MONSTR SENSE TECHNOLOGIES

Material Characterization Using the KRAKEN Turnkey Ultrafast Microscope

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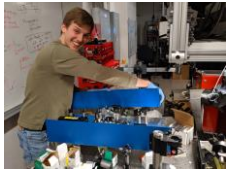
Optical Research Scientist
MONSTR Sense Technologies, LLC

2024 Advanced Materials Characterization Workshop

History of MONSTR Sense Technologies

2018 Spin-off from the University of Michigan



2019 Introduction of the BIGFOOT® Spectrometer

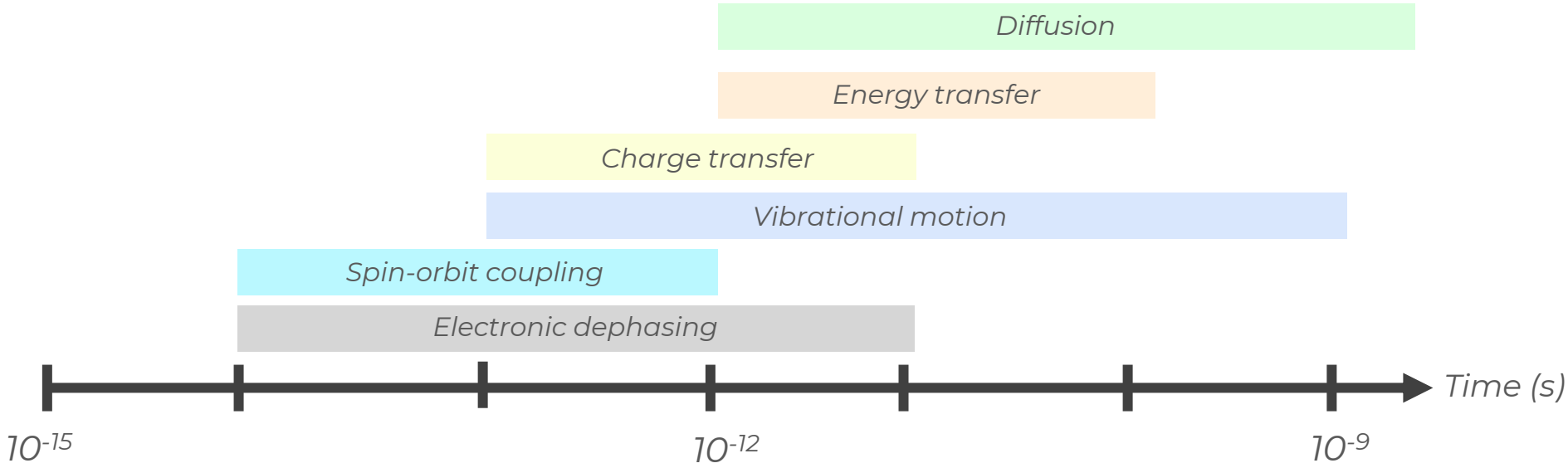
2021 Introduction of the NESSIE® Microscope

2022 NSF SBIR Award ($1.25M) for the development of an Ultrafast Nonlinear Microscope

2024 Introduction of the KRAKEN Turnkey Ultrafast Microscope

The Benefits of Ultrafast Microscopy

A universal probe of ultrafast processes and the electronic bandstructure that is compatible with rapid, 3D (volumetric) imaging.



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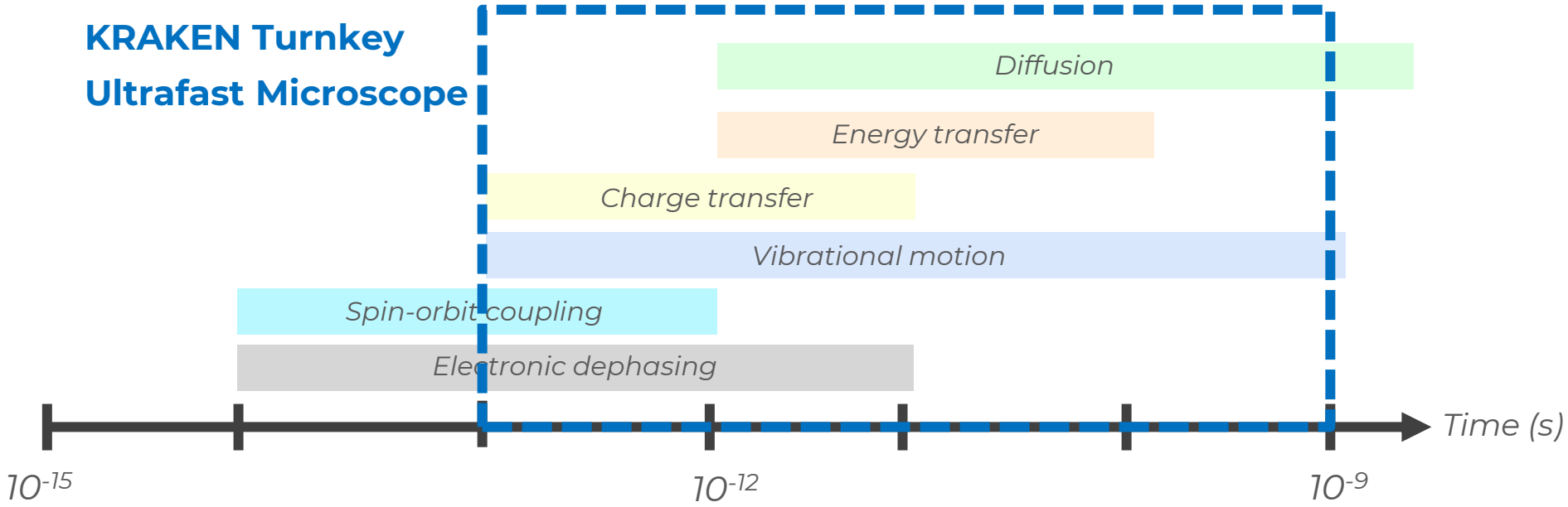
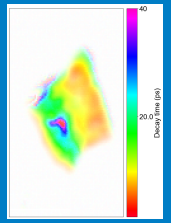


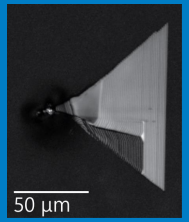
The capabilities & advantages of the KRAKEN Microscope

Measuring Ultrafast Processes

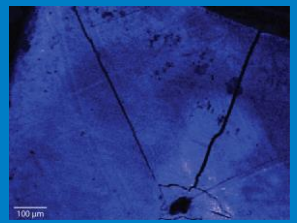
Trapped states in 2D Materials



Defect lifetimes in compound semiconductors



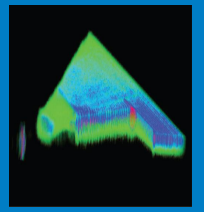
Charge transfer in perovskites



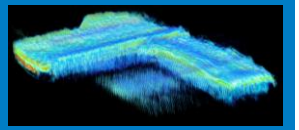
Data: E. Kirstein (TU Dortmund)

