TEST SITES AND TESTING OF 3-SUN MIRROR MODULES

L. Fraas, J. Avery, H. Huang, L. Minkin, R. Gelinas, and J. Fraas
JX Crystals Inc, 1105 12th Ave NW, Suite A2, Issaquah, WA 98027, lfraas@jxcrystals.com

ABSTRACT

The demand for solar photovoltaic cells and modules has far outstripped PV cell supply and module prices are rising. To solve this problem, JX Crystals is developing a 3-sun mirror module that uses 1/3 the cell area to triple module production at a lower cost.

Our concentrator module design uses existing planar cells. We simply cut standard SunPower A300 cells into thirds. In addition, our module design uses standard circuit lamination procedures and equipment. However, we add a thin aluminum sheet at the back of the laminated circuit for heat spreading. While a standard planar module contains rows of pseudo square cells, our low concentration modules consist of rows of third-cells. We then locate linear mirrors with triangular cross sections between the cell rows. The mirror facets deflect the sun's rays down to the cell rows (patent pending).

Herein, we report on the design configurations, present photographs of the test systems, and present the initial outdoor test results.

MIRROR MODULE CONCEPT

The cost of high purity silicon feedstock today is well over $50 / kg whereas the cost of aluminum is only about $2 / kg. Crystal growth adds more cost to the silicon solar cells. Therefore, substituting aluminum mirrors for single crystal cell area can dramatically reduce the cost of a module. This reasoning leads us to the 3-sun module concept shown in figure 1.

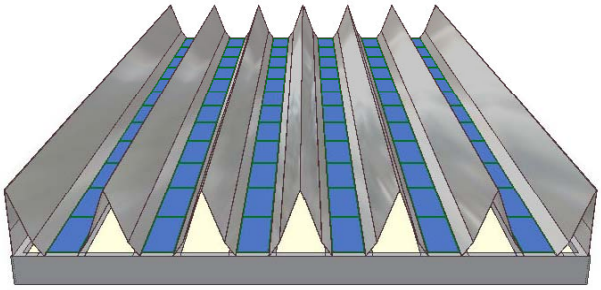

Figure 1: JXC 3-sun mirror module concept.

Our concentrator module design uses existing planar cells. As shown in figure 2, we simply cut standard 125mm x 125mm SunPower A300 cells into thirds. In addition, our module design uses standard circuit lamination procedures and equipment. However, as shown in figure 3, we add a thin aluminum sheet at the back of the laminated circuit for heat spreading. While a standard planar module contains rows of 125mm x 125mm cells, our low concentration modules consist of rows of third-cells with each row now 41.7 mm wide. We then locate linear mirrors with triangular cross sections between the cell rows (figure 1). The mirror facets deflect the sun's rays down to the cell rows.

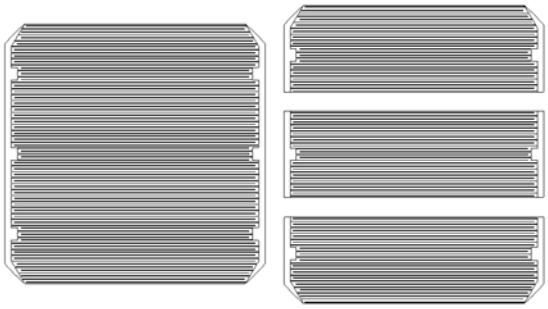

Figure 2: View from the back side of a A300 SunPower cell before and after being cut into 3rd cells.

