Modified Bose-Einstein condensation in an optical quantum gas

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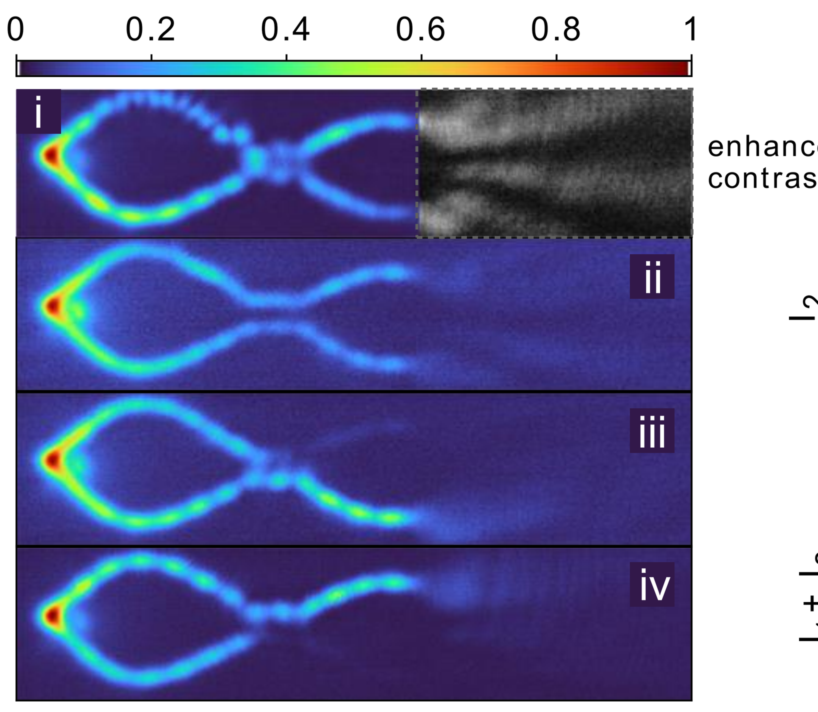
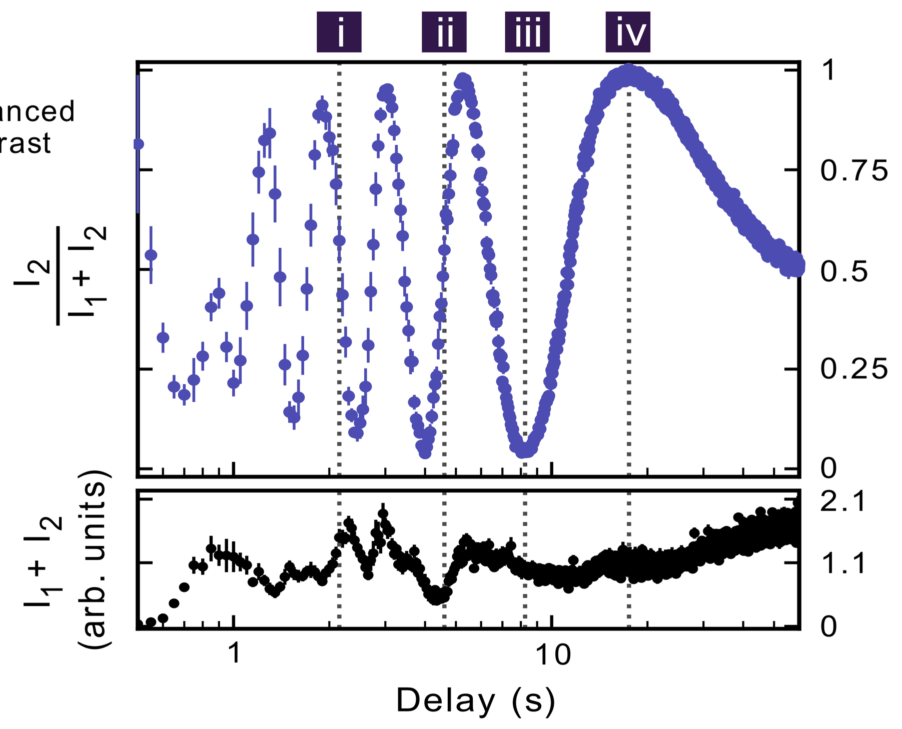
Introduction

