Scientists directly observe light-to-energy transfer in new solar cell materials

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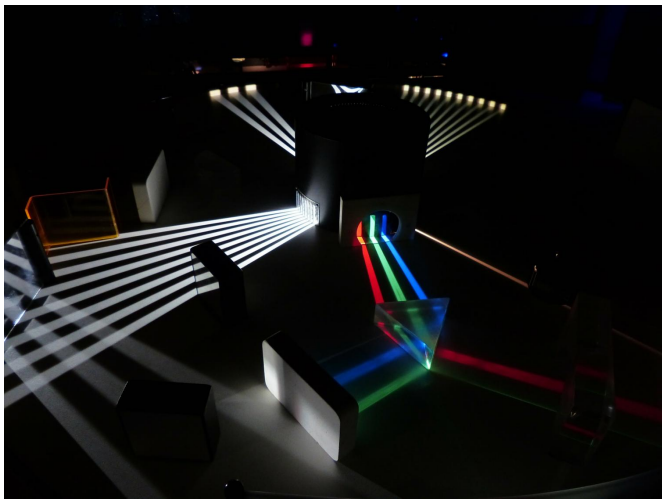

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Scientists at the U.S. Department of Energy's Ames Laboratory are now able to capture the moment less than one trillionth of a second a particle of light hits a solar cell and becomes energy, and describe the physics of the charge carrier and atom movement for the first time.

The generation and dissociation of bound electron and hole pairs, namely excitons, are key processes in solar cell and photovoltaic technologies, yet it is challenging to follow their initial dynamics and electronic coherence.

Using time-resolved low frequency spectroscopy in the terahertz spectral region, the researchers explored the photo-excitations of a new class of photovoltaic materials known as organometal halide perovskites. Organometallics are wonder materials for light-harvesting and electronic transport devices, and they combine best of both worlds— the high energy conversion performance of traditional inorganic photovoltaic devices, with the economic material costs and fabrication methods of organic versions.

"These devices are so new and so unique that the mechanism by which a particle of light, or photon, converts to charge carriers and how they move in a concerted way for energy conversion is not well understood, and yet that is the most fundamental processes in in solar cell and photovoltaic technologies," said Jigang Wang, an Ames Laboratory scientist and associate professor of physics at Iowa State University. "Why is this material so distinct? That has been the big question in the scientific community, and it has led to a fever of research and publication."

Ames Laboratory researchers wanted to know not only how the generation and dissociation of bound electron and hole pairs, namely excitons, happened in the material, they wanted to find out the quantum pathways and time interval of that event.

"If you look at the natural process, in photosynthesis, it's an extremely efficient process in some biological molecules, so it's also very coherent. We see a similar thing in a man-made system of a laser; a laser oscillates in a fixed wave pattern," said Wang. "If we can measure such a memory in the charge transport and energy migration in these materials, we can understand and control it, and have the potential to improve them by learning from Mother Nature."

Conventional multimeters for measuring electrical states in materials do not work for measuring excitons, which are electrically neutral quasiparticles with no zero current. Ultrafast terahertz spectroscopy techniques provided a contactless probe that was able to follow their internal structures, and quantify the photon-to-exciton event with time resolution better than one trillionth of a second.

Wang credited the contributions of researchers from multiple areas of expertise across the Ames

Laboratory with the significance of the discovery. "This was only possible with the collaboration of experts in material design and fabrication, computational theory, and spectroscopy," he said. "Having those capabilities in one place is what makes Ames Laboratory one of the most forward looking places in this kind of photonic materials research."

The research is further discussed in a paper, "Ultrafast terahertz snapshots of excitonic Rydberg states and electronic coherence in an organometal halide perovskite", authored by Liang Luo, Long Men, Zhaoyu Liu, Yaroslav Mudryk, Xin Zhao, Yongxin Yao, Joong M. Park, Ruth Shinar, Joseph Shinar, Kai-Ming Ho, Ilias E. Perakis, Javier Vela, and Jigang Wang; and published in *Nature Communications*.

More information: Liang Luo et al. Ultrafast terahertz snapshots of excitonic Rydberg states and electronic coherence in an organometal halide perovskite, *Nature Communications* (2017). DOI: 10.1038/ncomms15565

Provided by Ames Laboratory