AN ECR-IONIZER FOR A POLARIZED ION SOURCE

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Abstract

The production of an intense beam of polarized hydrogen ions with an ECR ionizer has been investigated. A deuteron tensor polarization of up to 85% of the theoretical value has been observed. The intensity is significantly improved compared to an electron beam ionizer.

Introduction

The question of a possible use of an electron cyclotron resonance ionizer for a polarized ion source has been raised at several workshops on polaried ion production [1]. The characteristic features of this ionization method and possible depolarization effects have been discussed by Clegg et al [2,3]. Due to the high electron density of an ECR plasma a higher efficiency is expected compared to an EB ionizer. Furthermore the space charge neutral ECR plasma enables to extract a beam of small energy spread. In addition the simple structure offers an easy handling; only microwave power and magnetic mirror field have to be adjusted. Neither a fragile filament nor a complex electrode system are needed.

Experimental arrangement

An ECR ionizer has been built at KfK. After some basic tests it was transfered to PSI where it was incorporated into a test bench equipped with a cold atomic beam. The ionizer is shown in fig. 1. The plasma is confined longitudinally by the field of a pair of solenoid magnets and radially by the field of a permanent sextupole magnet. Fig. 2 shows the resulting field in z and r direction. Microwaves of 2.45 GHz frequency are transmitted into the plasma chamber. The plasma chamber consists of a 300 mm long Pyrex tube of 60 mm diameter. Cooling is provided by a fan.

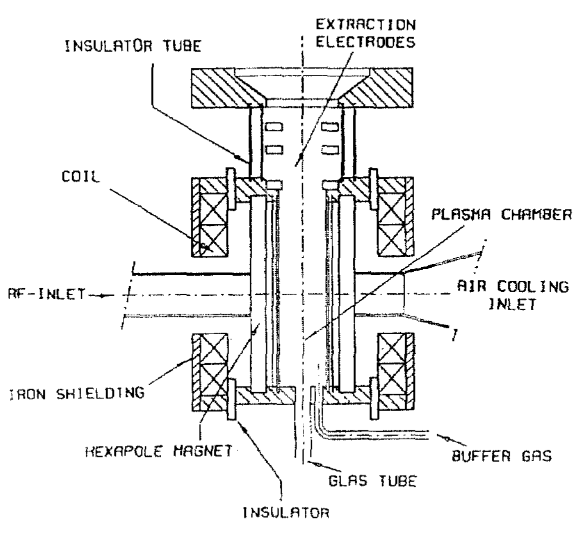

Fig. 1: Schematic view of the ECR ionizer.

a)

b)

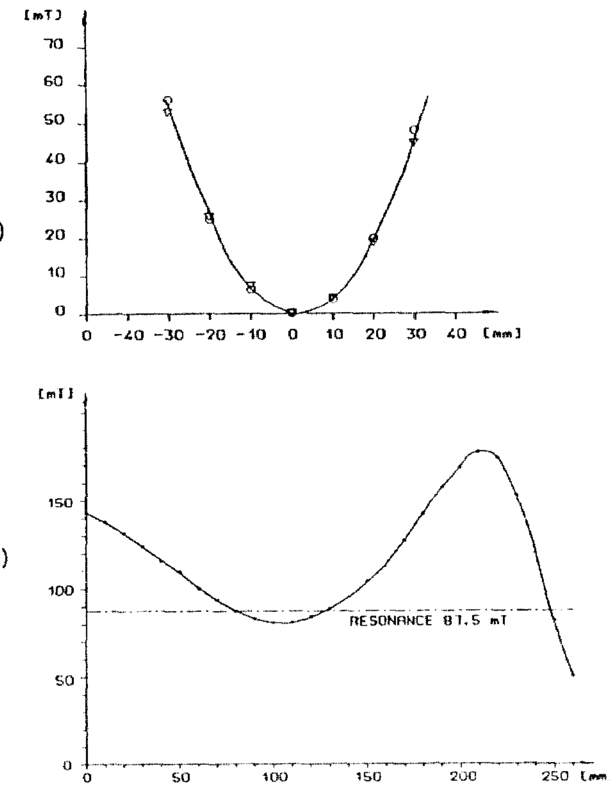

Fig. 2: a) Magnetic hexapolar field inside the Pyrex plasma chamber (Δ max. rad. component; o max. tang. component).

b) Longitudinal magnetic field, measured on the axis of the plasma chamber (zero corresponds to the position of the extraction system).

Fig. 3 shows the complete experimental set up. An atomic source similar to the one now operating at the PSI injector cyclotron [4] delivers a~30K cold atomic beam of about $5\cdot10^{16}$ atoms/sec. By means of a strong field transition (3-5) a deuteron beam is produced with a tensor polarization of -1. The atoms enter the ECR ionizer through a Pyrex tube of 20 mm diamter. The extracted ions are focussed by two electrostatic lenses into a 90^0 deflection magnet. After the deflection the tensor polarization can be measured by a polarimeter using the T(d,n) α reaction at about 40 keV. The tests were performed with deuterons because the polarization can be measured at a low energy and the vacuum requirements are less stringent, avoiding the complications of an ultrahigh vacuum system.

