Phase Imaging using Neutrons

For particle physicists, neutrons are small massive particles with a confinement radius of about 10^{-15} m and a distinct internal quark-gluon structure. In quantum mechanics, neutrons are described by de Broglie wave packets whose spatial extent may be large enough to show interference effects similar to what can be observed with visible laser light or highly brilliant x-rays from synchrotron sources. Measurements of the neutron wave packet's phase shift induced by different interaction potentials have a long and distinguished history in the exploration of the fundamental properties of quantum mechanics. If such phase sensitive measurements are further combined with neutron imaging approaches, two- or even three-dimensionally resolved spatial information on the quantum mechanical interactions of massive particles with matter can be obtained.
With our recent work, we have demonstrated how a grating based *shearing interferometer* can be efficiently used to retrieve such phase images with polychromatic neutron sources of little spatial and chromatic coherence. Figure 1 shows results for a test sample made of copper (Cu) and titanium (Ti) metal rods. Neutrons delivered at the new cold neutron imaging facility (ICON) at the Swiss Spallation Neutron Source were used.

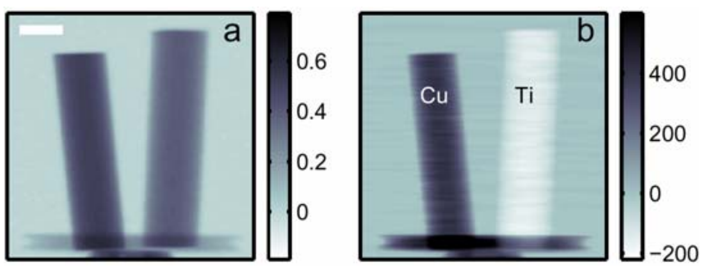

Figure 1: ***(a)*** *Conventional neutron attenuation image and* ***(b)*** *phase image of two metal rods. The scale bar corresponds to 5 mm.*

Due to the similar neutron capture cross-sections and the incoherent scattering lengths, there is not a large difference in the attenuation of the neutron beam in the rods (Fig. 1a). In Figure 1b, however, where the projected neutron nuclear phase shift is shown, a clear difference between Cu and Ti can be observed. It is interesting to note that Ti has a brighter color compared to the background, whereas Cu appears darker. This is due to the negative neutron scattering length density of Ti. Consequently, a negative phase shift is measured in the material.

Publications

- **Neutron phase imaging and tomography,**
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- **Neutron Vision**, *David Lindley*, Physical Review Focus **17**, story 20 (2006).

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