NTEGRA SPECTRA

AFM - RAMAN - SNOM - TERS

Atomic Force Microscopy (more than 30 integrated modes);

Confocal Raman/ Fluorescence/ Rayleigh Microscopy;

Scanning Near-Field Optical Microscopy (SNOM);

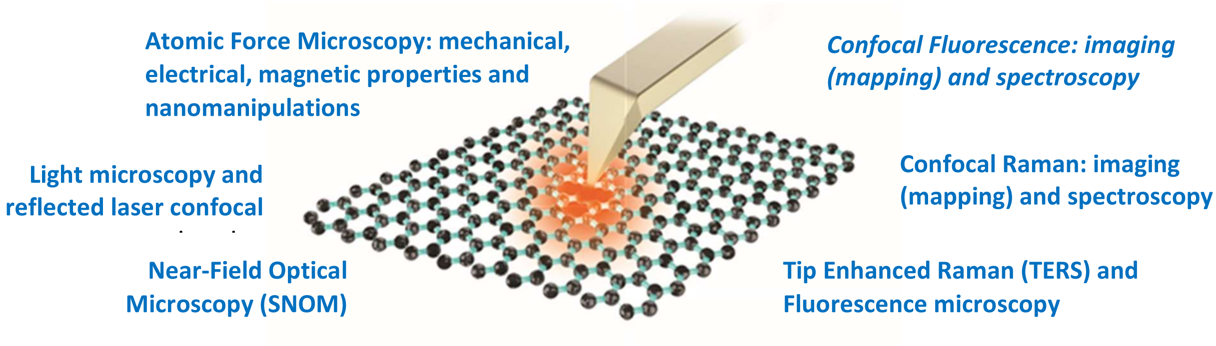
Tip Enhanced Raman and Fluorescence (TERS, TEFS, TERFS) and scattering SNOM (s-SNOM).

NTEGRA SPECTRA - FULLY INTEGRATED AFM-RAMAN-SNOM-TERS SYSTEM

NTEGRA Spectra - modular AFM fully integrated with various optical microscopy and spectroscopy techniques. Professional upright and inverted optical microscopes, confocal microscopes, Raman spectrometers, fluorescence lifetime imaging microscopes. Simultaneous optical measurements of the same sample area provide the widest range of additional information about the sample.

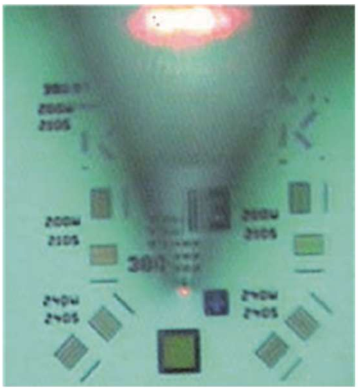
Tip Enhanced Raman Spectroscopy (TERS) maps with spatial resolution reaching down to 10 nm have been successfully obtained using specially prepared AFM probes (nanoantennas).

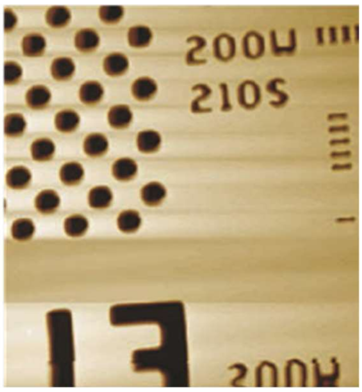
Scanning near-field optical microscopy (SNOM) is another approach to obtain optical images of optically active samples with resolution below diffraction limit.



