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Hybrid states of light and matter may significantly enhance OLED brightness

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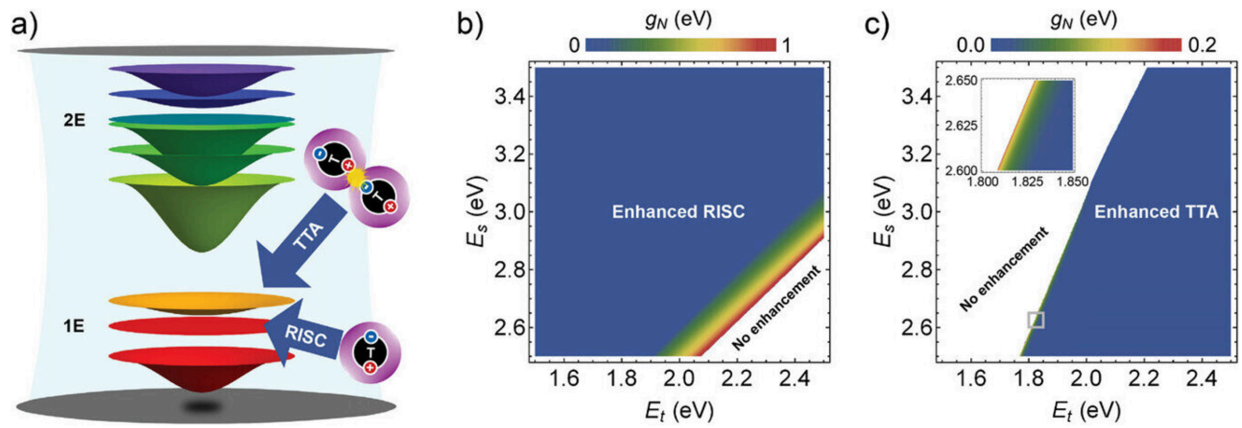

Overview of the study and enhancement maps. Credit: *Advanced Optical Materials* (2025). DOI: 10.1002/adom.202403046

Researchers developed a theoretical model that predicts a substantial increase in the brightness of organic light-emitting diodes (OLEDs) by leveraging novel quantum states called polaritons. Integrating polaritons into OLEDs effectively requires the discovery of new materials, making practical implementation an exciting challenge.

OLED technology has become a common light source in a variety of high-end display devices, such as smartphones, laptops, TVs or smart watches.

While OLEDs are rapidly reshaping lighting applications with their flexibility and eco-friendliness, they can be quite slow at converting electric current into light, with only a 25% probability in emitting photons efficiently and rapidly. The latter is an important condition for boosting the brightness of OLEDs, which tend to be dimmer than other light technologies.

Researchers from the University of Turku, Finland, and Cornell University, U.S., have now proposed a predictive model to overcome this problem. Their research is published in *Advanced Optical Materials*.

OLEDs are electronic components made from organic carbon-based compounds that produce light when an electric current is applied to them. In OLED displays, the pixels themselves emit light, unlike liquid crystal displays, which use LED backlighting.

When sandwiched between two semi-transparent mirrors, the organic emitters can couple with the confined light, creating new hybrid states of light and matter called polaritons.

By fine-tuning these states, it is possible to find a sweet spot where the remaining 75% dark states start becoming bright polaritons instead.

"While the general idea of using polaritons in OLED technology is not entirely original, a theory that examines the boundaries of performance gains has been missing. In this work, we carefully examined where the polariton sweet spot lies in different scenarios.

"We found that the strength of the polaritonic effect in OLEDs' performance depends on the number of coupled molecules. The fewer, the better," says Associate Professor Konstantinos Daskalakis from the University of Turku.

"With the molecules we studied and a single coupled molecule, the efficiency improved significantly. The dark-to-bright conversion rate increased by a whopping factor of 10 million at best," says Postdoctoral Researcher Olli Siltanen.

With a large number of molecules, the polaritonic effect was negligible. Therefore, the dark-to-bright conversion rate of present-day OLEDs cannot be enhanced simply by equipping them with mirrors.

"The next challenge is to develop feasible architectures facilitating single-molecule strong coupling or invent new molecules tailored for polariton OLEDs. Both approaches are challenging, but as a result, the efficiency and brightness of OLED displays could be significantly improved," Daskalakis explains.

The widespread adoption of OLEDs has been hindered by efficiency, but more importantly by brightness limitations, particularly when compared to traditional inorganic LEDs. The results of this study provide a path forward, laying the foundation for OLEDs that are not only more efficient but also capable of achieving performance levels previously thought impossible.

More information: Olli Siltanen et al, Enhancing the Efficiency of Polariton OLEDs in and Beyond the Single-Excitation Subspace, *Advanced Optical Materials* (2025). DOI: 10.1002/adom.202403046

Provided by University of Turku