Optically induced absorption modulation in a graphene-based metasurface

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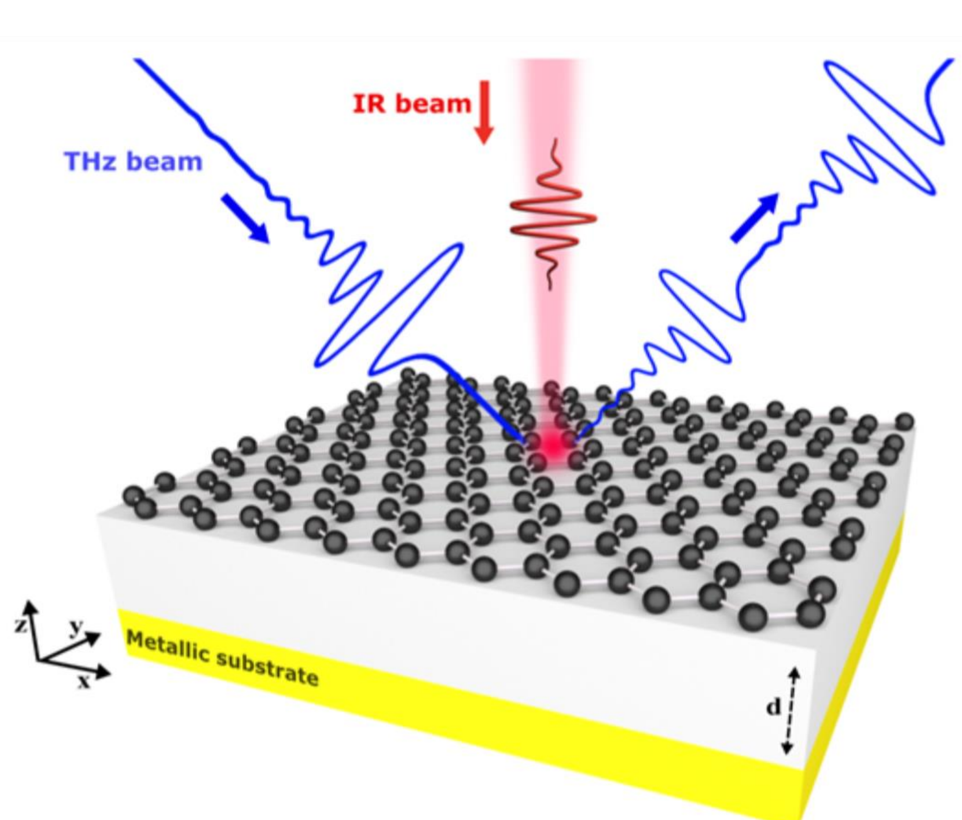
Introduction

We present the experimental demonstration of an ultrafast optically induced tunable, graphene-based absorber for operation in the THz regime. The graphene-based component consists of a uniform graphene sheet placed on a dielectric substrate which is grounded by a metallic plate. The mechanism of enhanced absorption is the coherent interference of the impinging and reflected waves that are found in phase at the position of the graphene sheet on the resonant frequency of approximately 2 THz. The sample is fabricated using a Silicon substrate covered by 400nm of Pt thick layer. On top a 20um thick SU-8 layer is deposited and finally a graphene monolayer grown by CVD is placed on top of the stack. For the experimental characterization of the sample we use a THz time-domain spectroscopic (THz-TDS) system. Graphene is modulated by an IR pump with maximum fluence equal to approximately 0.7 mJ/cm^2. Absorption modulation of 40% is recorded through photoexcitation.

