Todo list

Extra long title which spans serveral lines and therefore has to be split manually and the vertical spacing has to be adjusted

My Name

My university

(Diploma/doctoral...) Thesis

Supervisor:

Prof. Dr. Supervisor

Supervisor's Department, University of ...

March 2013

Abstract

A novel method... It is based on...

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Acknowledgements

First of all, I want to thank my supervisor...

I am very grateful for the guiding help of...

I am grateful to...

Chapter 1

Coupling Nanodiamonds to Photonic Structures

In the last chapter, we saw that the spectroscopic properties of SiV centers vary strongly among individual nanodiamonds. Nanodiamonds are further implemented in photonic structures for the application in metrology as well as in quantum cryptography or quantum computing. Therefore, it is important to have a good knowledge of the spectroscopic properties of the individual SiV center. A preselection of nanodiamonds including an SiV center with desired properties is performed. The selected nanodiamond is then transferred to target structures. In the scope of this thesis, nanodiamonds including SiV centers were coupled to two different kinds of structures:

think of other word

- Vertical-Cavity Surface Emitting Lasers: The aim is to create a hybrid-integrated single photon source, where an electric current is employed to create single photons. The diamond containing an SiV center is placed directly on the beam output. Hence the SiV center is directly pumped by the laser beam. This system is interesting for metrological applications, as it is the major building block for a portable device ready to calibrate single photon detectors.
- Plasmonic Nanoantennas: The aim is to enhance photoluminescence intensity. As described in previous chapters, not only ZPL position and linewidth, but also the photoluminescence intensity varies strongly among individual SiV centers. However, in metrology a photon flux rate high enough to be measured by a low optical flux detector is needed [**?**]. This increase in intensity is achieved by coupling the SiV centers in nanodiamonds to plasmonic antennas.

1.1 Additional Experimental Methods

To couple nanodiamonds to photonic structures, we pursued several different methods:

1. Directly spin-coat the structures with a nanodiamond solution and consecutively look for a structure containing a nanodiamonds with an SiV center exhibiting the desired spectroscopic properties. This method was tried with the antenna structures, as there are many antenna structures on one substrate (see Figure 1.8a), therefore there is a

chance that a suited nanodiamond is incidentally ends up at the right spot. However, it is not suitable for the VCSELs, first because of the morphology of the VCSELs and secondly, because there is a very limited number of VCSELs on one substrate.

2. Use an iridium substrate covered with nanodiamonds containing SiV centers, look for a suited nanodiamond and transfer it with a pick-and-place technique using a nanomanipulator. The nanomanipulator is essentially a thin tip in a scanning electron microscopy. The iridium substrate is prepeocessed with markers, to record the position of the preselected nanodiamond. The huge advantage is that the very best suited nanodiamond can be preselected. However, disadvantages of this process include the electron radiation during the pick-and-place process, which might affect SiV center fluorescence light and the further restriction that the nanodiamonds must be big enough to be picked up with the nanomanipulator.

3. Similar to method 2, however the transfer is performed with an atomic force microscope. While this method has the advantage that the nanodiamonds are not irradiated with electrons, the disavantage is that it is not possible to observe the picking process in real time. The area of the preselected nanodiamond has to be scanned after every pick-up try, which is very time consuming and therefore was not further pursued after some trials.

In the following, the pick-and-place technique of method 2 is described in more detail. It is the method most extensivly deployed in the scope of this thesis and requires specific experimental procedures.