Volumetric Imaging

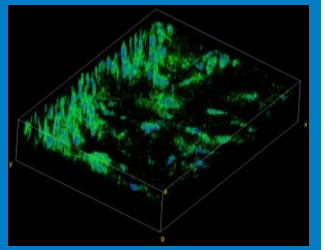
3D Morphology of defects



Addressing different layer structures in devices

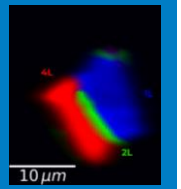


Morphology of tissue

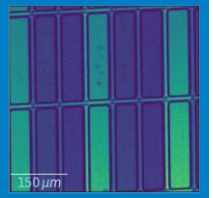


Hyperspectral

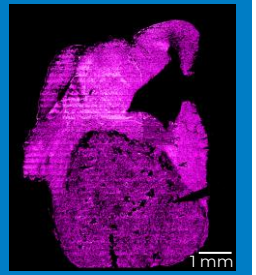
Layer number & strain in 2D Materials



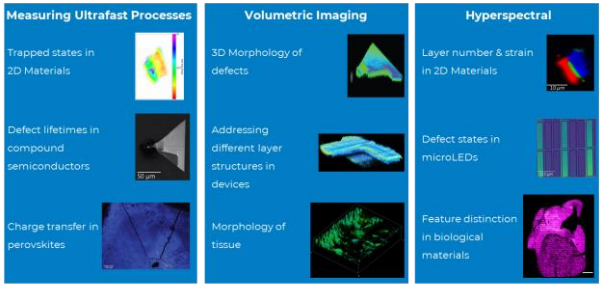
Defect states in microLEDs



Feature distinction in biological materials



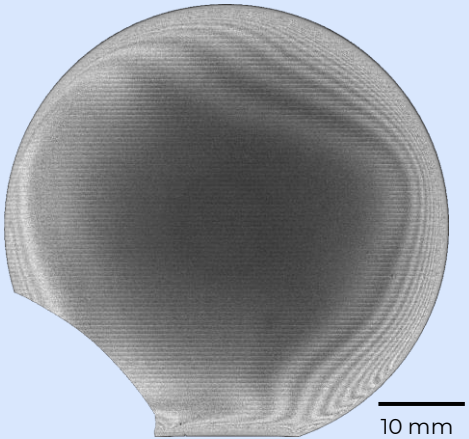
The capabilities & advantages of the KRAKEN Microscope



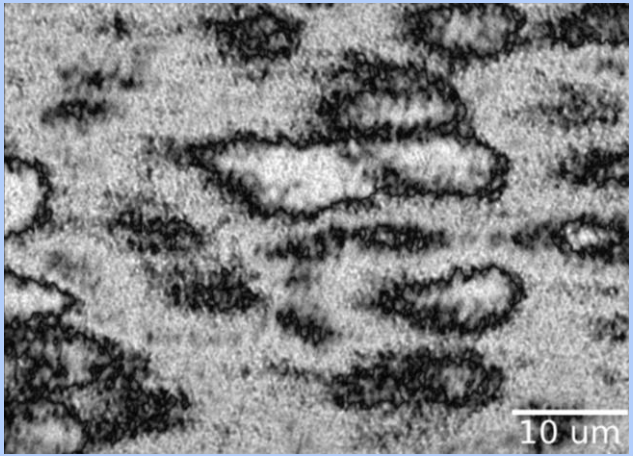
Assess Material Quality

Example: GaN template on sapphire

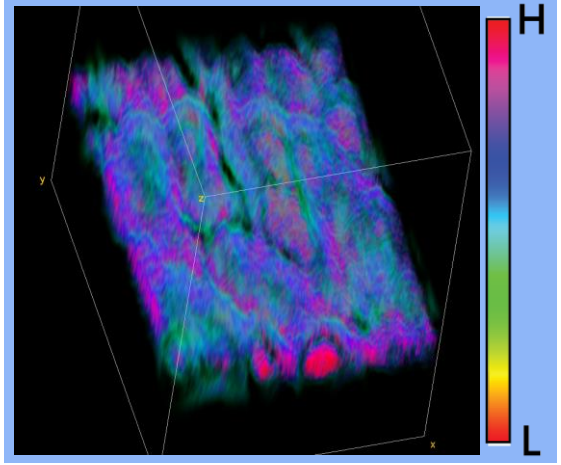
Rapid “in-line” overview scan



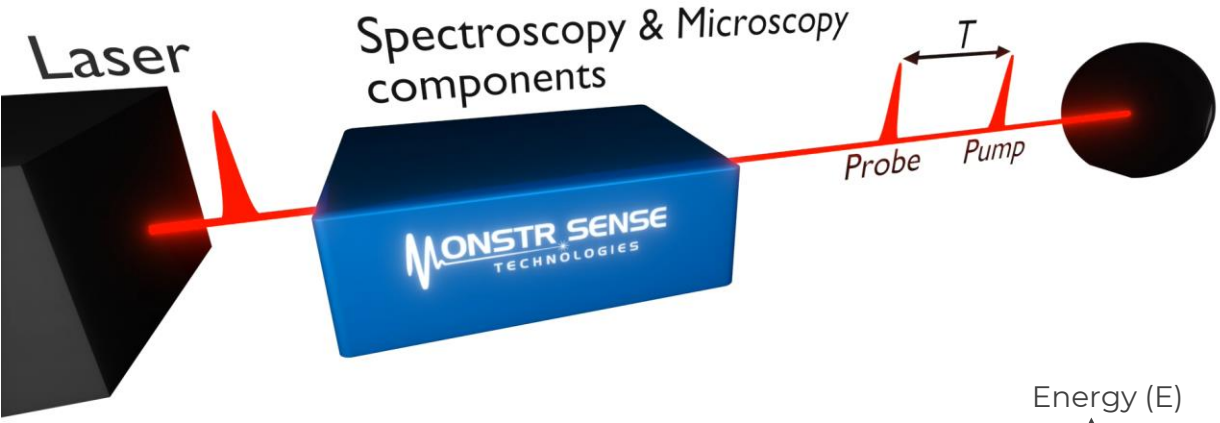
High-resolution zoom-in for better understanding of morphology

