# Equipment Loan for Concentrated PV Cavity Converter (PVCC) Research

## Cooperative Research and Development Final Report

## CRADA Number: CRD-08-285

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# Cooperative Research and Development Final Report

In accordance with Requirements set forth in Article XI, A(3) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

**Parties to the Agreement**: United Innovations, Inc.

**CRADA Number:** CRD-08-285

**CRADA Title**: Equipment Loan for Concentrated PV Cavity Converter (PVCC) Research

**Joint Work Statement Funding Table Showing DOE Commitment**:

| Estimated Costs | NREL Shared Resources |
|---|---|
| Year 1 | $ 178,000.00 |
| TOTALS | $ 178,000.00 |

**Abstract of CRADA Work**:

Interest in High Concentration Photovoltaics (HCPV) for terrestrial applications has significantly grown in recent years. A major driver behind this growth trend is the availability of high efficiency multi-junction (MJ) cells that promise reliable operation under high concentrations (500 to 1000 suns). The primary impact of HCPV on the solar electricity cost is the dramatic reduction in cell cost. For terrestrial HCPV systems, operating at concentrations ≥ 500 suns, the expensive MJ cells are marginally affordable. Most recently, triple-junction test cells have achieved a conversion efficiency of over 40% under concentrated sunlight. Photovoltaic Cavity Converter (PVCC) is a multi-bandgap, high concentration PV device developed by United Innovations, Inc., under subcontract to NREL. The lateral- (2- dimensional) structure of PVCC, as opposed to vertical multi-junction (MJ) structure, helps to circumvent most of the developmental challenges MJ technology has yet to overcome. This CRADA will allow the continued development of this technology by United Innovations.

This project was funded by the California Energy Commission and is the second phase of a two-part demonstration program. The key advantage of the design was the use of a PVCC as the receiver. PVCCs efficiently process highly concentrated solar radiation into electricity by recycling photons that are reflected from the surface of the cells. Conventional flat, two-dimensional receivers cannot recycle photons and the reflected photons are lost to the conversion process.

**Summary of Research Results**:

The objective of this project was to prove the feasibility of using multi-faceted optics as a solar concentrator and an optical cavity containing multiple, spectrally selective (Rugate) filters to economically capture portions of the solar energy, sending each portion to a detector tailored to a specific frequency range. The overall goal was to develop a solar energy conversion device with very high efficiency and low cost. To accomplish this goal the researcher established the following objectives:

1. Create an optical system with a Photon Utilization Factor (PUF) in the cavity greater than 0.9. The PUF is the probability of a photon entering the cavity to be captured in a matching converter cell.
2. Select four candidate materials from those in the III-V group that span the solar spectral range for the sub-cell photon converters.
3. Achieve composite field of view of +/- 30 degrees and light throughput efficiency of the facetted insect eye optics of at least 80%.
4. Achieve solar flux concentration ratio inside the cavity greater than 30 suns.
5. Determine the optimum operational cell temperature.
6. Achieve overall performance of the proposed system of >38% @ 25o C.
7. Develop a low-cost manufacturing process to achieve system costs of less than $3/watt.

Outcomes:

1. The researcher measured the PUF in the cavity at 0.806.
2. The researcher identified four candidate materials (III-V) for the sub-cells: InGaP, GaAs, InGaAsP, and InGaAs. Their transmission frequency bands are, respectively, 350-650 nm, 650- 850 nm, 850-1050 nm, and 1050-1800 nm.
3. Maximum composite field of view was +/- 30 degrees off normal. Light throughput efficiency of the facetted (insect eye) optics was 63%.
4. Highest solar flux concentration ratio inside the cavity was just over one tenth of a sun, that is, it was 0.11 suns.
5. The researcher determined the operational cell temperature to be 650 C @ 250 C and 50 suns.
6. The researcher calculated the overall performance of the system at 22.27 % @ 250 C and 50 suns.
7. The researcher provided insights into potential low-cost manufacturing steps for the system. They included nickel electroforming for the faceted optics. For the cavity, the researcher suggested spin forming of aluminum.

**Report Date**:

June 22, 2015

**Responsible Technical Contact at Alliance/NREL**:

Judy Netter for Carl Bingham (retired)

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