THz technologies with Layered materials

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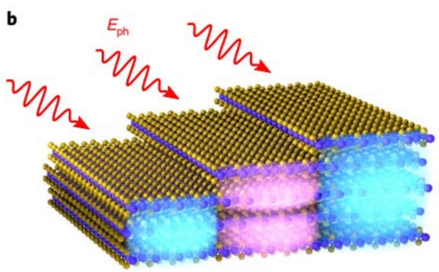
Quantum wells and layered materials heterostructures

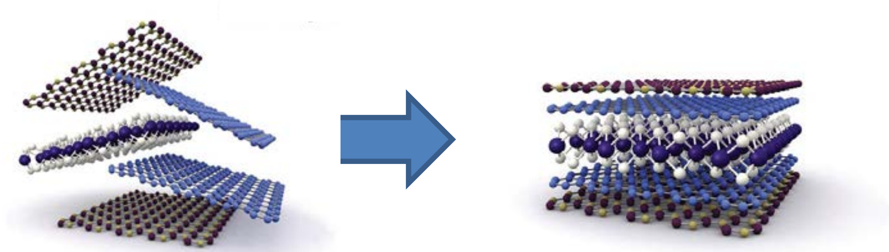


Smith et al., Nature Nanotech. 2018

- Layered materials “naturally” form **quantum wells** where carriers are confined in one dimension.
- Strong in-plane bonds and weak out-of-plane ones not only allow extraction of individual layers, but also enable terraced structures, each with a **well defined number of layers**.
- Confinement leads to quantised states and correspondingly **intersubband transitions**, similar to semiconductor quantum wells.

- Intersubband transition experimentally achieved in WSe_2 and MoS_2

Layered materials have saturated bonds on the surface, allowing staking of highly diverse materials **without the constraints imposed by crystal latter matching** in conventional semiconductor heterostructures.



[Science 353, aac9439]

It is now possible to deterministically assemble different layered materials into heterostructures with **abrupt and atomically clean interfaces**, similar to MBE but with a much larger variety of materials and combinations (over 2,000 LM materials exist).

Also, control on relative lattice alignment.

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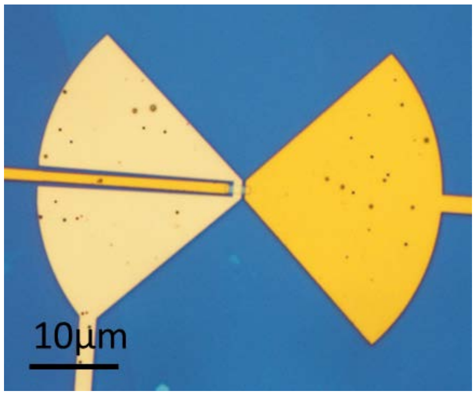
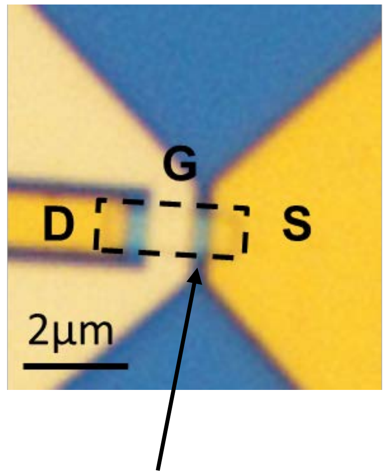
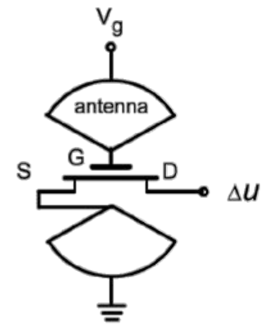
Layered materials heterostructures for RT THz detectors

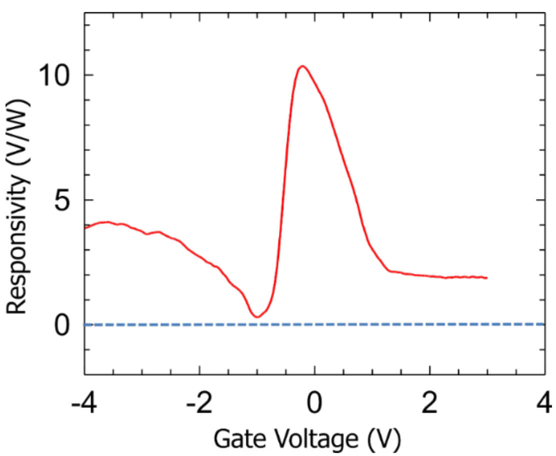
FET integrated with a **split bow-tie antenna**

