RESNICK INSTITUTE
science + energy + sustainability

RESEARCH HIGHLIGHTS

From the Resnick Sustainability Institute
Graduate Research Fellows at the
California Institute of Technology

Limiting Light Emission in Solar Cells

Emily Kosten

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Global Significance

In current PV modules, approximately half the cost is in “balance of systems” i.e. installation, structural supports, land costs, and electrical inverters to connect to the grid. Many of these costs scale with installed area. If we can move to higher efficiency cells these “balance of systems” costs may be reduced dramatically, reducing overall cost per watt.

Achieving high efficiency solar cells provides a promising route to low cost, sustainable solar energy.

This project aims to increase the efficiency of solar cells by managing the way light interacts with the solar cell. It combines elements from several disciplines including physics, applied physics, materials science, and optics.

Photo © Brett Walton/Circle of Blue: per http://www.circleofblue.org/waternews/2012/world/visions-of-solar-energys-future-compete-in-colorados-san-luis-valley/

Limiting Light Emission in Solar Cells

Emily Kosten

Project Summary

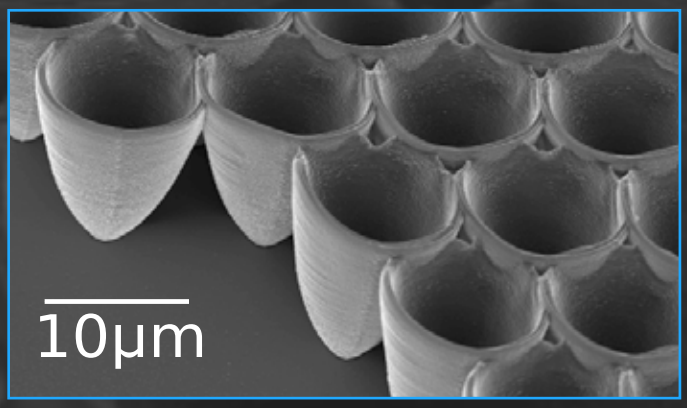
One approach to increasing solar cell efficiency is to manage how light interacts with the solar cell. In a conventional solar cell light is received from the sun in one direction, but emitted in all directions leading to efficiency losses. A concentrator system could be used to reduce the angles of light escape, however heating and series resistance can degrade the efficiency gains. Limiting light escape without concentration avoids these losses and leads to higher efficiencies.

In this project, we examine two approaches to limiting light emissions: (1) using light reflective cups and (2) using an angle restrictive optical element.

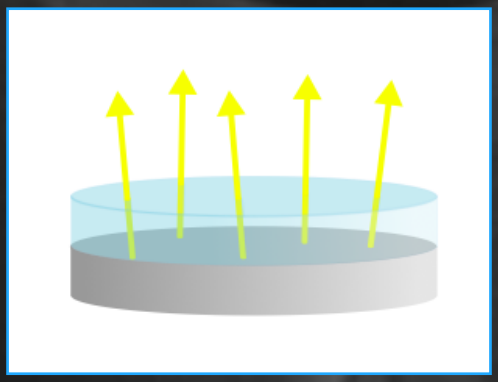
By only allowing light to enter and escape the cell in the direction of the sun, we allow for the possibility of unprecedented efficiencies with a single electrical junction.

Potential Impact

- Efficiencies greater than 38% may be achieved, while the current world record is 28.8%.
- Cells 1/60th the thickness of current technology may be utilized and still fully absorb the light.



These reflective cups only allow light to exit the solar cell via small holes at the bottom.



Limiting light emission with an angle restrictive optical element placed on top of a solar cell.

