Integrated all-optical transistors with polariton condensates

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Integrated all-optical logic could drive a new paradigm for computing architectures. Based on strong light-matter coupling all-optical transistors exhibiting ultrafast switching and room-temperature operation have recently been demonstrated using polaritons in vertical cavities [1,2]. Here, we leverage silicon photonics processing technology for realizing high index contrast grating microcavities with an organic polymer as photoactive material (Fig. 1a) to demonstrate polariton condensation and strong light-matter interaction integrated on a chip. In this configuration, the cavity modes are in the plane of the chip, and the light can be guided between separate cavities. Thereby we can overcome the scalability roadblock that existed with vertical cavities, which have been the work horse of polariton physics for decades.

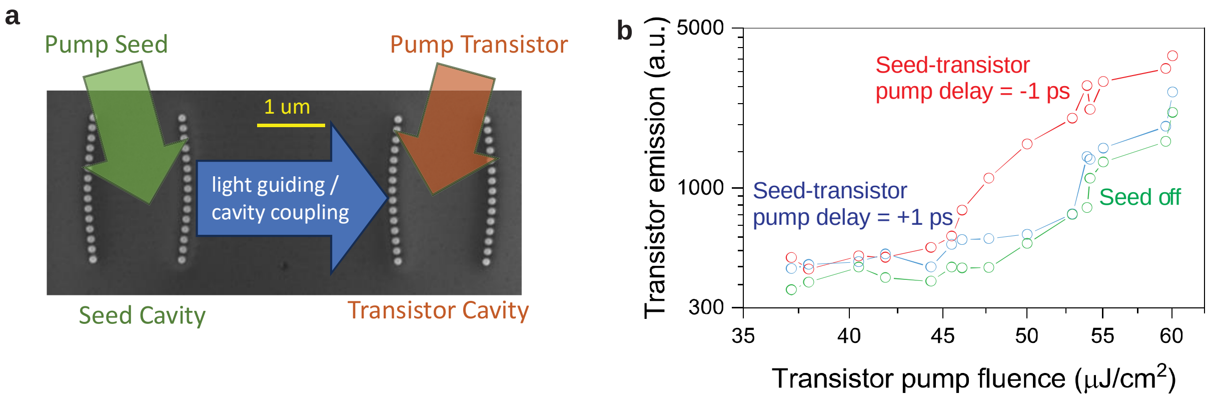

Figure 1: a, Scanning electron microscopy image and illustration of the excitation and coupling of the “seed” and the “transistor” cavities. b, When the polariton condensate in the seed cavity is pumped first, its output effectively seeds the condensate in the transistor cavity and thereby lowers the condensation threshold of the transistor cavity.

We observe all-optical transistor action and prove the cascadability of the device concept by realizing two identical, coupled microcavities where in one cavity (“seed”) a spontaneous polariton condensate is created as input to the other cavity (“transistor”) (Fig. 1b) where it then can induce the polariton condensation process. We investigate the ultrafast polariton condensation dynamics on sub-picosecond timescale and extract the key transistor metrics like signal amplification (up to factor 60) and on/off extinction ratio (up to 9:1).

Our results [3] open the door for integrated, ultrafast all-optical transistors with scalability allowing more complex optical logic circuits.

[1] A.V. Zasedatelev et al.. *Nature Photonics* **13**, 378–383 (2019).
[2] A.V. Zasedatelev et al., *Nature* **597**, 493–497 (2021).
[3] P. Tassan et al., *arXiv* 2404.01868 (2024).