Conversion of ortho- to para-D_2 in liquid phase by irradiation

K. Mishima[a)], M. Tanaka[b)], M. Utsuro[a)], Y. Nagai[a)], K. Kobayashi[c)], K. Okumura[c)], Y. Yoshino[c], Y. Fukuda[d)], T. Kohmoto[d)], Y. Kiyanagi[e)], M. Ooi[e)], and K. Kirch[f)]

[a)] *Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[b)] *Kobe Tokiwa Jr. Collge, Ohtani-cho 2-6-2, Nagata-ku, Kobe 653-0838, Japan*
[c)] *Research Reactor Institute, Kyoto University, Noda, Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan*
[d)] *Department of Physics, Kobe University, Rokkodai-cho 1-1, Nada-ku, Kobe 657-8501, Japan*
[e)] *Department of Quantum Energy Engineering, Hokkaido University, Kita 13, Nishi 8, Kita-ku, Sapporo, 060-8628*
[f)] *Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland*

Ultra-cold neutrons (UCN) with high density are one of the important tools in studying fundamental physics. Recently, the group from the LANL, USA succeeded in realizing the high density UCN over 100 UCN/cm^3 using a solid D_2 (sD_2) converter in the ortho state (I = 0, 2, where I is a total nuclear spin) and spallation neutron source[1]. Encouraged with this success, we have started a basic study on the sD_2 converter aiming at construction of high intensity UCN source. One of the important subjects to be investigated toward a practical UCN source based on the ortho sD_2 is to study conversion of the ortho- to para- D_2 (I = 1) due to the radiation exposure since growing of the para-sD_2 induces reduction of the UCN storage time and consequently gives rise to reduction of the UCN density.

As the first step of our work, the above radiation effect for D_2 in a liquid phase was investigated instead of a solid phase because of easiness.

The gamma-rays and small amount of neutrons were generated by bombarding a 30-mm thick Ta target with the 33-MeV electron beams ($\sim$5 kW) from the KURRI electron linear accelerator with a repetition rate of 100 Hz. After that, we replaced this target with a 15-mm thick Ta target to keep the gamma-ray flux with a less linac power. An ortho-D_2 was fabricated in a copper vessel in which a para-magnetic catalyst, Cr_2O_3 (oxysorb)is kept at temperature of a triple point for deuterium, i.e., 18.7 K by a 2-stage Gifford-McMahon cryostat. At this temperature, equilibrium concentration of the ortho-D_2 is 98.5%. Since the conversion time from ortho to para-D_2 is quite slow, this concentration is kept for a long time even at room temperature. Then, the ortho-D_2 gas was stored in another copper vessel and liquefied by cooling it down to either T = 24.5 K or 19.5 K. The data at T =24.5 K were taken at two different powers of the linac beam on the Ta target, 1.2 and 2.1 kW. A heat deposition on the liquid D_2 was estimated to be 150 mW/g for the linac power of 1.2 kW. The liquid ortho-D_2 was irradiated by the gamma-rays for 2$\sim$4 days, during which a sampling was done a few times by interruping the beam exposure.

The experimental setup is shown in Fig. 1. The heat deposition in the present work was comparable to the radiation level of the cold neutron source at PSI (SINQ) ($\sim$230 mW/g)[2]. The ortho-D_2 concentration was measured by means of the Raman spectroscopy in which a 514.5-nm line from a 10-W Ar ion laser and a combination of 2 sets of mono chrometers were used. The Raman spectroscopy was carried out at Dept. of Physics, Kobe University. Analyzing the observed D_2 molecular rotational bands of the irradiated samples, the ortho-D_2 concentrations deduced. In Fig. 2 are shown some of the Raman spectra for the D_2 samples.

The dotted curve is the result for a sample at room temperature (ortho concentration 66.6%), the dashed curve is that for a sample with a concentrated ortho D_2 by means of the catalyst, Cr_2O_3 (ortho concentration is 98.5%), and the solid curve is that for a sample irradiated during 24 hours (ortho concentration is 98.5%).

The unexpectedly large reduction of the ortho concentration observed at 24.5 K seriously contradicts with the SINQ result carried out at 25 K for a long time[2]. A more detailed analysis of the observed results and theoretical calculations is now in progress.

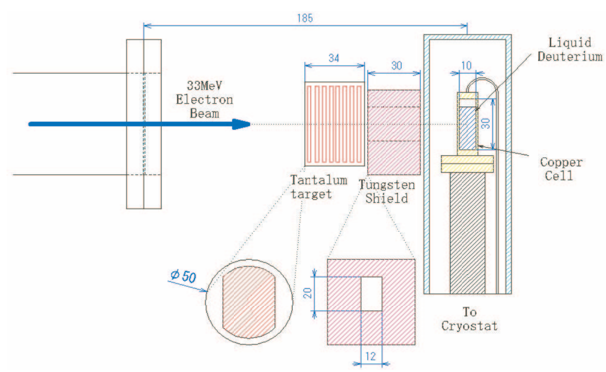

Figure 1: A schematic view of the experimental setup. An electron beam from the left side is introduced to a Ta target consisting of a thin Ta stack water cooled. Behind the target a tungsten collimator is located to collimate gamma rays. An ortho-D_2 sample is stored in a copper vessel and mounted on a copper cold finger.

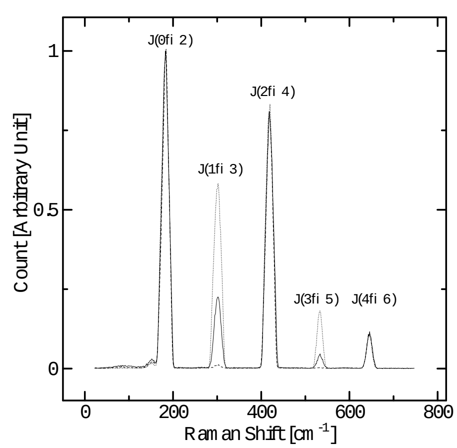

Figure 2: Raman spectra of the D_2 samples. See text. The indicated numbers represent the transitions of the rotational band for the D_2 molecule.

References

[1] C. L. Morris et al., Phys. Rev. Lett. **89** (2002) 27250-1.
[2] F. Atchison et al., to be published.