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Product Line
neaspec

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Applications Collection

Ultrafast Nano-Spectroscopy

probing ultrafast dynamics at the nanoscale

NANOSCALE ANALYTICS
advanced imaging & spectroscopy

Recommended Product: *IR*-neaSCOPE+fs

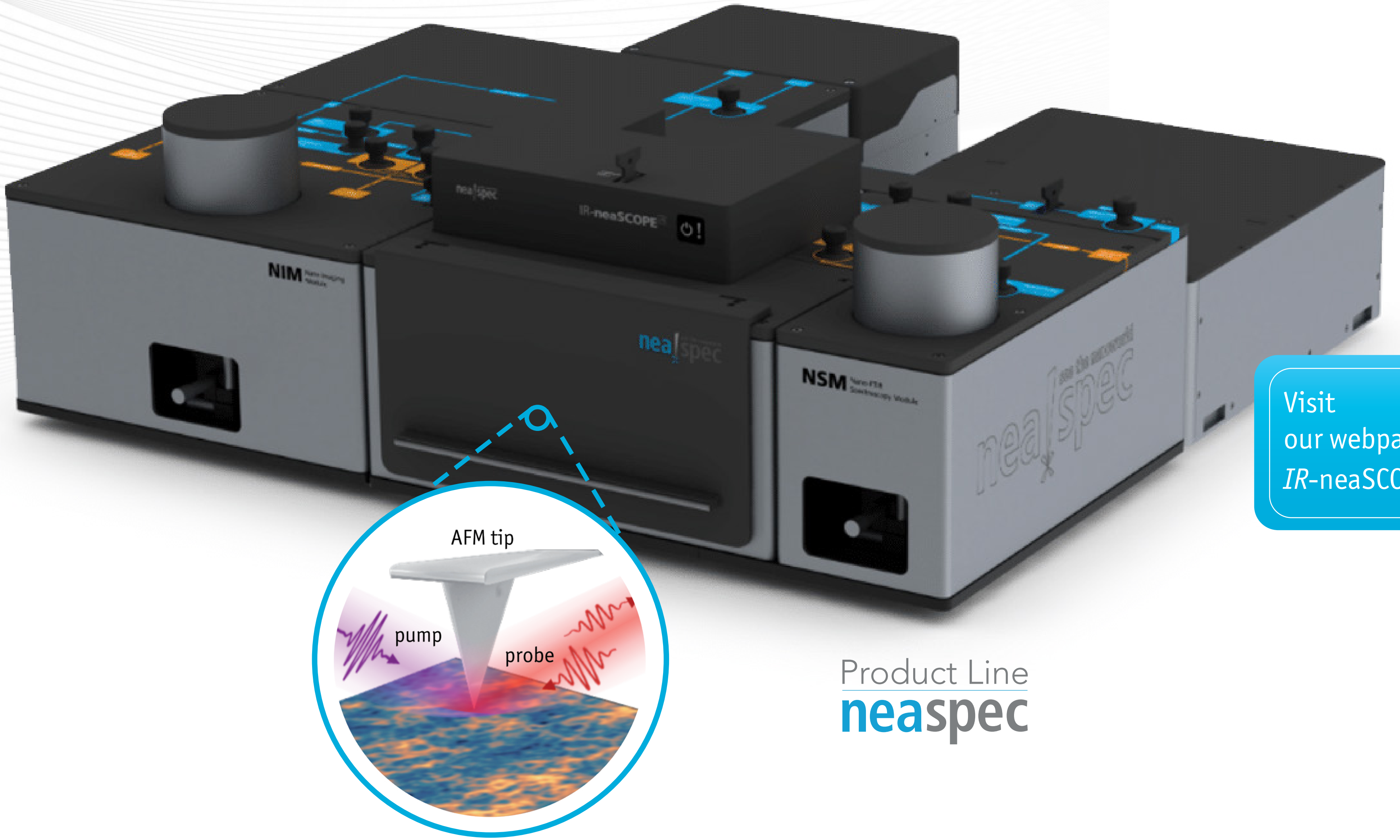
IR-neaSCOPE+fs pushes the spatial resolution limits of pump-probe spectroscopy. Based on nano-FTIR fs-laser system, it provides a fully integrated hardware & software solution for capturing time dynamic phenomena at the nanoscale.

