# Phase Dependent Quantum Dynamics of Andreev States in a Ballistic Graphene-based Josephson Junction

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Abstract

The response of a normal/superconducting ring to a time-dependent flux provides a way to investigate the dissipationless current-phase relationship as well as various dynamic processes giving rise to dissipation. By inductively coupling the ring to a radio-frequency resonator, such response, manifested as the complex susceptibility, can be measured by the change in the resonance frequency and the quality factor of the resonator respectively [Fig. 1(a)] [1]. Previous measurements done on metal/superconductor junctions revealed the microwave photon-assisted transitions between Andreev states as the main dissipation mechanism at low temperature and high frequency, in the linear regime where the susceptibility did not depend on the input power [Fig. 1(b)] [2]. In this study, we explore the non-linear regime in a boron-nitride encapsulated graphene/superconductor ring subject to high-power microwave irradiation. We observe a modification in the current-phase relation under irradiation with high frequencies and powers [Fig. 1(c)]. Also, an enhanced dissipation at phase zero in addition to the conventional one at phase π appears in the same regime [Fig. 1(d)]. We try to explain the observations within the framework of the semi-classical Green's function theory which has not been sufficiently established in graphene system close to the ballistic regime with much fewer transmission modes compared to the conventional metal/superconductor junction [3, 4].

References

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[3] Virtanen et al., Phys. Rev. Lett. 104, 247003 (2010)
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Figures

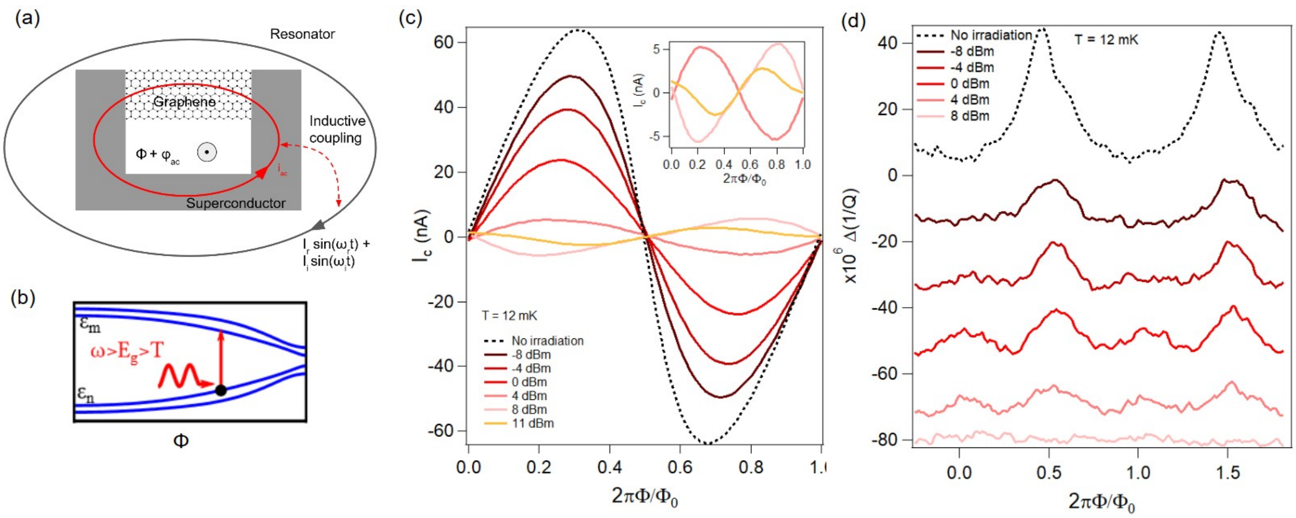


Figure 1: (a) Graphene/superconductor ring coupled to a resonator for susceptibility measurement at resonance frequency $\omega_r$ (60 MHz) with microwave irradation at frequence $\omega_i$ (40 GHz) (b) Microwave photon-assisted excitation to the higher Andreev states causing dissipation (c) Current-phase relation and (d) dissipation change $\Delta(1/Q)$ versus dc phase $2\pi\Phi/\Phi_0$ with different irradiation powers at 40 GHz. The temperature is 12 mK. Inset of (c) highlights the strong anharmonic current-phase relation under the highest irradiation powers. In (d) additional peak at phase 0 is also seen at high power.