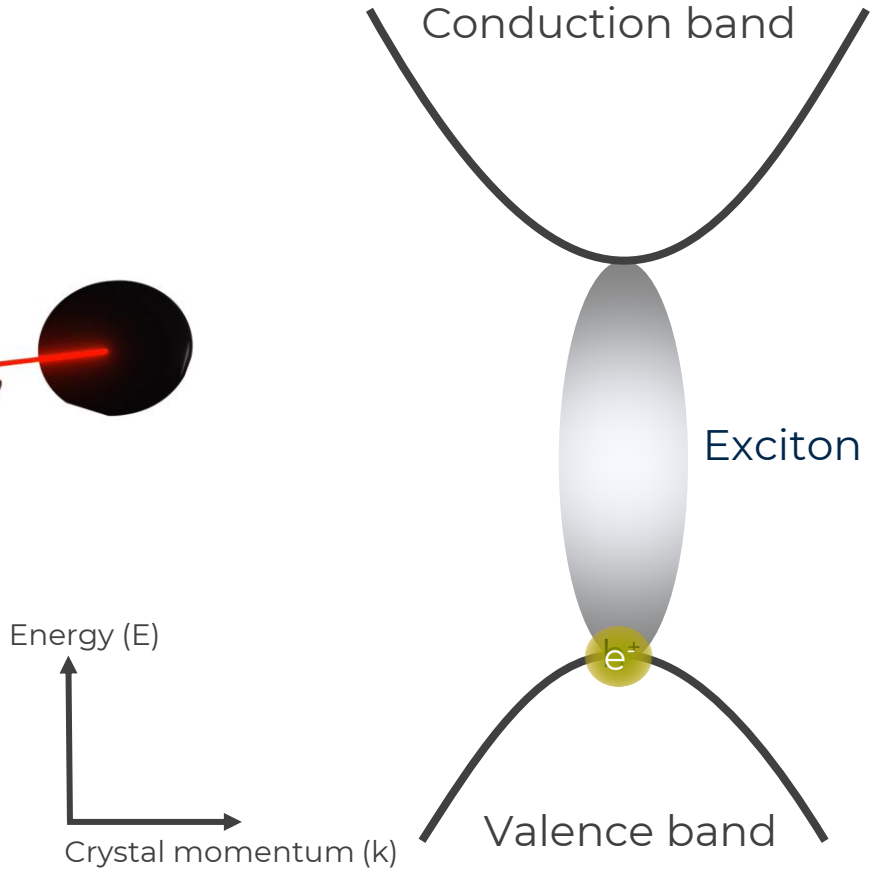


Volumetric scan for full morphology



How it works: Ultrafast Microscopy





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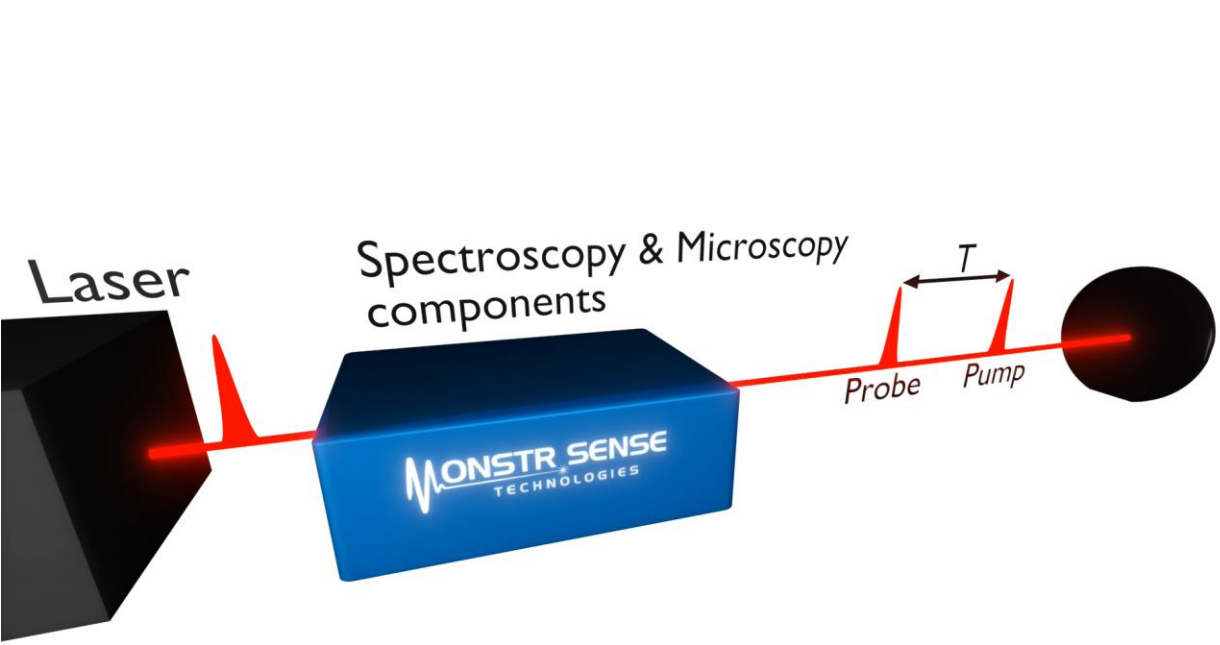

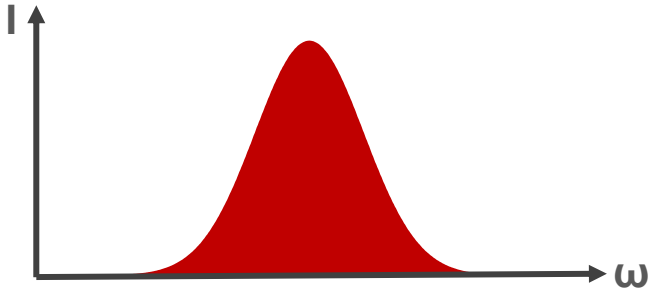

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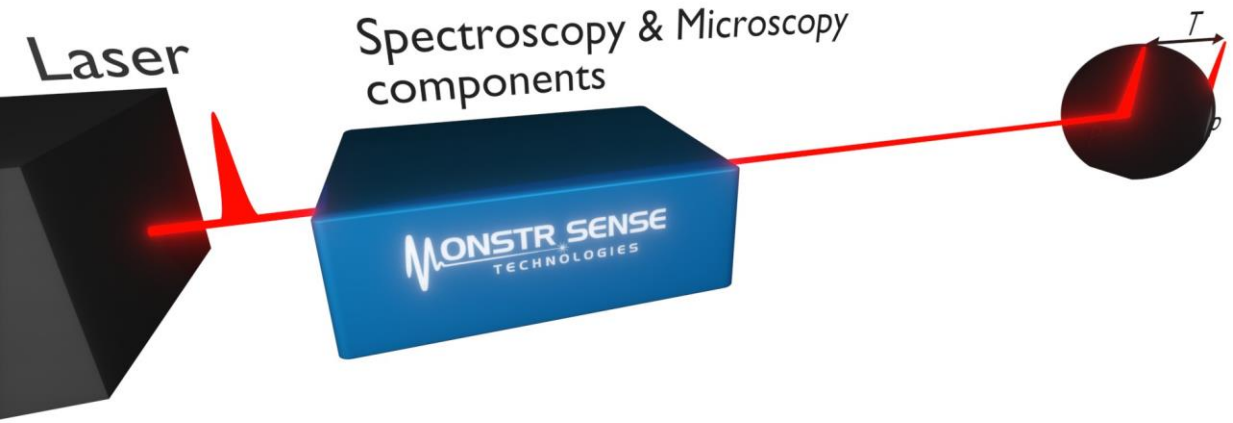
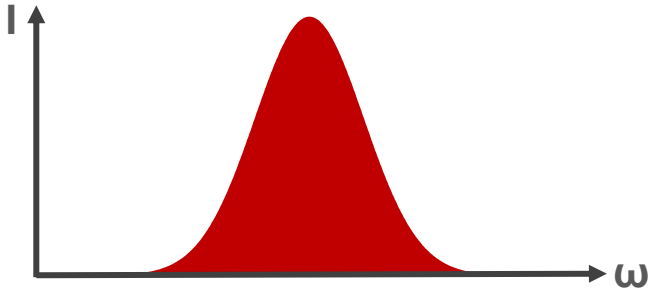