Here, we investigate the Bose-Einstein condensation of a photonic Bose gas in an environment with controlled dissipation and feedback. Our measurements offer a highly systematic picture of Bose-Einstein condensation under non-equilibrium conditions. We show that by adjusting their frequency, Bose-Einstein condensates naturally try to avoid particle loss and destructive interference in their environment [1].

Open Mach-Zehnder measurements

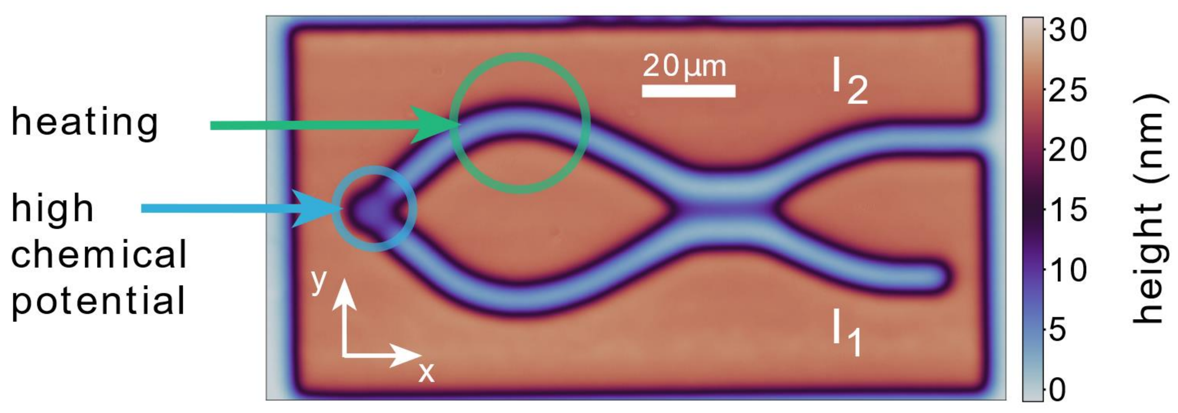


Normalized photon intensity for 4 different time delays (i-iv) between heating and optical pumping (high chemical potential).

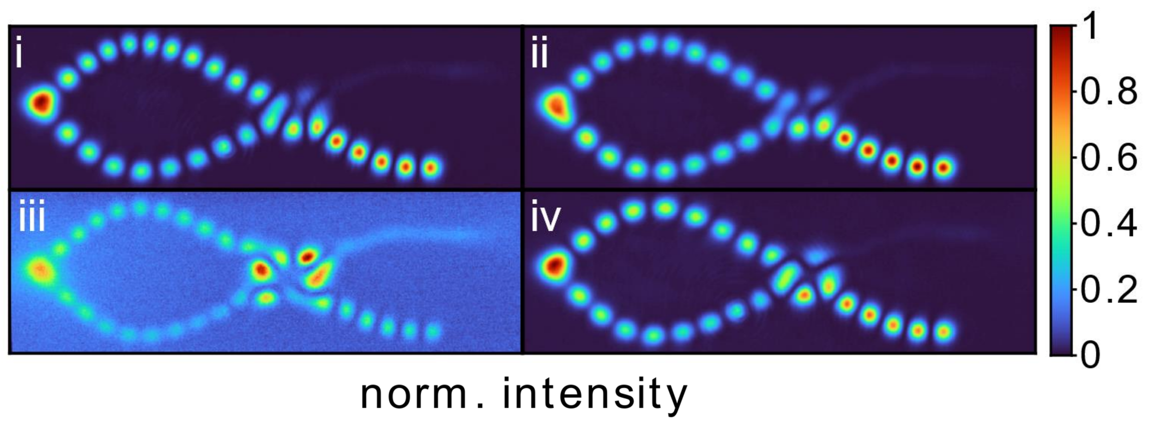


Normalized switching function (upper graph) and total intensity (lower graph).
Switching between constructive and destructive interference is observed.
Note the sinusoidal switching function.

