



CONCENTRIX SOLAR GMBH

## III-V solar states its performance case

Looking out of the window on the train from Madrid to Seville, you might catch sight of a phalanx of solar panels in a key test plant for compound semiconductor-based energy production. With sites like this becoming increasingly common, the concentrating photovoltaic industry gathered in Madrid to report their systems' latest results at the CPV Today summit, and **Andy Extnance** joined them.

If we were to look for a birthplace for the current resurgence of compound semiconductor solar technology, Madrid could make a strong claim. This year the Institute for Concentrator Photovoltaic Systems (ISFOC) has begun an authoritative study into the effectiveness of III-V-based systems. Although the tests are spread across Spain, this initiative was developed by the Universidad Politécnica de Madrid (UPM). Madrid also recently held the inaugural Concentrated Photovoltaics (CPV) Today summit. Antonio Luque, director of the Solar Energy Institute at UPM, underscored the importance of the meeting as he gave the first presentation, calling it "the starting gun in the race for CPV".

Despite clearly being taken aback by the buzzing 350-strong audience, Luque and his colleague Gabriel Sala opened proceedings by welcoming the broad interest as crucial for the industry. The obvious presence of investment bankers and analysts in the throng prompted conference chair Sala to call for improved understanding of the difference between concentrating and conventional silicon photovoltaics among the financial community.

The difference that Luque went on to detail predominantly revolves around the use of compound semiconductor cells at the heart of CPV solar arrays. These cells monolithically integrate GaInP and GaAs layers on top of a germanium substrate, with

each layer absorbing a different portion of the spectrum. These triple-junction cells comfortably hold the record for conversion efficiency of solar energy, delivering 40% compared with silicon's 27%.

The bad news is that this benefit comes with the additional expense common to compound semiconductor/silicon comparisons. However, Luque made the point that whereas silicon is now approaching its theoretical efficiency limit, he believes that monolithic III-V cells could reach at least 50% efficiency. For this to happen, a number of potential design advances could be exploited, for example by using quantum dots as an extra junction in the cells.

Until this happens, the refinement of current approaches still has much to offer. Geoff Kinsey, the technical lead in CPV products at US cell maker Spectrolab, explained what to expect from the company's latest generation of triple-junction technology. Due to hit the market in the third quarter of 2008, the C2MJ line is aiming to push the efficiency record to 42%. This 2% efficiency boost should translate to the company's day-to-day production averages, bringing these to more than 38% efficiency. By 2009 Spectrolab hopes to make as yet unspecified modifications of the materials used in their cells, to deliver a 43% hero-cell.

Azur Space, the European III-V cell manufacturer, cut its teeth in powering satellites, like Spectrolab



**Concentrated Photovoltaics (CPV) Today 2008** was held at the Mirasierra Suites Hotel in Madrid, Spain, on April 1-2.

The conference boasted more than 350 attendees, 24 speakers and 6 exhibitors, after initially being planned for an audience of only 150. "We had to open up into a second room to take the full capacity," said the organizers.



SOLAR SYSTEMS

**Solar Systems demonstrated** the effects of highly concentrated sunlight by using one of its concentrators to burn a hole in a piece of 6 mm thick copper.



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**The first 100 kW of** Concentrix's ISFOC installation in Puertollano was completed in February.

and Emcore. As such, the majority of its financing still comes from the space industry, with very little from CPV. In that sliver of CPV business, the company supplies system makers like Concentrix Solar and Sol3G with cells that attain 35% conversion efficiency at 500× concentration. However, according to the company's director of business development, Gerhard Strobl, more interest is needed to push his company's research for CPV further.

**Power networking**

Although there is room to improve cell efficiency, without an economic driver these possibilities would remain academic. A key point that CPV Today underlined is that, across the world, increased backing from the energy industry is providing this driver. So, with power companies forming a notable subset of attendees alongside the financiers, the leading system makers sought to show the promise of CPV in general and their products in particular.

Ironically, for a conference held amid the hotbed of Spanish CPV, the most definitive data on system performance came from German and Australian companies. One of the first three participants in ISFOC, German company Concentrix Solar, installed the first 100kW of its 300kW project allocation in February. Given the early stage of that work, Concentrix instead showed results of a typical September day in 2007 at a 5.75 kW plant in Llorca, Spain. Clear data showed module efficiency of more than 20% from before 10 a.m. until after 6 p.m. with output power peaking at more than 5 kW at 2 p.m. According to CEO Hansjörg Lerchenmüller, the efficiency benefits that this offers over competing silicon systems, which can offer only 14% module efficiency, readily convert to cost savings.

Lerchenmüller is undaunted that these early stage data come in at less than the 25% efficient modules that he says his company's technology is capable of. According to him, that performance level will help Concentrix beat the euro-per-watt cost of silicon by 2010. This will also be aided by the state-of-the-art production plant with annual module manufacturing capacity of 25 MW that the company is due to bring online in August.

Concentrix boasts the backing of energy companies Abengoa Solar and Good Energy, as well as an order backlog that will keep it busy for the whole of 2008. Having also spun out of the highly reputed Fraunhofer Institute for Solar Energy, Concentrix presented its results analysis with the assurance of a company set to be a key force in CPV.

