



# Land of opportunity

Over \$1 billion in venture capital flows to North-American solar start-ups in 2007

**At least 50 solar start-ups based in the United States are seeking to commercialize new concepts in silicon production, wafers, cells, modules, or inverters. Most of the cell and module innovators are focused on approaches using considerably less or no silicon material to harness the power of the sun – namely, thin film and concentrating PV. Many of the best and the brightest of this next generation of solar scientists and entrepreneurs are based in the start-up rich San Francisco Bay Area.**

The term »Silicon Valley« emerged in the 1970s to signify the burgeoning silicon-based semiconductor chip industry in the Santa Clara Valley, at the southern edge of the San Francisco Bay. Today, the term is applied more generally to a region that is home not only to semiconductor and computer heavyweights such as Applied Materials and Apple, but also Internet developers like Google and a wealthy host of high-tech venture investors who continue to spur the region's entrepreneurial spirit into ever new areas of innovation. Lately, Silicon Valley has emerged as the nation's hottest incubator of solar energy start-ups.

Of the 50 US PV start-ups identified by PHOTON International for this article – which does not include installers or companies still in stealth mode – 22 are headquartered in Silicon Valley or the greater San Francisco Bay Area. Venture capital investors are breaking records in

terms of funding these companies, perhaps only a handful of which will actually make it to commercial manufacturing. Indeed, some may end like Spheral Solar, whose investors spent \$140 million on a »revolutionary« crystalline silicon technology that has now been abandoned (see PI 10/2007, p. 80). There are surely other such failures in the making, reminding us of the nature of venture capital: risk.

But where there is risk, there is often also opportunity. And this is the case when it comes to the fast-growing, multi-billion-dollar market for solar energy. According to the Cleantech Venture Network LLC, a US-based group whose members include many of the world's largest VC firms, venture capital investment into North American solar companies this year is on pace to transcend \$1 billion for the first time, compared to \$318 million in 2006. This only includes deals that have actually been disclosed.



**Golden opportunities:** San Francisco's Golden Gate Bridge is the gateway to Silicon Valley and solar-friendly venture capital. It is not surprising that the Bay Area has by far the densest cluster of solar energy start-ups in North America.

During the first three quarters alone, solar start-ups reported 48 separate deals worth \$940 million, which also includes a number of solar thermal power plant companies. In the heart of Silicon Valley is one company that



**Entrepreneur of the year:** A developer of low-cost substrates for high-concentration cells, Wakonda won a \$10,000 award from NREL in November.



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many current start-ups must look to as a role model: San Jose-based SunPower Corp., whose single-crystal silicon solar cells – and majority owner Cypress Semiconductor – fit the regional moniker perfectly. It was just over three years ago that SunPower became a truly commercial enterprise with its first 25 MW capacity cell fab in the Philippines. As of late November, the Nasdaq-listed company has a market capitalization over \$10 billion and forecasts revenues of up to \$1.25 billion next year.

While SunPower would »love to emulate Apple,« as CEO Tom Werner said in a recent interview with PHOTON International (see PI 11/2007, p. 86), no doubt the newest Silicon Valley solar start-ups would love to emulate SunPower. One company would even love to become a supplier: neighboring Solaicx, the Santa Clara-headquartered monocrystalline silicon ingot start-up, which has raised about \$45 million in venture capital so far (see box, p. 71).

If all goes as planned in coming months, Solaicx will be the next ex-start-up from Silicon Valley. On Nov. 20, the company flipped the switch at its first full-scale plant in Portland, Oregon, where it is in the midst of commercializing a high-throughput continuous-growth Czochralski method for producing ingots (see PI 2/2007, p. 58). The initial 40 MW capacity facility will also make wafers and is planned to expand to 160 MW by the end of next year. The site has enough room to accommodate about 300 MW of wafer production.

