A single emitter emitting resonance fluorescence into a coherent beam

T. Lamich[1], **L. Zarraoa**[1], **S. Elsehimy**[1], **R. Veyron**[1], **M. W. Mitchell**[1,2]

[1] *ICFO - Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels, Barcelona, Spain*
[2] *ICREA - Institució Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain*

Resonance fluorescence from a single emitter is a paradigmatic quantum light source, in which a two-level system is coherently driven by laser light, and in response emits light that is anti-bunched, squeezed, and entangled. In 2021, Goncalves et al. [1] studied a variant of resonance fluorescence, in which the driven single emitter is placed in a probe beam containing a weak coherent state, a scenario that allows for both interference of laser light against resonance fluorescence, and stimulated emission by a single emitter.

We present an experimental implementation of the Goncalves et al. scheme, focussing on the exotic non-classical correlations produced in this way. A number of interesting and potentially useful features are predicted by Goncalves et al., including (under different conditions of pump-probe relative phase and power) the complete extinction of the probe, amplification of the probe and generation of extremes of antibunching and bunching, i.e., $g^{(2)}$ approaching zero or infinity. The predictions for transmitted power and $g^{(2)}$ can be given in terms of a single parameter, an effective coupling efficiency suggesting that interference can be used to make up for geometrical and technical limitations on the coupling to single atoms.

We use a single atom far-off-resonance trap in a "Maltese cros" geometry of four high numerical aperture lenses [2] to realise the interaction between a ^{87}Rb atom, a strong pump beam, and a weak probe beam as described in the proposed scheme [1]. We will present a scheme for using the transmission measurement not only to show the interference effects but also to sort individual atoms based on the relative pump-probe phase at the moment of measurement, thus achieving the post-measurement phase stabilisation necessary for the $g^{(2)}$ measurements.

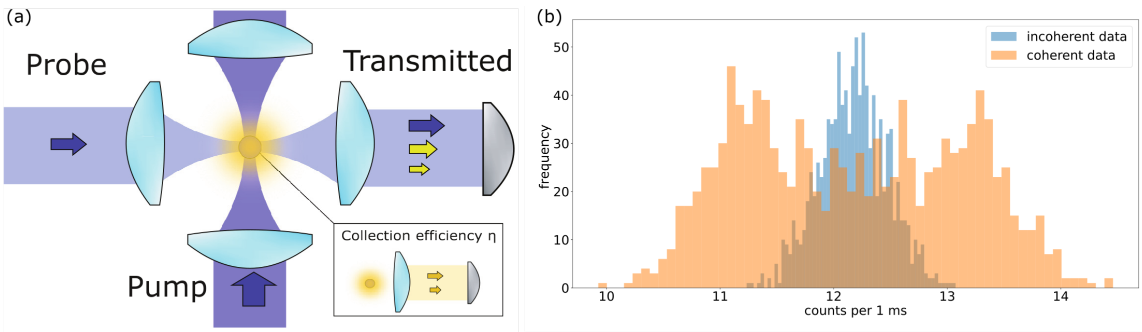

FIG. 1: (a) A strong pump beam excites a single atom acting as a single two-level emitter, while a weaker probe beam is also focused on the atom [1]. (b) Observation of phase-sensitive $g^{(1)}$ correlations in the transmitted probe beam. The blue histogram shows collected photons per millisecond averaged over the pump-probe phase, and the orange histogram shows the same with a nearly constant phase. The resulting arcsine-like distribution makes evident the interference of laser and resonance fluorescence light.

References

[1] D. Goncalves, M. W. Mitchell, et al. *"Unconventional quantum correlations of light emitted by a single atom in free space"*. In: Phys. Rev. A 104 (1 2021), p. 013724. doi:10.1103/PhysRevA.104.013724.

[2] L. C. Bianchet, N. Alves, et al. *"Manipulating and measuring single atoms in the Maltese cross geometry"*. In: Open Research Europe 1.102 (2022). doi: 10.12688/openreseurope.13972.2.