ECR Source for Beams of Negative Hydrogen Ions

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The Stern-Gerlach ion source for negative polarised $\vec{D}^-$ and $\vec{H}^-$ hydrogen beams with electron cyclotron resonance ionizer and cesium vapour target produces routinely negative polarised $\vec{D}^-$ and $\vec{H}^-$ ion beams with intensities above 10 μA. Accelerated ion beams between 2 and 3 μA are available for experiments on the target of the Q3D magnetic spectrograph with nuclear polarizations around 65 % for both hydrogen species.

Between December 2001 and February 2002 the source was running for 4 weeks without maintenance. There were three experimental blocks with two interruptions of a few weeks. First, polarized $\vec{H}$ and $\vec{D}$ ion beams were used to study the multinucleon transfer reactions 24 MeV ^{123}Sb($\vec{p},\alpha$)^{120}Sn, 24 MeV ^{122}Sn($\vec{p},\alpha$)^{119}In and 18 MeV ^{196}Pt($\vec{d},\alpha$)^{194}Ir. In January and February the source was used for unpolarized hydrogen beams. Beam intensities of more than 10 μA of negative deuterium or hydrogen ions were available at the entrance of the tandem. Ion beams of up to 3 μA on target were used for the study of the mass distribution of induced fission fragments of ^{236}U by the ^{235}U(d,pf) reaction. In the third block the ion microscope SNAKE required hydrogen ion beams with highest brilliance.

For unpolarized beams the electron cyclotron resonance ionizer works as regular ECR source. Fig. 1 shows a cross section of the ECR source, the electrostatic beam transport system and the cesium vapour target for the charge exchange from positive to negative hydrogen ion beams.

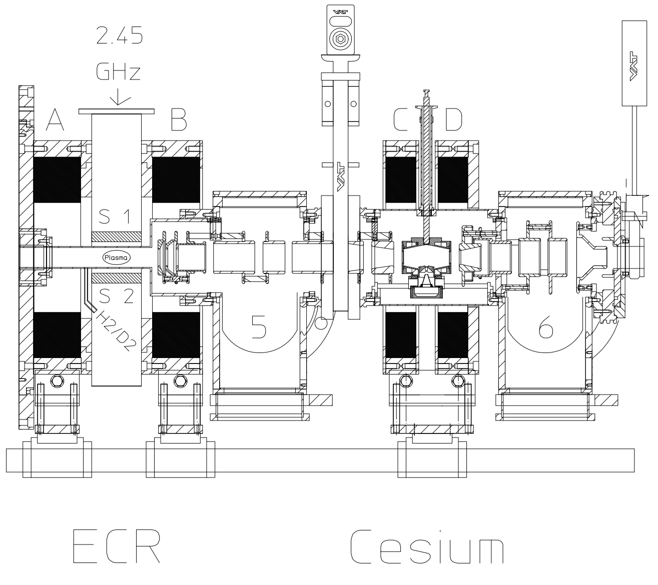

Fig. 1: Electron cyclotron resonance ion source for negative hydrogen ion beams. A and B are the coils for the axial ECR mirror field, S1 and S2 two of the six FeNdB permanent magnets for the radial sextupole field. The magnets C and D are used only for polarized beams.

The molecular hydrogen or deuterium gas is inserted into the ionization volume of the ECR source by a direct gas inlet and is ionized with an efficiency of a few percent by electron impact in the electron cyclotron resonance plasma. The plasma of the ECR ionizer is located inside the wave guide and thus directly coupled to the 2.45 GHz rf power of about 20 W. At the location of an E-field maximum of the H_{10} wave, two 40 mm holes in the small sides of the wave guide hold the cylindrical plasma vessel of pyrex. The electric rf field is perpendicular to the axial magnetic mirror field, which is produced by a pair of pancake coils with magnetic flux guidance. It has a minimum of about 875 Gauss located in between maxima of 1600 and 1400 Gauss. The cyclotron frequency for electrons is 2.45 GHz in a magnetic field of 875 Gauss. Free electrons are accelerated in phase with their cyclotron movement. The sextupole field for radial confinement of the plasma is provided by six dipole magnets of FeNdB. Two of them are located inside the waveguide. No absorption of the rf wave or overheating of the magnets has been observed. Almost all source parameters are identical with the values for polarized ion beam operation. Only the plasma current and the gas fluxes are slightly higher. The working parameters of the ECR plasma are given in table 1, an ion optical simulation is given in [1].

Table 1: Plasma parameters of the ECR source: The extracted ion beam refers to the mass analyzed negative ion beam after the cesium target. The pressure in the plasma vessel is around $1{\cdot}10^{-5}$ mbar at gas fluxes around $10^{-3}\ \frac{mbar\,l}{s}$. The pressure in vacuum chamber 5 is a factor of ten smaller.

	P	D
Current [μA]	1100	950
Voltage [V]	800	1000
Extracted Ion Beam [μA]	25	25

Proton Beam for SNAKE

Fig. 2 gives a survey of the ion optics for the superconducting ion microscope SNAKE.

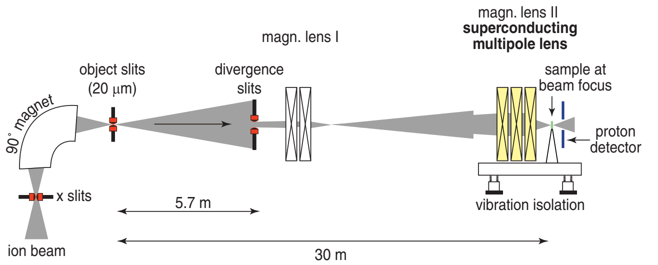

Fig. 2: Ion optics for the SNAKE experiment.

The object slits after the 90 degree bending magnet are closed to 20 μm. They define together with the divergence slits the accepted phase space of the ion beam. The divergence slits are opened in x to 1800 μm and in y to 1200 μm. The corresponding phase space is about 225 mm^2 mrad^2 eV. With an ion beam intensity of 7 pA on the target of the SNAKE experiment the brilliance of the ion beam is $3.1{\cdot}10^{-14}\frac{A}{(mm\,mrad\,\sqrt{eV})^2}$. This is one order of magnitude larger than the brilliance of the conventional sputter ion source of the tandem laboratory.

References

[1] A. Hofmann *et al.*, Annual report 1997, p. 120