Spontaneous nonlinear polariton patterns in a semiconductor microcavity

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Nonlinear patterns occur in a diverse range of nonlinear extended media, with examples including self-organization of cells in biology[1,2], self-assembly of molecules in chemistry[3] as well as nonlinear crystals and microresonators[4]. Solitons were investigated in atomic condensates and nonlinear optical fibers[5]. Due to giant optical nonlinearity and peculiar spin-dependent polariton-polariton interactions microcavity polariton platform enables a rich variety of nonlinear patterns and solitons to be explored. Current progress includes the observation of polariton hexagons[6] in a double cavity, and theoretical studies have demonstrated the possibility of roll, labyrinthine and honeycomb patterns[7]. A family of dissipative and conservative bright polariton solitons were also reported in microcavity and slab waveguides, respectively[8].

In this work we first demonstrate the formation and control of transverse spatial polygon patterns generated by modulation instability (MI) in a semiconductor microcavity polariton fluid under coherent driving by a blue-detuned pump. Pentagons, hexagons, heptagons and octagons, not reported before, are observed. We also investigate the statistical properties of the microcavity emission, simultaneously performing quantum noise and $g^{(2)}$ measurements. At threshold a sharp increase of signal noise is observed, accompanied by strong photon bunching as revealed by sharp jump of $g^{(2)}(0)$ values from 1 to 2. The chaotic light arises from the interplay between both pump bistability and modulation instability associated with pattern formation.

In the second experiment, we explore propagating nonlinear wavepackets in high quality semiconductor 1D microcavity wires. With increasing excitation power polariton wavepacket exhibits self-focusing indicating formation of a single soliton, followed by evolution into a set polariton bullets propagating with different velocity, which are generated by MI at higher powers. Polariton emission probably associated with Cerenkov coupling of solitons with dispersive waves is also observed. Interesting, that in the high density regime the nonlinear wavepackets are characterized by fast spatial oscillations of the circular and linear polarisation degree. The effect arises from the interplay between spin-dependent polariton-polariton interactions and the effective magnetic field due to photonic TE-TM splitting leading to quenching of Josephson oscillations between circularly polarized modes (self-trapping) and establishment of polarisation domains.

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