PORTABLE CONCENTRATING SOLAR POWER SUPPLIES

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ABSTRACT

JX Crystals Inc is developing a class of compact portable solar generators using commercially available 32% efficient multijunction solar cells. Three different sized solar generators with nominal power ratings of 12 W, 36 W and 75 W are described. The high solar cell efficiency will allow all three units to be small, portable, and light weight. (For example, the 12 W generator will fit in a pocket.)

The 36 W Charger is exemplary. The 36 W Charger in its stowed form will resemble a notebook computer case in size and form Deployed, its physical size is half that required for a traditional Silicon 16% solar cell Charger and one-quarter that for a 8% thin film solar cell Charger.

A challenge for the use of these 32% efficient cells is their cost. This cost can be reduced ten fold through the use of linear Fresnel lenses as per the designs described herein. The challenge is to preserve simplicity of operation. By using bypass diodes in the cell circuits and by orienting the lens focal line and cell circuit East and West, the smaller 12 W and 36 W units can be easily aimed at the sun and they will then maintain output without adjustment for 2 hours in the middle of a sunny day.

A simple 1-axis solar tracker is also proposed for the larger 75 W unit. It can fit within the stowed case where the case will fit within a backpack.

BACKGROUND

JX Crystals Inc is a small company that spun out of Boeing in 1992 with a license to make concentrator photovoltaic devices and systems. At that time, two of the present authors (L. Fraas and J. Avery) had invented [1] and demonstrated the first 35% efficient multi-color solar cells [2]. The goal of JX Crystals Inc has been and is to commercialize low cost terrestrial solar concentrator PV (CPV) systems. In order to accomplish the above goal, one can choose to pursue longer term materials research or shorter term product development. Herein, JX Crystals Inc chooses the shorter term product development option because it can create more jobs in manufacturing over the next 2 years by integrating the 30% cells already developed for space applications into compact lightweight portable battery chargers useful for soldiers and then civilians for numerous unspecified battery charging applications within a relatively short product development cycle. These battery Chargers can then familiarize the public with the CPV option and jump start production of other larger scale terrestrial CPV systems.

Light weight triple junction (TJ) solar cells have already been developed for space satellites. However, they are very expensive. High efficiency concentrated sunlight versions of these multi-color cells are also now available as can be seen in figure 1. There are significant benefits associated with using concentrated sunlight in that the cell efficiencies improve and the cell costs are dramatically reduced.

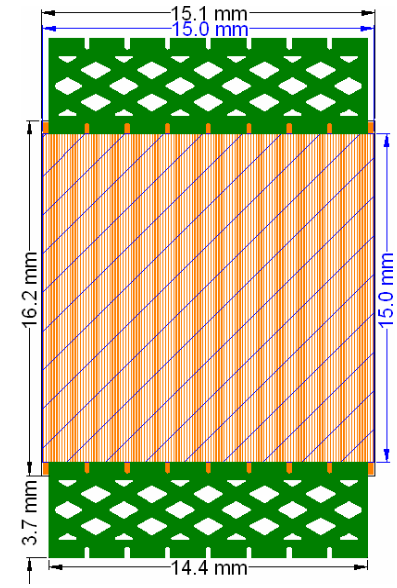


Figure 1: Commercially available multi-color TJ concentrator solar cell with over 30% efficiency.

Figure 2 shows efficiency vs solar concentration and cell temperature for the Spectrolab's cells shown in figure 1.

