Time-resolved ultrafast photocurrents and terahertz generation in freely suspended graphene

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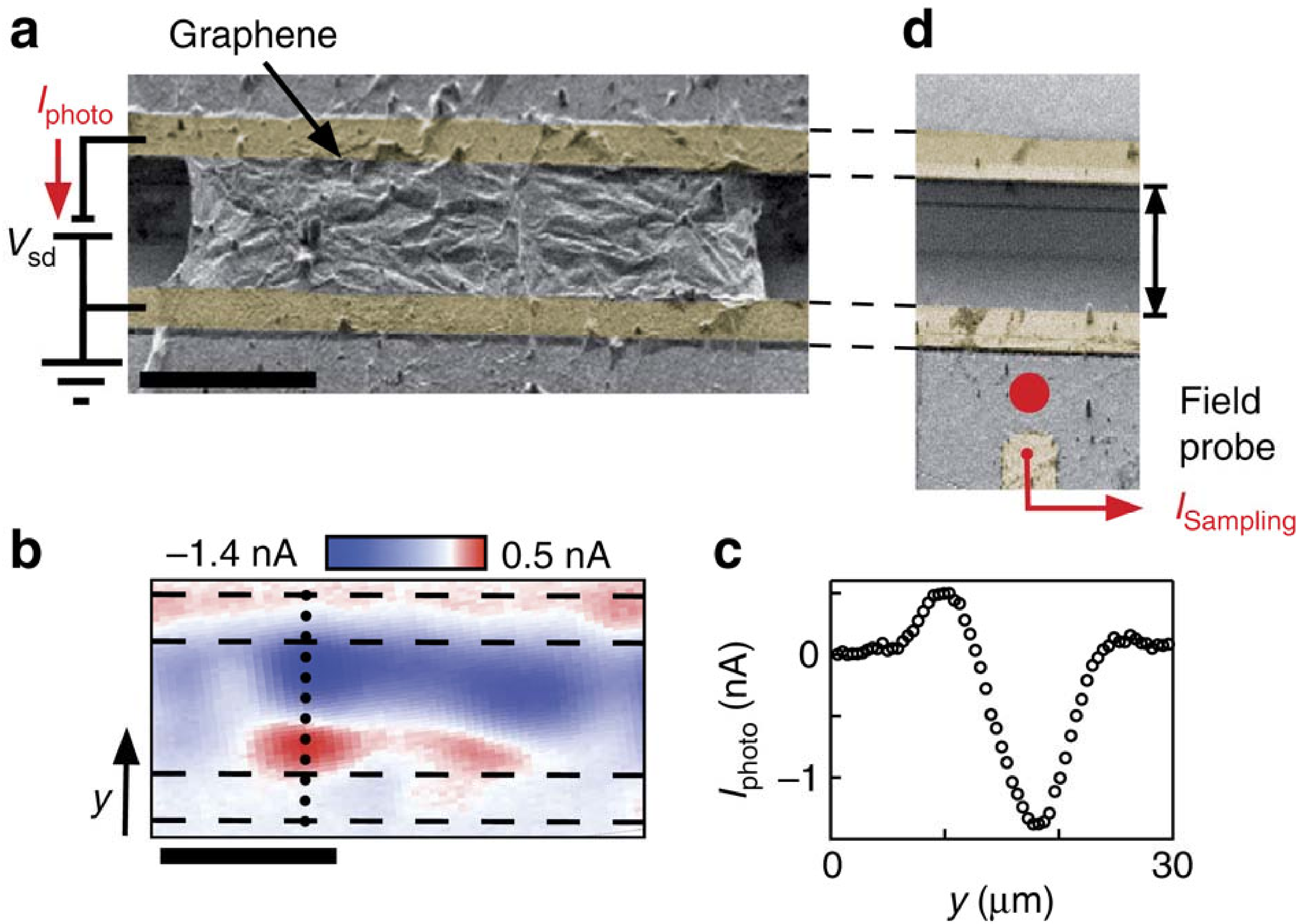
Background