»In today's marketplace at the wafer level, that is a \$600 million run-rate,«



**Amorphous in Ohio: Xunlight Corp., formerly MWOE Solar, raised \$7 million in June for its single- and triple-junction amorphous-silicon modules, currently being produced on a pilot line.**

noted Solaicx CEO and president Bob Ford at the Pacific Growth Equities Clean Technology & Industrial Growth Conference in San Francisco on Nov. 8 – a two-day event that brought together investors and clean-energy start-ups mostly from the solar and biofuels sectors. This year, Solaicx expects to produce 10 MW of wafers at its existing pilot line in Santa Clara and its new production plant in Portland. Next year, the company forecasts wafer output of 75 MW. »We really believe we have a breakthrough technology in single crystal silicon,« Ford said. »It's an exciting time for a little company like Solaicx.«

The company, whose CTO is PV pioneer Bill Yerkes, was selected this

summer by the US Department of Energy (DOE) to participate in the Solar America Initiative's (SAI) Photovoltaic Module Incubator Series, which is aimed at helping early-stage companies move from the laboratory into production. Solaicx is also participating in SAI research projects led by SunPower and GE, the latter of which is already a customer (see PI 4/2007, p. 80).

Unlike Solaicx, for most of Silicon Valley's next generation of midstream and upstream PV companies the name doesn't quite fit; they use little or no silicon. For example, concentrating PV (CPV) developers EnFocus Engineering, SolFocus Inc., and Solaria Corp. are three Silicon Valley companies also included in the PV Incubator Series. Only the latter of these companies uses silicon cells. And Solaria's low-concentration modules for commercial rooftop and ground-mounted plants require one half to one third the polysilicon of conventional PV panels (see box, p. 71 and PI 7/2007, p. 76).

### Concentrating PV

High-concentration PV developer SolFocus has raised about \$95 million since founding in 2005 as a two-man team operating out of a Silicon Valley garage – in the tradition of Apple (see box, p. 72). The company now has close to 100 employees, operates a 2 MW pilot line in the Bay Area, and is preparing to begin volume manufacturing at a 100 MW facility in India in 2008 through partner Moser Baer. Currently, the production site in India is producing 500 kW of dual-axis tracking systems to be installed in Spain by early next year (see PI 9/2007, p. 105 and PI 4/2007, p. 123). The technology uses one thousandth the PV

### Nanosolar: Ink-printed CIGS on metal foils

**PV innovation:** Founded in 2002, Palo Alto, California-based Nanosolar has developed and appears to be on the brink of commercializing CIGS thin-film PV based on high-throughput nanoparticle ink printing onto a metal foil substrate with module efficiency over 10 percent.

**Production:** Nanosolar plans to start production at its 430 MW cell plant in San Jose by the end of this year at an »unbalanced« production capacity, according to founder

and CEO Martin Roscheisen. Some process steps are in the 100 MW range, while others are in the 1 GW capacity range. Production at full capacity is scheduled for early next year. Nanosolar will

assemble these cells into modules at a 430 MW plant in Berlin. Due to uncertainties over when Nanosolar will receive product certifications from TÜV, the company says it is not yet estimating how much it will produce in 2008.

**Financial backing:** Nanosolar has raised about \$100 million from a suite of investors including Mohr Davidow Ventures, Benchmark Capital, Mitsui, Firelake Capital, Swiss Re, the founders of Google, and others. Nanosolar also inked a \$20 million contract through the Solar America Initiative.