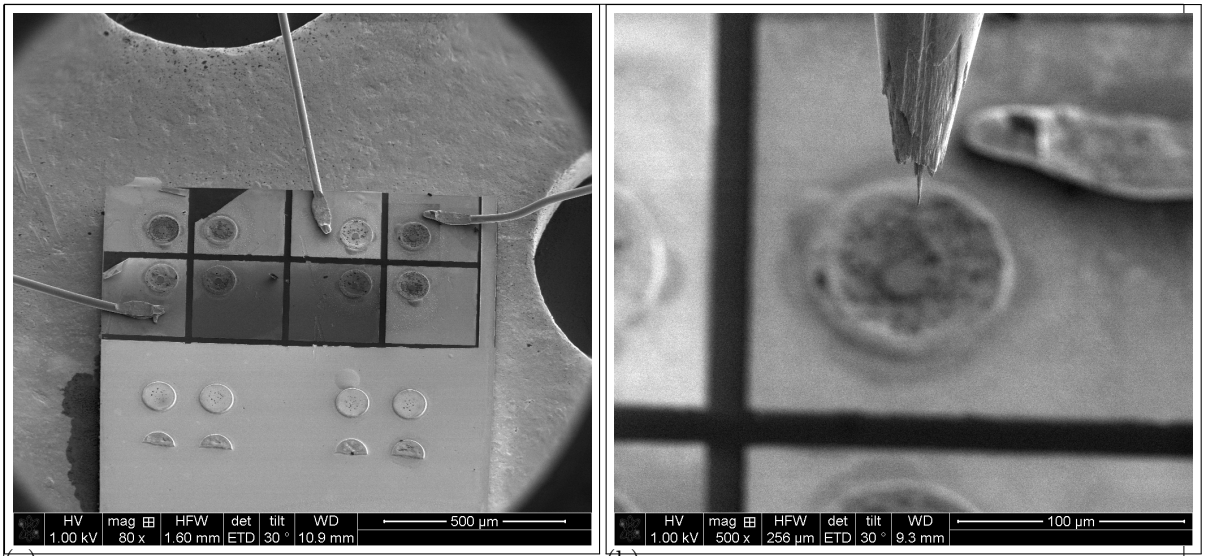
Nanomanipulator

Determination of Position of Nanodiamonds

Photo of Nanomanipulator

1.2 Coupling Nanodiamonds to Vertical-Cavity Surface Emitting Lasers

For metrology, the photon flux rate has to be high enough to be measured by a low optical flux detector [**?**].



(a) (b)

Figure 1.1: <caption>

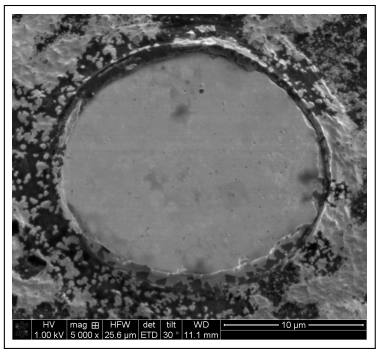


Figure 1.2: <caption>

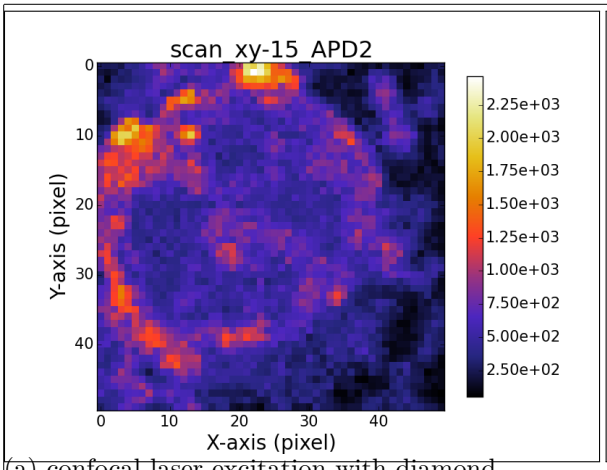
1.2.1 Pick-And-Place Process to Vertical-Cavity Surface Emitting Laser

1.2.2 Spectroscopic Measurements of Nanodiamond in Vertical-Cavity Surface Emitting Laser

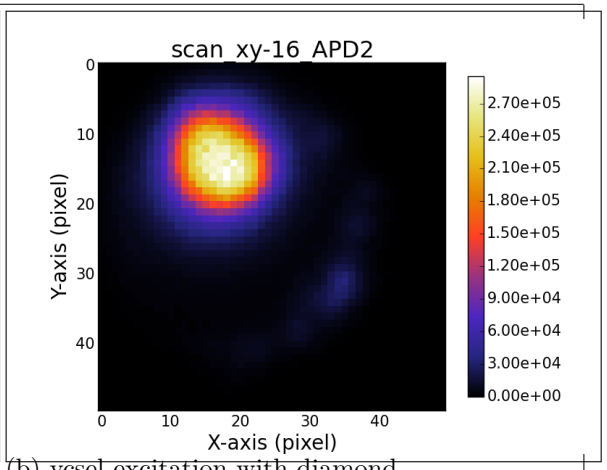
1.3 Coupling Nanodiamonds to Double Bowtie Antenna Structures

