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Interacting multiple zero mode formulation for a dark soliton in a Bose-Einstein condensate JUNICHI TAKAHASHI, YUSUKE NAKAMURA, YOSHIYA YAMANAKA, Waseda Univ. — The system of Bose-Einstein condensate (BEC) has a zero-mode (ZM) associated with the spontaneous breakdown of the global phase symmetry. However, to formulate the ZMs in quantum field theory for a finite-size system with spontaneous breakdown of symmetries is not trivial, for in the naive Bogoliubov theory one encounters difficulties such as phase diffusion, the absence of a definite criterion for determining the ground state, and infrared divergences. In order to remove this difficulty, we have recently proposed the new treatment of the ZM, which enable us to introduce a unique ground state in the ZM sector[1]. Using this ground state, we have evaluated the quantum fluctuation for the phase of condensate. In this presentation, we consider an atomic BEC system with a dark soliton that contains two ZMs corresponding to spontaneous breakdown of the global phase and translational symmetries. In our treatment, the original non-liner interaction of the field operator brings us the interaction between the two ZMs. We evaluate the standard deviations of the ZM operators and see how the mutual interaction between the two ZMs affects them.

[1]J. Takahashi, Y. Nakamura, and Y. Yamanaka, Phys. Rev. A **92**, 023627 (2015).

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