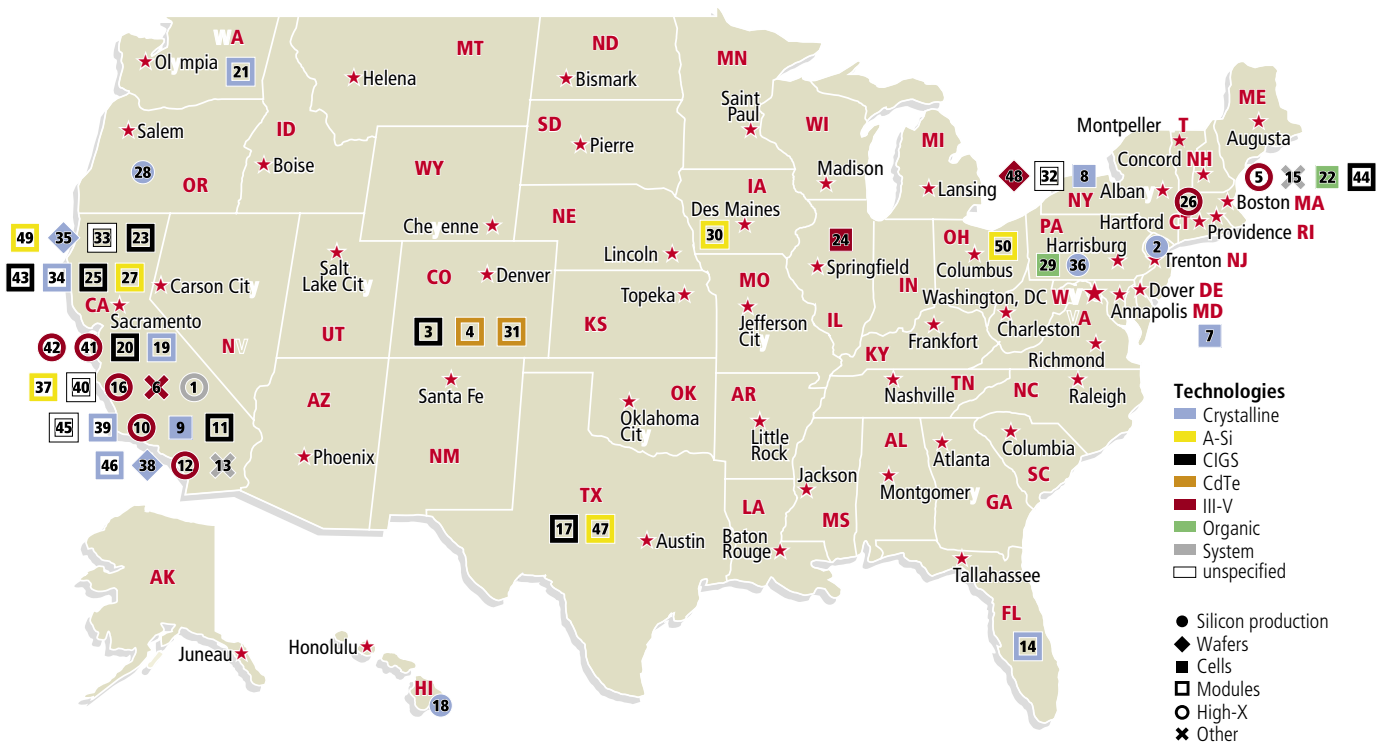
**Key players:** CEO Martin Roscheisen, EVP of Operations Werner Dumanski.



**Still smiling: Nanosolar founder and CEO Martin Roscheisen says his company is on track to begin commercial production by the end of the year.**

Will Beiser / Nanosolar Inc.