- *High charge carrier mobility – graphene based high speed electronic devices*
- *Combined with the excellent optical properties – optoelectronic applications*
- *Various kinds of THz sources and detectors has been proposed (frequency of plasma waves, tunable band gap double layer graphene, band gap in nanoribbons,)*
- *RC limited bandwidth of GPn based photodetectors was estimated to be 640 GHz,*
- *Common electronic apparatus cannot resolve underlying ultrafast charge carrier dynamics – available electronics cannot produce trigger signals faster than 10 picoseconds – limitation of measuring transients*

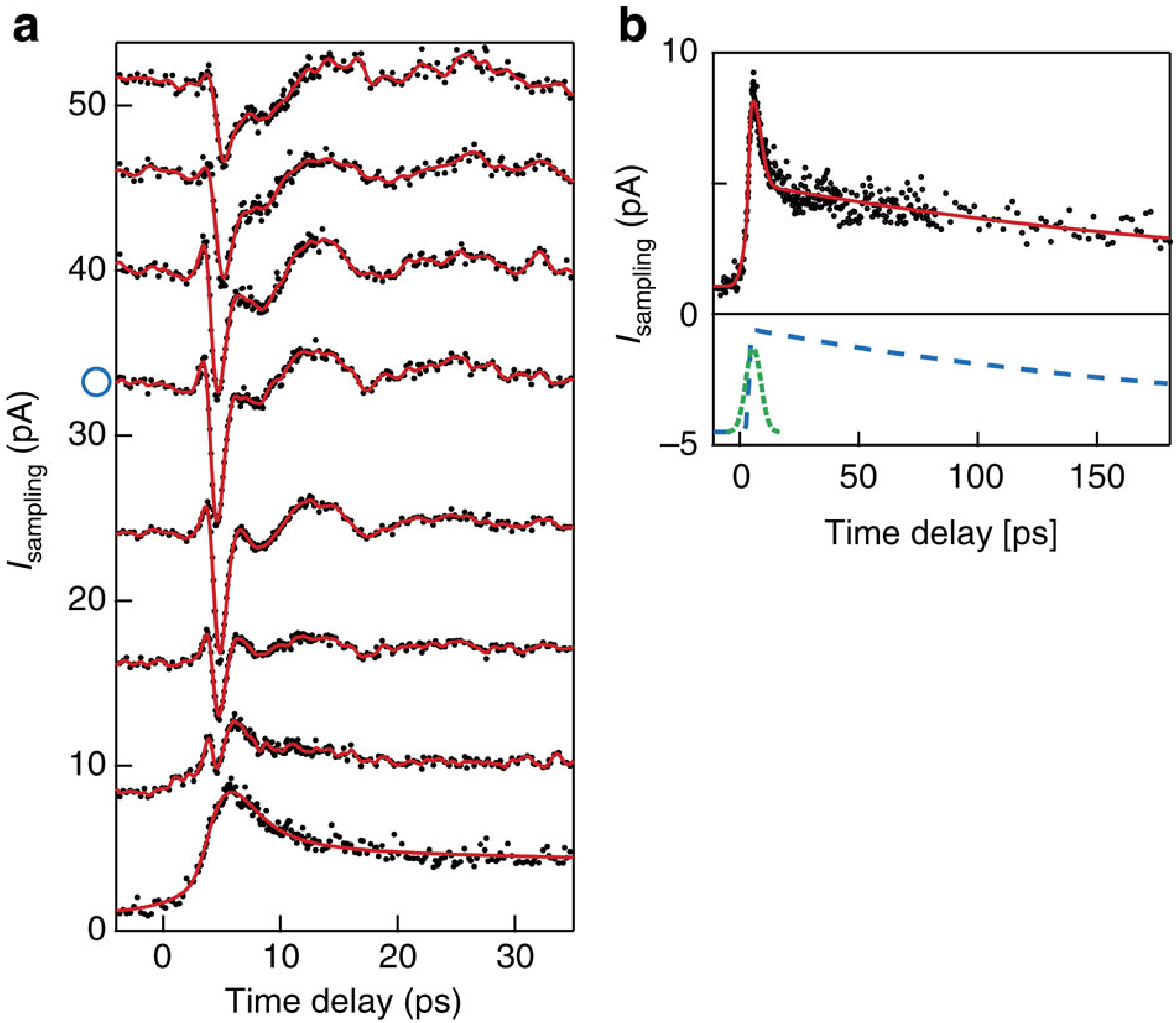
Present work

- Pump –probe photocurrent spectroscopy
- resolved photoelectric response upto 1 THz
- THz generation in optically pumped graphene
- EM radiation is detected by a coplanar metal stripline, which acts as a highly sensitive near-field antenna and waveguide with a bandwidth of up to 1 THz
- Our ultrafast experiments further clarify the optoelectronic mechanisms contributing to the photocurrent generation at graphene–metal interfaces
- verified that both built-in electric fields, similar to those in semiconductor-metal interfaces, and a photothermoelectric effect give rise to the photocurrent at graphene–metal interfaces at different time scales