1.3.1 Nanodiamond With Multiple SiV centers Coupled to Antenna

1.3.2 Nanodiamond With Single SiV center Coupled to Antenna

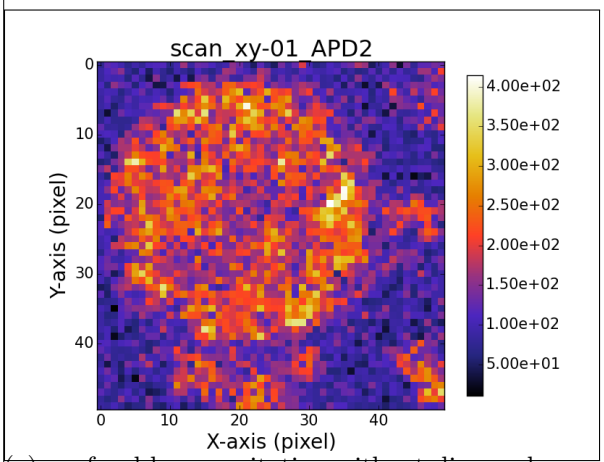


(a) confocal laser excitation with diamond

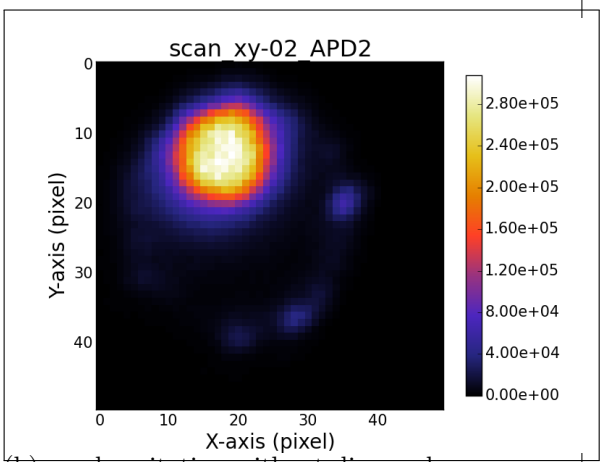


(b) vcsel excitation with diamond

Figure 1.3



(a) confocal laser excitation without diamond



(b) vcsel excitation without diamond

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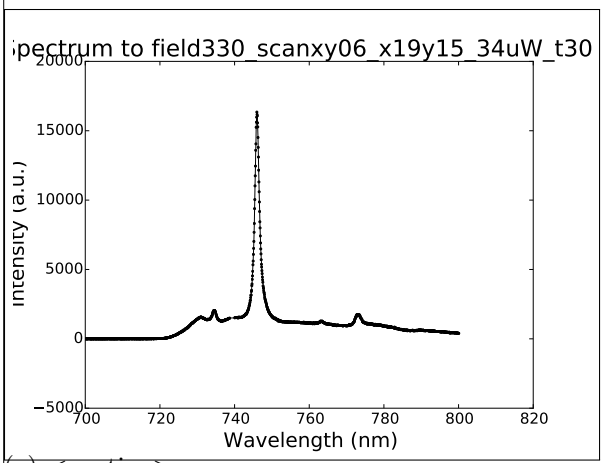

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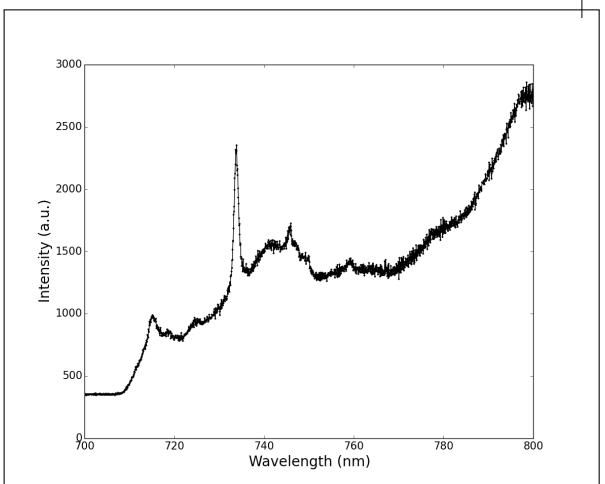

