

Applications Collection

Ultrafast Nano-Spectroscopy

probing ultrafast dynamics at the nanoscale

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}

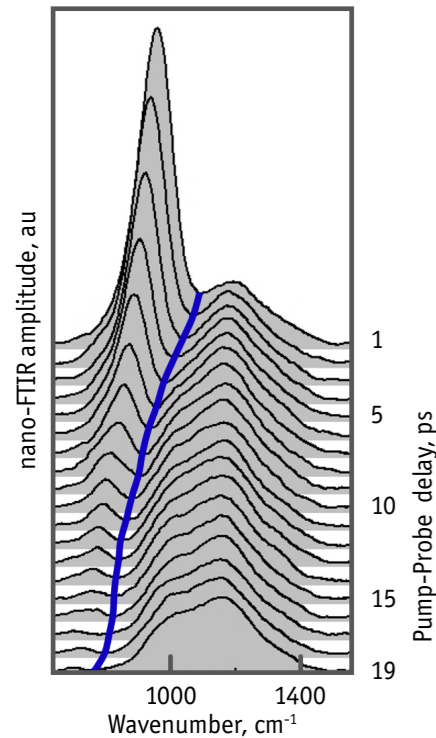


Product Line
nea|spec

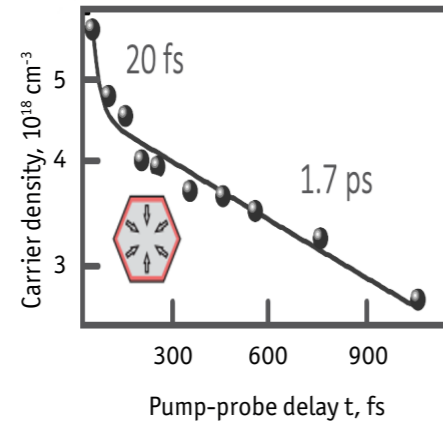
Probing carrier depletion in InAs nanowires by ultrafast nano-FTIR spectroscopy

The unique, patented dispersion-free dual beam-path design of *IR-neaSCOPE*^{efs} 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

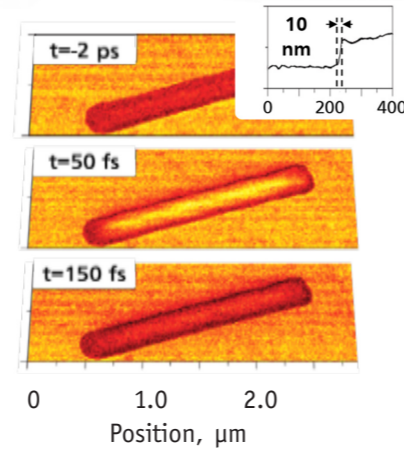


Carrier dynamics



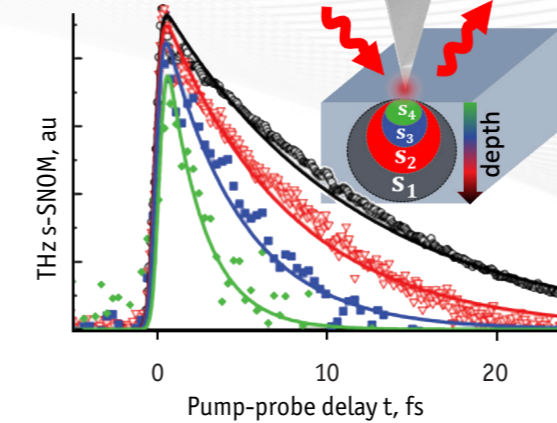
Ultrafast carrier injection due to femtosecond near-IR photoexcitation of InAs leads to the formation of a pronounced dip (blue line) in the nano-FTIR spectra (left), whose spectral position is determined by the plasma resonance of the created hot electrons and directly relates to the carrier concentration. Changing the pump-probe delay allows for monitoring of the carrier relaxation dynamics. Such an analysis performed with *IR-neaSCOPE*^{efs} 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.

