Enriching quantum simulations in optical lattices by using weak measurements and quantized light

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While optical lattices are well-established systems for quantum simulations, the quantum nature of light is typically neglected in all setups so far. We show theoretically that the light quantization significantly broadens the range of phenomena, which can be simulated. First, this makes possible the study of quantum walks subject to continuous weak measurements [1, 2]. The resulting many-body states are very different, from what can be obtained in both closed systems (with unitary evolution) and open dissipative systems without measurement. We demonstrate multimode oscillations of macroscopic superposition states, nonlocal non-Hermitian Zeno dynamics, long-range correlated pair tunnelling, protection and break-up of fermion pairs [2], as well as generation of antiferro-magnetic states [3]. We show the generation of multipartite mode entanglement [4] in this system, and feedback control of many-body states [5]. Second, the quantization of optical lattice potentials corresponds to the system, where not only the tunnelling particles are quantum, but the potential barriers are quantum as well. It leads to new quantum phases [6, 7] (dimers, trimers, etc. of matter waves similar to valence bond solids) beyond density orders (e.g. supersolids and density waves) directly benefiting from the collective light-matter interaction.

Keywords: quantum weak measurements, many-body states, multipartite entanglement

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[1] W. Kozlowski, S. F. Caballero-Benitez, I. B. Mekhov, Scientific Rep. **7**, 42597 (2017).
[2] G. Mazzucchi, W. Kozlowski, S. F. Caballero-Benitez, T. J. Elliott, I. B. Mekhov, Phys. Rev. A **93**, 023632 (2016).
[3] G. Mazzucchi, S. F. Caballero-Benitez, I. B. Mekhov, Scientific Rep. **6**, 31196 (2016).
[4] T. J. Elliott, W. Kozlowski, S. F. Caballero-Benitez, I. B. Mekhov, Phys. Rev. Lett. **114**, 113604 (2015).
[5] G. Mazzucchi, S. F. Caballero-Benitez, D. A. Ivanov, I. B. Mekhov, Optica **3**, 1213 (2016).
[6] S. F. Caballero-Benitez, I. B. Mekhov, Phys. Rev. Lett. **115**, 243604 (2015).
[7] S. F. Caballero-Benitez, G. Mazzucchi, I. B. Mekhov, Phys. Rev. A **93**, 063632 (2016).

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