Time-integrated and time-resolved photocurrent spectroscopy

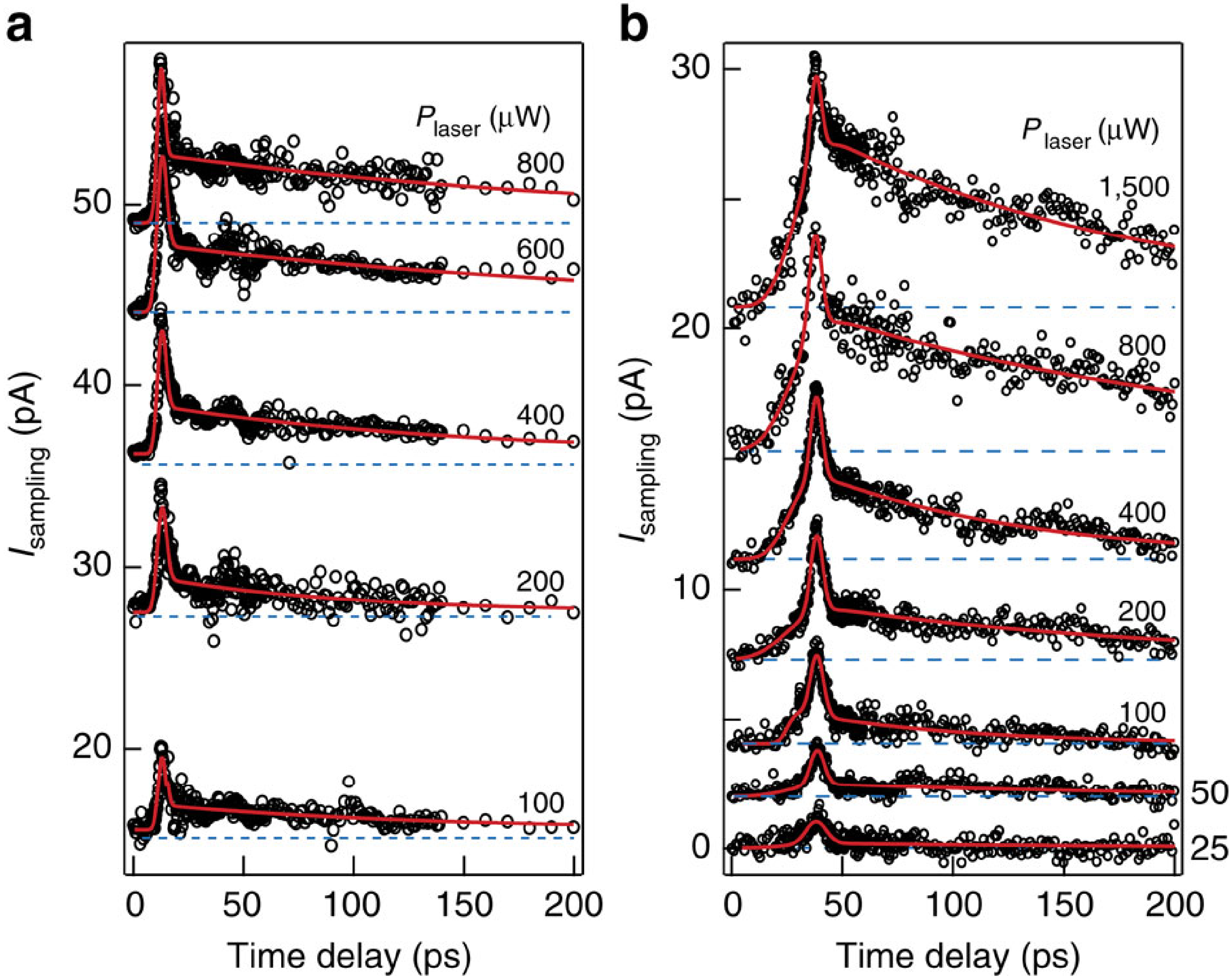


Ultrafast photocurrent circuitry for graphene

