High intensity polarized ion source

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A high intensity polarized ion source of atomic beam type has been successfully constructed. A unique method of controlling the polarization axis has been established incorporated with the acceleration technique. The polarized deuteron beam at intermediate energies will open up a rich field in the study of nuclear structure.

In the past 30 years, the study of spin dependent nuclear forces has been greatly facilitated by the use of polarized proton and deuteron sources. A rich field was recently opened up by using polarized protons of several hundred MeV, demonstrating that intermediate energy beams allow a clear insight of nuclear structure. Polarized deuterons, however, have been used mainly at low energies since most high energy accelerators are dedicated to the proton, an exceptional nucleus of $A/Z = 1$. The deuteron can be regarded as a heavy ion for the accelerator.

It is obvious that the deuteron, a particle with spin 1 and isospin 0, provides complementary information to the one from the proton, a particle with spin 1/2 and isospin 1/2. There also exist considerable advantages of the deuteron in the field of spin related physics. Polarization observable in some deuteron induced charge exchange reactions gives rich information on nuclear response which is accessible only by a complicated double scattering experiment in proton induced reactions. Also polarized neutrons can be easily produced from the breakup of polarized deuterons and will be very useful for the study of nuclear structure as well as the study of basic symmetry. The polarization transfer of deuteron inelastic scattering affords an excellent insight into the spin-flip isoscalar nuclear response which is still hidden in mystery.

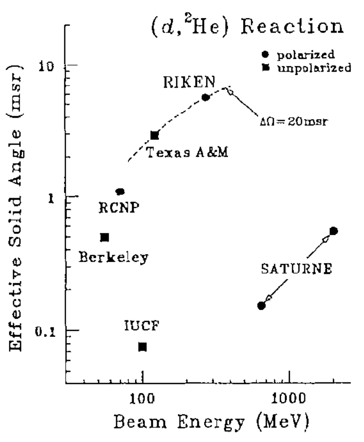

Fig. 1. Comparison of efficiency for the (d,pp) reaction measured at some facilities.

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The RIKEN Ring Cyclotron can accelerate deuterons up to 270 MeV. Equipped with the polarized ion source and with the large acceptance spectrograph, the facility provides unique opportunities to explore this attractive field. As an example, Fig. 1 shows some efficiency for the (d,pp) reaction measurement and demonstrates the great advantage of the facility.

The RIKEN polarized ion source of the atomic beam type is schematically shown in Fig. 2. It consists of a dissociator which creates a highly directed and intense beam of deuterium atoms, a pair of sextupole focusing magnets which cause the emerging atomic beam to be electron-spin-polarized, a pair of weak and strong field radio-frequency transition units which are used to transfer the atomic electron's polarization to the nucleus, and an ionizer which strips the electrons to produce the polarized ion beam. The system is differentially pumped to exhaust the unpolarized background gas. Total pumping speed exceeds 10,000 ℓ/s.

The atomic beam type ion source has been employed since it is well established and worldwide spread. Yet modern technologies are also introduced to enhance its performance. The dissociator nozzle is cooled down to about 35 K to lower the emerging atomic beam velocity, allowing more efficient focusing and ionization.[1] A small amount of nitrogen is fed in to form a coating at the nozzle surface so that the recombination is minimized at low temperature. The ionizer utilizes electron-cyclotron-resonance (ECR) acceleration in stead of the conventional electron beam method.[2] The neutral plasma of ECR provides high density of electrons and enhances the ionization efficiency. Also the energy spread of extracted ions is kept small, allowing an efficient beam transport. Currently the ion intensity of more than 100 μA is routinely observed with 65% polarization of the ideal value.

A unique feature is the control method of polarization axis. The spin quantization axis of extracted ions is established by the magnetic field of the ionizer and is along with the beam direction in most cases. Usually, the beam is injected with its polarization axis parallel to the cyclotron magnetic field in order to avoid Larmour precession. And the polarization axis is rotated after acceleration by using a superconducting solenoid. For energetic deuteron beams, however, a very large solenoid is needed to rotate the polarization axis since the anomalous gyromagnetic g-factor of deuteron is small. In addition, a solenoid can rotate the polarization axis only in one direction.

