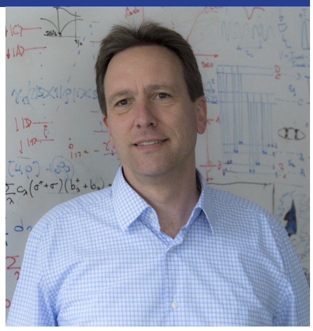
Paderborn Photonics Lecture

13.02.2019
LEcture Hall A1
16:15

Quantum frequency conversion of single photons as tool for quantum networks



Prof. Dr. Christoph Becher
Fachrichtung Physik,
Universität des Saarlandes, Saarbrücken

Abstract:
In quantum networks, remote nodes containing stationary qubits or quantum memories have to be interconnected by flying qubits, e.g. single photons. For long-range transmission, photons at telecommunication wavelengths offer minimal loss in fiber links. The majority of atomic or atom-like systems serving as stationary qubits and low-noise quantum memories, however, do not offer optical transitions at telecom wavelengths but commonly emit in the visible (VIS) to near-infrared (NIR) range. Thus, there is a demand for interfaces connecting the telecom-wavelength regime and the visible/NIR range while preserving quantum information encoded in a degree of freedom of a single photon, e.g. its polarization. One possible implementation of such an interface is quantum frequency conversion (QFC) of single photons. Furthermore, independent quantum bits are often subject to inhomogeneous line shifting or broadening effects, rendering distinguishable the photons which are emitted from these systems. Here, a method for erasing frequency differences between such photons would e.g. enable creation of remote entanglement of stationary quantum bits by quantum interference of indistinguishable photons. In my presentation I will show two examples for tackling these problems:
As an example for interfacing via QFC we present a complete device that produces entangled states between an atomic Zeeman qubit in a single trapped $^{40}Ca^{+}$ ion and the polarization state of a telecom photon with a high fidelity. We achieve this building upon an efficient polarization-preserving frequency converter connecting the Ca+ wavelength (854 nm) to the telecom O-band at 1310 nm. We further show that the QFC device leaves almost unaltered the atom-photon entanglement with a fidelity of ~ 98% [1].
As a second application we use QFC to transduce single photons emitted from independent semiconductor quantum dots (QD) at 905 nm to the telecom C-band at 1550 nm. Single photons are generated from the two QDs, contained in distant cryostats, via resonant pumping. Two QFC processes with efficiencies >30%, respectively, are used for highly stable and predictable frequency tuning and matching of the two emission lines to a common wavelength. The erasure of spectral differences then enables long-distance two-photon interference of two remote, independent sources in the telecom C-band [2].

[1] M. Bock et al., High-fidelity entanglement between a trapped ion and a telecom photon via quantum frequency conversion, Nature Commun. 9, 1998 (2018).
[2] J.H. Weber et al., Two-photon interference in the telecom C-band after frequency conversion of photons from remote quantum emitters, Nature Nanotechnol. 14, 23 (2019).

CeOPP
Center for Optoelectronics and Photonics Paderborn

TRR 142
Tailored Nonlinear Photonics