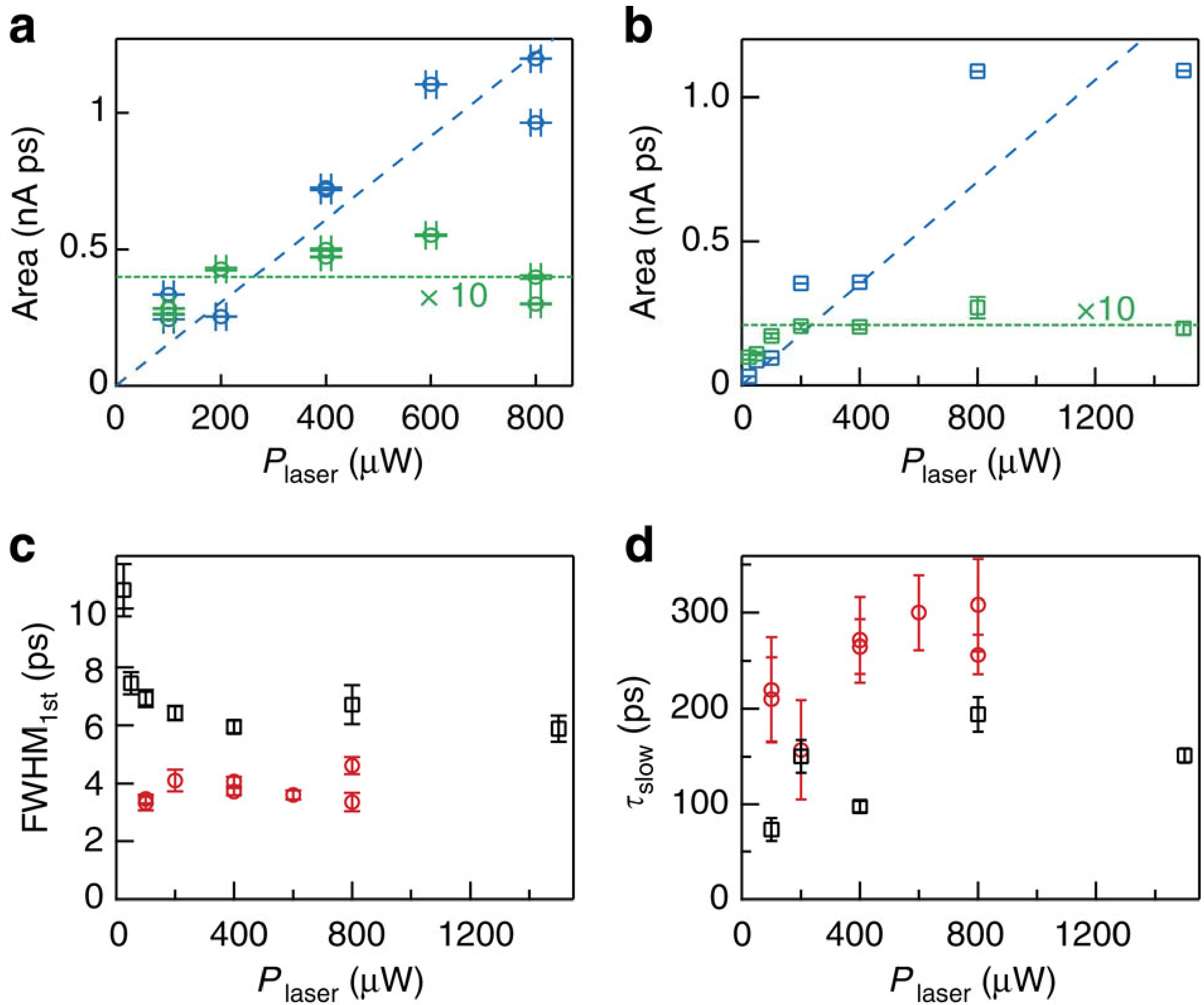


Time-resolved photocurrents in graphene

Built-in electric field and photo-thermoelectric effect