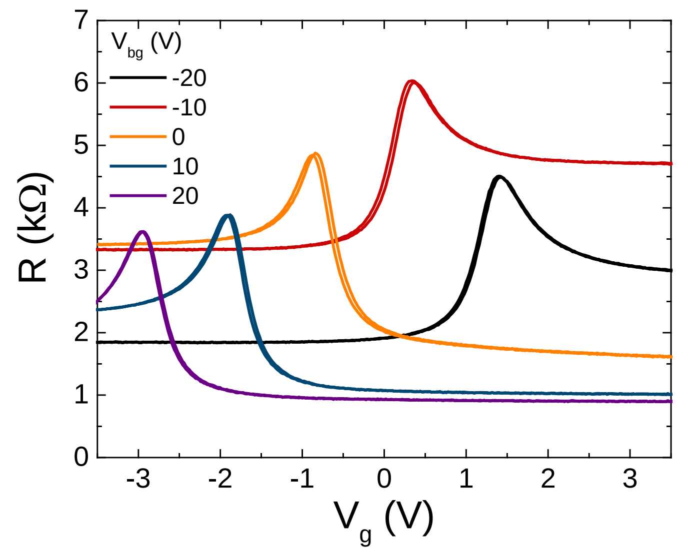




Encapsulated graphene







At 3.8THz:

- Responsivity: ~**10V/W**
- NEP: **700 pW/Hz$^{1/2}$**

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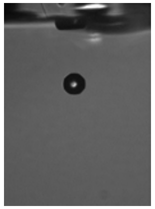
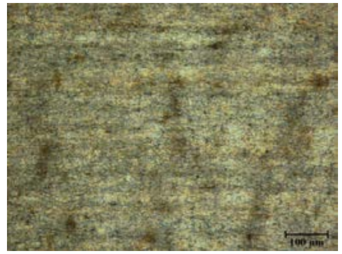
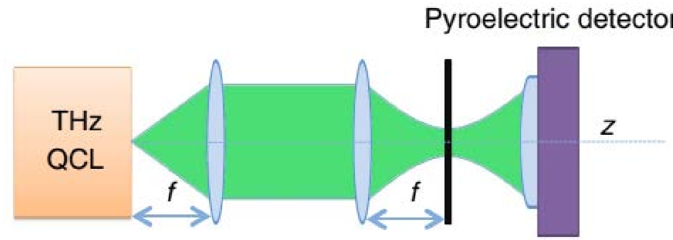
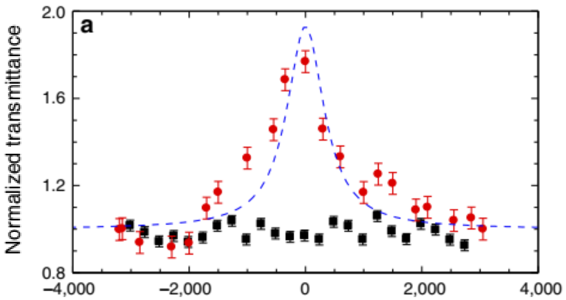
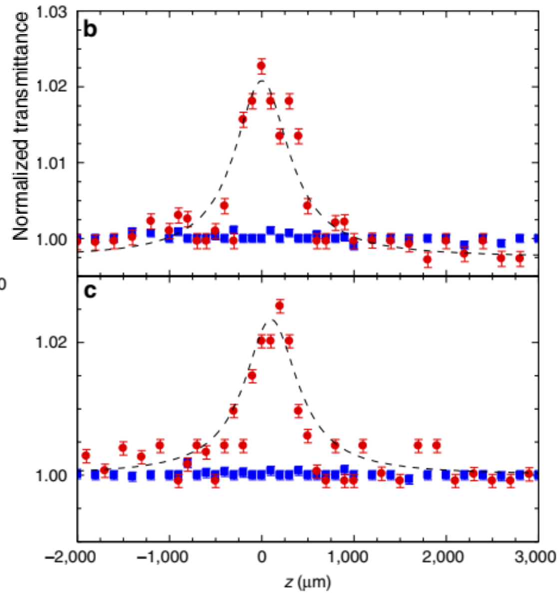
Printed layered materials as THz saturable absorber