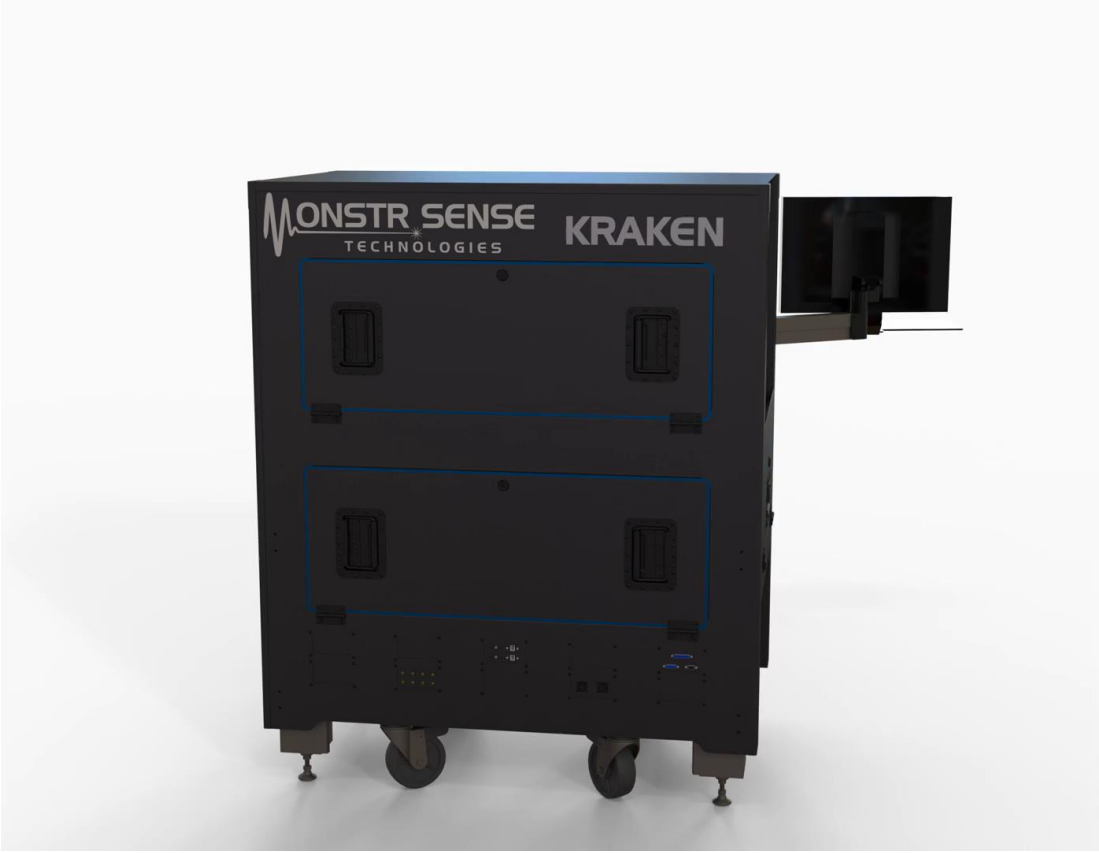


Probe reflectivity change = **probe of bandstructure**

Monitoring reflectivity changes: Interactions, strain, doping, defects...

⚠ Reflectivity change: 10^{-4} -10^{-6}

Ultrafast Microscopy made easy: The KRAKEN Microscope



Ultrafast Microscopy made compact: The KRAKEN Microscope

Small footprint:

50” x 31” x 60”

Ultrafast Microscopy made easy

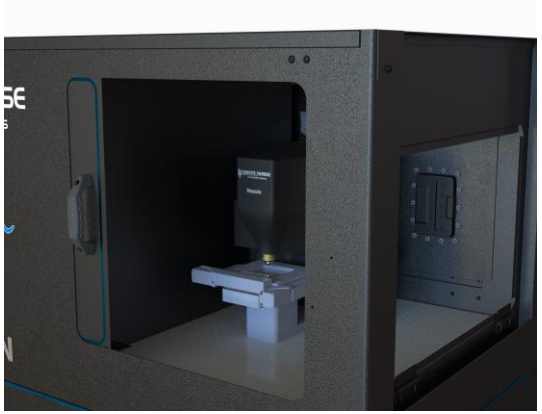
Step 1: Load sample into cryostat/onto the sample stage

Step 2: Set your required wavelength

Step 3: Fine tune your focus

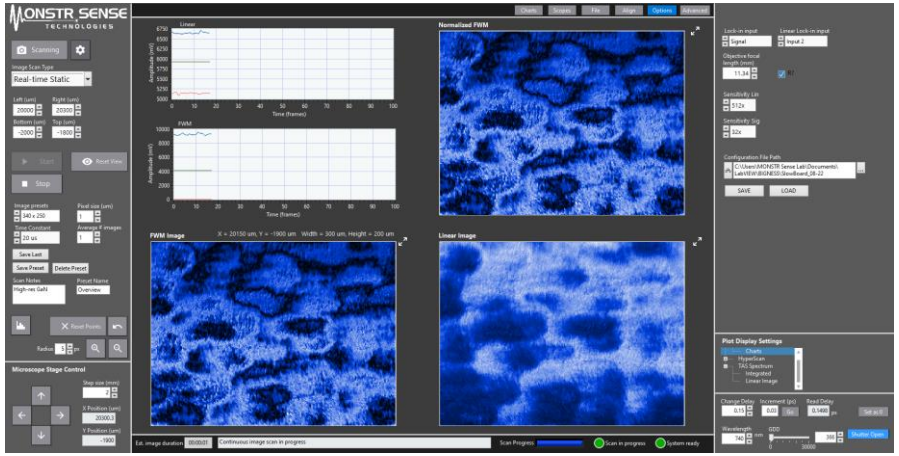
Step 4: Measure!

Software only

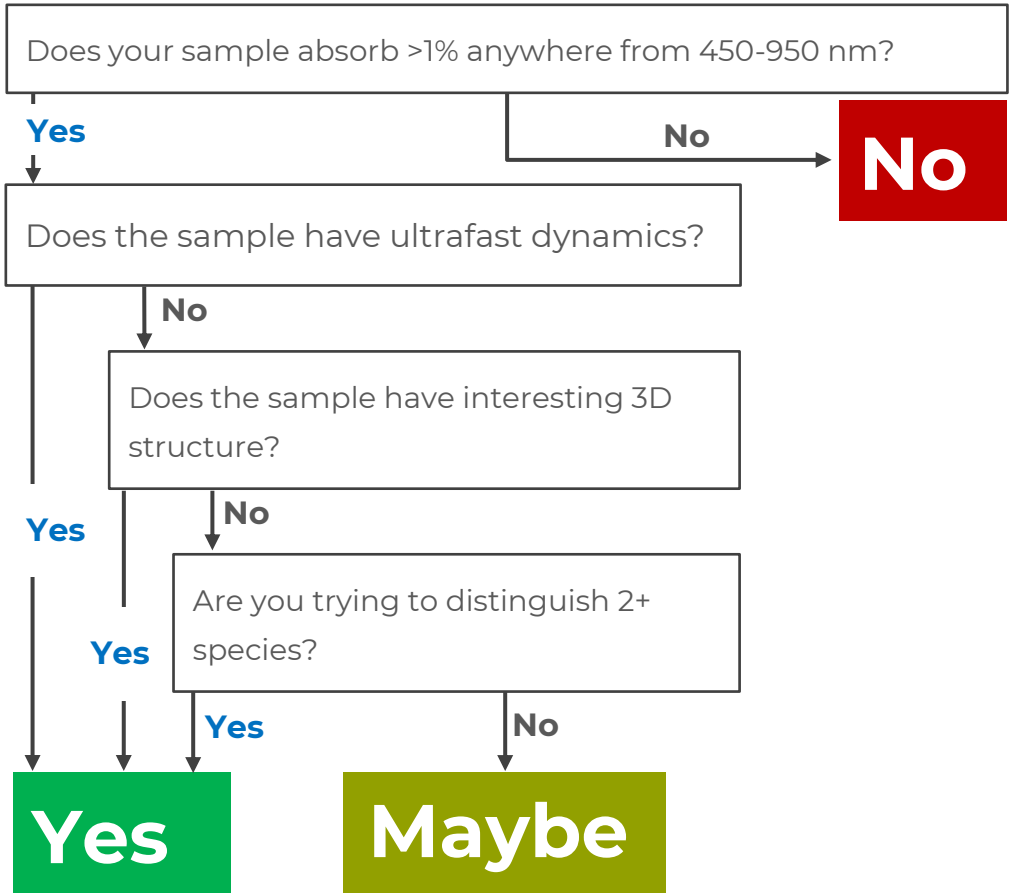


Less tinkering with parameters:

- Autofind your wavelengths for hyperspectral scans
- Autofind your delay steps for hypertemporal scans



How do I know whether ultrafast microscopy is for me?



