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Development of energy-selective and element-sensitive imaging using a compact D-D fast neutron generator

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This work is focused on the development of energy-selective techniques using a compact Deuterium-Deuterium (D-D) fast neutron generator. This was done in the context of a custom D-D generator located at the Paul Scherrer Institute which was specifically developed to have a small emitting spot size for transmission imaging purposes [1]. The basis of this study lies in the physics of the D-D fusion reaction: the neutrons produced are quasi-monoenergetic with an energy dependent on emission angle from roughly 2.2 to 2.8 MeV, based on the acceleration voltage limitation of the device. Samples can therefore be imaged at different emission angles corresponding to different neutron energies. Since neutron cross-sections have energy dependence unique to each element (unlike X-rays), this combination of information from different angles can be used in principle to distinguish one element or chemical from another. The inverse can also be performed; instead of determining the content of an unknown sample, measurements of a known and uniform sample can be used to produce cross-section data.

The first steps of this investigation included a feasibility study of these techniques. Detailed angle-dependent source emission spectra models were created according to different target composition assumptions. These models were used to estimate attenuation vs. angle for several samples of known composition and thickness which have particularly prominent cross-section structures in the energy range of interest (e.g. alumina). Over the full range of emission angles, plastic scintillators were used to measure count rates with sample present, without sample, and with a shadow cone, in order to determine the sample attenuation. This was done with a custom, automated mechanical apparatus around the source. Scatter correction was also implemented based on detailed Monte Carlo simulations of the source and room geometry. The experimental attenuation data were compared with simulations and found to be in good agreement, demonstrating the fundamental feasibility of the approach.

Ongoing work aims to expand these measurements to include a range of materials which are of interest to industrial or homeland security applications. Furthermore, the next step of performing full tomographic reconstruction at multiple angles is being explored, both with simulations and measurements. The aim is to find the practical capabilities and limitations of determining the presence of materials of interest in samples of unknown composition. The latest results and progress towards this goal will be presented and discussed.

References

[1] R. Adams, R. Zboray, H.-M. Prasser - *A novel fast-neutron tomography system based on a plastic scintillator array and a compact D–D neutron generator* - **Applied Radiation and Isotopes**, 107:1-7, January 2016.

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