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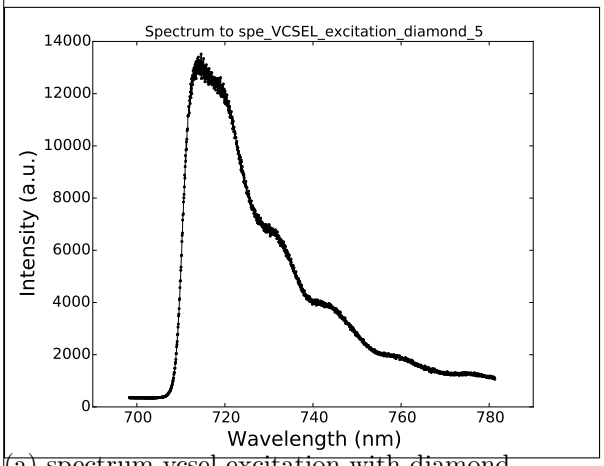
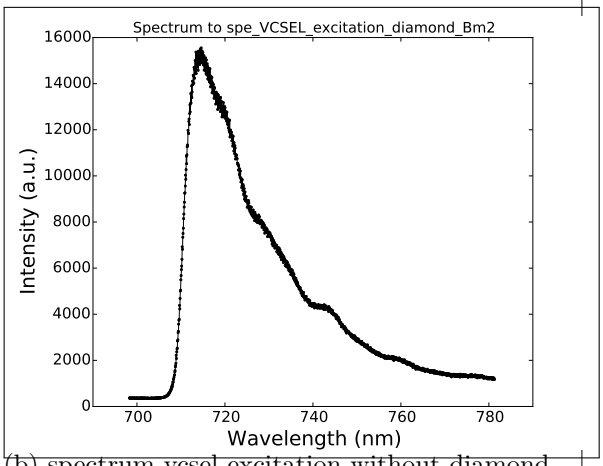


(a) spectrum vcsel excitation with diamond



(b) spectrum vcsel excitation without diamond

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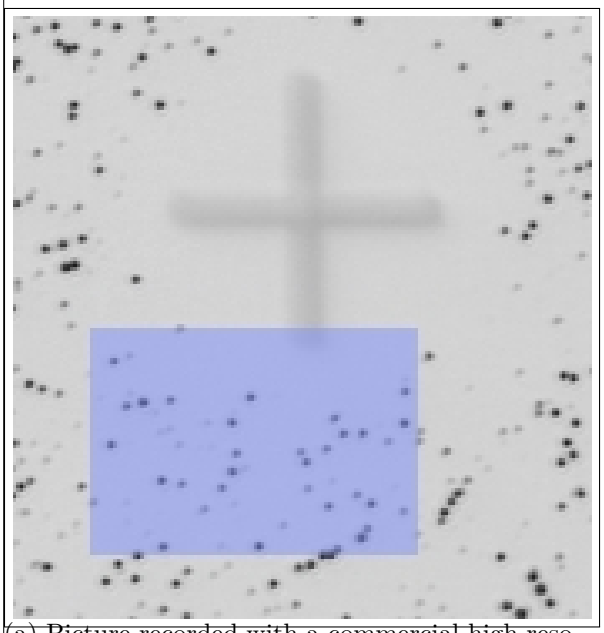
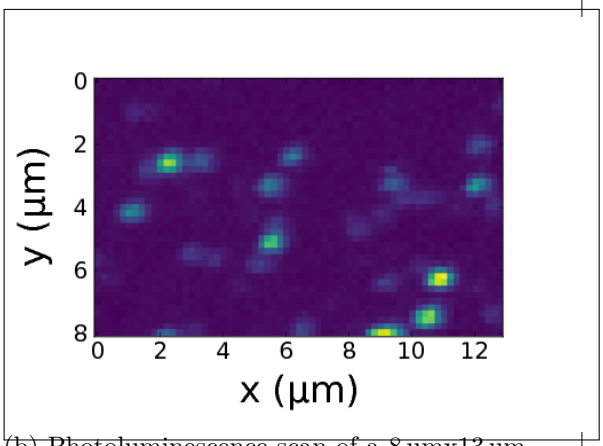
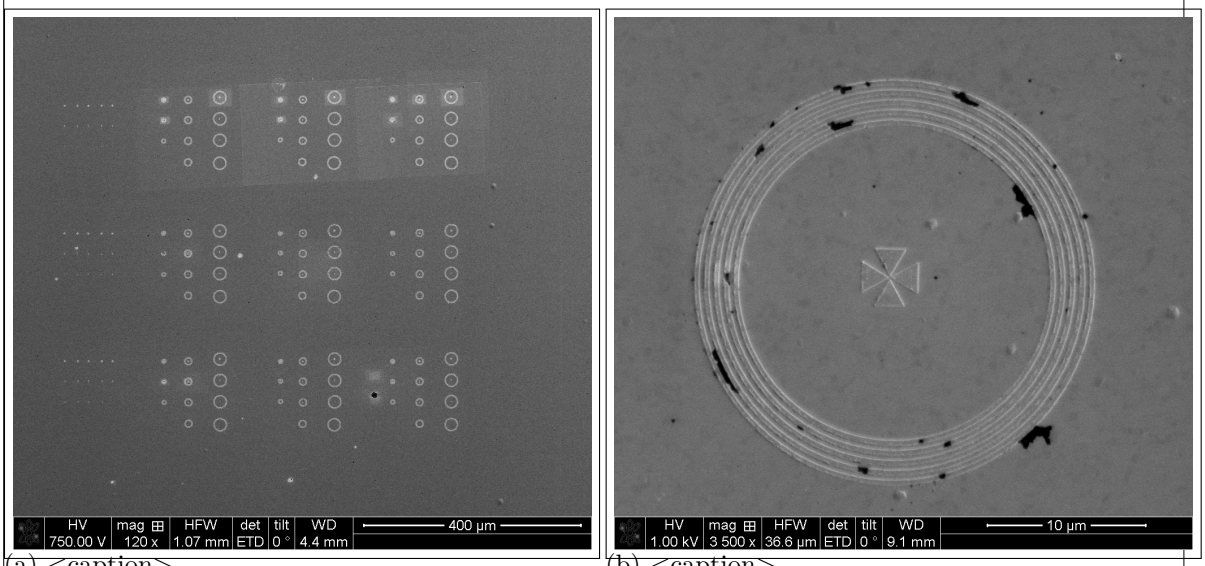


