Donato Vincenzi

University of Ferrara, Physics and Earth Sciences Department

Building-Integrated Concentrating Photovoltaic Technologies

Solar Energy Research Activities at the University of Ferrara Physics and Earth Sciences Department

Semiconductor bent crystals
Prof. Vincenzo Guidi, Ph.D.

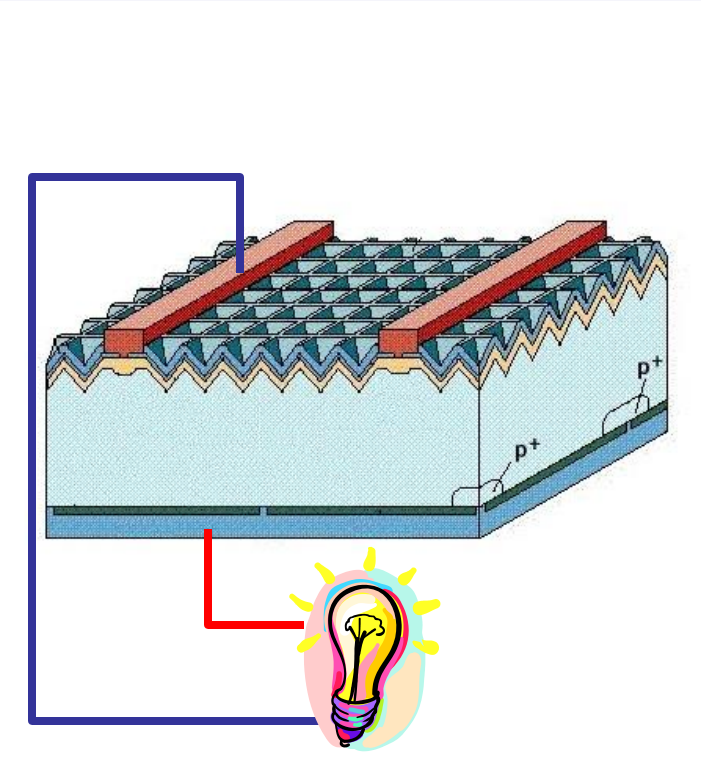
Concentrating Photovoltaics
Prof. Donato Vincenzi, Ph.D.

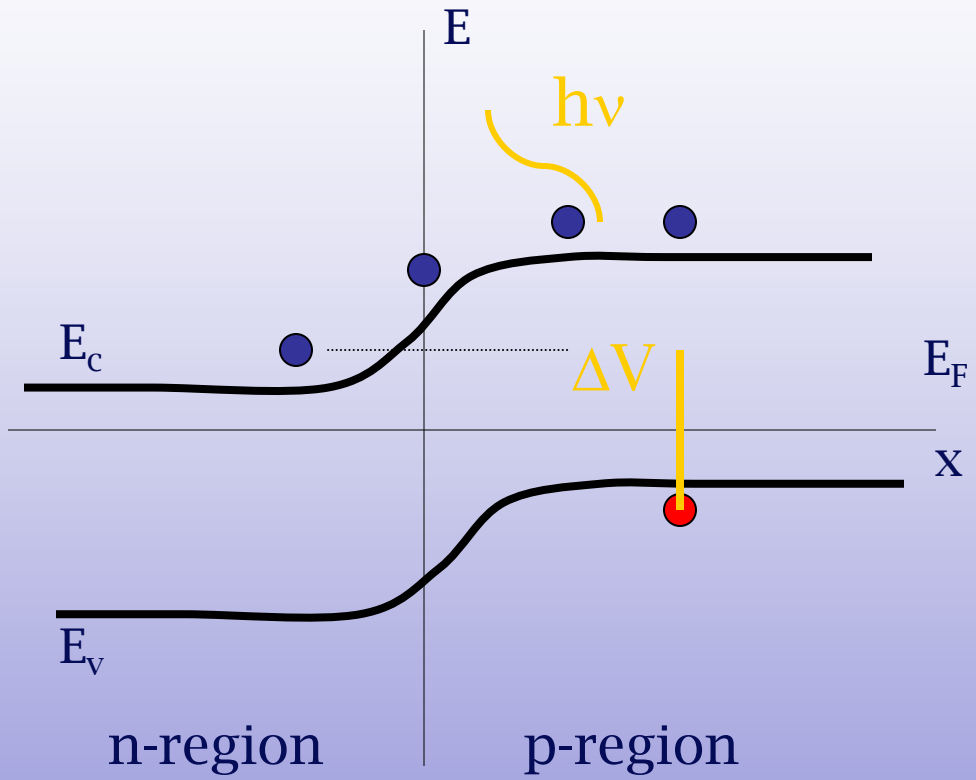
Semiconductor Gas Sensors
Prof. Cesare Malagù, Ph.D.

