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Few- and many-body photon bound states in quantum nonlinear media

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The emergence of multi-photon bound states is an intriguing phenomenon that can occur in quite different quantum nonlinear media, such as arrays of quantum emitters coupled to photonic waveguides and Rydberg atomic ensembles. To theoretical study these bound states within an unified framework we propose a spin-model formulation of quantum atom-light interactions. We solve the few- and many-body correlated dynamics of such states, investigating how their propagating properties within the media manifest themselves in the spatio-temporal correlations of the output field. For sufficiently large photon number we recover a classical soliton-like behavior that suggests that a quantum-to-classical transition from quantum bound states to classical solitons is a general property inherent to quantum nonlinear media.

Primary author(s) : CALAJO, Giuseppe (ICFO)

Presenter(s) : CALAJO, Giuseppe (ICFO)

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