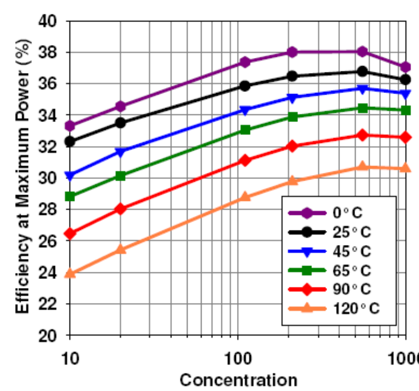
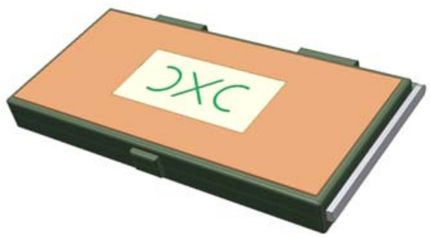


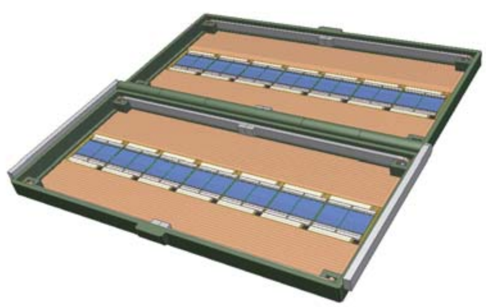
Figure 2: Cell efficiency and maximum power as a function of concentration ratio and operating temperature.

TECHNICAL CONCEPT FOR COMPACT EFFICIENT SOLAR BATTERY CHARGER

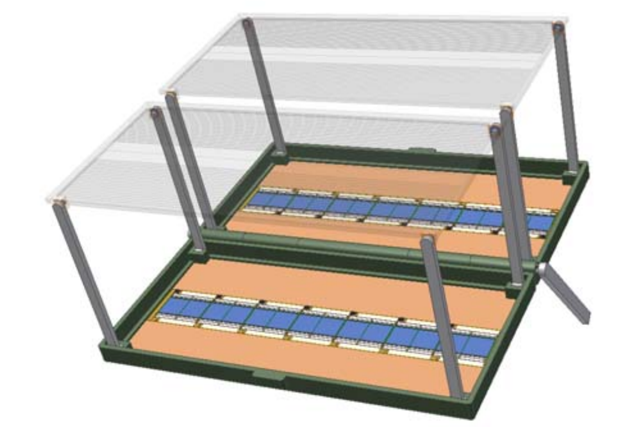
Imagine that a linear Fresnel lens is mounted on folding legs so that it can collapse down close to the cell plane to make a compact module. Then imagine two of these lens and circuit pairs in a foldable case. Then imagine this unit folded up into a very compact case as shown in figure 3a. The unit shown in this figure can generate 12 W and has dimensions in its folded form of only approximately 4" x 8" x 1". It can fit in a pocket. Figure 3b shows this 12 W unit open and figure 3c shows it deployed.



(a)



(b)



(c)

Figure 3: A concept for a compact solar battery charger. (a) Shows 12 W Charger in folded 4"x8"x1" case. (b) The case is opened showing the folded lenses. (c) The lenses are removed from the case, the lens legs are folded out and the lenses are inserted into corner slots. The charger is deployed in the sun with circuits aligned E and W and the side legs are swiveled out to the appropriate sun angle.

In the configuration shown in figure 3, the cell rows are horizontal. In the middle of the day, the sun travels slowly horizontally across the sky so that the sun's image will travel along the horizontal cell row. This means that this unit will maintain focus and electric power output for several hours without adjustment. The next section explains how this happens.

DESIGN RULES FOR LINEAR LENS PORTABLE SOLAR BATTERY CHARGERS

Spectrolab's commercially available multi-color cells are normally intended for use with point focus lenses at much higher solar concentration ratios than proposed for use here. However, they can be used at 10 suns concentration. The voltage they generate at various concentration ratios is shown in figure 4.

