

Infrared nanoscopy of biological and soft matter

Fritz Keilmann
Soft Condensed Matter Group
Ludwig-Maximilians-Universität
80539 München, Germany
fritz.keilmann@lmu.de

Infrared spectroscopic analysis rests on vibrations which label any chemical compound with a characteristic "fingerprint" spectrum in the 3-30 μm wavelength region—intrinsically. Combining IR with AFM allows to perform IR chemical recognition routinely at 20 nm spatial resolution.^{1,2} Known as scattering-type scanning near-field optical microscopy (s-SNOM) this instrument has become commercially available (neaspec.com).

Recently, we have enhanced s-SNOM by a coherent broadband mid-infrared illumination³ based on 100-fs pulses (thus even allowing nanoscale probing at ultrafast time resolution^{4,5}); with this illumination, a complete IR spectrum is obtained at any sample position of the tip ("nano-FTIR"). By scanning the sample, an IR-hyperspectral line image or two-dimensional image is recorded.

The technique of nano-FTIR is being applied to thin-film organic conductors where it revealed coexisting structural phases.⁶ Nano-FTIR hyperspectral imaging is likely valuable in all fields of nanoscience as has already been demonstrated in studies of protein,⁷ human bone,⁸ and extraterrestrial minerals.⁹

- (1) Knoll, B.; Keilmann, F. *Nature* **1999**, *399*, 134.
- (2) Huth, F.; Govyadinov, A.; Amarie, S.; Nuansing, W.; Keilmann, F.; Hillenbrand, R. *Nano Lett.* **2012**, *12*, 3973–3978.
- (3) Keilmann, F.; Amarie, S. *Journal of Infrared, Millimeter, and Terahertz Waves* **2012**, *33*, 479.
- (4) Wagner, M.; Fei, Z.; McLeod, A. S.; Rodin, A. S.; Bao, W.; Iwinski, E. G.; Zhao, Z.; Goldflam, M.; Liu, M.; Dominguez, G.; Thiemens, M.; Fogler, M. M.; Castro Neto, A. H.; Lau, C. N.; Amarie, S.; Keilmann, F.; Basov, D. N. *NanoLetters* **2014**, *14*, 894.
- (5) Eisele, M.; Cocker, T. L.; Huber, M. A.; Plankl, M.; Viti, L.; Ercolani, D.; Sorba, L.; Vitiello, M. S.; Huber, R. *Nature Photonics* **2014**, DOI:10.1038/NPHOTON.2014.225.
- (6) Westermeier, C.; Cernescu, A.; Amarie, S.; Liewald, C.; Keilmann, F.; Nickel, B. *Nature Communications* **2014**, *5*, 4101.
- (7) Amenabar, I.; Poly, S.; Nuansing, W.; E.H., H.; Govyadinov, A. A.; Huth, F.; Kruthokvostov, R. Z., L.; Knez, M.; Heberle, J.; Bittner, A. M.; R., H. *Nature Comm.*, **2013**, *4*.
- (8) Amarie, S.; Zaslansky, P.; Kajihara, Y.; Griesshaber, E.; Schmahl, W. W.; Keilmann, F. *Beilstein Journal of Nanotechnology* **2012**, *3*, 11.
- (9) Dominguez, G.; McLeod, A. S.; Gainsforth, Z.; Kelly, P.; Bechtel, H. A.; Keilmann, F.; Westphal, A.; Thiemens, M.; Basov, D. N. *Nature Communications in print* **2014**, DOI: 10.1038/ncomms6445.