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Indistinguishable near infra-red single photons from an individual organic molecule

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Over the past decade, the quest for photon-based quantum information processing schemes has fueled interest in multiphoton interference phenomena. In particular, linear optics quantum computation and quantum teleportation require the effect of two-photon quantum interference between single photons on a beam-splitter [1]. Ideally, a light source that delivers on demand single photons with similar wavepackets is desired for these applications. The indistinguishability of the photons generated by single quantum emitters was tested with two-photon quantum interference, for different test-bench systems like trapped atoms or ions in the gas phase [2-4]. Yet, these systems suffer from weak duty cycles or low light collection efficiency, as well as challenging methods for scaling to large numbers of emitters. Solid-state emitters such as semiconductor quantum dots were used to demonstrate the photon coalescence and to produce post-selected entangled states [5], but they usually display residual dephasing and spectral diffusion processes which spoil the coherence properties of the emitted photons. Individual fluorescent molecules in solids are another promising alternative for single photon generation [6-7]. At liquid helium temperatures and for well chosen fluorophore-matrix systems, dephasing of the transition dipole due to phonons is drastically reduced. Such molecules behave like two-level systems with a fluorescence quantum yield close to unity, thus offering optical properties similar to those of trapped single atoms. Moreover, the photostability of organic molecules trapped in crystalline hosts is excellent at cryogenic temperatures, and allows continuous optical measurements over days.

Using the zero-phonon line emission of an individual organic molecule, we realized a source of indistinguishable single photons in the near infrared. We performed a Hong-Ou-Mandel coalescence experiment and we observed a two-photon interference contrast as high as 50% at 2 K comparable to values obtained for self-assembled quantum dots in microcavity structures. This analysis suggests that dephasing of the molecular transition dipole due to phonons in the crystalline matrix is negligible at 2 K, enabling a single DBT molecule to deliver indistinguishable single photons. Yet, a quantitative study of the photon coalescence degradation by dephasing processes is required to verify the potentialities of this single photon source in quantum information processing. We quantitatively studied the photon coalescence degradation by dephasing processes due to the finite temperature of the matrix host, and we show that the coalescence efficiency drops by a factor of ten upon increasing the temperature from 2 K to 5 K. We show that this lost of coherence is in agreement with the temperature dependence of the ZPL widths [8].

Références

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