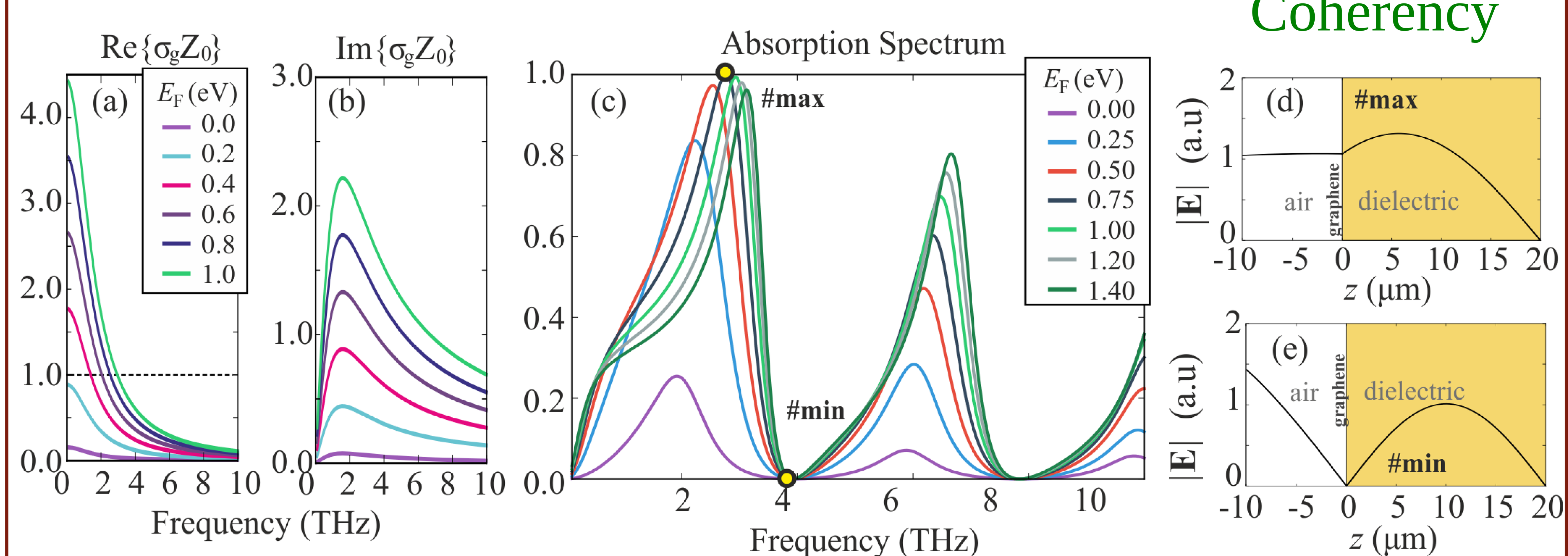
The structure



Stimuli: Optical pump by an amplified kHz Ti:Sapphire laser system, delivering 35 fs pulses at 800 nm and maximum energy of 2.3 mJ/pulse.

Characterization: THz time-domain spectroscopic (THz-TDS) system in reflection, range [0.5-12] THz.

