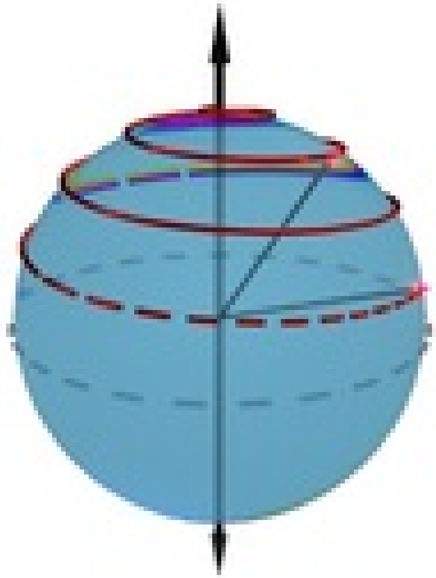
# Diamond Fabrication for Quantum Devices

Hannah Kline

# Uses of quantum mechanics

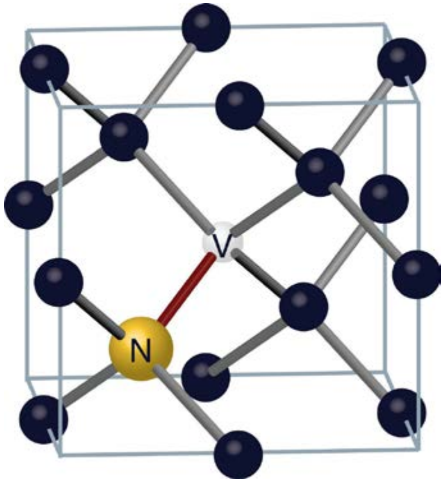
- Breaking  current encryption
- Secure communication
- High precision sensing
- Quantum computation

