A Single Atom Interacting with Light in Free Space

G. Leuchs

1. Max Planck Institute for the Science of Light, Staudtstrasse 2, 91058 Erlangen, Germany
2. Department of Physics, University of Erlangen-Nürnberg, Staudtstrasse 7 / B2, 91058 Erlangen, Germany
3. Department of Physics, University of Ottawa, 25 Templeton Road, Ottawa, Ontario, K1N 6N5, Canada
4. Institute of Applied Physics, Russian Academy of Sciences, 46 Ul'yanov Street, 603950, Nizhny Novgorod, Russia

One might regard the emission and absorption of light by a single atom in free space as one of the most fundamental processes in quantum optics, which has not yet been fully explored on the experimental side:

1. A single atom should be able to act as an efficient 100% reflector for narrow band coherent light provided the light power is not too high.
1. A single atom should be able to efficiently shift the phase of a narrow band coherent light by up to 180° if the light power is not too high. (First results, see [1].)
2. A single photon should be able to deterministically excite a single atom.

We are developing and testing a set-up for the demonstration of this reversal of spontaneous emission by placing a single atom at the focus of a deep parabolic mirror. Using an ionized atom one can hold it in place by electrodes, a variation of the Paul trap for ions. It is expected that such a 100% excitation by a single atom require sending in the time-reversed version of the photon, which would be emitted by the same atom if it were to decay. Regarding the spatial structure, a parabolic mirror generates the required ingoing spherical wave fronts. Concerning the temporal shape, the single photon wave packet should have an exponentially rising leading edge as opposed to the exponentially falling trailing edge of the wave packet created in a spontaneous emission process [2].

References

[1] M. Fischer, B. Srivathsan, L. Alber, M. Weber, M. Sondermann, G. Leuchs, Appl. Phys. **B 123**, 48 (2017).
[2] M. Stobinska, G. Alber, and G. Leuchs, Euro Phys. Lett. **86**, 14007 (2009).