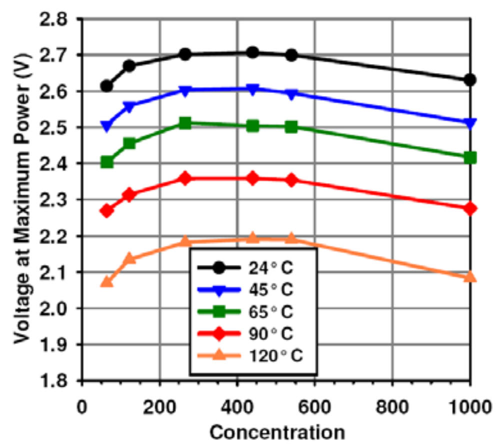


Figure 4: Voltage at maximum power for Spectrolab TJ cells.

At 10 suns concentration, each cell should produce 2.5 V at 45 C. Series connecting seven cell groups will then produce 17.5 V for battery charging. This then leads to the family of possible circuit configurations shown in figure 5.

Figure 5: Two possible circuit configurations with 7 groups of cells in series. The two examples shown have either 2 cells or 3 cells in parallel per group.

The upper circuit in figure 5 has seven groups with 2 cells in parallel per group. This is the circuit used for the 12 W Charger shown in figure 3. Notice that each cell group has a bypass diode. Now one can see why the charger shown in figure 3c can be left unattended for over 2 hours in the sun without requiring realignment. As long as 6 pairs are illuminated, the circuit will produce 15 V or more. The angle subtended by an end cell pair is 16 degrees and the sun moves 15 degrees per hour across the sky from E to W.

One can now see the design rules for a family of possible battery charges. For example, using 2 cells per cell group and one 4” wide (10 cm) lens per case shell leads to the 12 W Charger shown in figure 3. Using 3 cells per group and two 4” wide lenses in a parquet per shell will lead to the 36 W Charger shown in figure 6.

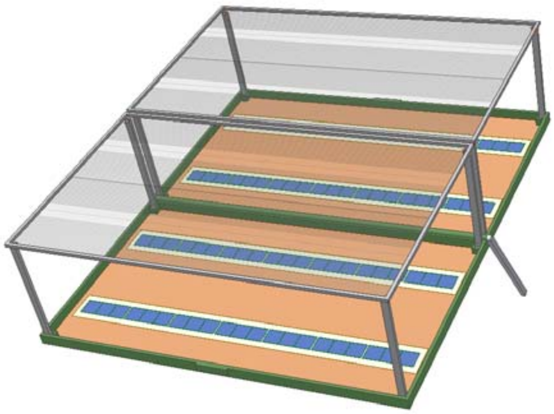


Figure 6: Deployed 36 W battery charger. Folded, it is about the size of a pad of writing paper.

One can now imagine 5 cells per parallel-cell-group and two 6” wide lens elements per shell and using seven parallel-cell-groups in series, one will arrive at a 90 W battery charger. However, this unit is large enough to think about auto sun tracking. In the case of auto tracking, one will only need six parallel-cell-groups in series to achieve the desired circuit charging voltage of 15 V. The resultant 75 W charger is shown in figure 7. It is small enough to fit in a backpack.

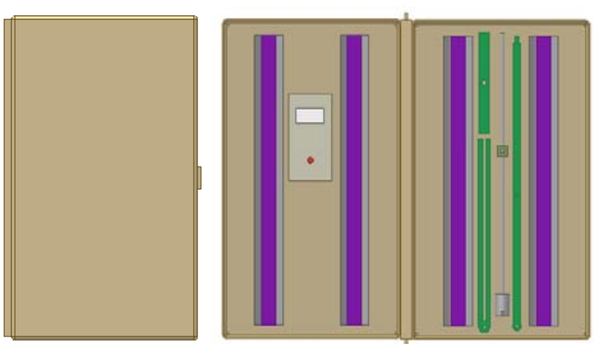


Figure 7: 75 Watt solar module: (a) Closed case [12.5” by 19.25”= 1638 cm^2]. (b) Open case before deployment [24.5” x 19.25”] showing circuits, tracking motor, controller, and legs.