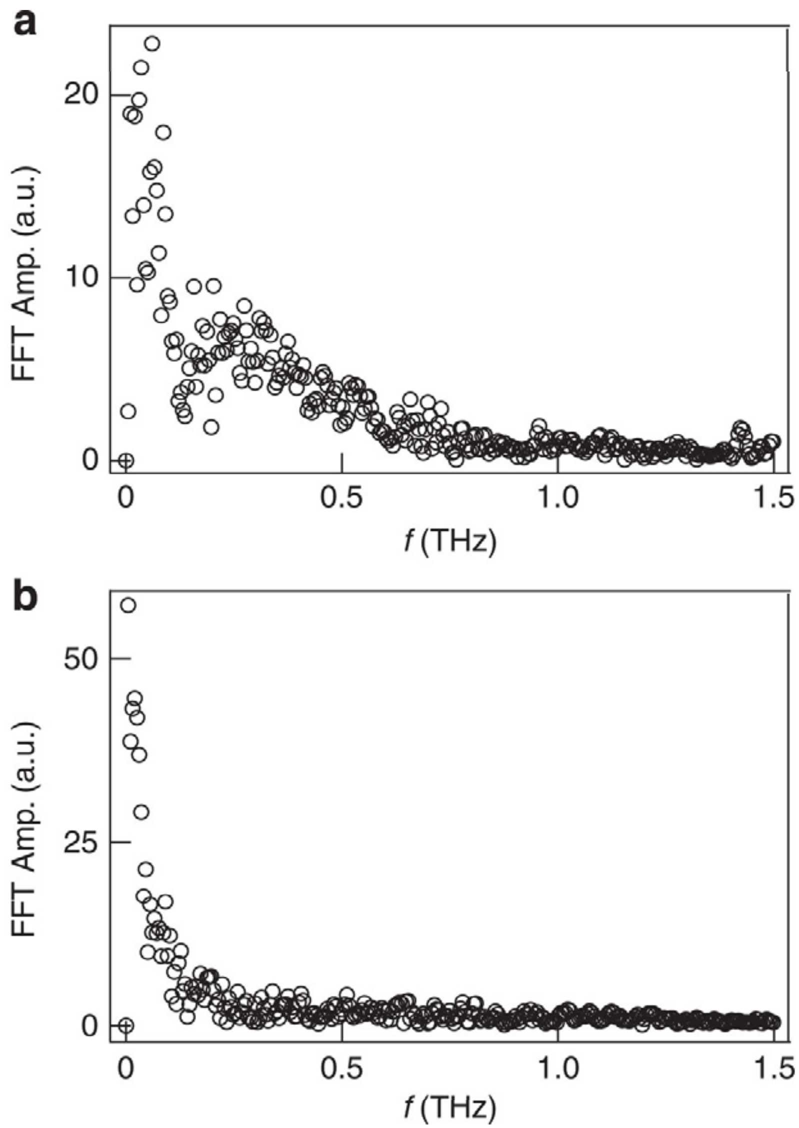


Laser power dependence of the ultrafast photocurrent at the graphene–metal interface

