COOLING HIGH INTENSITY ATOMIC HYDROGEN BEAMS TO LIQUID HELIUM TEMPERATURES

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Abstract

An atomic hydrogen source, designed to operate in the viscous flow range, has been built at BNL. A unique feature of this source is a miniature gap between a teflon tube which guides the beam and an accommodator which cools it. Across this gap a step-function in temperature, with the teflon temperature exceeding 100°K and the accommodator temperature below 8°K, was successfully maintained. This configuration collimates the beam enough to prevent significant diffusive losses without subjecting it to the temperature range of high recombinations. Initial results with an orifice of only one-tenth the dissociator aperture are indicative of particle density in the beam of well above 10¹⁰ cm⁻³.

Introduction

Solutions of polarized atomic hydrogen beams which are based on magnetic separation employ various forms of beam cooling. The advantage of cooling hydrogen atoms before their exposure to a magnetic field gradient for spin selection has been recognized for quite some time. The force on an atom due to the interaction of its magnetic moment with the magnetic field gradient, is such as to minimize its potential energy which changes by μB at high magnetic fields. However, for an atom to pass through such a magnet, its energy associated with perpendicular motion must be lower than μB. Consequently, an acceptance solid angle ΔΩ is roughly determined by

$$\Delta \Omega = \mu_B/kT$$

(1)

It is obvious from Equation (1) that by lowering the temperature by an order of magnitude, the polarized beam flux should increase by the same factor. Furthermore, for some ionizers, the ionization efficiency increases with density, and if beam cooling can be accomplished with only minimal loss or flux, another factor of T⁺⁰·⁵ can be gained in the overall intensity of a charged nuclear spin polarized beam.

At BNL, an experiment to test the possibility of cooling high intensity atomic beams has been constructed (see figure). In this device, an atomic hydrogen beam is produced by a conventional dissociator similar to that of PONI. The beam is guided by a teflon tube into an accommodator which cools the beam. The high collisionality makes even a 1 mm2 region of the surface unacceptable and the size of the source orifice combined with the high collisionality requires a very large accommodator diameter which is impractical. Our approach is to have a very small gap between the teflon section and the accommodator, which is enough to isolate them thermally. The teflon temperature is maintained above 80°K by means of a heater. In this way the beam is not subjected to a temperature range with high recombinations and it is collimated enough to prevent significant diffusive losses.

Physical phenomena in the accommodator are better understood due to extensive studies performed by Crampton and co-workers described in Reference 4, as well as many earlier papers which are cited in Reference 3 and 4. There are two competing effects which determine the optimum accommodator temperature for a given flux. The lower the temperature, the better the frozen H₂ coating as well as the lower the vapor pressure which minimizes scattering of H⁺ by H₂. However, the surface dwell time of H⁺ increases as the temperature decreases. Thus, to minimize recombination losses, the temperature must be increased. Consequently, there is an optimum temperature which for a given flux can be determined by adjusting the accommodator temperature. Nevertheless, at a different (higher) flux, the accommodator geometry must also be optimized to ensure enough wall collisions to cool the beam without having excessive recombinations. This optimization is much more difficult to achieve.
Initial Results

With an orifice of 0.8 mm² initial experiments have been performed. The various components seem to work well. At the foot of the cryostat, a temperature as low as 3.8 K was maintained without thermal loading (i.e., no atomic beam) and as low as 4.1 K with the dissociator on. Also, across the gap, a step function in temperature was successfully maintained. The teflon section was kept above 100 K while the accommodator temperature (as measured at the foot of the cryostat) was varied between 4 K and 8 K. A UTEC 100 RGA was placed in the chamber at a distance of 39 cm downstream from the accommodator exit to measure the density of the cooled atomic beam. Based on the calibration of this RGA against a calibrated ion gauge (done by the AGS Vacuum Group) for H₂, and based on the relative sensitivity of the RGA to H₂ and H, the density of the cooled atomic beam was determined to be 9.1 x 10¹⁶ cm⁻³, when the accommodator temperature was about 6 K. The significance of this result is that the orifice area is an order of magnitude smaller than that of the dissociator aperture.

Experiments are in progress to determine the optimum accommodator temperature. The procedure is to monitor the RGA signal as a function of the accommodator temperature. The range explored was 300 K to 56 K and 5 K to 4.7 K. Unfortunately, due to arcing, the dissociator power supply was operated at 65% of capacity during measurements at the lower temperatures. Nevertheless, the peak RGA signal was observed at an accommodator temperature of 5 K. The 5 K to 56 K has yet to be explored. Also, the cooling will be measured via the beam velocity which will be measured by the time-of-flight method.

References

2. See paper by A. Kuponou, et al., in these Proceedings.