PHOTOVOLTAIC CHARACTERIZATION OF MULTI-JUNCTION III-V CONCENTRATOR SOLAR CELLS UNDER ULTRA-HIGH FLUX OF REAL SUNLIGHT

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Most of photovoltaic (PV) cost-reduction approaches make the implicit assumption that the same area of expensive PV material that is needed to generate the electricity is also needed to collect the solar radiation. However, concentrator photovoltaics (CPV) changes this common paradigm in a fundamental manner by separation the function of solar energy collection from the function of solar energy conversion. The collection function is performed by large areas concentrating mirrors or lenses made of low-cost materials (e.g. glass, plastics, etc.) that concentrate light onto a small area of PV material. Now solar cells can be produced by expensive but most effective way. The highest efficiency solar cells known are of III-V multi-junction cells (up to ~ 41 %).

The above-mentioned trade-off of reducing costly solar cell material in CPV systems pushes the development of solar cells towards accepting ever-higher concentration levels. In practice, effective concentrations of 1000 suns and higher are feasible (1 sun = $1 mW/mm^2$). We refer these concentration levels (> 1000 suns) as "ultra-high flux" regime. The behavior of PV cells in this regime is far from fully understood. Testing is typically performed by exposing the cells to light under pulse solar simulators for very short periods of time. In contrast, we propose to characterize concentrator cells under continuous radiation using natural sunlight concentrated to ultra-high flux.

Recently we have shown that a fiber-optic/mini-dish concentrator can be used as an *indoor* test facility for ultra-high-flux characterization of concentrator solar cells [1].

In such a facility solar beam radiation is collected and concentrated outdoors and is focused into a high transmissivity optical fiber and then delivered indoors onto the solar cell being tested (Fig. 1). Radiation on the cell is moderated with a pizza-slice iris that is mounted on the dish window and preserves the angular distribution of delivered sunlight. Near-perfect flux uniformity is achieved with a square cross-section kaleidoscope, matching the size of the cell, placed between distal fiber tip and cell (Fig. 1 b). The current system can deliver about 1,000 suns on a $16 mm^2$ cell or 4,000 suns on a $4 mm^2$ cell. Removing the kaleidoscope and varying the fiber height above the cell, we can realize a wide range of flux distributions, including the extreme localized irradiation limit when the fiber touches the cell such that radiation projected beyond the fiber tip is negligible (Figure 1 c and d). This localized irradiation probe allows ultra-high local flux levels of up to 10^4 suns (1 sun = $1000 W/m^2$).

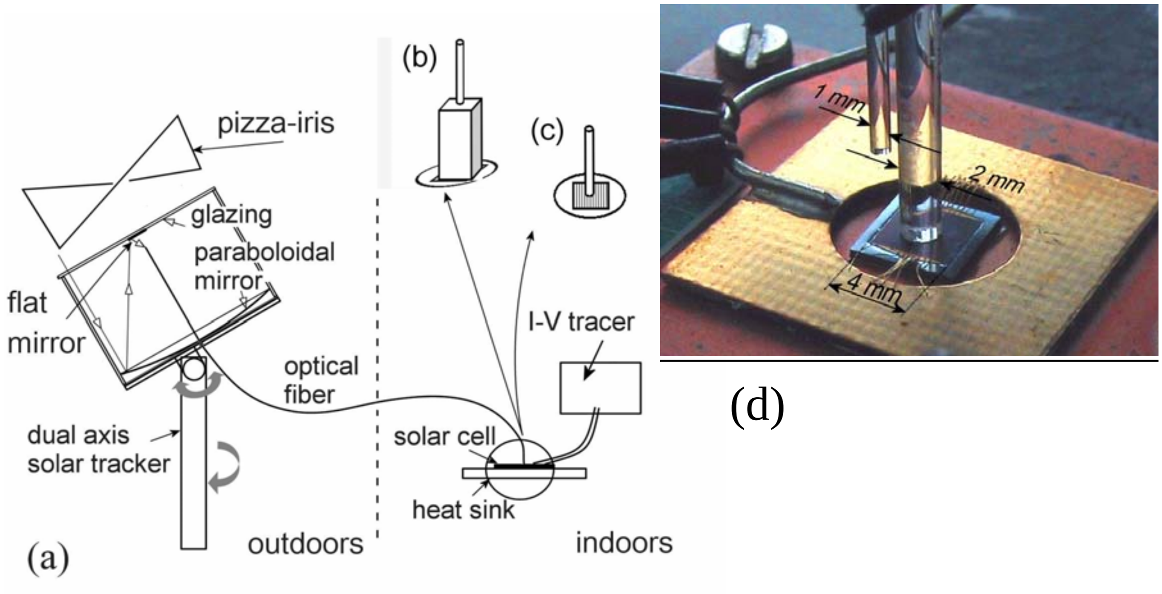

Fig.1. Schematic of our solar fiber-optic mini-dish concentrator test facility for uniform and localized irradiation modes of the experiments. (a) Solar radiation is concentrated outdoors by a concentrator prototype that is mounted on a dual-axis solar tracker. A mirrored parabolic dish is encased and topped with an anti-reflective coated glazing. A small flat mirror re-images the sun to the tip of an optical fiber which guides the concentrated sunlight to an indoor laboratory. Radiation input is moderated via a pizza-slice iris mounted on the dish window, preserving angular distribution of sunlight at the fiber exit. (b) Flux uniformity is achieved with a square cross-section kaleidoscope while (c) direct fiber/cell contact is used for localized irradiation probe. (d) Photograph of the direct contact between fiber and cell (produced at ISE) in the localized irradiation probe.

Both surprisingly high efficiencies of the tandem cells at fluxes up to 10,000 suns [1] as well as novel physical phenomena such as a hysteresis effect due to the tunnel diodes of multi-junction cells [2] were discovered with this facility. In addition we have developed new procedures for testing: (a) efficiency as a function of controlled variation of light concentration (ranging from 1 to 10,000 suns) [3-4]; (b) effects of non-uniform irradiation of the cell as opposed to uniform irradiation [3-4]; (c) testing the integrity and uniformity of the cell as function of light spot location on the cell [4]; (d) testing of very small cells (with photoactive area of 1 mm^2) [5].

References

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