Patented dual-beam design, dispersion-free optics and optional SDK provide compatibility with a large variety of pump & probe lasers for the realization of sophisticated high-power experimental setups and ground-breaking ultrafast research.

IR-neaSCOPE+fs

- fully integrated turn-key system
  → for concentrating on research rather than on technology
- highest temporal resolution
  → using chirp-free optics for light focusing and collection
- unprecedented customization potential
  → by flexible hardware & software interfaces

Enables ultrafast pump-probe spectroscopy at 10 fs temporal and 10 nm spatial resolution.



Visit our webpage *IR*-neaSCOPE+fs

Product Line
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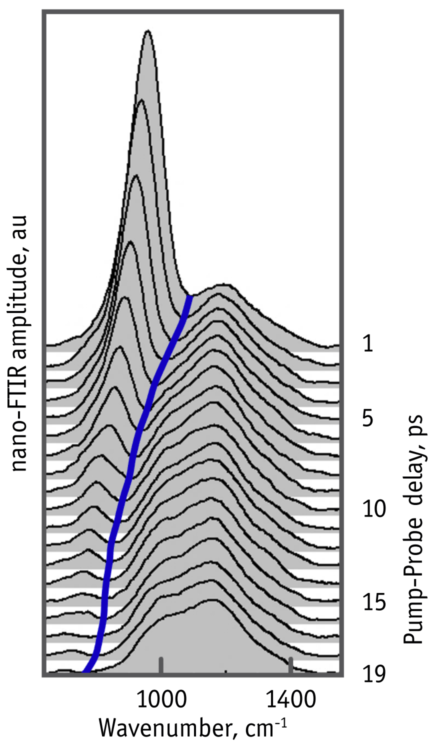
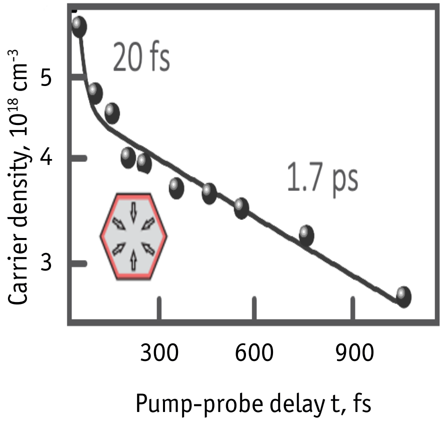
Probing carrier depletion in InAs nanowires by ultrafast nano-FTIR spectroscopy

The unique, patented dispersion-free dual beam-path design of *IR*-neaSCOPE+fs naturally supports pump-probe experiments with visible, IR and THz beams, and enables the nanoscale investigation of carrier dynamics in semiconductors with fs temporal resolution.

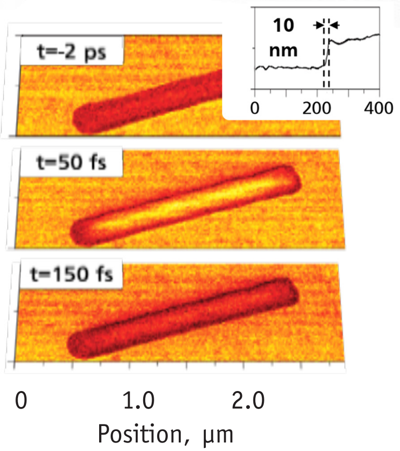
Ultrafast nano-FTIR



Carrier dynamics



nano-FTIR reflectivity



Ultrafast carrier injection due to femtosecond near-IR photoexcitation of InAs leads to the formation of a pronounced dip (blue line) in the nano-FTIR spectra (left), whose spectral position is determined by the plasma resonance of the created hot electrons and directly relates to the carrier concentration. Changing the pump-probe delay allows for monitoring of the carrier relaxation dynamics. Such an analysis performed with *IR*-neaSCOPE+fs on a single InAs nanowire with 10 fs temporal & 10 nm spatial resolution reveals an ultrafast formation of a surface depletion layer and even allows for the characterization of its depth.

