The spallation target of the ultra-cold neutron source UCN at PSI

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INTRODUCTION

A new type of ultra-cold neutron UCN source based on the spallation process is scheduled to start operation at PSI in 2008[1-3].

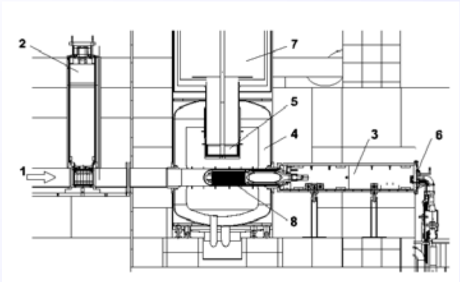

Figure 1: Layout of the UCN source: 1 proton beam, 2 collimator, 3 target shaft, 4 D_2O (Pre-)Moderator, 5 solid D_2 Moderator @ 6 K, 6 target head with coolant supply, 7 UCN storage volume, 8 target array (Cannelloni target).

Some Basic Parameters

- Operation in pulsed mode, duty cylce 1 % – average current 20 µA
- Gaussian beam profile (σ = 4 cm) of 590 MeV protons cut by a collimator
- Expected UCN density ~ 10^3 cm^{-3}

LAYOUT OF THE TARGET ASSEMBLY

Several design possibilities for the layout of the target assembly of the UCN source have been studied. Finally a design similar to the target system of the SINQ facility was chosen[4] – see Figure 2.

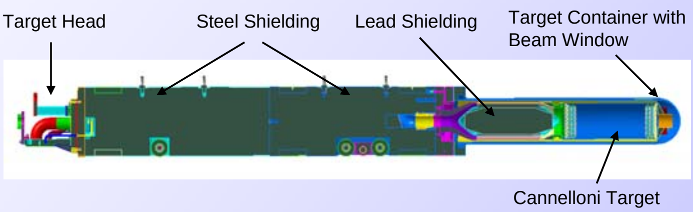

Figure 2: Side view of the UCN target assembly.

- The target container with integrated beam window is made from AlMg3.
- The Cannelloni target consist of 760 lead filled Zircaloy rods (see Figure 3).
- The 50 cm long lead shield behind the Cannelloni target serves as a shielding for neutrons in the forward direction together with the 220 cm steel shielding.
- The target head is the interface to the coolant (D_2O) circuit.

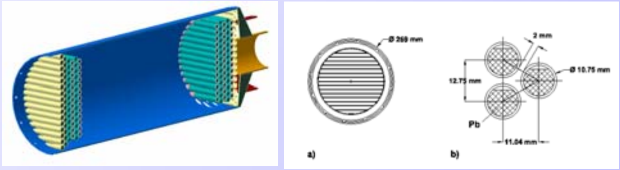

Figure 3: Detailed view of the Cannelloni target. It consists of an array of 760 Zircaloy tubes filled with lead. The pitch of the array is 1.275 cm and the distance between two rows is 1.104 cm.

OUTLOOK

The target of the UCN source is currently built in the workshop of PSI and will be delivered for final testing in the middle of 2007.

REFERENCES

[1] http://ucn.web.psi.ch
[2] A. Fomin et al., *PSI Report TM-14-01-01* (2000)
[3] F. Atchison et al., *The PSI UCN source*, p. 152, in Proceedings of the seventeenth meeting of the International Collaboration on Advanced Neutron Sources ICANS, Santa Fe, New Mexico (2005)
[4] M. Wohlmuther and G. Heidenreich, NIM A 564, p. 51, (2006)
[5] L. S. Waters et al., *LA-CP-02-408*, Los Alamos (2002)
[6] E. Groth, private communication

RESULTS

In a first step the position of the Cannelloni target was optimized with respect to the neutron flux in the solid deuterium moderator – see Figure 4.

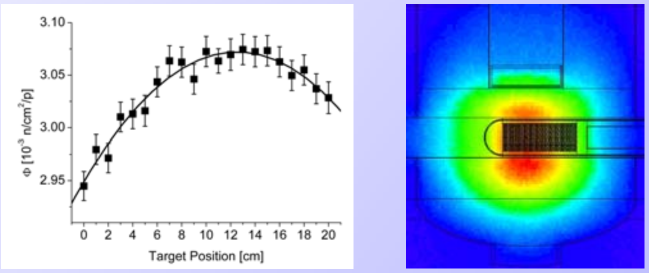

Figure 4: Left: Neutron fluxes (E_n < 0.625 eV) calculated with MCNPX[5] in the solid deuterium moderator. Right: Neutron flux map for target position 10 cm.

Thermo-mechanical design of the target assembly

Target Beam Window

To achieve a uniform distribution of the coolant velocity across the beam window two flow guides have been introduced. The fluid velocity is depicted in Figure 5 on the left. On the right in Figure 5 the wall temperature as a function of heat flux is shown.

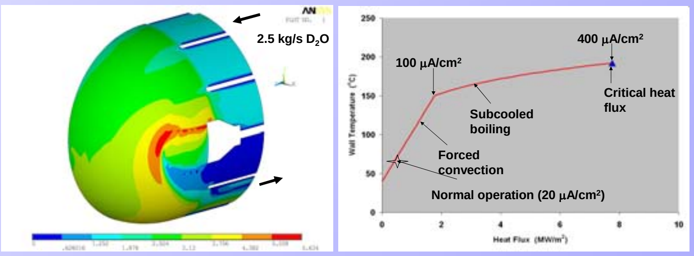

Figure 5: Left: Fluid velocity across the UCN target beam window with a mass flow of 2.5 kg/s. Right: Wall temperature of the beam window as a function of heat flux (D_2O temperature 40°C, static pressure 0.5 MPa, fluid velocity 2.5 m/s)

The Cannelloni Target

During a proton pulse approximately 840 kW of the 1.2 MW beam power are deposited in the target assembly. The maximum heat load in the lead is calculated as 440 W/cm^3. In case of no heat contact between the lead and the Zircaloy cladding the lead will melt after one second of operation. This corresponds to a strain rate of 1 % per second. Using measured stress-strain relations[6] the stress induced in the Zircaloy cladding can be calculated. Figure 6 shows the resulting temperature and stress in a Zircaloy Cannelloni when a perfect intermetallic connection between the lead and the Zircaloy is assumed.

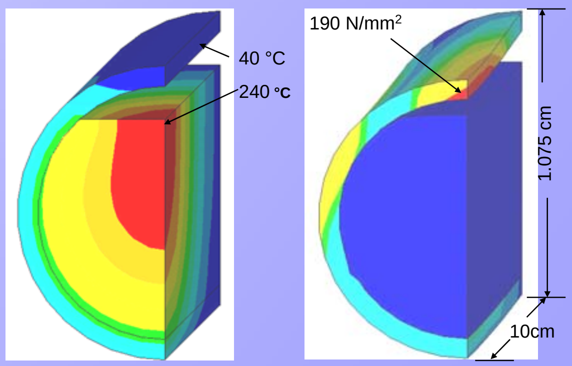

Figure 6: Left: Temperature distribution in a Zircaloy Cannelloni target with a perfect intermetallic contact between the lead and the Zircaloy. Right: Stress induced in the Zircaloy rod by the expanding lead.