NUCLEAR RESONANT SPECTROSCOPY: FRONTIERS AND APPLICATIONS

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The remarkable development of accelerator-driven light sources such as synchrotrons and X-ray lasers with their highly brilliant X-rays has brought quantum and nonlinear phenomena at X-ray energies within reach. In this contribution I will describe the development and progress of this field over the last decade and identify future research areas that will be stimulated by this evolution.

Nowadays, x-ray photonic structures like cavities and superlattices are employed as new laboratory to realize quantum optical concepts at x-ray energies. The prime candidates to be chosen as atomic emitters in this field are Mössbauer isotopes. Their extremely small resonance bandwidth facilitates to probe fundamental phenomena of the light-matter interaction like the observation of single-photon superradiance and the collective Lamb shift [1] as well as electromagnetically induced transparency with nuclei [2]. Further striking applications include spontaneously generated coherences [3], the reduction of the group velocity of light to a few m/s [4] and Rabi oscillations between nuclear ensembles [5], that could open new avenues towards nonlinear interactions between x-rays and matter. Ultranarrow nuclear resonances like those of ^{229}Th and ^{45}Sc could facilitate the realization of nuclear clocks with unprecedented accuracy.

Employing higher-order coherences of x-ray fields in the spirit of Glauber could even lead to novel concepts for quantum imaging at x-ray energies [6,7] with outstanding spatial resolution, e.g., for the determination of biomolecular structures. The future development of high-brilliance x-ray sources holds great promise for further breakthroughs in this exciting field.

Eventually, the realization of novel x-ray sources like the x-ray free-electron laser oscillator (XFELO) [8] with its extreme spectral brightness and unprecedented mode degeneracy opens perspectives to efficiently realize nonlinear optical effects like x-ray parametric down-conversion from which nonclassical states of light in the x-ray regime could be generated.

References

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