Performance of the Laser Driven Polarized Hydrogen Source at IUCF

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Abstract. A laser driven source of polarized hydrogen and deuterium has been installed in the Cooler Ring at the Indiana University Cyclotron Facility. Polarized nuclei from the source are injected into a storage tube, and the resulting target has been used in a scattering experiment with 200 MeV proton beam. This paper discusses the performance of the source, including measurements of atomic fraction and electron polarization.

For several years there has been interest in using spin exchange with an optically pumped polarized alkali vapor as a way of obtaining a source of highly polarized hydrogen or deuterium nuclei with a higher flux than can be achieved by other methods [1]. Development of this technique on the bench led to a target which, assuming spin–temperature equilibrium, had a higher figure of merit than conventional targets currently in use [2]. The source was then installed in the Cooler Ring at the Indiana University Cyclotron Facility (IUCF) and has now been tested with the proton beam. The analysis of

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nuclear polarization data is not complete and is discussed in the paper by M. Miller in this volume. Here we present data on the performance of the source in terms of electron polarization and atomic fraction.

The hydrogen nuclei are polarized in the glassware shown in figure 1. Molecules enter from the right and are dissociated by an rf plasma discharge. The atoms then enter the spin exchange cell. At the left a reservoir of potassium is heated and the vapor flows into the spin exchange cell. Circularly polarized light from a Ti:Al_2O_3 laser enters the spin exchange cell from the top. Its polarization is transferred to the hydrogen nuclei in three steps: first to the potassium valence electrons through photoabsorption, then to the hydrogen electrons through K–H spin exchange collisions, and finally to the hydrogen nuclei through H–H spin exchange collisions. The polarized hydrogen exits the spin exchange cell and enters an aluminum storage tube through which the proton beam passes. Some atoms pass directly from the spin exchange cell through a hole in the bottom of the storage tube and into the atomic polarimeter [1] which was used for the measurements reported in this paper.

The source used at IUCF differs from other laser driven sources in two ways. First, we have eliminated the transport tube, which decreases the number of wall bounces and thus improves the atomic fraction and polarization. Second, we no longer use a uniform magnetic field. In a typical magnet setting the field in the lower half of the spin exchange cell will vary between 110 mT and 120 mT, but decreases to about 20 mT at the top of the cell. This leads to a region near the bottom of the cell where potassium can be optically pumped without radiation trapping, and a region at the top where polarization is transferred from hydrogen electrons to hydrogen nuclei more rapidly.

Figure 2 shows the performance of the source during a test run of the target. These data were taken with a flow of 1×10^{18} atoms/sec, with a 6 mm diameter hole between the spin exchange cell and the storage tube, and with 1.5 W of laser power at the source. The figure shows that increasing potassium temperature led to an increase in the polarization and a decrease in the atomic fraction. Eventually the high potassium density in the spin exchange cell caused nearly complete molecular recombination.

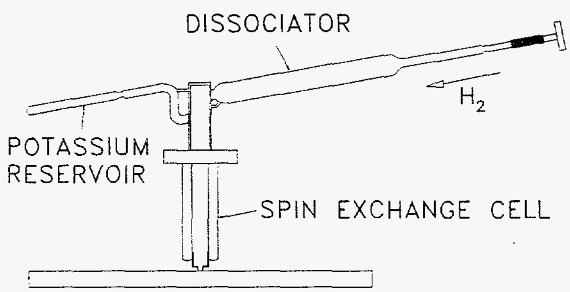

FIGURE 1. Glassware used for the Laser Driven Source

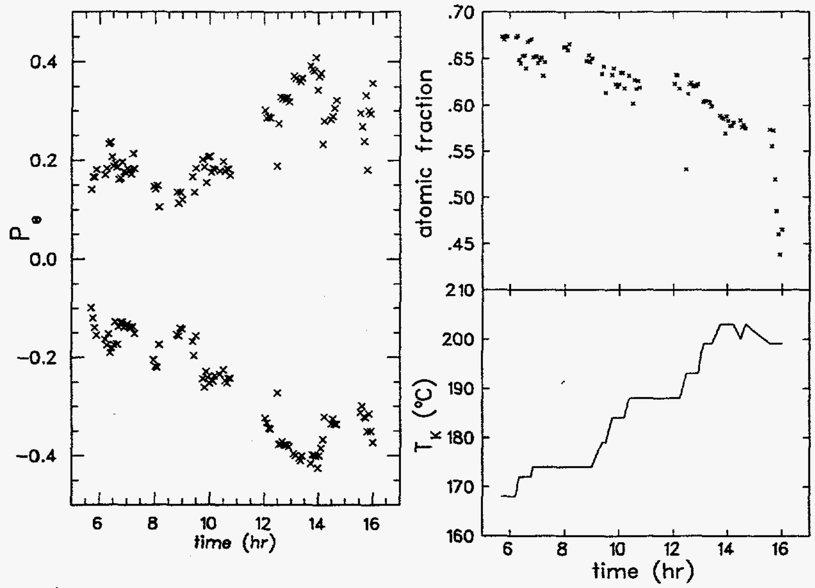

FIGURE 2. Performance of the hydrogen source during tests with the proton beam. Clockwise from left: electron polarization; atomic fraction; and temperature of the potassium reservoir over a 10 hour period.

More recently tests were made without the proton beam in preparation for future beam time. A 4 mm hole was used between the spin exchange cell and the storage tube, and the glass was coated using the afterwash technique described in ref. [3]. As expected from the smaller hole size, we found a lower atomic fraction, about 40%. We also found higher polarizations, and observed that doubling our laser power by adding a second laser made a significant improvement. The best result was a polarization of 63% with an atomic fraction of 35%, again at 1×10^{18} atoms/sec.

We thank D. Tupa for the loan of the two Ti:Al_2O_3 lasers, our glass blower W. Lawrence, A. Kenyon for helping with assembly and repair of the source, J. Doskow for maintaining our vacuum system, and the rest of the operators and staff at IUCF for all their assistance. This work was supported in part by the NSF under grants PHY94-20787 and PHY94-20470 and by the DOE under contract No. W-31-109-ENG-38 and grant DE-FG02-86ER40269.

REFERENCES

1. Poelker, M., *et al.*, Phys. Rev. A **50**, 2450 (1994).
2. Owen, B., *et al.*, in *Proceedings of the 12th International Symposium on High-Energy Spin Physics, Amsterdam, 1996,* edited by C. W. de Jager, *et al.* (World Scientific, Singapore, 1997), p. 490.
3. Fedchak, J. A., *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **391**, 405 (1997).