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PRESENT STATUS OF BNL POLARIZED SOURCES*

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Abstract - A review is given of the BNL polarized source development occurring since the 1986 Workshop in Montana, Switzerland. The polarized source in operation for the AGS produces ≈ 40 μA of $\vec{H}^-$ with 75 - 80 % polarization. Development of a cold atomic beam for a higher intensity source has concentrated on studies of spin selection and focusing with both a superconducting solenoid and sextupoles. Ionization of H^o by D^- charge exchange using the ring magnetron ionizer seems to be hindered by gas scattering, and work is in progress to improve this.

INTRODUCTION

Since 1984, the Brookhaven Alternating Gradient Synchrotron (AGS) has had the ability to accelerate polarized protons. The polarized H^- ion source used (PONI-1), has a ground state atomic beam source and a Cs^o beam ionizer. Since this source produces three orders of magnitude less beam than normal H^- operation for the AGS, it was clear that higher intensities were desirable. A program was begun to study ways to improve the PONI-1 output, as well as to work on developments which could lead to a new source producing higher intensities. We settled on two areas of research, one being the development of a 6 K atomic beam stage, and the second being the use of a D^- charge exchange ionization scheme. Research is in progress in both areas, and we hope to soon be able to combine the two systems.

PONI-1

This source has a ground state atomic hydrogen beam cooled to ≈ 80 K, and a Cs^o beam ionizer. It produces ≈ 40 μA of $\vec{H}^-$ in 500 μs pulses, at a rep rate of 0.5 Hz. Peak currents of up to 60 μA have been obtained when the cesium beam is operating optimally. The polarization is 75 - 80%. There has not been much work on this source since the Montana

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Workshop, since we have concentrated our effort on the development of a higher intensity source. On a low priority, we are preparing to test the focusing of the Cs^+ beam using magnetic quadrupoles, similar to what is done at the University of Washington.[1]

A 1.5 GeV Booster Synchrotron is under construction at Brookhaven, located between the 200 MeV linac and the AGS. For polarized beams, this Booster can be used as an accumulator, storing 10 - 20 H^- pulses at a 7.5 - 10 Hz repetition rate, before injecting into the AGS. We have so far tested PONI-1 at up to a 5 Hz rep-rate (presently limited by the control system), and found essentially the same output current at the higher rep rate. The pulse width decreased due to a shortening of the cesium beam pulse width, but this can probably be compensated by operating at a higher cesium supply rate to the ionizer.

COLD ATOMIC HYDROGEN BEAM

At the time of the Montana Workshop, we had produced a pulsed H^o beam cooled to 6 K, and measured a forward flux in the beam of 9.4×10^{18} $H^o/sr/s$. Time-of-flight measurements gave a most probable velocity of 680 m/s. Subsequently, changes were made to the dissociator (reduced volume), accommodator (flared the output channel), and pumping after the accommodator (increased cryopumping). These changes are described in more detail in Ref. 2. With these changes, the atomic beam density was increased by a factor of 34 over the Montana results. At 6 K, a density of 6×10^{11} H^o/cm^3 was measured 90.5 cm from the accommodator. (This density is without any focusing of the atoms). Time-of-flight velocity measurements were not made with this new geometry. In order to determine whether the velocity of the H^o beam was still the same as previously measured at the lower H^o density, H^o flux measurements were made using a thermoflake detector,[3] and compared at the same time to density measurements made with a quadrupole mass spectrometer. This was done over a span of more than two orders of magnitude in H^o density. The low density measurements were taken with an insert in the accommodator to bring it to the geometry used initially, thus overlapping the densities in which the velocity measurements had been made. A linear relationship was observed between the flux and density measurements, indicating that

the velocity is not changing. Assuming a 680 m/s velocity, the forward flux for the improved atomic beam is 3.3 x 10^{20} H^{o}/sr/s.

SPIN SELECTION AND FOCUSING

This area has received the greatest attention since the Montana Workshop. Our initial efforts went into the testing of a superconducting solenoid for focusing, as suggested by Niinikoski.[4] The solenoid consisted of three coils of 9.4 cm i.d. and a total length of 10 cm. The current in the outer two coils was opposite to the current in the middle coil, giving one a high gradient (up to 5.2 T at the coil i.d. and weak on axis). A schematic of the setup is shown in Fig. 1.