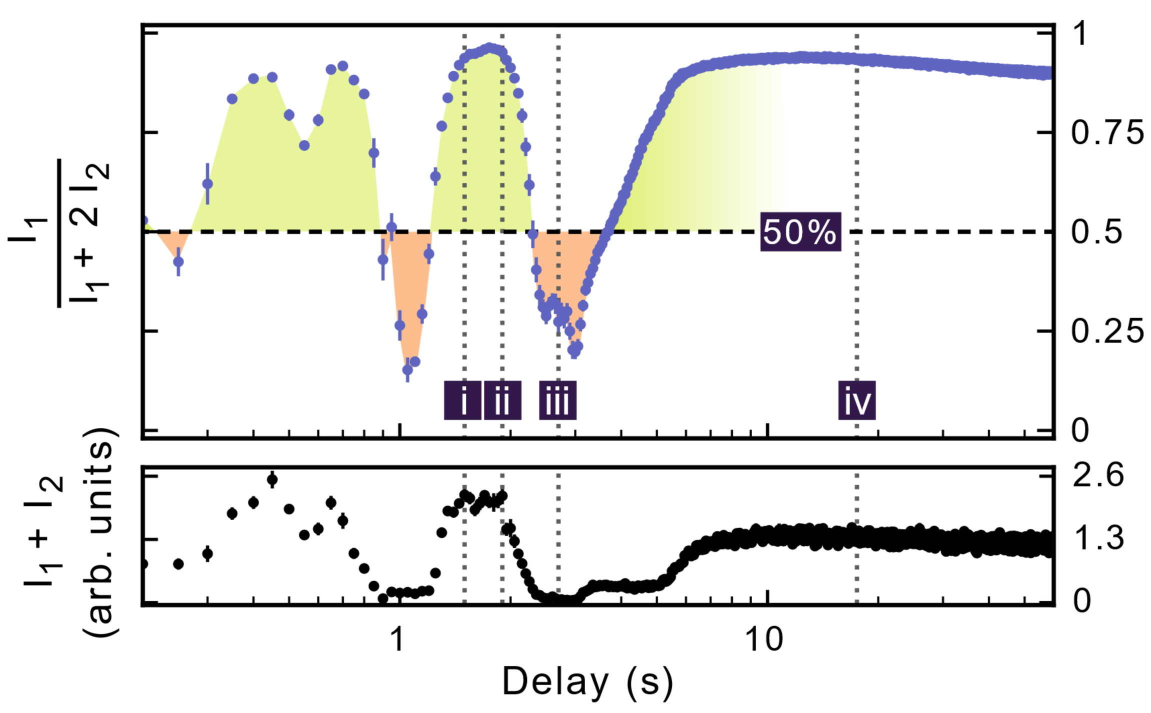
Semi-open Mach-Zehnder



Mach-Zehnder interferometer with lower output (I_1) closed.

