# Development of Thin Solid HD Target for Polarized Nuclear Laser Fusion Study:II

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Among possible spin alignments in the collision of D and T nuclei, the process for anti-parallel spin combination of T to D is forbidden to form a spin 3/2 compound nucleus $^5$He$^*$. Therefore, only 2/3 fraction of the DT interactions contributes to the reaction rate in the conventional unpolarized fusion scheme. Instead, if D and T could be polarized in parallel, all interactions will contribute to the reaction rate [1,2]. However, we face to a fundamental question: Does the polarization persist in a fusion process?

In advance to a polarized DT fusion study, polarized DD experiments will be instructive since DD laser fusion experiments are in progress with detecting fusion neutrons in a sufficient intensity [3]. Further, the recent studies on a polarized HD target will be directly applicable to DD fusion experiment based on the technical achievement of the polarized target project in our laboratory [4] with the "brute-force method" for proton polarization at 10 mK in the magnetic field of 17 T, and also based on the polarization transfer study from H to D with the application of the RF method [5].

Our experimental setup for the polarized target development consists of a target cell fixed on a 3 K refrigerator cold head inside of a vacuum chamber, a 150 ml gas cylinder outside of the vacuum chamber, and a gas feed capillary line connecting them with control valves.

Our first step for the polarized laser fusion study started in 2013 as the preparation of a PC-based portable NMR system as shown in Fig.1, which was developed by Ohta in our group [6], and a 0.6 Tesla ordinary electromagnet. The measured results at room temperature on a larger dummy probe of 1 mm copper wire 6 turns wound around a black rubber cylinder with 8.5 mm diameter and 30 mm long showed an asymmetrical NMR pattern due to the inhomogeneity effect of the magnetic field over the extension of the probe. Then, we prepared a second smaller probe of 0.254 mm silver coated wire 9 turns wound around a white rubber cylinder with 4.1 mm diameter and 20 mm long, which indicated the measured results of simpler patterns at room temperature as shown in Fig.2. Therefore, we employed the latter geometry for the condensed HD probe.

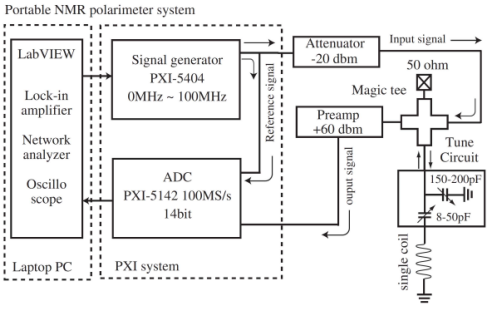


Fig.1:Portable NMR system developed by Ohta [6].

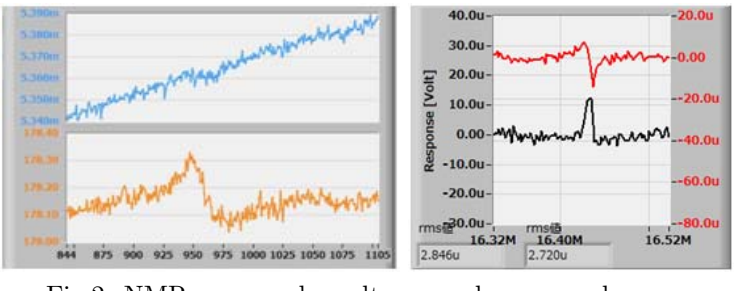


Fig.2: NMR measured results on a dummy probe; a) Mag. sweep, b) Freq. sweep.

Our HD-condensing cell was made of non hydrogenated KelF tube with the inner diameter 4.3 mm and the inside length 18 mm, the lower end fixed to the cold head of the 3 K refrigerator, while the upper end was connected to a high purity HD gas feed line. We already knew the operation of the refrigerator induces serious background noises in NMR signal, and therefore we stopped the operation during the NMR measurements, which continued over about 3 min, at most ended within 5 min. Concerning an empty cell without HD condensed, 5-min stop of the refrigerator did not induce the cell temperature rise beyond 20 K, in the condition of the anti-blockage heater power of the gas feed capillary line below 0.1 W. However, for the cell with the sufficient amount of HD condensed inside with the initial pressure of about 500 mbar in the 150 ml HD gas cylinder, only 1-min stop of the refrigerator induced the cell temperature rise near to 20 K, as shown in Fig.3. We are now improving the refrigerator-stopping performance with attaining the sufficient thermal equilibrium after a longer waiting time and the better thermal insulation by a thicker vacuum gap around the capillary line to the cell.