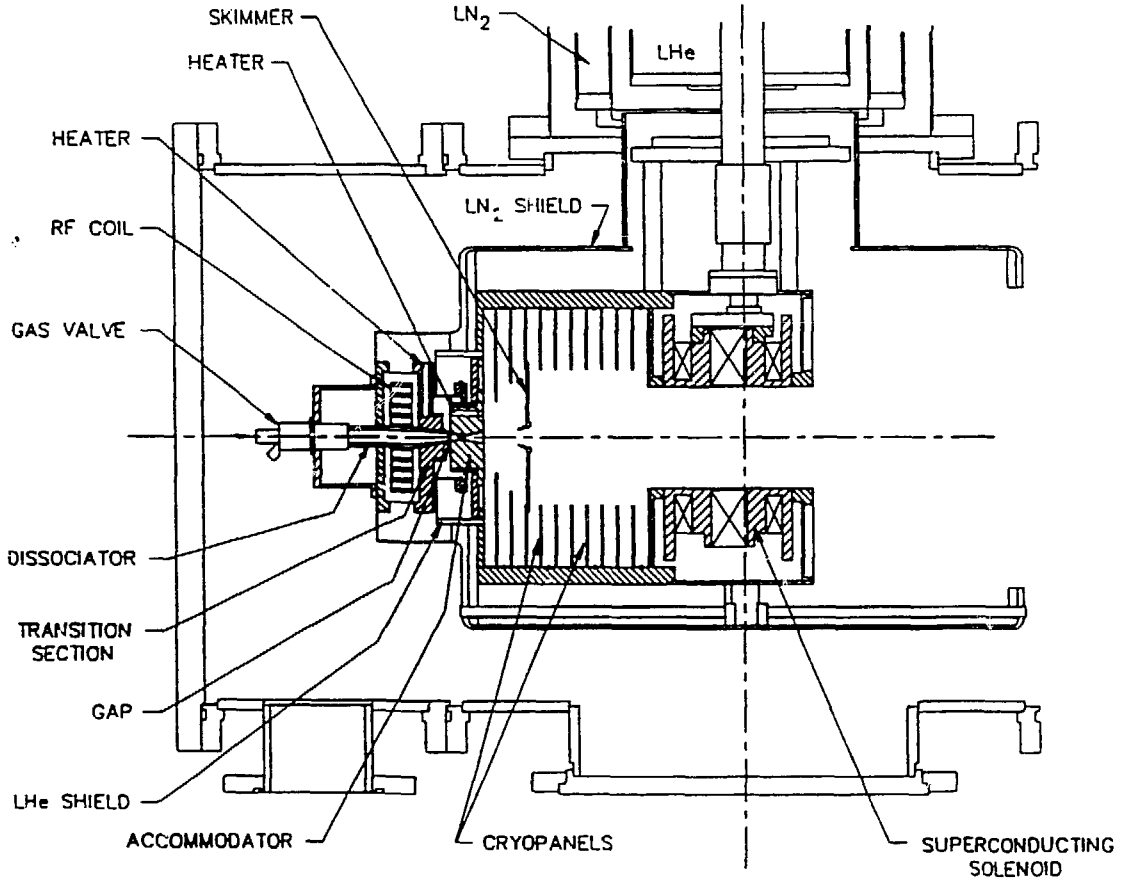

FIGURE 1 Schematic of the cold atomic beam with the superconducting solenoid.

When operating at low H^o densities, focusing was observed. The density, measured 65 cm from the solenoid exit, increased by a factor of 10 when the solenoid field was at its maximum value. We could not pass through a maximum in focusing. However, as the atomic beam density with the solenoid off was increased, the focusing decreased, until one reached a point where the H^o density at the quadrupole mass spectrometer was the same with the solenoid on or off. There was no operating density in which the focused H^o density was better than a conventional atomic beam source. It was determined that we were becoming limited by H^o - H^o intrabeam scattering, and from this the H^o - H^o scattering cross section at 2 K was inferred to be 100 $Å^2$.[5]

In addition to the intrabeam scattering problems, ray tracing calculations showed large aberrations in the solenoid focusing. The gradient in the solenoid was very nonlinear (weak on axis). We decided to next test a more conventional focusing system using sextupoles. Rather than take the time and expense of building an optimized sextupole system with maximum pole tip field, we have chosen to build a simple system to at first explore the density limitations. The first sextupole, located 10 cm from the accomodator, is a 10 cm long, 4 cm diameter aperture permanent magnet sextupole (Nd-Fe-B), having a pole tip field of 7 kG. The second sextupole is 10 cm away from the end of the first, and is electromagnetic. It is 10 cm long, with a 3.6 cm aperture and a maximum pole tip field of 6.3 kG (limited by cooling). The quadrupole mass spectrometer is 30 cm away from the the second sextupole, at the position where the ring magnetron ionizer will eventually be located. The permanent magnet sextupole can be retracted from the beam axis, so that with the second sextupole turned off we can measure the unfocused H^o density. We have so far had only two runs with the sextupoles, so the following results are preliminary. When operating at 4.6 K, the H^o focusing was observed to fall off as the unfocused density was increased. This falloff was not as rapid as had been observed with the solenoid, presumably due to the fact that defocused H^o could hit the magnet poles, recombine, and be pumped away, while in the cold bore of the solenoid the H^o atoms would scatter back into the beam. The maximum focused density observed at the mass spectrometer was $\sim 10^{12}$ H^o/cm^3. At 25 K, the focusing of the beam was better, and the focusing also decreased more slowly as the unfocused density was increased. At this