nano-FTIR reflectivity



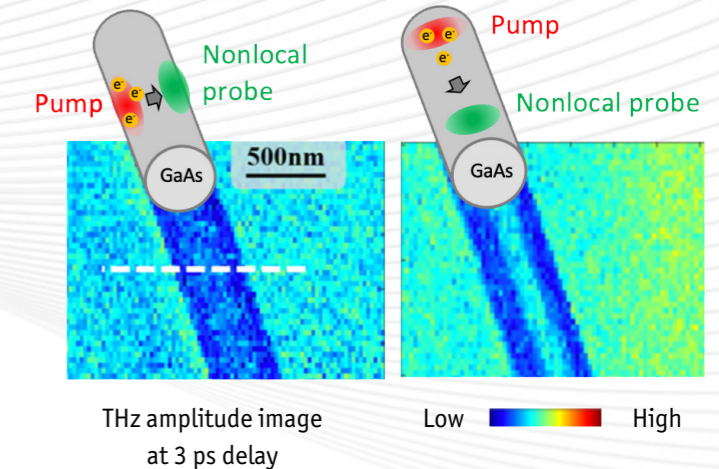
Investigating charge carrier confinement and transport in three dimensions in GaAs nanowires

neaSCOPE^{efs} 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.



Depth dependence of carrier dynamics

neaSCOPE^{efs} 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^{efs} 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*^{efs} 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.

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

Nanoscale pump-probe enables studying non-local electron dynamics

ADVANCED
FUNCTIONAL
MATERIALS

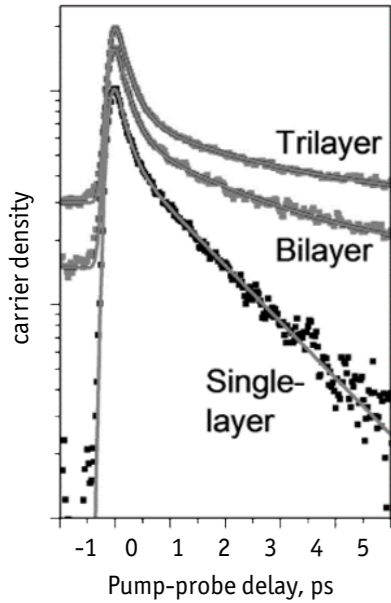
V. Pushkarev et al.,
Adv. Funct. Mater.
2022, 32, 2107403

ACS
Photonics

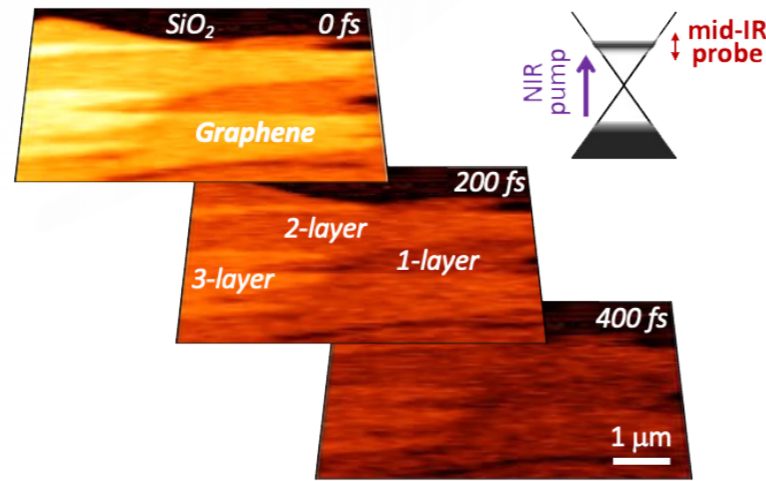
A. Pizzuto et al.,
ACS Photonics
2021, 8, 2904-11

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.

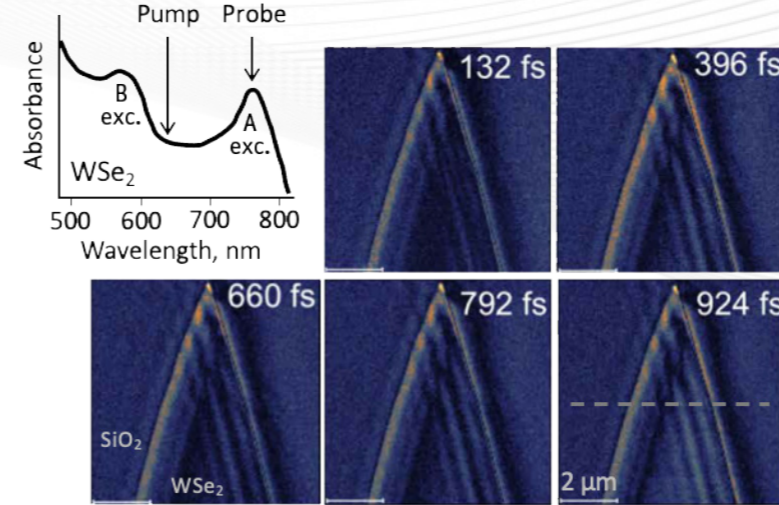
NANO LETTERS M. Wagner et al., Nano Lett. 2014, 14, 894