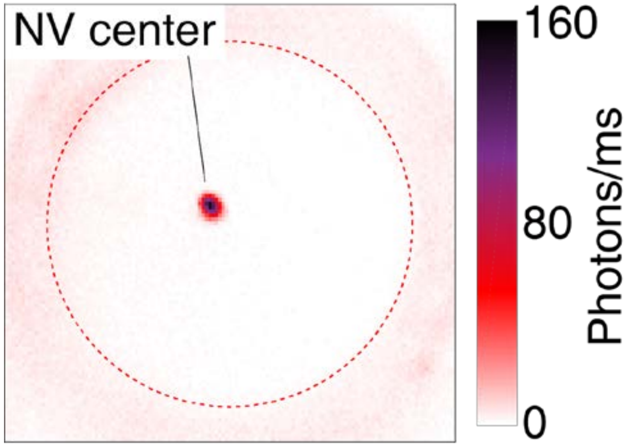


# Nitrogen vacancy center

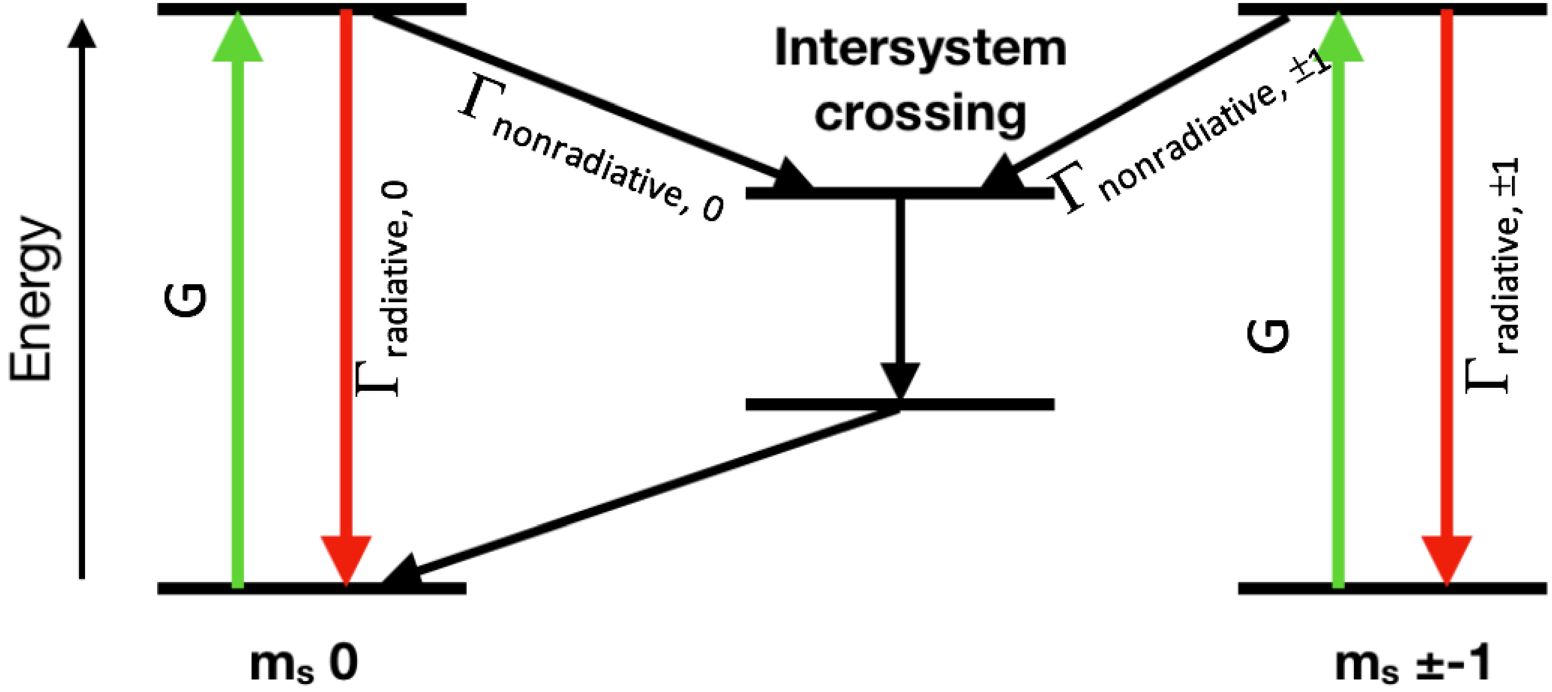
Penn
UNIVERSITY of PENNSYLVANIA

- Stable quantum system due to shielding from carbon atoms
- Optically addressable at room temperature
- Implanted with electron irradiation or ion implantation



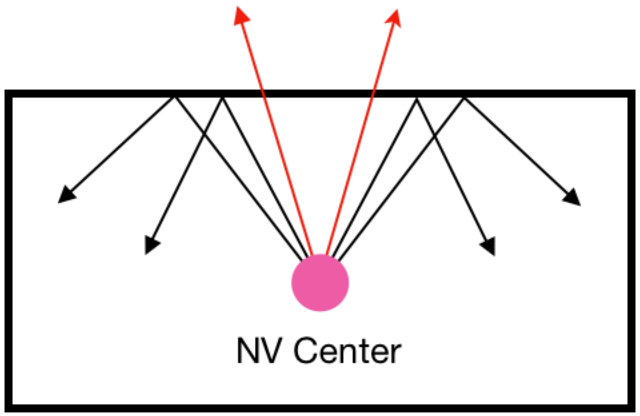



# Intersystem crossing



# Challenges of diamond

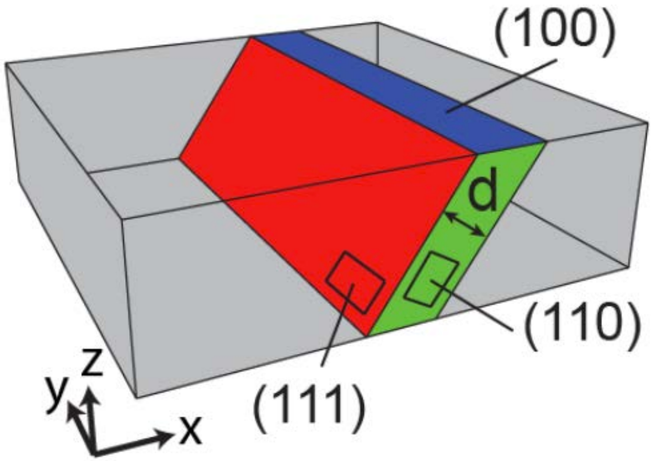
- High refractive index
- Low light output
- Less fabrication knowledge compared to silicon