# PV start-ups in the USA



Company	State/province	Business focus	Financial status
1 1-Solar Inc.	CA	Inverters with 15-year life	Seed financing: \$100k award in Calif. Clean Tech Open
2 AE Polysilicon Corp.	NJ	FBR granular silicon production	VC: Undisclosed. Owned 12% by Motech, \$8 mn from PA
3 Ascent Solar	CO	CIGS on plastic substrate	Public: Market cap of \$184 mn, raised \$20 mn in July
4 AVA Solar	CO	CdTe/CdS modules for commercial rooftops	VC: Raised two unspecified rounds and \$3 mn from DOE
5 Bandgap Engineering	MA	III-V cells for high-X systems	Seed financing: Won \$5,000 from NREL in 2007
6 Blue Joule Technologies	CA	Inverters for concentrating PV plants	Seed financing
7 Blue Square Energy	MD	C-Si cells on metallurgical Si substrate	Awarded \$3 mn from DOE in 2007, also angels and DOD
8 C-9 Corp.	NY	Silicon carbide cells	Seed financing: Department of Defense contract
9 CallSolar	CA	C-Si cells using metallurgical Si	VC: Raised \$9 mn in 2006, \$3 mn from DOE
10 Cool Earth Solar	CA	High-X PV using III-V cells	VC: Raised \$1 mn in May
11 Daystar Technologies	CA	CIGS on glass substrate	Public: Raised \$68 mn in Oct., market cap. \$137 mn
12 EnFocus Engineering	CA	High-X PV using III-V cells	Seed financing: \$2.9 mn from DOE in 2007
13 Envision Solar	CA	Prefab BIPV parking lot structures	VC: \$2 mn Series A in progress, \$30 mn orders, including NREL
14 Gamma Solar Corp.	FL	Bifacial cells and modules	Seed financing
15 Greenray Solar	MA	AC modules	VC: Awarded \$2.3 mn from DOE in 2007
16 GreenVolts Inc.	CA	High-X PV using III-V cells	VC: \$10 mn Series A follows \$1.5 mn seed round in June
17 HeliVolt Corp.	TX	CIGS on glass substrate	VC: \$101 mn Series B follows \$10.3 mn Series A in 2005
18 Hoku Scientific	HI	Silicon production based on Siemens reactor	Public: \$140 mn market cap, \$1.5 bn in contracts
19 Innovalight Inc.	CA	Nanoparticle silicon ink	VC: \$28 mn Series C follows previous \$7.5 mn and \$6.5 mn rounds
20 JNL Solar Inc.	CA	CIGS thin-film	Seed financing
21 JX Crystals Inc.	WA	Low-X using c-Si PV, high-X III-V	Seed financing, low volume sales
22 Konarka	MA	Organic thin-film PV	VC: \$45 mn round in October pushes total to \$98 mn
23 Miasole	CA	CIGS using vacuum-sputtering	VC: over \$56 mn raised to date
24 MicroLink Devices	IL	III-V cells for high-X systems	Seed: \$50,000 from Illinois, \$2.4 mn from DOE
25 Nanosolar	CA	CIGS nanoparticle ink on metal foil substrate	VC: Raised approx. \$100 mn, and \$20 mn from DOE
26 Opel International	CT	III-V cells and high-X systems	Public: Seeking \$25 mn after \$10.7 mn in June
27 OptiSolar Inc.	CA	A-Si thin-film	Seed financing
28 Peak Sun Silicon	OR	Silicon production based on novel FBR approach	VC: Undisclosed
29 Plextronics	PA	Organic thin-film PV	VC: \$37 mn and \$3 mn from DOE
30 PowerFilm Inc.	IA	A-Si thin-film on polymer	Public: Netted \$16 mn in 2007 IPO
31 PrimeStar	CO	CdTe/CdS for utility, commercial market	VC: Undisclosed GE investment follows \$6 mn in seed
32 Prism Technologies	NY	Holographic modules	VC: \$1.15 mn round in Feb, grants from NY state
33 Q1 NanoSystems/Blue Solar	CA	Materials neutral thin-film substrates, modules	Seed financing
34 Redwood Renewables	CA	Integrated PV roofing tiles	Seed financing
35 Ribbon Technology International	CA	Silicon ribbon growth, wafer manufacturing	Seed financing
36 RSI Silicon	PA	Solar-grade Si production	VC: Raised \$7.5 mn Series A in 2007
37 Signet Solar	CA	A-Si thin-film	VC: Undisclosed
38 Solaix	CA	Mono-crystalline silicon ingots, wafers	VC: \$45 mn to date
39 Solaria Corp.	CA	Low-X flat plate using c-Si PV	VC: \$77 mn to date
40 Solexant Corp.	CA	Undisclosed thin-film	VC: \$4.3 mn Series A
41 SolFocus Inc.	CA	High-X PV using III-V cells	VC: Raised \$95 mn to date
42 Soliant Energy	CA	Rooftop high-X PV using III-V cells	VC: Raised \$8 mn in 2006, \$4 mn from DOE in 2007
43 SoloPower Inc	CA	CIGS electrochemical deposition	VC: \$30 mn B round in July, \$2.4 mn from DOE
44 Stellaris	MA	Low-X CIGS	Seed financing
45 Stion	CA	Undisclosed thin-film, most likely CIGS	VC: Raised \$15 mn in June
46 Silicon Valley Solar	CA	Low-X flat plate using c-Si PV	VC: Raised \$10.2 mn in June
47 TekSun PV Manufacturing	TX	A-Si thin-film	Seed financing
48 Wakonda Technologies	NY	Low-cost substrate for III-V cells	Seed financing, \$10,000 from NREL in 2007
49 XsunX	CA	A-Si thin-film	Public: \$21 mn financing secured in Nov.
50 Xunlight Corp.	OH	A-Si single-junction, a-SiGe/nc-Si triple-junction thin-film	VC: \$7 mn Series A in June, DOE contracts

Production status    Laboratory    Pilot    Plant under construction    Commercial production

source: PHOTON International, company disclosures, DOE

material required by the same power of conventional flat-plate modules. None of it is silicon, but rather gallium arsenide-based triple-junction III-V cells using PV materials now favored over silicon in space due to higher conversion efficiencies that have reached over 35 percent in production and nearly 43 percent in the laboratory (see PI 9/2007, p. 240).

