Cube-D_2, a Device for the Investigation of Solid UCN Converters

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Super-thermal sources of ultracold neutrons (UCN), like Mini-D_2 [1] for the research reactor FRM-II at Garching, are nowadays under intensive worldwide investigation. Essential component of these facilities is the UCN converter. Materials like deuterium (D_2), deuterized methane (CD_4), or oxygen are considered to be suitable. The Cube-D_2 source is a multi-purpose device for studies of solid converters. In this report we describe the main components of the set-up and some experiments performed to find the optimum freezing procedure for the UCN converter (in our case solid deuterium). We also present an experiment planned at the Mephisto cold-neutron beam of FRM-II to test the possibility to produce UCN with Cube-D_2.

The set-up is composed of two main sections, the cooling stage and the gas handling system. Auxiliary parts are the para-to-ortho deuterium converter and the remote control system. The main component of Cube-D_2 is the converter cell. Deuterium is frozen in a cubic chamber from aluminum (46 mm outer side length). Two sapphire windows ($\emptyset$=12 mm) are mounted at the side walls to allow optical inspection. The bottom of the cell is in contact with a two-stage cold head. The entrance window for the cold neutrons (thickness 0.5 mm) on the front side is machined directly from the aluminum block. The produced UCN leave the target through the rear-side window, a glued 100 μ thick aluminum foil. Two diode sensors monitor the temperature of the cell. Temperatures down to 5 K at the surface are easily reachable. A heating resistor ($\sim 20\,\Omega$) together with a temperature controller allows to vary the temperature over a wide range [5÷300 K].

Despite of the small amount of deuterium needed (~2 mol), particular care has to be taken in handling such an explosive substance. Pure deuterium is stored in a reservoir (15 l, 3.6 bar) and successively distributed, via a sequence of metering valves, either to the aluminum cell or to the converter unit to be described next.

For efficient UCN production a high concentration of ortho-D_2 is mandatory [2]. In order to increase the small natural para-to-ortho conversion rate, liquid deuterium is placed in contact with a catalyst, in our case a ferromagnetic material, in the converter unit. The ortho-D_2 concentration was deduced using Raman spectroscopy [3]. It took only about 11 h to reach the ortho-D_2 concentration characteristic for the temperature (e.g. $(97\pm3)\%$ at liquid-deuterium temperatures).

Tests were performed to understand the influence of the freezing procedure on the properties of the created solid. First, deuterium was frozen directly from the gas phase at 16.5 K. Very stable temperature conditions were achieved in the cryostat ($T_{\mathrm{cell}} = 16.5 \pm 0.05$ K). At a pressure of 100 mbar a transparent solid block of deuterium was growing in the cell. The freezing process took about 5 h and was stopped for safety reasons when the pressure in the reservoir reached 1100 mbar. At that time the cell was filled to 75%. Figure 1(A), shows the result, a transparent crystal (the pattern behind the target is clearly visible). The second freezing test was performed at lower temperature (11 K) and with an inlet pressure of 50 mbar. The freezing went rather fast. This may have been the reason, why in the bulk some diffraction phenomena, normally associated with a polycrystalline structure, were seen (cf. Fig. 1(B)). Figures 1(t1 to t4) show the target with the deuterium in different stages of the transition from solid to liquid. Complementary information for a complete characterization are expected in the experiment planned at FRM-II.

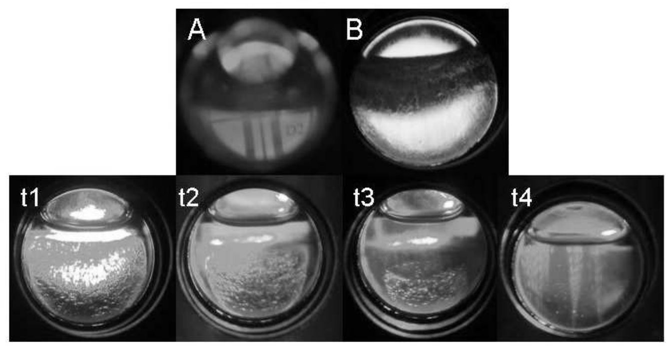

Fig. 1: Solid deuterium in the target cell. See the text for a detailed description.

The Cube-D_2 set-up will be used to test some components of the Mini-D_2 source, e.g. the efficiency of the deuterium converter, the UCN extraction and storage system and the unit for para-ortho-deuterium conversion. To explore these features a number of measurements is planned in the near future (spring 2006) at FRM-II. The full deuterium cell will be irradiated. The UCN produced in the cubic cell will be extracted to (or eventually stored in) an electro-polished stainless steel tube of up to 2 m length. The promising storage properties of such tubes were shown lately in an experiment at Institut Laue-Langevin [4]. The neutrons will be counted with a ^{3}He detector. Taking as reference a similar experiment performed at PSI [5] our challenge is to reach with the Cube-D_2 set-up a UCN count rate of at least 1/s. The UCN production shall be measured as a function of the deuterium amount in the cell and of the ortho-D_2 concentration.

References

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