Not sure?

Check out our Advanced Material Characterization service package: Affordable, fast, figuring out the best experimental parameters for you

The ultrafast advantage

Despite the prevalence of White Light Microscopy, PL and Raman, the KRAKEN Microscope has some key advantages:

Feature	Photoluminescence Microscopy	Raman Microscopy	White Light Microscopy	KRAKEN Microscope
Material specificity	✓	✓	x	✓
Sub-um spatial resolution	✓	✓	✓	✓
Responsive Imaging (> 1 fps)	✓	x	✓	✓
Temporal resolution	O	x	x	✓
Volumetric capability	O	O	O	✓

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KRAKEN Ultrafast Microscope Specs

Spatial resolution: < 1 µm

Axial resolution: < 8 µm

Field of view: 900 µm x 900 µm (upgrade to 120 mm x 100 mm at RT)

Wavelength range: 450 nm – 950 nm

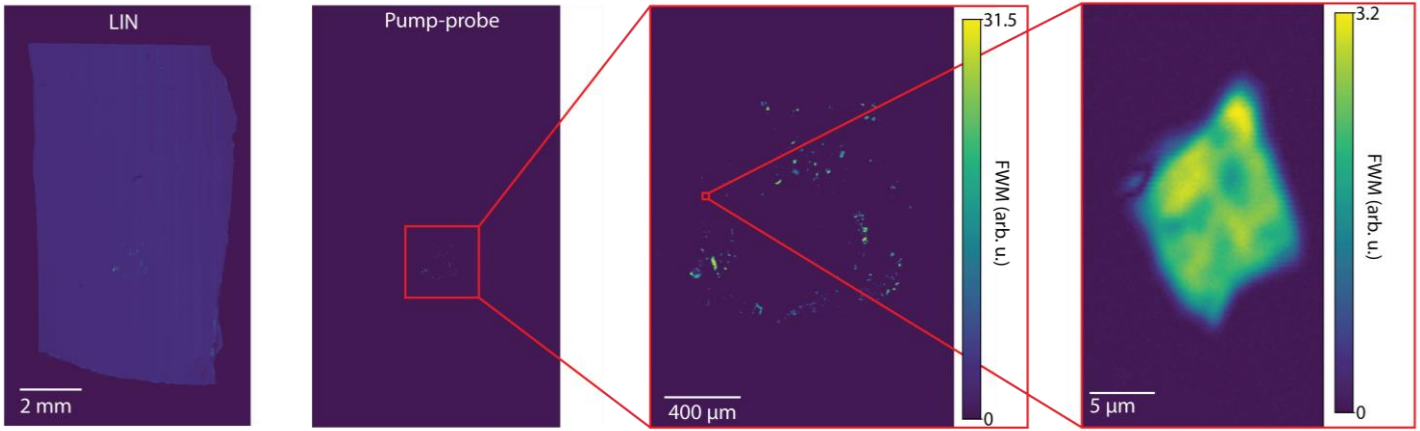
Decay range: 0-2000 ps

Laser power (at sample): 0-10 mW

Temperature range: 4K – 300K

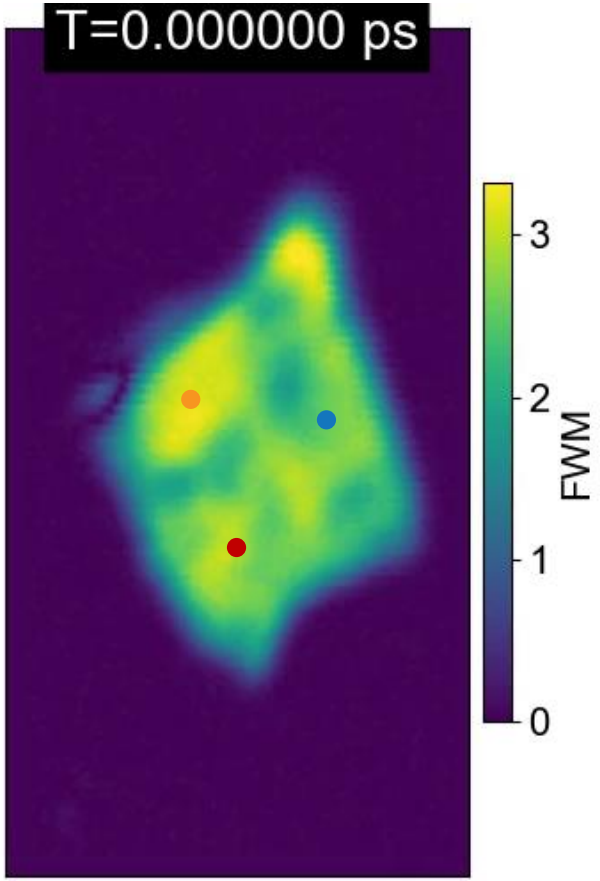
Using KRAKEN to find small samples on large substrates

Example: 2D Material on sapphire substrate



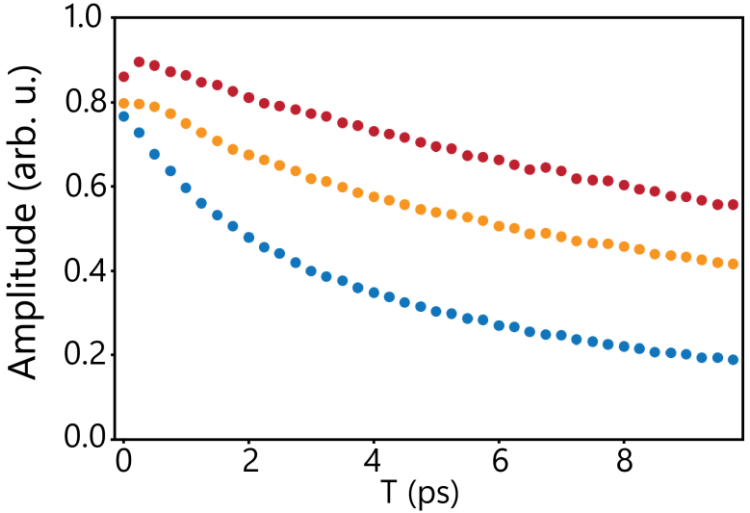
- Background-free technique that is highly sensitive to TMDs
- Use to measure layer number
- Use to assess sample quality
  - Dipole moment (strain, layer number, doping, environment, coupling, defects)
  - Resonance shifts (strain, layer number, doping, environment, coupling, defects)
  - Decay time (layer number, coupling, doping, environment, coupling, defects)

Detecting trapped states in 2D Materials



Sample: 1-4L $MoSe_2$

Decay can serve both as an indicator of layer number and track inhomogeneities within each layer region



