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0.0.1   Sideband

It is known that the photoluminescence spectra of SiV centers in nanodiamond are dominated by the zero-phonon-line. As a result phonon side band contributions remain small, a fact expressed in large Debye-Waller factors of over 70 % established previously [**?**, **?**]. Our own measurements are consistent with these of emitter H1 and emitter V1 results. We also find distinct sideband peaks in many SiV center photoluminescence emission spectra. The investigated emitters exhibit two different structures of sideband spectra: The spectra in group V exhibit one strong sideband peak, spectra in group H exhibit several weaker sideband peaks. Figure 1a and Figure 1b illustrate the respective observations.
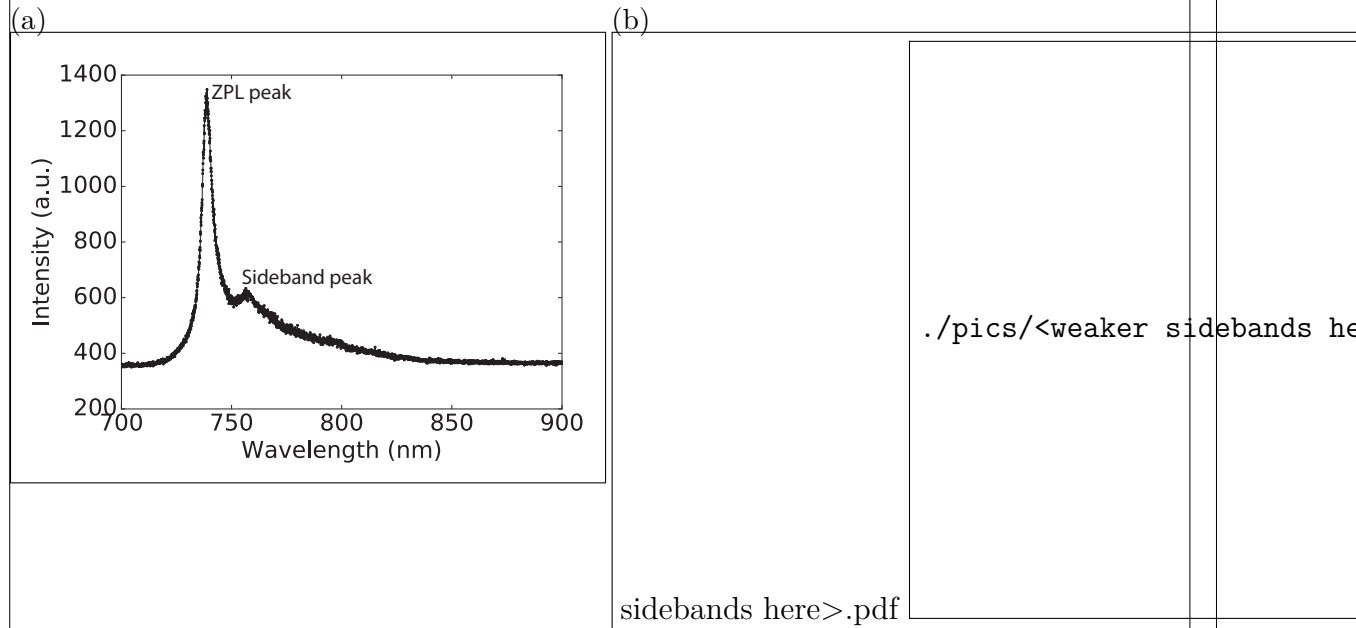
(a)

(b)

./pics/<weaker sidebands he

sidebands here>.pdf

Figure 1: Representative spectra of emitters showing single (a) and multiple (b) side band peaks. The former belong to group V, while the latter are members of group H.

