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Spontaneous symmetry breaking of photonic and matter waves in two-dimensional pseudopotentials

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We introduce the two-dimensional Gross-Pitaevskii/nonlinear-Schrodinger (GP/NLS) equation with the self-focusing nonlinearity confined to two identical circles, separated or overlapped. The model can be realized in terms of Bose-Einstein condensates (BECs) and photonic-crystal fibers. Following the recent analysis of the spontaneous symmetry breaking (SSB) of localized modes trapped in 1D and 2D double-well nonlinear potentials (also known as pseudopotentials), we aim to find 2D solitons in the two-circle setting, using numerical methods and the variational approximation (VA). Well-separated circles support stable symmetric and antisymmetric solitons. The decrease of separation L between the circles leads to destabilization of the solitons. The symmetric modes undergo two SSB transitions. First, they are transformed into weakly asymmetric breathers, which is followed by a transition to single-peak modes trapped in one circle. The antisymmetric solitons perform a direct transition to the single-peak mode. The symmetric solitons are described reasonably well by the VA. For touching (L=0) and overlapping (L<0) circles, single-peak solitons are found-asymmetric ones, trapped in either circle, and symmetric solitons centered at the midpoint of the bi-circle configuration. If the overlap is weak, the symmetric soliton is unstable. It may spontaneously leap into either circle and perform shuttle motion in it. A region of stability of the symmetric solitons appears with the increase of the overlap degree. In the case of a moderately strong overlap, another SSB effect is found, in the form of a pair of symmetry-breaking and restoring bifurcations which link families of the symmetric and asymmetric solitons.

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