Stefano Baricordi
Gabriele Calabrese
Giacomo Germogli
Gianfranco Paternò
Paolo Bernardoni
Michele Tonezzer
Sandro Gherardi

Enrico Bagli
Valerio Bellucci
Ilaria Neri
Laura Bandiera
Alessio Giberti
Andrea Mazzolari
Enrico Camattarri

Photovoltaic Conversion and Charge Separation





At sea level the global solar irradiance is about 1000 W/m^2, but traditional solar cells can convert up to 15 % of that value.

The production of electronic grade Silicon

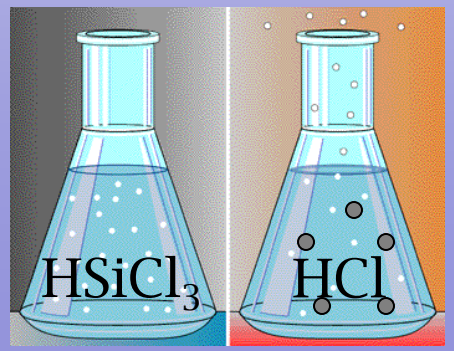
Quartz (SiO_2)
18 kg

Arc Furnace
$SiO_2 + 2C \rightarrow Si + 2CO_2$

Reaction with H_2 (1200 ˚C)
$HSiCl_3 + H_2 \rightarrow Si + 3HCl$

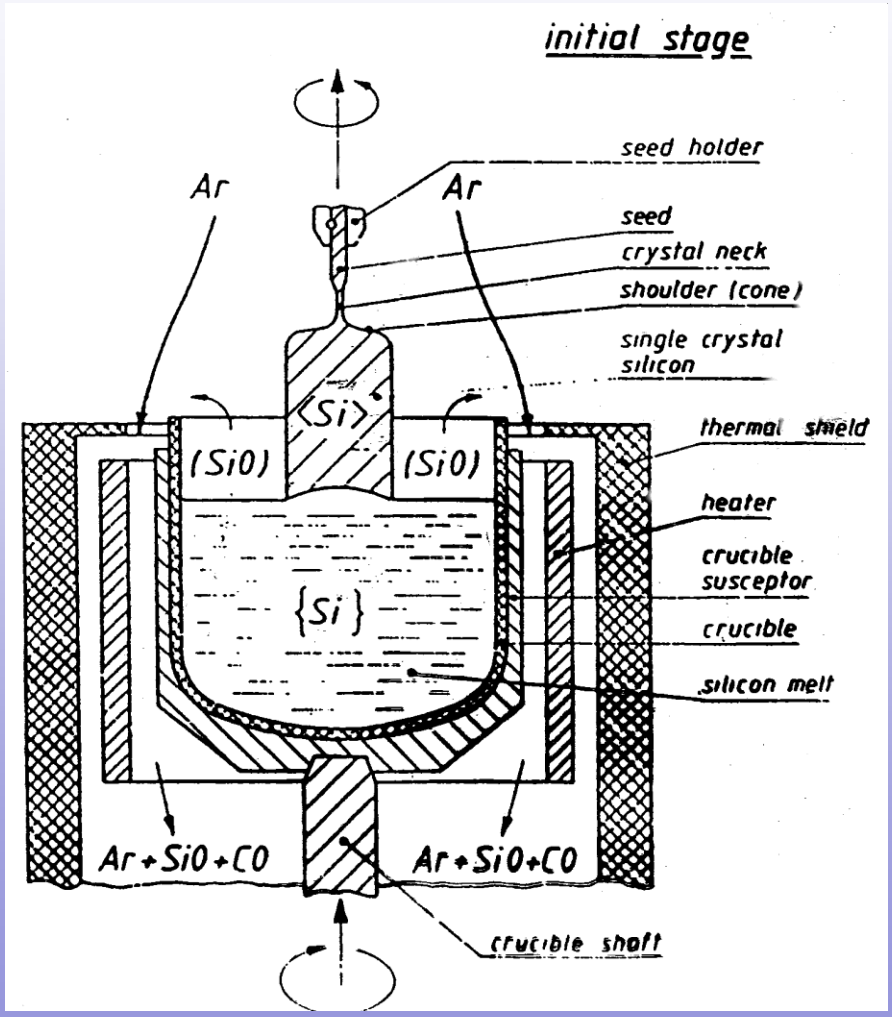
Distillation
(200-400 ˚C)

$HSiCl_3$



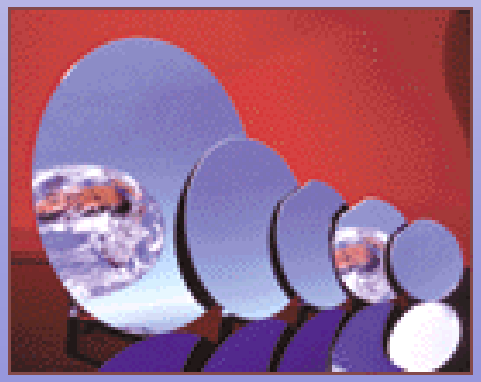
From feedstock to Silicon wafers

Czochralski growth (1400 ˚C)



