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A fast kicker magnet for the PSI 600 MeV proton beam to the PSI ultra-cold neutron source

D. Anicic, M. Daum*, G. Dzieglewski, D. George, M. Horvat, G. Janser, F. Jenni, I. Jirousek, K. Kirch, T. Korhonen, R. Künzi, A.C. Mezger, U. Rohrer, L. Tanner

PSI, Paul Scherrer Institut, WLGA 135, CH 5232 Villigen PSI, Switzerland

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Abstract

The new type of ultra-cold neutron source presently under construction at PSI requires the possibility of transporting the full high-intensity proton beam, currently 2 mA, for about 8 s every 800 s onto a spallation target located at the centre of the source. For this purpose, a fast kicker magnet with a rise time (5–95%) of 0.5 ms has been built. The required magnet and power supply have been manufactured at PSI and were installed during a shutdown. A first test of the fast beam switching process, however, for safety reasons with a reduced beam intensity of 20 μA, was performed successfully.

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1. Introduction

At PSI, the Paul Scherrer Institute in Villigen, Switzerland, a new type of ultra-cold neutron source based on the spallation process is under construction. A detailed description of the source parameters can be found in Ref. [1]. The essential elements of the source are a pulsed proton beam with the highest intensity ($I_p \geqslant 2$ mA) and a low-duty cycle ($\sim 1\%$), a heavy-element spallation target, a large moderator and converter system consisting of about 4 m^3 of heavy water at room temperature for the thermalization of the neutrons and 30 dm^3 of solid deuterium (sD_2) at a low temperature (~ 6 K) for further cooling and the production of ultra-cold neutrons (UCN, $T_{kin} \leqslant 250$ neV). Operating the UCN source in a pulsed mode makes it possible to keep sD_2 at a low temperature despite the large power deposition during the beam pulse of a few seconds.

*Corresponding author. Tel.: +41 56 310 36 68; fax: +41 56 310 32 94.
E-mail address: manfred.daum@psi.ch (M. Daum).

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Currently, the PSI proton ring cyclotron with an energy of 600 MeV and a beam power of 1.2 MW feeds two pion production targets (M, 1 g/cm^2 and E, 7–10 g/cm^2) and the spallation neutron source SINQ as a beam dump. Part of the proton beam can be split off at a maximum intensity of 20 μA by means of an electrostatic beam splitter [2] and directed to the PSI Nucleon Area with different experiments and applications [3,4]. One position in this Nucleon Area is the former PIOTRON [5], where the PSI UCN source is set up.

The UCN facility requires the full-intensity proton beam on its spallation target for about 8 s duration every 800 s. This 1% duty cycle is recommended by the requirements to keep the temperature of the source sufficiently low [6]. It also fulfills the requirements of the biological shielding, which is set up for an average beam intensity of 20 μA. The only reasonable method to achieve this goal with minimum disturbance of the other users of the PSI 600 MeV proton beam is by means of a fast kicker magnet. With this new device, the whole beam can be diverted within a switching time of less than 1 ms from the pion production targets M and E and the neutron spallation source SINQ towards the UCN target. After a beam-on time of up to 8 s it will be switched back.

2. Fast kicker magnet

In order to avoid losses of the 1.2 MW proton beam during the fast switching process, it was the original intention to dump the proton beam with the already existing magnet AVKI in the low energy (~ 870 keV) beam line between the Cockroft–Walton pre-accelerator and the 72 MeV injector cyclotron. A test experiment, however, showed that this mode could not easily be realized with stable cyclotron operation conditions. Thus, during the switching time, the proton beam cannot be turned off and it hits everything in its path. The shortest possible switching time was therefore mandatory to reduce activation of the respective beam line components. The proton beam line could be rearranged to provide about half a metre more space for the installation of the new fast kicker magnet.

2.1. Ceramic vacuum beam pipe

The vacuum chamber of the kicker magnet in the proton beam line was made using insulating material to avoid eddy currents, which would increase the switching time. The vacuum requirements in this region are determined by the neighbouring high-voltage electrostatic EHT splitter. A ceramic company provided 70 mm diameter round tubes. A flange and bellows system was brazed onto the metallized ends of the ceramic tube; Fig. 1 shows the completed vacuum beam pipe.

2.2. Magnet specifications

In order to minimise the inductance of the magnet, a window frame design was chosen. The

Fig. 1. Ceramic vacuum chamber with integrated bellows for the fast kicker magnet.