(a) Picture recorded with a commercial high resolution laser scanning microscope. The area shaded in blue represents the photoluminescence scan in image b)



(b) Photoluminescence scan of a 8 µmx13 µm



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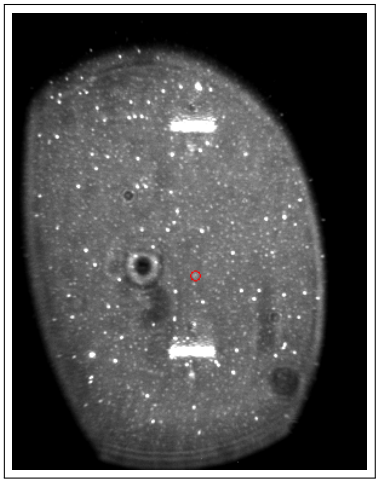

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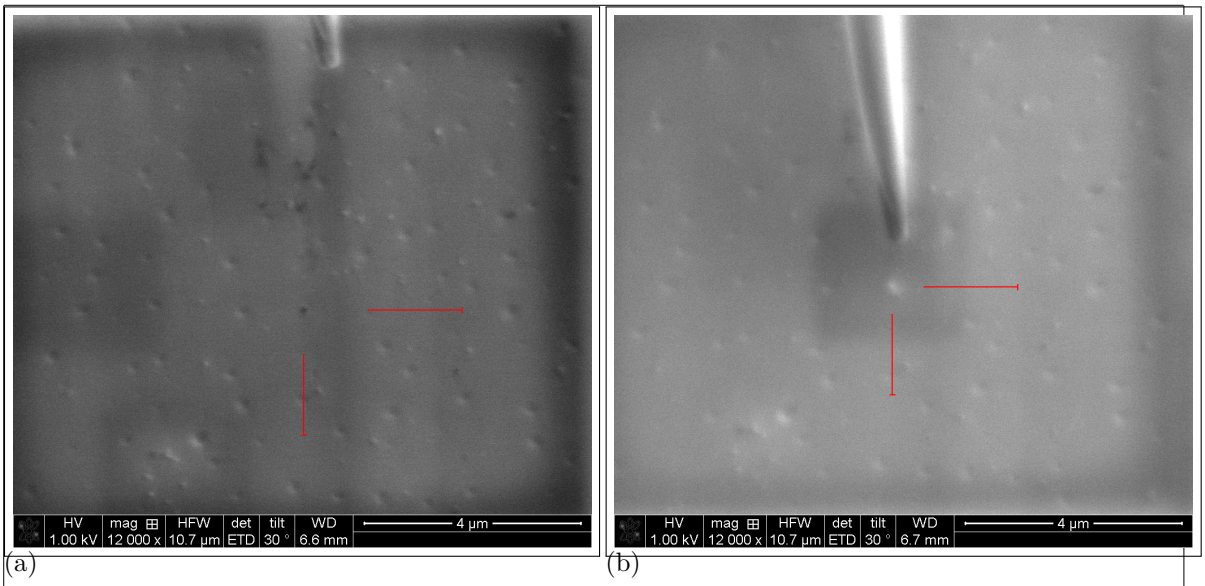
