Point Focus Solar Spectral Splitting Element for CPV Applications

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Abstract

Solar spectral splitting technologies have been investigated over the years as alternatives to improve the efficiencies obtained from photovoltaic devices. The approach allows for the circumvention of the limitations posed by multijunction cell technology - mainly lattice and current matching. In this study, a proposed optical splitter design is shown that is capable of concentrating the split light onto a single point for each respective wavelength.

Introduction

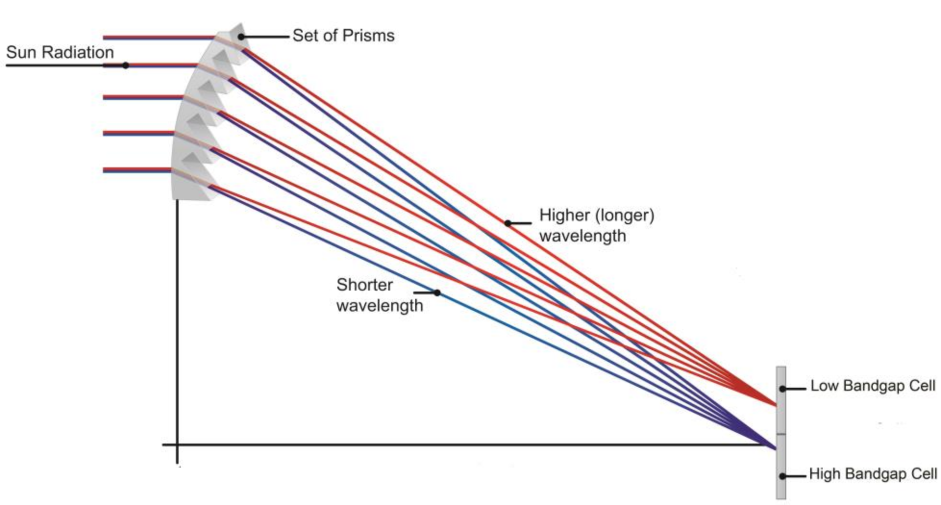
Spectral splitting was an idea originally an idea of multiple patent-holder, Joseph R. Dettling. He filed in his patent, suggesting the use of a concentrator, and a splitter to attain higher efficiencies for solar-based photovoltaics [1]. By making use of the split light, Dettling proposed that the cells be chosen such that their bandgaps are comparable to the energy level of the emitted photon based on the equation:

$$E = h\nu = \frac{hc}{\lambda}$$

In his patent, Dettling goes on to state that the exclusion of any of the two main constituents would compromise the performance of the system. Further studies performed in the field of optics [2,3] have shown that the use of multiple optical elements in a system however, will increase its losses with values typically ranging between 7% and 11% per optical element. It becomes important to therefore produce an optical element capable of simultaneously splitting and concentrating the light unto a predefined receiver.

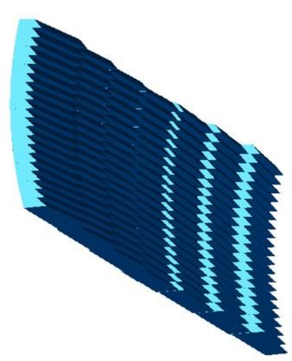
Mathematical Framework

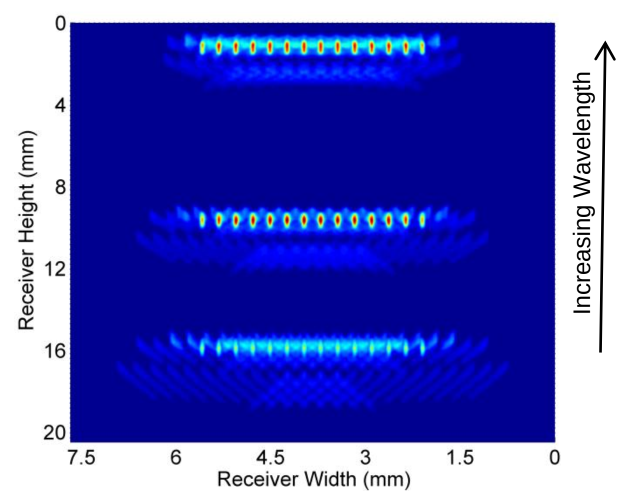
The optical design consists of prisms, arranged in a fashion such that the output light of all prisms lands on the exactly the same position. The result is a concentration via superposition of the exit wavelengths on the receiver. The figure below is a 2D cross section showing the device's operating principle.

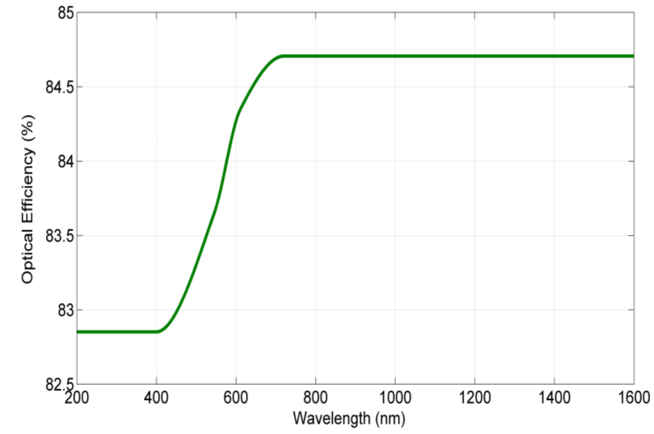


Results

The optical element takes into account the device's geometric parameters such as the angle of incidence, the deviation angle, the exit angle, and the distance the receiver is from the element. It is optimized such that reflection losses at each interface are minimized, and the size of any given output wavelength's spot does not exceed 5 mm in width and 5 mm in height all while maintaining an average concentration ratio exceeding 150. In addition, geometric constraints were applied to the design to produce a single, continuous element that is easy to manufacture. The results of these constraints is the element below with the receiver output and the optical efficiency shown.







1 . J. R. Dettling, "High efficiency converter of solar energy to electricity," (US Patents, 1977)
2 . J. Onffroy et. al, "High-efficiency concentration/multi-solar-cell system for orbital power generation," Energy to the 21st century, 371-376 (1980)
3 . Stefancich, Marco, et al. "Single element spectral splitting solar concentrator for multiple cells CPV system." *Optics Express* 20.8 (2012): 9004-9018.

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