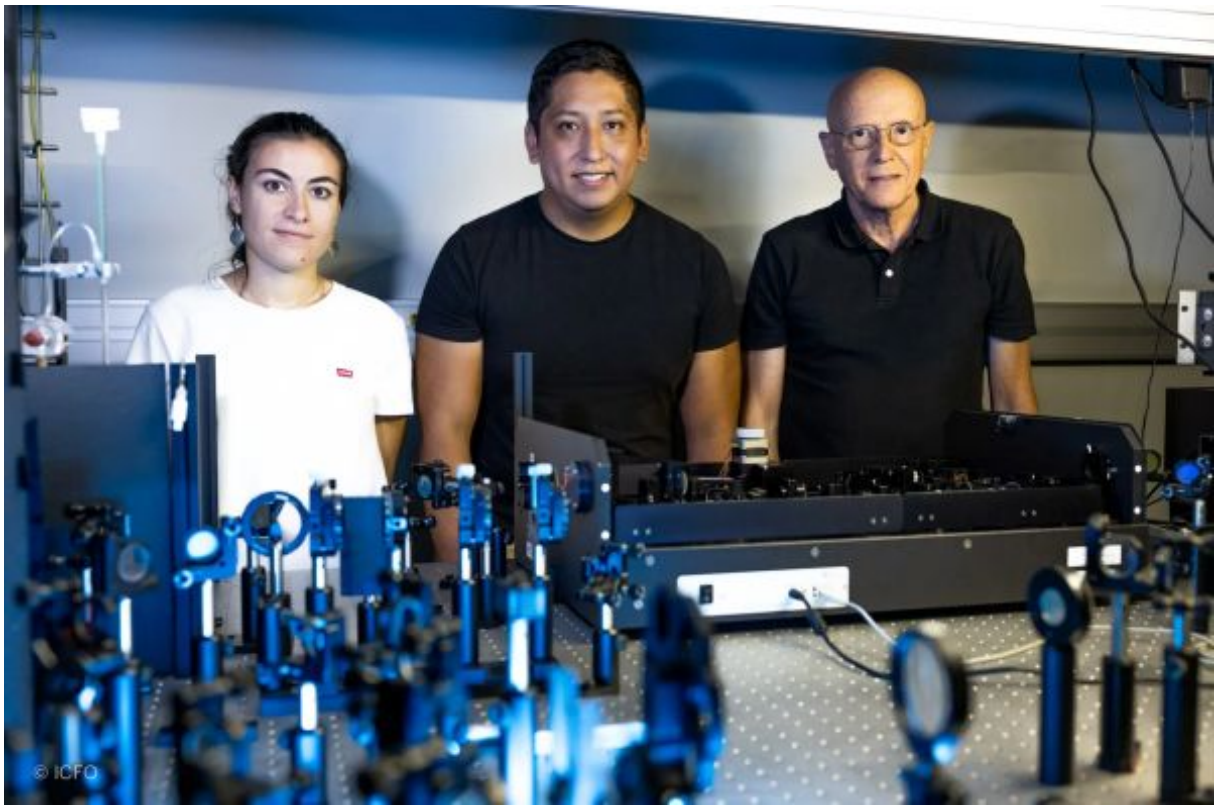


Solar cells gain efficiency by emitting light in fewer directions

ICFO researchers have increased the power conversion efficiency of organic solar cells by restricting the angles at which they emit light. The strategy, presented in Energy & Environmental Science, offers a promising path to surpass the standard theoretical efficiency limit for single-junction solar cells.

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Solar cells absorb sunlight and convert it into electricity. This process, however, is not perfect, and a large part of the solar energy is simply lost along the way. Some of it is lost as heat, while photons with insufficient energy pass through the cell without generating electricity. These are the loss sources that most scientists in the field try to minimize, but there is another important one known as **Boltzmann loss**.

Boltzmann losses arise because materials that absorb light can also emit light, and in a solar cell this emission is an unavoidable part of the energy-conversion process. The problem with solar cells lies in how this occurs. Because the Sun appears very small in the sky, sunlight reaches the cell within a narrow cone of directions. The solar cell, by contrast, emits in all

directions, over a broad cone that practically covers the full hemisphere above it. This mismatch between the narrow cone of incoming light and the broad cone of emitted light translates into a reduction in the useful work that can be extracted from the device.