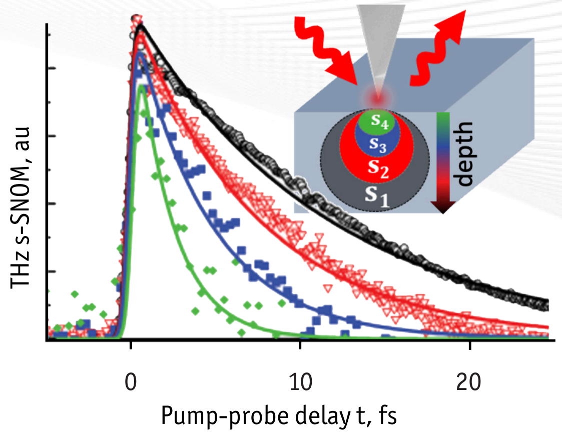
Ultrafast nano-FTIR opens path towards efficient electronics & laser sources

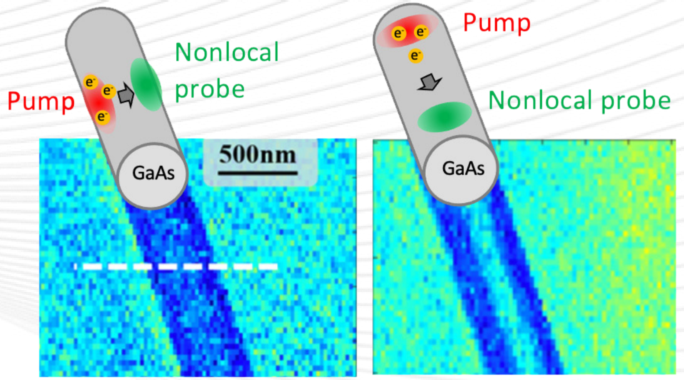
nature photonics — M. Eisele, et al., Nature Photonics 2014, 8, 841

NANO LETTERS — M. Wagner et al., Nano Lett. 2014, 14, 4529

Investigating charge carrier confinement and transport in three dimensions in GaAs nanowires

neaSCOPE+fs simultaneously measures multiple near-field harmonics that scoop different sample volumes, thus enabling depth-sensitive investigation of carrier dynamics. Largest optical access to the probing tip allow for unprecedented beampath customization including for non-local pump-probe nano-imaging.





THz amplitude image at 3 ps delay

Low High

Depth dependence of carrier dynamics

neaSCOPE+fs allows for depth dependent investigation of transient carrier dynamics based on the measurement of s-SNOM signal demodulated at higher harmonics of the tip tapping frequencies s_n that scoop smaller sample volumes. Varying time decay of the THz signal in of GaAs nanobars measured by ultrafast THz nanoscopy could indicate different relaxation time at the surface vs. bulk, suggesting an electron band bending and emphasizing a crucial role of interfaces onto the electron response in nanostructures.

Non-local ultrafast THz nanoscopy

neaSCOPE+fs customized to independently focus near-IR pump & THz probe beams enabled femtosecond-resolved investigation of nonlocal diffusion of photoexcited charge carriers in undoped GaAs nanowires. The appearance of THz contrast in the nanowire indicates the arrival of charges from the pump region. neaSCOPE+fs accurately timed the phenomenon, providing carrier diffusion time and elucidating strong anisotropy with respect to the nanowire axis, which demonstrates a capability to measure carrier drift/diffusion velocities in materials with anisotropic optoelectronic properties.

