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► **To cite this version:**

B. Vuaridel, J. Bywater, D. Crabb, W. Kaufman, R. Raymond, et al.. PRESENT STATUS OF THE MICHIGAN-MIT ULTRA-COLD POLARIZED HYDROGEN JET†. Journal de Physique Colloques, 1990, 51 (C6), pp.C6-541-C6-544. 10.1051/jphyscol:1990668 . jpa-00230938

HAL Id: jpa-00230938

<https://hal.science/jpa-00230938>

Submitted on 4 Feb 2008

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PRESENT STATUS OF THE MICHIGAN-MIT ULTRA-COLD POLARIZED HYDROGEN JET⁺

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Abstract—Progress is reported on the production of an intense polarized atomic hydrogen beam using microwave driven extraction of stabilized atomic hydrogen.

1 - Introduction

Electron spin-polarized atomic hydrogen can be stored at high densities over relatively long time periods in a high magnetic field (≈ 5 T) and at low temperatures ($\lesssim 0.5$ K). D. Kleppner and T. O. Niinikoski¹ proposed that a high density atomic hydrogen beam could be produced by using electron spin resonance (ESR) pumping to extract hydrogen atoms from a magnetic storage bottle. Such a microwave driven extraction process could provide an intense low velocity spin-polarized atomic beam with a narrow velocity distribution; it should be possible to attain a density of about 10^{14} atoms/cm² by using magnetic focusing. We plan to use such a spin-polarized jet to study p-p elastic scattering at 400 GeV and 3 TeV in the NEPTUN-A experiment at UNK².

2 - Experimental Arrangement

Our apparatus³ was designed specifically to develop the technique of producing a high density atomic hydrogen beam by microwave driven extraction. The vertical section contained a continuous flow dilution refrigerator with a cooling power of 27 mW at 0.35 K. We recently installed a new storage cell, shown in Fig. 1, which consists of double-walled copper tubing with an internal diameter of 25 mm, about half the diameter of our earlier storage cell. The space between the two walls formed the mixing chamber of the dilution refrigerator. The storage cell had a 10 mm diameter aperture on the upstream end to allow for the atomic hydrogen feed and a 5 mm diameter aperture on the downstream end where the atoms were extracted. A baffle arrangement allowed for good accommodation of the atoms. An oversized waveguide bypassed the baffles. All storage cell surfaces were stably coated by a ⁴He film at a partial helium pressure of a few 10^{-4} Pa. The helium film prevented rapid recombination of the atomic hydrogen. The hydrogen atoms were produced in an rf dissociator and then guided into the low temperature region by a Teflon tube and a teflon-coated copper nozzle at approximately 20 K. The 20 K atoms were then fed into the storage cell through the 10 mm diameter aperture. After thermalization by gas and wall collisions in the baffle, states *a* and *b* were trapped axially by the magnetic field and radially by the cylindrical storage cell walls at a temperature of about 300 mK. Microwaves were injected from the left in Fig. 1 to drive either the *a* to *d* or *b* to *c* transition and we detected atoms in either the *c* or *d* state that exited toward the right.

We installed two different detectors to observe the extracted atomic hydrogen beam. The thermal detector measured the thermal energy of 4.5 eV, which was released when two hydrogen atoms recombined on its surface. The compression tube detector, located downstream of a large bore sextupole, measured the increase of the partial pressure of molecular hydrogen in a known enclosed volume.

3 - Experimental Results

We investigated the extraction of atomic hydrogen from our storage cell at two combinations of magnetic field and microwave frequency: 5 T/140 GHz and 7.6 T/213 GHz. We compared the amount of recombination heat on the thermal detector with heat from the calibration heater. At 5 T/140 GHz the maximum observed rates was 5×10^{15} atoms/s. This was well below the rates observed at 7.6 T/213 GHz, probably because of the lower feed efficiency at the lower field. At 7.6 T/213 GHz we observed up to 1.2×10^{16} atoms/s on the thermal detector. We calculated that the thermal detector is sensitive to only 15% of the beam. Therefore, the total extracted hydrogen flux was estimated to be about 8×10^{16} atoms/s.

We used the sextupole to focus the extracted atoms onto the 10 mm diameter aperture of the compression tube. We measured the flux of atomic hydrogen for various sextupole fields. The results are shown in Fig. 2 by the dots. For comparison, the results of simulation calculations are given by open circles. For these calculations it was assumed that the atoms were extracted from the storage cell at 55% of the 5 T central field and that the temperature of the gas was 300 mK. It resulted in a velocity of the atoms of 200 ± 17 m/s after acceleration in the field gradient. The experimental results were in fairly good agreement with the calculation. This clearly demonstrates that the extracted atoms are both highly electron spin polarized and rather monoenergetic.

The calculated curve is slightly shifted toward the left of the experimental curve. The position uncertainty of the storage cell aperture in the field gradient may explain this discrepancy. When the beam was focused onto the compression tube aperture, we observed fluxes up to 3×10^{14} atoms/s. At a higher field (7.6 T), we expect to obtain about 10^{15} atoms/s using the same set-up. A new high efficiency feed system is being built to further improve the flux of the extracted atoms.