Most of the spectra in group V exhibit a characteristic shape, composed of the ZPL and one strong sideband peak. 70 % of the photoluminescence spectra with one distinct sideband peak exhibit a shift of the sideband peak from the ZPL between 37 meV to 43 meV. The range of line shifts for the prominent sideband peak coincides with a well-known feature at 42 meV, associated with SiV centers [**?**, **?**], but also to a larger number of optically active defects [**?**]. The occurrence of this 42 meV sideband feature for a large number of defects and the absence of isotopic variations [**?**], favors an assignment as non-localized lattice vibration. We furthermore observe that the dominant sideband peak shifts towards smaller distance from the ZPL for increasing ZPL center wavelength, i.e. increasing strain. Figure 2 presents a linear fit to data for emitters in group V.. The low phonon energy of the sideband feature and its shift with strain might arise from a local "softening" of the crystal lattice in the vicinity of a defect [**?**].
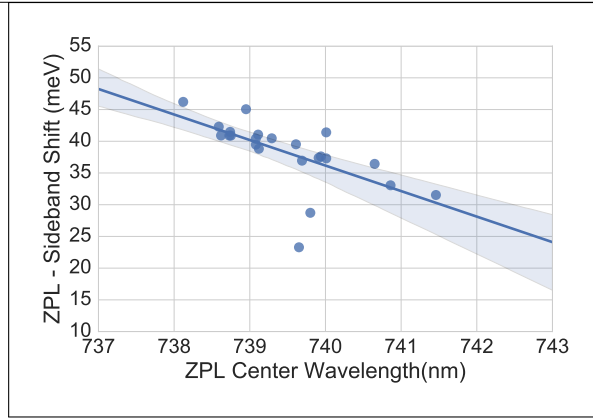
Figure 2: Shift of dominant sideband peak from the ZPL in spectra of SiV centers (group V, samples insitu50, insitu70, insitu100) vs. ZPL center wavelength. The linear fit shows that the shift decreases with increasing ZPL center wavelength, i.e. with increasing strain and exhibits a slope of $(-4 \pm 1)\,\mathrm{meV\,nm^{-1}}$. The shaded area is the $95\,\%$ confidence region.

A recent study [?] suggests that the $42\,\mathrm{meV}$ mode, similar to other broad phonon side band features, originates from a resonance attributed to phonons causing the dynamical Jahn-Teller effect with SiV centers [?]. As the Jahn-Teller coupling varies with strain it is also expected that the resonance shifts accordingly.

In the spectra of group V, we do not observe a typical SiV center sideband feature at $64\,\mathrm{meV}$, attributed to a local vibration of the silicon atom, frequently much stronger than the $42\,\mathrm{meV}$ sideband peak. A possible explanation is, that the lattice mode at $37\,\mathrm{meV}$ to $43\,\mathrm{meV}$ is so strong that the local vibrational mode at $64\,\mathrm{meV}$ cannot be separated from the tail of the lattice mode.

In group H we observe many spectra which exhibit several peaks within the spectral range of our detection range between $710\,\mathrm{nm}$ to $900\,\mathrm{nm}$. The challenge arises to unequivocally distinguish between peaks stemming from a phonon sideband and peaks stemming from shifted, less intense SiV center ZPLs.

Interestingly, we assert a tendency for peaks to accumulate at a shift of around $43\,\mathrm{meV}$, $64\,\mathrm{meV}$, $150\,\mathrm{meV}$ and $175\,\mathrm{meV}$. This pattern in the phonon side band of group H is consistent with side band shifts reported in [?, ?, ?].

The possibility exists, that some these peaks believed to be phonon side bands are actually shifted ZPLs stemming from other SiV centers. To address this question, we perform photoluminescence measurements at cryogenic temperatures.

0.0.2   Cryostatic Measurements

Remark:

den teil mit den cryogenic measurments musst du nochmal ordentlich aufschreiben.

(a)

Spectrum to spe_scan_xy-08x11y19_297uW_t18C

λ = 739.8 nm
Δλ = 7.11 nm

(b)

Spectrum to spe_scan_xy-08x11y19_297uW_t18C

λ = 739.8 nm
Δλ = 7.11 nm

(c)

Spectrum to spe_scan_xy-35x10y12_300uW_t12C

λ = 750.07 nm
Δλ = 1.94 nm

(d)