For the next step to the DT fusion experiment after the DD fusion experiment stage, a new polarization scheme is undertaken since the decay beta heating in a DT target induces serious difficulty to cool down to

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the temperature around 10 mK. We started the experimental study with employing ferromagnetic complex of Prussian blue analogue with the high capability of hydrogen adsorption [7] and a high internal magnetic field with a high Curie point beyond 20 K [8]. The preliminary results on the adsorption and recovery performances of the employed complex were reported in RCNP Ann. Rep 2013. Now, we are preparing a new setup with the complex cell connected to the HD-condensing NMR probe, both of which are individually fixed to the common cold head of the refrigerator and temperature controlled. The transfer performance of the recovered HD gas into the condensing NMR cell will be studied with the present new setup.

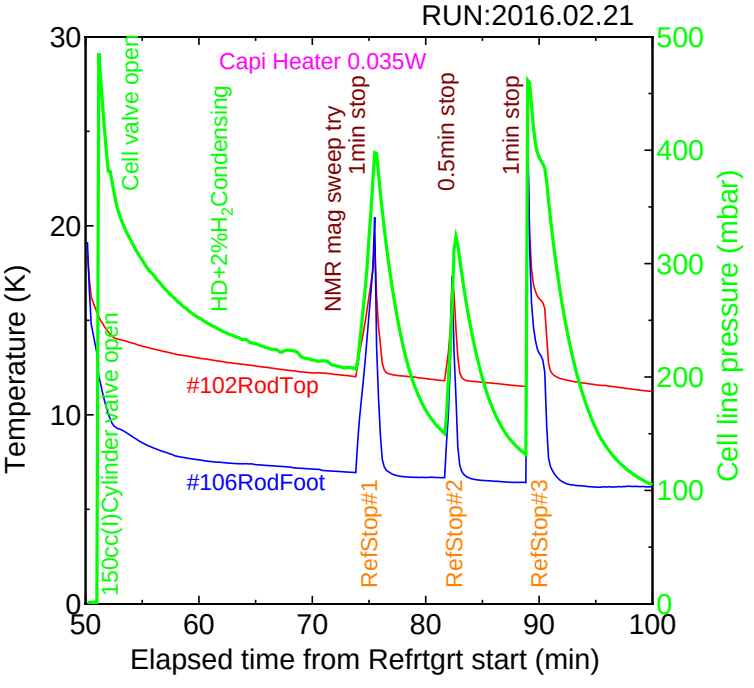


Fig.3:Refrigerator-stopping test of HD condensed NMR cell.

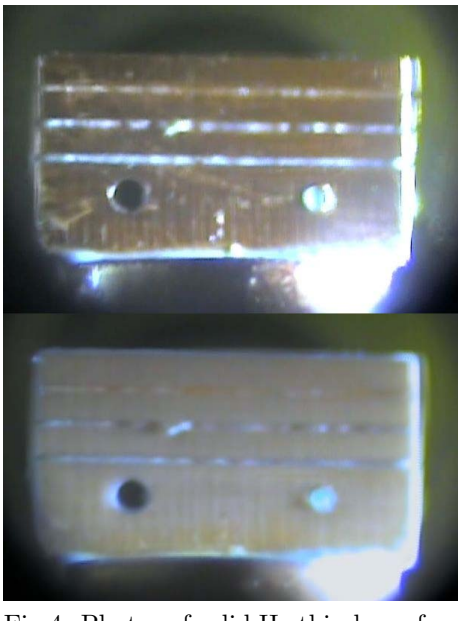

Fig.4: Photos of solid $H_2$ thin layer formation.

The remaining experimental task for the laser fusion scheme is the preparation of a substrateless thin solid HD or DT layer. For the present task, we employ the direct solidification method from gas phase [9], and we are now performing a series of experiments with preparing the third setup consisting of a vapor cell provided by a temperature-controlling skirt connected to the cold head of the refrigerator. In the present vapor cell, a thin copper plate cartridge machined with submilimeter slits and holes was fixed to the cell bottom, and we can observe the direct solidification event through the transparent viewing port of the cell. A preliminary pictures of the observed results with the cartridge of 6 mm high, 10 mm wide and 1 mm thick are shown in Fig. 4, where the upper part shows before the beginning of the condensation while the lower part indicates the growing of the thin solid layer on the cartridge. The three horizontal lines in the upper one were machined wth the depth of 0.1 mm, 0.2 mm and 0.3 mm, respectively, which were well filled with solid $H_2$ layer in the lower one. As the next step of the vapor cell cartridge, we prepared a new cartridge with a thin sapphire disc provided again by submillimeter slits and holes, which will be applicable to NMR study on the substrateless thin HD layer.

## References


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