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8.9 Status of the TRIUMF Optically Pumped Polarized H^- Ion Source

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A Lamb-shift type polarized H^- ion source has been in operation at TRIUMF since 1976 with currents up to 1 μA and ~75% polarization recently delivered on target. An increase in current by a factor of 5 to 10 is desired by experiments which require the cyclotron to operate in a medium energy resolution mode or which use the polarized proton beam to produce a polarized neutron beam. A further increase to 30 μA extracted would permit a limited meson production program with polarized protons and consequently increase the scheduled polarized beam time. An optically pumped polarized ion source has been built at TRIUMF to test the feasibility of producing intense polarized dc H^- beams (~50 μA) suitable for injection into the cyclotron.

The source is based on the optical-pumping technique proposed by Anderson.[1] The electron spins of sodium atoms in an optically dense vapour target are polarized using a dye laser tuned to the sodium D1 absorption wavelength. An electron-spin polarized atomic hydrogen beam is formed by passing protons through the sodium vapour. A diabatic field reversal technique, similar to that used in Lamb-shift sources, transforms the electron-spin aligned atomic beam into a proton-spin aligned atomic beam. Charge exchange in a second alkali vapour yields a proton-polarized H^- beam. The estimated current, neglecting aperture restrictions, is about 20 μA of H^- for each mA of protons with a sodium target thickness of $5\cdot10^{13}$ atoms/cm^2. The proton polarization is determined by how effectively the sodium can be polarized, the polarization transfer efficiency, and the quality of the diabatic field reversal. The total current depends on the initial proton ion source brightness, the beam diameter and the maximum sodium target thickness that can be reasonably polarized. These factors are being examined individually on the TRIUMF source prior to installation on the cyclotron.

A layout of the TRIUMF optically pumped ion source is given in Fig. 1. Protons are extracted in a dc mode from an electron-cyclotron-resonance ion source (ECRIS)

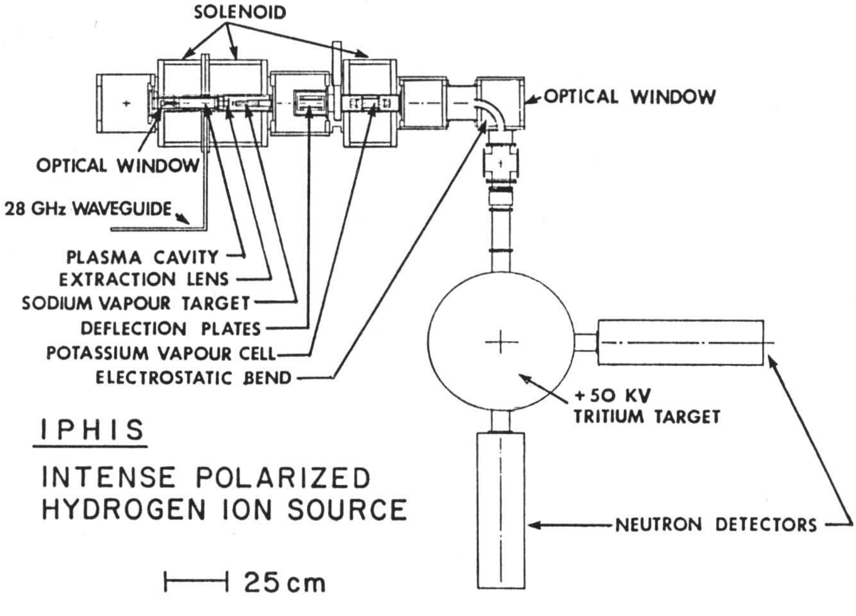

Fig. 1. Layout of the TRIUMF optically pumped ion source with scattering chamber for polarization measurements.

operating cw at 28 GHz and at powers up to 0.4 kW. The extraction electrodes and sodium vapour target are located in a 12 kG uniform axial magnetic field. The microwave power is fed radially into the multimode plasma chamber where the magnetic field is less than that required for resonance. The field profile is a mirror configuration with a peak of 12 kG and a saddle minimum of 8 kG. The power consumption is about 50 kW. Although the extraction electrodes have not yet been optimized, preliminary results show that 300 mA/cm^2 of positive current can be extracted through a 2 mm diameter extraction hole. With a quartz liner in the ECRIS multimode cavity it is possible to obtain proton fractions, $[H^+/(H^+ + H_2{}^+ + H_3{}^+]$, greater than 75%.