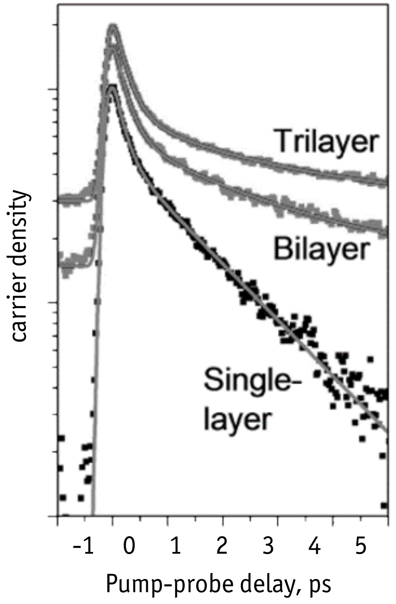
Nanoscale pump-probe enables studying non-local electron dynamics

ADVANCED FUNCTIONAL MATERIALS — V. Pushkarev et al., Adv. Funct. Mater. 2022, 32, 2107403

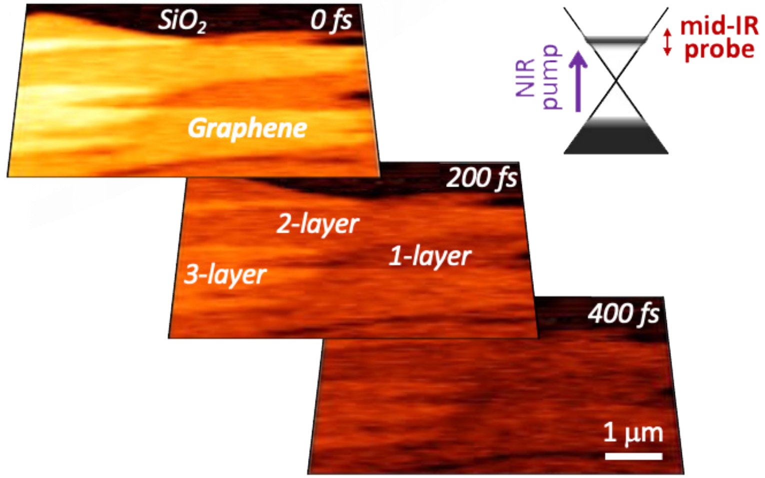
ACS Photonics — A. Pizzuto et al., ACS Photonics 2021, 8, 2904-11

Ultrafast optical modulation of graphene plasmons by pump-induced electron heating

IR-neaSCOPE^{+fs} is a unique ready-to-use nanoscale pump-probe system that provides ultrafast nano-FTIR spectroscopy with <10 nm spatial and <100 fs temporal resolution. Tip-enhancement provided by s-SNOM boosts the sensitivity and allows for lower pulse energy & MHz repetition rates for gentle time-resolved analysis of 2D materials at the nanoscale.



Nano-FTIR reflectivity



Transient near-field response measured by *IR*-neaSCOPE^{+fs} in exfoliated single- to tri-layer graphene revealed bi-exponential dynamics. The common rapid initial relaxation at the 100 fs time scale is assigned to a cooling of hot carriers via optical phonon excitation. Further picosecond decay depends on the number of layers indicating the relaxation via acoustic phonons. Modeling of the measured data allowed for an extraction of Drude weights and revealed ultrafast tuning of plasmon resonances under 100x weaker illumination vs. metallic nanostructures, indicating superiority of Graphene for next generation electronics.