Smooth diamond

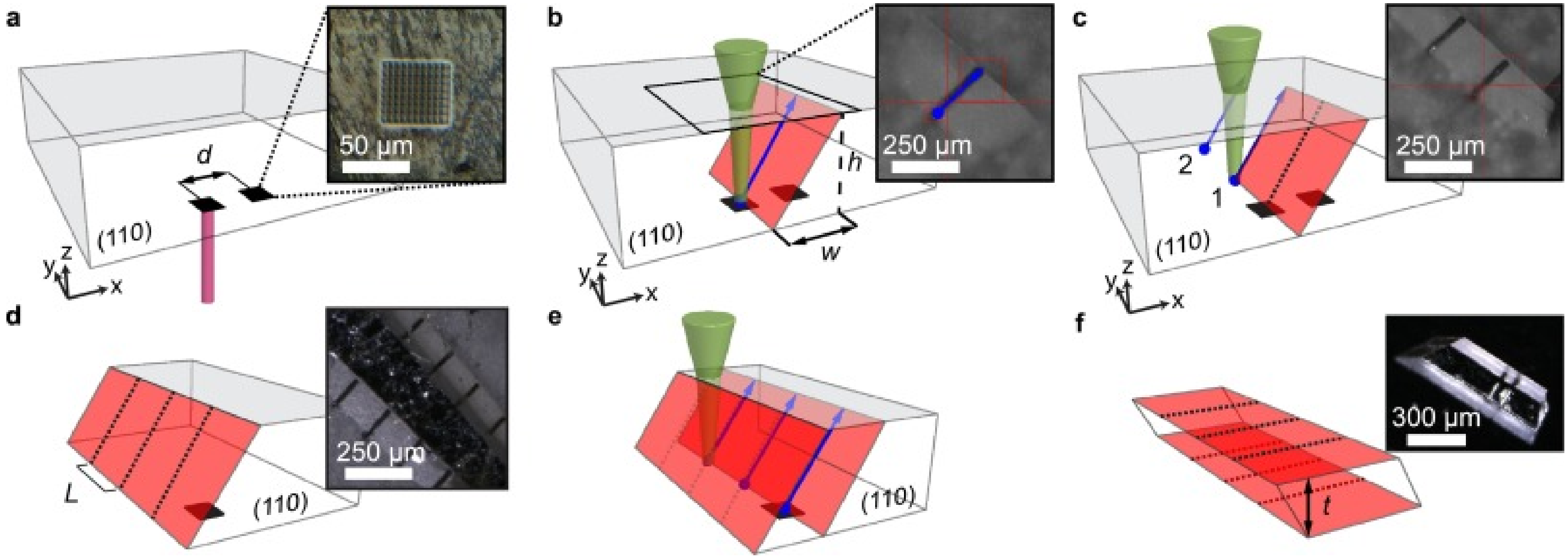
# Benefits of (111) diamonds

- 65% more photon emission/absorption
- Better optical coupling to NV center
- Higher doping efficiency
- Hardest face



