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Focus on Bose condensation phenomena in atomic and solid state physics

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Abstract. This editorial provides a short overview of the focus issue on Bose condensation phenomena in atomic and solid state physics sponsored by the POLATOM ESF Research Networking Programme.

Since the early days of quantum mechanics, the study of many-particle systems has unveiled a number of exciting unprecedented effects that stem from the quantum nature of their microscopic constituents. Traditional many-body systems whose physics has been successfully investigated through the years include liquid Helium, electrons in solid-state materials, protons and neutrons in nuclei, nuclear matter in stars, quark-gluon plasma in colliders and so on.

In the last few decades, two new systems have joined this party and have been the basis of remarkable experimental achievements: trapped gases of ultracold atoms [1] and fluids of coupled light and matter excitations [2]. On the one hand, the developments in the field of cold atoms have made it possible to create gases at temperatures well below quantum degeneracy and then manipulate these gases down to the single atom level, opening the way towards the realization of novel strongly-correlated states of matter [3] and new applications

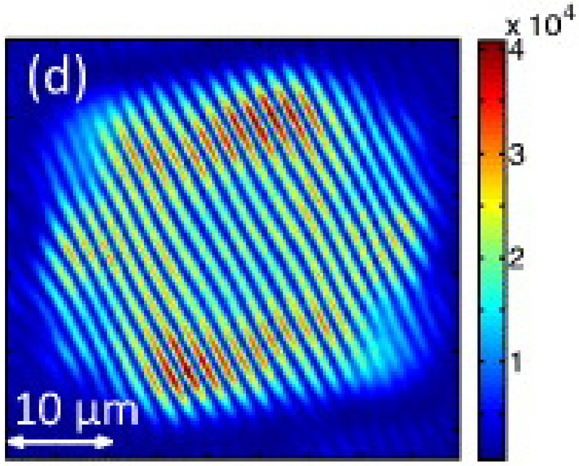

Figure 1. Interference pattern showing long-range order in a condensate of exciton–polaritons created by an optical parametric oscillator mechanism in a planar semiconductor microcavity. Panel reproduced from [11].

in future quantum devices and quantum simulations [4]. On the other hand, the general conceptual description of the quantum fluid of light [2] is being built up from the confluence of several, previously independent research directions on Bose–Einstein condensation (BEC) of excitons [5] and exciton–polaritons [6] in semiconductor systems and, more recently, photon condensation effects [7, 8], strongly interacting photons [9] and circuit quantum electrodynamics [10]. While sharing many ideas of traditional many-body physics, these systems introduce exciting new features in the arena, in particular a complex interplay of quantum statistics and inter-particle interactions with the driven-dissipative nature of the light–matter fluid.

Within the spirit of the POLATOM ESF Research Networking Programme that is sponsoring this focus issue, we aim to collect here a series of research papers that highlight the links and the scientific synergies between these fields. There are contributions on very different systems, from dilute and strongly-correlated ultracold atomic Bose and Fermi gases, to exciton–polariton gases in semiconductor microcavities (figure 1), to nonlinear optics in fibres and in bulk crystals, to circuit quantum electrodynamics in superconducting solid-state devices. But just a quick look at the titles shows how the same themes are simultaneously developed in very different contexts, e.g. solitons in atomic and polariton gases, optical lattices for atoms and acoustic and lithographically-patterned lattices for polaritons, spin dynamics in atomic, photonic and polaritonic gases, the many different regimes of spontaneous coherence from photon BEC to polariton lasing, as well as the rich non-equilibrium physics of dissipative atomic and photonic systems.

We hope that these papers will provide the interested reader with a timely survey of the ‘common perspectives for cold atoms, semiconductor polaritons and nanoscience’ that are at the heart of the POLATOM ESF Network. We hope too that this issue will stimulate further interactions among different fields of the physical sciences that share in the excitement of novel aspects of fluids of interacting quantum particles, and in the development of applications of this field in fundamental and applied science.

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