 20, 10 and 2 mmΦ collimators, respectively. The details of the production of the photon beam with the Compton backscattering are described in Ref.[3]

3 POLARIZATION OF PHOTON BEAM

In the head-on collision, the photon beam generated by 180° Compton backscattering of polarized laser beam is polarized completely. We tried to measure the gamma-

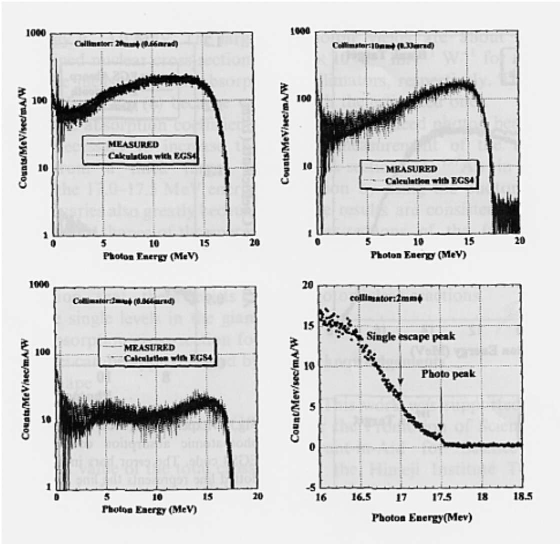

Figure 2: Energy spectra (solid line) of the back-scattering photons measured various collimators and the energy spectra (dotted lines) calculated using simulation code, EGS4.

beam polarization using nuclear fluorescence experiment. We measure the asymmetry,

$$A(\theta) = \frac{1}{P}\left\{\frac{\sigma(\theta, 0^\circ) - \sigma(\theta, 90^\circ)}{\sigma(\theta, 0^\circ) + \sigma(\theta, 90^\circ)}\right\}$$

In this equation, θ is the scattering angle, $\sigma(\theta, 0^\circ)$ is the yield for elastically scattered photons in the plane parallel to the electric vector of the incident photons and $\sigma(\theta, 90^\circ)$ is that in the perpendicular plane. P is the polarization of the incident photons. The intensity distribution function of a $0^+ \rightarrow 1^\pi \rightarrow 0^+$ photon scattering can be derived within angular correlation formalism[4] and is given by

$$\sigma(\theta, \phi) = 1 + \frac{1}{2}\left[P_2(cos\theta) + \frac{1}{2}\pi cos(2\phi) P_2^{(2)}(cos\theta)\right]$$

where π is parity. The asymmetry A to be +1 for positive parity state and –1 for the negative parity state under the condition of $\theta = 90^\circ$ and an even-even nucleus(J=0).

Elastically scattered photons from ^{12}C(15.11 MeV,1^+, T=1) were measured with the linearly polarized photons. The energy width of the incident photons is 6.6 –17.6 MeV. The polarization axis of the laser photons can be rotated by 90° by using a $\lambda/2$ wave–plate.

Figure 3 shows the preliminary energy spectra of $^{nat}C(\gamma_{pol}, \gamma)$ reaction. The upper part of this figure shows the elastically scattered photons in the plane parallel to the electric vector of the incident polarized gamma-rays and the lower one shows that in the perpendicular plane. We can find the elastically scattered photons only in the upper energy spectrum. The measured asymmetry is larger than 0.98 after background subtraction. This shows the gamma-ray polarization is ~98% for the incident energy of 15.11 MeV.

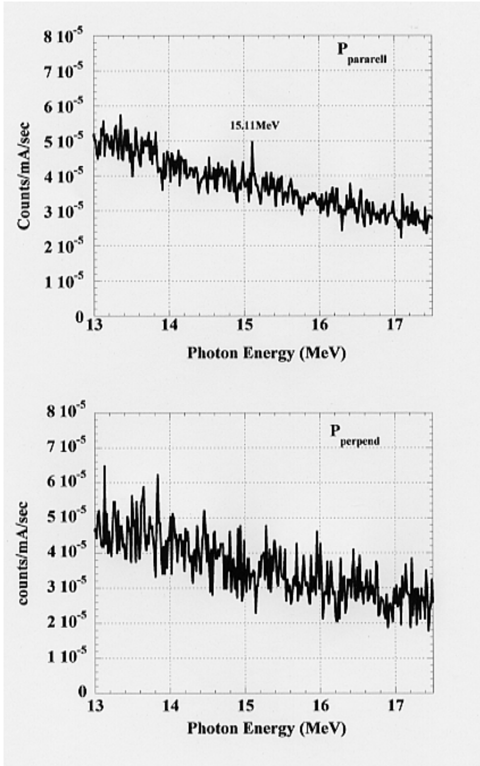

Figure 3: Energy spectra of the 12C(γ_{pol}, γ) reaction at incident energy of 6.6 to 17.5 MeV. The upper part of the figure shows the elastically scattered photons in the plane parallel and the lower shows that in the perpendicular plane.

4 SUMMARY

We produced a beam of high energy gamma-rays by Compton Backscattering of 1064 nm laser photons from 1 GeV electrons circulating in a storage ring, NewSUBARU. The photon energy width from the 20 mm φ correspondst0 6.6-17.6 MeV. By using these photons, we are measuring the polarization of the produced gamma-ray beam by Nuclear Resonance fluorescence(NRF), $^{12}C(\gamma_{pol}, \gamma)$ in order to check the performances of the facility.

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