Multi Band Gap High Efficiency Solar Converter (RAINBOW)

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A novel technique to increase solar array efficiency is to split the solar spectrum and focus each portion on a different cell band gap. This technique was first conceived by Wade Blocker and Ivan Bekey in 1978. This paper reports on the reexamination of the spectrally split, individually matched cell approach using modern-day optics and lightweight structures.

The system concept uses an optical concentrator, a collimator, a spectrum splitter (dichroic filters or prisms), and cells which are band gap matched to the passbands. Individual cell data are based on state of the art solar cells, when available, and on the results of single junction cell efficiency measurements under selective illumination. For band gaps for which photovoltaic data are not available, performance estimates are based on actual material data and derated to account for stages of development and real materials issues. In addition, overall system efficiencies are also projected and account for anticipated losses. This is called the RAINBOW system concept because it can be readily extended to a larger number of cell band gaps.

The JPL computer model calculates optimum band gaps for a system with different numbers of band gaps. Due to selective illumination, the efficiencies of each cell in a spectral splitter system are higher than under a full AMO spectrum. The model yields an optimum 9 cell system whose efficiency is between 42% and 50%. The calculated band gaps for this 9 cell system range from 3.06 eV down to 0.60 eV. Each band gap corresponds closely to a practical material which has been used for either photovoltaics (PV), thermophotovoltaics (TPV) or optoelectronics.

Initial system level efficiency calculations assume a linear Fresnel optical concentrator and dichroic filter beamsplitters. Key system trades include: number of cells and their band gaps, the most effective way to split up the input spectrum, the concentration ratio, mass and cost, The optimum systems are found to include four real cells: GaN or 6H-SiC, GaInP, GaAs and Ge. The projected system-level efficiencies are 40.04 % with GaN and 40.30 % with 6H-SiC. As high and low band gap cell performances improve, there may be a larger advantage to the use of more than 4 band gaps.

The optical concentrator reduces the overall cost impact of the relatively expensive cells and beam splitters. A preliminary cost estimate shows that the cost and mass of a RAINBOW system with three band gaps appear comparable to those of industry's SCARLET stacked-cell concentrator system. RAINBOW, however, can be expanded to a larger number of band gaps.

In summary, RAINBOW represents a unique combination of features. The use of separate cells offers the widest possible scope of material choices. Many different component combinations are possible. The relatively low temperature operation, due to reduced thermal input per cell, adds to the performance increase. Finally, RAINBOW is a flexible system which can readily expand as new high efficiency components are developed. RAINBOW is expected to convert over 40% of incident solar energy to electricity at the system level. This conclusion is based on preliminary analyses of cell and optics performances. Breadboard model hardware is being fabricated to obtain quantitative performance measurements.

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