## MEASUREMENT OF ELECTRON-SPIN POLARIZATION OF SODIUM ATOMS FOR OPTICAL PUMPING TYPE POLARIZED ION SOURCE

Yoshiharu MORI, Kiyoshi IKEGAMI, Akira TAKAGI and Sadayoshi FUKUMOTO

KEK, National Laboratory for High Energy Physics

A new type of polarized ion source which uses electron pick-up reactions of low energy $H^+$ ions from electron-spin polarized sodium atoms has been developed at KEK. Electron-spin polarized sodium atoms are produced by optical pumping with a single frequency dye laser which is tuned to the wavelength of the sodium $D_1$(589.593 nm) line. Electron-spin polarization of sodium atoms is strongly affected by the laser power and the sodium target density. It is quite important to measure the electron-spin polarization of optically pumped sodium atoms for the development of this polarized ion source. A very useful scheme for this purpose has been proposed and experimentally performed recently.[1] This scheme utilizes Faraday rotation based on an optically anomalous dispersion at the edges of a resonance line. It has no deteriorating effects on optically pumped atoms and gives a polarization value averaged over the target cell length.

The amount of Faraday rotation comes from the difference of the refractive indices for left and right circularly polarized light.

$$\theta = \frac{\pi \ell}{\lambda} (n_+ - n_-) \quad , \tag{1}$$

where $n_+$ and $n_-$ are the refractive indices for left and right circular polarization respectively, $\lambda$ is the wavelength of the light and $\ell$ is the target length. Refractive indices are affected by the magnetic field and the electron-spin polarization. So, $\theta$ can be written as follows.

$$\theta = \theta_0 + \alpha P \theta_0 \quad , \tag{2}$$

where P is the electron-spin polarization of the optically pumped sodium atoms and $\theta_0$ is the Faraday rotation angle for the unpolarized sodium atoms and $\alpha$ can be obtained theoretically.[2] $\alpha$ depends only on the magnetic field as shown in Fig. 1. If $\theta$ and $\theta_0$ are measured, the electron-spin polarization can be obtained from eq. (2).

Fig. 2 shows an experimental set-up of the Faraday rotation method. A single frequency dye laser (Spectra Physics 380-D) was used for the optical pumping. The output power of the laser was about 1.5 W maximum and the available frequency scanning range was 30 GHz. The frequency of the laser was carefully tuned to the particular resonant frequency of the sodium $D_1$ $\sigma^+$ or $\sigma^-$ line. Linearly polarized probe laser light from the wide band dye laser (Spectra Physics 375) was introduced to the sodium cell with the pumping laser light through a low transmission (2 %) mirror $M_1$. The wide band dye laser was tuned to the wavelength of 589.3 nm which was the most suitable wavelength for the Faraday rotation method.

A spectroscope was set at the wavelength of 589.3 nm and placed after the Gran-Thomson polariser which was rotated by 45 degrees with respect to the probe light polarisation plane. When the polarization plane of the probe light is rotated through an angle, $\theta$, by the Faraday rotation effect, the light intensity through the spectroscope is given by,

$$I(\theta) = 2I(0) \sin^2 \left(\frac{\pi}{4} + \theta\right) \quad , \tag{3}$$

where I(0) is the light intensity when the magnetic field is zero. $\theta$ and $\theta_0$ in eq. (2) can be obtained from eq. (3).

In Fig. 3, the measured values of the electron-spin polarization of sodium atoms are shown for the various laser powers as a function of the target thickness. At a target thickness of $2 \times 10^{13}$ atoms/cm$^2$, the spin polarization was 60 % at the maximum and this value agreed with the theoretically predicted polarization value. We are now preparing another single frequency dye laser. Polarization is expected to increase with two lasers.

In a preliminary experiment using the 16.5 GHz ECR ion source and a single frequency ring dye laser, we have obtained a polarized $H^-$ ion beam of 23 μA. The $H^-$ ion beam current as a function of the sodium target thickness is also shown in Fig. 3.


References

1) W.D. Cornelius et al., AIP Conf. Proc., No.80, p.173 (1981).
2) Y. Mori, K. Ikegami, A. Takagi and S. Fukumoto, to be published in KEK internal report.


