Waveguide QED with M"ossbauer Nuclei

P Andrejić[1], L M Lohse[2,3], and A Pálffy[4]

[1] *Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany*
[2] *DESY, Hamburg, Germany*
[3] *University of Göttingen, Göttingen, Germany*
[4] *University of Würzburg, Würzburg, Germany*
Contact Email: petar.andrejic@fau.de

Grazing incidence X-ray waveguides have become a well established platform for X-ray quantum optics. In these systems, X-rays are scattered resonantly by Mössbauer transitions in atomic nuclei. Due to the indistinguishability of the nuclei and the recoil-free Mössbauer transititions, the collective emission and absorption of radiation plays a large role. Recently a formalism has been developed to describe the collective nuclear response using the classical electromagnetic Green's function for the waveguide [1,2]. However, so far these works have considered only translationally symmetric systems, and plane wave driving fields. In this regime, the spatial structure of the nuclei in the direction of propagation is insignificant, and pure single mode Dicke super-radiance is observed.

We show that driving the waveguides at forward incidence instead allows for direct excitation of multiple guided modes, with centimetre scale attenuation lengths. In this regime, the embedded Mössbauer nuclei absorb and emit collectively into a super-position of these modes, with the resultant radiation field displaying pronounced interference beats on a micrometre scale. We show that this interference pattern leads to sub-radiance of the nuclear ensemble, with suppression of the dynamical beat at certain critical waveguide lengths. We also consider structuring the nuclear ensemble into micrometre scaled patches, and show that it is feasible to engineer the resultant inter-nuclear coupling to create mesoscopic hopping models, with potential for applications in quantum simulation and experimental exploration of mesoscopic quantum dynamics [3].

References

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