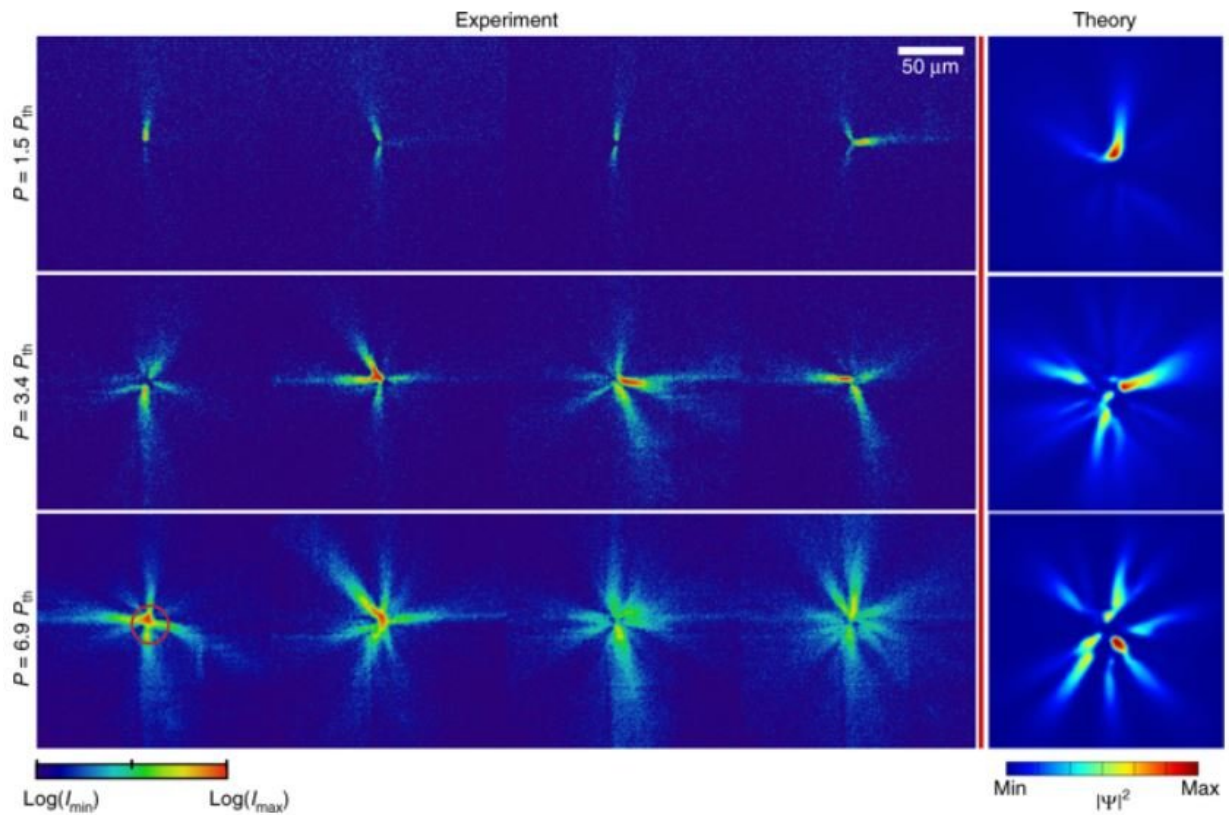


# First snapshot of exciton-polariton condensation process

December 18 2018



Single-shot condensation of polaritons. Photoluminescence (indicating polariton density) above condensation threshold. Theory at RHS shows remarkable agreement with experiment. Credit: FLEET

An ANU advance provides never-before-achieved 'snapshot' of Bose-

Einstein condensation.

Previously, observations of exciton-polaritons in a Bose-Einstein condensate were limited to statistical averaging over millions of [condensation](#) events.

'Snapshot' imaging of polaritons forming a condensate in a typical inorganic semiconductor was considered impossible.

Now, FLEET researchers at the Australian National University have led an international study imaging exciton-polaritons for the first time as a 'single shot', rather than averaging.

"This offers a unique opportunity to understand the details of Bose-Einstein condensation of exciton-polaritons," explains lead author Eliezer Estrecho.

Such fundamental advances also aid FLEET's research on excitonic condensation and superfluidity as a mechanism for electronic conduction without wasted dissipation of energy.

Exciton–polaritons are hybrid particles that are part-matter and part-light, bound together by strong coupling of photons and [electron-hole pairs](#) (excitons) within semiconductor microcavities, where they can form a Bose-Einstein condensate.

