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The thermal neutron beam option for NECTAR at MLZ

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Abstract

The beam port SR10 at the neutron source FRM II of Heinz Maier-Leibnitz Zentrum (MLZ) is equipped with a moveable assembly of two uranium plates, which can be placed in front of the entrance window of the beam tube via remote control. With these plates placed in their operating position the thermal neutron spectrum produced by the neutron source FRM II is converted to fission neutrons with 1.9 MeV of mean energy. This fission neutron spectrum is routinely used for medical applications at the irradiation facility MEDAPP, for neutron radiography and tomography experiments at the facility NECTAR and for materials testing. If, however, the uranium plates are in their stand-by position far off the tip of the beam tube and the so-called permanent filter for thermal neutrons is removed, thermal neutrons originating from the moderator tank enter the beam tube and a thermal spectrum becomes available for irradiation or activation of samples. By installing a temporary flight tube the beam may be used for thermal neutron radiography and tomography experiments at NECTAR. The thermal neutron beam option not only adds a pure thermal neutron spectrum to the energy ranges available for neutron imaging at MLZ instruments but it also is an unique possibility to combine two quite different neutron energy ranges at a single instrument including their respective advantages.
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1. Introduction

The project was motivated by the intentions to make a pure thermal neutron beam available for neutron radiography and tomography measurements at MLZ. Not only would this option extend the spectral range of the neutron energies in addition to the existing radiography and tomography facilities ANTARES operated at a cold/thermal neutron beam port and NECTAR operated at a fission neutron beam port, but also it would offer an unique possibility to combine the data measured by a pure thermal neutron spectrum and a fission neutron spectrum at the same instrument. Their combination promises to give special contrast for hydrogen. Data from fission neutron tomography can be combined with additional structural information from the thermal neutron tomography data. In that case the limited spatial resolution for fission neutron radiography and tomography can profit from the additional information gained with thermal neutrons, which may then be used for instance for mapping the hydrogen distribution in fuel cells or hydrogen storage materials. Fission neutron data, e.g. a hydrogen distribution, could be used for scattering corrections during the data evaluation of imaging data acquired with thermal neutrons. As the converter plates at the tip of the neutron beam tube SR10 may be removed via remote control, it is possible to simply switch between the fission neutron spectrum and the thermal neutron spectrum. Thereby the main components of the existing instrument are kept unchanged. To have this option available for routine operation only slight modifications at the SR10 are necessary like the installation of a temporary flight tube or the upgrade of a B_4C filter to make it movable. A preliminary installation of a simple aperture system for thermal neutrons, an evacuated flight tube and a compact detector for thermal neutrons at NECTAR made it possible to carry out first tests and flux measurements. The thermal beam option at NECTAR is expected to reach characteristic instrument parameters which are comparable to the average values of existing state-of-the-art radiography facilities worldwide, see Lehmann et al. 2011.

The concept of the current instrumental design and necessary changes for the future thermal beam option are described in the following sections as well as additional equipment, which is foreseen to extend the capabilities of NECTAR, e.g. detector upgrades. Examples of the first data acquired with a temporary flight tube and the DELCam detector in order to verify the feasibility of the thermal beam option are given.

2. Proposed Experimental Setup

The layout of the two instruments NECTAR (technical tomography) and MEDAPP (patient treatment and material testing) is shown in Fig. 1. Neutrons are produced by fission of 235-U inside the reactor core. After moderation by heavy water a thermal neutron spectrum enters the beam tube at the front window of SR10. At this position converter plates containing 500 g of 235-U may be placed, which when triggered by thermal neutrons are producing fission neutrons. After passing the instrument shutters, two permanently mounted filters (10 mm B_4C and 10 mm Pb) and other movable filters mounted on a filter bench, these fission neutrons are available inside the irradiation room of MEDAPP or at the sample position of NECTAR, see MLZ et al. (2015) / NECTAR / MEDAPP and Bücherl et al. (2011). By moving the converter plates to their stand-by position and removing the currently permanently mounted B_4C filter, it is possible to irradiate samples with a pure thermal neutron spectrum at both sample positions. Therefore, the thermal filter should be installed on the filter bench combined with the filter used for medical irradiation which is positioned by an electro-pneumatic drive and can be removed from the beam remotely. A modular collimator consisting of a set of apertures is proposed to replace the current collimator. It allows for a compact design yet making several different L/D ratios available. A sketch of the basic concept is shown in Fig. 2a. Inside or between the main collimator modules additional filter elements could be placed, e.g. lead or cadmium. This would result in an even more flexible collimator system. In order to prevent losses caused by air scattering and to minimize the risk of activation of equipment a flight tube (Fig. 2b and 2c) has to be installed at the MEDAPP irradiation room, either evacuated or filled with helium. Without a flight tube the flux at the sample position is expected to be less by approximately 30%. It can only be placed temporarily and has to be removed for treatment of patients at MEDAPP, which is the reason why a single person should be able to install or remove it without any additional equipment.