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NOTE ON LIMITS OF GROUND-STATE POLARIZED ATOMIC BEAM DENSITY*

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ABSTRACT

This note points out that neutral spin-selected atomic beams may have an upper density and intensity limit due to the requirement that the mean free path in the spin selection magnet must be of the same order as the flight path, or at least the transverse beam displacement due to focusing, in order to polarize the electron spins. This sets the design criteria which should allow the optimization of the source configuration.

According to our gas dynamic model [1] which is in fair agreement with our experimental results [1], the density of a cooled atomic beam should scale with the accommodator exit orifice area, provided that the density and Mach number in the orifice are constant, and that the density and pressure are sufficiently large to result in a final Mach number greater than about 3. This would basically allow to increase the atomic beam density in the spin selection magnet up to the limit where the mean free path becomes too short for the spin selection to result in high beam polarization.

On the other hand, superconducting solenoid focusing magnets would allow much larger cooled beams to be focused [2] in comparison with the classical six-pole channels. By requiring that the mean free path in the beam is equal to the bore diameter D_s of the spin selection solenoid, the beam density in the solenoid is limited to $n \leq 6 \times 10^{14}\ \mathrm{cm}^{-3} \times (D_s/\mathrm{cm})^{-1}$. The subsequent magnetic compression of the beam is again limited by the mean free path, unless confining walls can be used to avoid beam expansion due to atomic interactions. These considerations would suggest to us that the polarized beam density in the rf-transition or ionizer cannot be raised much above $10^{14}\ \mathrm{cm}^{-3}$ which, however, is two orders of magnitude higher than the density of the best sources today. Any subsequent improvement then would require significant reshaping of the rf-transition and ionizer, and/or increase in the ionizer efficiency.

We note also that the above limitations would also apply to beams formed from magnetically stored stable atomic hydrogen.

References:

[1] A. Hershcovitch, A. Kponou, and T.O. Niinikoski, "Cooling of high intensity atomic hydrogen beams to liquid helium temperatures", in these Proceedings.

[2] M. Ellila, T.O. Niinikoski, and S. Penttila, "Solenoid optics for slow atomic beams", to be published in Nucl. Instrum. & Methods.

See also rapporteur's report, Session (E), E. Steffens.

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