Solar Power Without Semiconductors

A magneto-optical effect that has been overlooked for more than 100 years may one day be harnessed to create semiconductor-free solar cells.

BY MARIE FREEBODY, CONTRIBUTING EDITOR

It sounds implausible – using sunlight to generate an electric charge without the use of semiconductors, or, at the very least, metals. But professor Stephen C. Rand and graduate student William M. Fisher of the University of Michigan, Ann Arbor, claim that shining light through a nonconducting material such as glass or liquid is all that is required to trigger an unexpectedly strong magneto-optical effect.

Instead of absorbing light to generate an electron-hole pair (which also generates a considerable amount of heat), as in a semiconductor, a different physical effect is taking place. The solar panel proposed by the researchers does not absorb incident sunlight but rather stores it as a charge separation from which power can be drawn.

This somewhat capacitive power source, or "optical battery," is described in a *Journal of Applied Physics* paper published online March 21, 2011. In the work, Rand and Fisher simulate a generator with a 1-m-diameter concentrator to focus light with a wavelength of 0.6 µm (to represent sunlight) through a 1-cm-thick bundle of sapphire fibers extending over 10 m.

The resultant end-to-end voltage generated in each fiber is 3.56×10^5 V, with an extractable power of 29.7 W. This yields a theoretical optical-to-electrical power conversion efficiency of nearly 3 percent.

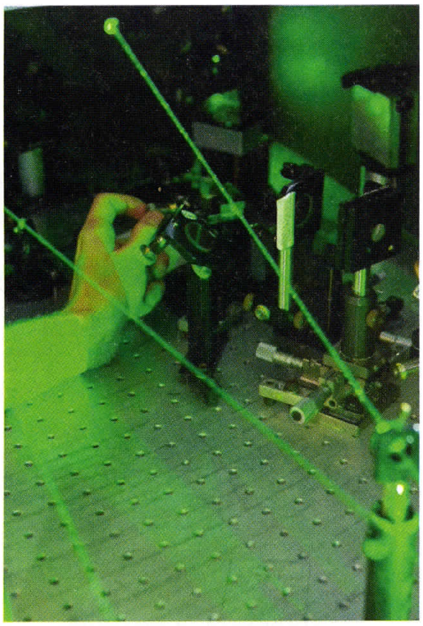
Although it is not in the realm of some of today's more expensive semiconductor photovoltaic devices, which can achieve nearly 50 percent efficiency, the researchers believe that it can boost the efficiency of such devices to a more respectable 10 percent and perhaps much higher by using a sufficiently high input power from a laser beam or a solar concentrator – particularly in conjunction with the use of a waveguide and optimized conversion media.

"So far, our proposal for an electrical generator is mostly theoretical. We have established the existence of a family of new optical phenomena, but the basic components of a prototype generator have not been built or evaluated, so we are at too early a stage to guess whether this could ever offer a practical alternative to solar cells," Rand said.

Arcing electrons

Within the atoms of a nonconducting material, electrons remain near the nucleus. But the investigators discovered that the electrical and magnetic components of light drive electron motion away from the nucleus, inducing the atom or molecule to acquire a static dipole moment.

In simple terms, the electric field initiates motion of electrons from rest in a direction parallel to the electric field. The magnetic component of the light field then causes a deflection of the electron around its axis. This small deflection grows rapidly in amplitude, marking out an arc shape back and forth around the nucleus. As this arclike motion gets bigger, the magnetic moment associated with it also gets bigger, and the electron moves away from the nucleus.



Using the electric and magnetic components of light, University of Michigan scientists have induced new magnetic effects in ordinary optical materials. The finding could lead to a new kind of solar cell that operates without semiconductors or absorption. Courtesy of the University of Michigan.

The result is an optically charged capacitor with the potential to provide an efficient source of electrical energy with very little unwanted heat generation.

Rand admits that this is not the first magneto-optic effect to be discovered, but that all the known magneto-optic effects are extremely weak. They are so weak that it is very hard to make anything practical with them, although they are used in current optical data storage media such as compact discs. This new family of optical phenomena, however, produces effects approximately 10^8 larger than they are supposed to be and is comparable to strong electric effects.

So far, the researchers have observed strong magnetic emission from ordinary optical materials in the lab, but work is under way to observe and characterize the charge separation effect that could eventually power a generator.

"Our laboratory experiments imply that tesla-level magnetic fields can also be generated with only moderately intense light fields," Rand said. "However, the induced magnetic field oscillates at the frequency of light with an average value of zero. So, additional applications are likely to be limited to maintaining the orientations of magnetic moments in polarized samples, or for reading or writing data stored in magnetic memories."

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