Spectral characterization of single photons and entangled photon pairs

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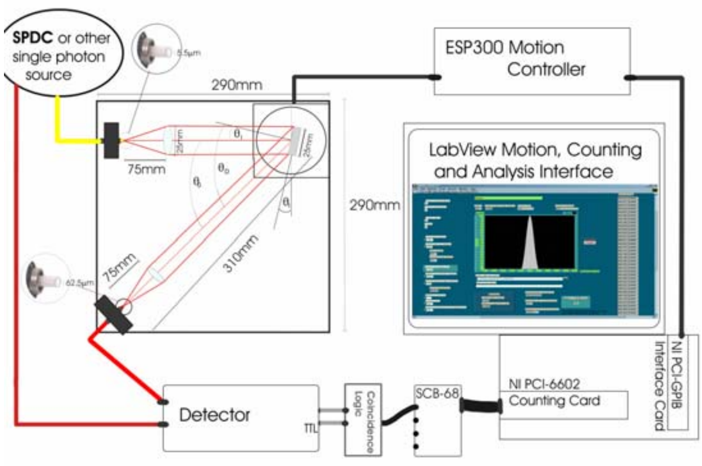
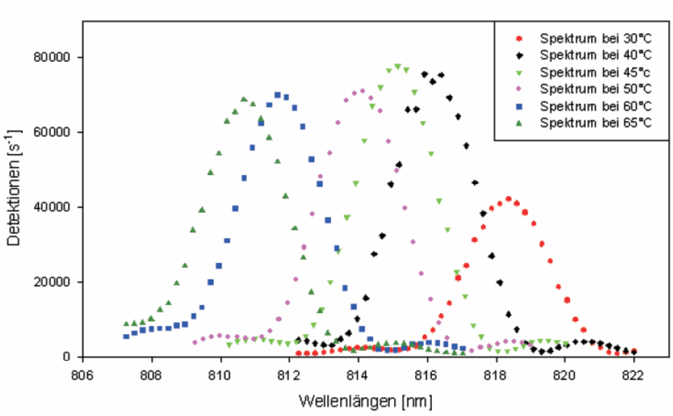
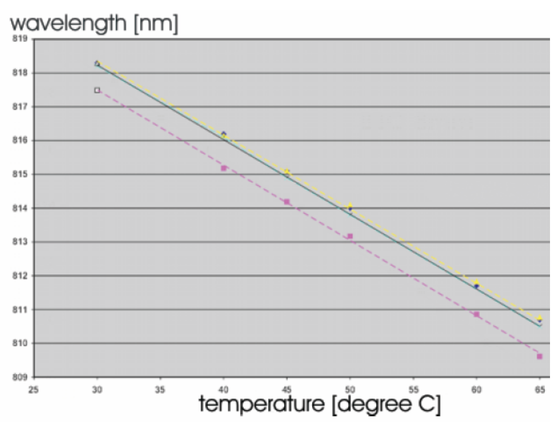
In quantum communication and cryptography experiments which utilize the properties of single-photons and/or photon pairs, knowledge of the spectral bandwidth of the photons is of great importance. Since no commercial spectrometers exist that fulfill the high demands of such experiments, a mobile fiber-coupled single-photon monochromator was constructed which possesses the necessary efficiency and resolution.



The ray of single photons from a single-mode fiber is spectrally dispersed by a rotatable reflection grating and coupled into a multi-mode fiber with a detector attached. The entrance and the detector slits are formed by the cores of both fibers with a diameter of 5.5µm and 62.5µm, respectively. Both lenses of f=75mm were chosen to maximize the illumination of the grating (1200 grooves per mm). The internal components are optimized for the near infrared wavelength range and a detector with a Si-APD is currently used. In that range a resolution of 0.21 nm and an efficiency of 14% was achieved.
The single-photon signal is optionally passed to a coincidence logic and a control-PC, which collects the data and drives the rotation stage including the grating. The whole scanning and analyzing process is automated.

The possibility of directly analyzing the spectral distribution of photons makes it possible to verify theoretical calculations, characterize and optimize entangled-pair sources, or, by an appropriate choice of filters, improve quantum-cryptographic setups. This was demonstrated for different Spontaneous Parametric Down-Conversion (SPDC) sources.





By measuring the spectra of single photons from a type-I like ppKTP SPDC source, it was possible to confirm a linear relation between the crystal's temperature and the center wavelength of the photons' spectral distribution and to tune the source. The left plot shows spectral measurements of only one crystal at different temperatures, the right one the temperature-wavelength relation for different crystals. Additionally, the bandwidth of the sources varies with the crystal length as expected.

In the near future we extend the wavelength range by the use of a gated InGaAs-detector and continue with an experimental examination of bandwidth-related effects on entanglement of photon-pairs from SPDC. Such effects are a critical factor for any applications based on quantum-interference when pulsed pump lasers have to be used [1].

[1] W. P. Grice and I. A. Walmsley, Phys. Rev. A, **56**, 1627–1634 (1997)