Stimulated emission depletion microscopy with silicon vacancy centers in diamond

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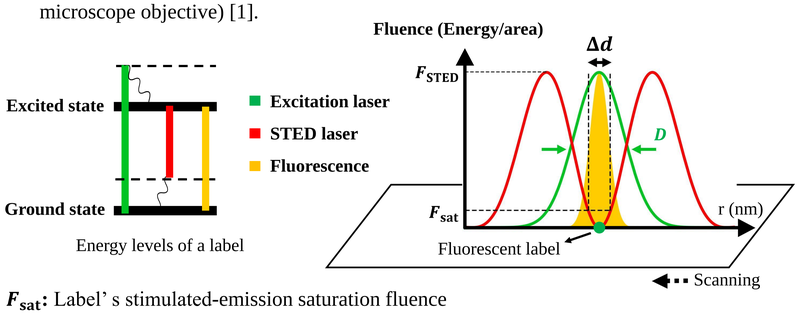
Introduction

- **Stimulated emission depletion (STED) microscopy** is a technique that can image fluorescent labels with a spatial resolution (Δd) superior to the optical diffraction limit ($D \sim \lambda/2\,\mathrm{NA}$, λ: wavelength of light, NA: numerical aperture of microscope objective) [1].



F_{sat}: Label' s stimulated-emission saturation fluence

$$\Delta d\,(F_{STED}) \approx \frac{D}{\sqrt{1 + F_{STED}/F_{sat}}}$$

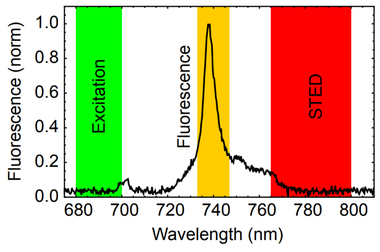
Suitable labels for STED microscopy:
- **Low F_{sat}**
- **High photo-stability**

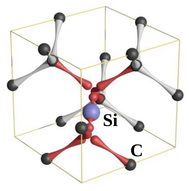
Organic fluorophores suffer from photo-bleaching [2].

Methodology

Silicon vacancy (SiV) center in Diamond

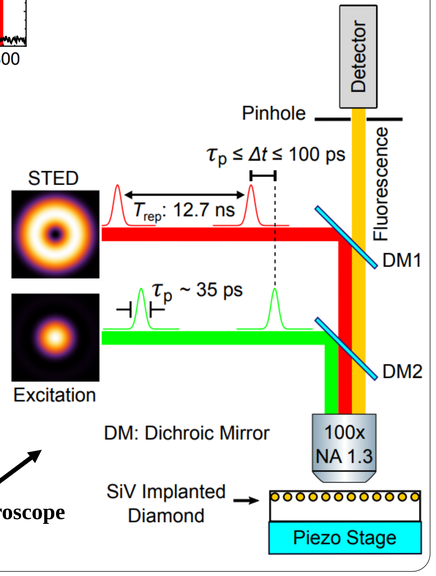
SiV' s spectrum





Why SiV?

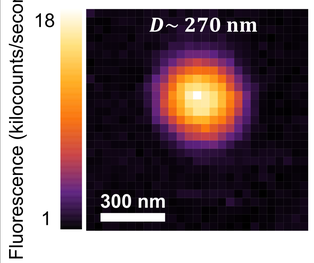
- **Bright (~10^6 counts/second) [3]**
- **High contrast in bio-samples (Narrow spectrum in near-infrared)**
- **Hypothesis: low F_{sat} (Small phonon side-band)**
- **Photo-stable in small nanodiamonds (< 2 nm) [4]**



Home-built pulsed STED Microscope

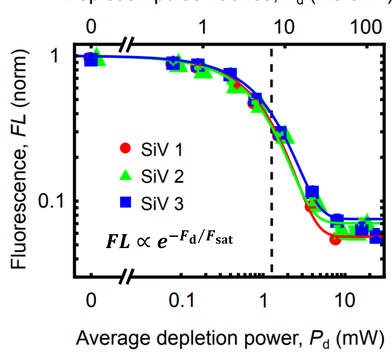
Results

Confocal image of a SiV center



F_{sat} (SiV) $= 6.8 \pm 0.6$ mJ/cm^2

Fluorescence quenching of SiV centers



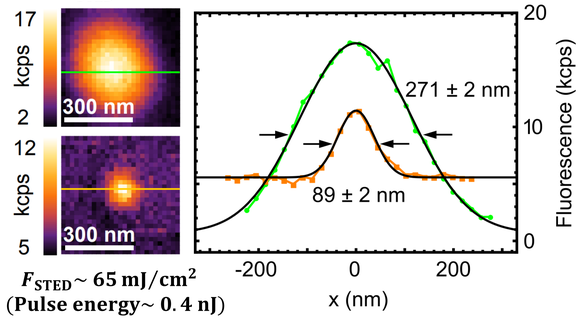
Stimulated-emission cross section:

