Experimental report

23/08/2018

Proposal: **3-14-377**

Council: 4/2017

Title: Replica guide technology R&D for UCN transport

Research area: Methods and instrumentation

This proposal is a continuation of 3-14-369

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Samples:

Instrument	Requested days	Allocated days	From	To
PF2 EDM	0	7	05/06/2018	12/06/2018
PF2 TES	7	7		

Abstract:

UCN transfer characteristics will be optimised for neutron guides prepared by a combination of technologies: sputtering, electroplating and replica technologies. The tests serve as benchmark measurements to inform on the suitability of this technology to develop UCN guides of non-standard shape (T-piece, Y-shapes, elbows) with optimised transfer properties. These guides will be able to operate at room temperature as well as under cryogenic conditions.

Experimental Report 3-14-377: UCN replica guide R&D on PF2 EDM

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Experiment 3-14-377 conducted in June 2018 is a stage in the R&D programme to develop technologies and establish procedures for replica neutron guide production. For an earlier experiment in February 2017 we produced one guide section; although this represented the first guide produced successfully using our replica techniques the transfer parameters needed significant improvement. Roughly an order of magnitude lower transfer efficiency was recorded for the replica guide compared to the high quality guides (surface roughness R_z = 80Å-90Å coated with a 2500Å-3000Å Be layer) produced for cryoEDM using conventional techniques. The various (electro-chemical) -procedures for the coating and removal of the substrate have been further refined for the production of a next batch of guides which were tested in the experiment we report on here. We regained a good fraction of the transfer losses with the new guides produced taking the transfer parameters close to those of guides produced by the classical techniques. As stated in the experimental proposal, although the coating quality of this process is unlikely to be able to compete with guides of an uncomplicated geometry (cylindrical or rectangular) the real interest in this technology comes through its application to guides of a more complex geometry (curved or transition pieces) where substantial transfer losses are sustained when using conventional guide coating arrangements.

Experimental set-up

The experimental layout includes an S-bend coupled the PF2 beam to remove the higher energy neutrons from the spectrum. Neutrons are guided towards the detector array after passing through the test guide mounted in the vacuum chamber.

A UCN "four-element" detector is used as well as a single large area detector of 3000 mm^2. The "four-element" detector comprises of four solid state detectors covered with a ^{6}Li layer and register the alpha and triton particle of the neutron conversion reaction n(^{6}Li, α)^{3}H. Metal masks acting as energy filters can be mounted in front of the detectors which thus operate at four cut-off energies: Al (55 neV), Cu (168 neV), stainless steel (188 neV) and "open" (no cut-off). Similarly the single large area detector holds a ^{6}Li conversion layer and is operated with the various metal masks.

Guide transmission measurements

Three new replica guides have been produced and tested. The guides differ in substrate and substrate removal techniques, cleaning specifics and general handling of the sputtering and electroplating processes. Figure 1 shows the neutron count rate in the energy spectrum of the alpha and triton signals following the neutron conversion reaction for the three replica guides as well as for the cryoEDM reference guide. The data is taken with the single large area detector on the PF2-EDM beamline. The triton peak (at 2.73 MeV) is located in channel region 90-120 and the alpha peak (at 2.05 MeV) is located in channel region 40-80. The detector dead time is significant (between 5% and 25%) due to the high UCN flux at the EDM beamline and the use of the large area detector. The data shown in the figures have been corrected for the associated effects on the registered count rate.

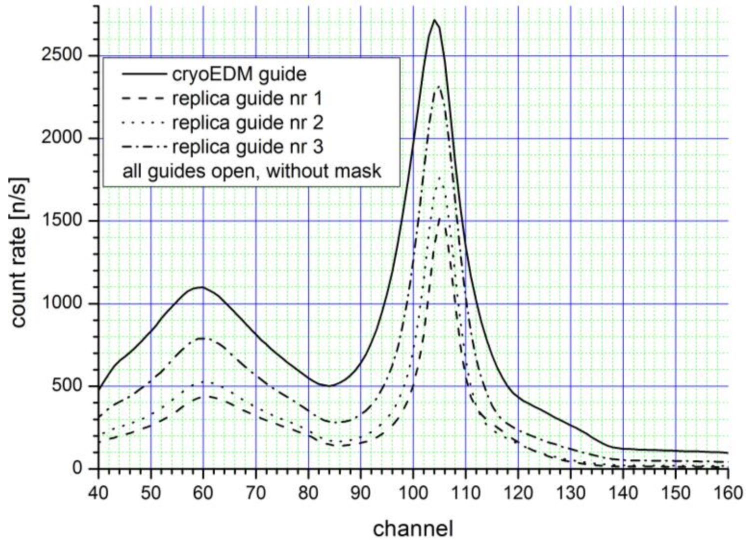

Figure 1: The neutron count-rate as recorded by the large area detector for the three replica guides and the cryoEDM guide installed in the chamber. The plots show data taken with the detectors all operating in the "open" configuration without a mask.