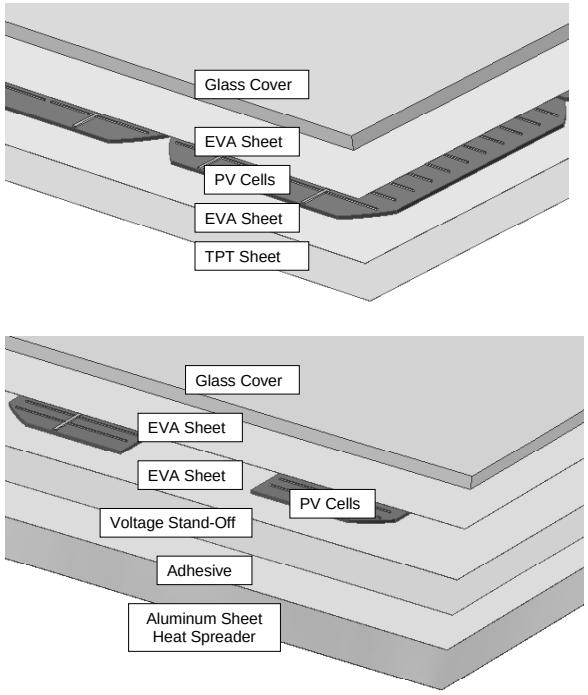

Figure 3: TOP VIEW The standard planar silicon module laminant and BOTTOM VIEW The addition of a metal sheet heat spreader to spread the heat uniformly over the whole back plane so that the air contact area for heat removal is preserved.

FIRST PILOT PRODUCTION RUN

In order to launch this new product, JX Crystals has received a contract from China. This contract is funding a 100 kW demonstration project at the Flower Port in Shanghai. In addition to funding this first demonstration project, this contract is also funding qualification testing for UL approval, the set up of various test sites to collect performance data in the South Western US, and initial manufacturing startup. We have designed the JXC 3-sun 180 W module shown in figure 4 for this 100 kW demonstration project. Our plan is that this 100 kW field will consist of 28 single axis N-S horizontal beams with 24 of these modules astride each beam.

JX Crystals Inc
180 W 3-sun PV Mirror Module
6 x 12 cell array
1.56 m x 0.81 m x 0.16 m

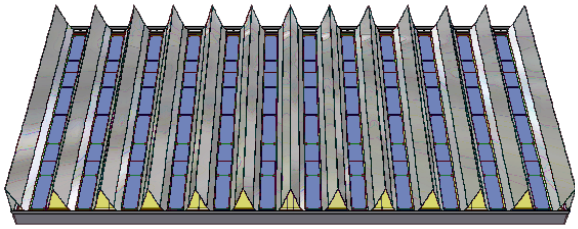

Figure 4: TOP JXC 3s-180 module design and BOTTOM Photo of first fabricated panel.

TEST RESULTS

At this time, we have fabricated 20 of these 3-sun modules in a first experimental pilot production run. Two of these first modules were then sent to Array Technologies in Albuquerque NM for outdoor testing. As shown in figure 5, these 2 modules were mounted along with a Sharp 175 W planar module on a 2-axis tracker. All three modules were tested and produced very similar amounts of power as shown in table I. Figure 6 shows the power outputs for the modules in Figure 5 throughout the day.

Figure 5: Two JXC 3s-180 modules and one Sharp 175 W module on 2-axis tracker in Albuquerque NM.

Table I: Test results for modules shown in figure 5.

	3-Sun # 10	3-Sun # 7	Sharp 175
Voc	44.51	45.25	39.95
Isc	5.75	5.74	6.11
FF	0.66	0.66	0.67
Vmax	33.82	34.39	30.36
Imax	4.98	4.98	5.35
Pmax, watts	168	171	163

Test conditions: 1.1 suns, 21oC, 12:48 pm,
8 Feb. 2006, Albuquerque NM
at Array Technologies.

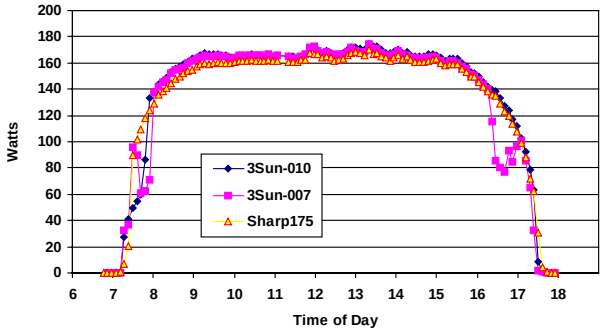

Figure 6: Power outputs for 3-sun #10 and #7 vs Sharp 175 on 2/10/2006 in Albuquerque.

Our JXC3s-180 module design allows for 2 different cell-wiring schemes changeable within the J-box. All 72 cells can be wired in series as was the case for table I or the 36 series connected cells on the left half of a module can be wired in parallel with the series connected 36 cells on the right half. Paralleling the two halves will be appropriate when modules are mounted on horizontal beam trackers to reduce the effects of row-to-row shading in the mornings and late afternoons.

