Performance of ^{3}He polarimeter for the SEPIS polarized ^{3}He ion source

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A bench-test device was constructed to check whether or not the principle of SEPIS (Spin Exchange Polarized Ion Source) [1] is valid for production of nuclearly polarized ^{3}He ions. This device also allows us to measure the ^{3}He nuclear polarization by a polarimeter based on the beam foil spectroscopy method. The principle of the polarimeter is intuitively described below. Nuclearly polarized $^3He^+$ ions with a kinetic energy of about 20 keV are incident on a thin carbon foil. Most of the $^3He^+$ ions emerging out of the foil become neutral but in the excited states. Then, ^{3}He nuclear polarization is periodically transferred to photons emitted from these excited states through the hyperfine interaction, which is called a quantum beat. As a result, emitted photons show periodic changes of the circular polarization. The Stokes parameter, i.e., the degree of circular polarization, is given by

$$S/I = A(t)P_N, \qquad (1)$$

where P_N is a ^{3}He nuclear polarization, and A(t) is called an analyzing power. It is a reasonable approximation to use a time averaged value of A(t) because the periodic pattern expected in the beam direction is averaged due to the finite length of the sensitive area for the photon detector.

Performance of the polarimeter presently constructed was achieved by using atomically polarized ^{3}He I instead of nuclearly polarized ^{3}He. The atomically polarized ^{3}He I was created by the tilting foil method. According to this method an unpolarized $^3He^+$ ion beam incident on a thin carbon foil, whose normal direction is tilted with respect to the beam direction, is atomically polarized after penetrating the foil. It is known that the polarization direction is $\vec{n} \times \vec{v}$, where $\vec{n}$ is the normal direction with respect to the foil surface, and $\vec{v}$ the beam velocity, respectively, and the generated atomic polarization is expected to increase with the tiling angle.

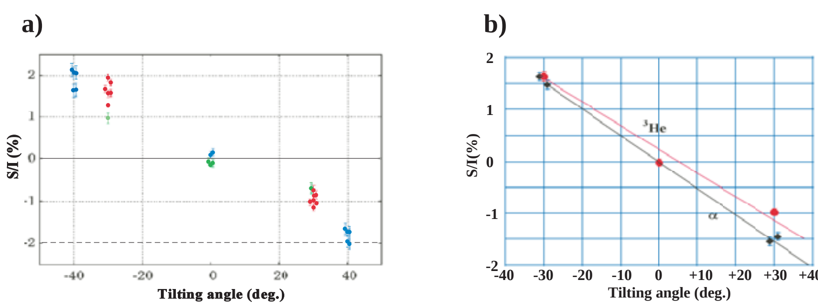

Fig. 1. Experimental results on the polarimeter. a) Observed Stokes parameters, S/I for the 389 nm lines of ^{3}He I atom plotted as a function of tilting angles.

In the present work, a 19.0-keV $^3He^+$ and 25.3-keV $^4He^+$ ions were introduced on a 4-μg/cm^2 carbon foil, and the Stokes parameters, S/I's for photons corresponding to the transition from the 3^3P_J (J=0,1,2) to 3^3S_1 state in He I were observed with a beam intensity from 0.5 to 2.0 eμA. The observed S/I's for the $^3He^+$ incidence are summarized in Fig. 1-a), which strongly demonstrates that the atomic polarization changes its sign according as the sign of tilting angle, and increases its absolute value with the tilting angle. A more important result is that the data are reproducible enough precise to test the validity of SEPIS requiring the measurements of ^{3}He nuclear polarization better than 0.5 %.

In Fig. 1-b), a tilting angular dependence of S/I is plotted both for ^{3}He (averaged data) and ^{4}He, where the lines indicated are drawn only for eye guide. It is quite interesting to mention that S/I for ^{4}He is somewhat (~20%) larger than that for ^{3}He. This clearly indicates that a part of the created atomic polarization shares with the nuclear polarization in case of ^{3}He through the hyperfine interactions [2].

References

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