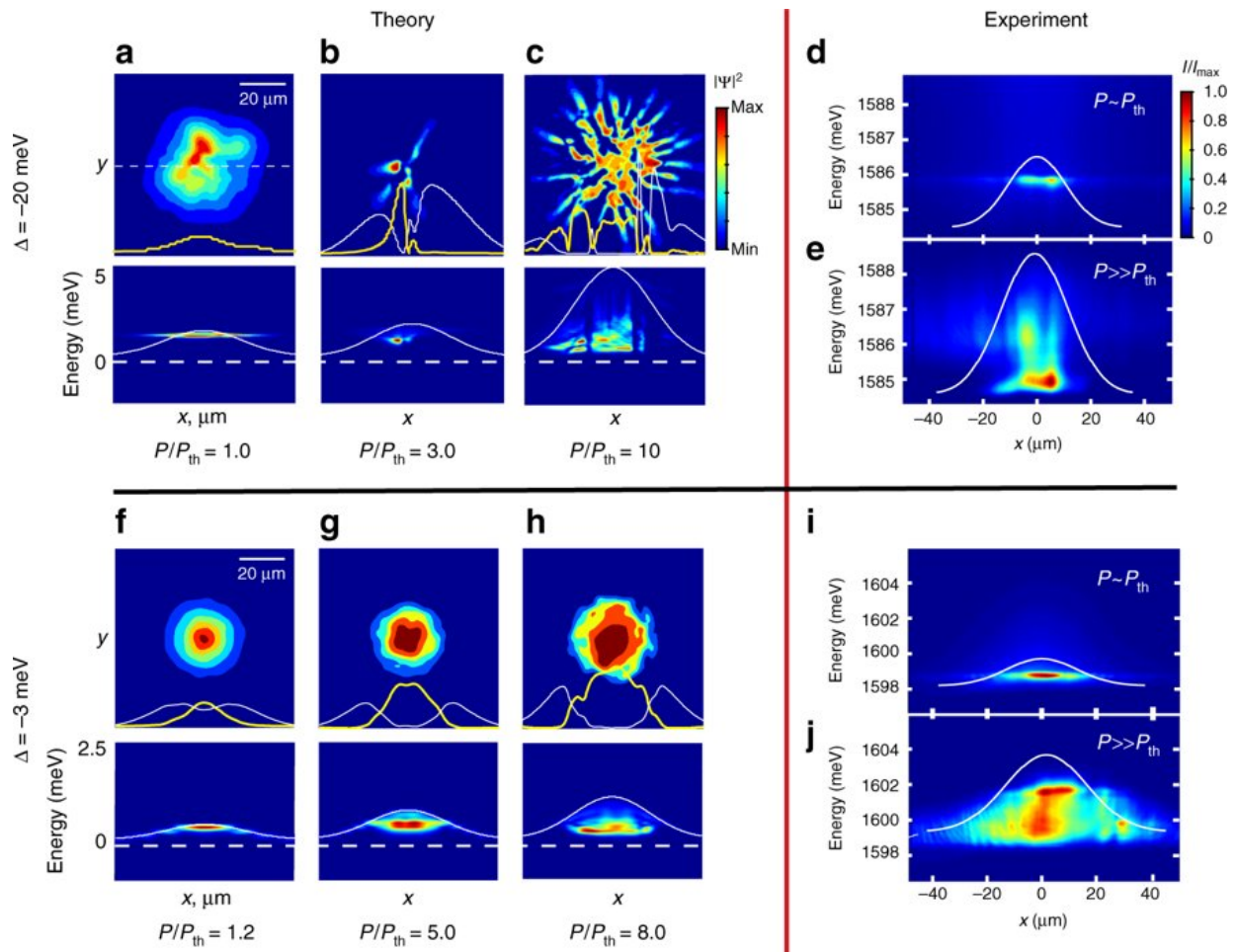
A Bose-Einstein condensate (BEC) is a quantum state of matter in which all particles have the same energy and wavelength, meaning that quantum effects can be seen on a macroscopic scale. A BEC can form a superfluid, i.e. flow without resistance.

However because exciton-polariton lifetime is measured in picoseconds (trillionths of a second), observations of BECs have previously always

included averaging over million lifetimes of exciton-polaritons.

This is like taking a long exposure of moving objects—you get a blurred image.

The ANU team made sure that their sensitive camera captures only one lifetime or 'single-shot' of the condensate, enabling them to observe never-before-seen behaviour of exciton-polaritons.



Theoretical results and spatially resolved energy measurements. Credit: FLEET

## The study

The single-shot imaging is performed by analysing coherent cavity photoluminescence due to the decay of exciton-polaritons. "Before now," says Associate Prof. Elena Ostrovskaya, "this was thought to be impossible in inorganic microcavities, because emissions simply weren't bright enough."

The density of exciton-polaritons trapped in inorganic microcavities is too low to be detected in single-shot mode partly because the exciton-polariton doesn't live long enough for the density to build up.

To get a better signal, the team used ultra-high quality samples designed and made by their collaborators in the USA, extending the lifetime of polaritons by an order of magnitude and pushing the density high enough for the sensitive camera to detect.

The imaging revealed that contrary to the smooth condensate observed in averaged experiments, the condensate actually forms filaments (see image below) whose orientation varies from shot-to-shot.

This filamentation is a result of polariton interaction with an incoherent reservoir, and is an intrinsic property of non-equilibrium condensation.

This feature is especially pronounced for exciton-polaritons with photon-like character and is less evident for exciton-polaritons with exciton-like behaviour, which are closer to equilibrium.

The study found remarkable agreement between experiment and numerical simulations, validating the background theory of exciton-polariton condensate dynamics.

The work paves the way for further fundamental studies of quantum

phase transitions and non-equilibrium condensation in solid-state systems.

The single-shot experiments could prove critical for our understanding of the fundamental (and still debated) nature of the condensed phase in these systems.

The study, "Single-shot condensation of exciton polaritons and the hole burning effect," was published in *Nature Communications* in August 2018.

**More information:** E. Estrecho et al. Single-shot condensation of exciton polaritons and the hole burning effect, *Nature Communications* (2018). [DOI: 10.1038/s41467-018-05349-4](https://doi.org/10.1038/s41467-018-05349-4)

Provided by FLEET

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