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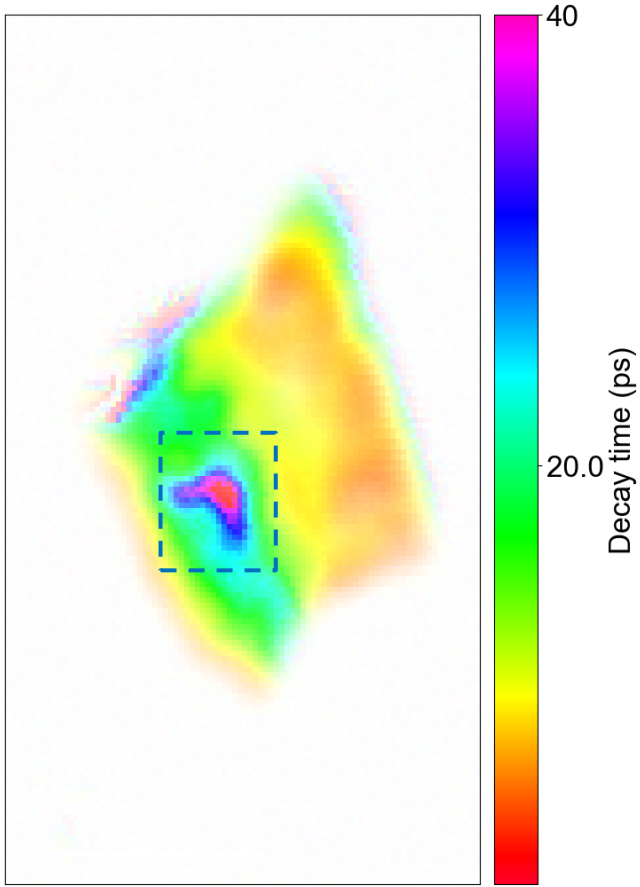
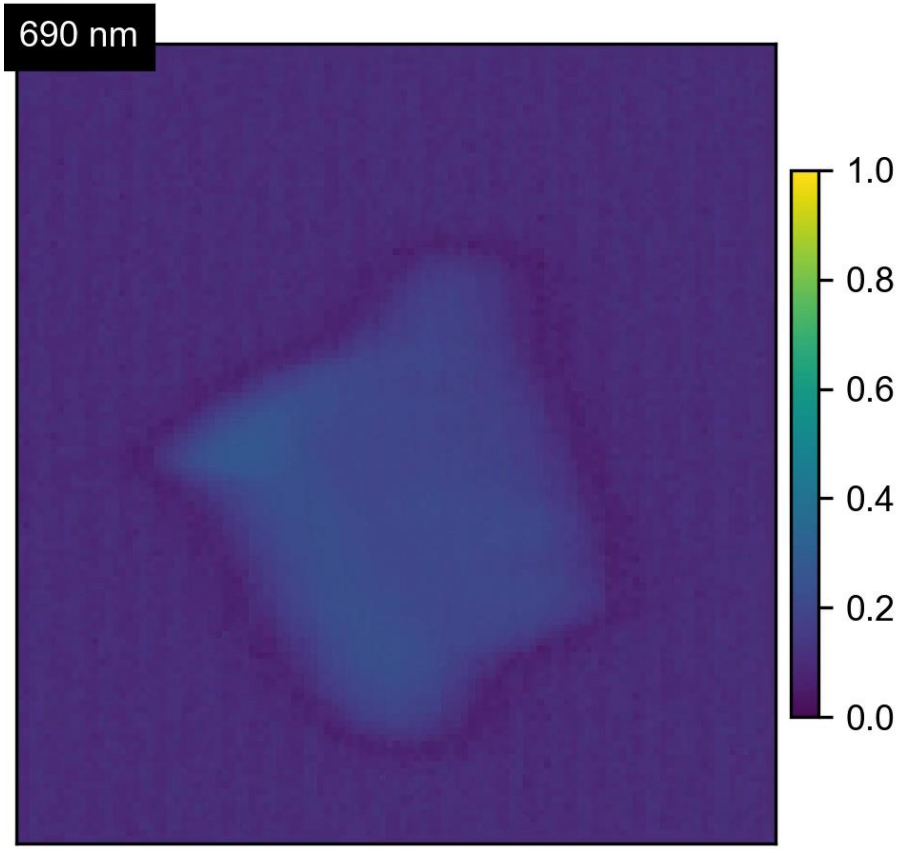


Sample: 1-4L $MoSe_2$

Regions of long-lived states indicate trapped states that cannot radiatively decay immediately

This inhomogeneity is only visualizable by a combination of femtosecond timing resolution, spectral specificity & rapid imaging

Hyperspectral Imaging for Sample Characterization

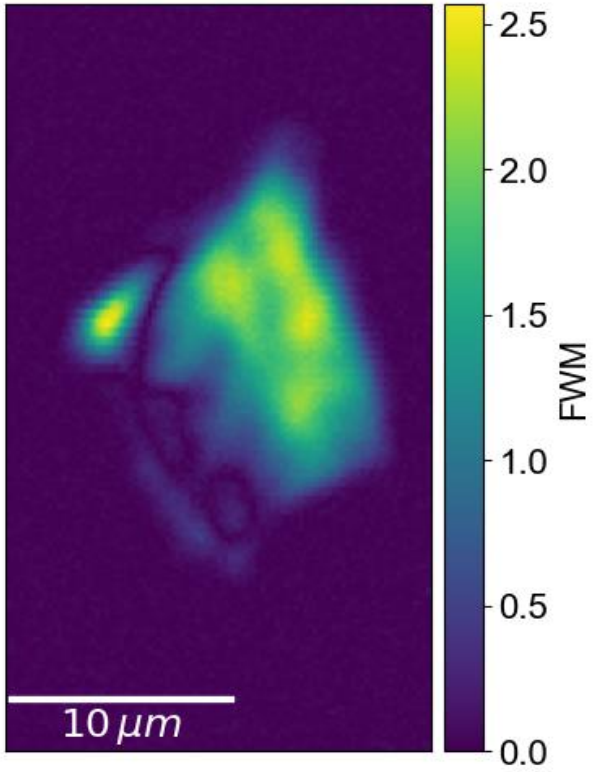


Sample: 1-4L $MoSe_2$

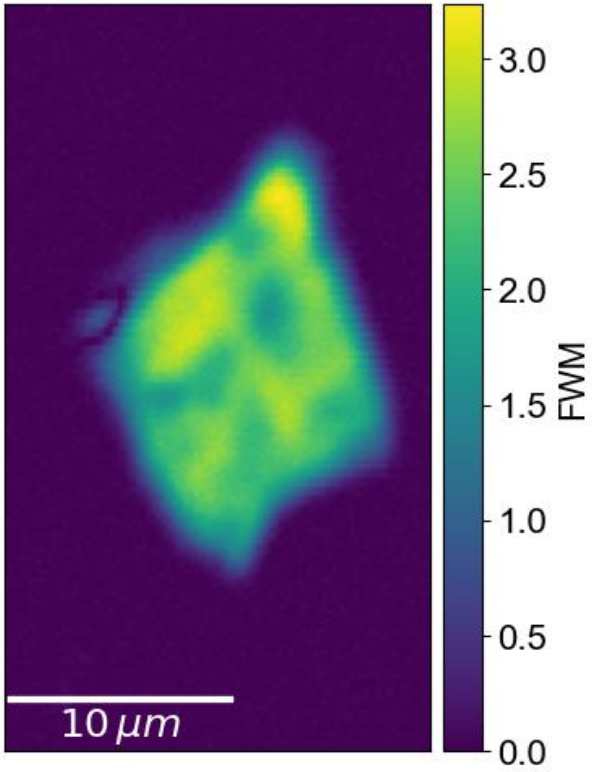
Hyperspectral image acquired by spectrally sweeping the laser (5 nm spectral resolution)