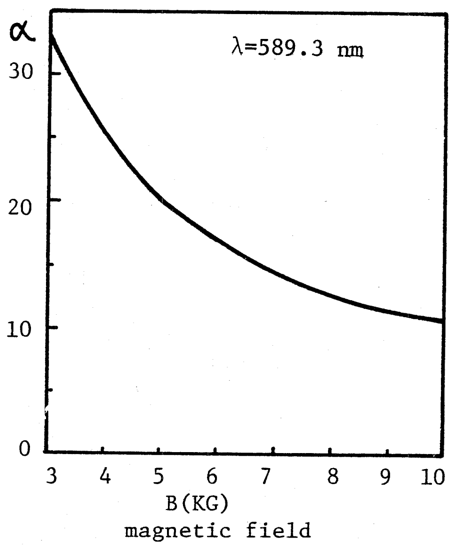


Fig.1 Calcurated value of α as a function of a magnetic field.

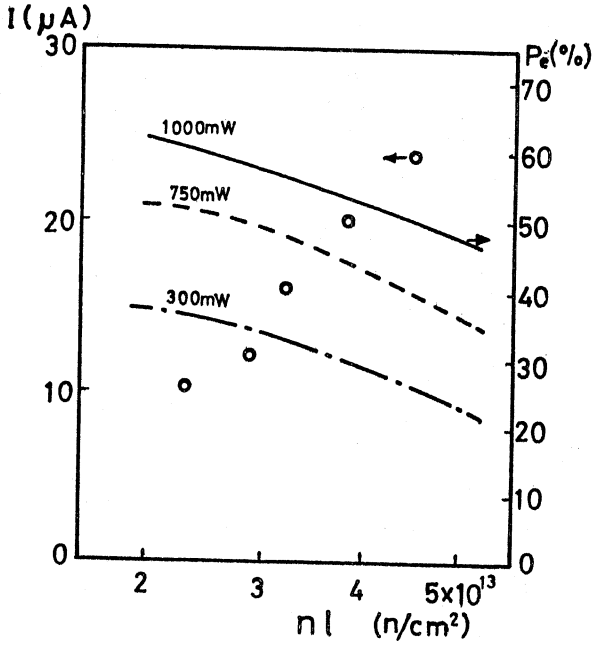


Fig.3 Electron-spin polarization of sodium atoms and polarized $H^-$ ion current as a function of sodium target thickness for three laser powers.

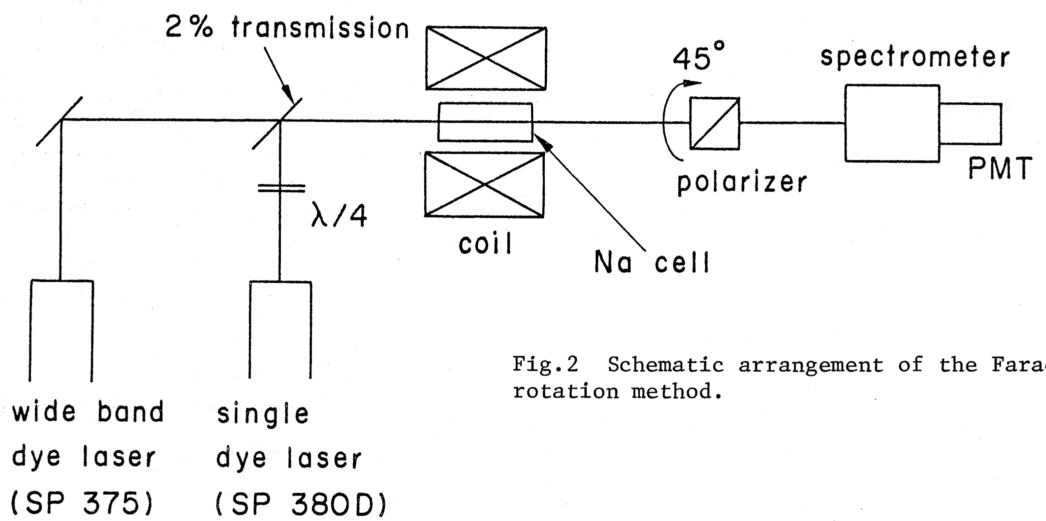


Fig.2 Schematic arrangement of the Faraday rotation method.