ESRF	**Experiment title:** The Lamb Shift in Collective Nuclear Resonant Scattering	**Experiment number**: HS 4099
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Report:

The interaction of many identical two-level atoms with a common radiation field leads to a profound modification of the temporal, directional and spectral characteristics of their collective emission compared to that of a single atom. A prominent example is the phenomenon of superradiance that manifests as a strong acceleration of the collective spontaneous emission [1]. A multitude of superradiant and other cooperative optical phenomena have then been studied in the regime of visible light, particularly after short-pulsed laser systems became available for time-resolved studies. Later it was noticed that the superradiant emission goes along with a radiative shift of the transition energy, the collective Lamb shift [2,3]. In the optical regime this shift appeared to be extremely difficult to observe due to its small magnitude and atom-atom interactions masking it.

The availability of pulsed x-ray sources (synchrotron storage rings and X-ray lasers) and nuclear two-level systems with transition energies of several 10 keV a.k.a. Mössbauer isotopes, makes it possible to study cooperative effects also in the regime of hard X-rays. The outstanding energy resolution of the Mössbauer effect enables one to analyze spectral properties of the cooperative emission with very high accuracy. In this experiment, we succeeded to observe the collective Lamb shift for single-photon superradiant emission from ensembles of ^{57}Fe atoms [4], see Fig. 1. An essential feature of this experiment is the use of a planar low-Q cavity in which the ^{57}Fe atoms were embedded and from which the X-rays were resonantly reflected under grazing angles of a few mrad [5].

The experiment resulted in a publication in *Science* in the same year [4].

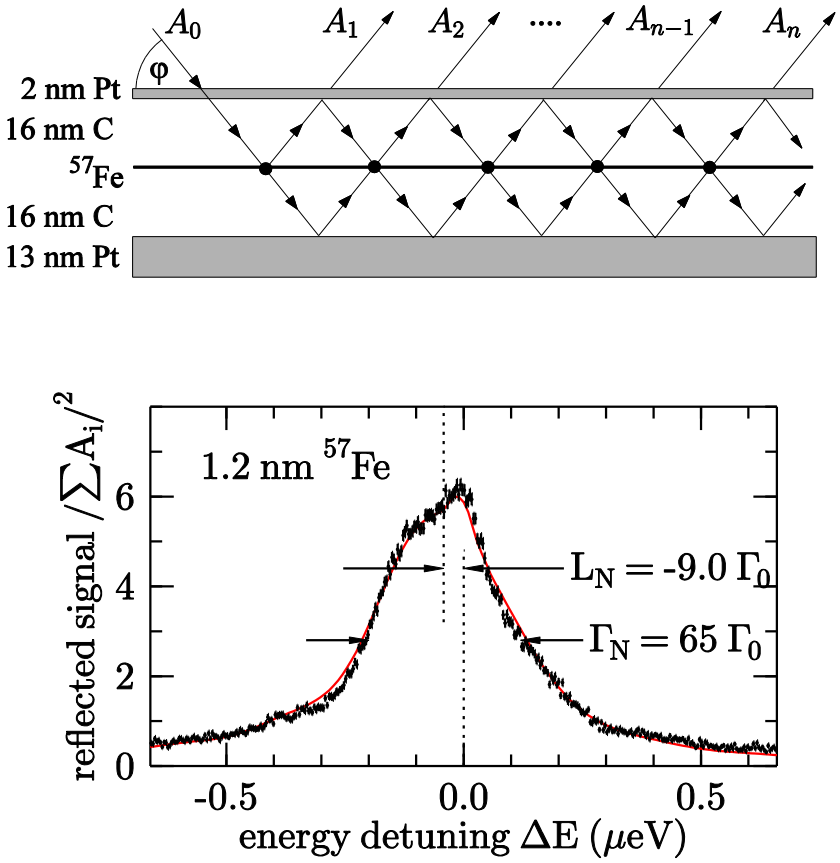

Fig. 1. Top: Geometry of a planar x-ray cavity to study the properties of superradiant cooperative emission from an ultrathin layer of ^{57}Fe atoms embedded in the center of the guiding layer. Bottom: Measured spectral response from a 1.2 nm thick layer of ^{57}Fe embedded in the cavity. Superradiant emission manifests as a homogeneous spectral broadening of 65 times the natural linewidth Γ_0. The collective Lamb shift is the displacement of the center of mass of the curve by -9.0 Γ_0.

References

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