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## Todo list

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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 [1, 2]. 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. ?? and ?? illustrate the respective observations.

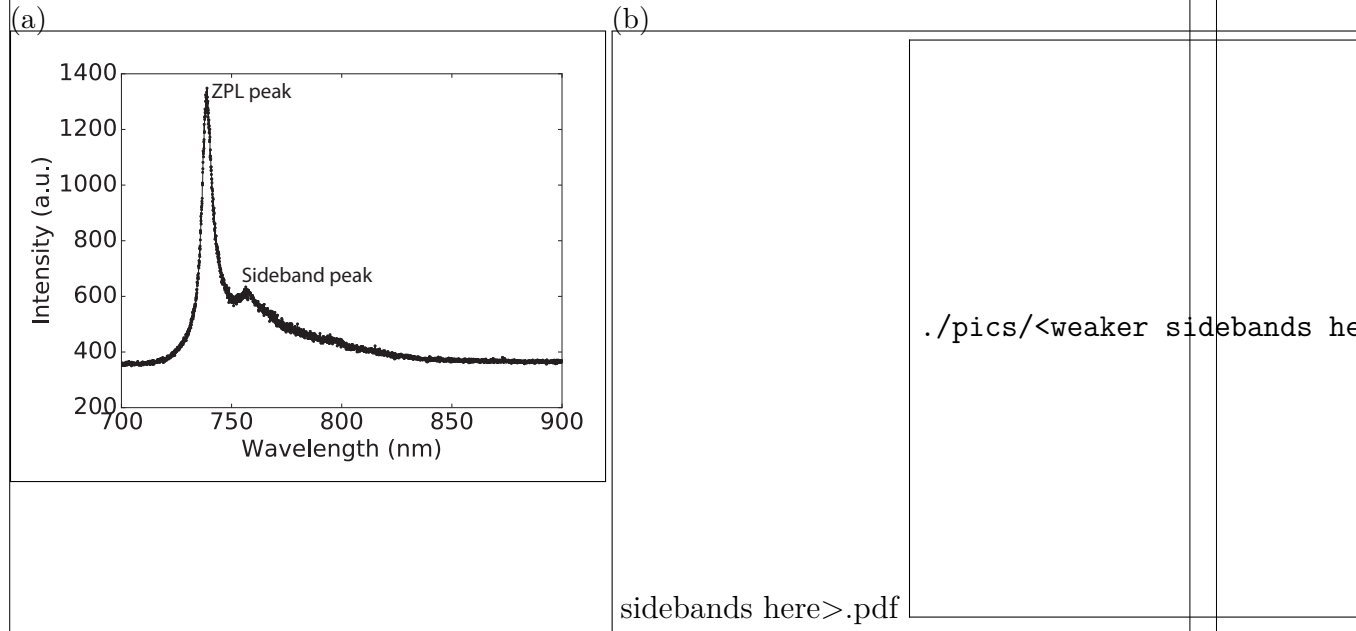


Figure 1: Representative spectra of emitters showing single (a) and multiple (b) sideband peaks. The former belong to group V, while the latter are members of group H.

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 [3, 4], but also to a larger number of optically active defects [4]. The occurrence of this 42 meV sideband feature for a large number of defects and the absence of isotopic variations [5], 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. ?? 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 [4].

A recent study [6] suggests that the 42 meV mode, similar to other broad phonon side

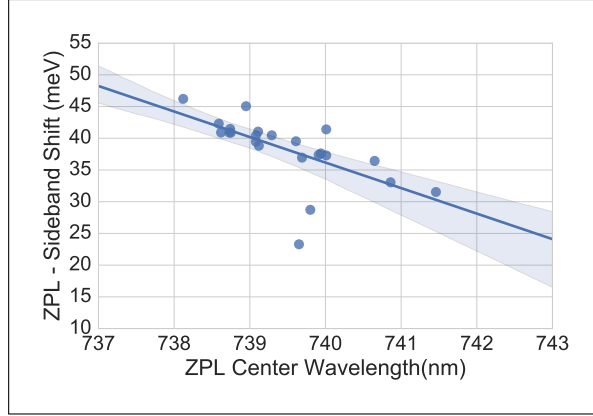


Figure 2: Shift of dominant sideband peak from the ZPL in spectra of SiV centers (group V, samples insitu50, insitu70, insitu100) vs. ZPL center wavelength. The linear fit shows that the shift decreases with increasing ZPL center wavelength, i.e. with increasing strain and exhibits a slope of  $(-4 \pm 1) \text{ meV nm}^{-1}$ . The shaded area is the 95 % confidence region.

