Photon-assisted tunneling in hBN encapsulated graphene quantum dot under coherent THz illumination

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Photon-assisted tunneling (PAT) is an attractive process for the study of light-matter interaction phenomena. In PAT, the electron tunneling through a quantum dot is enabled via the quantum absorption of an electromagnetic wave. Up to now, only a few works and a few quantum systems have demonstrated PAT under THz illumination [1-3]. Graphene quantum dots (GQD) of typical size ~100 nm size have great potential for PAT under THz illumination as their energy level splitting to quantum electron confinement falls in the THz range [4], and room temperature bolometric detection of THz radiation have been demonstrated in GQD-based devices [5].

Here, we investigate the quantum response of hBN encapsulated GQD to coherent THz illumination and demonstrate photon-assisted tunneling. We fabricate a single electron transistor made of a hBN encapsulated GQD of 120 nm diameter connected to source and drain electrodes by two narrow constrictions (40 nm) and surrounded by three lateral gates: G_1, used to control the quantum dot chemical potential, and G_2 and G_3, used to set the two constrictions as tunneling barriers (Fig 1(a)). The device is placed in a dilution ^{4}He–^{3}He cryostat at 40 mK with optical access, enabling its illumination with coherent THz radiation from a GaAs Schottky diodes source. Without illumination, the electronic transport in the GQD is in the Coulomb blockade regime as illustrated in Fig 2(b)-left: at low SD bias voltage, an electron can tunnel through the GQD only if a GQD energy level is available between energy levels of source and drain. As a consequence, the tunneling current through the quantum dot exhibits the Coulomb peaks pattern as the GQD chemical potential is swept using the G_1 gate voltage (black curve, Fig 1(c)).

As we switch the THz coherent illumination on, a new transition can be enabled through the absorption of a THz photon: Fig 2 (b)-right illustrates a possible mechanism for this photon-assisted tunneling, and shows the GQD chemical potential shift associated to this new transition is given by the energy of the absorbed photon. Our experimental measurement exhibits an additional satellite current peak whose gate voltage shift increases as the THz illumination frequency increases (highlighted by dashed line Fig 1 (c)). This frequency dependence matching the dependence expected from PAT indicates we observe PAT in our experiments. This demonstration of light matter interaction between coherent THz radiation and discrete electronic levels in GQD opens up very interesting perspectives for both fundamental studies and the development of quantum THz devices.

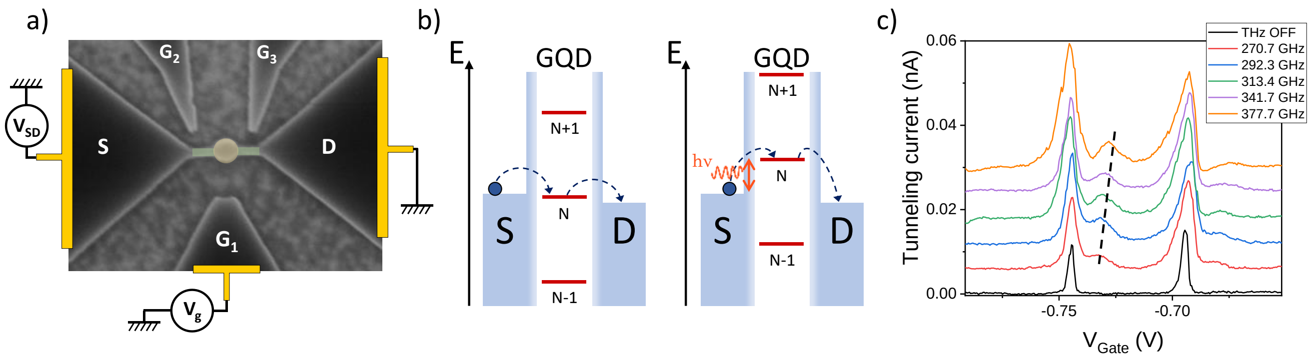

*Fig. 1: **a)** SEM picture of the hBN encapsulated GQD including schematics of the connected electrodes and bias/gate voltages. **b)** Energy diagram illustrating the tunneling process of an electron from source to drain electrodes through the GQD. Left: tunneling without illumination. Right: tunneling mediated by the absorption of a THz photon. **c)** Experimental measurement of the tunneling current under illumination through the GQD presented Fig (a) for increasing THz excitation frequency, offsetted for clarity.*

References:

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