Like SolFocus, more recent start-up Enfocus Engineering of Sunnyvale also uses these »space cells« for its high-concentration device, which is being designed specifically for commercial rooftops. Several CPV developers based in southern California – Amonix, Boeing, and Soliant Energy – were also selected to lead SAI teams in March. GreenVolts Inc. and Cool Earth Solar, two more high-concentration PV start-ups based in the San Francisco Bay Area, did not receive DOE awards, but appear to be advancing nonetheless, even if in small strides. Cool Earth secured \$1 million in angel investment in May, while GreenVolts this November completed a \$10 million Series A round of financing to complement its previously inked contract with investor-owned utility Pacific Gas & Electric to build a 2 MW plant by the end of 2008.

Of course, launch of the market for high-concentration CPV systems depends heavily on supply of multi-junction cells (see PI 4/2007, p. 122). Space cell suppliers Emcore Corp. of New Mexico and Boeing-subsi-dary Spectrolab, two leaders in this area, have contracted to deliver a combined 126 MW of terrestrial multi-junction cells by the end of 2008 (see PI 10/2007, p. 73). But several start-ups have emerged in recent months seeking to of-

## Solaicx: Continuous single crystal growth

**PV innovation:** Silicon Valley-headquartered Solaicx, founded in 2002, has developed a continuous process for growing monocrystalline ingots in a Czochralski furnace that it claims can yield 5.5 times the throughput of batch growers.

**Production:** Solaicx, which has been operating and selling wafers from its pilot grower in Santa Clara for the past 16 months, on Nov. 20 celebrated the opening of its first full-scale production facility in Portland, Oregon – a 40 MW capacity plant with eight growers and employing close to 100 workers initially. Solaicx plans to produce

75 MW of wafers in 2008, reaching a year-end capacity of 160 MW. The facility has enough room to support 300 MW. The company reports that it has secured adequate silicon feedstock supplies into 2009.

**Financial backing:** \$45 million to date from angel investors and VCs such as Applied Ventures, Big Sky Partners, D.E. Shaw Research, Firsthand Capital, and Greenhouse Capital.

**Key players:** CEO Bob Ford, CTO Bill Yerkes, VP of Sales and Marketing John Sedgwick, Chief Engineer Dave Bender, VP of Manufacturing Jeff Jones.



**Started up:** From left to right, Solaicx CEO Bob Ford, CTO Bill Yerkes, and VP of Sales and Marketing John Sedgwick.

fer less expensive high-efficiency cells. One new player is MicroLink Devices of Illinois, a developer of dual-junction gallium arsenide-based cells for use in 500x concentrators, which received a \$3 million award under the Incubator Series and is also receiving state funding. The National Renewable Energy Laboratory's (NREL) annual Clean Energy Entrepreneur of the Year award, presented in November, went to a recently founded company also engaged in concentrator cells: New York-based Wakonda Technologies. The company is seeking to replace the expensive single crystal germanium substrate in multi-junction cells – a mate-

rial that is also potentially scarce in the long run (see PI 7/2006, p. 80) – with a low-cost metal foil.

While the vast majority of money flowing into North American start-ups is private, government money is key and often comes with other perks.

»We are happy to receive funding from the DOE,« says Bulent Basol, CTO of Milpitas, California-based SoloPower Inc., whose company was awarded \$3 million in the SAI Incubator Series. The start-up joins Miasole and Nanosolar (see box, p. 68) as Silicon Valley developers of thin-film panels based on CIGS (copper, indium, gallium, and selenide) technology. »This can only accelerate the research we are already doing,« says Basol. »The money is not that much, but the value is much greater.« SoloPower, like other participating companies, will work closely with NREL, the leading US PV research institute, on its project.