temperature, we were able to reach ~ 3 x 10^{12} H^o/cm^3 at the mass spectrometer. These numbers are preliminary until a careful recalibration of the mass spectrometer is carried out. We will continue our studies, comparing operation further at 6 K vs 25 - 30 K. We will then make a decision on our operating temperature, and design a sextupole system optimized for that velocity.

RING MAGNETRON IONIZER

The ionizer we are developing uses a magnetron surface-plasma source to produce D^- ions. The polarized H^o beam crosses this D^- beam and is converted to H^- by resonant charge exchange. The D^- and H^- beams can then be separated by mass analysis. At Montana, results of tests of the ionizer with an unpolarized H^o beam were reported. At that time, 500 μA of H^- was produced, with an H^o density of $10^{12}/cm^3$ in the ionizer. The ionizer was then installed on a room temperature atomic beam source (the atomic beam stage of the ZGS polarized source). The ionizer was placed in the vacuum chamber of the previous electron bombardment ionizer on the source. Following the ionizer, other new components added were an einzel lens, an E x B mass filter, a second einzel lens, and a Faraday cup. In order to test the extraction system optics, etc., the dissociator was moved to a location just above the ionizer box, to give as large H^o density in the ionizer as possible. With this setup, an unpolarized H^o density of 3 x $10^{11}/cm^3$ was measured in the ionizer location, and up to 50 μA of H^- was extracted. The efficiency, therefore, was only one third of what it was on the test stand. (The ionization efficiency was therefore approximately the same as the cesium beam ionizer on PONI-1). While poor extraction optics could be partly responsible, the loss in efficiency seems to primarily be due to the poorer pumping of D_2 away from the ionizer region in the new setup. This causes both H^o beam scattering before entering the ionizer, and stripping of the extracted H^- beam. A quadrupole mass spectrometer was installed in a chamber below the ionizer. From observations of the attenuation of the H^o beam when the ionizer gas was pulsing (ionizer discharge off), the D_2 line density during typical source operation was determined to be nl = 5.4 x $10^{14}/cm^2$.

A new ring magnetron has now been constructed. This is shown schematically in Fig. 2, and a photo is shown in Fig. 3.

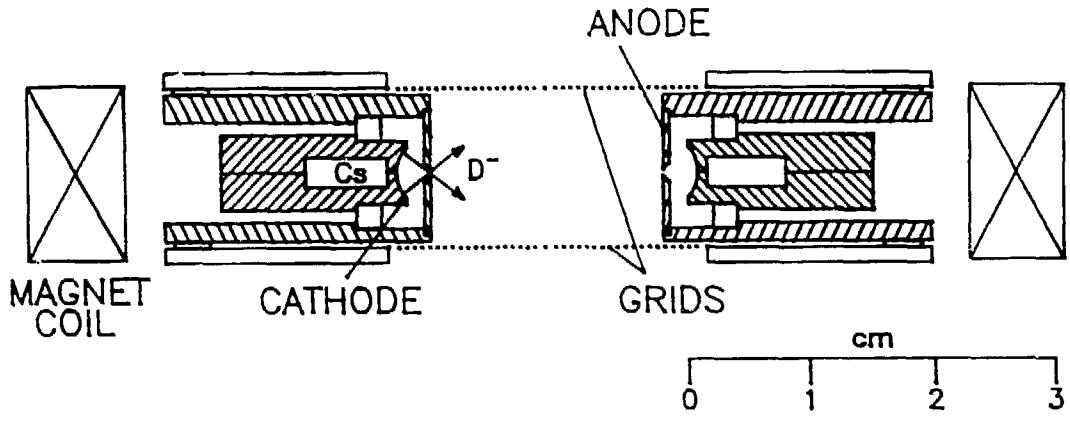

FIGURE 2 Schematic of the present version of the ring magnetron ionizer.

