POLARIZATION MEASUREMENT OF OPTICALLY PUMPED POLARIZED H^- ION SOURCE AT KEK

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(ABSTRACT)

An optically pumped polaried H^- ion source which uses an electron pick-up reaction of loe energy H^+ ion from optically pumped sodium atoms has been developed for the acceleration of a polarized proton beam in the 12 GeV synchrotron at KEK. In this polarized ion source, a 16.5 GHz ECR ion source is used as a H^+ ion source. In a preliminary experiment, we have obtained about 10 ~ 25 μA H^- ion beam of 83 ± 27 ~ 39 ± 21 % polarization.

1. Introduction

In KEK, a new 750 keV preinjector has been constructed for the acceleration of polarized proton beam in the 12 GeV synchrotron.[1] In this project, a new type of polarized ion source which aims to produce an intense polarized H^- ion beam has been developed.

The polarized ion source utilizes the charge-exchange reactions between fast H^+ ions and electron-spin polarized sodium atoms produced by optical pumping.[2] In this scheme, there were two large difficulties which should be solved; one was how we could get a high electron-spin polarization of optically pumped sodium atoms at its large target thickness more than 1×10^{13} atoms/cm^2 and the other was how we could solve the emittance blow-up problem of H^0 beam at the magnetic field of 10 kG. The strong magnet field is necessary to avoid the depolarization due to the spin-orbit interactions of 2P state of hydrogen atoms formed by the charge-exchange reactions.[3]

We had overcome these difficulties by using single frequency ring dye lasers and a 16.5 GHz ECR ion source as an H^+ ion source. The single frequency dye laser has a large power density compared with a broad band dye laser because of its narrow spectrum width (100 MHz), so it makes an efficient pumping at a large target

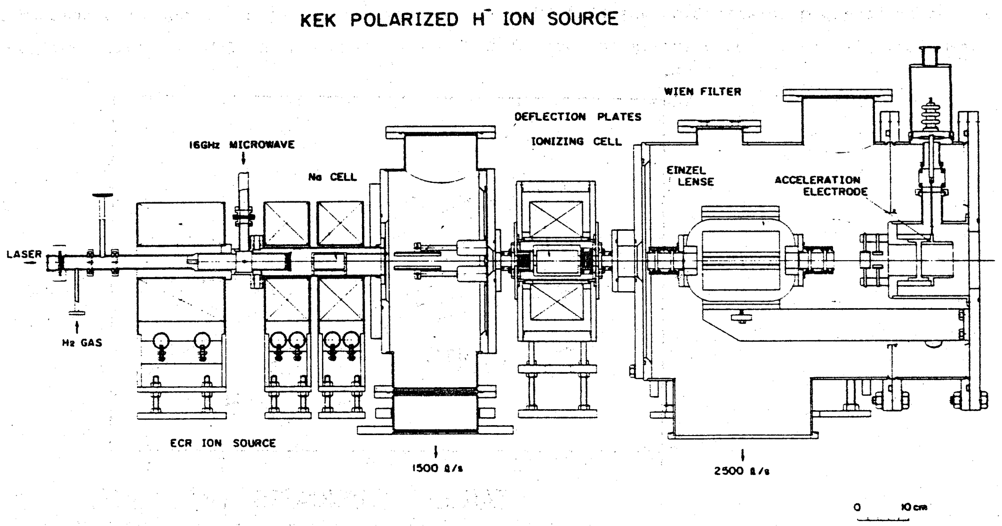

Fig. 1 Schematic layout of the optically pumped polarized H^- ion source at KEK.

thickness more than 10^{13} atoms/cm^2. As for the frequency stability, the single frequency dye laser has an excellent performance and it would be adequate for long period operation.

The 16.5 GHz ECR ion source was developed as an intense H^+ ion source. In this ion source, low energy H^+ ions is extracted at the high magnetic field of 9 kG and also capt ure spin-polarized electrons of optically pumped sodium atoms in the same magnetic field.

