Cryogenic near-field imaging and spectroscopy at the 10-nanometer-scale

Max Eisele
Tobias Gokus
Andreas Huber
neaspec GmbH, Bunsenstrasse 5, 82152 Martinsried, Germany

max.eisele@neaspec.com

Near-field microscopy and spectroscopy has become one of the key technologies for modern optics, combining the resolving power of AFM based measurements with the analytical aspects of conventional optical spectroscopy. Near-field microscopy has already proven itself vital for modern nanomaterials and has been used in applications such as chemical identification [1], free-carrier profiling [2], or the direct mapping of propagating plasmons [3,4], phonon [5], and exciton polaritons [6]. Key information like the local conductivity, intrinsic electron-doping, absorption, or the complex-valued refractive index can routinely be extracted from these measurements with a spatial resolution of < 10 nanometer.
In combination with femtosecond light sources, near-field microscopy has also enabled ultrafast pump-probe experiments [7] with a combined 10-femtosecond temporal and 10-nanometer spatial resolution [8]. Carrier-relaxation dynamics in black phosphorus [9] or graphene [10] are just two examples of the broad range of potential applications for ultrafast near-field nano-spectroscopy.

Within this talk we will also introduce the newest technological breakthrough in the field of near-field optics - Cryogenic near-field imaging and spectroscopy. Extending ambient near-field measurements to cryogenic temperatures will open a complete new world for nanoscale optical microscopy and spectroscopy, enabling the direct mapping of phase-transitions in strongly correlated materials [11] or the detection of low-energy elementary excitations at the surface of graphene systems (Figure 1). A first commercial cryogenic system with a temperature range from < 10 - 300 Kelvin is now available from neaspec [12] making this technology broadly available to the community.

References

[1] I. Amenabar et al., Nature Comm. 8 (2017) 14402
[2] J. M. Stiegler et al., Nano Lett. 10 (2010) 1387
[3] J. Chen et al., Nature 487 (2012) 77
[4] Z. Fei et al., Nature 487 (2012) 82
[5] E. Yoxall et al., Nature Photon. 9 (2015) 674
[6] F. Hu et al., Nature Photon. 11 (2017) 356
[7] M. Wagner et al., Nano Lett. 14 (2014) 894
[8] M. Eisele et al., Nature Photon. 8 (2014) 841
[9] M. Huber et al., Nature Nanotech. 12 (2017) 207
[10] G. X. Ni et al., Nature Photon. 10 (2016) 244
[11] A. S. McLeod et al., Nature Phys. 13 (2017) 80
[12] www.neaspec.com

Figures

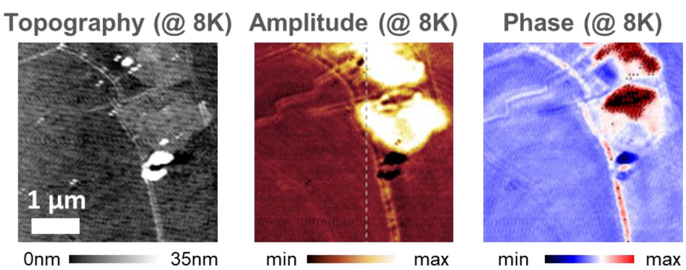

Figure 1: Cryogenic near-field optical microscopy. Topography, near-field amplitude, and near-field phase image of an epitaxial graphene sample measured at an excitation wavelength of 9.7µm. The sample temperature for these measurements is set to 8.0 Kelvin. Clear interference pattern of propagating surface-plasmon polaritons are visible at grain boundaries and defect sites [3,4].