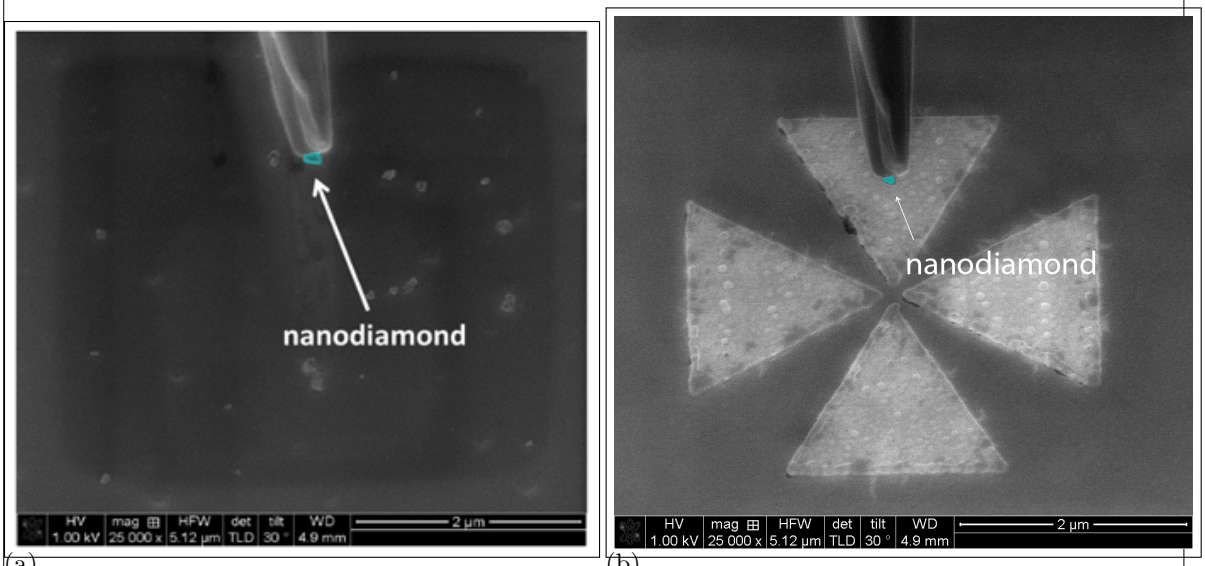


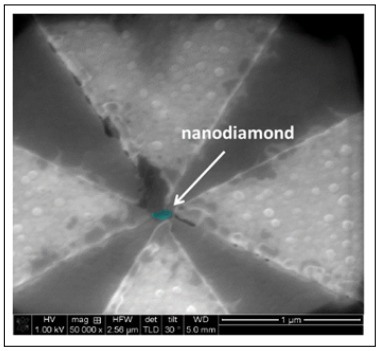
(a) (b)

Figure 1.10: caption



(a) (b)

Figure 1.11



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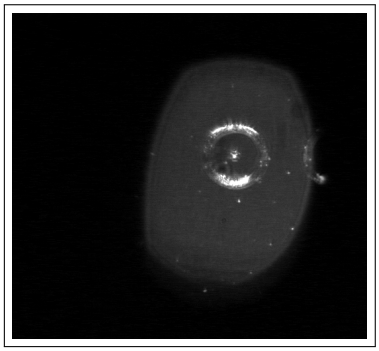

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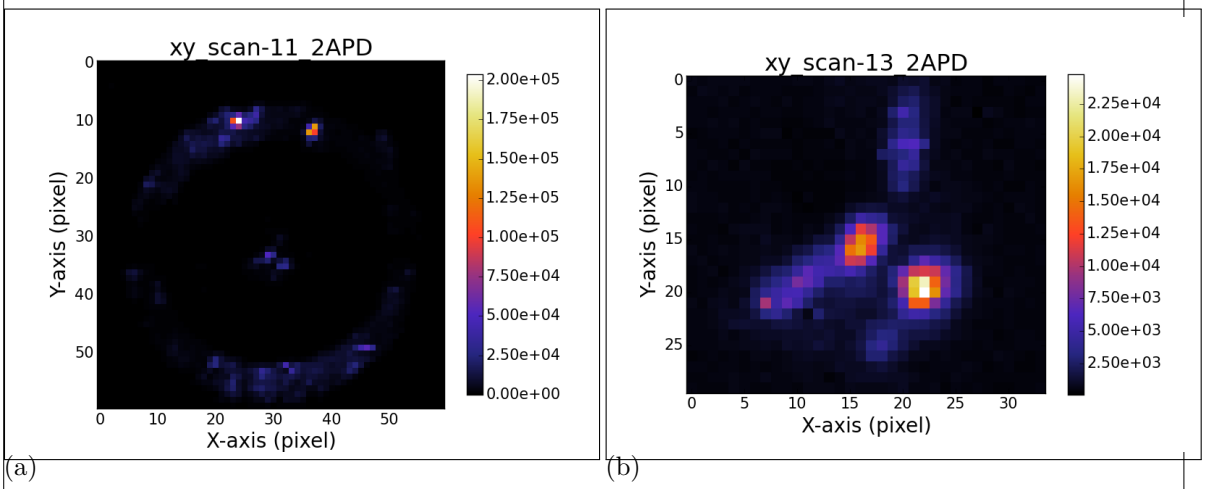

