A STUDY OF THE FORMATION OF INTENSE ATOMIC HYDROGEN BEAMS

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A microwave dissociator based on a surface wave plasma source has been developed for the HERMES hydrogen target. We have achieved longterm stable operation with high atomic fractions in the nozzle beam. Compared to a conventional RF–dissociator, higher degrees of dissociation have been obtained for high gas throughputs and particularly for deuterium. It has been observed, that a water layer dominates the recombination properties on the nozzle surface. Additionally, first results of atomic and molecular beam attenuation studies are presented.

Nuclear polarized hydrogen and deuterium atoms and ions produced by so–called Atomic Beam Sources (ABS) are widely used to determine spin dependent observables in nuclear and particle physics. As several applications would profit from an enhanced beam intensity, there is strong interest for a further improvement of AB sources.

Anticipating an increased intensity of the HERMES ABS, a programm has been initiated to develop a nozzle beam with high atomic fraction and phase space density. In this framework, a new type of microwave dissociator (MWD) based on a 2.45 GHz surface wave discharge and an Atomic Beam Test Stand (ABT) with various disgnostics have been set up. A first report has been given in 1997 at Urbana [1], describing the design of the MWD as well as first results on its performance for hydrogen.

Since then, systematic studies on the production of highly–dissociated, cold atomic beams of hydrogen and deuterium have been performed [2]. Using a simple testbench and considering theoretical aspects of surface wave discharges, the oxygen admixture needed to obtain a maximum atomic fraction could be reduced to $Q_{\mathrm{O2}} \leq 0.15\,\mathrm{flux}\%$ by an enhanced discharge tube cooling and appropriate surface treatment. This value is about a factor five to ten lower than the ones reported in ref's [3,4]. As a consequence, we obtain long–term stable operation with high atomic fractions α in the beam. Typically, during six days of continous running under nominal working conditions of the HERMES ABS, α decreased only slowly from more than 80 % to 75 %. The high initial value could always be reproduced after warming up the nozzle.
The measurements of the atomic fraction were performed using the ABT shown in Fig. 1. The ABT consists of a 4–stage differentially pumped vacuum sys-

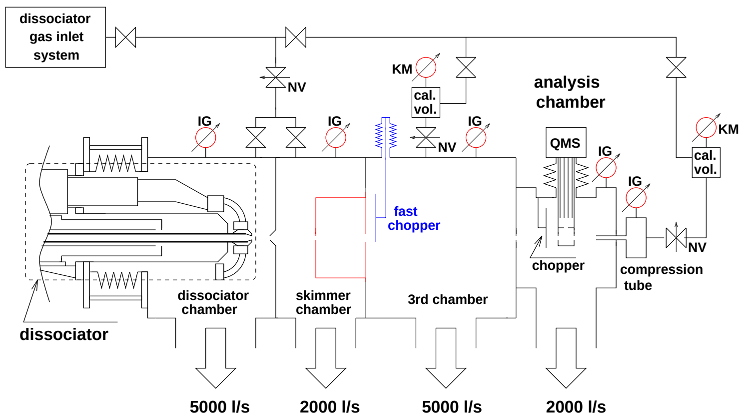

Figure 1: Schematic picture of the Atomic Beam Test Stand (ABT). The symbols NV, IG and KM denote needle valves, ion and capacitive pressure gauges.

tem with a nominal pumping speed of 14,000 l/s. The dissociator is mounted on a large manipulator, providing an axial movement of up to 80 mm. The separation wall at the end of the skimmer chamber can be set to various axial positions. The third stage is planned to accomodate a fast chopper for velocity measurements by the TOF method. In the 4th stage, the so-called Analysis Chamber, a crossed-beam quadrupole mass spectrometer (QMS) is mounted from the side with a slow chopper in front. Because of the efficient differential pumping layout, we typically obtain signal–to–background ratios of 8 : 1 for H_2 with discharge off, and 60 : 1 for H_1 and 4 : 1 for H_2 with discharge on, respectively. The chopper–QMS unit is placed on a manipulator which enables investigations of the beam profile or entire removal of the QMS out of the beam path for intensity measurements with a calibrated compression tube.

Besides studies of the long–term behaviour, comparative measurements with the RF–dissociator (RFD) presently used in the HERMES ABS have been performed. The results shown in Fig.2 indicate that the MWD yields higher degrees of dissociation than the RFD in the range of high throughputs, particularly for deuterium. However, it can be stated that for hydrogen and moderate flow rates, the new dissociator does not exceed the performance of the RFD.

Another interesting result has been obtained investigating various nozzle surfaces with respect to their recombination properties. Unlike recent measurements investigating the same subject [4], we have found that individual prop-

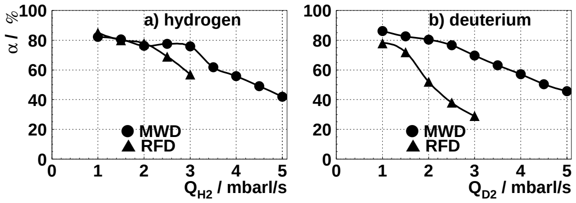

Figure 2: Degree of dissociation as a function of hydrogen and deuterium throughput for the MWD and the RFD.

erties of different coatings are suppressed to a large extent by an ice layer resulting from the oxygen admixture mentioned previously. Even with a bare Cu nozzle cooled down below 200 K, atomic fractions in the order of 70 % have been obtained.

The attenuation of the atomic beam has been investigated in the course of recent studies. We have observed, that the effective cross section for single scattering losses at the residual gas decreases with nozzle throughput. Considering additionally measurements on the fluxes lost in each pumping stage, we have found first indications for the fact that residual gas scattering is not sufficient to explain the attenuation of the atomic beam. Intra–beam scattering (IB) might be an additonal loss mechanism with a dominant contribution especially in the range of high nozzle throughputs [5]. As IB losses are expected to decrease with decreasing beam temperature, in our next steps we will carry out TOF measurements on the present nozzle beam and investigate the performance of a two–component beam, where the inner nozzle beam is cooled and confined by a surrounding carrier jet [6].

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