Measurement of the nuclear polarization in H_2 and D_2 molecules after recombination of polarized hydrogen or deuterium atoms

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When polarized hydrogen atoms recombine in a storage cell, the residual H_2 molecules may still show nuclear polarization [1]. In a collaboration between PNPI, University of Cologne and FZ Jülich a device was built in the framework of an ISTC project (No. 1861) and a DFG project (436 RUS 113/977/0-1) to measure the polarization of hydrogen (deuterium) atoms and hydrogen (deuterium) molecules after recombination of polarized atoms depending on different surface materials, temperatures and magnetic fields.

When the polarized atomic beam source (ABS) of the ANKE experiment is not in use at COSY, investigations of the interaction of polarized atoms with the surface of a T-shaped storage cell inside a superconducting solenoid were carried out. The polarization of both, atoms and molecules, was measured with a Lamb-shift polarimeter (LSP) [2].

After some improvements of the Wienfilter of the LSP, which was used here as a mass filter to separate the protons and the H_2^+-ions after ionization of hydrogen atoms and molecules in the cell, the recombination of atoms to molecules was measured for a gold surface. Moreover, it was shown that in the temperature range from 45 to 120 K the recombination was close to 100%. The known ratio ($\sim 11:1$) of the production of H_2^+ ions and protons from H_2 molecules was verified by injecting only molecules into the storage cell (see Fig. 1). When the atomic beam of the ABS was switched on to fill the cell the measured ratio increased by just 10%. This means that mostly molecules are in the cell and only the incoming atoms are changing this ratio. When the flux of

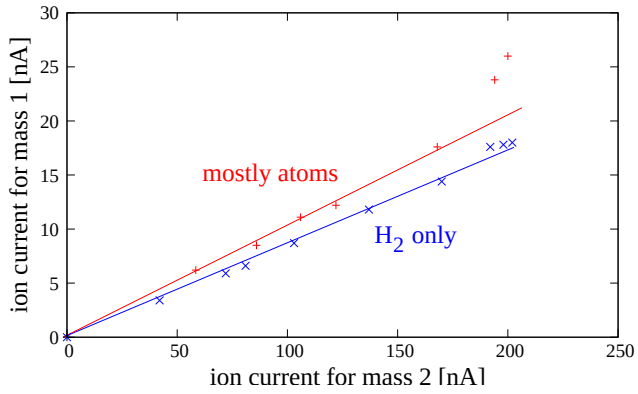

Fig. 1: The ratio of the proton and H_2^+ ion currents in the cup of the LSP when the Wien filter was used for mass separation. The slopes for the measurements with only H_2 in the cell (blue) and mostly hydrogen atoms (red) differ not much. This corresponds to a nearly perfect recombination on the surface.

the incoming atoms was increased so that the amount of H_2^+ ions was higher than 180 nA the ratio of the number of protons and H_2^+ ions was not stable anymore (see Fig. 2). At this point the mean free path of the H_2^+ ions was shorter than the length of the storage cell and more and more H_2^+ ions are lost due to collisions with the H_2 molecules. The smaller protons can still pass the storage cell and reach the cup. Therefore, all ongoing measurements must be made at small fluxes from the ABS to avoid these saturation effects.

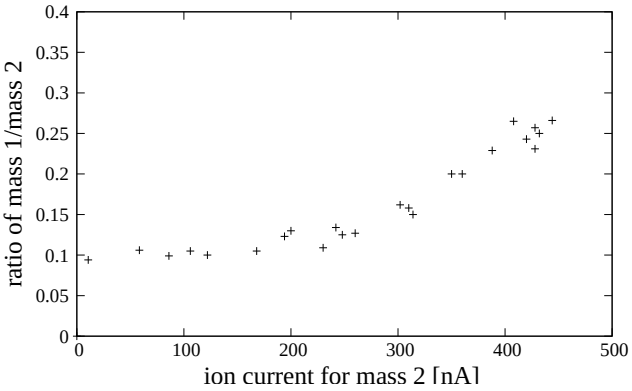

Fig. 2: The ratio of the proton and H_2^+ ion currents in the cup of the LSP increases when the density in the target cell was increased and the H_2^+ ion currents are higher than 180 nA.

To our surprise these protons are still polarized with polarization values up to 0.45. This corresponds to the naive model that one unpolarized atom on the surface will recombine with a polarized atom from the ABS and, therefore, half of the initial polarization was found in the molecule. Wise at al. [1] have shown before that the polarization of molecules on a copper surface depends on an external magnetic field. It was found that at 300 K and a magnetic field of more than 0.8 T about 50% of the initial atomic polarization preserves for the molecules. On a gold surface at 45 K and 0.3 T 50% of the initial polarization was preserved. Right from the beginning of the measurements it became obvious that the polarization of the H_2 molecules was slowly decreasing as function of time and after about one week an equilibrium at 0.15 was found at 45 K and 0.2 T. This effect can be explained by water covering of the surface, which was known to produce a high recombination rate at this temperature. The dependence of the molecular polarization on the magnetic field can now be measured for the first time with the new apparatus.

References:

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[2] R. Engels et al., Rev. Sci. Instr. **74** (2003) 4607.

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