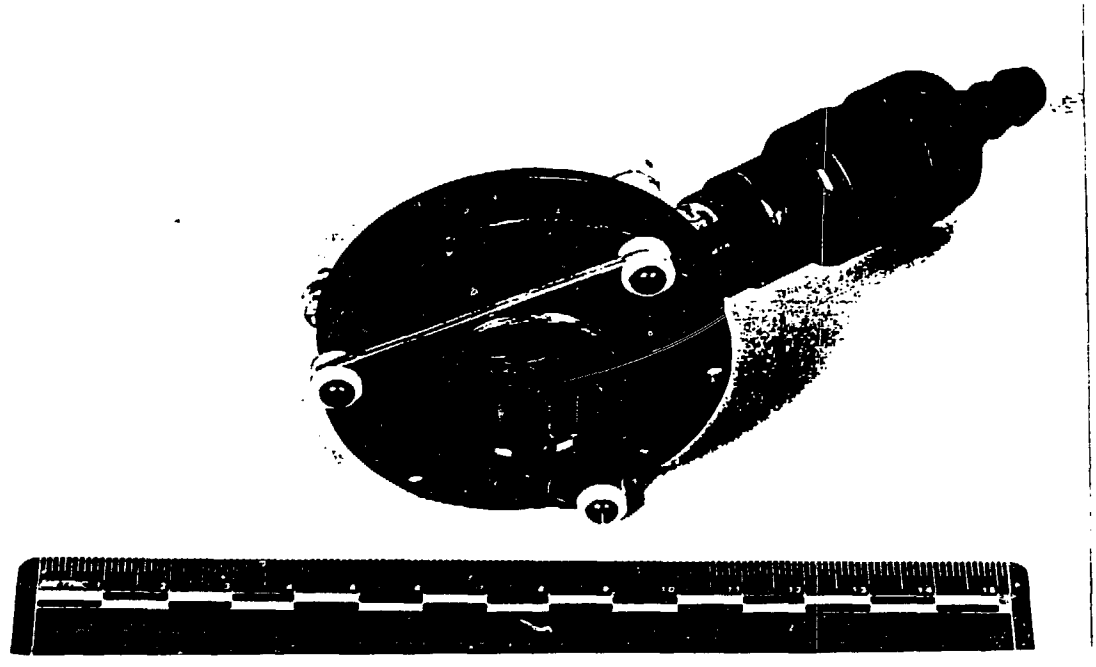

FIGURE 3 Photo of the ring magnetron ionizer. The magnet coil has been removed.

Several changes were made in order to shorten the ionizer, and therefore improve the pumping away from the center of the ring. The cathode length was reduced by a factor of two, and the cathode now has only one focusing groove. The source magnet was redesigned, and is now a 1.4 cm long solenoid coil, which is pulsed at the source rep-rate. These changes reduced the effective length of the ionizer from 5 cm to 1.2 cm. The diameter of the ionization region is 1.9 cm. In addition, the region around the ionizer was opened up to also facilitate pumping of the D_2.

We are just beginning to test this new ionizer, and have not yet obtained any results. If gas scattering continues to be a problem, we may have to consider alternative ionizers, since the problem will become worse with the cold atomic beam. Should the efficiency improve, we will then measure the polarization of the beam. We do not expect this to be a problem, since the cross section for ionization of H_2 by D^- is small. A Lamb shift polarimeter[6] is being constructed to measure polarization at 10 - 20 keV.

CONCLUSIONS

The cold atomic beam and the ring magnetron ionizer have so far been developed in parallel. The final H^o density obtainable with the cold atomic beam will be determined by limits due to gas scattering in the spin selection magnets. The ionizer efficiency is also limited by gas scattering. It is therefore difficult to determine at this point whether or not the combination will yield 1 mA of polarized H^-. We hope to combine the elements and do a full system test within the next 6 - 9 months.

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REFERENCES

1. C.A. Gossett, "Recent development of the University of Washington colliding beams polarized ion source", these Proceedings.

2. A. Hershcovitch, A. Kponou, B. DeVito, "Status of the BNL cold atomic beam and its focusing magnets", these Proceedings.

3. K.C. Harvey and C. Fehrenback, Jr., Rev. Sci. Instrum. 59, 1117, (1983).

4. M. Ellila, T.O. Niinikoski, and S. Penttilla, Nucl. Inst. Meth. B14, 521 (1986).

5. A. Hershcovitch, Phys. Rev. Lett. 63, 750 (1989).

6. Yu.A. Plis and L.M. Soroko, Instrum. and Experimental Techniques, 20, 656 (1977).