Development of Measurement and Control System for Polarized ^{3}He Ion Source Based on Electron Pumping

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Abstract

A polarized ^{3}He ion source based on electron pumping has been developed at RCNP, Osaka University. The measurement system mainly consists of two parts. One is a part where a polarization of a Rb atom is measured based on the Faraday rotation effects. Another one is a part where a nuclear polarization of a ^{3}He particle is measured by the beam-foil spectroscopy. To reduce the statistical errors in these measurements, a helicity of a pumping laser is changed by controlling a pockels cell. These measurements and a controlling are operated by the SUN workstation.

1 Introduction

A new polarized ^{3}He ion source based on electron pumping[1] is being developed at the Research Center for Nuclear Physics, Osaka University[2]. It is necessary to measure a Rb atomic-polarization and a ^{3}He nuclear-polarization to investigate a performance of the ion source. The Rb atomic polarization is measured by using of the Faraday rotation effects which causes a rotation of the plane of a polarization of the light penetrating into an atomic-polarized medium along the magnetic fields[3]. On the other hand, the ^{3}He nuclear-polarization is measured by the beam-foil spectroscopy[4][5]. In the beam-foil spectroscopy we measure a circular polarization of photons emitted from the polarized ^{3}He particle after transversely go through a carbon foil, $5\mu g/cm^2$ in thickness.

2 Measurement of Rb atomic polarization

A set up for a measurement of the Rb atomic-polarization is shown in Fig. 1. A linearly polarized light from a diode laser goes through a Rb oven located in the magnetic field (2~3T) and a $\lambda/2$ plate and is splitted into a parallel and a perpendicularly polarized lights to the plane of the incidence by a polarizing beam splitter. These splitted lights are respectively detected by photo-diodes. Electric currents generated by the two photo-diodes are converted into voltages signals using operational-amplifiers and are feed into the ADC. The Faraday-rotation angle is measured rotating the $\lambda/2$ plate with a stepping motor which is controlled by the SUN workstation.

In Fig. 2 plotted points are the observed ratio of the two components of the lights splitted by the polarizing

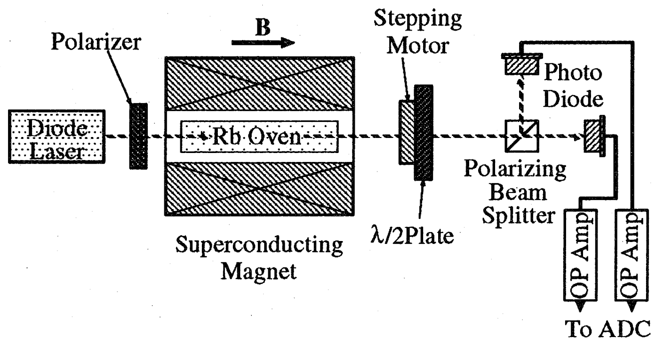

Fig. 1 The experimental set up for a measurement of the Rb atomic polarization.

beam splitter. From this figure the Faraday rotation angle is determined in the precision of ± 0.05 degrees when the Rb oven temperature is 20 °C. This precision corresponds to that of the Rb atomic- polarization of ± 0.03.

3 Measurement of ^{3}He nuclear-polarization

The ^{3}He nuclear-polarization produced by the ^{3}He polarized ion source is measured by the beam-foil spectroscopy[4][5]. A schematic view of this equipment is shown in Fig. 3. We observe circularly polarized photons emitted via the transitions between the 3^3P_J (J=2,1,0) and 2^3S_1 states of ^{3}He I. Fig. 4 shows a typical photon spectrum (closed circles) for a ^{4}He incidence instead of a ^{3}He observed by a monochromator located at the polarimeter position. It is shown from Fig. 4 that the 3^3P-2^3S transition is relatively intense. The life time of this transition (~100 ns) is known to be much longer than hyperfine interaction periods, therefore, this transition is suitable for the beam-foil spectroscopy. To observe this transition selectively, a 391.5 nm wavelength-filter (a transmission efficiency of 41.5 % at 20 nm FWHM) is inserted between a convex lens and a $\lambda/4$ plate. A spectrum with this filter is also shown in Fig. 4 (open circles). It is seen that the filter successfully chooses only the 3^3P-2^3S 389 nm transition.

Thus, the ^{3}He nuclear-polarization is obtained by measuring the intensity asymmetries of the circularly polarized light for the 3^3P-2^3S transition[5]. However, because of a failure of a power supply of a pumping laser

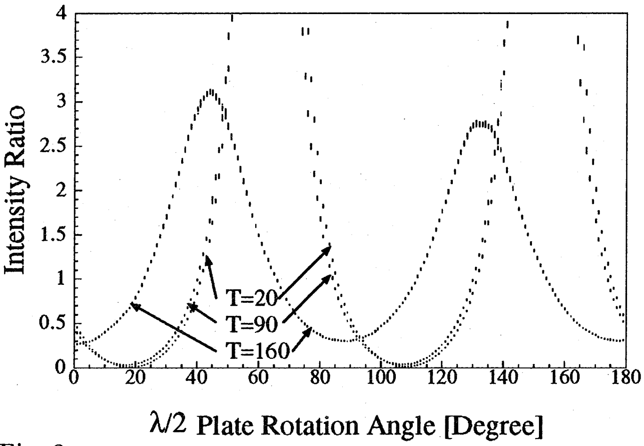

Fig. 2 Intensity ratio of a parallel polarized light to a perpendicularly polarized light to the plane of the incidence vs. the $\lambda/2$ plate rotation-angle at three different temperature of the Rb oven.

for the Rb (an alexandrite pulsed laser), we cannot produce the polarized ^{3}He beam at the moment.

