

Title:

Integrated, ultrafast all-optical polariton transistors

Abstract:

Since the breakdown of Dennard scaling approximately 15 years ago, the clock frequency of processors has remained stalled at a few GHz. Although all-optical transistors that can switch at THz speed could bring a leap in performance, this promise was not fulfilled during decades of research due to low optical nonlinearities and bulky components. Now the foundations of a new generation of devices are investigated that harnesses the so-called strong light-matter interaction regime with novel materials and integrated photonic structures that could enable compact, ultrafast all-optical logic circuits with attojoule switching energy [1,2].

In this work, the experimental progress towards this goal will be presented, including a cascading setup where a spontaneous polariton condensate is created in one cavity (Seed) and fed into another cavity (Transistor) to induce polariton condensation [3,4]. Additionally, rapid polariton condensation dynamics on a sub-picosecond timescale will be presented, and important transistor metrics such as signal amplification (up to a factor of 60) and on/off extinction ratio (up to 9:1) will be determined.

These findings indicate the potential for developing integrated, ultrafast all-optical transistors that are scalable, allowing for more complex all-optical logic circuits.

Furthermore, a method for controlling these ultrafast all-optical transistors will be presented, utilising phase-change material-based memory cells.

This work was funded by EU H2020 EIC Pathfinder Open project “PoLLoC” (grant agreement no. 899141) and EU H2020 MSCA-ITN project “AppQInfo” (grant agreement no. 956071).

References

- [1] Anton V. Zasedatelev, Anton V. Baranikov, Denis Sannikov, Darius Urbonas, Fabio Scafirimuto, Vladislav Yu. Shishkov, Evgeny S. Andrianov, Yurii E. Lozovik, Ullrich Scherf, Thilo Stöferle, Rainer F. Mahrt, Pavlos G. Lagoudakis, “A room-temperature organic polariton transistor,” *Nat. Photonics* 13, 378–383 (2019).
- [2] Anton V. Zasedatelev, Anton V. Baranikov, Darius Urbonas, Fabio Scafirimuto, Ullrich Scherf, Thilo Stöferle, Rainer F. Mahrt, Pavlos G. Lagoudakis, “Single-photon nonlinearity at room temperature,” *Nature* 597, 493–497 (2021).
- [3] D. Urbonas, “Tunable coupled microcavities for enhanced light-matter interaction,” *ETH Diss.*, no. 26125, 2019.
- [4] P. Tassan, D. Urbonas, B. Chmielak, J. Bolten, T. Wahlbrink, M. C. Lemme, M. Forster, U. Scherf, R.F. Mahrt, T. Stöferle, “Integrated ultrafast all-optical polariton transistors,” *arXiv:2404.01868v1*, (2024).