Observation of superradiant emission on a narrow intercombination

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Cold samples of calcium atoms are prepared in the metastable $^3P_1$ state inside an optical cavity resonant with the narrow band (375 Hz) $^1S_0 \rightarrow ^3P_1$ intercombination line at 657 nm. We observe superradiant emission through hyperbolic secant shaped pulses released into the cavity with an intensity proportional to the square of the particle number, a duration much shorter than the natural lifetime of the $^3P_1$ state (Fig. 1), and a delay time fluctuating from shot to shot in excellent agreement with theoretical predictions [1]. Our incoherent pumping scheme to produce inversion on the $^1S_0 \rightarrow ^3P_1$ transition should be extendable to allow for continuous wave laser operation. This laser would operate in the so called bad-cavity regime, which can in principle lead to extremely narrow emission linewidth [2], immune to fluctuations of the laser cavity length.

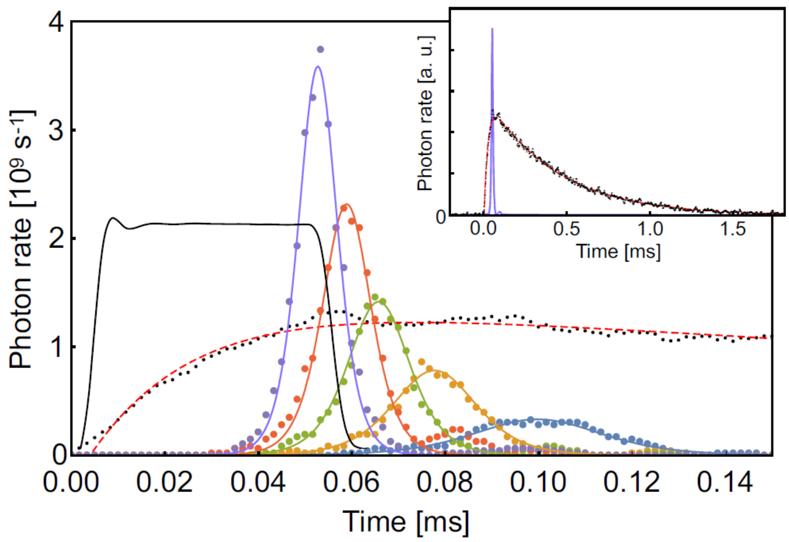

Figure 1. The inset (upper right corner) compares the natural non-cooperative exponential decay with an observed life time of 420 µs (black dots) with the case when a short (≈ 10 µs) superradiant pulse is emitted (blue graph). The red dashed line is a fit with two exponential functions. In order to present both graphs in the same plot, their vertical axes are scaled differently. The main panel shows superradiant light pulses for particle numbers N = 12800, 19700, 26500, 34000, 42300 from right to left. The solid black line indicates the pump pulse that acts to populate the $^3P_1$ state. The black dots, modeled by the dashed red line graph, repeat the natural decay curve of the inset.

[1] M. Gross and S. Haroche, Phys. Rep. 93, 302 (1982).

[2] D. Meiser, J. Ye, D. R. Carlson, and M. J. Holland, Phys. Rev. Lett. 102, 163601 (2009).