Principle of operation

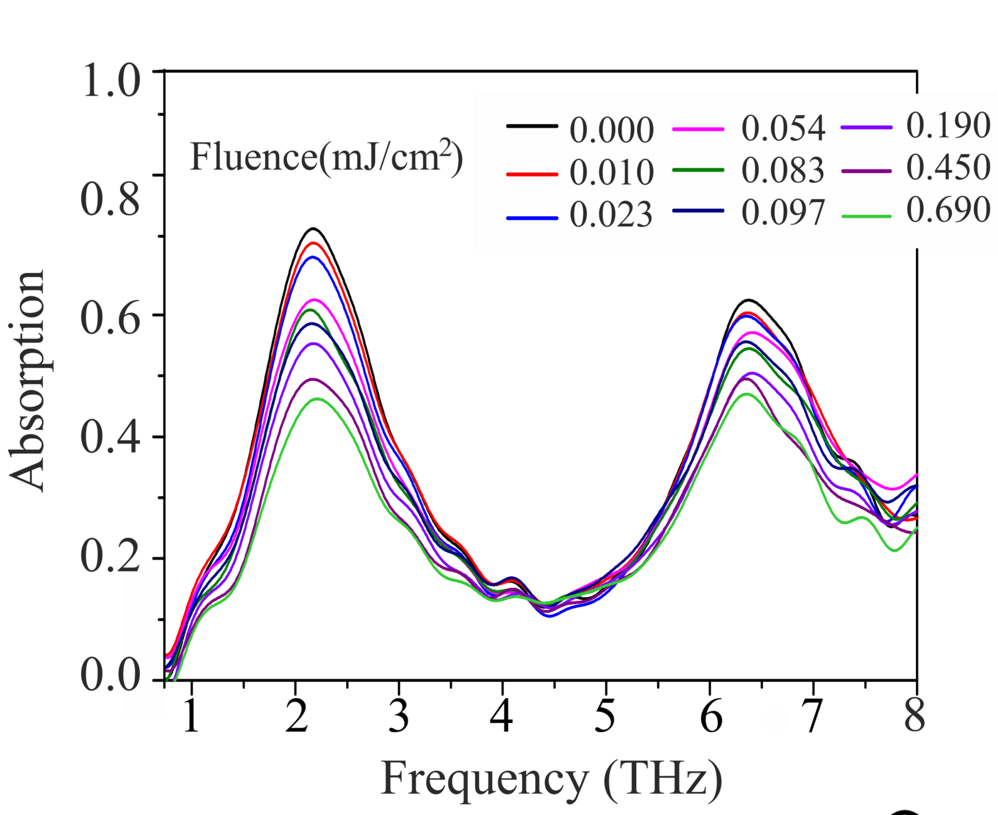


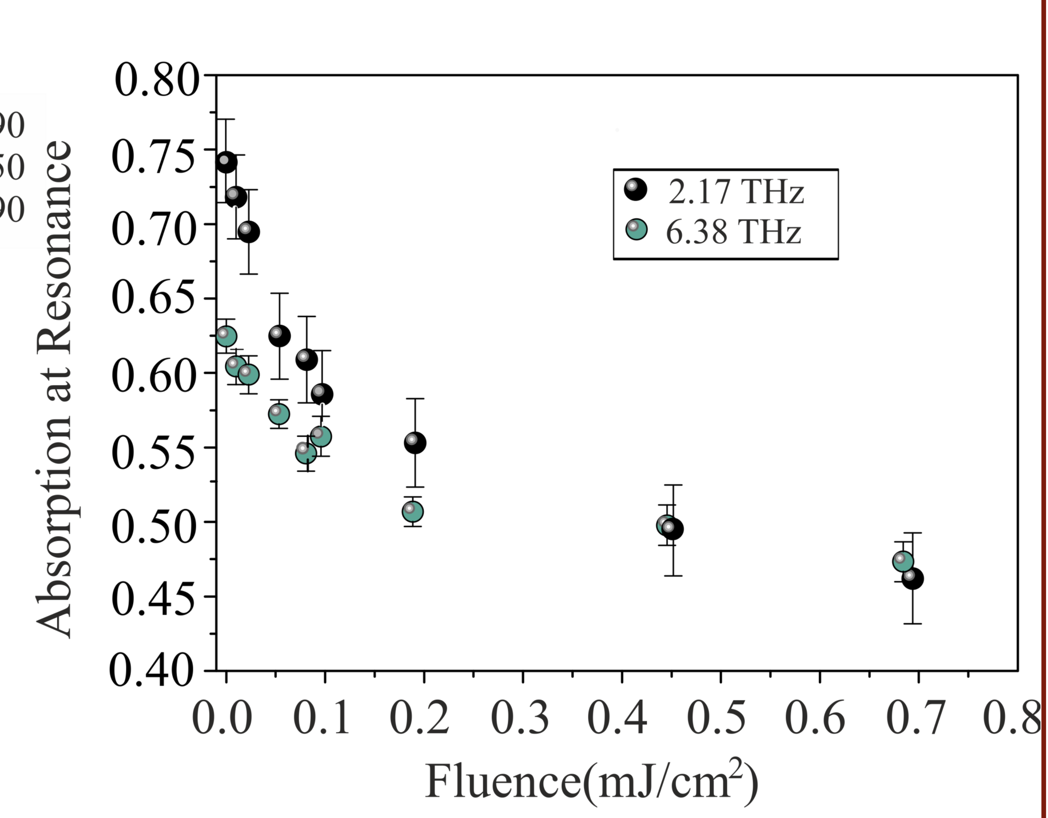
Conditions for perfect absorption:

- Freespace / surface impedance matching: $\mathrm{Re}\{\sigma(\omega)Z_0\} = 1$
- Conerency of impinging and reflected wave: $\mathrm{Im}\{\sigma(\omega)Z_0\} = -\sqrt{\epsilon_r}/\tan(k_g h)$

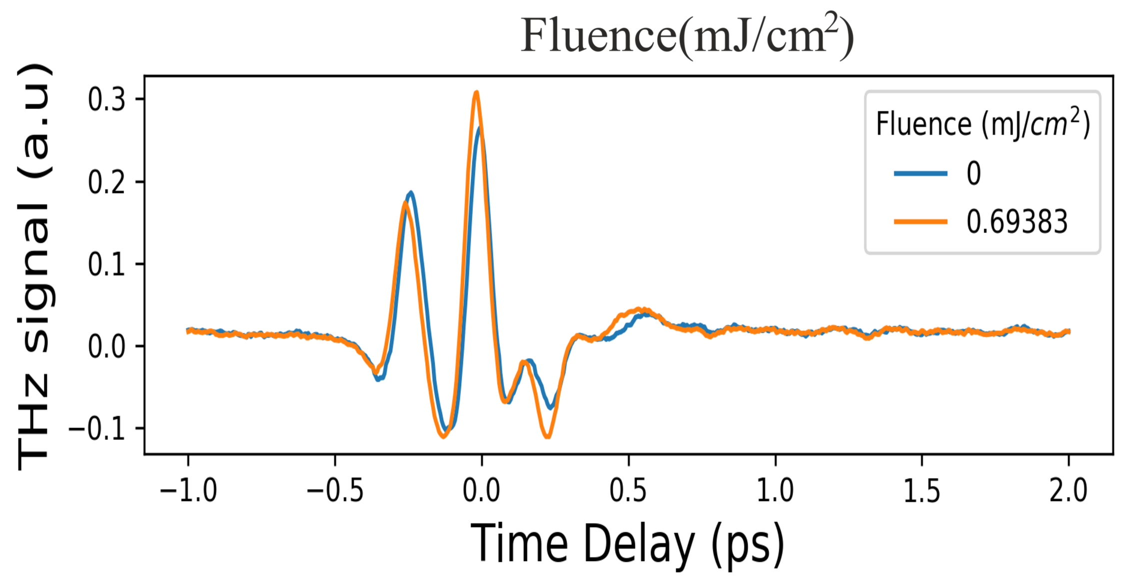
Target Functionality: Tunable enhanced and perfect, non-reflective covering layers for **electromagnetic shielding applications.**

