Magnon dynamics studied by time-resolved resonant X-ray scattering

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Abstract

Coherent elastic scattering, namely, nuclear resonant scattering (NRS) unites a number of different scattering processes that can be used to investigate properties of condensed matter especially of magnetic structures. Since NRS is an X-ray technique, it opens the possibility to combine it with diffraction methods to obtain very high spatial resolution down to atomic length scales. For example, nuclear resonant X-ray diffraction in grazing incidence geometry can be used to determine the lateral magnetic configuration in a lattice of ferromagnetic nanostructures [1]. However, also spin dynamics can be probed by nuclear resonant scattering of synchrotron radiation [2]. Here a single coherent mode is induced by resonant excitation with radio frequency magnetic fields and mapped by NRS.

By exploiting the time structure of the synchrotron in a pump-probe experiment ultrafast and precise control of quantum systems at X-ray energies can be studied. These energies involve photons with oscillation periods below one attosecond. Coherent dynamic control of quantum systems at these energies is one of the major challenges in hard X-ray quantum optics. We demonstrate that the phase of a quantum system embedded in a solid can be coherently controlled via a quasi-particle with sub-attosecond accuracy. In particular, we tune the quantum phase of a collectively excited nuclear state via transient magnons with a precision of one zeptosecond. These small temporal shifts are monitored interferometrically via quantum beats between different hyperfine-split levels. This experiment demonstrates zeptosecond interferometry and shows that transient quasi-particles enable accurate control of quantum systems embedded in condensed matter environments [3, 4].

References

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