The count rates obtained with the three replica guides show that these guides have a drastically improved transmission efficiency compared to our first replica guide. Whereas we reported a transfer efficiency an order of magnitude lower than the cryoEDM guide for the first replica guide tested in 2017, the relative transfer efficiency ranges from 0.55 to 0.85 for the three new replica guides.

Separate measurements have been made of each replica guide with the large detector equipped with the three masks to allow comparison of the neutron transmission as function of UCN cut-off energy. Figure 2 shows the neutron count rate with replica guide nr. 3 installed in the chamber for each of the three cut off energies as well as a measurement with the detector operated in the "open" configuration. Similar spectra have been obtained during this beam time for the other two replica guides as well as the for the cryoEDM guide.

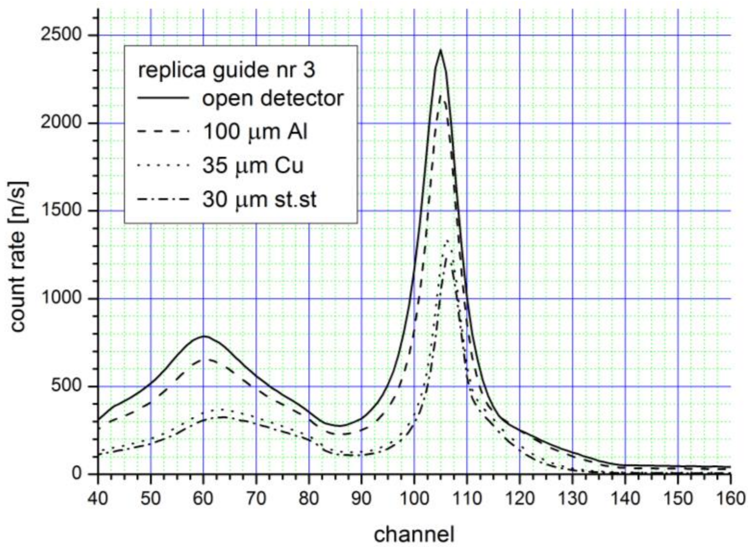

Figure 2: The neutron count rates as recorded by the large area detector with replica guide nr. 3 installed in the chamber. The detector has been equipped with an Al, Cu and stainless steel mask to obtain the transmission as function of a varying cut-off energy.

The results of the transmission measurements using the single large area detector have been collated in the plot shown in Figure 3. Also included in the plot are the relative transmission numbers obtained from the first replica guide that was tested in February 2017. One can see that the performance of the replica guides has improved significantly with the new batch tested in June 2018 and is starting to approach the transmission of that obtained by the highly polished Be coated cryoEDM guide.

Conclusions

We tested the transmission of a new batch of replica guides. We have furthered the techniques for its three stage production process and produced self-standing replica UCN guides with transmission characteristics that are getting close to those of the highly polished Be coated reference guide made by conventional techniques. At Rutherford Appleton Laboratory we are introducing a number of monitoring devices to better characterise and control the guide production process in order to be able to produce replica guides of a reproducible quality. With the improved transmission numbers obtained with replica guide nr. 3 we are also reaching a point where one can consider making a first replica guide of a more complicated geometry.

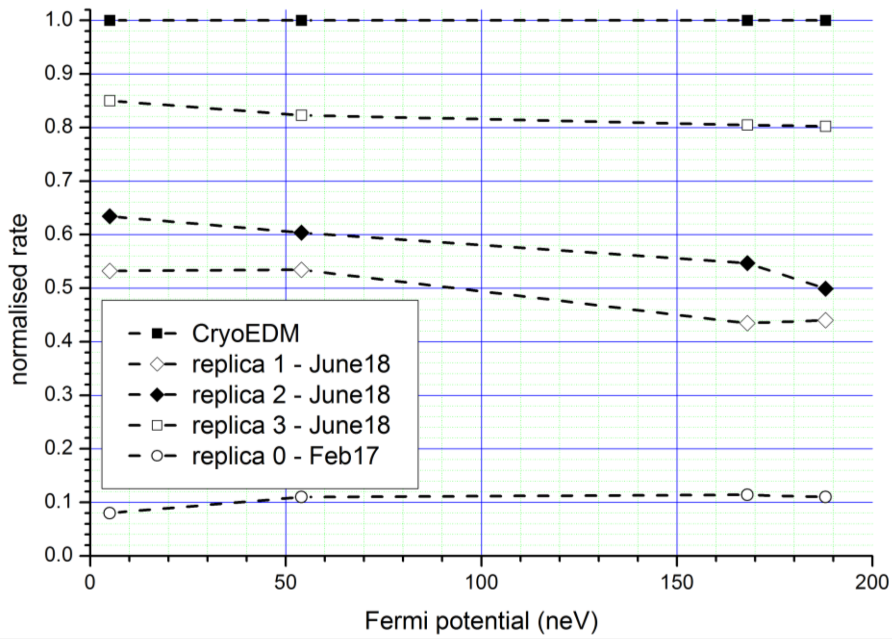

Figure 3: The count rates of the three replica guides normalised to that of the cryoEDM guide. The second batch of replica guides (June18) shows a substantial improvement to that of the first replica guide (Feb17) with tranmissions approaching that of the cryoEDM guide.