The interest for single photon emitters (SPE) has tremendously grown over the last decades, due to their possible application in quantum information. Famous SPE are, for example, quantum dots of InAs/GaAs or NV centers in diamond. A SPE emits only one photon at the time, and therefore it is a natural candidate for solid quantum bits. The usual way to characterize them is to perform an intensity interferometry experiment (Hanbury Brown and Twiss (HBT)). Such an experiment measures the autocorrelation function \( g^{(2)}(\tau) \) of emitters. The \( g^{(2)}(\tau) \) function of a SPE presents a dip at very short delay \( g^{(2)}(0) < 1 \), a phenomenon called anti-bunching. Here, we used a unique home-made set-up of cathodoluminescence (CL) in a scanning transmission electron microscope (STEM) coupled to an HBT experiment allowing nanometer resolution. The \( g^{(2)}(\tau) \) obtained with our STEM-CL set-up is called hereafter CL−\( g^{(2)}(\tau) \). The details of the experiment are explained in [1,2] and in figure 1. Two HBT set-up have been built, one working in the visible range with two single photon avalanche detectors and the other working in the near UV range using photomultipliers.

As a proof of principle, we will present results on NV centers acquired with the first set-up. The CL−\( g^{(2)}(\tau) \) acquired on a nano diamond is shown in figure 2-b) and presented in detail in [2]. We can clearly see a dip at short time delay, proving the possibility to study SPE with fast electrons (60 keV). Then we will present a new UV-SPE in hexagonal Boron nitride studied with the second set-up, showing that characterizing SPE with fast electron can open new horizon on quantum information device. In order to go further in the understanding of this new technics, we will see that even if the interaction mechanisms of photoluminescence (PL) and CL-STEM are close enough to give the same emission spectra [3], they may lead to huge differences in their \( g^{(2)}(\tau) \) function, called respectively PL−\( g^{(2)}(\tau) \) and the CL−\( g^{(2)}(\tau) \). Indeed the interaction of electrons with mater produces a plasmon which will decay into multiple electron-hole pairs at the gap energy (\( E_{g e-h} \)), while the PL-photon mater interaction produces only one \( E_{g e-h} \). Thus, if there is more than one SPE in the sample, one electron can excite simultaneously multiple centers leading to the synchronization of emission and thus to the emission of packets of photons. Therefore if the number of excited center is above ten the CL−\( g^{(2)}(\tau) \) function will presented a huge bunching effect (\( g^{(2)}(0) > 1 \)) in stark contrast to the expected flat PL−\( g^{(2)}(\tau) \) function (\( g^{(2)}(0) = 1 \)) see figure 3.


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Fig. 1: Sketch of the set-up. a) the STEM. b) Transmitted electrons are used to produce ADF and BF images. The light coming out of the sample is sent to an optical fiber which can either go to a spectrometer c) or the autocorrelation experiment d). In c) one can see the emission spectrum of an NV center in diamond and the emission map, filtered at 570 nm.

Fig. 2: SPE studied in a STEM [2]. a) The ADF image of the diamond. b) Associated experimental $g^{(2)}(\tau)$. The dip of the blue curve is lower than the dip of the red one, respectively acquired with an excitation on the area marked by the blue and red square in a). This shows that the $g^{(2)}(\tau)$ is sensitive to excitation variation of at least 100 nm resolution.

Fig. 3: The bunching effect. Continuous lines are the experimental results from CL–$g^{(2)}(\tau)$ of a nano-diamond (size ≈ 100 nm, containing a few hundreds of NV centers). The excitation current ranges from 1.6 pA to 137 pA. On the inset, PL–$g^{(2)}(\tau)$ with excitation on the same sample (but not the same diamond) for two different excitation powers.