Core-shell CdSe/CdS quantum dot based single-photon emitter for SPAD calibration at room temperature

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The characterization of a core-shell CdSe/CdS quantum dot emitter at room temperature will be presented. For the characterization, the photon flux, the spectral distribution and the single-photon purity are determined. The central wavelength of the quantum dot is 642 nm, the bandwidth (FWHM) is about 18 nm. Furthermore, the relative detector calibration of two single-photon detectors (SPADs) will be shown using this quantum emitter.

INTRODUCTION

Single-photon emitters receive more attention in several quantum technology fields e.g. in quantum key distribution, quantum computing and quantum-enhanced optical measurements [1]. They are also interesting for the radiometry and metrology, because of, ideally, the absence of background and multi-photon emission. Such source has the potential to become a standard source in radiometry [2]. Moreover, a single-photon source is ideal for calibrating single-photon detectors, because of the omitted influence of the photon statistics on the calibration results [3].

For that reason, PTB is focussing on the development of different kinds of single-photon emitters at different wavelengths. In this contribution, the results of the characterization of a core-shell CdSe/CdS quantum dot emitter as well as a detector calibration using this emitter are presented. Here, core-shell quatum dots were used because of their brightness and narrow spectral bandwidth (compared to the already absolute characterized nitrogen-vacancy centers in nanodiamond) at room temperature [4].

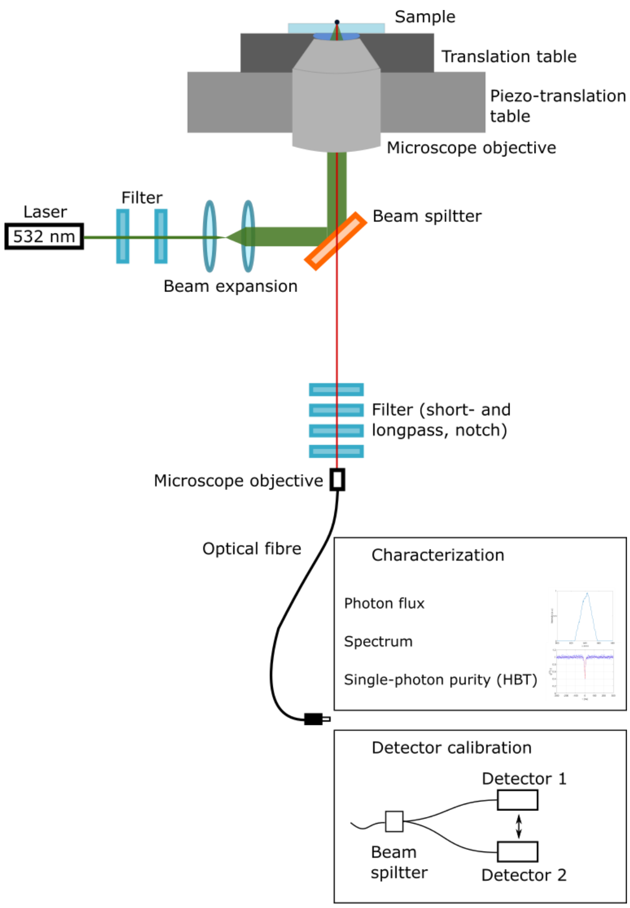

Figure 1. Measurement setup used for the characterization and the relative detector calibration.

EMITTER AND SETUP

As an emitter, core-shell quantum dots consisting of a CdSe core and a CdS shell placed on a standard cover glass were used, which were prepared by the Friedrich Alexander University (FAU) [4].

The sample is placed in a confocal microscope setup (see Figure 1) and is excited by a continuous wave laser operating at a wavelength of 532 nm. An oil immersion objective (NA 1.4) is used for a high collection of the emission. In the first case, the characterization, the confocal setup is consecutively connected to a detector, spectrometer as well as a Hanbury-Brown and Twiss interferometer (HBTI). In the second case, the detector calibration, two detectors are linked to the confocal microscope via a 50/50 beam splitter.

All measurements were carried out at room temperature.

CHARACTERIZATION

By scanning the sample, one quantum dot was selected for further investigations. The photon flux of the core-shell quantum dot was determined to be approx. 390 kcounts per second. The second order correlation function $g^{(2)}(\tau)$, as an indicator for the single-photon purity, was measured with a Hanbury-Brown and Twiss interferometer (HBTI), at $\tau = 0$ its value is approx. 0.4, indicating the non-classical character of the source, see Fig. 2a.

The spectral distribution of the quantum dot emitter is shown in Figure 2b, the central wavelength is at 642 nm, the FWHM is approximately 18 nm (Figure 2b). The lifetime of the quantum dot was determined to approx. 7ns.

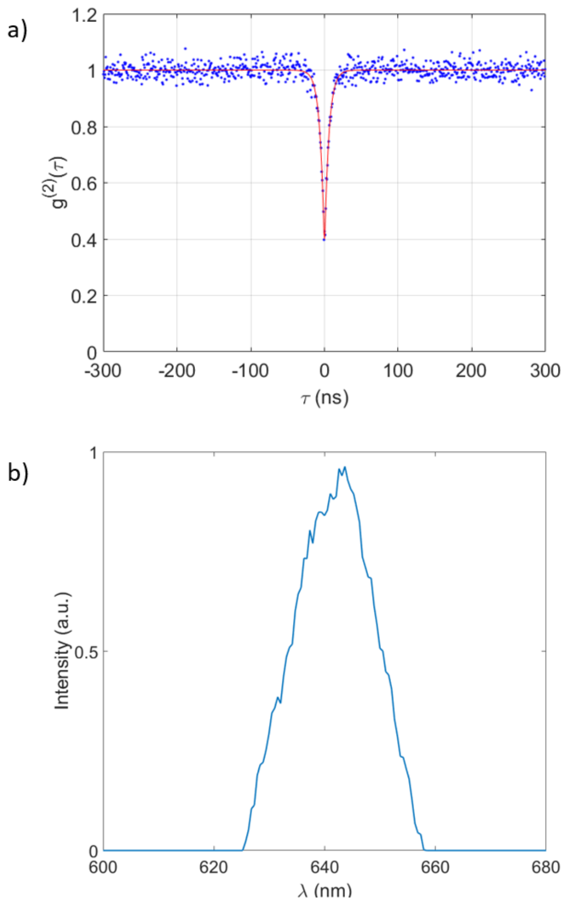

Figure 2. a) Single-photon purity of the CdSe/CdS quantum dot and b) its spectral distribution.

DETECTOR CALIBRATION

For the relative calibration the single-photon emission is divided by a 50/50 beam splitter. Two single-photon detectors (SPADs) are connected to the beam splitter. The detectors are of the same type (COUNT-T100-FC). After measuring the photon flux rate at both detectors at the same time, the detectors are switched and the photon flux rate is measured again. By analysing the measured photon fluxes, the ratio of the detection efficiency can be determined [5]. Preliminary evaluation gives a detection efficiency ratio of:

$$r = 1.023 \pm 0.086 \ . \tag{1}$$

Further details and results will be shown at the conference.

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