Direct measurement of the $\sin(2\phi)$ current phase relation in a graphene superconducting quantum interference device

Simon Messelot*†[1], Nicolas Aparicio[1], Elie De Seze[1], Eric Eyraud[1], Johann Coraux[1], Kenji Watanabe[2], Takashi Tanigushi[3], and Julien Renard[1]

[1]Institut Néel – Centre National de la Recherche Scientifique - CNRS, UGA, G-INP – Institut NEEL, 25 rue des Martyrs, BP 166,38042 Grenoble cedex 9, France

[2]National Institute for Materials Science – Namiki 1-1, Tsukuba, Ibaraki 305-0044, Japon

[3]International Center for Materials Nanoarchitectonics – 1-1 Namiki Tsukuba, Ibaraki 305-0044 JAPAN, Japon

Résumé

There is a rising interest in superconducting circuits for the use of Josephson junction (JJ) devices with current phase relations (CPR) that differ from the canonical $I(\phi) = Ic \sin(\phi)$. In particular $\sin(2\phi)$ elements find applications for instance in protected qubit architecture. In semiconductor based SNS junctions, higher order harmonics naturally exist due to the high transmission of Cooper pairs through the junction. Different junction materials have been investigated among which graphene, however, the CPR in these works remains dominated by the first $\sin(\phi)$ harmonic. We present a method to control and read simultaneously the CPR of a superconducting quantum interference device (SQUID) based on graphene Josephson junctions using a double SQUID structure. A small symmetric SQUID forms a tunable Josephson element (JE) that can be set in the symmetric regime using gate voltages. Tuning the magnetic flux in this SQUID allows us to control the various harmonics of its CPR. An additional loop including a third Josephson junction serves as reference arm for conventional DC biased CPR measurements, in which the magnetic flux controls the phase ϕ across the Josephson element. We measured the CPR in the different regimes of the Josephson element. We show that the $\sin(2\phi)$ harmonic can be dominant at $0.5\Phi0$ flux in the Josephson element. This direct visualization of $\sin(2\phi)$ oscillations of the CPR enables quantitative measurement of the second order harmonic amplitude: we can estimate here that the $\sin(2\phi)$ harmonic accounts for 90% of the total critical current. Finally, we discuss limitations of the conventional CPR measurement technique and we detail a method to reach a quantitative extraction of the relevant parameters.

*Intervenant

†Auteur correspondant: simon.messelot@neel.cnrs.fr