# Superfluid stiffness of twisted graphene

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Superfluid stiffness measurements offer a powerful probe of the superconducting state and a primary means to characterize their pairing symmetries. While a range of techniques are available for bulk materials to measure superfluid stiffness, for two-dimensional (2D) materials with a small sample volume and low transition temperatures, alternative methods are required. Inspired by recent advances in quantum measurement technologies, we develop a radio-frequency reflectometry technique adapted to measure the superconducting kinetic inductance in 2D materials at milliKelvin temperatures.

We apply this technique to twisted graphene where superconductivity is highly unusual, occurs at extremely low carrier densities, and shows strong parallels with high-Tc superconductors including proximity to a correlated insulating state [1,2,3]. Although hotly debated, superconductivity in this system has been investigated primarily using transport measurements which carry little information about the nature of superconductivity. Therefore, important questions such as the pairing symmetry and the role of interactions remain unanswered. We measure superfluid stiffness as a function of temperature, supercurrent bias and carrier density across the entire superconducting dome in both the electron and hole doped sectors of twisted multilayer graphene samples. We provide interpretations for possible superconducting pairing symmetries and discuss the role of electronic correlations towards superconductivity.

## References

[1] Cao et al, Nature 556 (7699), 2018
[2] Hao et al, Science 371 (6534), 2021
[3] Park et al, Nature 590 (7845), 2021

## Figures

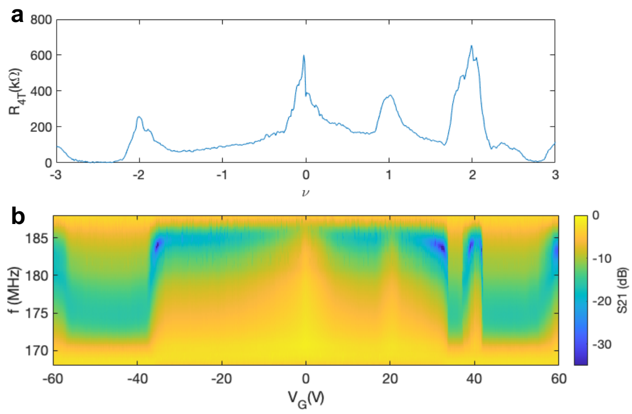

**Figure 1:** (a) Four-terminal resistance as a function of filling $\upsilon$ (b) Corresponding $S_{21}$ measurement of the resonator as a function of gate voltage $V_G$, where $\upsilon = V_G/20$. The resonator shows clear frequency shifts at the transitions into superconducting states at $\upsilon=-2$ *and* $\upsilon=2$.

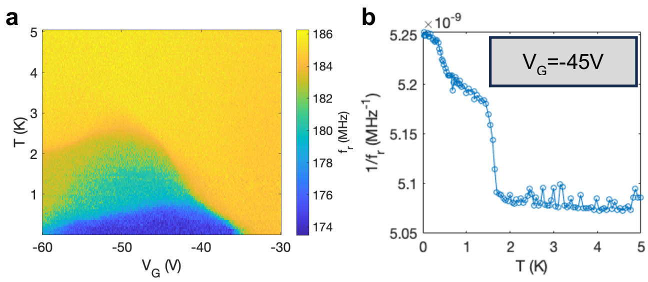


**Figure 2:** (a) Extracted resonator frequency $f_r$ within the "hole-like" superconducting dome as a function of $V_G$ and temperature T. (b) Inverse resonator frequency 1/fr as a function of temperature at $V_G$=-45 V ($\upsilon$=-2.25). *The inverse resonance frequency is proportional to superfluid stiffness.*