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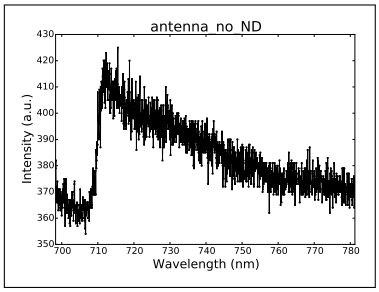

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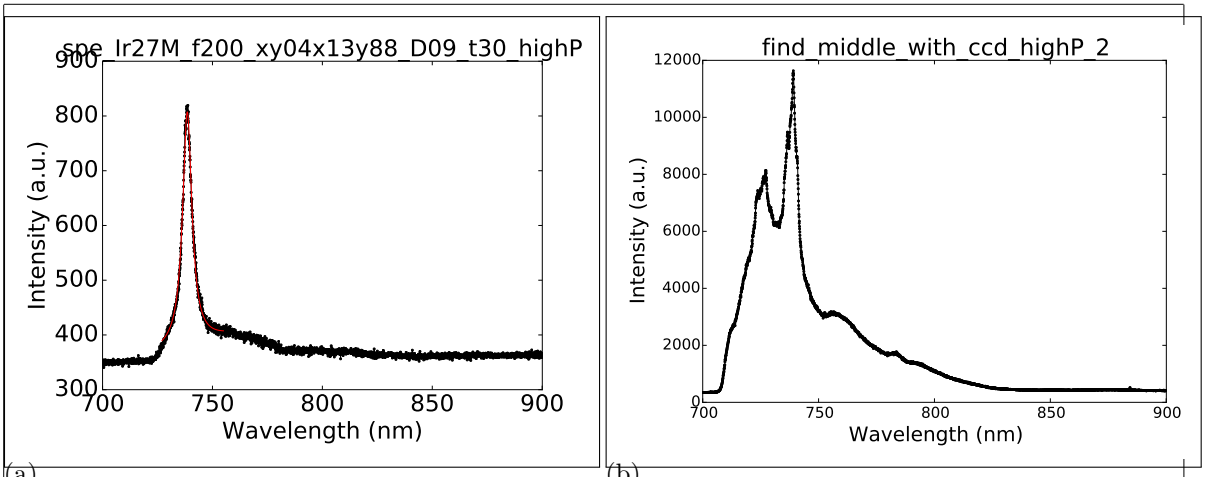

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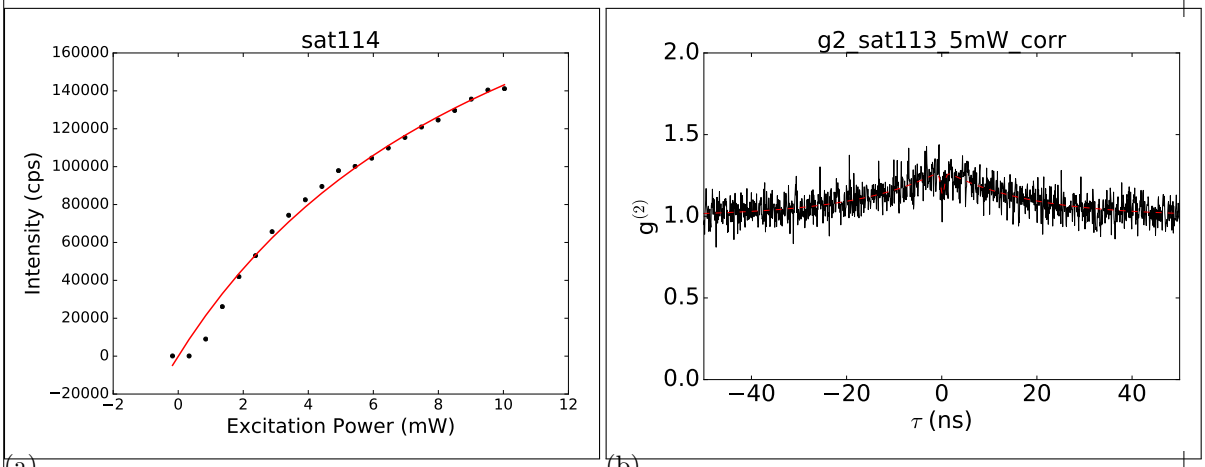

