Quasi-long-range spatial coherence in an exciton-polariton condensate

W. H. Nitsche[1,*], N. Y. Kim[1], G. Roumpos[1], S. Höfling[2], A. Forchel[2], Y. Yamamoto[1,3]

1) E. L. Ginzton Laboratory, Stanford University, Stanford, CA, U.S.A.
2) Technische Physik, Universität Würzburg, Würzburg, Germany
3) National Institute of Informatics, Tokyo, Japan

* nitsche@stanford.edu   http://www.stanford.edu/~nitsche/

Abstract: We measured the first-order spatial correlation function of a Bose-Einstein condensate of exciton-polaritons in a semiconductor microcavity. It behaves as the Berezinskii-Kosterlitz-Thouless theory predicts and decays with a power-law.

Bose-Einstein condensation (BEC) is accompanied by superfluid behavior and spatial coherence. It has been observed with atomic gases [1-2] and exciton-polaritons [3-4]. True long-range order cannot exist in two-dimensional condensates [5-6], however in finite-sized systems, quasi-long-range order is possible at sufficiently high superfluid densities. If the superfluid density drops below a critical value, two-dimensional condensates are predicted to undergo the Berezinskii-Kosterlitz-Thouless (BKT) transition [7-8], which results in the creation of free vortices, destroying the spatial coherence. This transition has been demonstrated in superfluid liquid helium [9] and superconducting films [10-11].

Our recent measurements [12] also show that the first-order spatial coherence function $g^{(1)}$ of an exciton-polariton condensate confirms the predictions of the BKT theory. We create an exciton-polariton condensate in a semiconductor sample (at 5 K) which consists of quantum wells embedded in a micro-cavity between two Bragg mirrors. An interference setup (as shown in figure 1a) is used to measure $g^{(1)}$ of the condensate.

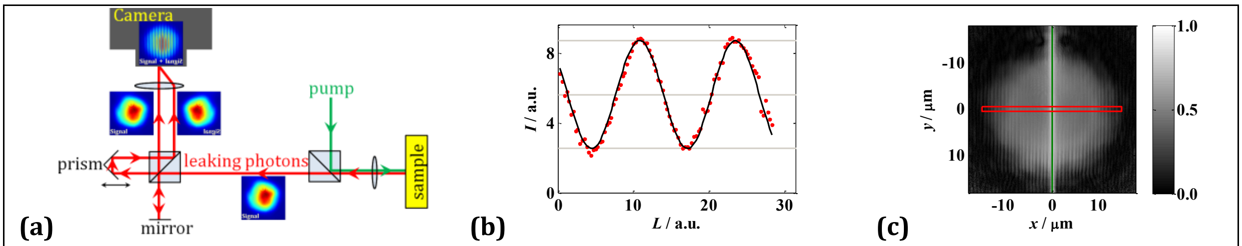

Figure 1: Experimental Michelson interference setup [13] to measure the fringe visibility (a). The intensity of each pixel behaves like a sine function if plotted as a function of the path length change L or prism position (b). By performing the sine fit for each pixel (b), we get the two-dimensional visibility plot (c). The region marked by a red rectangular has been used to extract the data shown in figure 2a.

We observe that it decays like a power-law of the form $g^{(1)}(x, -x) \propto |x|^{-a_p}$) where the exponent a_p is approximately $^1/_4$ at threshold, as predicted by the BKT theory. We also confirm that, as predicted by calculations which explain the power-law decay through the thermal excitation of phononic phase fluctuations [14], the measured a_P is nearly the same as $1/(n_s \lambda_T^2)$ where n_s is the superfluid density and λ_T the thermal wavelength.

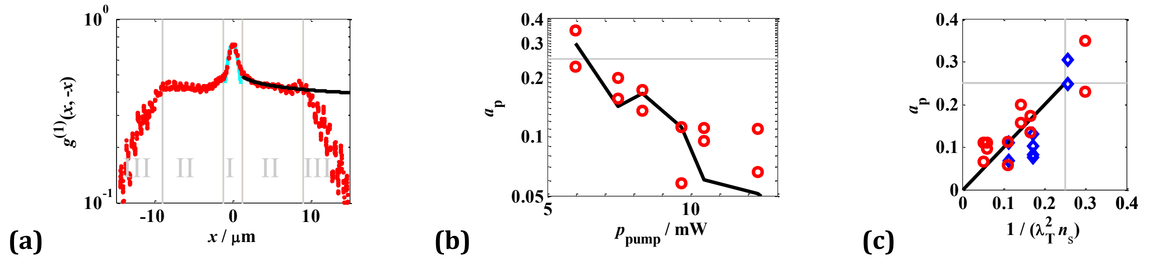

Figure 2: (a) Measured spatial coherence function (red dots) at a pump-power above condensation threshold. In region I for small distances, $g^{(1)}$ decays like a Gaussian (cyan fit), similar to the case of a thermal distribution. In region II for larger distances, $g^{(1)}$ behaves like a power-law; the black line shows a fit with $a_P \simeq 0.08$. For very large distances (region III), a much faster decay is observed which we attribute to a decrease of the condensation fraction towards the edge of the condensate. (b) The measured exponents a_P (red circles) are approximately $^1/_4$ at condensation threshold, and less at higher pump powers. The black line shows our calculated result for $1/(n_s \lambda_T^2)$ and as expected, it matches the measured data points. (c) The measured exponents as a function of $1/(n_s \lambda_T^2)$. Most data points are in the vicinity of the predicted black line $a_P = 1/(n_s \lambda_T^2)$. Red circles have been measured at a detuning of -1 meV (same detuning as for a & b) and blue diamonds at +4 meV.

We believe that this is the first observation of the BKT mechanism with exciton-polaritons. Applications might include the distinction of exiton-polariton condensation from VCSEL lasing in similar samples, since the BKT mechanism only applies in the first case.

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