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#4-200 Optimization of a new neutron imaging station at the CROCUS zero-power reactor

We outline the development and optimization of a neutron imaging beamline at the CROCUS zero-power research reactor by the means of Monte Carlo simulations. Neutron imaging is a radiographic technique that uses neutrons, providing advantages due to its sensitivity to light elements, such as hydrogen. It has the potential to support neutron imaging, serving as a neutron source for this technique. Neutron imaging provides a non-destructive way to analyse internal structures and material compositions in which are found important for applications in material science, nuclear engineering, and cultural heritage studies. For example, new hydrogen-based materials (Yttrium hydrides moderators) are being explored for small modular reactors, and neutron imaging is useful for iterating and verifying these new materials. CROCUS has a unique geometrical properties that need to be taken into account in the design of a neutron imaging station. For instance, an already existing irradiation channel in the concrete shielding is conveniently located at mid-core height, non-tangential but direct, allowing for flexible detector placement in a range from 0.5 to 7 meters to the core centre. The irradiation channel has an aperture of 30 cm, thus taking the advantage of the collimated neutrons exiting the core and entering the channel, making them suitable for neutron imaging. A neutron imaging detector can be flexibly installed behind the channel. In order to estimate neutron fluxes and spectra in possible detector locations, we employed the Serpent 2 Monte Carlo code. Initial simulations revealed that the reactor' s default configuration was unsuitable due to a very low neutron output in the irradiation channel behind the 30 cm water thick reflector of CROCUS. To address this, several design iterations were tested, including introducing an air channel (i.e. an empty tube submerged into the water) in the reactor reflector to increase neutron intensity. Our simulations show that an added air channel, namely, a plastic tube of diameter 10 cm and 25 cm length, would increase the neutron flux by 50 folds. Other parameters, like the air channel's diameter and length, were further optimized, e.g. by shortening the channel and allowing a water section between it and the fuel to further convert fast neutrons to thermal neutrons without significantly decreasing flux. The reactor configuration with optimized air channel was then chosen as the basic design for a proof-of-principle experiment.

Following the computational optimization, first neutron radiography measurements will be performed at CROCUS in Spring 2025. The imaging system is composed of a commercial neutron imager ("MIDI") which includes an ANDOR DW936N-#BV (Ikon-L) CCD camera cooled to −62℃, paired with a Zeiss Makro-Planar 2/100 ZF.2 T* lens, providing a 77 mm x 77 mm field of view (up to 150 mm * 150 mm possible, depending on the beam size). The system captures images at a resolution of 2048 x 2048 pixels with a pixel size of 0.038 mm, a focal length of 0.5 m, and a readout speed of 0.33 µs per pixel. We plan to further optimize these parameters to produce the highest possible resolution of neutron images. In this contribution, we present the design optimization and results of the first experiments and compare them to similar neutron imaging efforts such as the station in VR-1 reactor in Czech republic and AKR-2 in Germany. Further developments are planned to enable computed tomography, mixed fast and thermal imaging and gamma radiography. Once commissioned, we also plan to open the neutron imaging facility to other scientific and industrial users as a potential national platform for neutron imaging, in support of higher-end imaging facilities like the ones (NEUTRA, ICON, BOA) at the Swiss Spallation Neutron Source SINQ, PSI.

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