Remote two-photon interference at 1550 nm via quantum frequency conversion of quantum dot photons

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Currently, numerous research activities in the field of quantum communication focus on demonstrating fundamental building blocks of quantum networks, such as quantum memories or quantum repeaters [1]. Ideally, a quantum repeater network utilizes a pool of identical emitters that provide indistinguishable single photons. A basic test to asses quantum emitters for this task is a Hong-Ou-Mandel (HOM) type two-photon interference experiment between photons stemming from remote single photon sources. In contrast to trapped atoms and ions, single photons from identical but distinct solid state sources strongly differ from one another due to a variety of interactions between the emitter and its environment. In particular, they typically exhibit an emission wavelength mismatch much larger than their linewidth making two-photon interference impossible. Consequently, any remote HOM experiment with solid state emitters must include a tuning step to bring both photons into resonance.

In order to establish long-distance quantum networks it is inevitable to distribute the single photons via optical fibers. To minimize losses induced by the fiber-transmission, the photons are best prepared at telecom wavelengths. However, most single photon sources emit at near-infrared wavelengths instead, leading to a drastically reduced transmission-distance. This severe disadvantage can be approached by quantum frequency conversion (QFC): materials with a non-vanishing second-order nonlinearity can mediate an energy exchange between the single near-infrared photons and a coherent pump field, transducing them to telecom wavelengths. In a number of experiments it was shown that this process is both efficient and conserves all desirable single-photon properties [2-4].

In the present talk, we show results obtained from a HOM experiment between single photons in the telecom C-band [5]. The photons stem from two remote semiconductor quantum dot (QD) samples emitting around 904 nm and reveal a frequency mismatch of 8 GHz, four-fold larger than the respective linewidths. Subsequent to their emission the photons are down-converted to 1557 nm with the help of two independent QFC setups. In contrast to previous experiments, QFC is now not only employed to bridge the large gap between the near infrared and the telecom regime, but also to precisely tune both photons with respect to each other. In a series of HOM experiments at different detunings, we achieve a maximum interference visibility of $>25\,\%$, corresponding to the resonance case. Additionally, we theoretically model our results based on the separately measured spectral properties of both QDs. Theory and experiment are in very good agreement, emphasizing that the interference visibility is only limited by uncorrelated spectral diffusion and not by the conversion scheme itself. Our results further corroborate that QFC is a vital tool to establish an interface between quantum emitters and a fiber-based quantum network.

References

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