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Experiments with hydrogen atoms at ultra-low energies

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We present a recent progress towards experiments with hydrogen atoms at ultra-low temperatures, probing the ultra-low energy domain with the lightest and simplest of neutral atoms, which has served as a test probe of the fundamentals of physics throughout the era of modern physics. This work is a part of an international collaboration GRASIAN (Gravity, Spectroscopy and Interferometry with Atoms and Neutrons) [1].

Experiments will be carried out in a double-trap system. First we will accumulate and evaporatively cool H gas below 1 mK in a large Ioffe-Pritchard trap (IPT) recently built in Turku [2]. Then, the cloud of cold H will be transferred into a second, more shallow trap T_2 for further manipulation in the phase-space, aiming on reaching temperatures in the μK region for further experiments. We will release ultra-slow atoms from the trap onto the ideally flat surface of superfluid helium, from which their quantum reflection will lead to formation of gravitational quantum states (GQS) in the potential well created by the surface and Earth gravity. Precise measurements of the GQS energies will improve constraints on the existence of the unknown short-range forces between atoms and materials surface. Precision optical and microwave spectroscopy will be performed at the conditions when the atomic velocity related effects are eliminated, e.g. improving the accuracy of the 1S-2S interval. Bose-Einstein condensation of magnetically trapped gas will be re-visited and tried for H bound in the GQS. Our methods and results will be useful for experiments with antihydrogen pursued at CERN.

We report on the first experiments where we have demonstrated magnetic capture and confinement of H gas at temperature below 50 mK in our IPT. The loading of H into the sample cell (SC) was performed using a cryogenic H dissociator operating at 0.7 K followed by two stage thermal accommodators at 0.5 and 0.3 K feeding the gas into the SC. Measuring the heat released in recombination of atoms during and after the loading, we found that atomic flux of over 3×10^{13} atoms/s reaches the SC and $\sim 2\times10^{14}$ atoms are trapped at temperature of ~ 50 mK. At the next stage the trap T_2 will be assembled together with components necessary for the 1S-2S spectroscopy.

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