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- /†/ This research was supported by a grant from the U. S. Department of Energy. We would like to thank Professors A. D. Krisch, D. Kleppner, and T. J. Greytak for their support and advice.

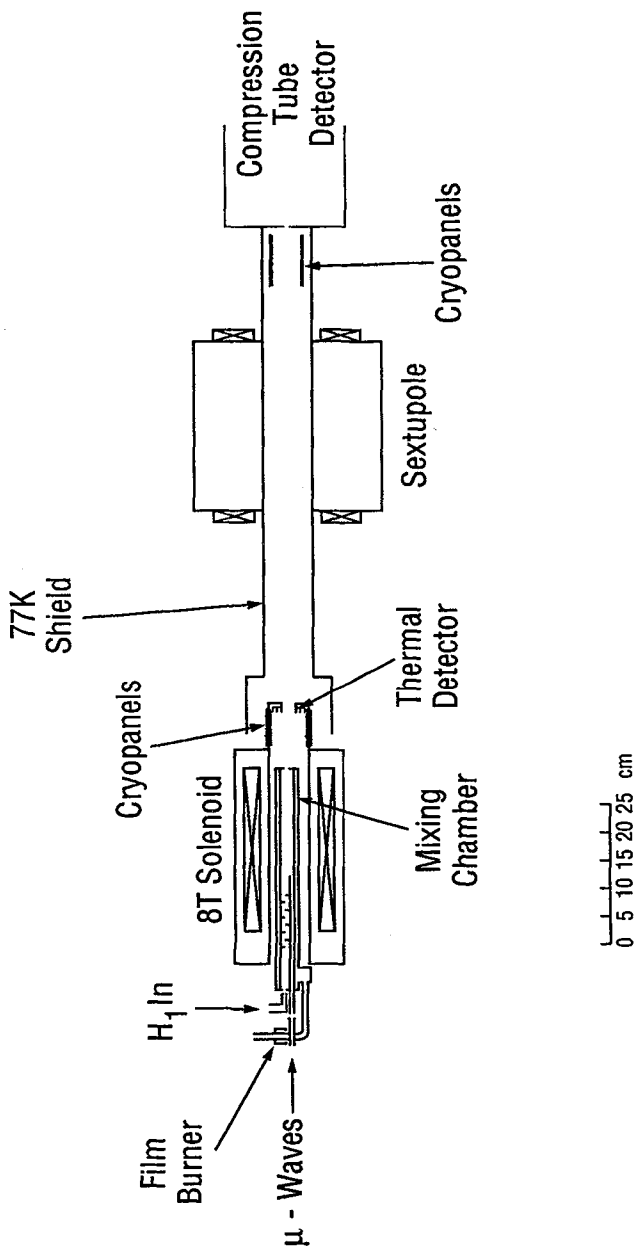


Fig. 1 - Layout of the storage cell and extracted beam detectors.

QMS Signal vs Sextupole Current

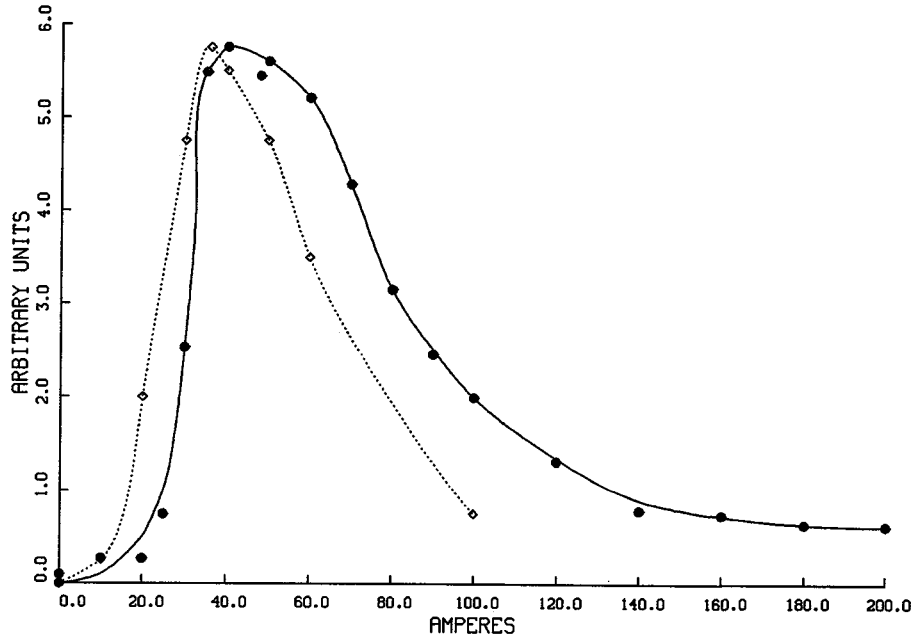


Fig. 2 - Flux of atomic hydrogen as measured by the compression tube. The experimental results are shown by the dots and the open circles are a simulation assuming a 100% electron spin-polarized monoenergetic beam. The curves are to guide the eye.