Very High Efficiency Solar Cells
Value, Opportunities and Challenges

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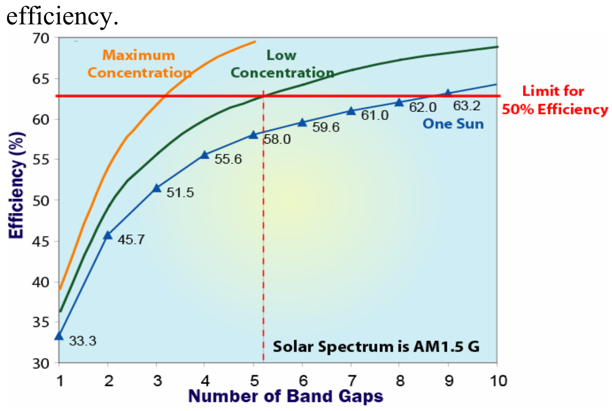
Very high efficiency solar cells can enable low cost, affordable solar electric power generating systems. The central challenge facing photovoltaic (PV) solar power is the need for a solar cell which allows high performance at acceptable cost. In a PV system, many of the non-solar cell costs are area-dependent and transaction-dependent.

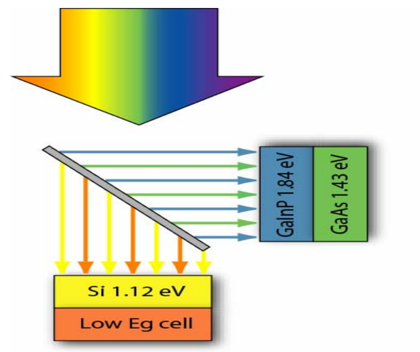
The answer to the challenges in PV lie not in continuing the search for a single "silver bullet" material but in combining the advantages of various materials. The conventional approach to improving the trade-off between efficiency and cost is to search for new materials. However, a potential solar cell material must meet a large number of requirements, and even single materials that meet all of these requirements achieve less than half of the maximum possible theoretical efficiency.

Our approach allows integration of various materials, physical mechanisms, and devices, enabling a dramatically increased design space that leads to multiple innovations and translates into higher performance and lower cost. At the device level, this approach enables higher efficiency and/or reduced cost from the individual components, both by reducing the wavelength range that the solar cells convert and by allowing the development of novel devices that beneficially utilize different materials or physical processes. This approach opens an important portal for innovation, both allowing the development of new devices and providing a path for them to enter the market, since the benefits of new technologies, such as bio- or nano-technology, can be integrated without being required to match performance and cost in all areas. Increasing the number of bandgaps and low levels of concentration as shown in the following figure can increase the module and system energy conversion efficiency.



Efficiency depends on the number of materials used for the photovoltaic junctions and on the intensity of sunlight on the solar cell. Increasing performance – and having a path to continual efficiency increases – requires the ability to increase the number of materials. However, existing PV technologies use either a single material, or require monolithic tandem solar cells. Monolithic tandems are limited to materials which are lattice-matched systems and for which the individual solar cells have identical current. In practice, this means that while tandems have a higher efficiency limit than a single junction, they are also material limited. The material costs with tandems are high, so they seek to reduce their costs through concentration, but require mechanical tracking systems which does not permit point-of-use applications such as rooftops or portable applications.

Very High Efficiency Solar Cell (VHESC) modules are being designed for modules that operate at greater than 50 percent efficiency. The high-efficiency module is based on co-design of the optics, interconnects, and solar cells. Low concentration is used to capture much of the performance benefit of concentration, reduce the material costs and lead to systems with no moving parts (static concentrators). Following is a concept drawing of the system architecture proposed.



The new system architecture is based on a "parallel" or lateral optical concentrating system, which splits the incident solar spectrum into several bands and allows different optical and photovoltaic elements in each band. The optics and the solar cells are co-designed to achieve the maximum conversion efficiency of the module.

The new architecture significantly increases the design space for high-performance photovoltaic modules in terms of materials, device structures, and manufacturing technology. It affords multiple benefits, including increased theoretical efficiency, new architectures that circumvent material/cost trade-offs, improved performance from non-ideal materials, device designs that can more closely approach ideal performance limits, and increased flexibility in material choices.

The design approach focuses first on performance, enabling the use of existing state-of-the-art photovoltaic technology to design high performance multiple junction III-Vs for the high and low energy photons and a new silicon solar cell for the mid-energy photons, all while circumventing existing cost drivers through novel solar cell architectures and optical elements. Our approach is driven by proven quantitative models for the solar cell design, the optical design and the integration of the two.

The design rules, initial designs, solar cell and module results will be presented. The lateral solar cell architecture increases the choice of materials for multiple junction solar cells, by allowing the solar cell in each spectral band to be optimized independently of the others. In this way, the lattice and current matching constraints are reduced. Further, since the devices do not need to be series connected, spectral mismatch losses are reduced, which is important for tandems in terrestrial environments.