Characterisation of nitrogen-vacancy based single-photon sources

Beatrice Rodiek*, Marco López*, Helmuth Hofer*, Xiao-Liu Chu**,***, Stephan Götzinger**,*** and Stefan Kück*

**Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig*
***Friedrich-Alexander-Universität Erlangen-Nürnberg, 91054 Erlangen*
****Max Planck Institue for the Science of Light, Erlangen, Germany*

mailto:beatrice.rodiek@ptb.de

We present the optical characterisation of a single-photon source based on nitrogen-vacancy in nanodiamonds for its use as a standard source for calibrating single-photon detectors. The characterisation is carried out in terms of its photon rate, wavelength and anti-bunching. A photon rate of approx. 1 million photons/s with almost a perfect single-photon emission; i.e. strong antibunching, $g^2(0)$=0.06, was achieved.

1 Introduction

Nitrogen-vacancy (NV-) center based single-photon sources are promising candidates as standard sources in quantum metrology because of their negligible background and high purity in single-photon emission [1, 2]. In radiometry, unlike a strongly attenuated laser, single-photon sources are ideal for the calibration of single photon detectors, e.g. single-photon avalanche photodiodes (SPADs), because of their negligible multi-photon emission [3]. Here, the main aim is the determination of the quantum detection efficiency of the detector.

Thus, in order to assess the suitability of the single-photon source to more efficiently calibrate SPAD-detectors, we optically characterised a sample containing NV-centers, which was developed within the scope of the EMRP project SIQUTE.

2 Samples and experimental setup

The investigated nanodiamonds doped with NV-centers have a size of approx. 100 nm and are spin coated on a standard cover glass. The excitation of the nanodiamonds and the collection of the emitted photons is realised by a homebuilt confocal microscope (Fig. 1).

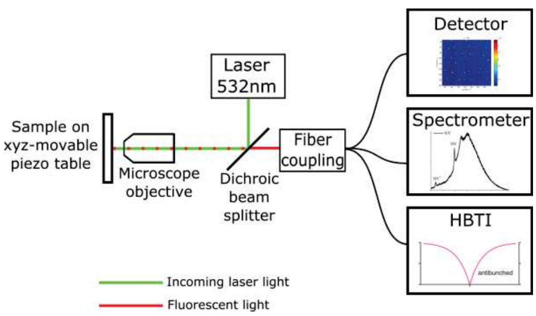

***Fig. 1** Schematic representation of the characterisation setup.*

In this setup, a 532 nm continuous wave laser is used to stimulate the colour centers. The laser beam is focused on a nanodiamond with an oil immersion objective, which is also used to collect the fluorescent emission of the NV-center. In order to achieve high photon collection efficiency, an objective with a high numerical aperture of 1.45 is used.

The fluorescence light emitted by the NV-center is coupled into a single mode optical fiber used as a pinhole in the confocal setup. This fiber optic can be connected to several setups and devices, e. g. to a spectrometer, a detector and a Hanbury-Brown and Twiss interferometer (HBTI), to determine its photon rate, spectrum and 2nd order correlation function.

3 Results

Figure 2 shows an 80 µm x 80 µm scan of the investigated sample. Each bright spot is a fluorescent emitter, which has to be optically characterised to determine its possible single-photon properties.

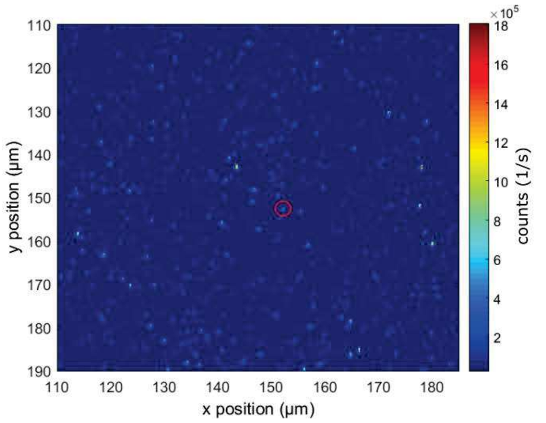

***Fig. 2** Scan of the sample; the red circled NV-center emission is characterised in detail.*

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As can be observed, the count rate of the NV-center emission, measured with a Si-SPAD, is between 200 kcounts/s and 1.8 Mcounts/s, while the background emission is approx. 30 kcounts/s.

From these NV-centers, the red-circled one was chosen for further investigations, because of its excellent single photon properties. The count rate of this emitter, determined with a Si-SPAD detector, was 576 kcounts/s, which corresponds to a photon rate of 960 kphotons/s.

The 2nd order correlation function, as a proof of the single-photon fidelity at zero time delay, is as low as 0.06 (see Fig. 3). This indicates that an almost perfect single-photon source is achieved.

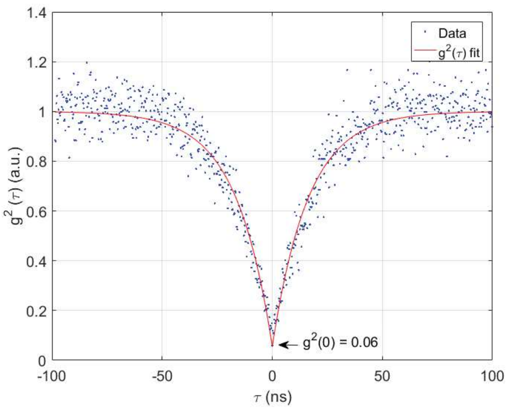

***Fig. 3** 2nd order correlation function of the NV-center circled with red in figure 2.*

The lifetime, calculated from the fitted model to the 2nd order normalized correlation function, was determined to 17 ns.

Additionally, we determined from the spectrum of the NV-center the relative spectral distribution of the emission (Fig. 4).

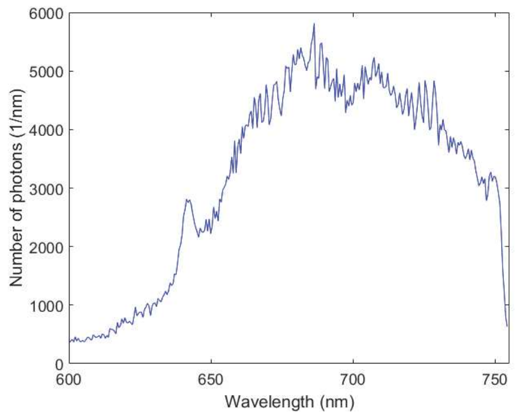

***Fig. 4** Relative spectral photon distribution of the fluorescent light emitted by the NV-center.*

Note that the steep decrease in the number of photons at 750 nm is due to use of a short pass filter in the detection path.

4 Conclusion

We have characterised an almost perfect single-photon emitter using an NV-center in a nanodiamond. The NV-center has a photon rate of approx. 1 million photons/s and the 2nd order autocorrelation function at 0 s time delay is as low as 0.06. The relative spectral photon distribution of the single-photon emission was also determined.

The characterised single-photon emitter is a promising candidate to be used as standard source for the calibration of single-photon detectors because of its high purity single-photon emission. Investigations into this direction will be carried out in the nearest future.

5 Acknowledgement

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