Decay of Macrovortices in Superfluids: A Cavity-QED Perspective

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We investigate the decay dynamics of multiply-quantized vortices (MQVs) in two-dimensional trapped Bose–Einstein condensates, focusing on the interplay between Bogoliubov excitations of two kinds: Core and bulk phonon modes. By analyzing the Bogoliubov–de Gennes (BdG) spectrum, we identify unstable core modes and their coupling to phonon excitations, which together govern the splitting of an MQV into singly quantized vortices. We develop an effective theoretical framework that maps the vortex core excitation onto a quantum emitter coupled to a bosonic field, establishing a direct analogy with cavity quantum electrodynamics (QED). In this picture, the MQV behaves as an excited state, while Bogoliubov phonons play the role of quantized radiation modes. This mapping enables us to interpret vortex decay as an emission process, where the decay rate is controlled by the phonon density of states and can be strongly modified by system size and boundary conditions, in close analogy with Purcell-enhanced or suppressed emission in optical cavities.

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