TWO PHOTONS INTERFERENCE (TPI)
USING SILICON AVALANCHE PHOTODIODES
APPLICATION NOTE

ID Quantique's id100 series offers compact and affordable state-of-the-art single photon counting detectors based on silicon avalanche photodiode with best-in-class timing resolution and low dead time. This application note describes the use of the id100 single photon counting detector for the measurement of two photons interference in a single photon source experiment.

Introduction

The two photons interference experiment [1] shows that two molecules embedded in solid samples can be used to generate lifetime-limited photons for use in the investigation of photon interference and correlation effects [2]. The energy spectrum of these molecules at low temperatures is composed of electronic and vibrational levels. Each electronic transition is composed of a narrow zero-phonon line (ZPL) and a phonon wing that stems from the vibrational coupling of the molecule with the host matrix. In order to capture the emission on the narrow 0-0 ZPL transition, a second incoherent pumping scheme is applied by exciting the molecule to higher frequency than the 0-0 ZPL. This state quickly decays to the electronic ground state and emits a visible photon.

By measuring the difference on the arrival time of the photos on both id100 detectors, it is possible to assure the single photon character of the source

Experimental Setup

Figure 1 illustrates the experimental setup for the two photons interference experiment. In this experiment a solution of dibenzanthanthrene (DBATT) in n-tetradecane is used as a sample. This sample is sandwiched between the glass substrate, onto which electrodes are evaporated. An electric field is applied to the electrodes, introducing a shift on the molecular levels and, consequently, overlapping the ZPL of the two emitters.

Hemispherical cubic zirconium solid immersion lens are placed on top of the glass substrate, as show in figure 1. The hemispherical lenses are combined with aspheric lenses of high numerical aperture (NA=0.55) providing an effective NA of 1.12, ensuing a very tight focus of about 300nm.

Two set of samples with the combined lenses are placed inside two independent microscopes with a liquid helium bath cryostat. A tunable laser source is used to excite the samples. A CCD camera is used to find the best focus position while the spectrometer records the emitted spectrum, allowing for setting the narrow bandpass filters. The emitted photons from the fluorescence excitation spectrum are then collected by the id100 avalanche photodiode (APD) from ID Quantique.

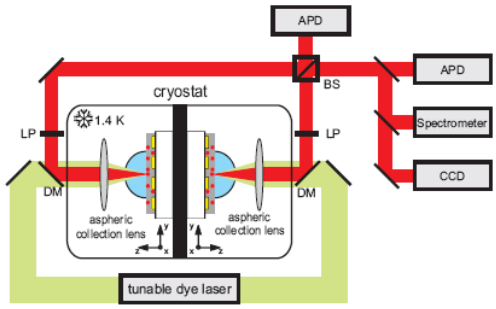

Figure 1: Courtesy of Robert Lettow, ETH Zürich [1].

Laser system

A coherent 899-29 laser with 590 nm wavelength (λ) and 1MHz line width is used to excite the samples. The laser power is chosen according to excitation transition. In general, for a low excitation regime (excitation via ZPL and collection of fluorescence) the laser power is approximately 1nW. When incoherent pumping which is used to collect the ZPL photons the laser operates in the microwatt regime.

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The laser beams are coupled via galvo mirror scanners and telecentric lens systems. The samples are aligned with a precision of a couple of nm. A homemade piezo-on-slider system is used to allow 3D positioning of both samples in microscopes.

The alignment remains stable once the set of samples are placed inside the cryostat.

Detection System

Two id100 detectors are used on this experiment for measuring the number of emitted photons: free-space input with 20μm active area (id100-20) or multi mode fiber input (id100-MMF50).

The detectors are places at a distance of about 2m from the photon source. In order to focus the emitted photons from the fluorescence excitation spectrum a 10x objective (Thorlabs, AC254-050-A1) is used. In addition, a 100mm lens (Zeiss, CP-Achromat 5X/0.12 infinite) is positioned at about 10mm from the id100-20 surface to center the light into the 20μm active area.

Experimental Results

By using a setup where 2 id100 detectors are used after a beam splitter to measure the same input (Hanbury Brown-Twiss setup) it is possible to measure the arrival time difference between the two detectors. Since the input is a single photon source, both detectors will never click at the same time, proving the single photon character of the source. With a time resolution of typically 40ps for the id100, a good measured is guaranteed.

On this experiment results approximately a million photons per second are emitted. The observed fluorescence spectrum (figure 2) shows a dominant line at 590nm, but several emission lines between 600 - 650nm are observed.

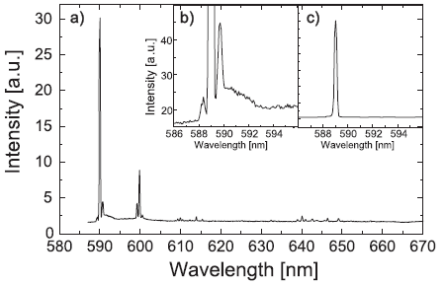

Figure 2: Measured spectrum [1].

References

[1] R. Lettow, V. Ahtee, R. Pfab, A. Renn, E. Ikonen, S.G¨otzinger and V. Sandoghdar, “Realization of two Fourier-limited solid-state single-photon sources”, OPTICS EXPRESS Vol. 15, No. 24 15842-15847 (2007).

[2] L. Mandel, “Photon interference and correlation effects produced by independent quantum sources”, Phys. Rev.A 28, 929–943 (1983).

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