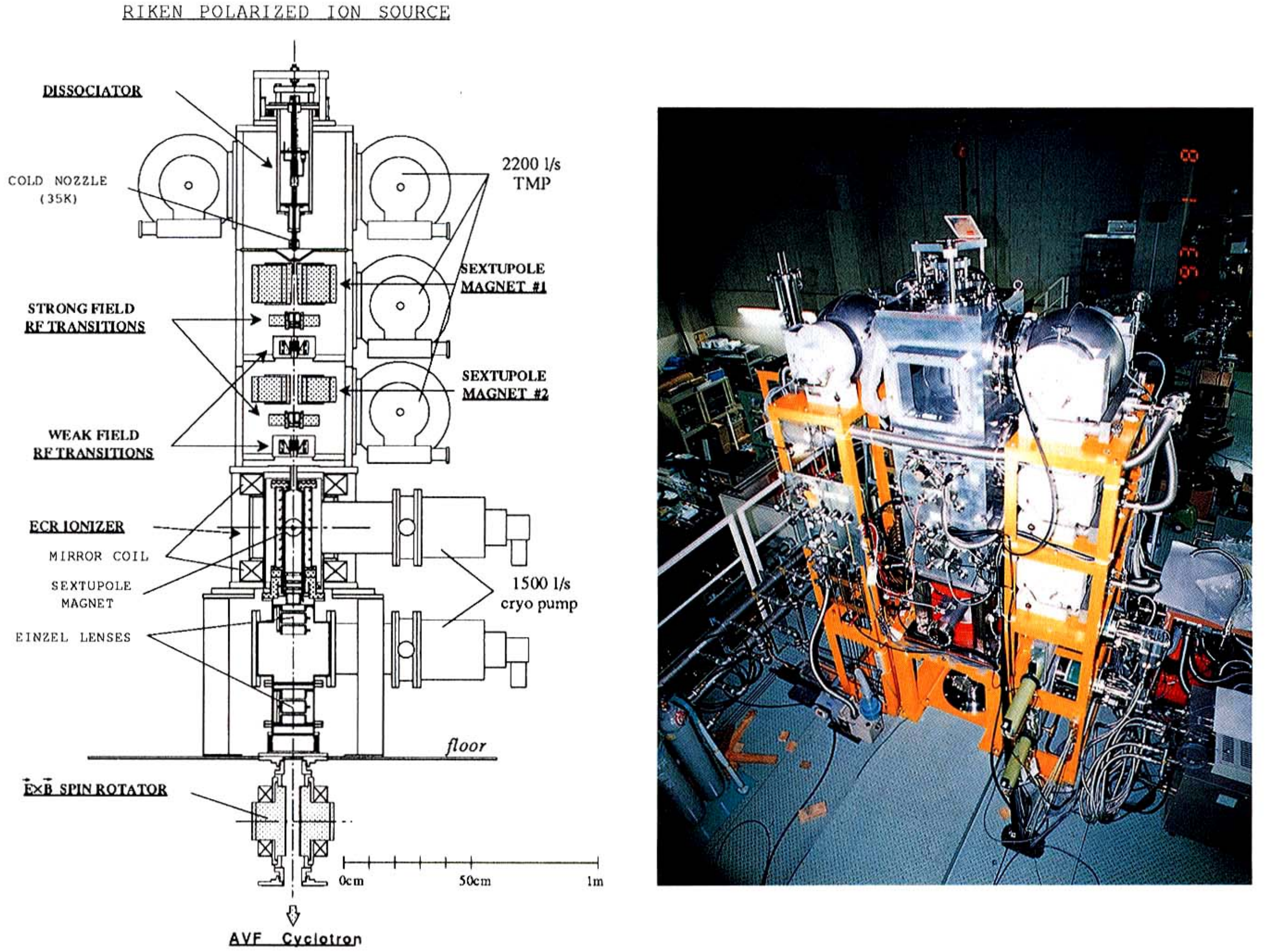

Fig. 2. Side view of the polarized ion source.

In our system, the polarization axis is freely controlled by using the Wien filter downstream of the ion source. While the beam is injected and accelerated with its polarization axis inclined to the cyclotron magnetic field, a single turn extraction does not lead to a loss in the amplitude of polarization. The Wien filter is tuned by monitoring the polarization at the exit of the cyclotron. According to this principle, we have succeeded in rotating the polarization axis without reducing the polarization amplitude or the beam intensity.

Owing to the newly developed but well proven technology, the RIKEN polarized ion source has been successfully constructed and is reliably operating. Some physics programs using the polarized deuteron beam are currently under way.

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References

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