Development of Beam-Foil Polarimeter for Polarized ^{3}He Ion Source Based on Electron Pumping

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The development of a polarized ion source based on electron pumping method [1] is now being promoted at RCNP. ^{3}He nuclear polarization produced by this ion source is measured by the beam-foil spectroscopy method[2].

The polarimeter is located in a uniform magnetic field (10 Gauss) produced by a Helmholtz coil to prevent the depolarization of polarized ^{3}He by a disturbing magnetic field from the AVF cyclotron, terrestrial magnetism, etc. A liquid N_2 trap is attached to the vacuum chamber of the polarimeter to avoid the collisions of polarized ^{3}He with the redisual gas in the polarimeter.

A schematic view of this polarimeter is shown in figure 1. This polarimeter consists of two detection systems for photon observation. One is an analyzer which measures a photon helisity. The other is used for the ^{3}He beam monitoring.

The dexcited photons from He I atoms formed after penetration of $^3He^+$ ions through a carbon foil are focused by two convex lenses. The circular polarization of the dexcited photons is converted to the linear polarization by a $\lambda/4$ plate, and finally the linear polarization is measured by a polarizer (Poraloid). The analyzed photons are detected by a photo multiplier (Hamamatsu R329P). The lens system was designed so that Ω/M can be maximum value, where Ω is a solid angle and M is a lateral magnification. As a result of a calculation, the Ω and M are respectively determined to $0.0388\times4\pi$ and 2.22. The length of the observation region along the beam axis is $\sim$ 7 mm. This is experimentally confirmed using an LED (figure 4). The analyzing power for the dexcited light oscillates along the beam direction. Since the observation length is much longer than quantum-beat period, the oscillating pattern can be averaged (figure 4).

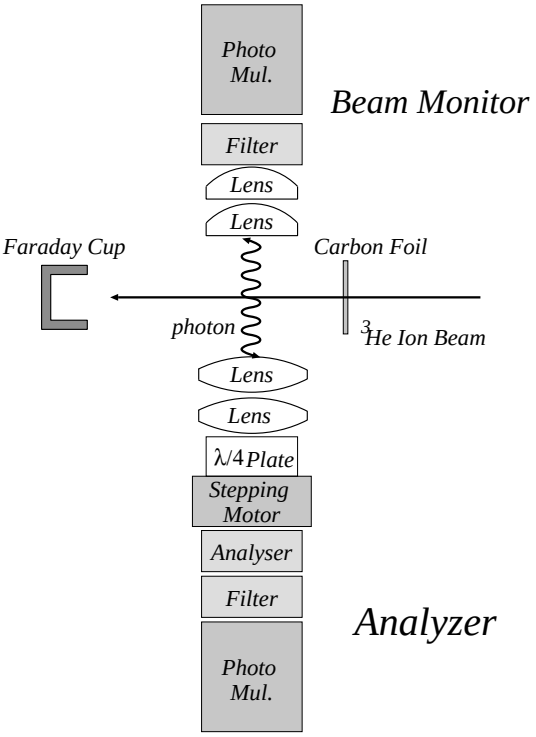

Figure 1: Schematic view of the beam-foil polarimeter

The transition between the 3^3P_J and 2^3S_1 states in He I, where J is 0,1 or 2, is selected by a wave length coherent-filter located in front of the photo multiplier. This transition has

a higher intensity and a longer life time (∼100 nsec) than the others. Figure 2 shows observed spectra, where an upper spectrum is taken without a filter and lower one is taken with a filter.

During the course of the present measurement, photon counting rate is ∼10 kcps with a beam current of 100 nA. The S/N for photo detection is 50 with this beam current. Under this condition, the nuclear polarization is determined with a precision better than 0.005 in 6 minutes measurement.

The performance of this polarimeter is tested by using ^{3}He polarized by the tilted foil method [3]. The results are shown in figure 3. The circular polarization is defined in terms of the Stokes parameter as,

$$\frac{S}{I} = \frac{N(\sigma^+) - N(\sigma^-)}{N(\sigma^+) + N(\sigma^-)}, \qquad (1)$$

$$N(\sigma^\pm) = C(\sigma^\pm)/B(\sigma^\pm), \qquad (2)$$

where $C(\sigma^\pm)$ and $B(\sigma^\pm)$ are, respectively, counts of the analyzer and the beam monitor detector for $\sigma^\pm$ photons. Then, nuclear polarization of ^{3}He, P, is given by

$$P = \frac{S}{I}A, \qquad (3)$$

$$A = 0.207, \qquad (4)$$

where A is an analyzing power. When the foil tilting angle is reversed it is observed that the circular polarization of the dexcited photons consistently change its sign. From this result, the validity of this polarimeter was confirmed.

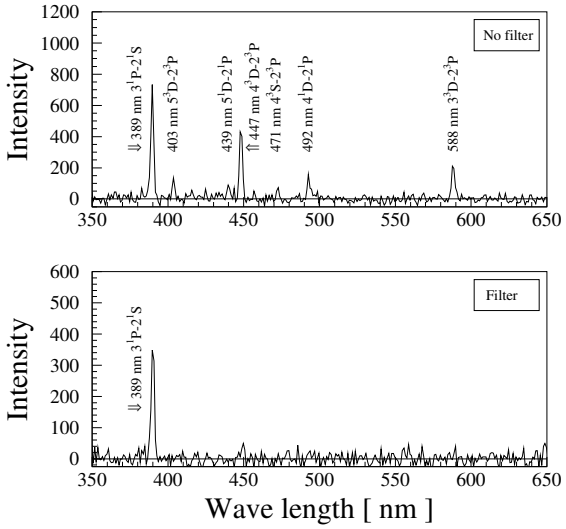

Figure 2: Photon spectra from HeI atoms formed after ^{3}He$^+$ atoms penetrate a 5 $\mu g/cm^2$ carbon foil. The upper figure is taken without filter and the lower one is taken with a filter.

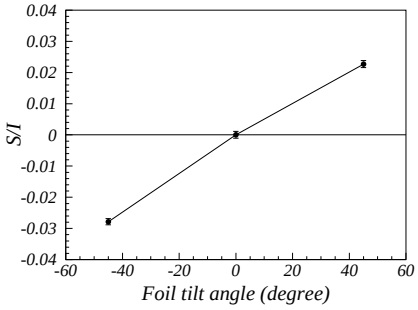

Figure 3: The observed polarization of ^{3}He generated by the tilted foil method.

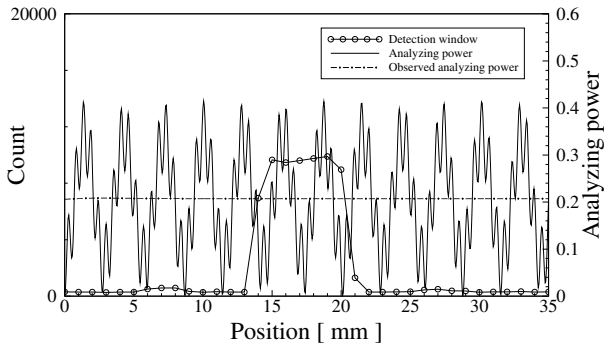

Figure 4: Relationship showing areal distribution of the analyzing power and the detector resolution.

References

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