It is interesting to note that the First Solar CdTe thin film module has a similar power rating of 75W. However as shown in figure 8, this triple-junction low concentration PV (TJ-LCPV) backpack is dramatically smaller. As one would expect based on the ratio of efficiencies of 30 % / 10%, the TJ-LCPV backpack is 3 times smaller when opened and 6 times smaller when looking at the closed case.

Also very important to backpackers, it should be considerable lighter. Based on extrapolations from data to be presented in the next section for the first 12 W prototypes, the weight of this TJ-LCPV backpack unit should be about 3.6 kg or 7.8 pounds.

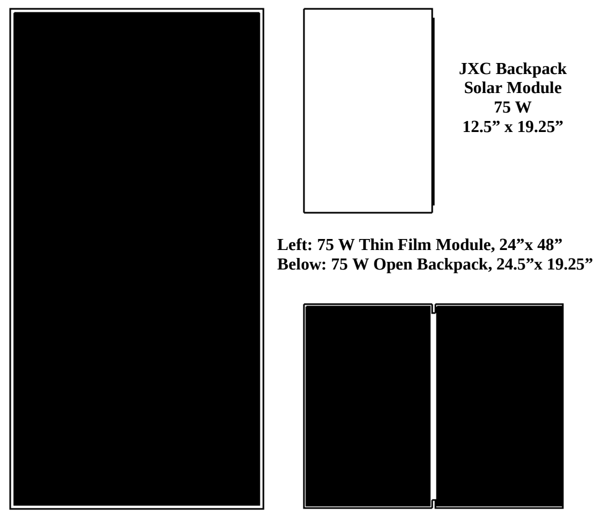


Figure 8: First Solar 75 W Thin Film Module vs JX Crystals 30% TJ LCPV 75 W Backpack Solar Module

SIMPLE SINGLE AXIS DEPLOYABLE SOLAR TRACKER

If one can imagine autonomous micro robots that crawl, walk, and fly, it should be quite easy to arrange for a solar module to follow the sun. In fact, this can be done with a single axis tracker as shown in figures 9, 10, and 11.

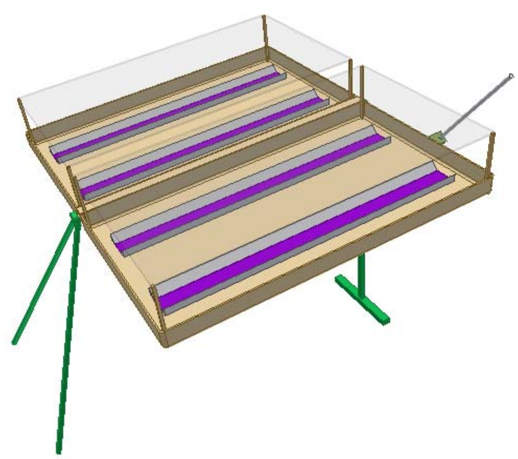


Figure 9: 75 W backpack module in deployed and tracking position.

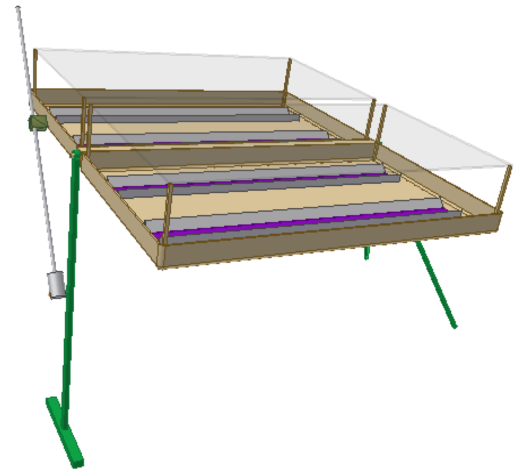


Figure 10: 75 Watt backpack module deployed and following the sun highlighting tracking motor and drive screw.