band features, originates from a resonance attributed to phonons causing the dynamical Jahn-Teller effect with SiV centers [7]. 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 meV, attributed to a local vibration of the silicon atom, frequently much stronger than the 42 meV sideband peak. A possible explanation is, that the lattice mode at 37 meV to 43 meV is so strong that the local vibrational mode at 64 meV cannot be separated from the tail of the lattice mode.

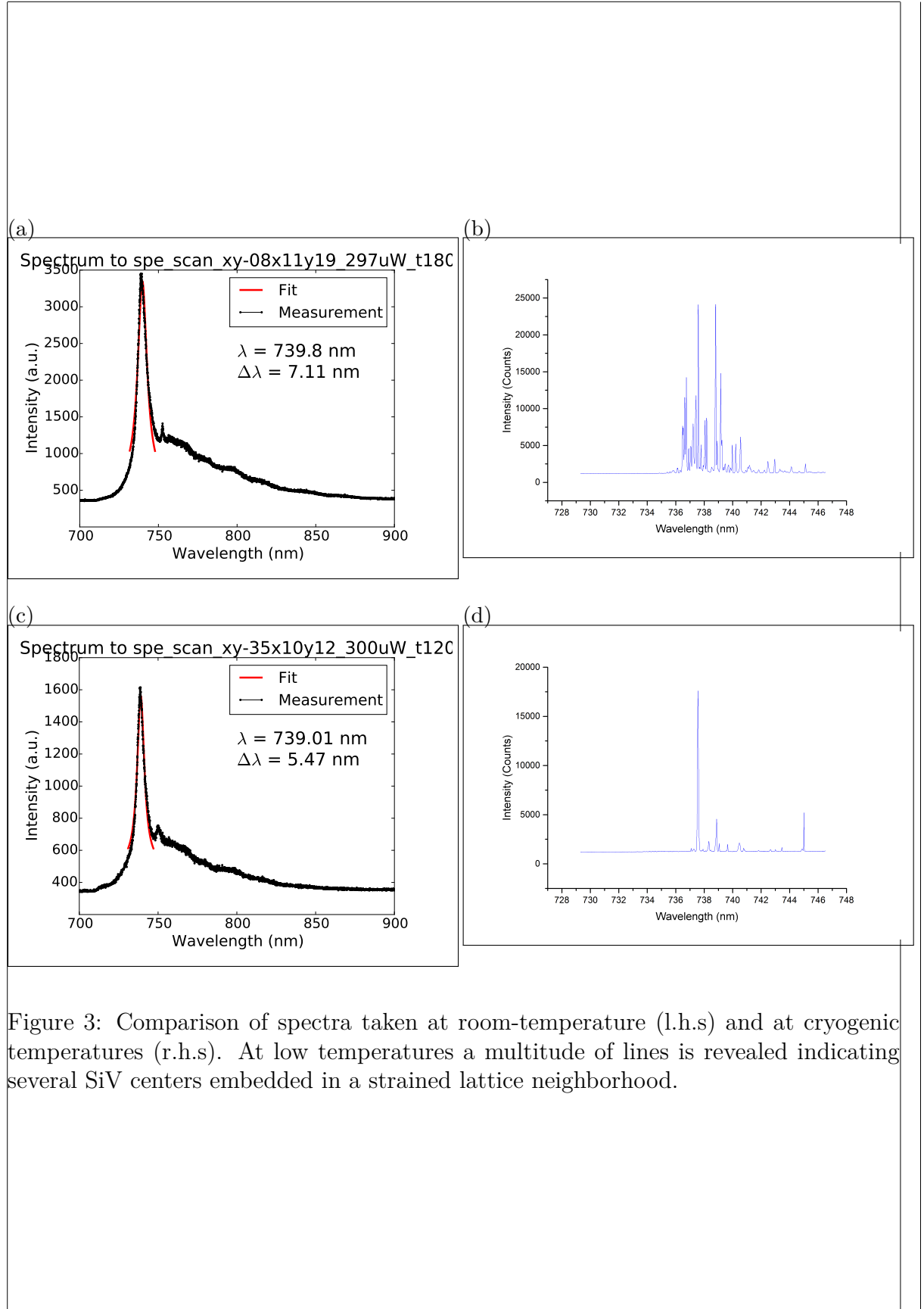
In group H we observe many spectra which exhibit several peaks within the spectral range of our detection range between 710 nm to 900 nm. The challenge arises to unequivocally distinguish between peaks stemming from a phonon sideband and peaks stemming from shifted, less intense SiV center ZPLs.