The sodium polarization has been measured and optimized using an optical rotation method.[2] The results are summarized in Fig. 2, where the sodium polarization is shown as a function of target thickness under various conditions. The optical pumping efficiency is increased by reducing the bandwidth of the pumping laser from a nominal 30 GHz to about 6 GHz by means of an intra-cavity etalon, since the Doppler broadened D1 line is only about 4.5 GHz wide. The primary polarization loss mechanism occurs as the result of the collision of sodium atoms with the cell wall. A Viton wall liner decreases this loss by increasing the time between depolarizing wall collisions by a factor of 15. A further increase in pumping efficiency was observed with bi-directional pumping with the same laser. It is noteworthy that even at the higher densities, there is no evidence of significant radiation trapping. With a second pump laser it should be possible to reach ~90% sodium polarization at a thickness of $5 \cdot 10^{13}$ atoms/cm^2. Thus optical pumping of sodium can produce highly polarized sodium, even with modest laser power.

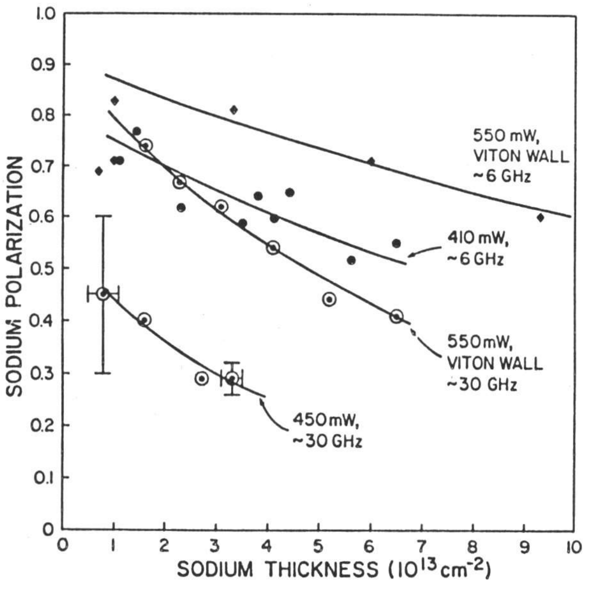

Fig. 2. Measured polarization of a sodium vapour target vs. the target thickness for optical pumping with ~30 GHz and ~6 GHz bandwidth at the sodium D1 line with and without a Viton wall liner.

Initial measurements at TRIUMF of the neutral beam have been made using a calorimeter and also by secondary emission. The measured emittance (normalized at the 90% level) is ~0.007 π cm-mrad with a 2 mm diameter extraction hole and a 4 mm diameter sodium cell collimator. The measured "neutral current" was however only 10% of that estimated from the known cross-sections.

Experiments to measure and optimize the beam polarization are presently being carried out. A scattering chamber has been set up to permit angular asymmetry measurements from the reaction ^{3}H(d,n)^{4}He at 50 keV. With this reaction it is possible to measure the tensor polarization when deuterium rather the hydrogen is used. A maximum 33% tensor polarization can be expected for D^- when an electron-spin polarized atomic beam created in a high magnetic field is ionized in a low field. Initial measurements comparing the H^- produced by double charge exchange in the sodium vapour with and without optical pumping have confirmed that the beam is indeed polarized and that the electronic polarization transferred to the protons is not less than 75% efficient at 12 kG, provided that proper beam energy and spin direction are chosen.

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References

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