### CIGS Valley

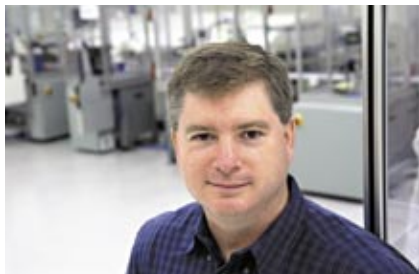
The company closed a \$30 million investment round in July and has the largest incubator project at \$29.3 million. SoloPower is funding \$26.93 million of the project itself and is targeting annual manufacturing capacity of 20 MW by the end of 2008. The company sees potential for 120 MW of capacity by 2010. Of course, with CIGS, you just never know, considering difficulties at Daystar Solar and Miasole, the latter of which actually had 50 MW of capacity in place at the end of last year but has so far failed to begin commercial production due to unacceptably low efficiencies.

SoloPower will seek to establish CIGS manufacturing using an electrochemical

## Solaria: Replacing PV with plastics

**PV innovation:** Founded in 1999, Silicon Valley-based Solaria Corp. has developed a cell multiplication process that can slice 5 to 6 inch mono- or multi-crystalline cells into 2 mm wide strips. These are then alternated with low-cost, injection-molded linear plastic troughs in a standard-sized PV cell. Through substitution of expensive crystalline PV with inexpensive low-concentration plastics, Solaria is aiming to make modules at 15 to 30 percent below the cost of conventional flat-plate modules.

**Production:** Solaria has a 2.5 MW pilot production line in operation in Fremont, California. The first volume production - a 25 MW capacity



**Focused:** Solaria CTO Kevin Gibson at the company's pilot production facility in Fremont, California.

cell and module line in the Philippines – is scheduled to come on line in mid-2008. All volume production is being pursued through contract manufacturing arrangements. In July, Solaria inked a 10-year deal for up to 1.35 GW of cells from Q-Cells AG, which holds a 33-percent stake in the company.

**Financial backing:** Solaria has collected a total of \$77 million in three rounds of financing from Q-Cells AG, Sigma Partners, NGEN Partners, Moser Baer, and others.

**Key players:** CEO Suvi Sharma, CTO Kevin Gibson, COO Alelia Funcell, EVP of Sales and Marketing Marc van Gerven.

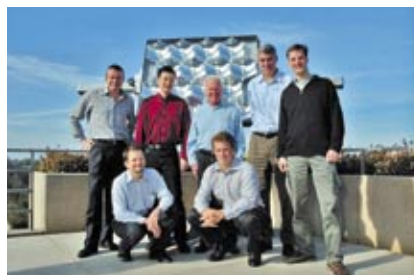
deposition process, further diversifying the range of techniques now being pursued in the area. Miasole is using a vacuum deposition sputtering-based approach, while Nanosolar is pursuing nanoparticle ink printing, and reports that its ambitious plan to start production by the end of 2007 at its 430 MW plant in San Jose are largely on track (see PI 10/2007, p. 74). Yet another interesting Silicon Valley thin-film start-up is Innovalight Inc., based in Santa Clara, which in October closed a \$28 million Series C round. Recently, the company, which is not participating in the SAI but does work with NREL, supplied its silicon nanocrystals – in the form of a printable silicon ink – to a laboratory research group that demonstrated multiple exciton generation (MEG), which has the potential to boost the obtainable power conversion efficiency of a solar cell. Innovalight plans to introduce its first thin-film modules using its printable silicon nanocrystals in 2009.

### Beyond Silicon Valley

Of course, not all no- or low-silicon US solar start-ups are based in Silicon Valley, or even California. For example, Texas-based HelioVolt, which also works with NREL but is not part of a Solar America team, in November closed a \$101 million Series B round of financing toward its rapid semiconductor printing approach to CIGS – using vacuum and/or atmospheric deposition for coating materials onto a glass substrate (see box, p. 72). »We can replace \$1 worth of crystalline-silicon wafers with 3¢ worth of CIGS,« said founder and CEO B.J. Stanbery at the Pacific Growth Equities conference on Nov. 8. Currently HelioVolt is preparing to announce its first volume manufacturing location in the US, which is likely to

### SolFocus: High-concentration PV

**PV innovation:** Founded in 2005, Mountain View, California-based SolFocus Inc.'s first-generation system is a passively cooled 6.5 kW dual-axis tracker. The system uses hexagon-shaped, two-mirror modules to direct 500 times normal sunlight onto over 35-percent efficient gallium arsenide-based III-V cells from Spectrolab. Estimated system efficiency is 17 percent. A more compact second-generation module with projected efficiency of 26 percent is under development.