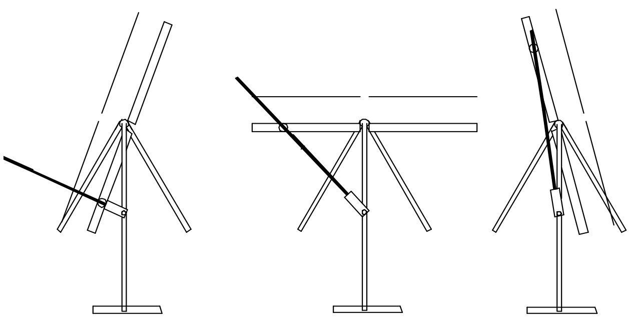


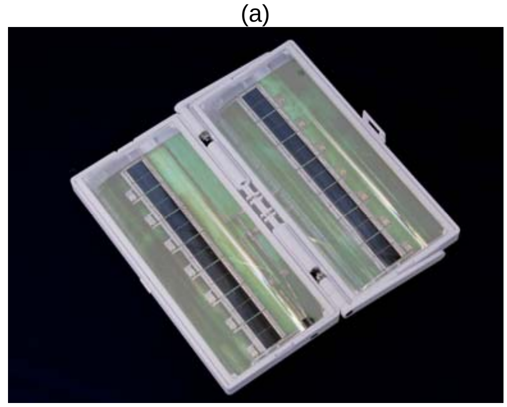
Figure 11: 75 W unit viewed from north facing south showing tracking in early morning (left), at noon (middle), and in late afternoon (right) as low power clock motor turns drive screw.

TEST RESULTS FOR FIRST 12 W PROTOTYPES

JX Crystals Inc has received a contract under the American Reinvestment and Recovery Act (ARRA) to develop the portable solar battery chargers described above. The contract is administered by the US Army Research Laboratory. This is a 2 year contract which began at the end of 2009. This contract begins with the smaller 12 W unit and will progress with time to the larger 36 W and 75 W units.

As of this writing, JX Crystals Inc has procured the required TJ cells from Spectrolab and the required linear Fresnel lenses from MMM and fabricated and tested three 12 W pocket sized units. One of these units used a copper backed circuit and the other two have used aluminum backed lighter circuits. Figure 12 shows one of these 12 W units as a package and during various stages of assembly for operation. The lens active width is 100 mm and the Al package weighs 570 g or about 1.25 pounds.

(a)



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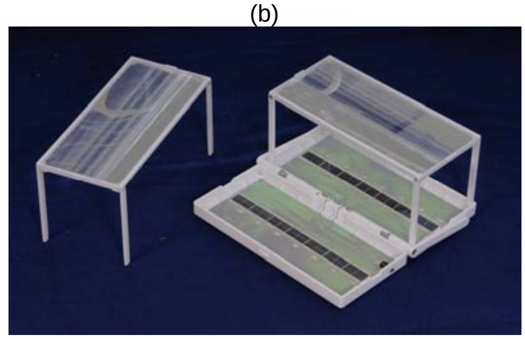

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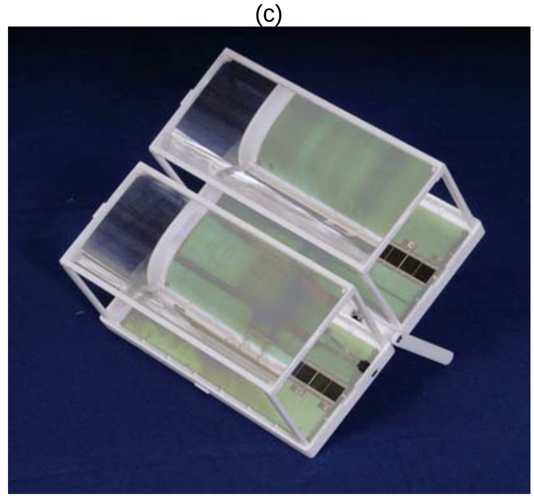

(d)

Figure 12: A pocket sized portable solar battery charger is shown (a) in stowed package, (b) opened with lenses inside, (c) with lenses removed, and (d) in final operating position.

