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Single-photon sources for quantum technologies - Results of the joint research project SIQUTE

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In this presentation, the results of the joint research project “Single-Photon Sources for Quantum Technologies” (SIQUTE) [1] will be presented. The focus will be on the development of absolutely characterized single-photon sources, on the realization of an efficient waveguide-based single-photon source at the telecom wavelengths of 1.3 µm and 1.55 µm, on the implementation of the quantum-enhanced resolution in confocal fluorescence microscopy and on the development of a detector for very low photon fluxes.

INTRODUCTION

The aim of the EURAMET joint research project “Single-photon sources for quantum technologies” (SIQUTE) was the development of highly efficient and predictable single-photon sources for a variety of application, amongst others for radiometry at the low photon flux level. The vision was to develop a single-photon source, which would be a new standard for different fields of research and application. European national metrology institutes (NMIs) and universities joined forces for this common effort.

RESULTS OF THE SIQUTE PROJECT

Within SIQUTE, a variety of results were obtained, which brings quantum technology and especially quantum radiometry further into the scope of the European NMIs. The results obtained within this project will be presented at the conference, main results are described in the following:

Absolute single-photon source [2]: An NV-centre based single-photon source was absolutely characterized and calibrated in terms of wavelength, background, second order correlation function $g^{(2)}(t)$, stability and photon flux. The photon flux was measured with a low noise silicon photodiode traceable to the primary standard for optical flux taking into account the absolute spectral power distribution using a calibrated spectroradiometer. In Fig. 1, the spectra of the NV-centre emission are shown, given in absolute photon flux per wavelength $N_{ph,\lambda}(\lambda)$ and in absolute radiant flux per wavelength $\Phi_{\lambda}(\lambda)$.

Silicon-vacancy (SiV-) centre based single-photon source [3]: The absolute photon flux of the emission of a SiV-centre in nanodiamond was directly measured with an absolutely calibrated photodetector at photon rates below 100 000 photons per second. A predictable single photon rate was achieved and used for determining the quantum efficiency of an avalanche photodiode (see Fig. 2).

Waveguide-based single-photon source [4]: A setup for the generation of single photons in the telecom band based on spontaneous parametric down-conversion (SPDC) was established. The process employed is based on the spontaneous decay of a pump photon at 710 nm into signal and idler photons at 1310 nm and 1550 nm. Very high photon pair rates up to 10^7 s^{-1}, a signal-to-background ratio of approx. 600 μW^{-1} and a heralding efficiency up to 64 % were measured. Measurements of the heralded $g^{(2)}$-functions vs. pump power yield an extremely small $g^{(2)}(t = 0) = 0.001$ at 20 nW pump power, only limited by detector dark counts. Furthermore, the photon indistinguishability was measured in a Hong-Ou-Mandel (HOM) interference experiment. The visibility was measured as a function of the pump power and reaches visibilities > 90 % for low pump powers due to the absence of detector noise and multi-photon contributions, see Fig. 3.

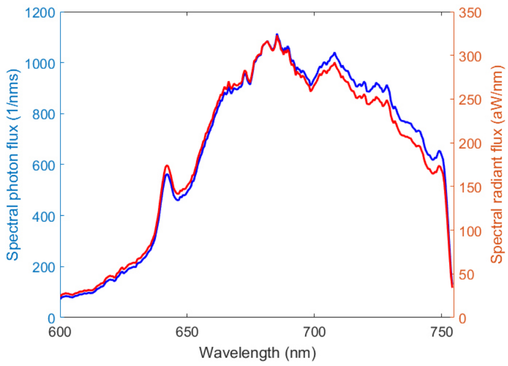

Figure 1. Spectra of the NV-centre emission: absolute photon flux per wavelength $N_{ph,\lambda}(\lambda)$ (blue line) and absolute radiant flux per wavelength $\Phi_\lambda(\lambda)$ (red line).

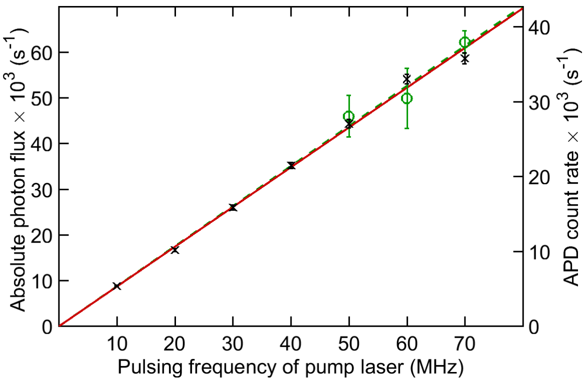

Figure 2. Circles: Photon flux measured a calibrated silicon photodetector. Crosses: APD count rates. Straight line: Fit to the data through origin.

Quantum-enhanced resolution [5] was obtained in confocal fluorescence microscopy by exploiting the non-classical photon statistics of single nitrogen-vacancy colour centres in diamond. This was achieved by developing a general model of super-resolution based on the direct sampling of the k^{th}-order autocorrelation function of the photoluminescence signal. This model shows that it is possible, in principle, to resolve arbitrarily close emitting single-photon emitters.

Detector development [6]: A transfer standard detector system able to measure 50 fW with an uncertainty below 1 % at the wavelength range from 650 nm to 750 nm was designed and realized. It consists of a low noise low dark current Si detector (Hamamatsu S1227 33 BR) in conjunction with a custom-made switched integrator amplifier (SIA), which achieves a conversion factor as high as 10^{12}. The noise level measured can be as low as 1 fW/Hz½ which corresponds to approx. 3500 photons/Hz½ at a wavelength of 750 nm. Allan deviation analysis has shown that a measurement time of 100 s should lead to a standard deviation as low as 400 photons/s.

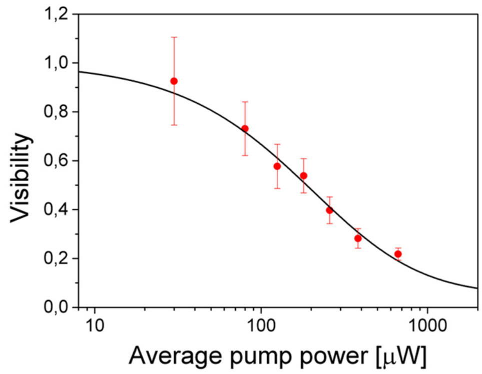

Figure 3. Visibility of the HOM dip as a function of average pump power, decreasing towards higher pump powers due to multi-photon contributions.

SUMMARY

In this contribution, the main achievements of the joint research project SIQUTE were presented.

ACKNOWLEDGEMENT

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