to underestimate the number and extent of forest fires[7]. Their results nevertheless highlight the key role of policy and enforcement in helping to preserve biodiversity in the Amazon. Feng *et al.* clearly show that forest-policy regulations can be beneficial in conserving the extent and habitat quality of Amazonian rainforests, and can reduce the extent of deforestation, degradation and forest fires there. Most crucially, the Brazilian government's past forest policy seems to have mitigated the effects of droughts. Climate change will probably make drought increasingly common in the Amazon basin[1], and it is clear that strict policies will need to be imposed and enforced to reduce forest fires and their effects on the ranges of species and on biodiversity.

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1. Marengo, J. A., Tomasella, J., Soares, W. R., Alves, L. M. & Nobre, C. A. *Theor. Appl. Climatol.* **107**, 73–85 (2012).
2. Nepstad, D. C. *et al. Nature* **398**, 505–508 (1999).
3. Davidson, E. A. *et al. Nature* **481**, 321–328 (2012).
4. Feng, X. *et al. Nature* **597**, 516–521 (2021).
5. Nepstad, D. *Science* **344**, 1118–1123 (2014).
6. Hansen, M. C. *et al. Science* **342**, 850–853 (2013).
7. Libonati, R. *et al. Sci. Rep.* **11**, 4400 (2021).
8. Hopkins, M. J. G. *J. Biogeogr.* **34**, 1400–1411 (2007).

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Applied physics

Light detection nears its quantum limit

Sebastian Klembt

Organic molecules are increasingly crucial in quantum-optics technologies. An experiment shows how the strong coupling between confined organic molecules and light can improve photon detection at room temperature. **See p.493**

Experiments in quantum optics aim to explain the intrinsic quantum properties of light. The past few decades have seen substantial improvements in both theory and experiment to understand, control and manipulate quantum states of light. Innovative nanotechnological techniques could enable a new generation of all-optical devices, such as switches and amplifiers, that operate at the fundamental quantum limit. At this limit, quantum optics have helped to launch the field of quantum technologies, in which quantum states of light lie at the core of transformative technological applications. On page 493, Zasedatelev *et al.*[1] report an innovative way to use phenomena called optical nonlinearities in organic microcavities (light-trapping structures) that allows light detection at the single-photon level in ambient conditions.

Advances in nanotechnology and spectroscopic techniques[2,3] have paved the way for single organic molecules to be used in cost-effective quantum optical devices that, crucially, can be operated at room temperature. The ability to study optical nonlinearities using a single molecule and just a few photons has spurred interest in quantum information-processing applications, in which strong optical nonlinearities are of great importance.

Technological advances concerning microcavities and their nanotechnological fabrication have enabled the production of particles called exciton-polaritons. These particles arise from the strong light–matter coupling between photons and excitons, which are bound states of an electron and a hole (electron vacancy). Exciton-polaritons are associated with strong optical nonlinearities and, after first being observed in classical semiconductor materials[4], were successfully introduced in the field of organic photonics[5,6]. In general, an organic semiconductor material is sandwiched between two highly reflective mirrors (Fig. 1a). The result is a microcavity with a length that is half the wavelength of the confined light (this wavelength is approximately 490 nanometres in the present work).

The system of exciton-polaritons in an organic microcavity is characterized by a sudden onset of stimulated scattering and a transition to a ground state (Fig. 1b), in which the particles form a phase of matter called a condensate. Organic molecules exhibit vibronic excitations, whereby the electronic and vibrational energy levels of a molecule change owing to the absorption or emission of a photon of a specific energy. It has been shown that these vibronic excitations can trigger the condensation of exciton-polaritons, enabling the implementation of optical transistors (electronic amplifiers or switches) that provide substantial amplification and sub-picosecond switching times[7] (1 ps is 10^{-12} s).

