Superradiance with X-Rays in Free Space

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Superradiance, *i.e.*, spontaneous emission of coherent radiation by an ensemble of N two-level atoms in collective states, is one of the enigmatic problems of quantum optics [1,2]. The startling gist is that although the atoms have no dipole moment they radiate with intensity $\sim N^2$ in particular directions. We recently investigated the spatial aspects of superradiance for fixed but distant non-interacting atoms spontaneously emitting in free space [3-5]. In our model, the correlations among the particles are produced via successive measurements of photons at particular positions such that the detection is unable to identify the individual photon source. In this case, the initially fully excited atomic system steps down the ladder of symmetric Dicke states each time a spontaneously emitted photon is recorded [4,5]. Detecting m photons from N > m atoms amounts to measuring the m-th order photon correlation function. Measuring this function allows (a) the production of any symmetric Dicke state of the initially uncorrelated atoms and (b) the observation of the superradiant emission pattern of the resultant Dicke state. As it turns out the same technique is also applicable for initially uncorrelated incoherent classical sources [6]. We applied this scheme to demonstrate directional superradiance in the X-ray domain with light at $\lambda = 13.2$ nm from the FLASH free-electron-laser facility at DESY, Hamburg, made incoherent by a diffuser.

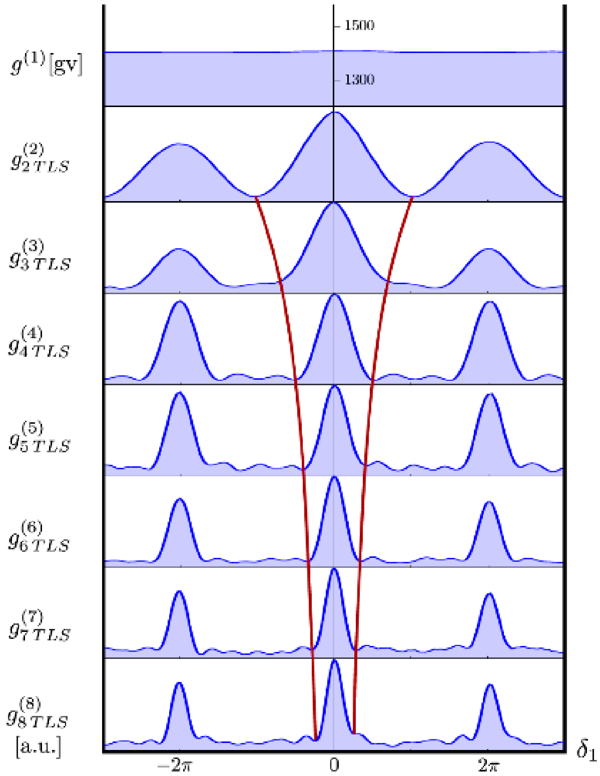

Figure 1: Normalized m-th order photon correlation function for m = 1,..., 8 as a function of the position of the 1-st detector for N = m statistically independent classical light sources. The sources are aligned equidistantly along a line and emit incoherent XUV photons at 13.4 nm. For m = 2,..., 8, the focussed emission of the m-th photon at $\delta_1 = 0$ after m-1 photons have been recorded at δ_2 , ..., $\delta_{m-1} = 0$ is clearly visible

References

[1] R H Dicke, Phys. Rev. **93**, 99 (1954)

[2] M O Scully, E S Fry, C H R Ooi and K Wódkiewicz, Phys. Rev. Lett. **96**, 010501 (2006)

[3] R Wiegner, J von Zanthier,and G S Agarwal, Phys. Rev. A **84**, 023805 (2011)

[4] S Oppel, R Wiegner, G S Agarwal and J von Zanthier, Phys. Rev. Lett. **113**, 263606 (2014)

[5] R Wiegner, S Oppel, D Bhatti, J von Zanthier and G S Agarwal, Phys. Rev. A **92**, 033832 (2015)

[6] D Bhatti, S Oppel, R Wiegner, G S Agarwal and J von Zanthier, Phys. Rev. A **94**, 013810 (2016)