All techniques can be applied to the same sample

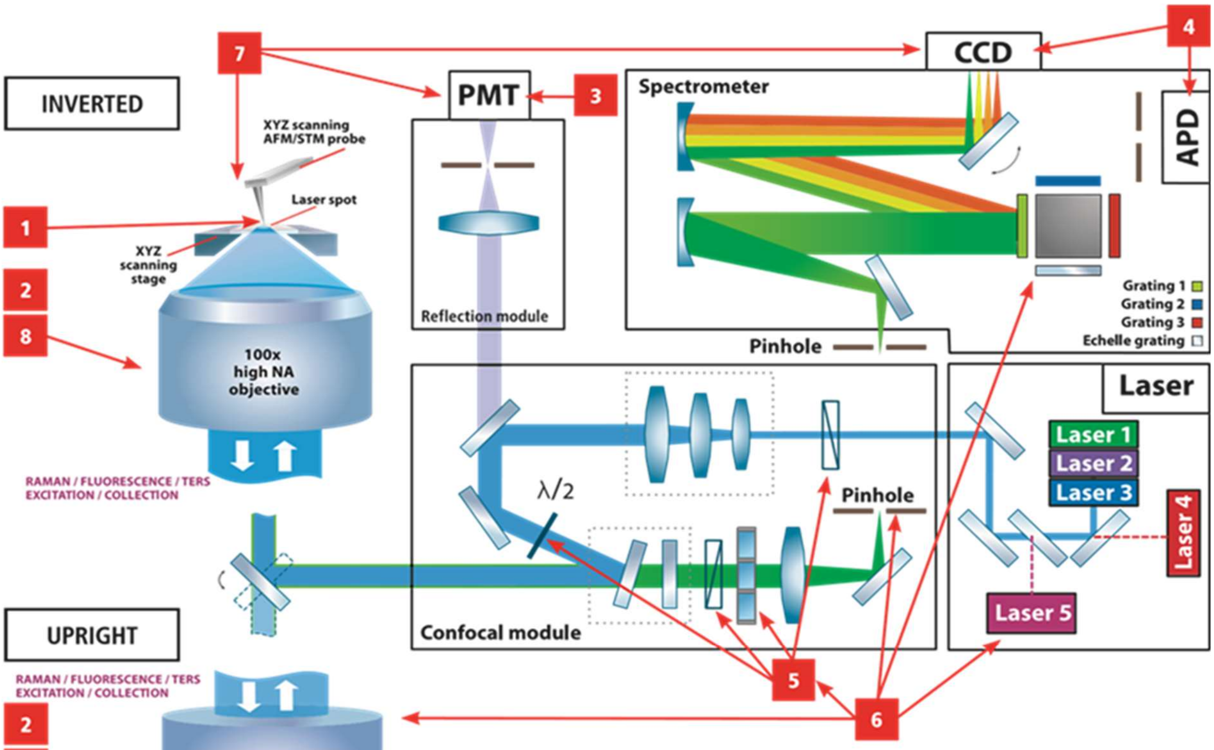
AFM WORKING SIMULTANEOUSLY WITH 400 nm RESOLUTION UPRIGHT OPTICS

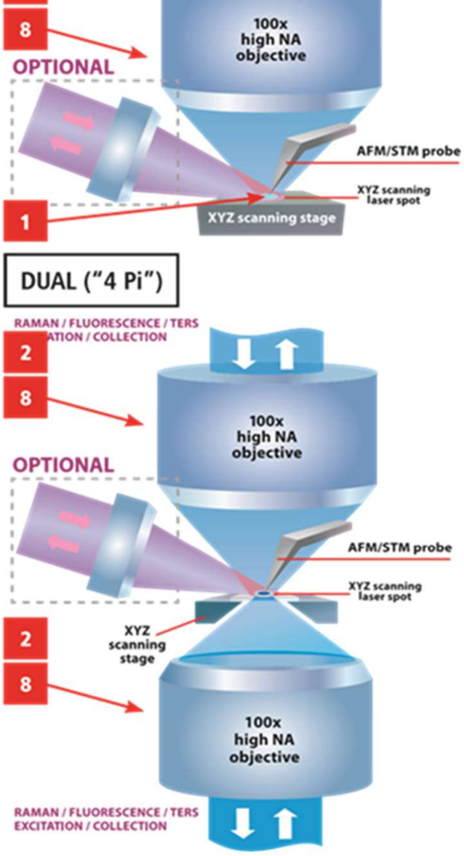




AFM + Confocal Microscope with high magnification optics in upright configuration. Note extremely high imaging resolution of 100x objective as seen on 1µm height characters on Si substrate (a). Due to the high numerical aperture (0.7) of the objective, opaque silicon AFM probe looks "transparent" on the image, end of the tip can be seen. AFM scanning (b) can be obtained simultaneously with both white light and confocal Raman/fluorescence imaging. Thanks to the additional beam scanning option, a tightly focused laser spot can be positioned exactly at the apex of the AFM probe - as required for TERS experiments.