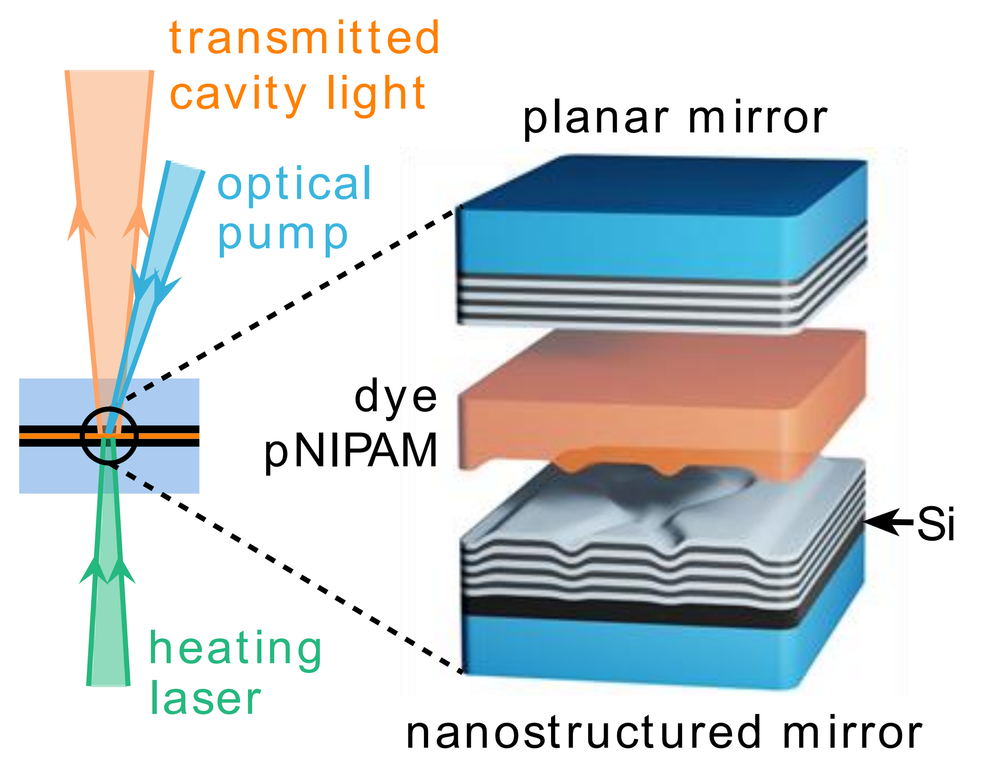


Standing wave pattern created by back reflection in the lower (closed) arm.



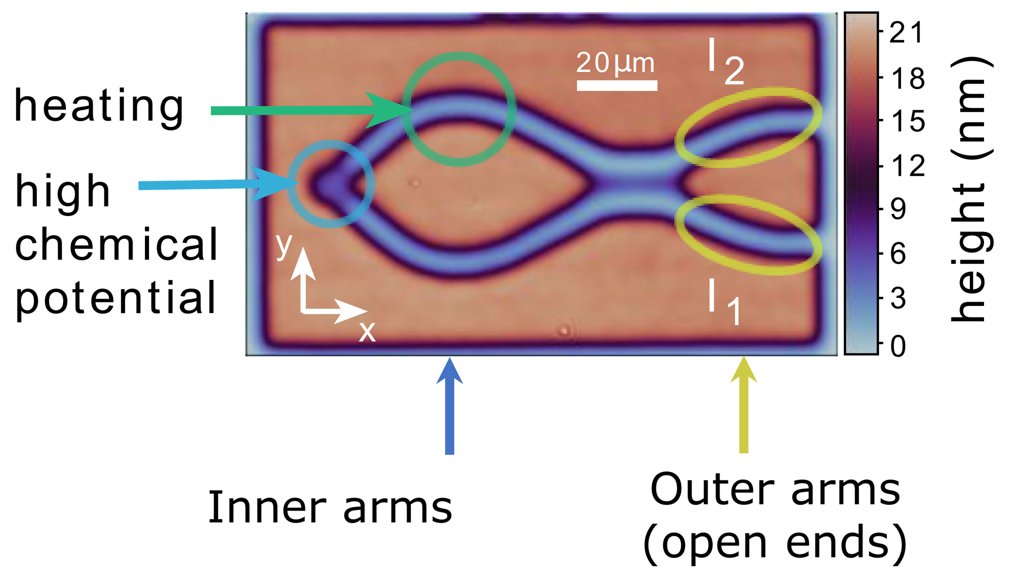
We notice a clear imbalance between the intensities in favour of the intensity in the lower (closed) arm, I_1.

Experimental setup



The optical pump creates a high chemical potential; photons condensate [2].

