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Commensurate Resonances and the Increase of the Gap in Superconducting Films by Non-Superconducting Layers

Parallel plates immersed into a system have helped to understand fundamental concepts in Physics, such as the Casimir effect and the Fabry-Perot interferometer. Motivated by these phenomena, we consider films with a SISIS structure, where S and I represent superconducting and insulating layers, respectively. We find a novel kind of resonance promoted by the normal layers that play the role of parallel plates and yield spatially localized quantum states. Recently, strong localization has been shown to promote superconductivity, but here localization stems solely from commensurability. The gap is substantially enhanced when there is commensurability between the total film length and the distance between the insulating barriers. The superconducting gap between the normal layers is three to four times larger than that of the bulk. The outcome surpasses the well-known shape resonances proposed by Thompson-Blatt and later shown to explain the variation of the critical temperature as a function of superfluid density in the two-dimensional gas. To observe the commensurate resonances, quantum size effects must be present, transverse modes are standing waves perpendicular to the film. Our results are obtained from the BdG equations for Bi films, where quantum size effects are possible due to the abnormally large mean free path.

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