

Coherent ^{181}Ta Time-Domain Nuclear Resonant Scattering at 6.2 keV

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The 6.214 keV nuclear resonance of ^{181}Ta has exceptional application potential. For example, it is relevant to Ta-based materials science, including superconducting-qubit technologies. It also offers new opportunities in nuclear quantum optics, particularly for frequency-comb concepts. Yet systematic, time-resolved, and evaluated synchrotron data have so far been lacking.

Here we report recent experiments at ESRF beamline ID20 that close this gap by establishing coherent nuclear resonant scattering from well-prepared ^{181}Ta foils and by mapping their time response under controlled sample-preparation and magnetic-field conditions. UHV-annealed Ta foils yielded reproducible coherent forward-scattering spectra, with linewidths of about 70–80 natural linewidths.

Field-dependent measurements in longitudinal magnetic fields up to 650 mT revealed a strong enhancement of the delayed resonant signal and, most notably, a pronounced photon echo near 385 ns. This response is consistent with a frequency-comb-like magnetic level splitting of the ^{181}Ta nuclear transition.

These results establish a quantitative experimental basis for ^{181}Ta synchrotron Mössbauer spectroscopy and open new routes toward precision hyperfine studies and temporally structured nuclear resonant photons.