

Tailoring the quantization of vortex bound states in iron based superconductors

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The iron based superconductors have many unique properties, including for example, multiband and small Fermi energy, etc. These will exhibit some novel features in the vortex bound states. Due to the spatial confinement to the quasiparticles within a vortex, it was predicted in 1964 by Caroli, de Gennes and Matricon (CdGM) that the bound states with energies of $E = \mu\Delta^2 / E_F$ ($\mu = \pm 1/2, 3/2, 5/2, \dots$) should exist. These discrete energy levels have never been clearly observed. By doing STM measurements on $\text{FeTe}_{0.55}\text{Se}_{0.45}$, we observed the long sought discrete CdGM bound states [1] which roughly satisfies the theoretically predicted ratio 1:3:5. Furthermore evidence for the the discrete CdGM vortex bound states were also found in another IBS $\text{KCa}_2\text{Fe}_4\text{As}_4\text{F}_2$, now they deviate from the widely believed 1:3:5[2]. We interpret this deviation based on an exact solution to the BdG equations [3]. Recently, we observed a new-type necklace like vortex pattern in $\text{KCa}_2\text{Fe}_4\text{As}_4\text{F}_2$ [4], as shown In Figure 1. We attribute this novel vortex pattern as a consequence of the self-interference of the CdGM states with opposite angular momenta (with the help of impurity scattering). This peculiar vortex pattern can only happen in unconventional superconductors with small Fermi energy (corresponding to a moderate and large quasiparticle wave length) and suitable impurity scattering.

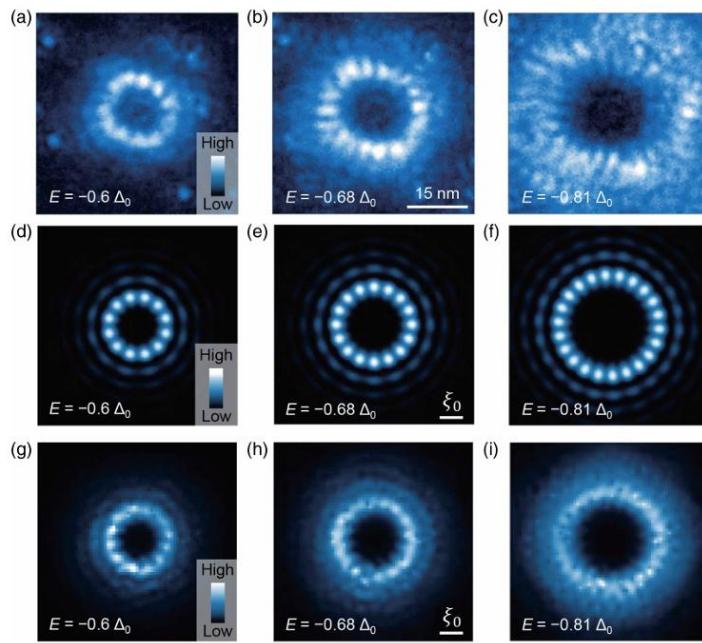


Figure 1. Isolated vortex core and calculation results by using the disorder-corrected CdGM states. (a)–(c) dI/dV mappings of a necklacelike vortex core measured at different energies ($\mu_0 H = 0.2$ T). (d)–(f) Calculated vortex pattern with two-level approximation. (g)–(i) Numerical calculation results by exact diagonalization of the disorder-corrected CdGM states.

References

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