Spectrum to spe_scan_xy-35x10y12_300uW_t12C
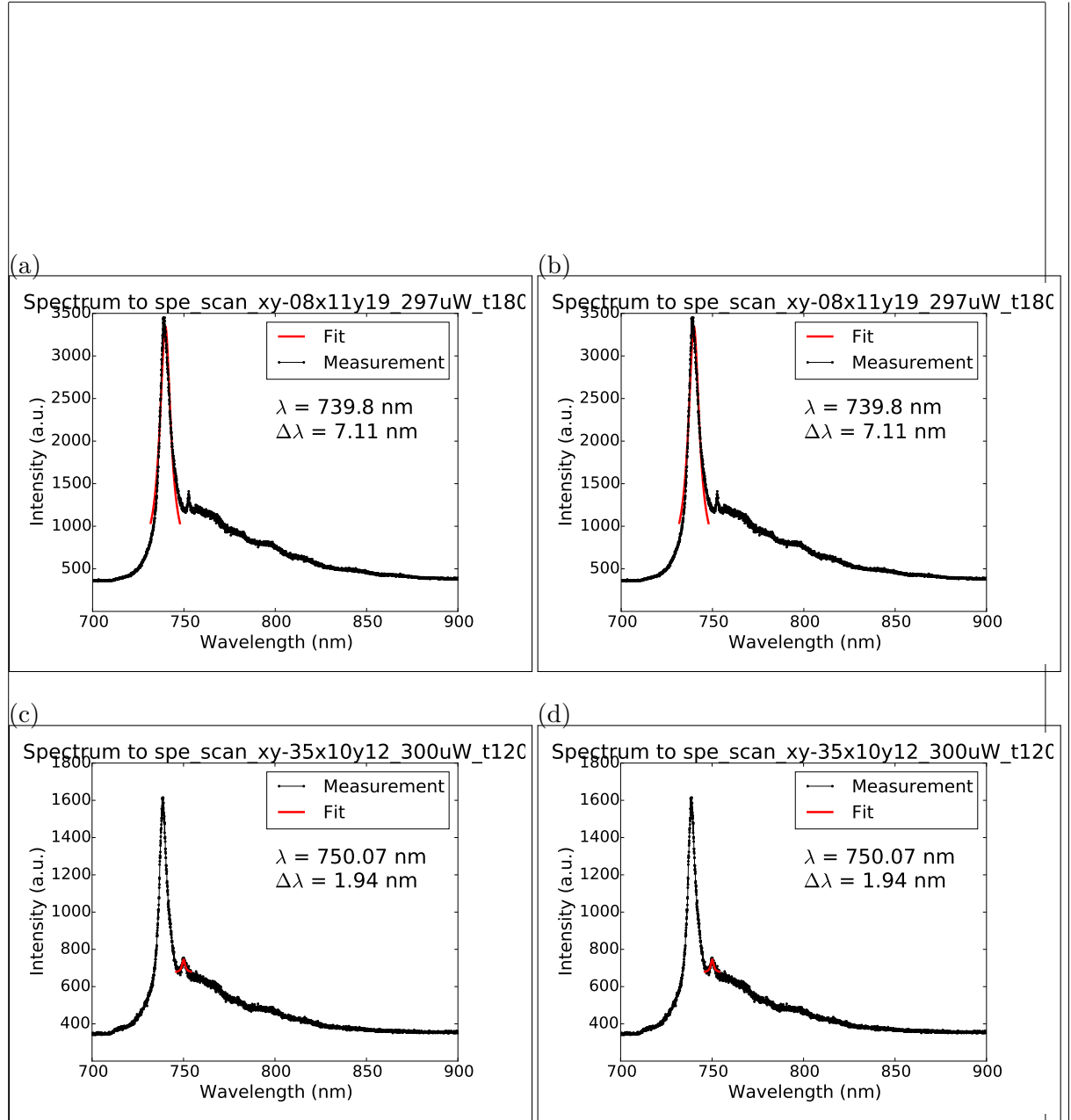
λ = 750.07 nm
Δλ = 1.94 nm

Figure 3: Comparison of spectra taken at room-temperature (l.h.s) and at cryogenic temperatures (r.h.s). At low temperatures a plethora of lines is revealed indicating several SiV centers embedded in a strained lattice neighborhood.

Hier fehlen noch dinge.

- platzhalter durch richtige figures ersetzen. Text steht schon.

At cryogenic temperatures phonon side band contributions vanish, allowing a focused investigation of zero-phonon-lines. In particular, for SiV centers a four-way splitting of the zero-phonon-line is expected, see **??**. To conduct low-temperature measurements, we were allowed to use the setup of J. Becker, group of C. Becher, Saarland University. It differs from the confocal setup used in this thesis merely by the fact that the sample is efficiently cooled using a cryostat.

We report measurements for two individual nanodiamonds both situated on sample insitu70o in **??**. Figure 3d and Figure 3d show spectra recorded at cryogenic temperatures while Figure 3a and Figure 3c show spectra recorded at room temperature for comparison. Instead of the four-fold degeneracy expected for SiV centers in low-strain diamond, the cryogenic measurements indicate a plethora of various lines. The observation is best explained by the presence of several SiV centers some of which are subject to varying levels of strain in their local lattice neighborhood. Given the fact that zero-phonon-lines are found spread over a significant range of wavelengths, a non-negligible impact of lattice strain on SiV center luminescence is revealed.

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