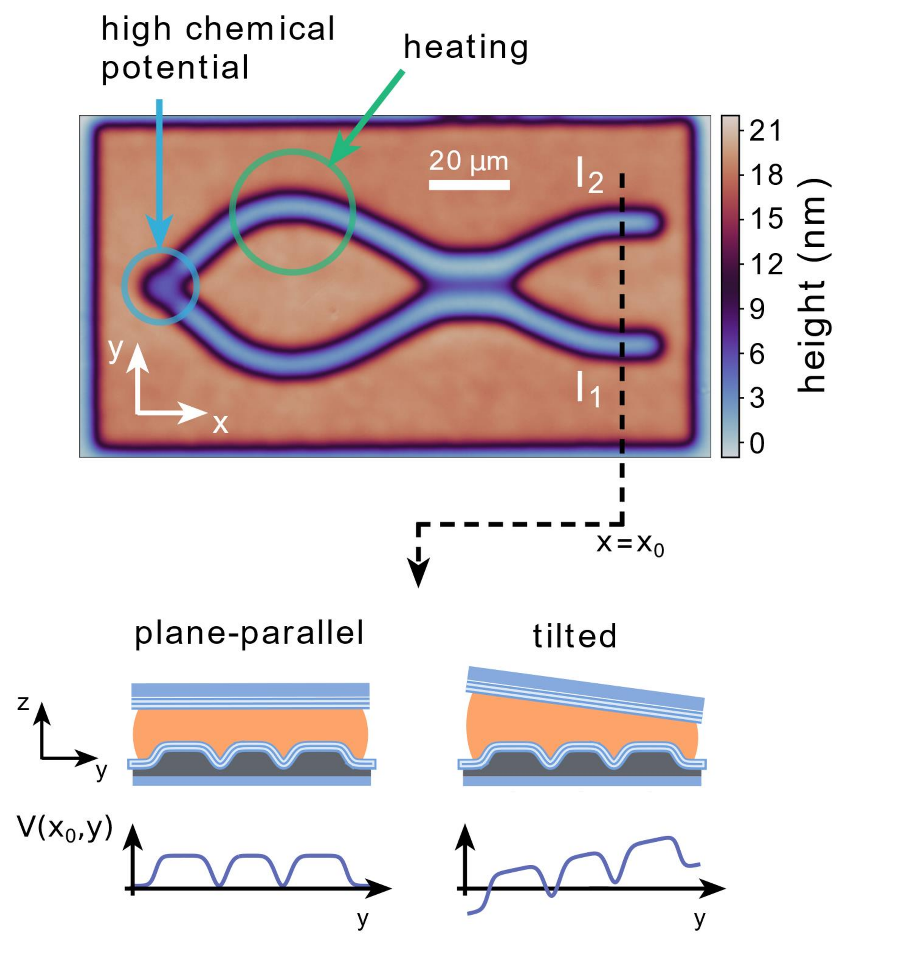
The heating laser is used to change the refractive index of the dye, hence changing the potential landscape.

