X-ray Quantum Optics with Atomic Nuclei

Ralf Röhlsberger, Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

One of the most intriguing phenomena of quantum optics is electromagnetically induced transparency (EIT): Exposing a medium to intense laser light of a certain wavelength makes it transparent for light of a different wavelength for which it would be completely opaque otherwise. After its discovery several decades ago, EIT still receives enormous interest today because it allows to control optical properties at the level of single quanta of light and matter.

With the advent of high-brilliance, accelerator-driven light sources such as modern synchrotron radiation sources or X-ray lasers, it has become attractive to extend quantum optical techniques to the X-ray regime. Recently, we have shown that phenomena like electromagnetically induced transparency can be observed in the regime of hard X-rays, using the 14.4 keV nuclear resonance of the Mössbauer isotope ^{57}Fe.

Embedding ensembles of Mössbauer nuclei in cavities and collectively exciting them with pulses of synchrotron radiation allows one to prepare superradiant eigenstates of resonant atoms. The radiative coupling of such ensembles in the cavity field can be employed to generate atomic coherences between different nuclear levels. This forms the basis for the new field of nuclear quantum optics in the regime of hard x-rays. Recently observed phenomena include slow light, Fano resonances, spontaneously generated coherences, and collective strong coupling of light and matter.