Solar concentrator increases collection with less loss

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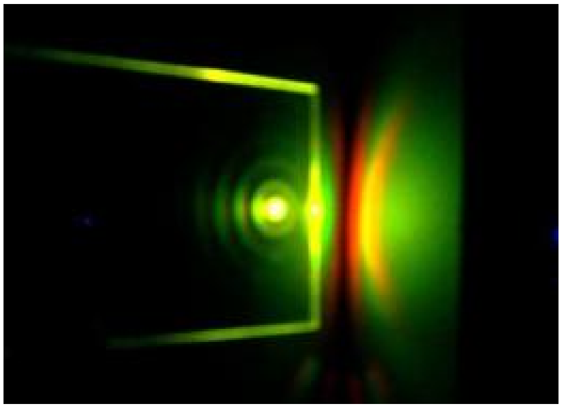

An LSC is illuminated by a laser beam (central spot) resulting in luminescence that is emitted from the edges and projected onto a white business card. The faintly visible concentric rings and different colors of light on the business card result from microcavity effects. Credit: Chris Giebink, Penn State

(PhysOrg.com) -- Converting sunlight into electricity is not economically attractive because of the high cost of solar cells, but a recent, purely optical approach to improving luminescent solar concentrators (LSCs) may ease the problem, according to researchers at Argonne National Laboratories and Penn State.

Using concentrated sunlight reduces the cost of solar power by requiring fewer solar cells to generate a given amount of electricity. LSCs concentrate light by absorbing and re-emiting it at lower frequency within the confines of a transparent slab of material. They can not only collect direct sunlight, but on cloudy days, can collect diffuse light as well. The material then guides the light to the slab's edges, where photovoltaic cells convert the energy to electricity.

"Currently, solar concentrators use expensive tracking systems that need to follow the sun," said Chris Giebink, assistant professor of electrical engineering, Penn State, formerly of Argonne National Laboratory. "If they are a few tenths of a degree off from perfection, the power output of the system drops drastically. If they could maintain high concentration without tracking the sun, they could create electricity more cheaply."

LSCs can do this, potentially concentrating light to the equivalent of more than 100 suns but, in practice, their output has been limited. While LSCs work well when small, their performance deteriorates with increasing size because much of the energy is reabsorbed before reaching the photovoltaics.

Typically, a little bit of light is reabsorbed each time it bounces around in the slab and, because this happens hundreds of times, it adds up to a big problem. The researchers, who included Giebink and Gary Widerrecht and Michael Wasielewski, Argonne-Northwestern Solar Energy Research Center and Northwestern University, note in the current issue of Nature Photonics that "we demonstrate near-lossless propagation for several different chromophores, which ultimately enables a more than twofold increase in concentration ratio over that of the corresponding conventional LSC."

The key to decreasing absorption is microcavity effects that occur when light travels through a small structure with a size comparable to the light's wavelength. These LSCs are made of two thin films on a piece of glass. The first thin film is a luminescent layer that contains a fluourescent dye capable of absorbing and re-emitting sunlight. This sits on a low refractive index layer that looks like air from the light's point of view. This combination makes the microcavity and changing the luminescent layer's thickness across the surface changes the microcavity's resonance. This means that light emitted from one location in the concentrator does not fit back into the luminescent film anywhere else, preventing it from being reabsorbed.

"We were looking for some way to admit the light, but keep it from being absorbed," said Giebink. "One of the things we could change was the shape and thickness of the luminescent layer."

The researchers tried an ordered stair step approach to the surface of the dye layer. They looked at the light output from this new configuration by placing a photovoltaic cell at one edge of the collector and found a 15 percent improvement compared to conventional LSCs.

"Experimentally we are working with devices the size of microscope slides, but we modeled the output for larger, more practical sizes," said Giebink. "Extending out results with the model predicts intensification to 25 suns for a window pane sized collector. This is about two and a half times higher than a conventional LSC."

The researchers do not believe that the stair step approach is the optimal design for these LSCs. A more complicated surface variation is probably even better, but designing that will take more modeling. Other approaches may also include varying the shape of the glass substrate, which would produce a similar effect and potentially be simpler to make.

"We need to find the optimum way to structure this new type of LSC so that it is more efficient but also very inexpensive to make," said Giebink.

Provided by Pennsylvania State University

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