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Time-resolved studies of the superconducting order parameter in a BCS superconductor NbN

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Numerous femtosecond time-resolved studies of relaxation phenomena in high temperature superconductors have been performed over the last 20 years. Several competing theoretical models have been proposed, yet an overall consensus on the underlying relaxation processes is still lacking, largely due to the fact that also their ground state properties are still under debate. On the other hand, no systematic study of the dynamics in the conventional BCS superconductor existed. Here we present the first spectrally and time-resolved studies of the THz conductivity dynamics in a prototype BCS superconductor NbN. The excellent agreement of the equilibrium complex THz conductivity (0.2 - 4 THz) with the BCS theory, enabled us to apply this analysis also in the non-equilibrium state and to study the time evolution of the order parameter (superconducting gap, 2ΔNbN(4K) = 1.5 THz) as a function of temperature and excitation density over two orders of magnitude.

Unlike in high temperature superconductors [1], the absorbed energy density required to suppress superconductivity is found to match the superconducting condensation energy. The analysis of the excitation dependent Cooper-pair breaking rate with the phenomenological Rothwarf-Taylor model [2] enabled us to determine the microscopic quasiparticle recombination rate and the value of the electron-phonon coupling constant. Probably the most fascinating observation, however, is the apparent imbalance between the photoinduced reduction of the condensate density, and that of the superconducting gap, which is observed throughout the pair-breaking process (˜ 10 ps) and superconducting state recovery dynamics (˜ 100 ps), which is discussed in terms of the enhanced pairing strength in the non-equilibrium superconductor.

[1] P. Kusar, et al., Phys. Rev. Lett. 101, 227001 (2008); A. Pashkin, et al., Phys. Rev. Lett. 105, 067001 (2010).
[2] J. Demsar, et al., Phys. Rev. Lett. 91, 267002 (2003); V.V. Kabanov et al., Phys. Rev. Lett. 95, 147002 (2005).

Authors: DEMSAR, Jure (Universität Konstanz, FB Physik, D-78457 Konstanz); BECK, M.

Co-authors: GOLTSMAN, G.; SCHÄFER, H.; KLAMMER, M.; LANG, S.; KABANOV, V. V.

Presenter: DEMSAR, Jure (Universität Konstanz, FB Physik, D-78457 Konstanz)

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