AFM / CONFOCAL RAMAN & FLUORESCENCE / SNOM / TERS OPTICAL SCHEME





1. **AFM probe and laser beam are perfectly coordinated with each other. The AFM probe can be placed within the laser spot with nanometer precision - as it is necessary for tip-enhanced optical effects. Movement in 6 different axes is controlled by closed-loop sensors.**
2. **High resolution and numerical aperture objective is rigidly integrated into the SPM base. It provides unprecedented optical system stability - designed for long-term scanning and weak-signal experiments.**
3. **Reflected laser light is used to obtain fast confocal laser (Rayleigh) image.**
4. **TE-cooled (down to -100 °C) CCD or EMCCD serves as a sensitive spectroscopy detector. Alternatively avalanche photodiode (APD) or photon multiplier (PMT) can be used for single photon counting.**
5. **Flexible polarization optics in both excitation and detection channels. User defined optical filters. All motorized, under software control.**
6. **Excellent software integration has been realized. All system modules (AFM, optics and mechanics) are driven by the same software package. Lasers, gratings, polarizers, pinholes and so on, can be chosen and adjusted from the fully integrated software.**
7. **AFM and confocal Raman maps are acquired simultaneously and analysed in the same software package.**
8. **Solutions for all possible TERS geometries. Dual scan option: scan by sample plus scan by tip /by laser beam.**

MODES

- *AFM (mechanical, electrical, magnetic properties, nanomanipulation etc.);*
- *White Light Microscopy and Confocal Laser (Rayleigh) Imaging;*
- *Confocal Raman Imaging and Spectroscopy;*
- *Confocal Fluorescence Imaging and Spectroscopy;*
- *Scanning Near-Field Optical Microscopy (SNOM);*
- *Tip Enhanced Raman and Fluorescence Microscopy (TERS, TEFS, TERFS).*

CONTROL ENVIRONMENT

- *Temperature;*
- *Humidity;*
- *Gases;*
- *Liquid;*
- *Electrochemical environment;*
- *External magnetic field.*

BASIC SYSTEM CONFIGURATIONS

INVERTED SETUP

- *Optimized for transparent samples;*
- *Highest optical resolution achievable (<200 nm) simultaneously with AFM;*
- *Highest efficiency of Raman/fluorescence photon collection (with immersion optics) simultaneously with AFM;*
- *Probe scanning in addition to sample scanning;*
- *Equipped with heating stage, temperature controlled liquid cell and environmental chamber;*
- *Fits most commercial inverted microscopes, supporting advanced imaging modes.*

UPRIGHT SETUP

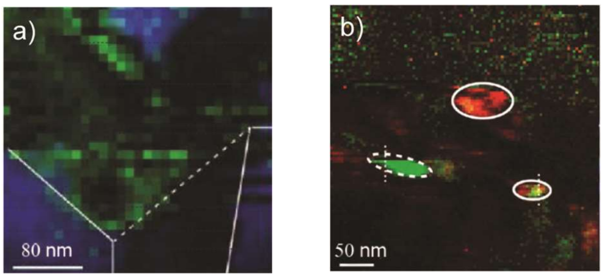
- *Optimized for opaque samples;*
- *Highest optical resolution (280–400 nm) simultaneously with AFM;*
- *Highest efficiency of Raman/Fluorescence photon collection simultaneously with AFM;*
- *Beam scanning in addition to sample scanning (necessary for TERS);*
- *Equipped with heating stage, environmental chamber.*

TIP ENHANCED RAMAN SCATTERING (TERS)

CHEMICAL (SPECTROSCOPIC) IMAGING WITH ULTRA HIGH SENSITIVITY AND SPATIAL RESOLUTION DOWN TO 10 nm

A specially prepared AFM probe (usually metal coated cantilever or etched metal wire) acts as a "nanoantenna" localizing and enhancing excitation laser light near the apex. The nanoantenna effectively performs as a "nano-source" of light. Scanning a sample across the nanoantenna results in spectroscopic imaging of the sample (Raman scattering/TERS, fluorescence etc.) with spatial resolution down to 10 nm - ~30 times below diffraction limit.