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

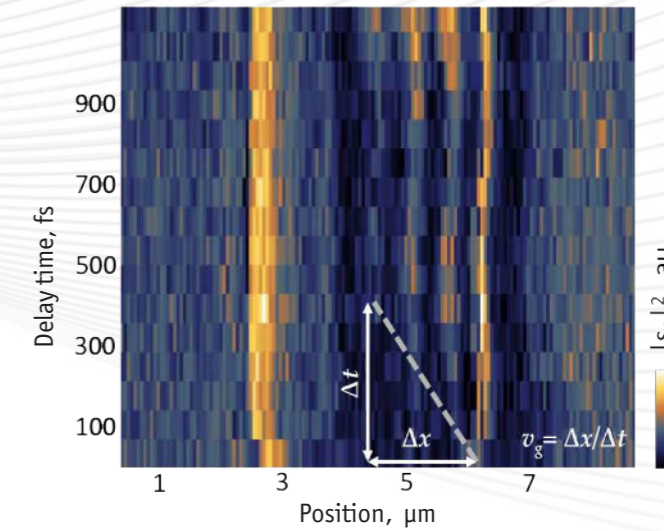
Femtosecond polariton interferometry of transient exciton-polaritons in WSe₂ with near-IR probe

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



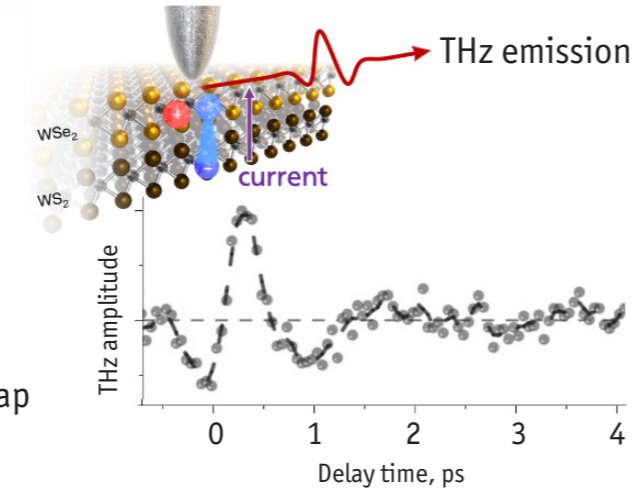
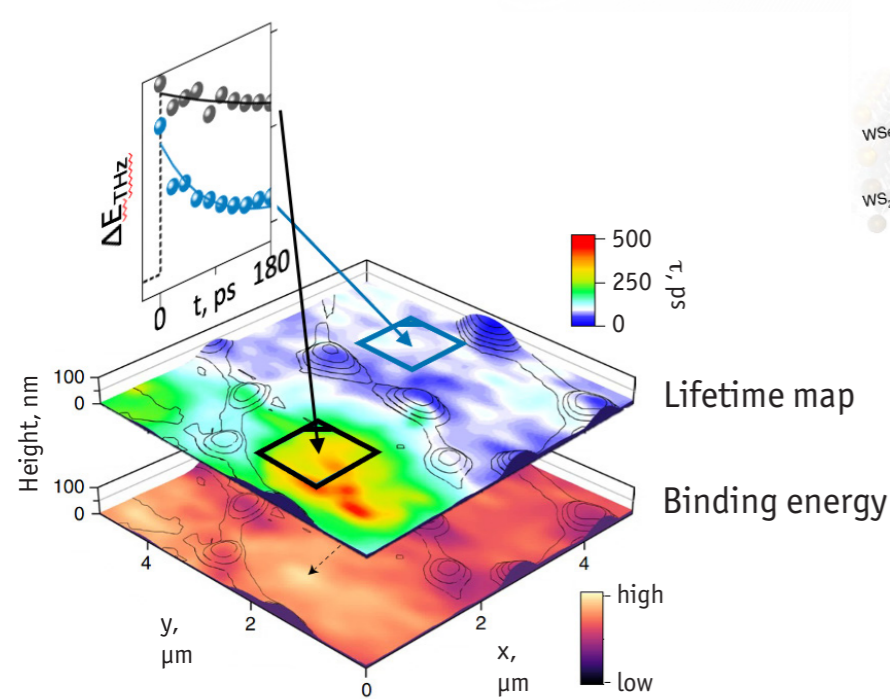
neaSCOPE^{fs} equipped with custom ultrafast visible pump (~650 nm) and near-IR probe (760 nm) illumination captured the transient formation & propagation of exciton-polaritons (EPs) in WSe₂ down to single monolayer in thickness. Analysis of position vs. time profile (right) revealed a remarkably slow 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 MAAAS 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 WSe₂/WS₂ 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.

