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Electron-phonon interaction in nanostructures at sub-Kelvin temperatures

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We revisit the Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity by studying the effect of the asymmetry of the attraction band with respect to the chemical potential, on the physical properties of the superconductor. The attraction band is defined as the interval $\mathcal{B} = [\mu - \hbar\omega_c, \mu + \hbar\omega_c]$ in which the pairing interaction is manifested. Although in the standard BCS formalism μ —the center of the attraction band—is identified with the chemical potential, this represents only a convenient choice and not a physical constraint. Since the chemical potential and the attraction band may be influenced differently by the external conditions (e.g. pressure) or preparation methods (e.g. changing the mobility band by changing the chemical composition of the superconductor), it is natural to assume that μ is not identical to the chemical potential. Therefore, in our study we denote the chemical potential of the system by μ_R and we analyze the effect of the difference $\mu - \mu_R$ on the physical properties of the superconductor. We find that if $\mu \neq \mu_R$ the energy gap Δ and the temperature of the superconductor-normal metal phase transition T_{ph} change; the ratio $\Delta(T=0)/T_{ph}$ changes also with $\mu - \mu_R$ (see Fig. 1). More dramatically, when $\mu \neq \mu_R$ a population imbalance appears in equilibrium and the superconductor-normal metal phase transition becomes of the first order. If $\mu - \mu_R$ varies monotonically with pressure or doping, then a feature like the superconducting dome appears when the temperature of the phase transition is plotted vs. pressure or doping concentration.

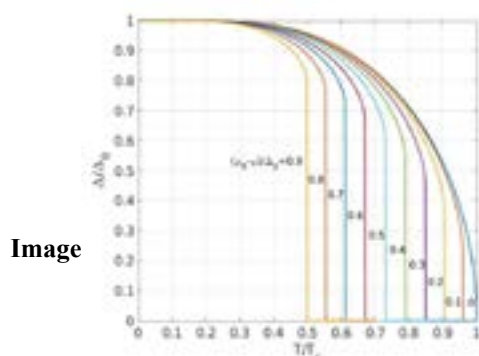


Fig. 1: The energy gap as a function of temperature, for different values of $\mu - \mu_R$. Δ_0 and T_c are the energy gap at zero temperature and the critical temperature in the standard BCS theory. The superconductor-normal metal phase transition occurs when Δ jumps to 0.

Biography

Dragos Victor Anghel is a Senior Scientist (1st grade) at Horia Hulubei National Institute of Physics and Nuclear Engineering in Romania. His research interests are theoretical condensed matter physics, mesoscopic physics, nanoscopic detectors and complex systems.

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