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Phase-dependent dissipation in SNS junctions: topology and non-equilibrium dynamics

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An (SNS) junction with two superconductors coupled by a normal metal hosts Andreev bound states whose energy spectrum is phase-dependent and exhibits a minigap, resulting in a periodic supercurrent. However, phase-dependent dissipation also appears due to finite-time relaxation of Andreev bound states, providing an ultra-sensitive tool for the carrier dynamics.

In the weakly driven regime, we have measured dissipation in a phase-biased junction built around a bismuth nanowire, a second order topological insulator, which was previously shown to host one-dimensional ballistic edge states. We have found absorption peaks at the Andreev level crossings in accordance with predictions of telltale signs of topological junctions [1,2].

I will also present our most recent results on SNS junctions strongly driven out of equilibrium by microwave field where novel physics emerges due to redistribution of quasiparticles. Strong driving power can significantly modify the distribution function from thermal equilibrium, activating additional transitions. We have measured the evolution of both the supercurrent and dissipation, extracted simultaneously from the ac magnetic susceptibility of a phase-biased graphene-superconductor ring driven out of equilibrium by microwave irradiation [3]. Increasing the frequency beyond the system relaxation rate has several consequences: Firstly, the phase dependence of supercurrent is modified in agreement with time-dependent Usadel equations. Secondly, the dissipation with irradiation frequency higher than the minigap shows a distinct enhancement around $\varphi = 0$ where the minigap is the largest and the dissipation is very weak in equilibrium. Using Kubo formalism, we explain this effect by the nonequilibrium distribution function with partial occupation above the minigap permitting transitions between levels on the same side of the minigap.

More generally, our results demonstrate that phase dependent dissipation measurement allows a deeper understanding of the relaxation mechanisms than supercurrent in superconducting junctions.

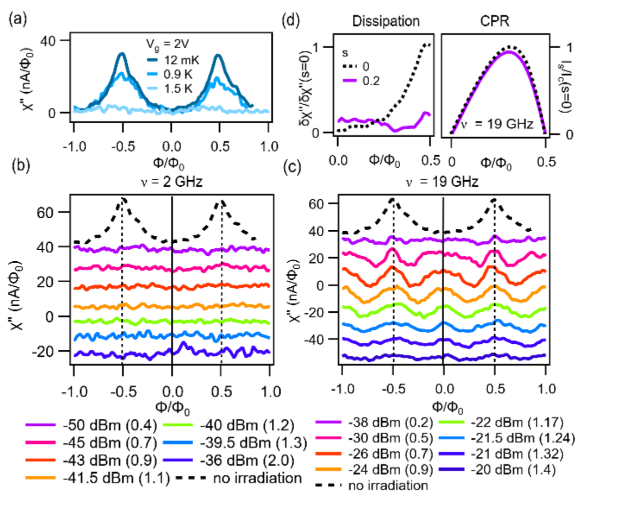

FIG. 1. Effects of microwave irradiation on dissipative part of the susceptibility χ" of a graphene junction:
a) χ" (ϕ) without irradiation T= 12 mK, 0.9 K, 1.5 K.
b, c) T = 12 mK, black dashed line is χ" (ϕ) without irradiation. For (c) at frequency larger than the minigap χ" (ϕ) changes from $2\phi_0$ periodic without irradiation to ϕ_0 periodic at higher irradiation power. The irradiation power is converted to the normalized value (s=eV/hf).
d) Left: δχ" normalized by the un-irradiated value. Right: supercurrent normalized by its value without irradiation. Vg =2 V and T = 12 mK for (b, c, d).

[1] Murani et al, Phys. Rev. Lett. **122**, 076802 (2019) ; [2] Fu and Kane, Phys. Rev. B **79**, 161408(R) (2009)
[3] Dou et al, arXiv:2011.07308