SUPPLEMENTAL MATERIAL

Spontaneous pattern formation in a polariton condensate

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Tomographic reconstruction of the real-space condensate density

In order to verify that the spontaneous pattern formation occurs in a single-energy state and that it constitutes the only significant contribution to the spectrally integrated PL, for pump powers close to condensation threshold, we performed a tomographic reconstruction of the polariton density with energy resolution. The procedure consists in collecting the PL signal of the main arm and focusing it onto the slits of the spectrometer (oriented in the y direction of Fig. S1) in order to reproduce the real-space polariton density on them. By scanning the position of the focusing lens (along the x direction of Fig. S1), different real-space slices enter the slits of the spectrometer, allowing to retrieve the energy information for each real-space slice. The results obtained, for a pump power of 250 μW, are summarized in Fig. S1. In Fig. S1a we show the spectrally integrated real-space image, obtained by summing over all the energy range acquired. In Fig. S1b, instead, we selected only the real-space emission at the energy of the patterned condensate. It can be seen, by comparing the two figures and also referring to the spectrally integrated CCD image of Fig. 1b, that the spontaneous 12-lobe pattern really appears in a single-energy condensed state. An additional direct proof of the single-energy condensed state is the coherence between all the lobes of the pattern evidenced from the interference fringes that appear all over the PL signal, when overlapping it with a magnified version of one of its lobes. The fact that the main contribution to the PL signal comes from a single state, allows us to perform the phase extraction from a spectrally integrated interferogram, like the one shown in Fig. 1d.

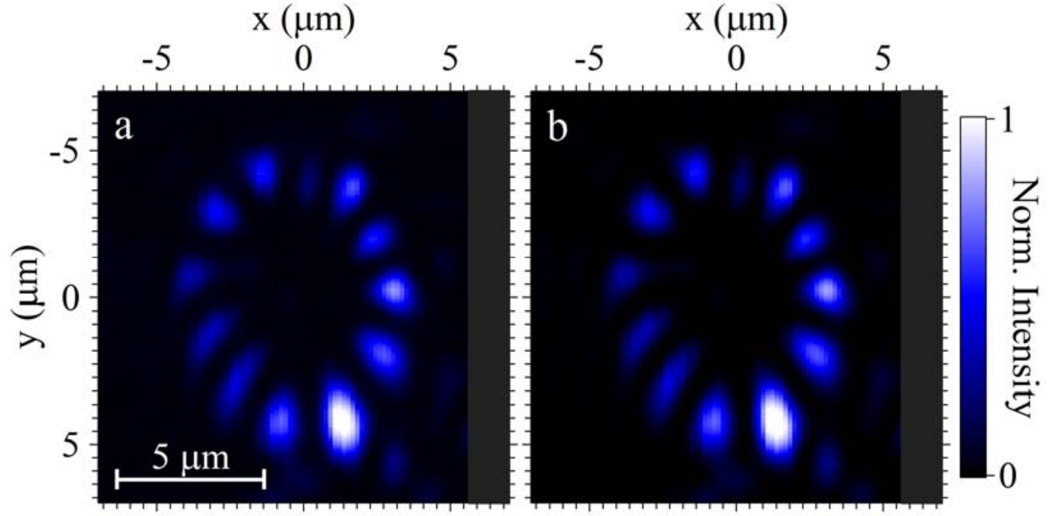

FIG. S1: (a) Spectrally integrated polariton density. (b) Spectrally resolved polariton density at the energy of the condensate (~1.675meV). Both images are acquired above condensation threshold, for a pump power of 250 μW. There is an evident matching between the two images. Note: the grey shaded region has been added to the graphs to keep the same axis formatting as in Fig. 2 and it corresponds to missing data, anyway outside the region of interest.

Optical excitation profile used in the simulations

In order to reproduce the experimental findings, in our simulations we make use of the ring-shaped pump shown in Fig. S2. The ellipticity, defined as the ratio of the short axis over the long axis, is chosen in agreement with the experimental value to be approximately ε = 0.9.