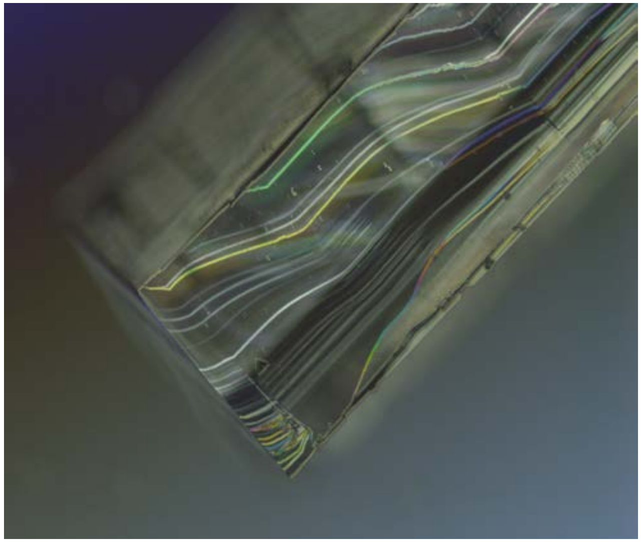

- Not generally, commercially available

# Previous two laser method



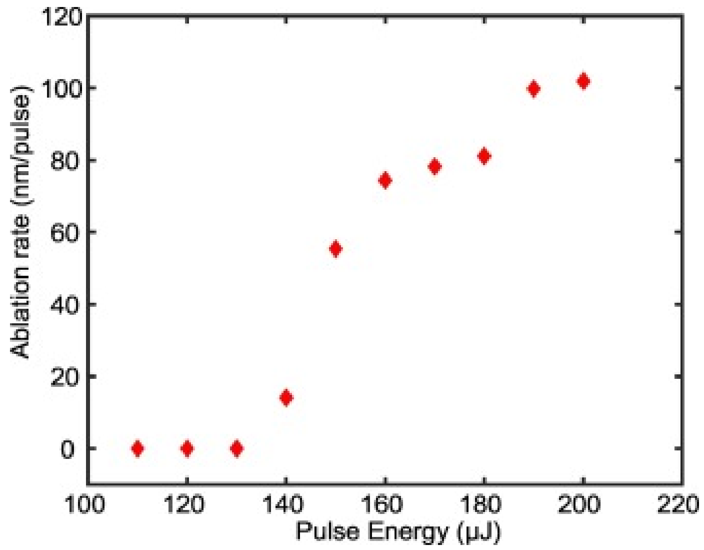
# Goals of project

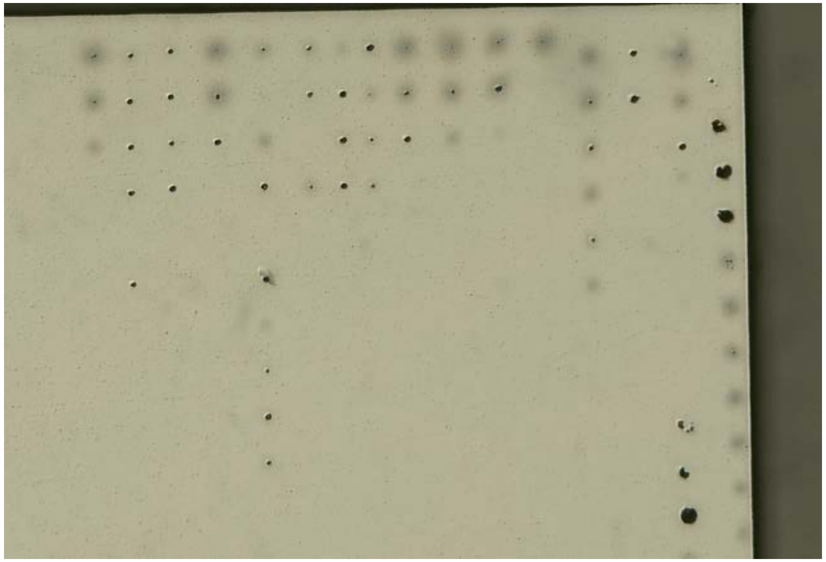
- Have a 1 laser method
- Less damage
  - Smaller cleave lines
  - Less Wallner lines
- Thinner pieces
- More efficient



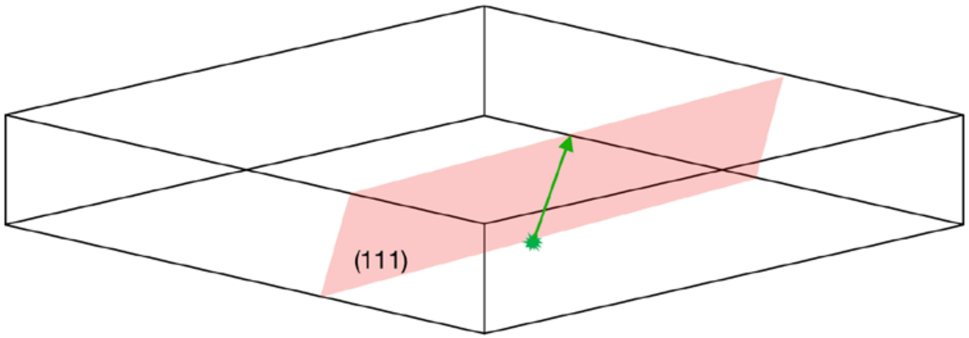
## Parameter testing using only 532 nm laser