GRAPHENE

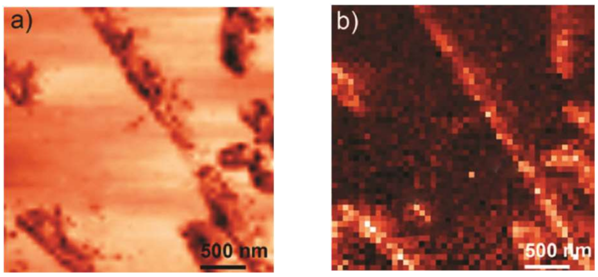


a) *TERS maps of single layer CVD Graphene on copper substrate. Green color: areas of pristine graphene (2D band intensity). Blue color: CH-terminated graphene areas (CH-bands intensity).*

b) *TERS map of mechanically exfoliated single layer graphene on Au substrate. Green color: 2D band intensity. Red color: D-band intensity (areas with strong defects).* ***Spatial resolution of all nanoRaman (TERS) maps is <12 nm.***

J. Stadler, T.Schmid, and R. Zenobi, Nano Letters (2010), 10, 4514-4520

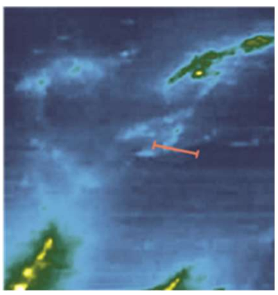
PEPTIDE NANOTAPES



a) STM image of individual self-assembled peptide nanotapes.
b) TERS map of the aromatic ring marker band.
Spatial resolution of nano-Raman (TERS) map is <80 nm.
Sensitivity: individual peptide nanotape.

Melissa Paulite, Carolin Blum, Thomas Schmid, Lothar Opilik, Klaus Eyer, Gilbert C. Walker, and Renato Zenobi, ACS Nano, 2013, 7 (2), pp 911–920

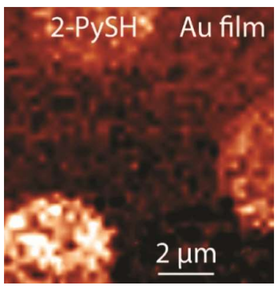
CARBON NANOTUBES



Nano-Raman (TERS) map of nanotube bundle aggregate (G-band intensity). ***Spatial resolution of TERS map is <14 nm.***

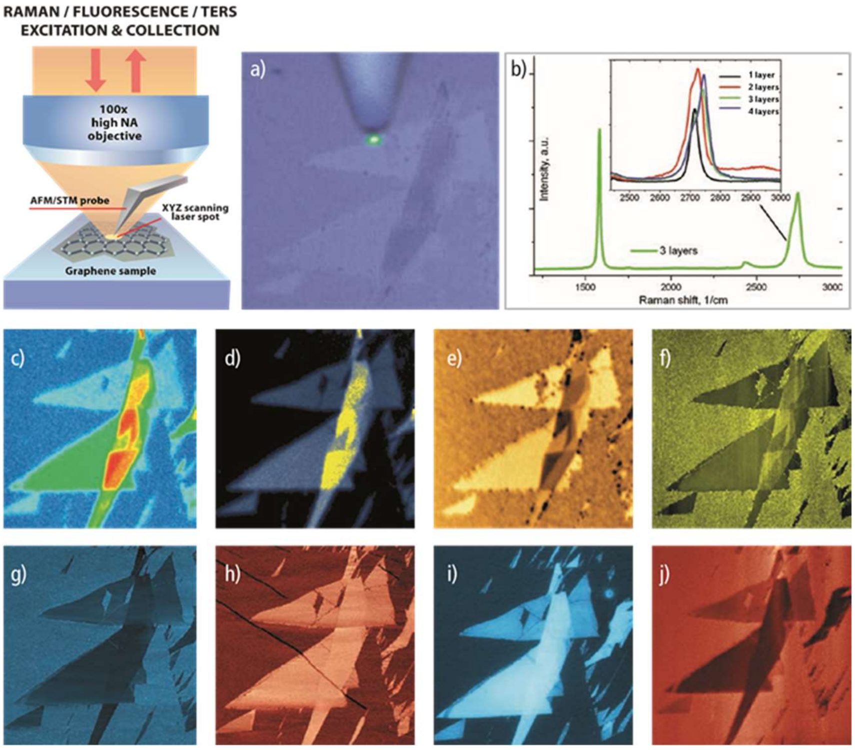
A. Chan & S. Kazarian, Nanotechnology 21, 445704 (2010)

