Quantum phase transitions in epitaxial graphene for quantum-limited sensing

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We investigate quantum limited sensing of single GHz/THz photons with charge neutral epitaxial graphene. Exploting Quantum Phase Transitions (QPT), we assess the reliability of such a material as sensing element aiming to the development of a fully integrated single photon emitter/sensor device based on silicon carbide platforms.

Quantum Phase Transition is the ground state reconstruction of a system in response to the change of a certain parameter. At the QPT critical point the system responsivity to this parameter diverges, and this effect can be potentially used to boost the sensitivity of a measuring device. These basic considerations motivated numerous theoretical proposals for QPT-based sensors.[1,2] Here we suggest to exploit the fact that at the QPT point the system permittivity diverges at $T \rightarrow 0$ and to study conceptually new quantum-limited bolometric designs.

We have previously found that graphene doped close to Dirac point works as an excellent radiation sensor in the wide range of frequencies – from 10 GHz to 1 THz,[3,4] and it has the potential for the single-photon resolution. Recently we have discovered that such an extraordinary sensitivity is related to the metal-insulator QPT in graphene, which occurs at the critical magnetic field Bc=0.1 T. In this work, we explored the use high quality molecularly doped epitaxial graphene grown on SiC[5] for the implementation of graphene-based structures comprising high-sensitivity impedance-modulated reflectometers and radio frequency bolometers (Figure1). For the latter we obtained thermal conductance values in the lower range of Gth≈10-16 W/K and the respective noise equivalent power of NEP≈10-21 W/√Hz at operational temperatures below 50 mK. Remarkably, these values outperform the reported current state of the art. We plan to build on these results to aim at the development of scalable graphene calorimeters with sensitivities compatible with 10 GHz single photon energy values (≈7·10-24 J) for circuit quantum electrodynamics.

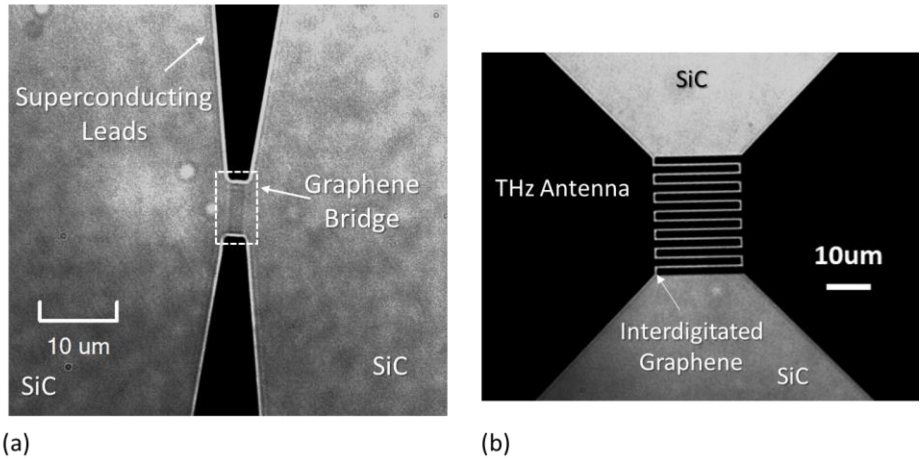

Figure 1 (a) Transmission optical micrograph of epitaxial graphene contacted by superconducting leads for RF-thermometry experiments. (b) Transmission optical micrograph of an interdigitated graphene element couple to an antenna for quantum limited detection of THz radiation.

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