# Effects of disorder on the polariton condensates in CdTe microcavities

D. Sanvitto[1], A. Amo[1], D. Ballarini[1], M. D. Martin[1], L. Viña[1], D. Solnyshkov[2], G. Malpuech[2] and R. André[3]

[1]*Semicuam. Dep. Física de Materiales, Univ. Autonóma de Madrid, 28049 Madrid, Spain*
[2]*LASMEA, CNRS, Universite Blaise-Pascal Clermont Ferrand II, 63177, Aubiere, France*
[3]*CEA-CNRS. Institut NEEL-CNRS, BP166 .38042 Grenoble Cedex 9, FRANCE*

We reveal the effects of microscopic inhomogeneities and the finite laser spot size on the formation dynamics of polariton condensates in CdTe based microcavities. By studying the temporal evolution of polariton photoluminescence (PL), after non-resonant pulsed excitation, both in the far- and near-field, we are able to trace the dynamics of different states along the polariton dispersion and to image their spatial profiles. At high pump power, the spatial distribution of the polariton condensate changes depending on the size of the excitation spot. For small laser spot the emission appears localized in real-space and very flat in k-space. Using a bigger excitation spot the PL reveals the existence of different emission lines very close in energy and showing independent spatial configuration. This suggests a transition to an Anderson glass phase due to the coupling of the states in different potential wells.

**Keywords:** polariton, semiconductor microcavity, condensation
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## INTRODUCTION

Bose Einstein condensates (BEC) are states of bosonic particles characterized by the macroscopic occupation of their ground state below a critical temperature with the appearance of a spontaneous formation of long range coherence. Polaritons, a state of matter mixed with light that arises from the strong coupling between photons and electrons in semiconductor microcavities, have recently shown non-equilibrium phase transition associated with a spontaneous build up of coherence in the ground state [1], in a very similar manner to what observed in atomic BEC. In semiconductor microcavities it has been predicted [2] that the local disorder, due to natural in-plane fluctuations of the photonic mode energy, gives rise to localisation of the polariton condensate in real space. However, depending on the excitation spot size, the transition to an Andersen glass can also be observed.

## EXPERIMENTAL DETAILS

We have studied a $Cd_{0.4}Mg_{0.6}Te$ two-wavelength-microcavity [3] with a Rabi splitting of 26 meV, and slightly negative detuning (~5 meV) between the quantum well excitons and the electromagnetic mode of the cavity. The PL measurements are performed at 5 K with the sample excited by 2 ps-long pulses from a Ti:Sapphire laser strongly detuned, at higher energies, from the polariton emission. Spectrally resolved images of the near- or the far-field of the microcavity are collected either through a CCD or a streak camera, allowing for time-integrated (two-dimensional) or resolved (one-dimensional) images.

## RESULTS AND DISCUSSION

Thanks to our combination of spectral-, spatial-, momentum- and temporal-resolution, we are able to follow the dynamics of the formation of the condensed states, including the temporal evolution of the energy-shift, due to polariton interactions, and the mode competition due to localization. Figure 1a shows the spatial extent of the polariton emission from the sample surface when a laser spot of 100 $\mu m^2$ is used to excite at high energies carriers in the CdTe microcavity. PL shows emission from a spatial localized point not bigger than 25 $\mu m^2$ contoured by a dimmer symmetrical ring. The latter

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is a signature of coherent emission due to slight misfocused detection. The strong localization of the polariton condensate is confirmed by our dispersion relation. Indeed the image of Fig 1b shows the dispersion of the condensed polariton ground state (corresponding to Fig. 1a) strongly occupied with a narrow linewidth (~01 meV) only limited by our spectrometer resolution. As can be seen the polariton dispersion is flat in momentum space, and narrow in energy, confirming condensation in a spatial trap.

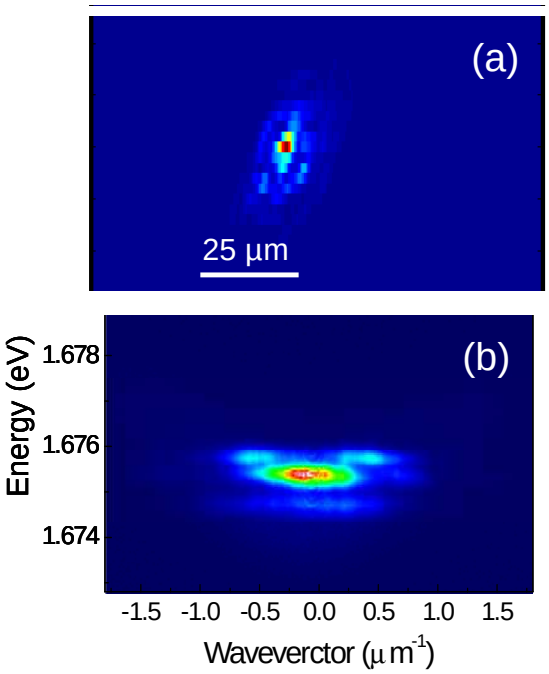


**FIGURE 1.** False color map of (a) X and Y spatial image of the polariton ground state emission under high pump excitation. The polaritonstate is characterized by fringes showing coherent emission and is observed to be very localized in real space (less than 25 $\mu m^2$). (b) Energy vs k-vector of the polariton photoluminescence under same condition as (a), showing a narrow line emission and a flat dispersion.

A different behaviour is observed when the spot size is multiplied by 10 times. In this case the emission is blurred in energy, (data not shown), due to the effect of the blue shift which is changing during the course of the pulsed experiment. For this reason a time resolved map of the states is necessary to get insight onto the nature of the polariton emission, allowing the observation of different lines separated in energy. Time resolved snapshots of the first 2 different energy lines are plotted in Fig. 2. In this case the scenario is strongly modified compared to the one in Fig. 1. Polaritons are now distributed in a wider spatial region filling all of the excitation spot. In spite of being localized in confining potentials of small dimensions the emission is quite homogeneous in all of the area [4]. This observation suggests that at high excitation powers and large excitation spots the condensate undergoes an Anderson-type transition to a glass phase. This is sustained by the fact that for each energy line, the emission shows a different spatial configuration, depending on the energy coupling amongst the localized states.

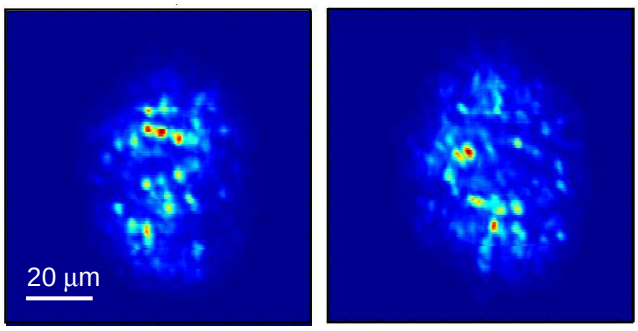


**FIGURE 2.** False color map of the first two energy lines observed under time- and spatially-resolved detection after a pulse of 2 ps has arrived. The power is higher than the threshold needed for condensation and the excitation spot is $2.5x10^3$ $\mu m^2$. It is possible to observe that each emission line is characterized by different spatial extensions showing that condensation is achieved in a wide area and not only in local potential traps.

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