THIOL MONOLAYER



TERS map of two isometric thiols in a self-assembled monolayer (SAM) on a gold surface. SAM pattern was produced by micro-contact printing.
Sensitivity of Raman (TERS): single monolayer.
J. Stadler, T.Schmid, L. Opilik, P. Kuhn, P.S. Dittrich, and R. Zenobi, Beilstein J. Nanotechnology (2011), 2: 509-515

GRAPHENE STUDIED BY VARIOUS OPTICAL, AFM AND SPECTROSCOPY TECHNIQUES



a) White light image of graphene flakes with AFM tip and Raman laser spot; b) Raman spectra of flakes with different thickness; c) Raman map: G-band intensity; d) Raman map: 2D (G') band mass centre; e) Rayleigh light intensity; f) AFM: Height (topography); g) AFM: Lateral force (friction); h) AFM: Force Modulation (elastic properties); i) AFM: Kelvin Probe (Surface Potential); j) AFM: Electrostatic Force (Charge Distribution)

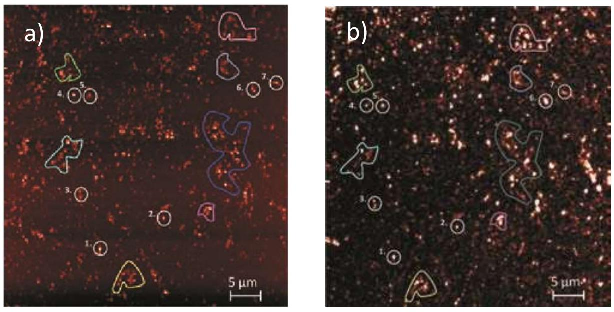
Combination of AFM, Confocal Raman/ Fluorescence/Rayleigh microscopy and SNOM provides unique opportunities for graphene investigation. Different AFM techniques allow studying of mechanical, electrical, magnetic and even elastic properties of graphene flakes. Studies of local work function, conductivity, capacitance and other surface properties are available.

At the same time Raman microscopy (available simultaneously with AFM) provides information about flake thickness, structural uniformity, presence of impurities and defects etc. Additionally, Rayleigh imaging and SNOM measure local optical properties of the sample providing further information about flake structure.

Importantly, most of the measurements can be performed under environmental control: at variable humidity and temperature, in controlled atmosphere, in liquid and even (in some configurations) in electrochemical environment and with external magnetic field.

MORE APPLICATIONS

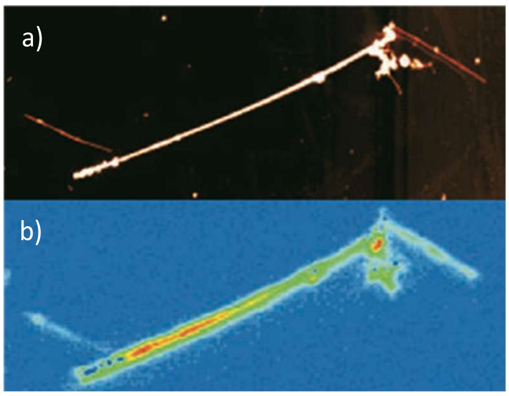
NITROGEN-VACANCY (NV) COLOR CENTERS IN NANODIAMONDS



Observation of nitrogen-vacancy (NV) color centers in discrete detonation nanodiamonds. a) AFM topography image; smallest particles observed are discrete isolated nanodiamonds of ~5 nm size. b) Confocal fluorescence map of the same sample area; nitrogenvacancy luminescence from isolated nanodiamonds is clearly seen.

C. Bradac et al., Nature Nanotechnology 5, 345 - 349 (2010)

SILICON NANOWIRE



a) AFM topography.
b) Confocal Raman map (spectral shift of 520 cm-1 Si band) of individual silicon nanowire.

Data from P. Dorozhkin, NT-MDT and M. Bloomfield, Renishaw

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