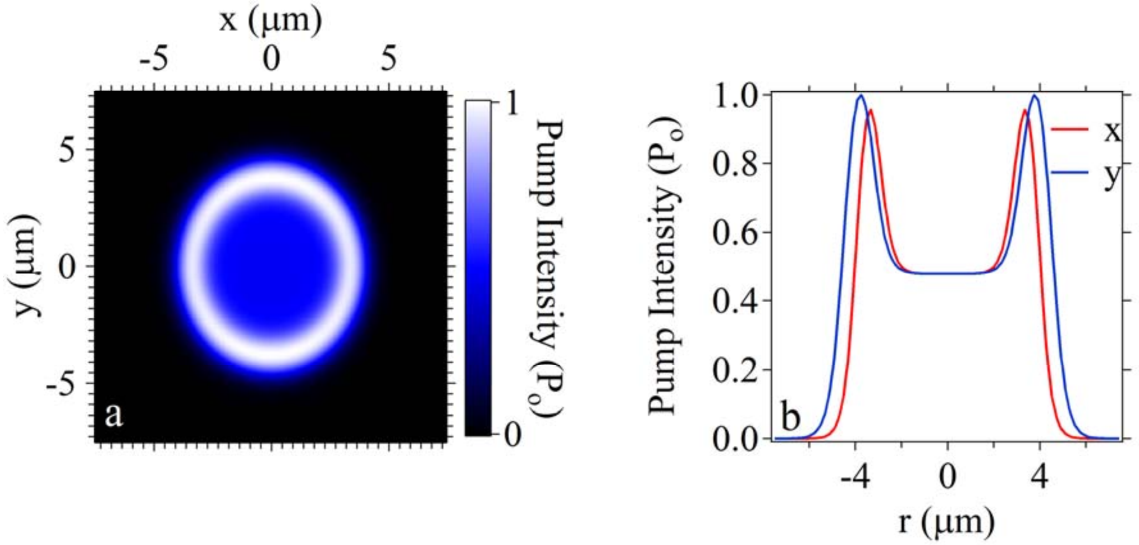

FIG. S2: a) Pump intensity real-space map. b) Profiles of the pump intensity along x and y axes.

Further details on the simulation parameters

The parameters used in our simulation have been established by experimental measurements and in previous publications. We have previously measured the dispersion of the lower polariton branch on this sample, using a photoluminescence experiment, from which we estimate the effective mass (m_C) and the Rabi splitting ($2V$). The condensed polariton lifetime (γ_C), the reservoir lifetime (γ_R) and the condensation rate (R_R) were already estimated in reference[1]. The polariton-polariton interaction (g) was chosen in agreement with Shelykh et al.[2]. The remaining parameters g_R and G are phenomenological parameters[3, 4] chosen to reproduce a condensate blueshift of around 1 meV, which we have measured experimentally.

Specifically about the relaxation rate of the reservoir, in Ref.[4] it was explained that the relaxation rate γ_R can be significantly larger than γ_C. This is also necessary to obtain realistic results from the theoretical model. For small reservoir relaxation rates, all excitons in the reservoir quickly scatter into the polariton condensate and this can generate oscillatory dynamics between the reservoir and the polariton condensate. This is unrealistic. It is understood that the representation of the many exciton states by a single reservoir is a simplification of the physics of the system. It can also be noted that among the hot excitons in the system, one can distinguish between an active reservoir of excitons that can directly scatter into condensed polaritons and an inactive reservoir of those that cannot[5] (energy momentum conservation laws must be fulfilled for scattering to take place). This prevents complete depletion of the active reservoir, which is continuously fed by the inactive reservoir. While in experiments involving pulsed excitation it is important to account for these two reservoirs to obtain the correct dynamics[5, 6], in continuous wave experiments it is accepted that the use of a single reservoir with a large decay rate fully captures the important physics[4, 7].

References for the supplemental material

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