IR-neaSCOPE^{+fs} reveals ultrafast femtosecond switching in Graphene

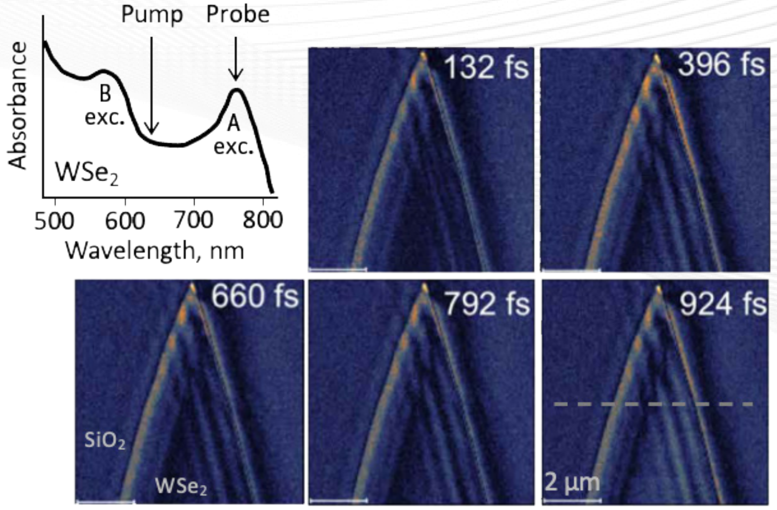
NANO LETTERS

M. Wagner et al.,
Nano Lett.
2014, 14, 894

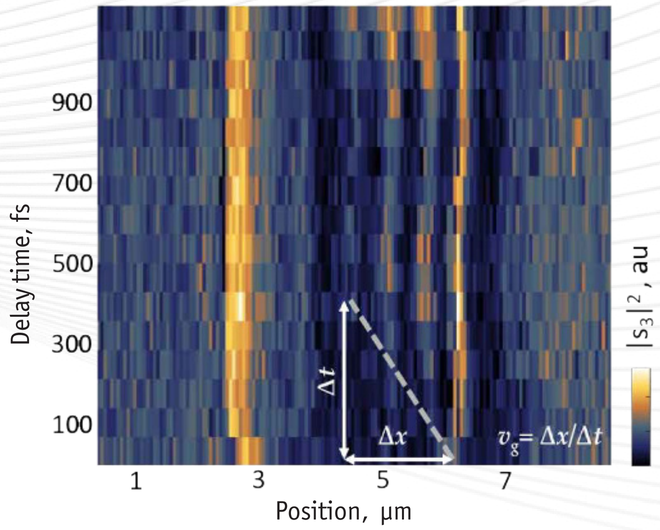
Femtosecond polariton interferometry of transient exciton-polaritons in WSe_2 with near-IR probe

neaSCOPE^{+fs} is purposely designed to provide high interferometric stability for pump-probe at NIR and visible frequencies. Reflective optics and integrated delays enable investigations of exciton-polariton dynamics in TMDs at the relevant time & energy scales by easy integration of custom light sources.

s-SNOM reflectivity



Reflectivity line profile



neaSCOPE^{+fs} equipped with custom ultrafast visible pump (~650 nm) and near-IR probe (760 nm) illumination captured the transient formation & propagation of exciton-polaritons (EPs) in WSe_2 down to single monolayer in thickness. Analysis of position vs. time profile (right) revealed a remarkably slow polariton group velocity ~0.017c attributed to a strong Coulomb interaction in the thin transition metal dichalcogenide (TMD) and an increased damping due to collision with photoinjected electrons. Understanding the spatiotemporal evolution of EPs in TMDs paves the way for the utilization of slow light phenomena in optical memory, processing and sensing.