Interestingly, we assert a tendency for peaks to accumulate at a shift of around 43 meV, 64 meV, 150 meV and 175 meV. This pattern in the phonon side band of group H is consistent with side band shifts reported in [4, 8, 1].

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

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 used a confocal setup similar to the one described in ??. It differs merely by the



fact that the sample is efficiently cooled to 4 K using a cryostat.

In ?? measurements of two individual nanodiamonds are shown, both situated on sample insitu70o. ?? and ?? show spectra recorded at cryogenic temperatures while ?? and ?? 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 multitude of various lines. The observation is best explained by the presence of several SiV centers 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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# Bibliography

- [1] Elke Neu, Martin Fischer, Stefan Gsell, Matthias Schreck, and Christoph Becher. Fluorescence and polarization spectroscopy of single silicon vacancy centers in heteroepitaxial nanodiamonds on iridium. *Phys. Rev. B*, 84(20):205211, nov 2011. 1, 2
- [2] Elke Neu, David Steinmetz, Janine Riedrich-Möller, Stefan Gsell, Martin Fischer, Matthias Schreck, and Christoph Becher. Single photon emission from silicon-vacancy colour centres in chemical vapour deposition nano-diamonds on iridium. *New Journal of Physics*, 13(2):25012, feb 2011. 1
- [3] F P Larkins and A M Stoneham. Lattice distortion near vacancies in diamond and silicon. I. *Journal of Physics C: Solid State Physics*, 4(2):143–153, feb 1971. 1
- [4] H. Sternschulte, K. Thonke, R. Sauer, P. C. Münzinger, and P. Michler. 1.681-eV luminescence center in chemical-vapor-deposited homoepitaxial diamond films. *Physical Review B*, 50(19):14554–14560, nov 1994. 1, 2
- [5] Andreas Dietrich, Kay D Jahnke, Jan M Binder, Tokuyuki Teraji, Junichi Isoya, Lachlan J Rogers, and Fedor Jelezko. Isotopically varying spectral features of silicon-vacancy in diamond. *New J. Phys.*, 16(11):113019, nov 2014. 1
- [6] Elisa Londero, GergÅŚ Thiering, Monika BijeikytÄŰ, Jeromino R. Maze, Audrius Alkauskas, and Adam Gali. \emph{Ab initio} study on the Herzberg-Teller effect in the optical excitation spectrum of silicon-vacancy center in diamond. pages 1–5, may 2016. 1
- [7] Kai Mei C Fu, Charles Santori, Paul E. Barclay, Lachlan J. Rogers, Neil B. Manson, and Raymond G. Beausoleil. Observation of the dynamic Jahn-Teller effect in the excited states of nitrogen-vacancy centers in diamond. *Physical Review Letters*, 103(25):1–4, 2009. 2
- [8] A. M. Zaitsev. Vibronic spectra of impurity-related optical centers in diamond. *Physical Review B*, 61(19):12909–12922, may 2000. 2