Hyperspectral Imaging for Sample Characterization

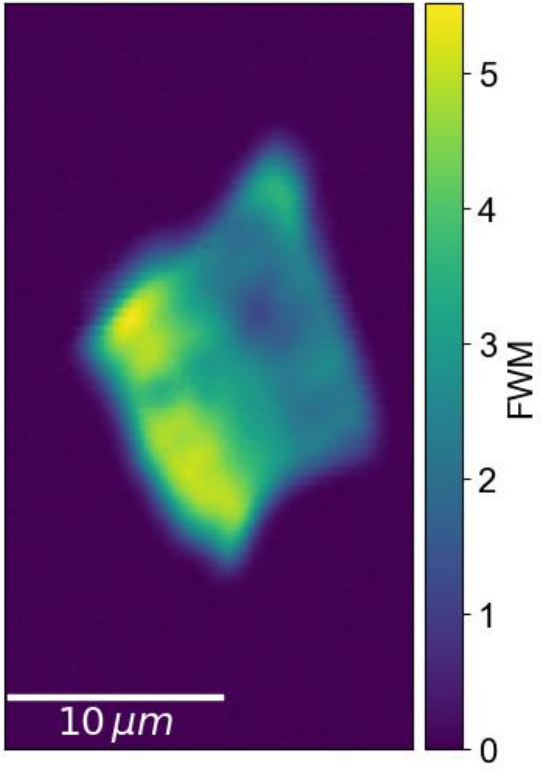
730 nm



743 nm

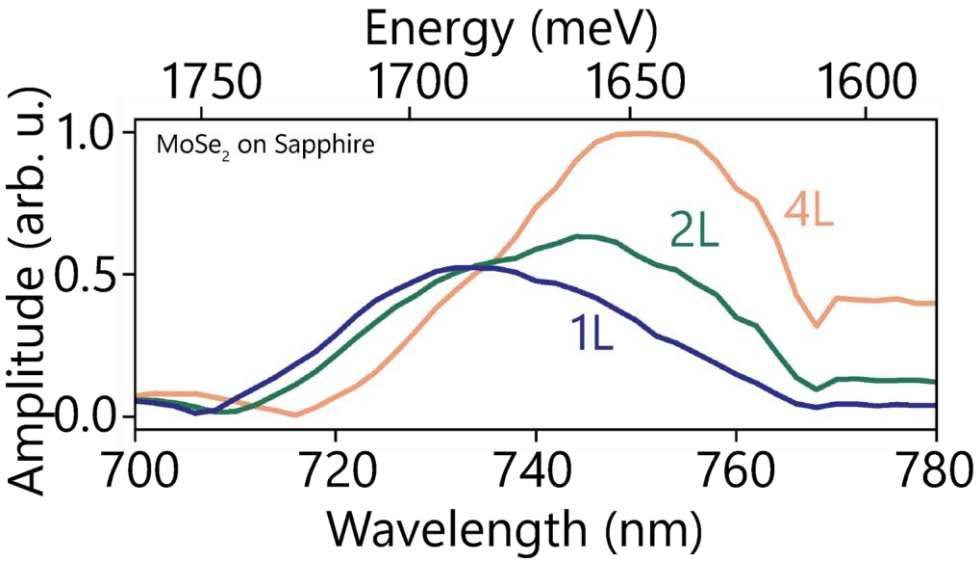


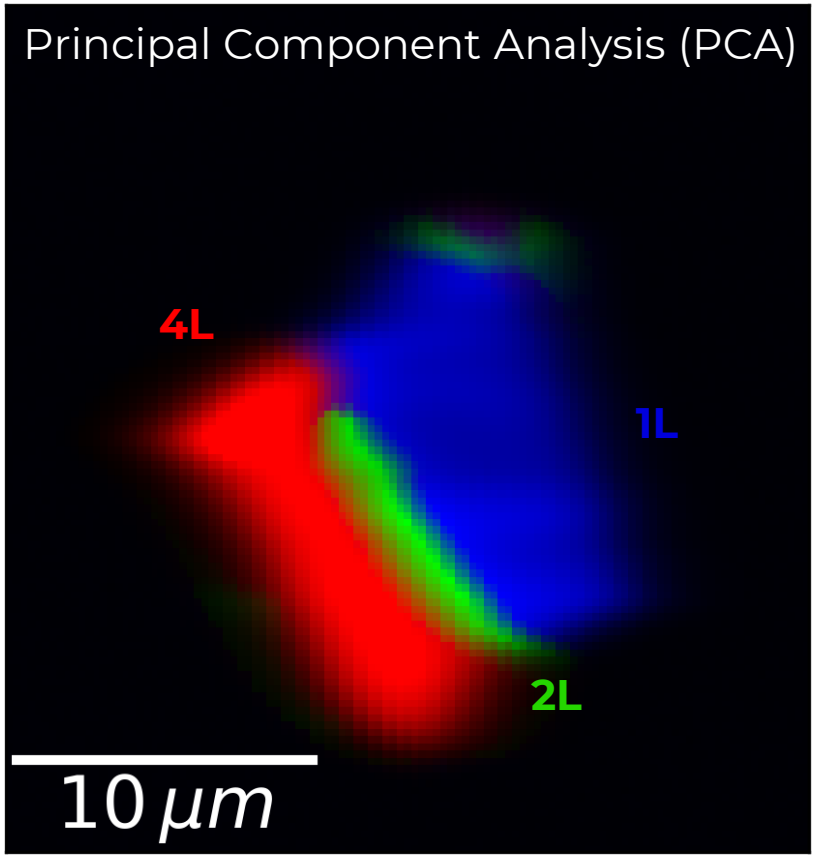
750 nm



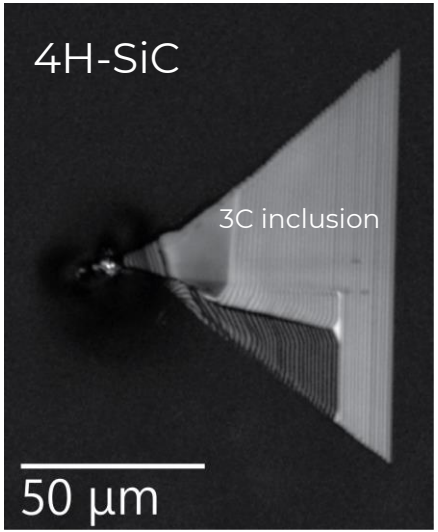
Layer number determination in $MoSe_2$

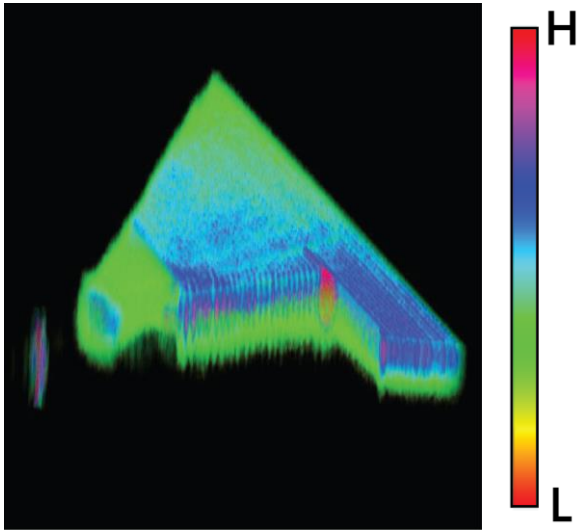
- KRAKEN measurement spectrally sensitive to layer number
- Unlike Photoluminescence (PL), no significant signal quenching