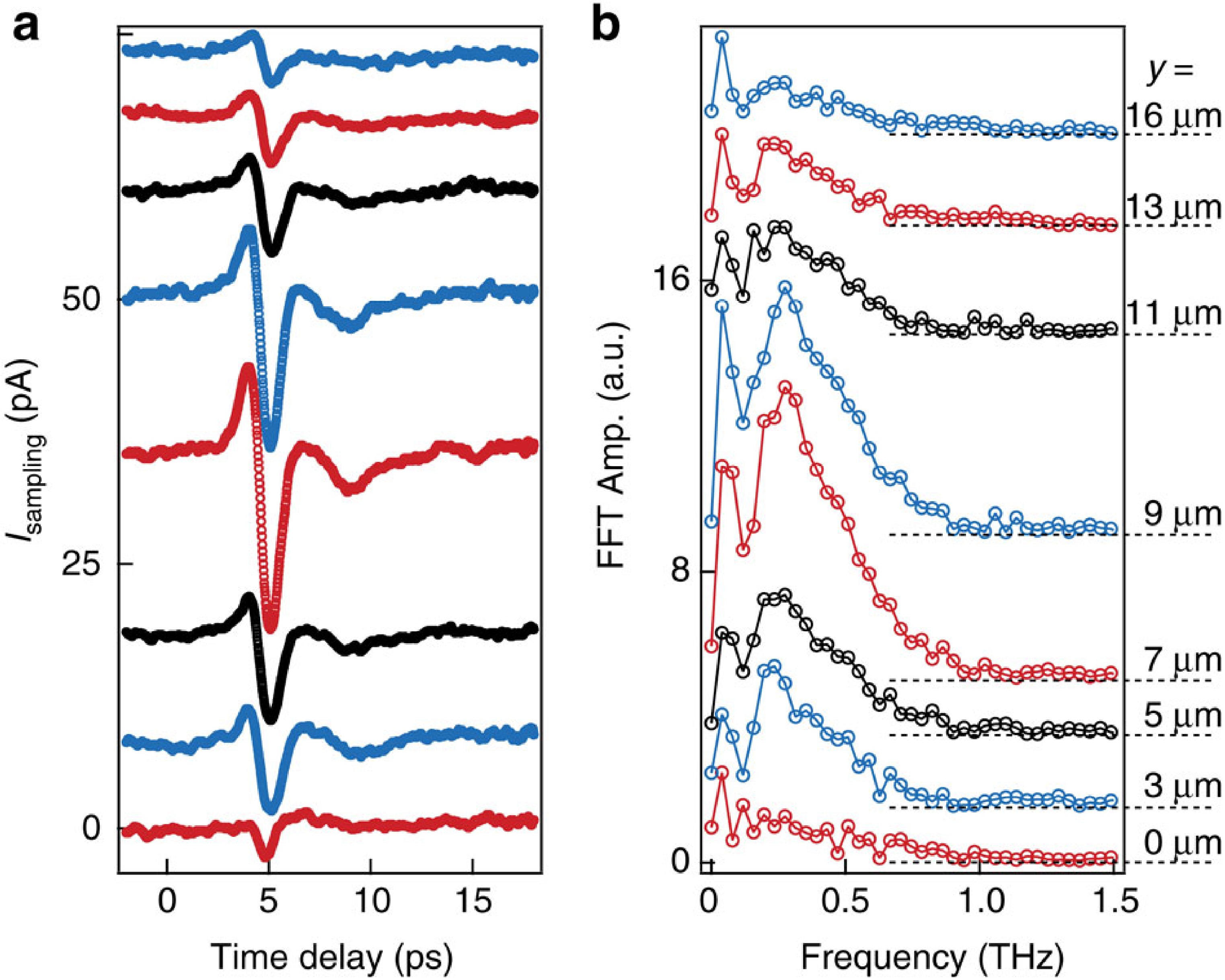


Fit parameters for $I_{sampling}$ versus P_{laser} at the graphene–metal interface