To investigate an overall performance of the ^{3}He polarimeter a test of this system by using a 17.9 keV ^{4}He-beam (with no nuclear-polarization) instead of the ^{3}He beam was performed. Fig. 6 shows the asymmetries of the 389 nm photons observed by the polarimeter as a function of time starting from the pumping laser ignition. From this measurement an obtained asymmetry R is

$$R = 0.9978 \pm 0.0077,$$

and a resulting polarization P is

$$P = \frac{R-1}{A} = \frac{0.9978 - 1 \pm 0.0077}{0.207} = -0.011 \pm 0.037,$$

where A is an analyzing power for the circular polarization measurement. Since the measurement was performed with the ^{4}He incidence with no nuclear-polarization, no asymmetry should be observed. The result is in reasonable agreement with no polarization.

4 Data taking and Control system

To flip a helicity of the pumping laser light, a pockels cell is used by controlling a high voltage supplied to the pockels cell by using an I/O register board.

The ADC, GPIB and I/O resister boards are on the VME and these boards are virtually addressed on a memory of the workstation by VME/Sbus interface board (SF110:Solflower Computer Inc.) and controlled by this workstation CPU[6].

5 Conclusion

The measurement and control system for polarized ^{3}He ion source recently installed at RCNP is designed and constructed.

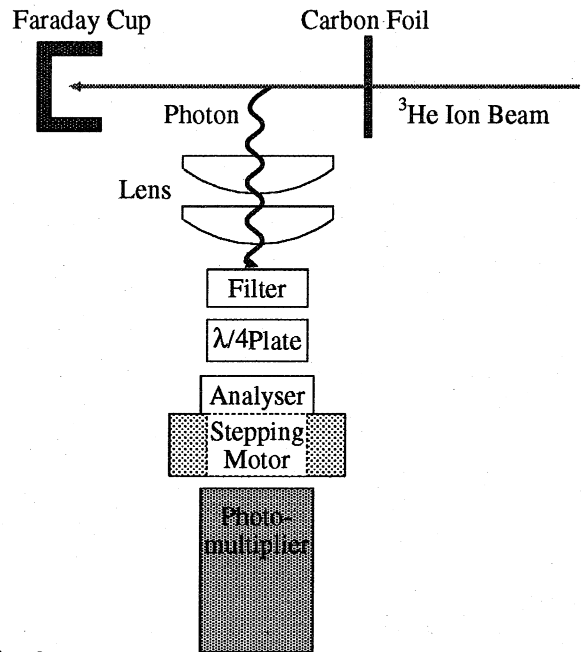

Fig. 3 A schematic view of a ^{3}He polarimeter based on the beam-foil spectroscopy.

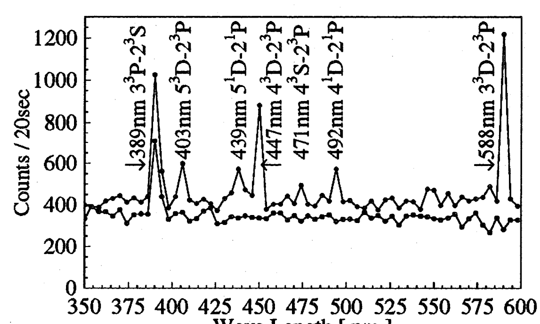

Fig. 4 Photon spectra emitted from an incidence of 17.9 keV ^{4}He beam on a carbon foil. Closed circles were data taken by a monochromator without a filter, while open circles were taken with a filter.

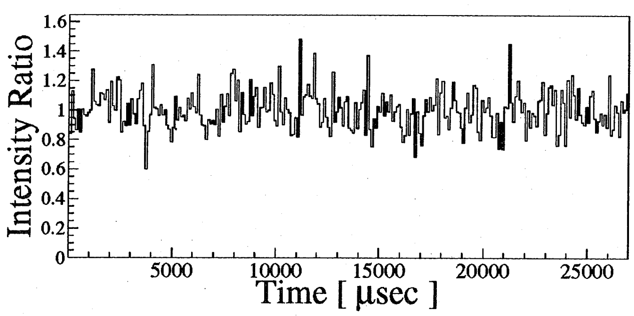

Fig. 5 An asymmetry of intensity of the 3^3P-2^3S photons by the ^4He incidence. A data aquisition time is 3600 sec.

By these system it is confirmed that the Rb atomic-polarization is measured in the precision of 0.03, and the ^3He nuclear-polarization is in that of 0.037 in 1 hour.

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