Photon funnel could direct and regulate light into solar cells

July 26 2013, by Lisa Zyga

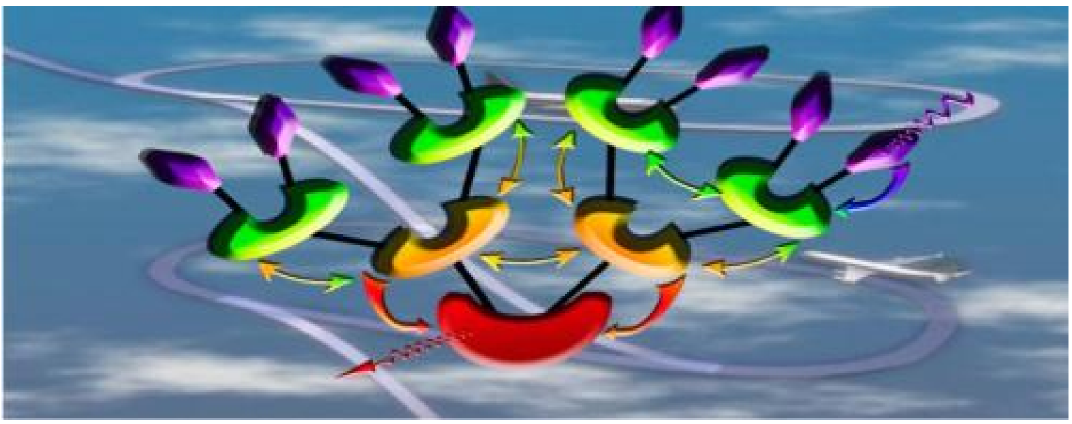

Illustration of the light-harvesting funnel array that directs energy to a focal point along diverse routes, and then slowly off-loads the energy to a solar cell or other device. Credit: Raymond Ziessel, et al. ©2013 American Chemical Society

It has often been said that solar cells are like artificial versions of the photosynthetic apparatuses found in plants, such as leaves, since both harvest sunlight. But nature's leaves can do something that most solar cells cannot do: protect themselves against photochemical damage from overexposure to sunlight.

In an attempt to protect artificial light-harvesting devices from sun damage, chemists have designed a funnel-shaped molecular-scale array that harvests photons, spreads the energy around the array, and off-loads the energy at a relatively slow rate to a solar cell or other device. By regulating the amount of energy that enters the solar cell, the new array could extend the lifetime of the solar cell, which must function in harsh conditions associated with prolonged exposure to sunlight.

The researchers, Raymond Ziessel, Gilles Ulrich, and Alexandre Haefele at the University of Strasbourg in France, along with Anthony Harriman at Newcastle University in the UK, have published their paper on their artificial light-harvesting array in a recent issue of the *Journal of the American Chemical Society*.

"UV light is harmful to the cells and to the supporting structure," Harriman told *Phys.org*. "Photons are lost by way of annihilation, and optimal performance requires a steady flux of photons. This is even more important for water-splitting devices, which is where we see our light harvester having real applications."

The new array consists of 21 Bodipy ("boron-dipyrromethene") dyes, which are highly fluorescent dyes known for their good light absorption and emission. The Bodipy dyes are arranged in a funnel-like design that converges onto a focal point. When exposed to light, the array guides the excitation energy from incident photons through the funnel through a series of cascading energy transfer steps until the energy reaches the focal point.

The most important feature of the design is its ability to self-regulate its energy. When the focal point is in an excited state, further energy transfer to the focal point is restricted. In order to increase the amount of energy that reaches the focal point, the topology of the array provides diverse travel routes for the energy to ensure different arrival times. The strategy involves redistributing excess energy within the array until the focal point is no longer "saturated."

This mechanism for protecting against overexposure to sunlight is not strictly based on the mechanisms used by plants. In nature, various different mechanisms have evolved for this purpose, although the details of these mechanisms are still under active debate.

While the properties of the new array are intriguing, the scientists add that the actual synthesis is also state-of-the-art. Using Bodipy dyes as building blocks allows certainty about the emergent structure, unlike when using other molecules, such as dendrimers, where it is difficult to assure complete growth with each layer.

In the future, the molecular-scale funnel could protect solar cells by functioning as a sensitizer; that is, transferring energy in a controlled way to the solar cells or other external devices. The array also provides a benefit in stability compared with using a mixture of compounds. And although the array restricts energy transfer, it does not decrease solar cell efficiency.

"At present, the limiting efficiency is coupling together the two systems," Harriman said. "In principle, there should be no decrease in efficiency. The real advantage will come from using a large-area collector and a small-area solar cell."

In the future, the researchers plan to improve the transfer of photons from the array to the solar cell.

"We are trying to build systems where the photons move easily from cluster to cluster before being trapped by the solar cell," Harriman said. "Also, we are looking into ways to push the photons towards the solar cell, rather than rely on random migrations. This kind of quantum coherence might be important in certain cases in nature but is way beyond the current capability of artificial systems. We have ideas on how to improve and we foresee rapid progress in this field."

More information: Raymond Ziessel, et al. "An Artificial Light-Harvesting Array Constructed from Multiple Bodipy Dyes." *Journal of the American Chemical Society*. DOI: 10.1021/ja4049306