Zasedatelev *et al.* have now demonstrated an innovative switching scheme. They compared condensate formation using a laser beam (called the pump beam) with and without a second laser pulse (the seed beam) and analysed the contrast in ground-state population between these two cases. Remarkably, when the power of the seed beam was reduced to roughly 1 attojoule (10^{-18} J) so that each beam pulse contained only one photon on average, a measurable population contrast remained. Crucially, the

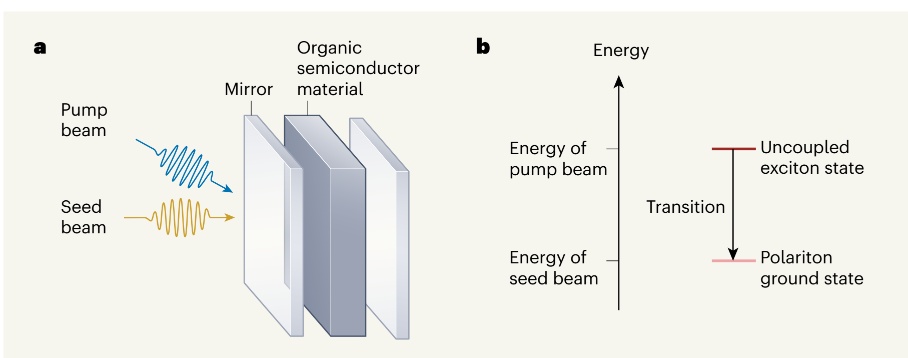

Figure 1 | Transitions of exciton-polaritons in an organic microcavity. a, Zasedatelev *et al.*[1] placed an organic semiconductor material between two highly reflective mirrors to form a light-trapping structure called an organic microcavity. They then directed two pulsed laser beams, known as the pump beam and the seed beam, at the microcavity. **b**, This process produced composite light–matter particles called exciton-polaritons that transitioned from a state with the same energy as the pump beam (the uncoupled exciton state) to a state with the same energy as the seed beam (the polariton ground state). Such transitions were mediated by phenomena known as vibronic excitations that are specific to organic molecules. The authors discovered that measurements of the difference between the number of exciton-polaritons in the ground state with and without the seed beam can be used to detect light at the single-photon level.

authors implemented a single-shot measurement technique to avoid contributions to the exciton-polariton condensation from states of light containing more than one photon.

Regarding potential applications, it is worthwhile to consider the statistical methods needed to judge whether the seed-beam pulses contained a few photons or even a single photon. For all-optical logic operations that are energy efficient, a pulse comprising a few photons – or, ideally, one photon – carries crucial information and should be detected, preferably with 100% probability. The presented scheme has certain limitations in this respect. When a pulse contains an average of 60 photons, the population contrast is 160%; this is, in principle, sufficiently large for the pulse to be detected even in a single-shot experiment. However, this contrast falls to 60% for roughly 10 photons and 11% for a single photon. Therefore, to distinguish safely between one and zero photons, the authors used sets of 300 single-shot events, with and without the seed beam and averaged over the fluctuating ground-state population.

Follow-up work will show how far this method can be pushed, because the configuration of the seed beam, the size of the condensate and other crucial experimental settings were not fully optimized in the presented proof of concept. It remains to be seen whether fundamental limitations will ultimately prevent the detection of individual photons in a single-shot experiment using the authors' technique. However, even with the current limitations, the potential for switching induced by a few photons or a single photon, using a relatively cheap method at room temperature, should be of great interest to photonics researchers. These scientists have invested substantially in the fabrication of near-perfect single-photon sources[8,9], albeit with different applications in mind.

"The potential for switching induced by a few photons or a single photon at room temperature should be of great interest."

Given that the field of organic quantum optics is relatively young, and technological advances and methodological improvements are happening frequently, improved switching capabilities will probably emerge soon. The authors' results will certainly inspire scientists in the fields of organic polaritonics (the study of strong light–matter interactions) and nonlinear optics, and will eventually advance the development of cost-effective organic quantum technologies.

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1. Zasedatelev, A. V. *et al. Nature* **597**, 493–497 (2021).
2. Chikkaraddy, R. *et al. Nature* **535**, 127–130 (2016).
3. Maser, A., Gmeiner, B., Utikal, T., Götzinger, S. & Sandoghdar, V. *Nature Photon.* **10**, 450–453 (2016).
4. Carusotto, I. & Ciuti, C. *Rev. Mod. Phys.* **85**, 299–366 (2013).
5. Kéna-Cohen, S. & Forrest, S. R. *Nature Photon.* **4**, 371–375 (2010).
6. Plumhof, J. D., Stöferle, T., Mai, L., Scherf, U. & Mahrt, R. F. *Nature Mater.* **13**, 247–252 (2014).
7. Zasedatelev, A. V. *et al. Nature Photon.* **13**, 378–383 (2019).
8. He, Y.-M. *et al. Nature Nanotech.* **8**, 213–217 (2013).
9. Somaschi, N. *et al. Nature Photon.* **10**, 340–345 (2016).

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