Table II shows flash test results for all 20 modules. We have also measured module performance using mirrors from 2 separate suppliers. The results are shoen in table III.

Table II: Flash test module-performance summary.

ID	Voc	Isc	Pmax	FF	Imax	Vmax
N01	24.6	10.5	171	0.66	8.9	19.2
N02	24.5	10.6	184	0.71	9.9	18.5
N03	24.5	10.3	178	0.71	9.4	18.9
N04	23.8	10.6	175	0.69	9.9	17.6
N05	24.6	10.6	186	0.71	9.9	18.8
N06	24.3	10.4	179	0.71	9.4	19.0
N07	24.4	10.2	171	0.69	9.6	17.9
N08	24.6	10.4	179	0.70	9.4	19.0
N09	24.5	10.3	175	0.70	9.1	19.3
N10	24.5	10.3	173	0.69	9.5	18.3
N11	24.5	9.9	173	0.72	9.0	19.2
N12	23.8	10.1	166	0.69	9.1	18.3
N13	24.5	10.5	182	0.71	9.8	18.5
N14	24.5	10.2	173	0.69	9.0	19.3
N15	24.5	10.0	177	0.72	9.3	18.9
N16	24.7	10.0	175	0.71	9.3	18.9
N17	24.5	10.8	185	0.70	10.1	18.4
G01	24.5	10.5	181	0.70	9.5	19.0
G02	24.5	10.5	177	0.69	9.1	19.3
G03	24.6	10.4	171	0.67	9.0	18.9
Ave	24.4	10.3	176	0.70	9.41	18.8
Max	24.7	10.8	186	0.72	10.06	19.3
Min	23.8	9.9	166	0.66	8.90	17.6

Table III: Performance comparison for two different types of mirrors.

	Mirror Type-A	Mirror Type-B
ID	Pmax	Pmax
JXC-N004	174.66	181.1
JXC-N006	179.19	190.0
JXC-N016	174.90	183.9
Average	176.25	185.00

TESTING PLAN

Our first outdoor testing of 3-sun mirror modules began in July of 2005. At that time, an early smaller 3-sun module and a Sharp module were mounted on a carousel tracker in Southern California. Those two modules are still operating today and the performance results today are the same as they were last July. Both modules were and still are operating with a solar conversion efficiency of approximately 12%.

Our plan now is to distribute these newer 3-sun modules to various locations for qualification testing. As of this writing, we have already sent 3 modules to Arizona Public Service. They plan to mount them on a horizontal beam tracker. We have also sent 3 module to Arizona State University for thermal cycle tests. We hope soon to send two more 3-sun modules with mirror type A and mirror type B along with a Sharp module for comparison to ASU for mounting on a 2-axis tracker. Continuous outdoor monitoring will provide more information on mirror durability.

APPLICATIONS

We have already noted the potential cost advantage of the 3-sun module and its evolutionary advantage. There are two additional advantages. The first additional advantage is that these modules easily fit on existing single-axis trackers. The second additional advantage is that the mirrors are attached with edge brackets that simply screw onto the module frame and are easily removable and adaptable to different tracker configurations as shown in figures 7 and 8.

As mentioned above, our 3-sun modules can be used on single-axis horizontal beam trackers. In this case, the only two changes are the parallel wiring in the J-box and the need for mirror extenders as shown in figure 7. Mirror extenders can be added as shown on the South module to capture all the sunlight at noon in the winter.

Alternately, for a fixed elevation azimuth tracking carousel as shown in figure 8, the mirrors can have triangular cut ends to accommodate the suns elevation angle changes throughout a day.

The carousel design in figure 8 is particularly suited for mounting on the flat rooftops on commercial buildings. It has a very low profile for low wind resistance and no roof penetrations are necessary. Installation can be rapid and standardized.