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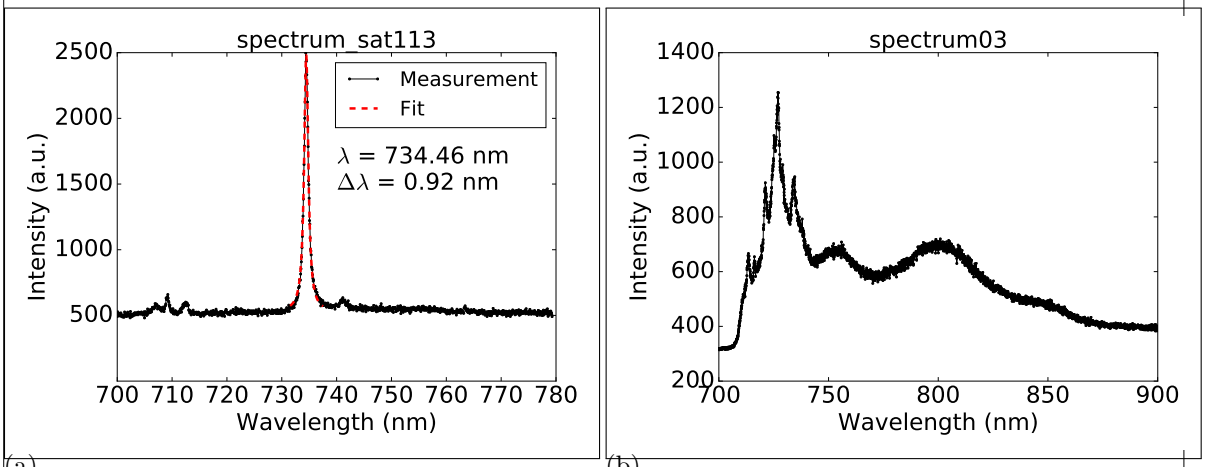

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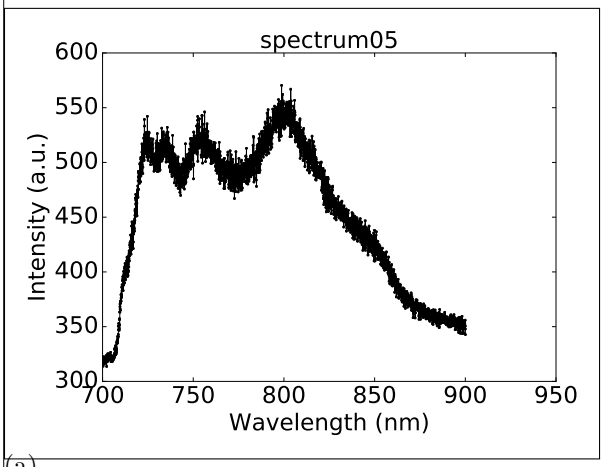

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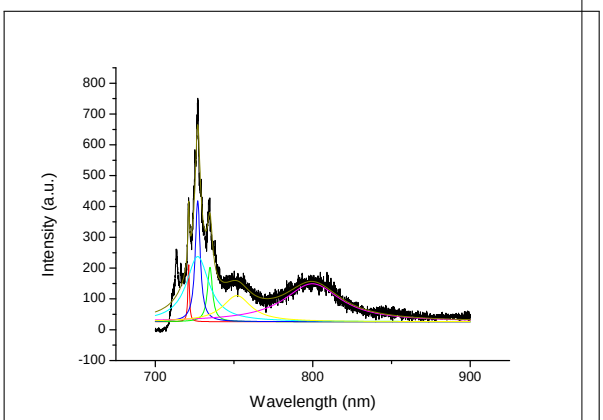

(b)

Figure 1.19: <caption>

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