Ultra Broadband Terahertz Spectroscopy of few-layer graphene films

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In addition to being a true 2D material composed of a single sheet of carbon atoms in a hexagonal crystal structure, graphene shows numerous exotic features. Ranging from extraordinary mechanical properties and thermal transport to an unusual optical response and charge carriers behaving like massless Dirac fermions giving rise to ballistic transport over hundreds of nanometers and half-integer quantum hall effect[1] and Klein-tunneling[2] at room temperature, the special properties of graphene continue to draw vast amounts of interest.

Because of graphene's extremely high carrier mobility and the promise of devices with the thinnest possible conducting channels one of the most promising applications is in high speed radiofrequency electronics[3] forecasted to operate in the terahertz(THz) frequency region[4]. Graphene is also anticipated to facilitate THz sources and detectors due to its small and widely tunable bandgap[5]. In particular several proposals of solid state THz lasers based on graphene as the active medium have been made[6,7,8], as well as proposals of graphene photodetectors[9,10] for the THz region. Despite many applications and the obvious relevance of the electrodynamic and optical response in the THz region only a few experimental THz spectroscopy studies[11,12,13] exist, most of them limited to bandwidths from about 0.1 to 3 THz.

In initial experiments we investigate the terahertz response of graphene using time domain spectroscopy. Ultra broadband THz pulses are generated and detected in a laser induced plasma in air (time and frequency representation of the pulses are shown in figures (a) and (b)).

CVD grown graphene films (microscope image shown in figure (c)) and graphene films produced by the Langmuir-Blodgett method from reduced graphene oxide flakes(microscope image shown in figure (d)) are investigated and compared. We report on the recent results of these ultra broadband THz experiments exploring the linear and nonlinear response of single- and few- layer graphene using the air-plasma source.

References

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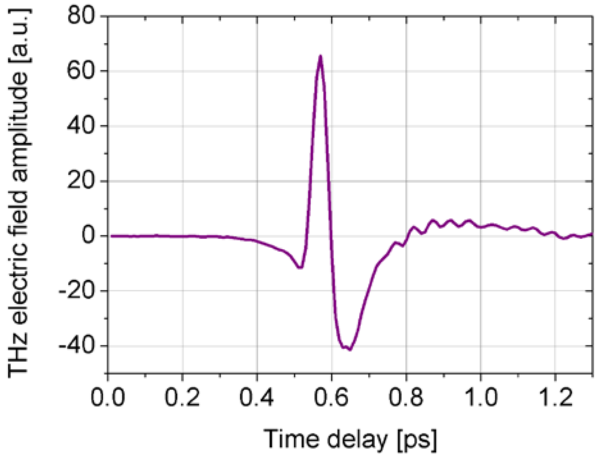
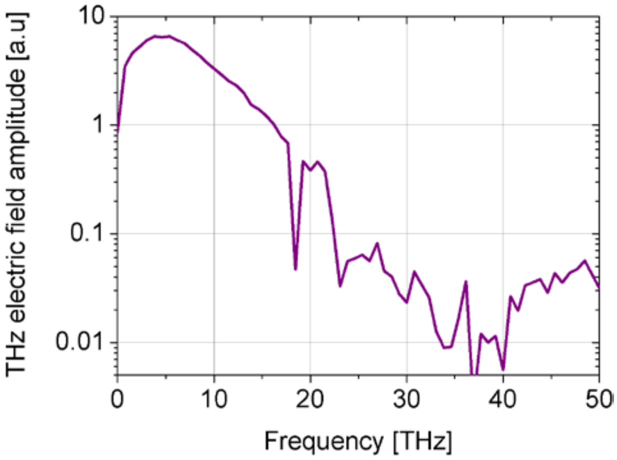
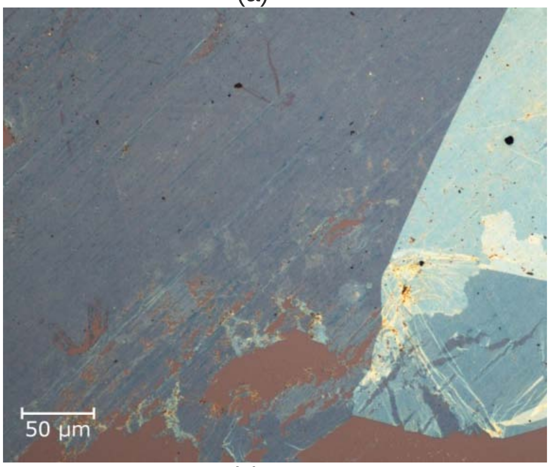
Figures



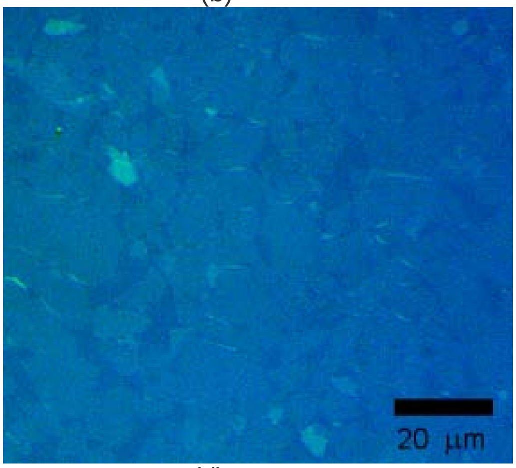
(a)



(b)



(c)



(d)

Figure (a) shows the time representation of an ultra broadband THz pulse generated and detected in laser induced plasma in air.

Figure (b) shows the frequency representation of an ultra broadband THz pulse generated and detected in laser induced plasma in air.The shown pulse has a bandwidth of ~30 THz and a peak dynamic ratio of ~100

Figure (c) shows an optical microscope image of few layer CVD graphene transferred to a 90 nm SiO2 on Si substrate. The graphene film was originally grown on copper foil.

Figure (d) shows an optical microscope image of a continuous film made up of graphene flakes, produced by the Langmuir-Blodgett technique.