

Magnetic nanoparticles dynamics investigated via X-ray photon correlation spectroscopy

THE INDUSTRIAL CHALLENGE

Magnetic nanoparticles (MNPs) play a pivotal role in medical imaging, especially in the cutting-edge domain of magnetomotive ultrasound. NanoEcho is an innovative company focusing to improve cancer diagnostic tools. However, refining the design of their magnetomotive technique requires better understanding of MNP suspended in a tissue-like material. For instance, a full understanding of how MNPs respond to varying magnetic fields of the probe is important. Therefore, the *operando* analysis would offer a valuable insight into specific process parameters that could elevate contrast. This would ultimately increase the efficacy of diagnostic tools and lead to enhanced healthcare outcomes.

WHY USING A LARGE SCALE FACILITY

Photon correlation spectroscopy employing visible light is a common laboratory method for investigating the dynamics of suspended particles. However, characterizing the dynamics of nanoparticles and their response to varying magnetic fields in a tissue-like material, which is thick and opaque to visible light, requires a more penetrating light. Fortunately, X-rays have indeed this power making the X-ray Photon Correlation Spectroscopy (XPCS) the most suitable method for such investigation. The method relies on the highly coherent X-rays produced by synchrotron sources, such as ESRF-EBS and MAX IV.

HOW THE WORK WAS DONE

The XPCS experiment was carried out at the ID10 beamline at ESRF-EBS (France) where the technique also was pioneered. The geometry was adapted to accommodate NanoEcho's probe, which controls the magnetic field, and the phantoms (Fig. 1). Custom sample holders (phantoms) were 3D printed to fit within the experimental requirements. Samples were composed of MNPs suspended in tissue-like material, e.g., polyvinyl alcohol gel matrix. Each sample was positioned in a 40 μm focused beam and its speckle patterns (Fig. 2) were collected at 10 ms intervals by a detector 6.8 m downstream. Radiation

damage due to the intense X-ray beam required frequent sample renewal by shifting to a fresh measuring position. Series of speckle patterns were collected for MNP samples of different types, concentrations, and process parameters (e.g., intensity and frequency of the probe's magnetic field).

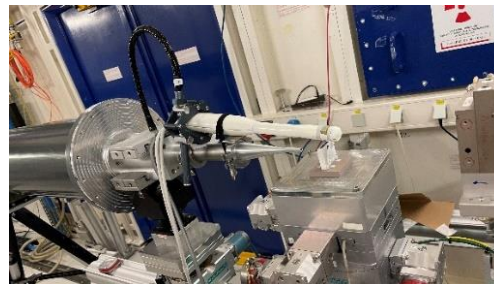


Figure 1. XPCS setup at ID10, ESRF, including NanoEcho's prototype probe and 3D printed sample holder. The beamline's standard XPCS.

For each time series, speckle patterns were correlated to obtain the time-averaged temporal autocorrelation function of the scattered intensity.

THE RESULTS AND EXPECTED IMPACT

The autocorrelation functions obtained from the *operando* XPCS experiment confirmed the expected periodic behaviour of MNPs under the oscillating magnetic fields generated by NanoEcho's probe.

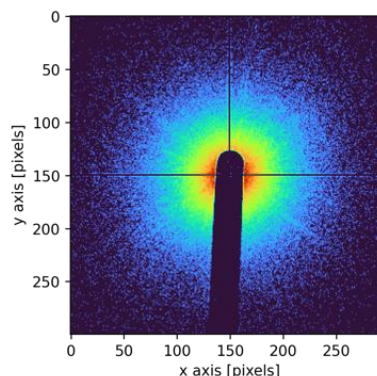


Figure 2. Raw speckle pattern on ID10's detector after 10 ms exposure.

This shed light onto anisotropic effects and variations of relaxation rate as function of process parameters (both intensity and frequency of the magnetic field), indicating under which conditions the phantom responds best.

Contacts: Magnus Santesson – NanoEcho AB, ms@nanoecho.se
 Tomas Santesson – Lund University, tomas.jansson@lund.lu.se
 Simone Sala – RISE AB, simone.sala@ri.se; and Petru Niga – RISE AB petru.niga@ri.se

Vinnova's project No: 2021-03826 **Duration:** November 2021 -- September 2023

Funded by Sweden's Innovation Agency, Vinnova, in order to build competence and capacity regarding industrial utilisation of large-scale research infrastructures such as MAX IV and ESS.