These three units have been both flash tested and tested in operation outdoors. Fig. 13 shows the flash test results.

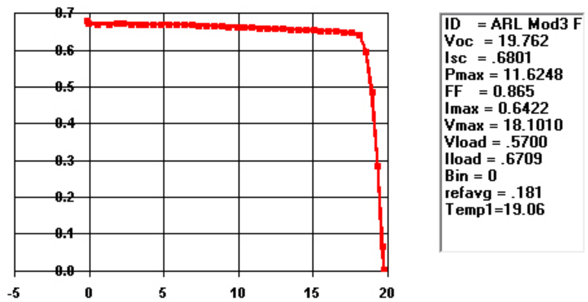

Figure 13: The flash test results Pmax = 11.6 W and Vmp = 18.1 V.

Figure 14 shows the outdoor test configuration and Table 1 summarizes the outdoor test results.

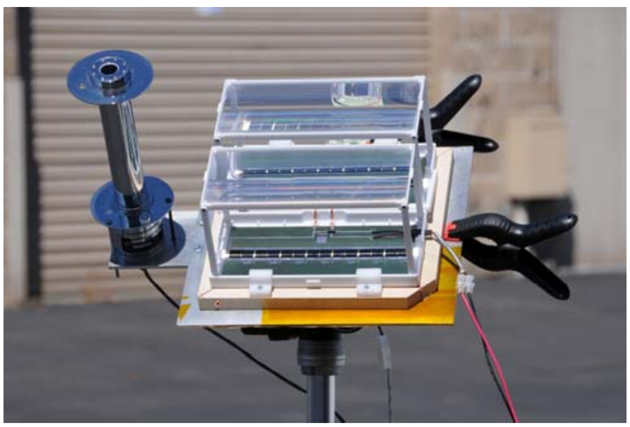

Figure 14: Outdoor test configuration for pocket sized solar battery charger (right) with Normal Incidence Pyroheliometer (NIP on left).

Table 1: Outdoor test results for pocket sized solar battery charger (5-13-2010).

ID	Pmax (W)	FF	Imax (A)	Vmax (V)	NIP	TC sub
Cu Sub	10.96	0.829	0.644	17.01	0.956	21
Cu Sub	10.37	0.813	0.649	15.99	0.952	51
Al Sub	10.92	0.837	0.642	17.01	0.952	24
Al Sub	10.24	0.815	0.642	15.96	0.948	51

SUMMARY AND CONCLUSIONS

JX Crystals Inc is developing a class of compact portable solar generators using commercially available 32% efficient multijunction solar cells at approximately 10 suns. Three different sized solar generators with nominal power ratings of 12 W, 36 W and 75 W have been described. The high solar cell efficiency will allow all three units to be small, portable, and light weight. (For example, the 12 W generator will fit in a pocket.)

A challenge for the use of these 32% efficient cells is their cost. This cost can be reduced ten fold through the use of linear Fresnel lenses as per the designs described herein. The challenge is to preserve simplicity of operation. By using bypass diodes in the cell circuits and by orienting the lens focal line and cell circuit East and West, the smaller 12 W and 36 W units can be easily aimed at the sun and they will then maintain output without adjustment for 2 hours in the middle of a sunny day.

The 36 W Charger in its stowed form will resemble a notebook computer case in size and form. The 75 W unit in its stowed form will fit in a backpack. Deployed, the physical sizes of these units are half that required for a traditional Silicon 16% solar cell Charger and one-quarter that for a 8% thin film solar cell Charger with similar power ratings.

A simple 1-axis solar tracker is also proposed for the larger 75 W unit. It can fit within the stowed case where the case will fit within a backpack.

ACKNOWLEDGEMENT

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