ICFO researchers, **Dr. Francisco Bernal Texca**, **Chiara Cortese**, **Dr. Mariia Kramarenko**, and **Dr. Quan Liu**, led by **ICFO and UPC Professor Jordi Martorell**, have now found a way to reduce Boltzmann losses experimentally. In the study, recently published in Energy & Environmental Science, the team used an inverted organic solar cell based on the PM6:Y6 blend and, by converting the solar cell into an **optical cavity**, they **inhibited photon emission at large angles**, thereby narrowing the emission cone.

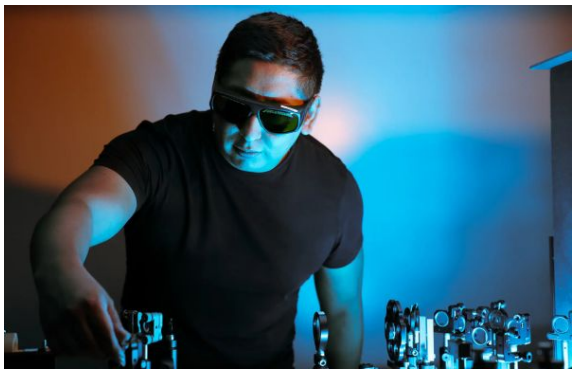
i¿½Our study is a significant step forward in the solar energy conversion field as it opens a completely unexplored route to surpass the Shockley-Queisser limit,i¿½ says Dr. Franc sco Bernal Texca, first author of the article. This efficiency limit, which accounts for the intri sic loss mechanisms considered in the Shockley-Queisser model, is theoretically set at 33. 6%. i¿½If the emission cone can be narrowed to more closely match the absorption c ne of incoming sunlight, which is exactly what our work demonstrates experimentally, **solar cells will, in principle, be able to approach efficiencies close to 43%**.i¿½ Professor Jordi Martorel , lead researcher of the study, adds that i¿½although the path towards achieving such gain is demonstrated here in an organic solar cell, the underlying principle is not specific to org nic materials and is, in principle, applicable across photovoltaic technologies i¿½ The key to narrowing the emission cone is the use of a metal as the front electrode, en bling high reflectivity over a wide angular range for the emitted light. A layered str cture surrounds this silver-based electrode to form, together with the silver electrode at th back of the cell, an optical cavity. This makes it possible to combine broad-angle reflectivity, which effectively narrows the emission cone, with high transmission in the direction f the incoming sunlight. Moreover, i¿½the simplicity of the cavity cell design does not i troduce any additional fabrication complexity, unlike many of the approaches current y being explored to surpass the Shockley-Queisser limit,i¿½ explains Ber al Texca. Overall, the framework opens **a general route for improving photovoltaic efficiencies**, pushing them closer to their theoretical limits. According to Prof. Martorell: i¿½Achievi g higher efficiencies is essential, because they directly translate into a lower cost per watt a d more efficient use of land and materials for solar energy deployment.i

Reference:

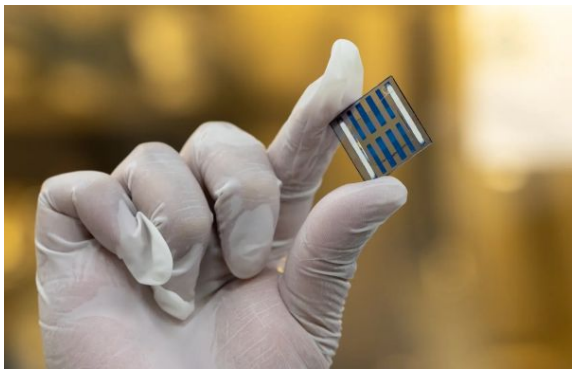
Francisco Bernal-Texca, Chiara Cortese, Mariia Kramarenko, Quan Liu, Jordi Martorell; Inhibited photon emission to overcome Boltzmann losses in an organic solar cell with a cavity configuration. Energy Environ. Sci. 2026.
DOI: https://doi.org/10.1039/d6ee03772k

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Francisco Bernal Texca in the lab. Credit: ICFO.



Close-up picture of the device. Credit: ICFO.