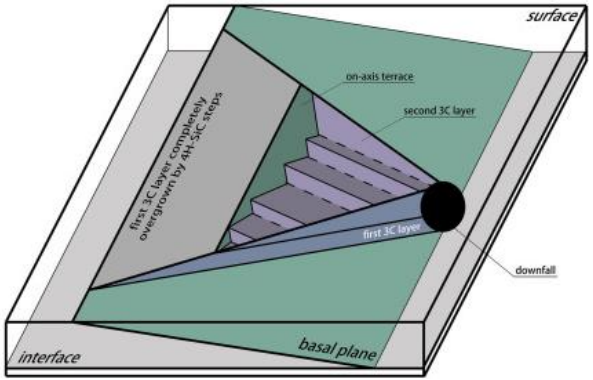




Volumetric Imaging of Defects in SiC





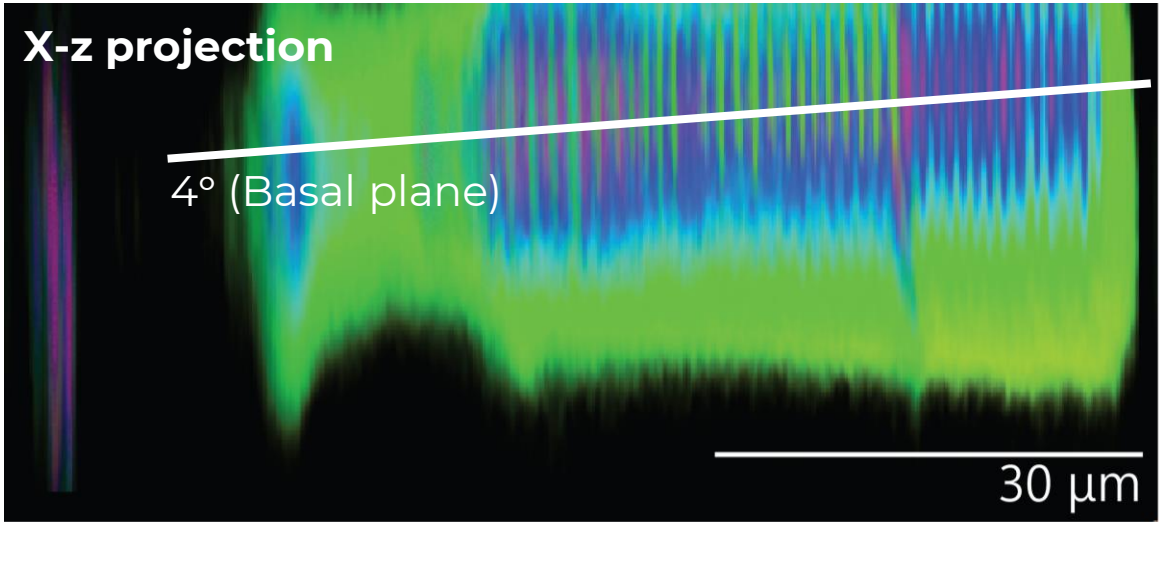


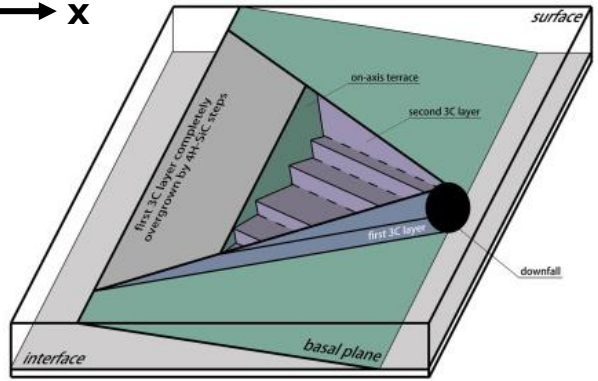
J. Guo. et al., Journal of Crystal Growth, 480, 119-125 (2017)

Ridges across the triangle are not found in any optical microscopy literature data

- Most likely caused by the 3C-4H interface acting as a Fabry-Perot etalon with 4° angle

Volumetric Imaging of Surface Triangles



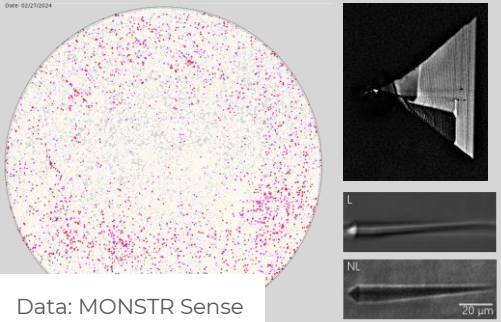


J. Guo. et al., Journal of Crystal Growth, 480, 119-125 (2017)

- X-z projection shows 4° triangle growth along basal plane
- Triangle has different levels of depth for different parts

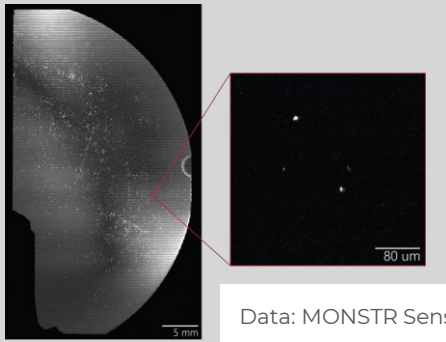
Summary

SiC epitaxy wafer (6”) defects
App: power electronics



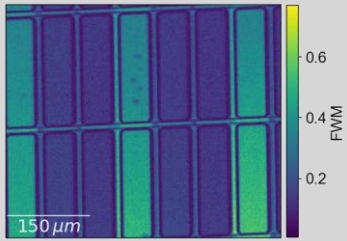
Data: MONSTR Sense

GaAs quantum well wafer (2”)
App: laser diodes



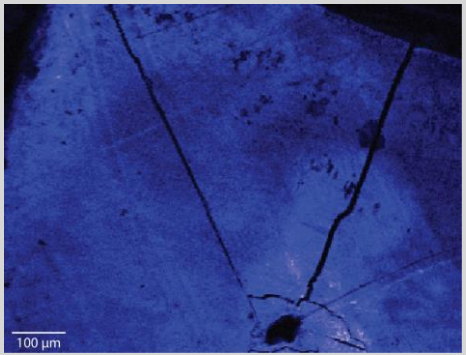
Data: MONSTR Sense

µOLEDs
App: displays



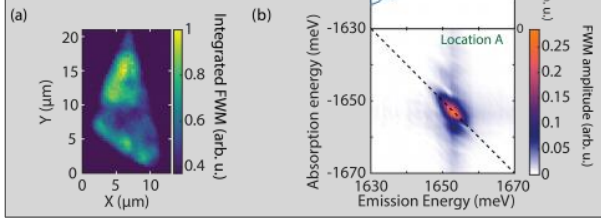
Data: MONSTR Sense

Perovskites
App: solar cells



Data: E. Kirstein/TU Dortmund

TMD monolayers and heterostructures
App: TBD



Data: T. L. Purz et al., J. Chem. Phys. 156, 214704 (2022)

MONSTR SENSE TECHNOLOGIES

Thank you for your attention!

Questions?

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Advanced Materials Characterization 2024

Meet us at our booth

Torben Purz, Ph.D.
Expertise: Semiconductors, 2D materials, pump-probe imaging, transient absorption imaging, multi-dimensional coherent spectroscopy

Matt Clark, Ph.D.
Expertise: Biological materials, vibrational imaging (CARS, SRS), photothermal imaging, multiphoton microscopy