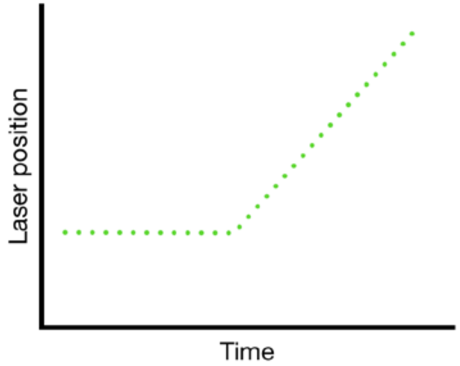
- Bursts were used to test
  - Height
  - Rate
  - Power

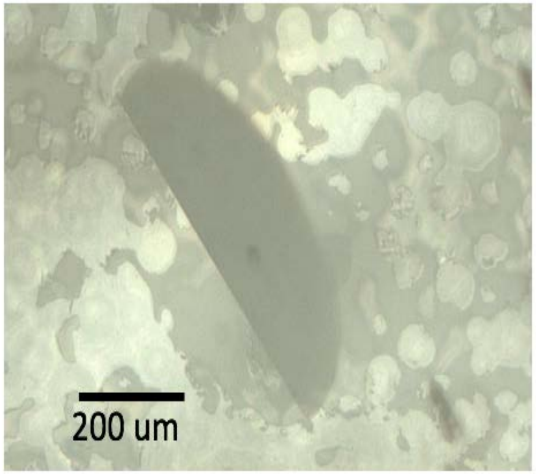


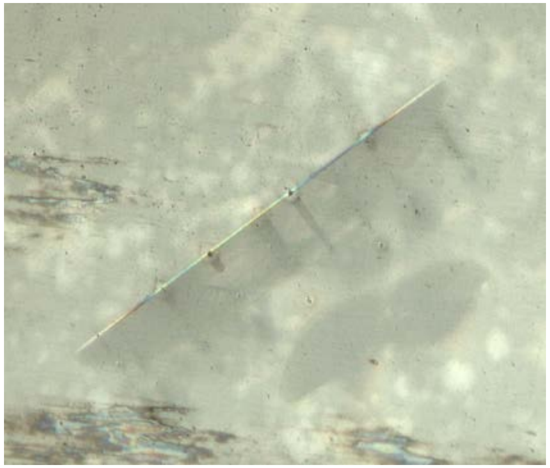
# New fabrication process



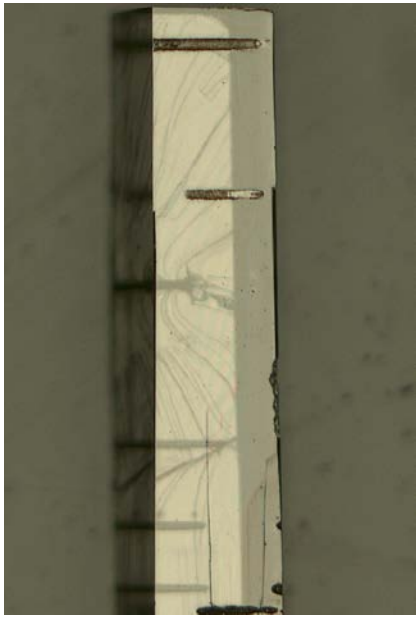




Initiation

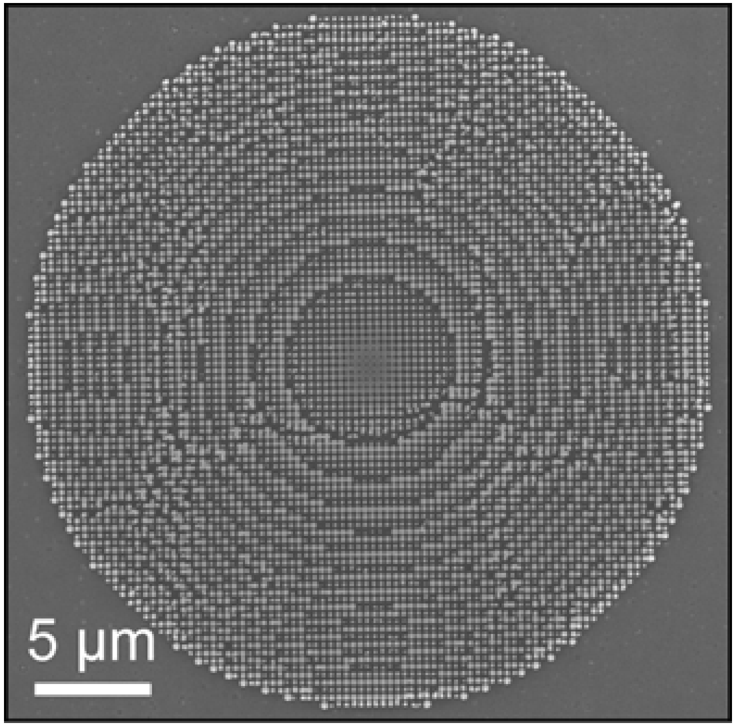


Propagation

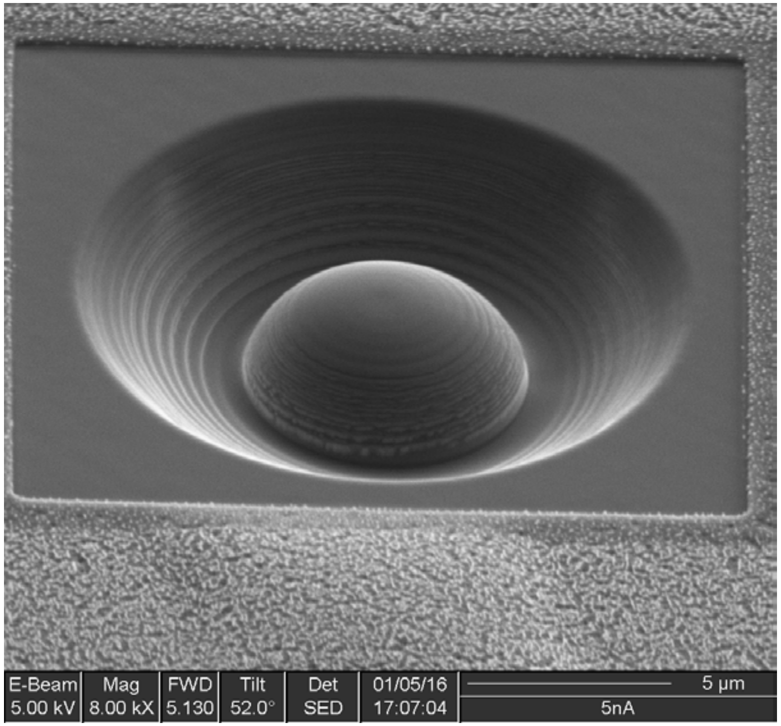


Cleaved piece

# Integration with current NV center projects




Metalens




Solid immersion lens

# Applications

- Atomic force microscopy to detect magnetic resonance

  (Sample sent to University of California- Santa Barbara)

- Seed crystals for chemical vapor deposition growth of (111)

  diamonds (Sample sent to Michigan State University )

- Quantum control
  - Computing, sensors (magnetic, electrical, biological), memory, telecommunications

# Acknowledgements


- Henry Shulevitz
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## References:


