DEVELOPMENT OF A NEW PLASMA IONIZER FOR USE IN A D.C. ATOMIC-BEAM-TYPE POLARIZED ION SOURCE

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We are investigating the idea that a deuterium (hydrogen) plasma beam confined in a magnetic field may be used to ionize via charge-exchange polarized hydrogen (deuterium) atoms from a conventional atomic beam source. Such ionization is expected to be very efficient, first because of the large charge exchange cross-section for low incident particle energies, and second because the polarized atom target thickness may be increased by storage in a cell through which the plasma beam passes. Neutral polarized H (D) flux equivalent to $\sim 10\,\mathrm{mA}$ is commonly achievable into a storage cell. Thus for any application to a polarized ion source, comparable plasma ion current density is needed. Initial tests reported here examine the properties of a plasma beam emerging from an ECR discharge. First results show that a well confined plasma beam of several mA can be obtained about 10 cm downstream from the ECR discharge.

1 Introduction

Conversion efficiencies of ionizers in d.c. polarized ion sources are usually of order of a few percent [1]. However, new approaches to improve ionization systems leading to much higher beam currents seem now to be realistic. The first step would be to maximize the polarized atom density within the ionizer using a windowless storage cell similar to those now commonly used for polarized targets in storage rings [2,3]. The second step would be having polarized $\vec{\mathrm{D}}^0(\vec{\mathrm{H}}^0)$ atoms ionized by very slow $\mathrm{H}^+(\mathrm{D}^+)$ ions ($\sim 1\,\mathrm{eV}$) via resonant charge exchange [4] ($\sigma_{c.e.} \geq 5 \cdot 10^{-15}\,\mathrm{cm}^2$).

The major problem in using such low energy H^+ or D^+ ion beams arises from their space charge [1]. Without space-charge compensation, no beam transport for mA-beams through the storage cell is possible for energies as low as 1 eV. We are now investigating the idea that a quasi-neutral deuterium (hydrogen) plasma beam confined in a 1 kG magnetic field and passing through the storage cell may be used to ionize the polarized atoms (see Figure 1).

High ion beam densities are in principle possible in this case since space charge compensation is provided by the accompanying electrons. Using a plasma beam produced in an electron-cyclotron-resonance (ECR) source seems most promising, [5] since these sources are known to generate a high density plasma at limited gas pressure.

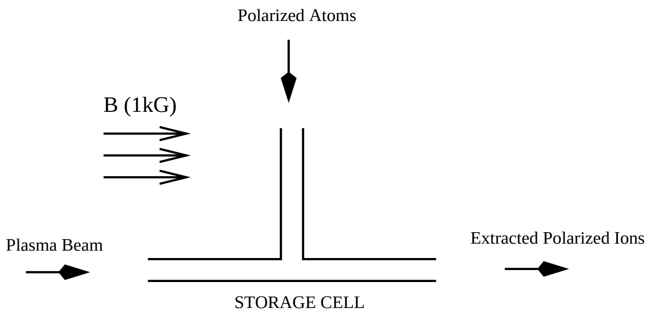

Figure 1: Sketch of proposed ionizer for polarized atoms

2 Experimental setup

At our testbench, 2.45 MHz microwaves of up to 1 kW power are fed into the plasma chamber through an AlO_2-window. A calibrated flow of H_2 gas is fed into the plasma chamber while the pressure inside this chamber is monitored.

Water-cooled coils enclosed by soft iron provide a uniform 940 ± 10 G magnetic field covering the plasma chamber and a short drift region of about 20 cm for the plasma beam. A short, circular iron collar around the plasma chamber causes a highly localized axial dip in the magnetic field to match the ECR condition (875 G) within the chamber volume. The exit aperture allows the plasma beam to emerge along the axis of the B-field.

A pumping station provides a Balzers TPH 2200 Turbo (2200 l/s N_2) in series with a Leybold TMP 150 (150 l/s N_2). The large pumping speed allows the pressure in the plasma chamber during operation to be $1 \cdot 10^{-3}$ mbar while maintaining a pressure of $\sim 1 \cdot 10^{-5}$ mbar in the region of the drifting plasma beam.