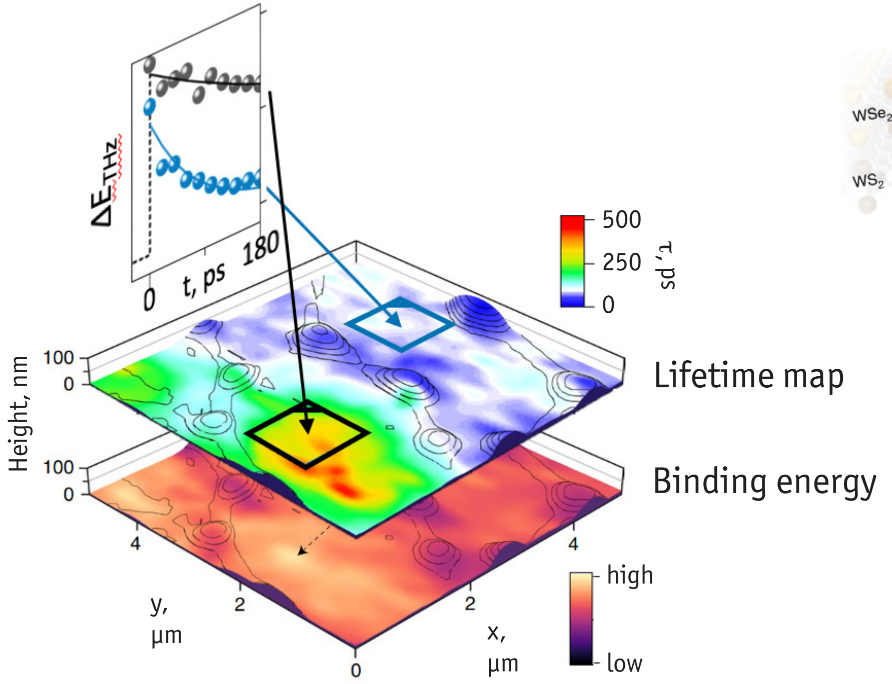
SciAdv AAAS

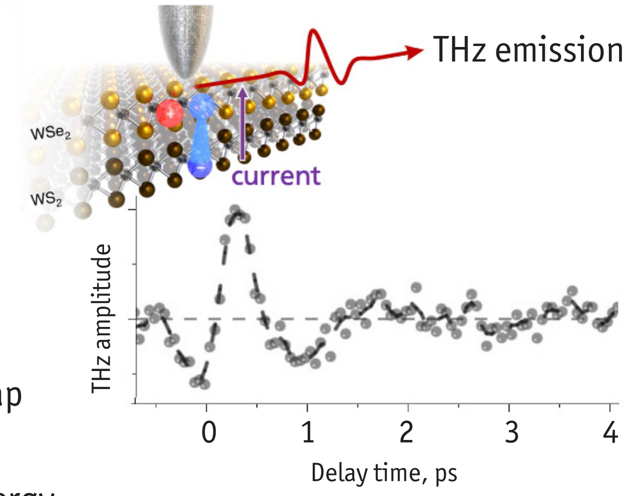
M. Mrejen et al.,
Sci. Adv.
2019, 5, 2

neaSCOPE enables *in-situ* ultrafast coherent control of TMD systems at the nanoscale

Investigating exciton tunnelling & emission in vdW materials using ultrafast THz nanoscopy

Dual-beam path design of neaSCOPE+fs provides two independent ports for illumination and light collection. Combined with a patented high-NA parabola, it enables nanoscale pump-probe with integrated TDS or custom THz sources for time-resolved nanoscale analysis of quantum materials.





neaSCOPE+fs measured pump-induced changes of the local THz response ΔE_{THz} along a surface of WSe_2/WS_2 heterobilayer, providing precise maps of exciton binding strength & lifetime (left). Areas of prolonged lifetime indicate an advantageous local atomic registry (e.g. stress, twist angle, etc.). In addition, interlayer tunneling of pump-generated excitons creates an out-of-plane current that acts as a source of a coherent THz emission. neaSCOPE+fs was able to measure this emission on a subcycle time scale, providing direct access to femtosecond charge transfer dynamics (incl. tunneling current and time (top) constant. This demonstrates ultrafast in-situ investigation of Mott phase transitions, energy harvesting and light emission in atomically thin heterostructures at the nanoscale targeting the development of advanced functional nanomaterials.

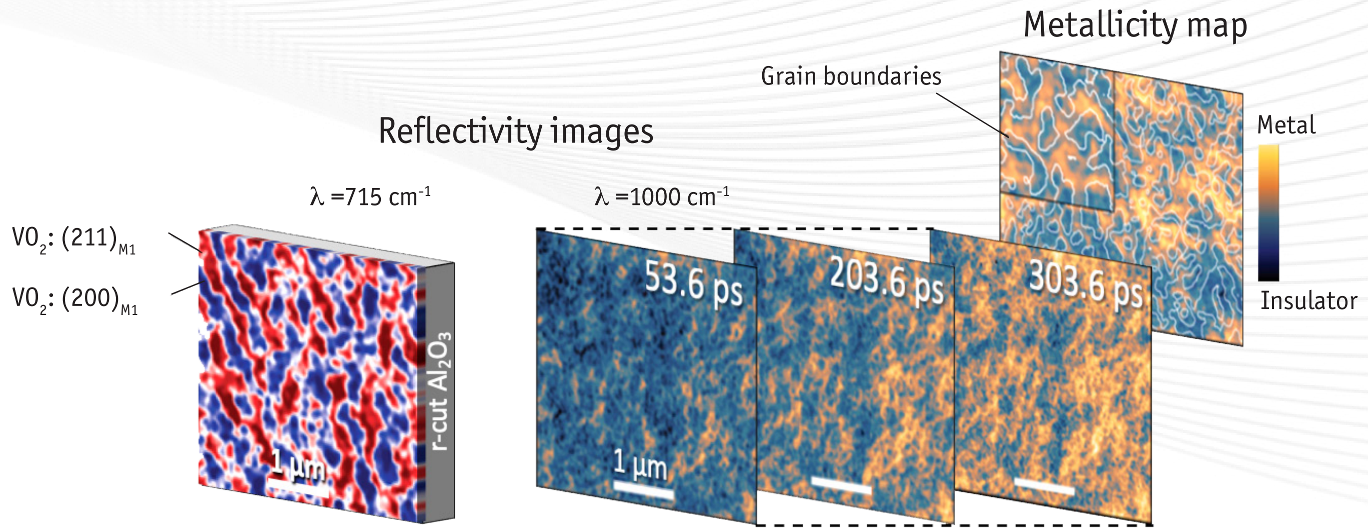
neaSCOPE+fs can directly probe femtosecond exciton dynamics at the nanoscale

