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Towards real-time simulation of false vacuum decay in quantum field theory

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Tabletop experiments with ultracold atoms provide the opportunity to simulate non-perturbative phenomena in quantum field theory. In the proposed experiment, we consider two weakly coupled, one-dimensional Bose-Einstein condensates. The evolution of the population imbalance, in the mean field approximation, is described by a scalar field moving in an effective potential. We discuss in detail the rich nonlinear dynamics in this system for the Josephson and macroscopic quantum self-trapped regimes. We study the effect of quantum fluctuations through numerical simulations using the Truncated Wigner approximation. The primary and secondary instabilities consist in resonant excitations of characteristic modes with spinodal and parametric instabilities that cause bands of fluctuation modes to grow exponentially in time. We perform the analytical study of the excited modes and their respective growth rates and compare with the numerical results. The excitation of fluctuations acts as an effective dissipation term in the equation of motion of the condensate. This causes the damping of the imbalance oscillations and final thermalization of the system in the two regimes. Our study provides the basis for comparison with existing experimental measurements and suggestions for future experimental implementations.

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