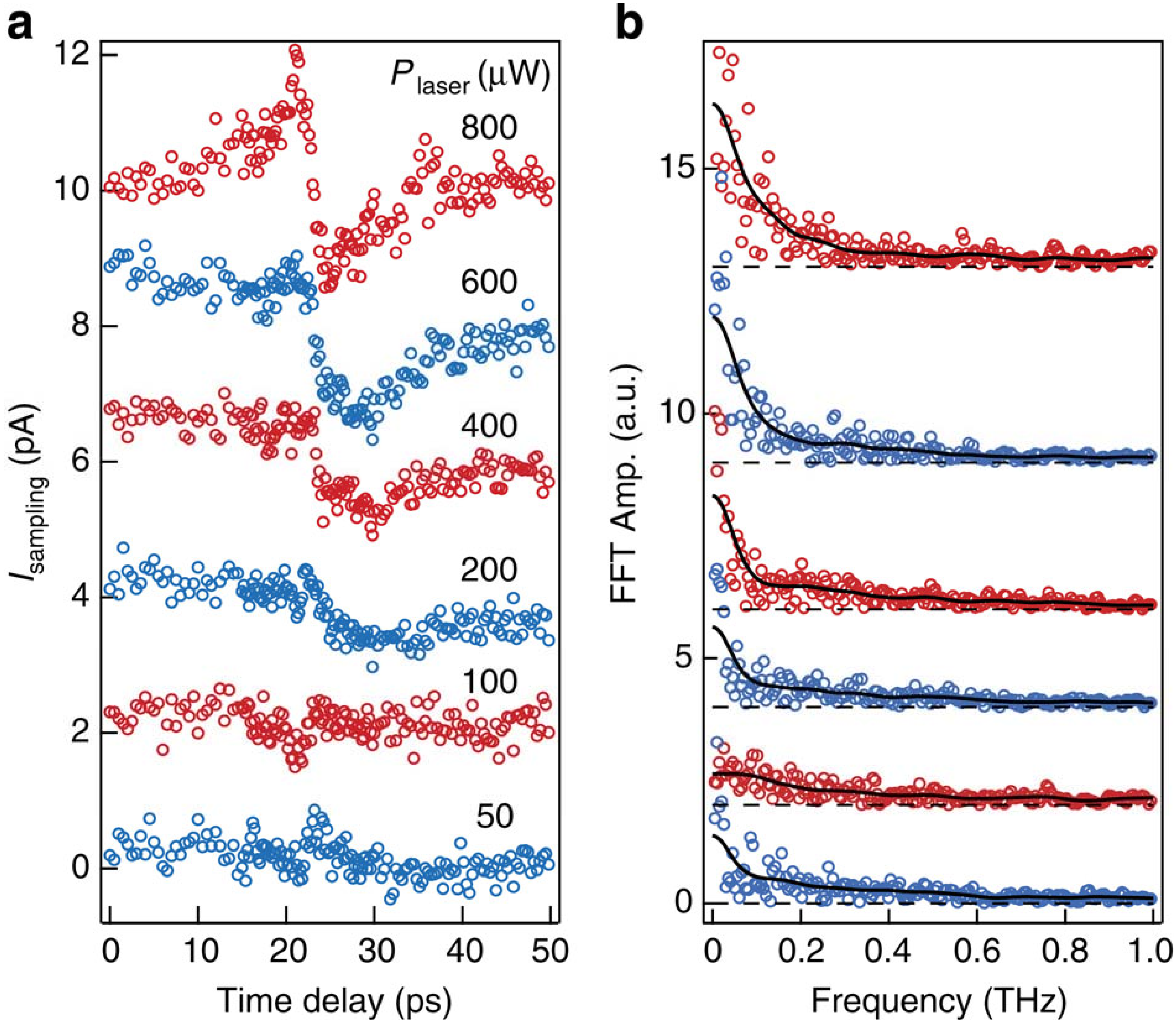
Photocurrent oscillations in freely suspended graphene