NANO LETTERS — T. Siday et al., Nano Lett. 2022, 6, 2561-68

nature photonics — M. Plankl et al., Nature Photonics 2021, 15, 594–600

Transient heterogeneity of light-induced phase transition in VO_2

Low drift delivered by center-symmetric design of neaSCOPE+fs enables repeated nanoimaging of the same area at multiple time delays or frequencies. Powerful SDK allows for integration of existing OPA & OPO sources for extending pump-probe analysis of quantum materials to the nanoscale.



Steady-state s-SNOM nano-imaging near resonant energies of VO_2's IR-active phonon (~715 cm^{-1}) exposed hidden preexisting disorder within its thin film's monoclinic phase. Correlation of the resulting domain map with transient contrast at 1000 cm^{-1} due to light-induced dielectric-to-metal phase transition (imaged by *IR*-neaSCOPE+fs) directly elucidated anchored heterogeneous nucleation of metallicity at rate 40 nm/ns originating from the grain boundaries. Such nano-analysis could play a key role in establishing the local character of emergent phenomena in quantum materials undergoing light-induced phase transitions.

Time-resolved nanoscopy provides key insights into transient phase separation

NANO LETTERS — A. Sternbach et al, Nano Lett. 2021, 21, 9052-60

Other Applications realized with *IR*-neaSCOPE^{+fs}

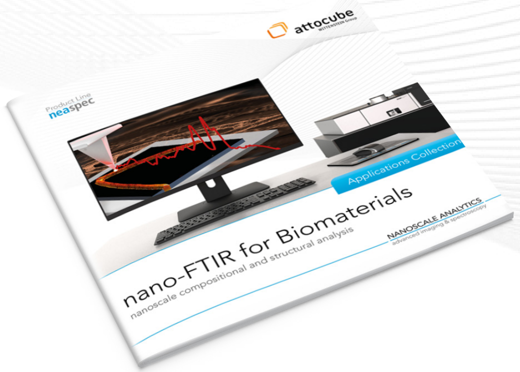
nano-FTIR for Polymers

chemical characterization at the nanoscale

Nanocomposite polymers, multilayer thin films, nanofibers and other polymer nano-forms often offer new properties or enhanced performance compared to bulk materials, demanding tools for chemical analysis with nanoscale spatial resolution for their investigations. nano-FTIR and s-SNOM are two leading techniques for nanoscale chemical mapping and identification.

nano-FTIR for Biomaterials

nanoscale compositional and structural analysis



nano-FTIR can perform in-situ study of melanine in human hair for cosmetics treatment analysis. Shed light on bio-chemistry of cell membranes & improve efficiency of drug delivery. Analyze protein secondary structure in amyloid fibrils. And elucidate the nuclear organization of white-blood cells.

Inorganic Materials

spectroscopic chemical analysis at the nanoscale

nano-FTIR spectroscopy and imaging have been successfully applied for material identification & mapping with nanometer precision using material-specific infrared spectroscopic signatures. This applications collection focuses on nanoscale investigation of inorganic materials in energy-storage, mineralogy, archaeology and corrosion sciences.

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