Limiting Light Emission in Solar Cells

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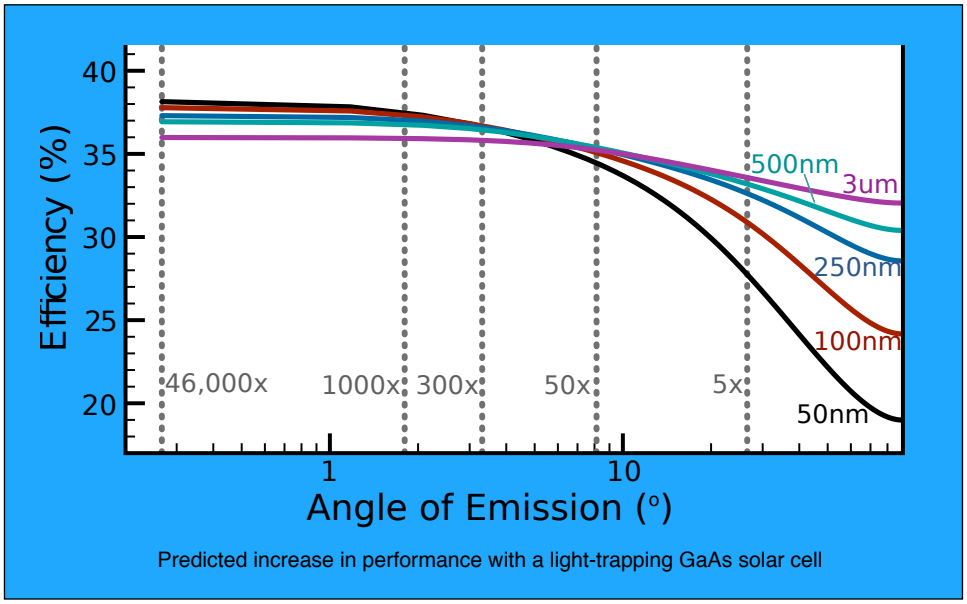
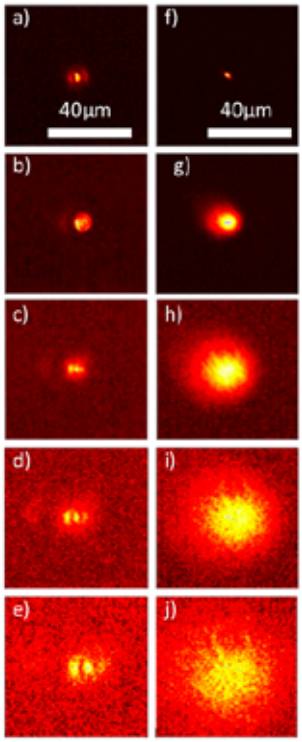
The Science

In the early stages of this project we focused on theory, demonstrating that significant efficiency increases are possible with a thin, light trapping GaAs cell. Our early experimental work focused on the feasibility of fabricating micron scale angle restrictors via two photon lithography. However, our most recent work has focused on demonstrating a voltage increase in a high efficiency GaAs cell. This voltage increase, attained using a multilayer dielectric angle restrictor, is indicative of increased photon recycling within the GaAs cell. High efficiency GaAs cells are limited in their voltage by photons that are re-emitted from the cell. Using angle restriction we can more effectively recycle these radiatively emitted photons, increasing the voltage.



Predicted increase in performance with a light-trapping GaAs solar cell



The cone optics pictured on the previous page give the light emission pattern seen in the left column, showing collimation relative to light emission from a hole, seen in the right column. *Per J. Atwater et. al. Appl. Phys. Lett. 99, 151113 (2011).*

Key Results & Future Steps

Until recently, it was thought that no benefit would be achievable with reduced emission in a realistic solar cell. We demonstrated theoretically that with proper design the benefits could be significant. Furthermore, we recently demonstrated an experimental increase in voltage as a proof of principle.

In the future, we hope to demonstrate not only an experimental voltage increase, but an overall efficiency increase with a more sophisticated interference-based optic to limit light escape.

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Publications

- **Highly Efficient GaAs Solar Cells by Limiting Light Emission Angle.** Emily D. Kosten, Jackson H. Atwater, James Parsons, Albert Polman and Harry A. Atwater. Light: Science & Applications (2013) 2, e45; DOI:10.1038/lsa.2013.1
- **Microphotonic parabolic light directors fabricated by two-photon lithography.** J. H. Atwater, P. Spinelli, E. Kosten, J. Parsons, C. Van Lare, J. Van de Groep, J. Garcia de Abajo, A. Polman, and H. A. Atwater. Appl. Phys. Lett. 99, 151113 (2011); http://dx.doi.org/10.1063/1.3648115