Frequency analyis of ultrafast photocurrents in graphene

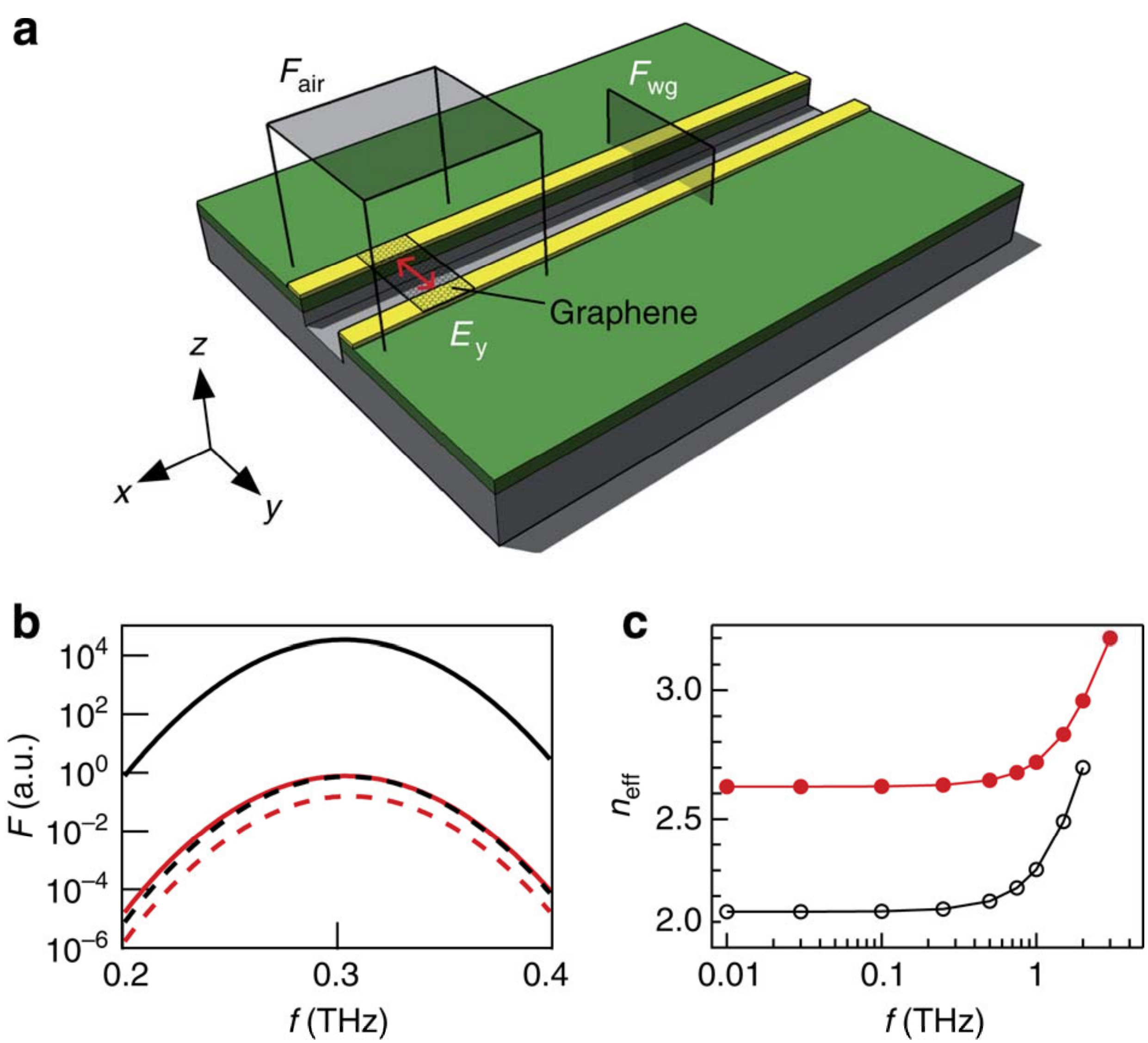


Terahertz response of graphene



Power dependence of $I_{sampling}$ at the centre of the graphene

Numerical stripline investigations



Finite-difference-time-domain and finite-element-method simulation

Discussions

- *Photo excited charge-carriers in graphene can very efficiently relax by the emission of optical phonons with a subsequent interband recombination or via plasmon emission on a sub-picosecond timescale*

- *Present detection system (coherent scheme) unable to detect incoherent re-combinations /thermionic emissions*

- *Oscillatory signal $I_{sampling}$ to be an indication of an electron-hole plasma in the graphene, which is AC-coupled to the strip lines.*

- *The required symmetry breaking to stem from the overall non-uniformity of the samples or from an ultrafast interaction between the few (1–3) individual layers of graphene.*

- *The fact that the prominent frequency does not change with position; but it does so with an increase in laser power, corroborates the interpretation that a plasmonic excitation generates the terahertz radiation*

- *Our results open the possibility to design and fabricate graphene-based ultrafast photodetectors, photoswitches, photovoltaic cells, and terahertz sources*

Thank you

Robin John
PH08D023