A fast and bright source of coherent single-photons using a quantum dot in an open microcavity

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A semiconductor quantum dot is a potentially excellent source of single photons: the radiative lifetime is sub-nanosecond, just tens of picoseconds following Purcell enhancement in a cavity, allowing the creation of billions of photons per second; the interaction with phonons is relatively weak such that successively emitted photons exhibit a high degree of two-photon interference. Significant challenges are to create an efficient source, and to reduce the noise such that photons created far apart in time also exhibit a high degree of two-photon interference. We show how these challenges can be met by embedding a gated quantum-dot in an open microcavity.

In our gated devices, quantum dots exhibit near transform-limited linewidths, both at wavelengths in the near infrared (920–950 nm) and in the near-red (around 780 nm). A microcavity is constructed using a planar semiconductor "bottom" mirror (part of the semiconductor heterostructure) and a curved "top" mirror. With a very high-reflectivity top mirror, a single quantum-dot enters the strong-coupling regime of cavity-QED with a cooperativity exceeding 100 [1]. Clear vacuum Rabi-oscillations are observed. With a modest-reflectivity top mirror, an efficient single-photon source is demonstrated [2]. The end-to-end efficiency, the probability of creating a single photon at the output of the experiment's final optical-fibre following a trigger, is 57%; the photon purity $(1-g^{(2)}(0))$ is 97.9%; the two-photon interference visibility is 97.5% and is maintained even on interfering photons far apart in time (1.5 μs in the experiment).

The future potential of this platform both as a realisation of the canonical "one-dimensional atom" and as a source of more complex photonic states will be discussed.

References

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