**High hopes: SolFocus is installing 500 kW of its 6.5 kW high-concentration PV system in Spain in early 2008.**

**Production:** Started as a two-man, garage-based start-up, SolFocus now has nearly 100 employees. The company has a 2 MW pilot line in Silicon Valley that has been making test units, which are currently deployed in several US states. Volume manufacturing at 100 MW

capacity is being set up in India through partner Moser Baer. Production in commercial volumes is expected to begin in 2008. SolFocus plans to grow to 400 MW of annual production by 2010. By early 2008, its first large-scale installations

are scheduled for completion in Spain through research institute ISFOC, which has purchased 200 kW and 300 kW plants. SolFocus has secured 10 MW of cells from Spectrolab.

**Financial backing:** SolFocus has raised \$95 million in three rounds from

New Energy Associates, Moser Baer, NGEN Partners, Yellowstone Capital, and others.

**Key players:** CEO Gary Conley, CTO Steve Horne, VP of Engineering Eugenia Corralas, Ignacio Luque-Heredia, founder of Inspira, a SolFocus subsidiary.

begin at 20 MW.

Not surprisingly, given that NREL is based there, Colorado has also become a hotspot for many early-stage PV companies. One of the most ambitious is AVA Solar, a new outfit spun off from Colorado State University, which is leading a \$16.83 million PV incubator project, of which it is funding \$13.83 million itself to demonstrate its CdTe thin-film module production process. AVA this September said it will build a new 200 MW capacity plant in Colorado – the state's first commercial plant – scheduled to start production by the end of next year (see PI 10/2007, p.

74). Colorado's PrimeStar Solar, a spin-off of NREL, is trying to build on a 16.5-percent efficient CdTe cell technology developed at the national lab. In September, the company received an unspecified strategic investment from GE Energy. Ascent Solar, a Colorado-based spin-off of ITN Energy Systems, is developing monolithically integrated CIGS modules on a plastic substrate. The company is one of six US start-ups that is already publicly traded (see article, p. 120).

Of course, if America's solar initiative is to reach its goal of making solar energy cost-competitive across the United States by 2015, crystalline silicon will not be left out of the mix. After all, multi- and monocrystalline PV cells accounted for about 90 percent of the 2.5 GW of PV cells produced in 2006 (see PI 3/2007, p. 136). Two of the 10 companies selected in the DOE's incubator series – Blue Square Energy of Maryland and Silicon Valley-based CaliSolar – are developing crystalline silicon cells using directly purified metallurgical-grade silicon, a lower-quality feedstock that holds promise as a cheaper alternative to traditional solar-grade silicon. CaliSolar sees the potential to reach an annual production capacity of 200 MW in 2010.

If crystalline silicon innovators such as CaliSolar and Solaix prove successful, at least some of the next generation of Silicon Valley solar companies will remain true to the name.

Garrett Hering

### HelioVolt Corp.: CIGS launch

**PV innovation:** Austin, Texas-based HelioVolt, founded in 2001, uses a rapid semiconductor printing process it calls FASST (field-assisted simultaneous synthesis and transfer), which uses either vacuum or atmospheric deposition to coat CIGS materials onto a glass substrate. It demonstrated 10- to 12-percent product on a pilot line.

**Production:** HelioVolt opened a pilot production facility in Austin in mid-2006 and is preparing to announce a 20 MW plant at

a still-undisclosed location in the US. The plant, which will be expandable to 40 MW, is scheduled

to open in 2008, producing standard-sized modules by the end of the year.

**Financial backing:** \$111.3 million in two rounds from New Enterprise Associates, Paladin Capital, Masdar CleanTech Fund, and others.

**Key players:** Founder and CEO BJ Stanbery, VP of Engineering Bob Oswald, VP of Marketing

John Langdon, VP of Business Development Iga Hallberg.



**PV-integrated circuits: HelioVolt founder and CEO Billy J. Stanbery (left) with the mayor of Austin, Texas, Will Wynn at the opening of the HelioVolt's pilot plant.**

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