2. Optical Pumping

Electron-spin polarized sodium atoms are produced by optical pumping with single frequency dye lasers which are tuned to the wavelength of the sodium D1 line. In the magnetic field sufficiently strong to obtain good Zeeman splitting, the ground state (3S) and 3P state of sodium atoms are split into fine structure levels. Electron-spin polarized sodium atoms are obtained by optical pumping between 3S1/2 state and 3P1/2 state by absorption of left (σ^+) or right (σ^-) circular polarized laser light.

Optical pumping is largely affected by laser power and frequency. It is very important to measure the elecyronspin 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 developed so far. This sceme utilizes Faraday rotation based on an optically anomalous dispersion at the edges of a resonance atoms and gives an average polarezation value over the target cell length.

Fig. 2 shows the measured electron-spin polarization of sodium atoms as a function of the target thickness for various pumping laser powers. With one pumping laser, electron-spin polarization attained about 60 % when the target thickness was 2 x 10^{13} n/cm^2. When the target thickness increased more than 2 x 10^{13} n/cm^2, the polarization decreased gradually. This effect should be due to the absorption of the light intensity and it could be overcome by increasing the laser power.

3. Measurement of Proton-spin Polarization

Proton-spin polarization was measured with the nuclear reaction of ^{6}Li(p, ^{4}He)^{3}He. The experimental scheme is shown in Fig. 3. The polarized ion source was placed in the high voltage dome. The beam was accelerated by a Cockcroft-Walton accelerator and then focused by the quadrupole magnets. The beam current and the beam profile were measured by the current monitors and the profile monitors, respectively. A Wien filter to change the spin direction from the horizontal to the vertical was placed before the scattering chamber. The solid state surface barrier detectors were placed at the angles of 115° and 155°, respectively. The thickness of the ^{6}Li target was about 50 ~ 100 μg/cm^2. The measurements were performed at the beam energy of 355 keV and the proton-spin polarization was obtained using the analysing power of this reaction, which was estimated from the data taken by L. Brown et al.[4] Fig. 4 shows the preliminary results of the measured beam polarization as a function of the beam current. The beam current was measured after the acceleration by the current monitor. It was changed by varying the target density of the optically pumped sodium atoms. As demonstrated in this figure, the proton-spin polarization was 83 ± 27 % at the beam current of 10 A and it decreased gradually according to the beam intensity. At 15 μA, the polarization was 59 ± 15 % and at 25 μA, 39 ± 21 %. This configuration of the proton-spin

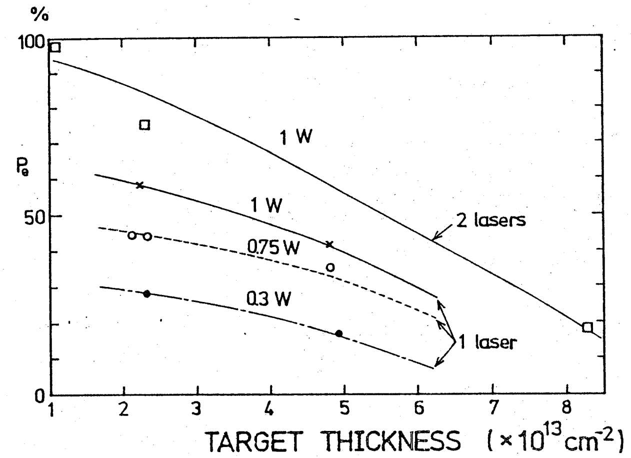

Fig. 2 Measured electron-spin polarization of sodium atoms as a function of the target thickness.