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

M. Plankl et al.,
Nature Photonics
2021, 15, 594-600

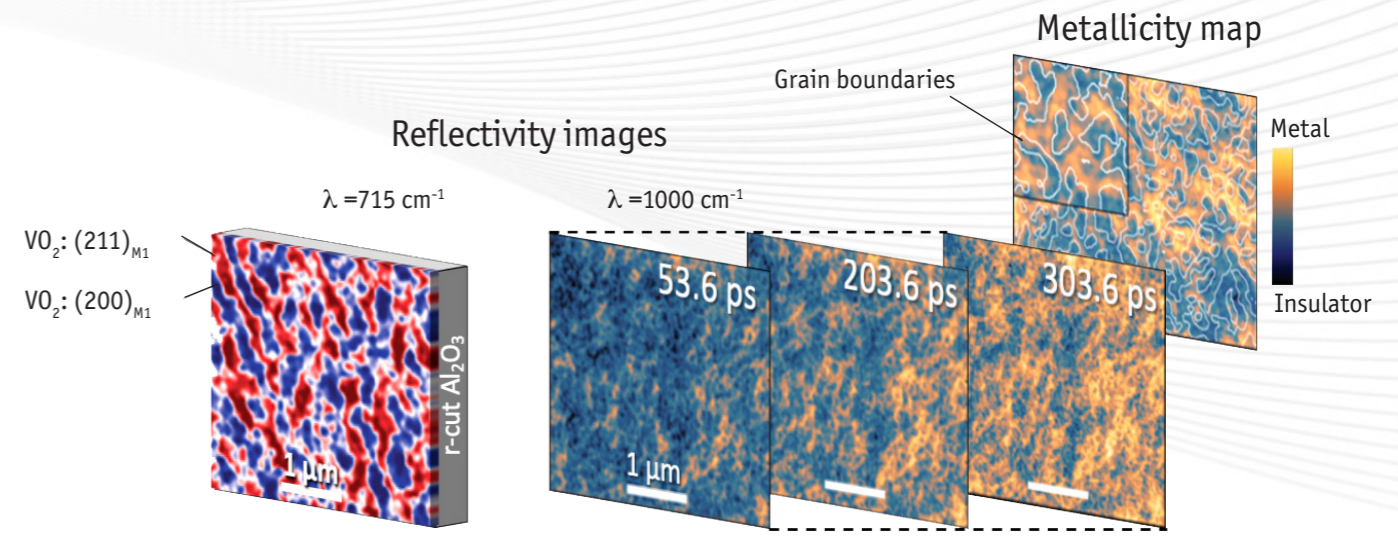
NANO LETTERS

nature photonics

neaSCOPE^{fs} can directly probe femtosecond exciton dynamics at the nanoscale

Transient heterogeneity of light-induced phase transition in VO₂

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 VO₂'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.

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

NANO LETTERS

Time-resolved nanoscopy provides key insights into transient phase separation

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

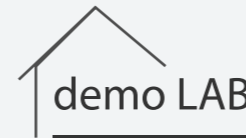
spectroscopic chemical analysis at the nanoscale



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.



Additional Services



Evaluate the capabilities of our technology & products.

Successful test results could significantly increase the approval chance of your grant application.



Monthly reviews of neaspec publications.

Keep you up to date in the field of nanoscale analytics and help you discover new neasCOPE applications.





attocube
WITTENSTEIN Group

attocube systems AG | Eglfinger Weg 2 | 85540 Haar
Germany | info@attocube.com | www.attocube.com

© 2022-01, attocube systems AG

www.attocube.com