Infrared Pump-Probe Imaging and Spectroscopy with 10nm Resolution

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Abstract: We introduce pump–probe sub-diffraction infrared imaging and spectroscopy with 100fs temporal and 10nm spatial resolution. On graphene single-layers, we demonstrate time-resolved access to local optical conductivity at technologically relevant mid-infrared frequencies.

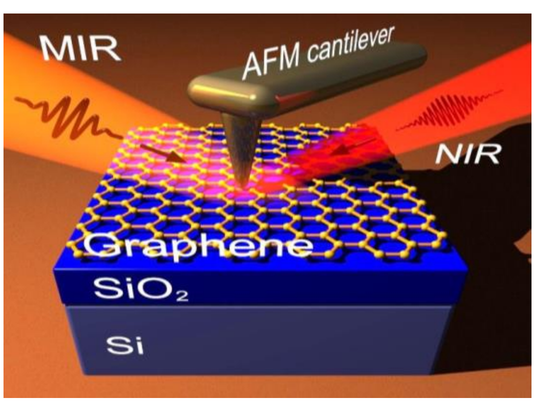
OCIS codes: (180.4243) Near-field microscopy; (300.6300) Spectroscopy, Fourier transforms.

1. Introduction to nano-FTIR, Infrared Imaging and Spectroscopy with 10nm Resolution

The performance of the next-generation electronic devices based on Graphene is strongly influenced by the structure-function relationship. A novel technique which combines the best of two worlds, the nano-scale spatial resolution of Atomic Force Microscopy and the analytical power of infrared spectroscopy (nano-FTIR), makes now possible the nanoscale mapping of such nano-devices. Infrared imaging and spectroscopy, which offers direct information regarding molecular and crystal structure, free-carrier concentration and conductivity is now accessible with 10nm spatial resolution [1-3].

2. Ultrafast plasmonics in Graphene

Well-established fiber-based near-field methods are unfortunately limited to visible and near-IR frequencies. In contrast, nano-FTIR described here is capable of probing a broad spectral region from visible to far-infrared frequencies [3]. In our experiment we combine for the first time mid-infrared nano-FTIR and ultrafast 100fs laser excitation to study time-dependent phenomena at the nanoscale (Fig. 1). The pump-probe spectroscopy results revealed ultrafast optical modulation of the infrared plasmonic response of graphene opening thus the gate to ultrafast graphene-based plasmonic devices. In terms of its efficiency, optical control of plasmons in graphene challenges conventional electrostatic gating (Fig. 1), but occurs on a much faster, sub-picosecond time scale as demonstrated in our experiment. Remarkably, modyfing graphene's plasmonic behavior requires 2 orders of magnitude less pulse energy than for metal-based structures. For the same pump fluence, the intensity modulation depth of the plasmonic response using ultrafast nano-FTIR on Graphene exceeds 15 times the metal based plasmonics.



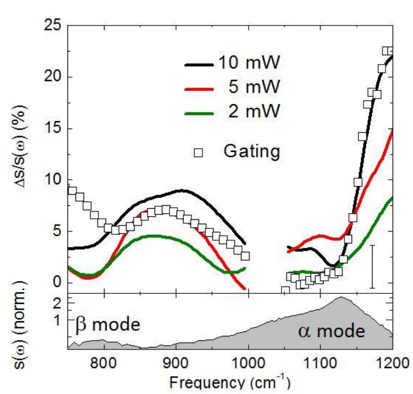


Fig 1. Sketch of the ultrafast nano-FTIR experiment of exfoliated graphene (left), and absolute signal S and pump-induced spectral changes ΔS/S for 2, 5 and 10mW near-IR pump-power at zero time-delay (right) compared to electrostatic gating.

This first infrared pump−probe experiment beyond the diffraction limit demonstrates the capability of this technique and paves the way to the exploration of a wide range of problems in condensed matter physics, biology, and chemistry.

3. References

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