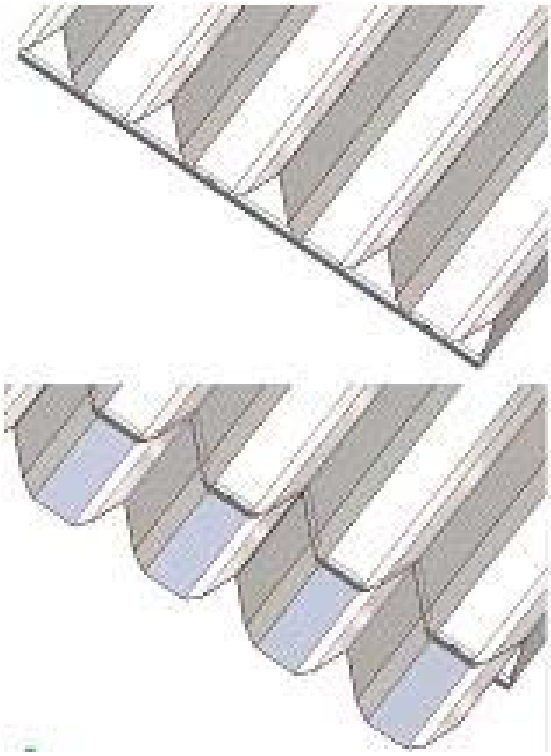

Figure 7: TOP The mirror array is mounted with screws through end brackets attaching it to the frame. BOTTOM Mirror extenders can be added at South end of a row of modules mounted on horizontal beam trackers.

CONCLUSIONS

We have described a new 3-sun module that has the potential to triple PV power production at half the cost of today's single crystal planar modules once these new modules enter high volume production. We have reported the test results for the first pilot production batch and shown that these modules produce power comparable to today's single crystal planar modules of a similar size. Our design is evolutionary and does not require the construction of new factories but it addresses the current silicon shortage potentially providing a path for continued rapid growth in PV systems.

ACKNOWLEDGEMENTS

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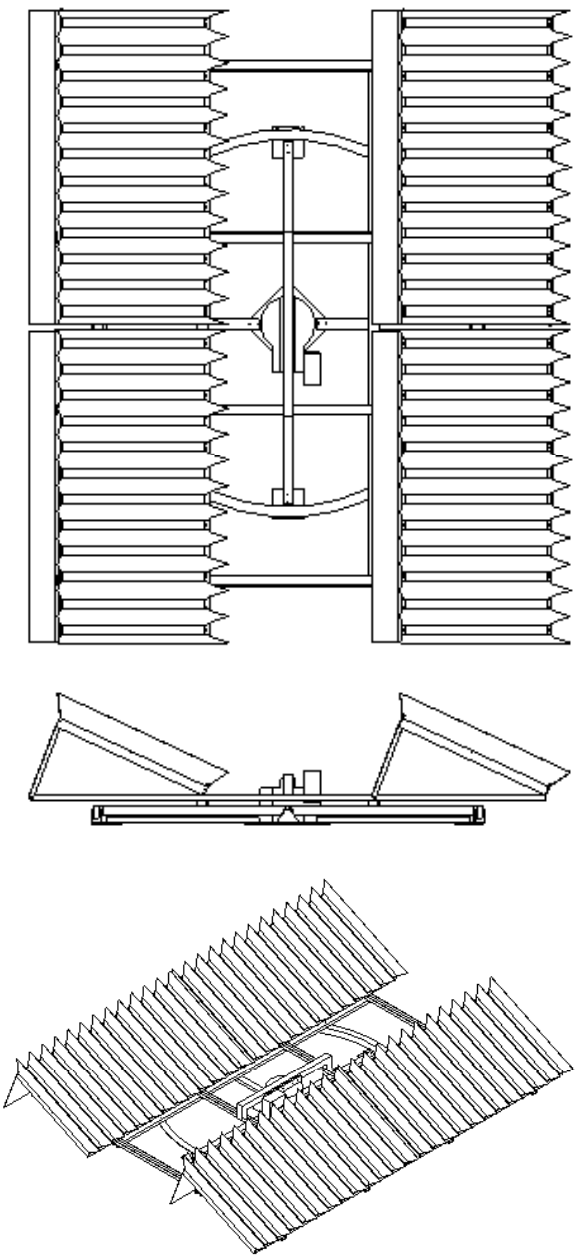

Figure 8: Low-profile carousel design with 4 JXC3s-180 Solar PV Mirror Modules for mounting on flat commercial building rooftops. Dimensions: 103" Wide x 124" Long x 25.5" Tall.