Development of high intensity ultracold neutron production with ortho-deuterium

M. Utsuro[a], M. Tanaka[a,b], K. Mishima[c], Y. Nagai[a], T. Shima[a], Y. Fukuda[d], T. Kohmoto[d], T. Momose[e], A. Moriai[f], K. Okumura[g], H. Yoshino[g]

[a] Research Center for Nuclear Physics, Osaka University
[b] Department of Sanitary Technology, Kobe Tokiwa College
[c] Graduate Course of Science, Osaka University
[d] Department of Physics, Faculty of Science, Kobe University
[e] Graduate Course of Science, Kyoto University
[f] Division of Research Reactor, Japan Atomic Energy Research Institute
[g] Research Reactor Institute, Kyoto University

Ultracold neutrons(UCN) with the velocity of about 6m/s are utilized in various kinds of fundamental physics experiments on neutrons. Ortho-deuterium molecules have much attractive properties as the UCN converter material[1] lying in the rotational ground state at the low temperature below about 20K. The translational molecular motions play also the important role with the phonon spectrum in solid deuterium(SD2) for UCN cooling down, as a superthermal converter providing the UCN density beyond that corresponding to the thermal equilibrium. The LANL project on SD2-UCN source recently recorded the ever highest UCN density[2]. Another PSI project with much higher UCN density is planned to utilize the cyclotron spallation neutrons. However, all these SD2-UCN projects are supposed as the SD2 converter to be inserted into high radiation fields directly coupled to pre-moderators, which will bring severe thermal and material conditions to the UCN converter.

Solid deuterium has the crystal structure of hexagonal closed pack with much different sound velocities for the a- and the c-axes in the crystal, and thus the intersections between the phonon curves[3] and the momentum *vs.* energy relation for a neutron corresponding to the most effective incident neutron energies for UCN production strongly depend on the relative angle between the crystal axes and the direction of the neutron incidence. Thus, we have proposed[4] a new concept studied here of a single crystal UCN converter of ortho-deuterium at the exit of a cold neutron guide from a pulsed source, making us rid of the high radiation load problems in the internal type of UCN conveter.

The high purity ortho-deuterium gas was prepared with the magnetic catalyser contained in an aluminum cartridge inserted in the $30\mathrm{mm}^{\phi}\times 50\mathrm{mm}^{h}$ copper cell at the top of a two-stage helium refrigerator with the cooling capability down to about 9K, then ortho-concentration of about 98% was attained[5] with the catalyser at the temperature a little below 20K.

According to the studies at the Prof. Momose's laboratory in Kyoto University, the key factors for the optimized crystallizing procedure are the direct and gradual growth of the single crystal from deuterium gas under well controlled optimum gas flow rate and also at the optimum temperature of the crystallizing cell. In our neutron experiments, these key factors were exactly followed for our UCN converter preparation in the $2\mathrm{cm}^{W}\times 6\mathrm{cm}^{H}\times 3\mathrm{cm}^{D}$ crystallizing cell in the refrigerator.

The identification of the crystal orientation was carried out with the time-of-flight method to observe the Bragg scattering of the chopper-pulsed cold neutron beam at the exit of C2 guide tube, JRR-3M reactor, JAERI. We specially prepared our experimental setup with collimators, a narrow slit chopper and a 2m long evacuated extension guide tube in the

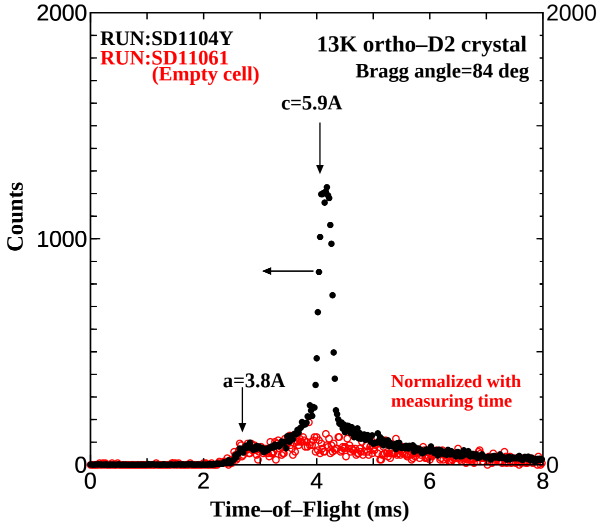

Figure 1: The measured results of the time-of-flight Bragg scattering experiment on ortho-deuterium single crystal UCN converter.

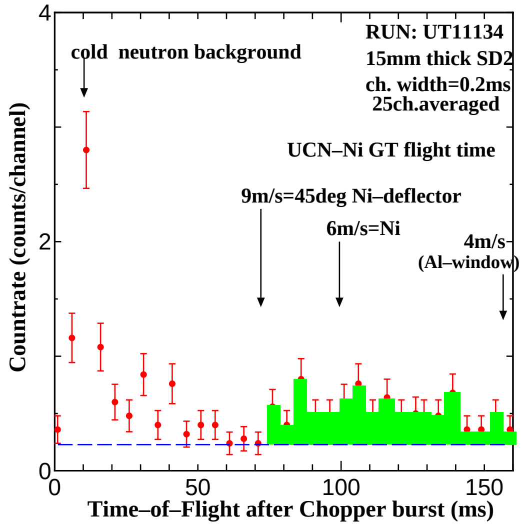

Figure 2: The measured results of the time-of-flight discrimination of UCN produced in ortho-deuterium crystal UCN converter.

upstream of our cryomachine. The typical time-of-flight spectrum measured with about 2cm thick deuterium crystal is shown in Fig.1, which indicates clearly the contribution from the very pure lattice structure composed of the c-direction of the hexagonal deuterium crystal, just as complete agreement with our expectation on the crystal orientation.

Two kinds of techniques were used for our discrimination of the UCN component, *i.e.* the time-of-flight discrimination through a 50cm long vertical UCN guide, and the nickel filter method reflecting subcritical UCN inserted in front of a ^{3}He UCN detector. Both kinds of the discriminations gave similar results on the UCN countrate. One of such results obtained on the converter at 11K under much severely reduced beam size for background reduction is shown in Fig.2, where the countrate in the UCN time region is in reasonable agreement with our expectation. Further progress to the continuous beam measurements with the full beam size of the guide will give the UCN countrate of about 300 c/s.

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