- [1] Jamali, M.; Gerhardt, I.; Rezai, M.; Frenner, K.; Fedder, H.; Wrachtrup, J. Microscopic Diamond Solid-Immersion-Lenses Fabricated around Single Defect Centers by Focused Ion Beam Milling. *Review of Scientific Instruments* **2014**, *85* (12), 123703.
- [2] Parks, S. M.; Grote, R. R.; Hopper, D. A.; Bassett, L. C. Fabrication of (111)-Faced Single-Crystal Diamond Plates by Laser Nucleated Cleaving. *Diam. Relat. Mater.* **2018**, *84*, 20–25.
- [3] Jamali, M.; Gerhardt, I.; Rezai, M.; Frenner, K.; Fedder, H.; Wrachtrup, J. Microscopic Diamond Solid-Immersion-Lenses Fabricated around Single Defect Centers by Focused Ion Beam Milling. *Rev. Sci. Instrum.* **2014**, *85* (12), 123703.
- [4] Grote, R. R.; Huang, T.-Y.; Mann, S. A.; Hopper, D. A.; Exarhos, A. L.; Lopez, G. G.; Garnett, E. C.; Bassett, L. C. Imaging a Nitrogen-Vacancy Center with a Diamond Immersion Metalens. *ArXiv171100901 Phys.* **2017**.

# Questions?