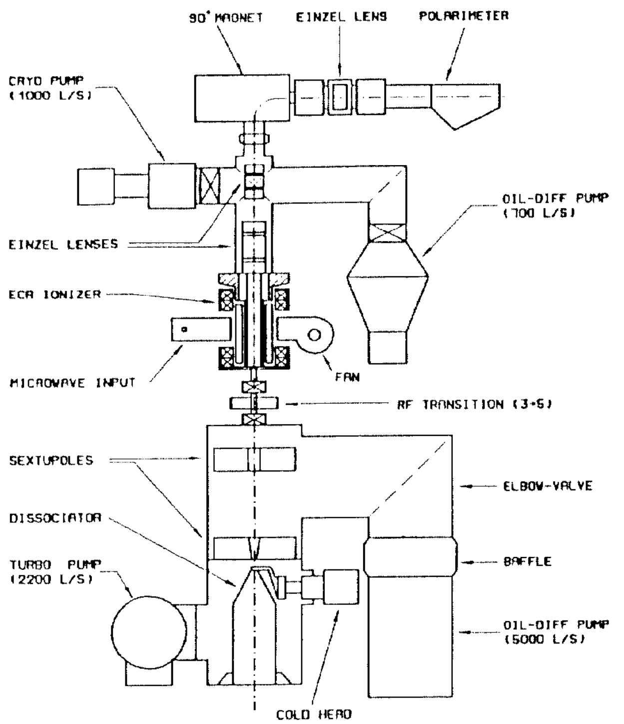

Fig. 3: Schematic diagram of the ECR test bench at PSI.

Results

The results of our tests can be summarized as follows:

1. The observed polarization is independent of the magnetic field and of the microwave power, indicating that no depolarizing hyperfine-state mixing occurs in the ECR-zone. The ranges covered by this test are ± 10% around the magnetic field value optimized for best intensity and 15 to 200 W for the microwave power. Usually the ionizer is operated with less than 50 W.

2. The extraction geometry should be designed in such a way that the pumping of the plasma chamber is optimized and a wall material with a low recombination coefficient has to be used. The observed polarization was 20% with a "classical" stainless steel extraction system with 10 mm holes, 40% with a Pyrex paved system and 85% with a large diameter system allowing an almost undisturbed passage of the atomic beam through the ionizer. With such an open geometry, the addition of a small amount of buffer gas is helpful to stabilize the discharge and optimize the efficiency.

3. Depending on the extraction system beams of up to 1mA (difference between sextupole on and off) have been extracted. With a three-electrode system giving a beam with good transmission to the polarimeter, the observed performances were as follows: 600 µA extracted, 400 µA at the analyzing magnet and, after a 90° bend, 150 µA within an emittance area of 60 mm mrad √MeV. Fig. 4 shows the result of an emittance measurement. The corresponding values for present sources equipped with an EB "Superionizer" are 75 µA within an estimated emittance of 80 mm mrad √MeV at PSI and 30 µA within a measured emittance of 100 mm mrad √MeV at KfK (the intensity difference between both sources is due to different performances of the atomic beam apparatus).

Conclusion

In conclusion, the ECR ionisation technique is very promising for the improvement of polarized ion sources based on the atomic beam method. There are many possible options for future efforts, like higher microwave frequency, other magnetic field configurations, development of surfaces allowing "storage" of the polarized atoms. We hope that the positive outcome of this first test will generate more investigation of this technique to intense polarized beam production.

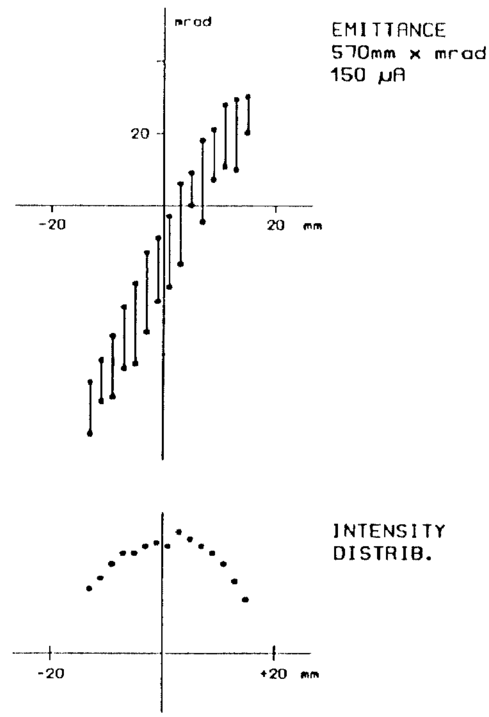

Fig. 4: Measured emittance and intensity distribution after the 90° bend.

Acknowledgements

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