3 Measurement System

For the diagnostics of the plasma beam, a new monitor was developed (see Figure 2). The plasma beam enters a cylindrical stainless steel chamber through a 2 mm diameter aperture and is converted into neutral gas when hitting an axial stainless steel disk. The pressure rise caused by the entering plasma particles is then measured with a Penning gauge which is closely coupled to the chamber and operates in the 1 kG external field. An attached line allowes a measured flow of H_2 from a mass flow controller to enter the monitor for overall system calibration.

With stepping motors the monitor can be moved in x,y,z along the drift region of the beam. A LabVIEW [6] interface was developed to control the position of the monitor and scan the beam profile automatically.

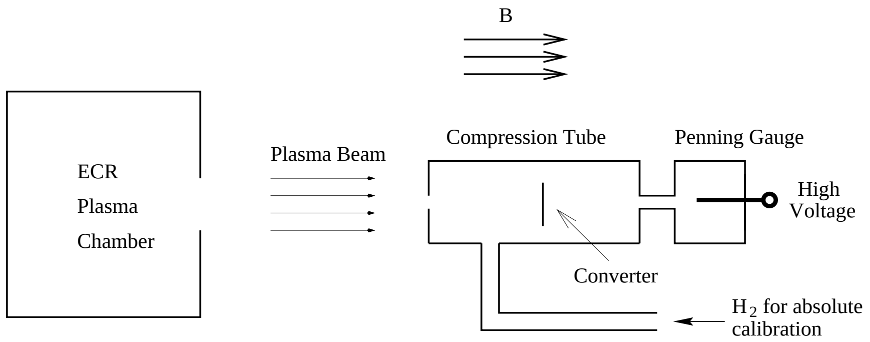

Figure 2: Sketch of monitor to measure plasma beam emerging from ECR discharge

4 Initial Results

For the measurements shown below, 0.2 sccm of H_2 gas was constantly fed into the ECR discharge where about 300 W of microwave power was dissipated. The plasma beam generated under these conditions emerged from the ECR chamber through a 5 mm aperture.

The scanned intensity profile using the monitor described above shows that after drifting a distance of $\sim$ 10 cm the plasma beam is well confined within a diameter of 5 mm at an integrated beam current of 0.7 mA (Figure 3). Increasing the $\mu-$wave power into the ECR discharge to 1 kW resulted in a 6 times higher peak beam intensity, suggesting $\sim$ 4 mA integrated beam current if the beam profile stayed similar.

5 Conclusion

It was shown that a several mA plasma beam of 5 mm diameter can be produced. This tightly confined beam is ideally suited to realize a high efficiency d.c. ionizer for polarized atoms stored in a storage cell.

Acknowledgments

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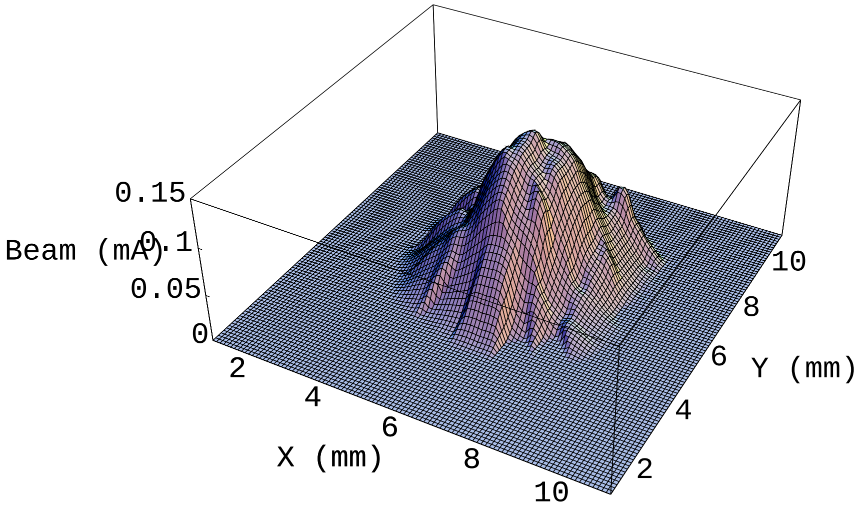

Figure 3: Measured intensity profile of plasma beam 10 cm downstream from plasma chamber (raw data, spline through 150 data points)

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