$$\sigma_{STED} = \frac{E_{ph}\,(\text{photon energy})}{F_{sat}}$$

Fluorescent label:	SiV [5]	Nitrogen vacancy [6]	Organic fluorophores [7]
σ_{STED} $\times 10^{-17}$cm^2	4.0 ± 0.3	$1 - 2$	$3 - 15$

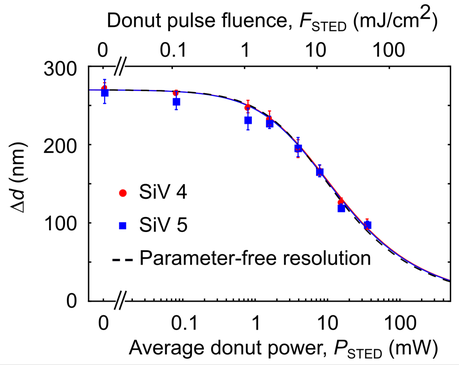
STED resolution enhancement with SiV centers

$F_{STED} = 0$

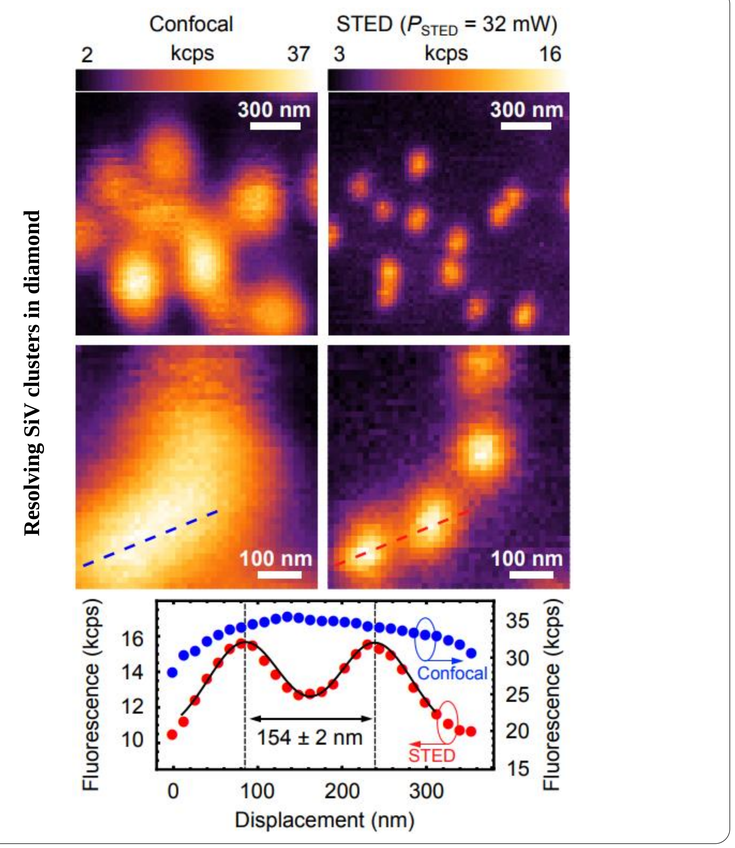


$F_{STED} \sim 65$ mJ/cm^2
(**Pulse energy~ 0.4 nJ**)

- **No bleaching or blinking was observed (for weeks).**
- **For 5 nJ ⟶ Δd (SiV) ≈ 20 nm**

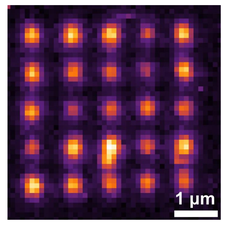


Results

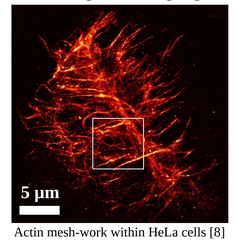


Applications & future work

Quantum information



Biological imaging



Actin mesh-work within HeLa cells [8]

- Excited-state absorption spectroscopy of SiV centers in diamond
- Diamond micro-ring color center lasers

References

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Please feel free to email me at yasersilani@unm.edu if you have a question or comment.