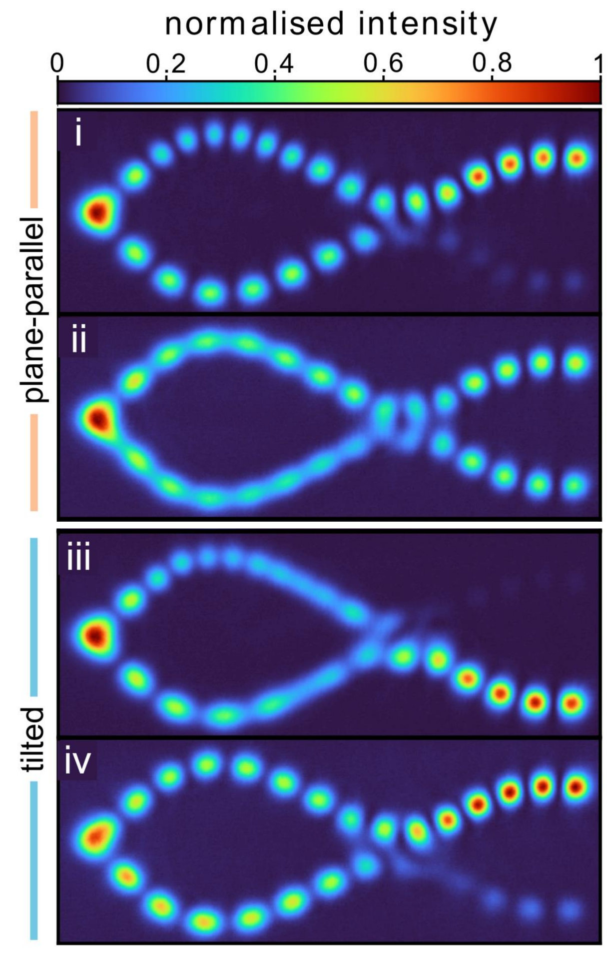


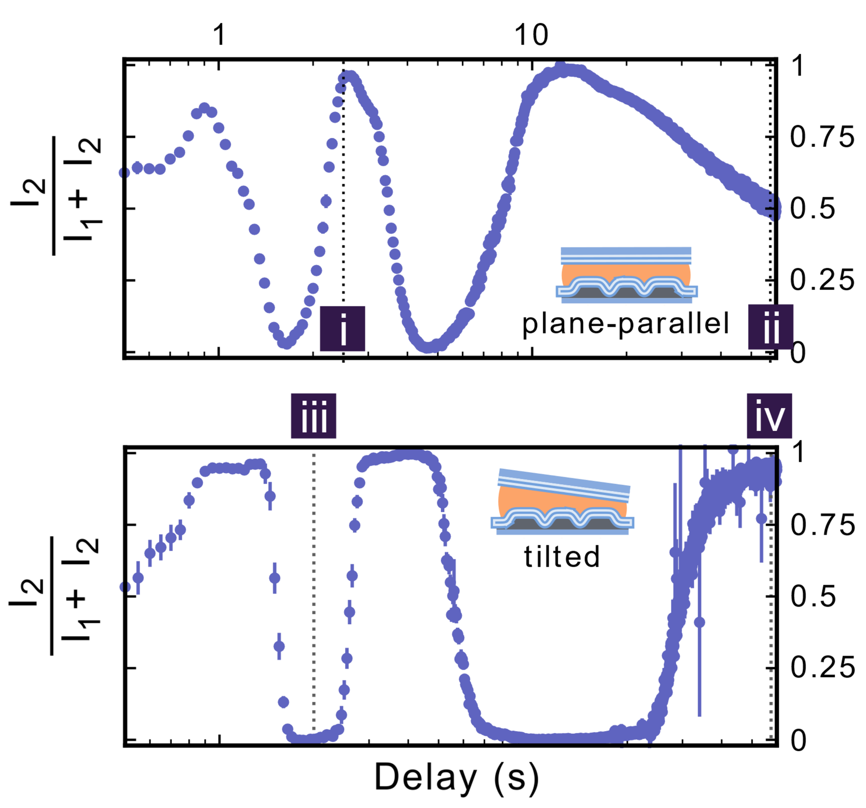
Height map of a nanostructured mirror with an open Mach-Zehnder design.

We heat the upper, inner arm for a local change in refractive index.

Closed Mach-Zehnder – tilted & plane-parallel







In the plane-parallel case the upper and lower outputs are identical. We see a sinusoidal switching function.

Tilting one microcavity mirror introduces a potential gradient to the photon gas. This reveals an almost discrete switching behaviour and demonstrates that the condensate adjusts its frequency such that a maximum degree of constructive feedback is achieved for all optical path length differences.

[1] Vretenar, M., Toebes, C. & Klaers, J. Modified Bose-Einstein condensation in an optical quantum gas. *Nat Commun* **12,** 5749 (2021).

[2] Mario Vretenar, Ben Kassenberg, Shivan Bissesar, Chris Toebes, and Jan Klaers, Phys. Rev. Research **3**, 023167.

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