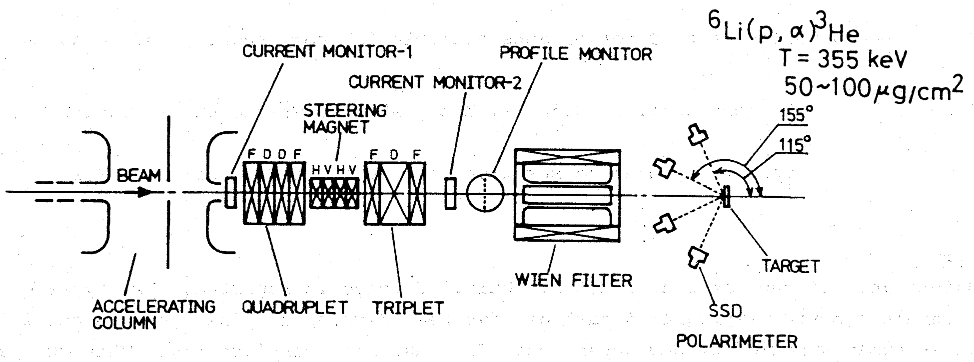

Fig. 3 Schematic layout of the measurement of proton-spin polarization.

polarization is very similar to that of the electron-spin polarization appeared in Fig. and it is conceived that the proton-spin polarization should reflect the electron-spin polarization of the optically polarized sodium atoms directly. From these data, however, it seems impossible to estimate directly the depolarization effect due to the spin-orbit coupling of H^0 atom formed by the charge-exchange reaction because of the large error bars.

4. Conclusion

The beam from the optically pumped polarized ion source using 16.5 GHz ECR ion source was successfully accelerated by the Cockcroft-Walton preaccelerator and the proton-spin polarization was measured using the reaction of ^{6}Li(p, ^{4}He)^{3}He. We have obtained in the preliminary experment 10μA H^- ion current of 83 ± 27 % polarization, 15μA of 59 ± 15 % and 25μA of 39 ± 21 % so far. It was found that an optically pumped polarized ion source worked in principle by using an ECR ion source.

Also, we found that there are many problems to be further studied and improved in future. The beam intensity and the proton ratio of the ECR ion source should be improved. We have to increase the efficiency of the optical pumping at larger target thickness of sodium atom. In order to do this, of cource, it will be helpful to add one more dye laser and also, to use pottasium atoms as a pumped target replacing sodium atoms because its smaller hyperfine structure energy reduces the absorption line width.

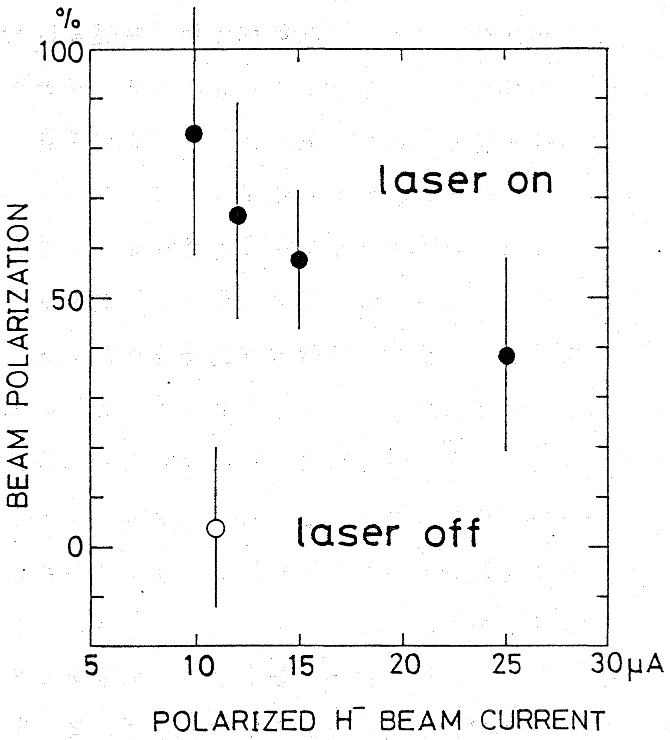

Fig. 4 Measured proton-spin polarization as a function of the accelerated H^- ion current.

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