Observing quantum emitters and measuring their lifetime using fast electrons

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1. INTRODUCTION

Electron microscopy techniques have been used to probe the optical properties of materials in the subwavelength scale [1]. In particular, it has been shown that using cathodoluminesncence [2] and by a propitious choice of electron beam energy and target material, resolution below 10 nm is attainable [3]. However, typical cathodoluminescence experiments only probe the spectral information of the emitted light, being an analogue of photoluminesncence at the nanoscale [4].

In this contribution, two types of experiments attempting to implement quantum optics techniques in the electron microscope will be presented. In these experiments a 1-nm-wide 60 keV electron beam was used to excite the sample. Fundamentally, we have measured the second order correlation function ($g^{(2)}(t)$) of the emitted light of different materials using a Hanbury-Brown and Twiss interferometer (an intensity interferometer, Fig. 1a).

2. RESULTATS

Experiments have been performed on a VH HB501 microscope operated at 60 kV. The samples have been kept at 150 K. The typical electron beam current was of the order of a few tens of pA and the beam width was of the order of 1 nm.

With the first set of experiments we have shown that single photon emission from NV^0 centers in diamond can be observed (that is, light antibunching is seen from these objects, Fig. 1b) [5]. More interestingly, we have detected changes in the $g^{(2)}(t)$ function within single 150 nm wide diamond crystals. With the same setup, we have detected a new single photon source in h-BN emitting in the 350 nm range.

In the second set of experiments, we have used the same interferometer to measure the $g^{(2)}(t)$ of nanodiamonds containing hundreds NV^0 emitters. Surprisingly, we have observed a large bunching effect in the nanosecond time scale. This bunching arises due to the simultaneous excitation of multiple centers by a single incoming electron and it gives information about the excitation mechanism behind light emission in cathodoluminescence [6]. This effect allows the measurement of objects' lifetimes in close proximity.

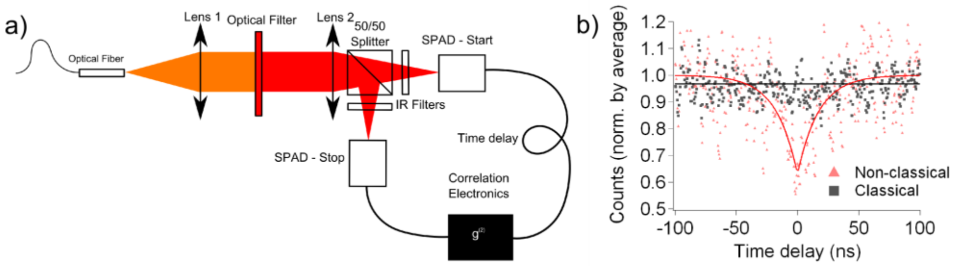

Figure 1. a) Sketch of the intensity interferometer used in our experiments. b) Typical $g^{(2)}(t)$ curve, showing light antibunching from NV^0 centers excited by fast electrons (red curve) compared to a classical emitter (black curve), such as a large ensemble of emitters.

3. CONCLUSION

To conclude, we have used two sets of experiments to show how a typical quantum-optics technique (light intensity interferometry) can be used in a cathodoluminescence setup to obtain information from individual quantum emitters at the nanometer length scale (such as single photon sources).

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