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Time-of-Flight Neutron Imaging for Material Identification and Characterization

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Neutron imaging is a non-destructive, spatially resolved technique that is frequently employed to analyze samples for which x-rays have a low penetration capability or provide poor contrast. While in many cases even complex structures can be mapped using a broad neutron energy spectrum without energy-resolution (white beam imaging), some sample properties only provide sufficient contrast at selected neutron energies. In addition, energy-resolution is frequently required to obtain quantitative information on a sample. Energy-resolved neutron imaging is even capable of probing information that is completely inaccessible to x-ray techniques, such as the atomic composition down to the isotope level.

For neutrons with energies up to the thermal region, velocity selectors and monochromators can be used to generate monoenergetic neutron beams. However, these components reduce the neutron flux significantly. A much more efficient approach to obtain energy-resolved information is to use the time-of-flight (ToF) technique at a pulsed beamline. The ToF approach is also viable for the higher energy neutrons where velocity selectors and monochromators stop working but which are required for example to measure the atomic composition via neutron resonance imaging. While ToF is a standard technique for neutron diffraction, most neutron imaging detectors do not provide the necessary timing resolution. In recent years, the development of different types of event-mode imaging detectors that provide significantly better timing resolution increased the use of ToF also in the imaging community.

This presentation will focus on the material properties that can be probed with ToF neutron imaging, showcasing different measurements where the techniques have been used. This includes the mapping of crystallographic information via Bragg-edge imaging, magnetic fields via polarized neutron imaging, and atomic composition of light and heavy elements via fast and epithermal neutron imaging. While for example the atomic composition measurements have already been used for of nuclear fuel characterization, the presentation should mainly provide a basis for discussions on new ways in which ToF neutron imaging can be used to support fusion and nuclear applications.

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