Experimental demonstration





- The optical stimuli modifies the electric conductivity as it appears with a delay in the pump-probe THz measurements.
- THz measurements do not resolve the fast dynamics in the first femtoseconds of the interaction



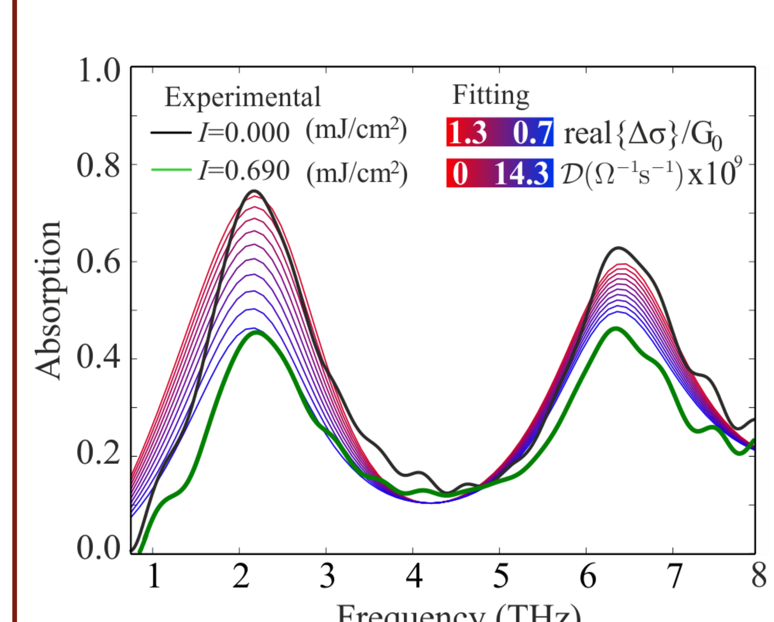
decrease of the absorption points to negative conductivity dynamics

Absorption modulation of 40% with fluence 0.7 mJ/cm^2

Modeling

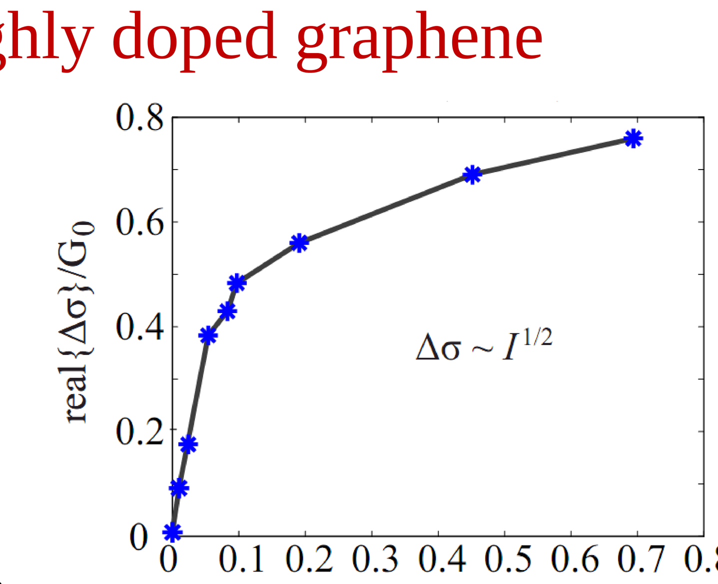
The sign of the photoinduced conductivity depends greatly on the doping level in the graphene

- Positive photoconductivity in neutral charge point graphene
- Negative photoconductivity in highly doped graphene



$$\Delta\sigma(\omega) = \frac{\mathcal{D}\tau}{1-i\omega\tau} + \frac{iF}{(\omega^2-\omega_0^2)+i\omega\gamma}$$

scales with $I^{1/2}$



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