Australian company Solar Systems could be considered one of the pioneers of the current wave of CPV technologies. It has existed since 1990 and has operated commercial systems for 10 years. It is also a convert from silicon to compound semiconductor cells and confirms a 46% efficiency difference between the two with its own data.

Solar Systems' existing systems are typically dish concentrators, in comparison to the planar

heliostat arrays common elsewhere in the world. John Lasich, the company's CTO, was able to present data on a 130kW peak output dish power plant, where the best dishes delivered 23.7% efficiency. At another facility, two years of data showed a single 33 kW receiver producing 196kWh per day, under 7kWh/m<sup>2</sup> of solar radiation on average. This corresponded to 21.2% system DC efficiency, which dropped to 19.6% when converted to the AC that is compatible with the electricity grid.

Solar Systems can claim its own energy company backer in the shape of TruEnergy, a subsidiary of China Light and Power, as well as strong support from the Australian government. These partners will help the company convert to heliostats for deployment in a 154MW power plant due for full commissioning in 2013. On this massive scale – and using Spectrolab cells – Solar Systems will once more be forging a path for modern-day CPV.

For other system makers, proving manufacturing ability was of more importance than showing results. Amongst these was Concentración Solar la Mancha – now part of the Renovalia Energy group, which claims to be the major installer of photovoltaic parks in Spain. Its CEO, Miguel Trinidad, is an automobile industry veteran, who is seeking to exploit his manufacturing experience. The kind of discipline demanded by that industry, Trinidad reasons, is key to getting the costs of CPV down.

**Strategic concerns**

Emcore brought the biggest delegation from a single company, representing its broader focus compared with its rival Spectrolab. Instead of its GaAs-based cell development, the company used its presentation to promote its CPV systems. Earl Fuller, the vice-president leading this business unit, promoted his systems by citing Emcore's prior experience as a provider of capital equipment in manufacturing compound semiconductor reactors. Fuller talked about system deals that include participating in ISFOC, and an 850kW deployment in Spain, but could claim little in the way of installed capacity.

This system focus unsettled some at the conference, who could otherwise be Emcore's cell customers. They feared that Emcore could vertically integrate all of its cell production, tipping their preference in favor of Spectrolab's record-holding, albeit costlier, cells. However, the presence of newer, alternative III-V cell manufacturers at CPV Today, like Solar Junction and Taiwan-based LED manufacturer Arima, might have reassured these worries. Furthermore, rumors suggested that the likes of Sharp and Samsung might soon further broaden CPV cell supply.

Emcore's system focus also meant that there was no mention of its major terrestrial III-V cell customer, Green and Gold Energy, which itself generated some comment. Internet speculation about the relationship between the companies wiped a third off Emcore's stock price in a day, just two weeks

prior to CPV Today. Some attendees speculated that Emcore might be trying to disown Green and Gold, but David Danzilio, head of Emcore's photovoltaics division, denied this. Instead he pointed out that for his colleague Fuller, Green and Gold is a competitor and hence should not be mentioned in talks focused on Emcore's power-generating systems.

The controversy surrounding Emcore and Green and Gold served as a focus for a concern expressed by many at the conference. They felt that the presence of investment analysts and bankers could be a mixed blessing. With some attendees citing experience in the telecoms industry, whispered anxieties of the solar industry being pumped up into an economic bubble by unscrupulous financial types underlay the otherwise positive tone.

For Green and Gold's part, CEO Greg Watson made a confident show of his company's technology, developed using AUS\$500,000 (\$472,000) investments from Watson and private investors. Now, Green and Gold is close to making its SunCube systems commercially, further funded by \$6 million earned licensing manufacturing rights outside the company's native Australia. Watson claimed a "real world" peak efficiency of around 30% for his modules on the roof of the Green and Gold facility in March 2007. He also presented standard test data but questioned the usefulness of the recent

IEC 62108 standard for safety and reliability of the CPV module. The lack of an accredited test for output power meant that no direct comparison could be made with silicon photovoltaics. This fact, Watson felt, bore the signs of undue influence from silicon industry participants in defining the standard.

The final talk came from the mayor of the Spanish town of Puertollano, where two ISFOC installations are sited. During the conference, descriptions of Puertollano approached a kind of CPV El Dorado. Take the train from Madrid to Seville, Lerchenmüller said, look out of the window and there you'll see our installation. Indeed as well as ISFOC, Puertollano will soon host a separate research center belonging to system maker SolFocus.

Puertollano, which has christened itself the "International City of Energy", is historically a coal-mining town. As well as retaining a strong petrochemical industry, it boasts the first monosilicon wafer plant in Spain. BP Solar is also investing €100 million (\$155 million) here to build one of the largest solar module plants in Europe.

The presence of these power incumbents so close to the ISFOC pilots is a good reminder of the reality of CPV technology, which is clearly beginning to happen and is starting to grow. Yet there is still much work to be done to find a place out of the shadow of CPV's larger power-generating rivals. ●



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