- Ink-jet printed saturable absorbers
- Transparency modulation up to 80% at 3.5 THz
- Easily printable on flexible substrates

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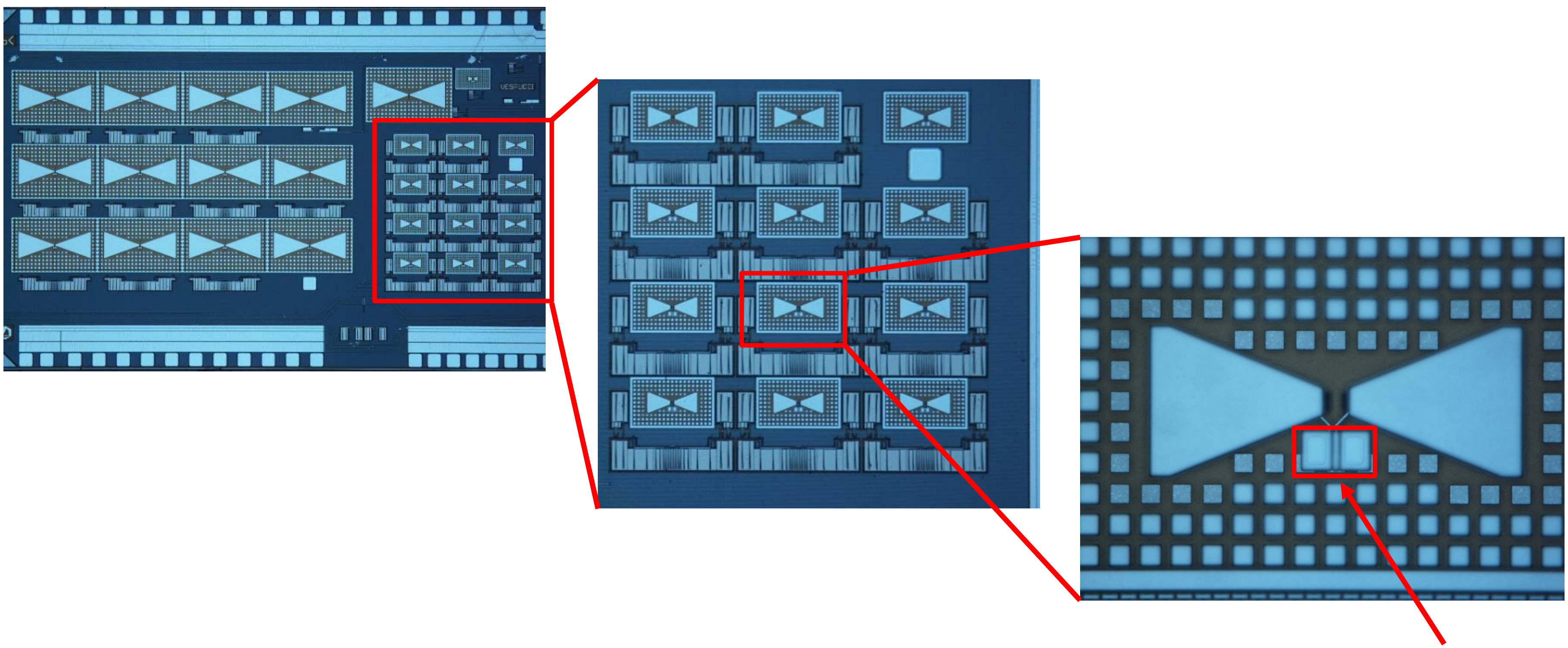
Bianchi et al., Nature Comm. 8:15763

Integration of layered materials with CMOS for THz imaging

- Arrays of detectors, designed for 300GHz and 850 GHz
- Fully integrated, also amplifiers, etc.
- Fabrication fully compatible with CMOS fab, LM added at last stage

FONDAZIONE BRUNO KESSLER



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