Monocrystal ingots

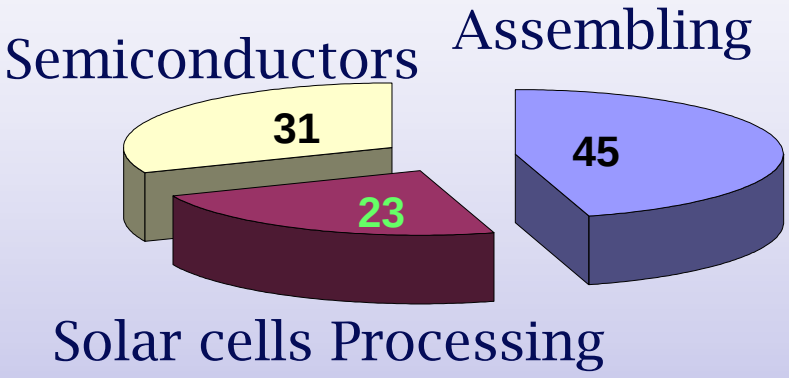
ID Saw, lapping, polishing



Wafers (1 kg)

Economical Analysis of PV panels

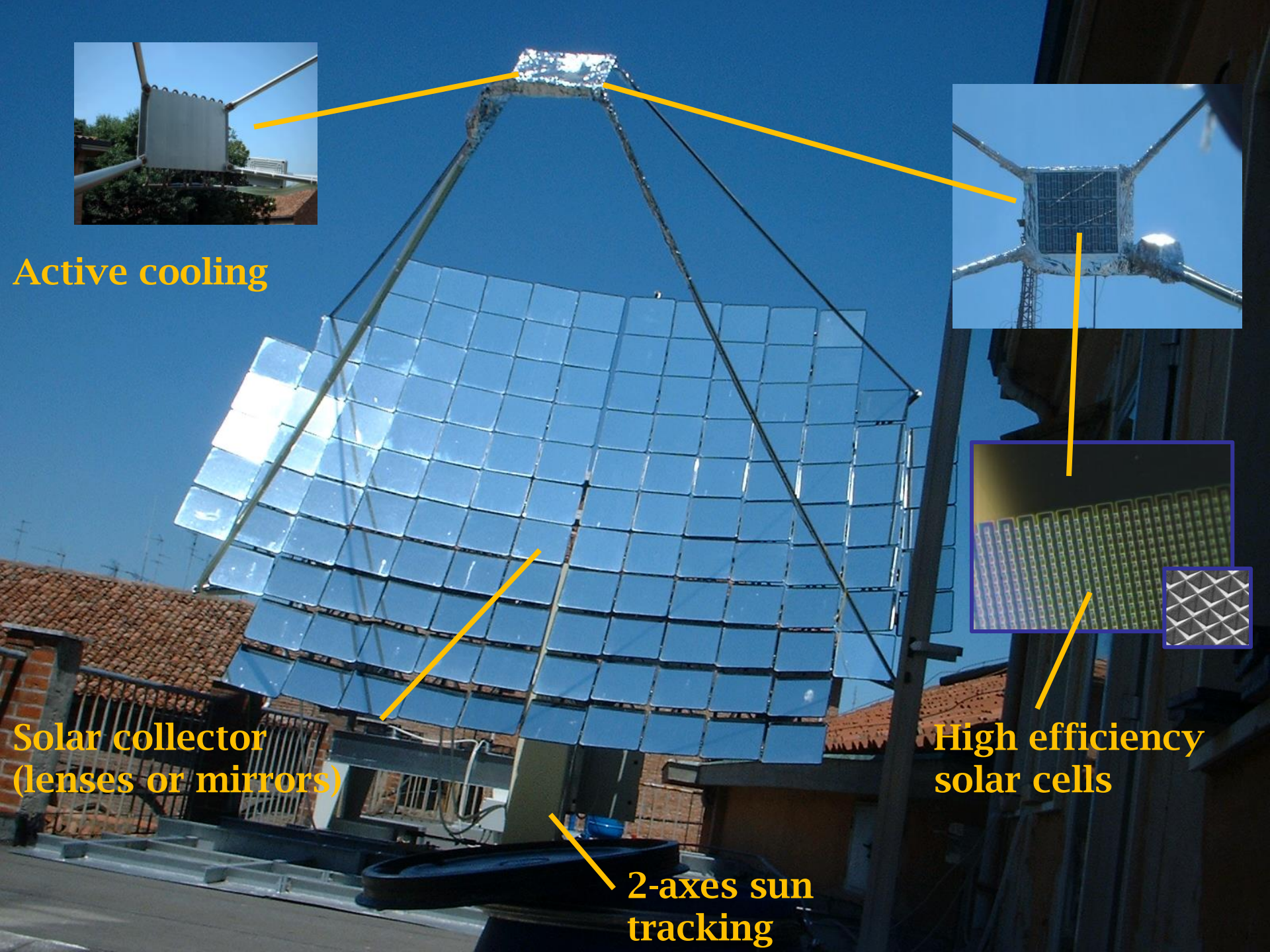
Basically the cost can be divided into three components

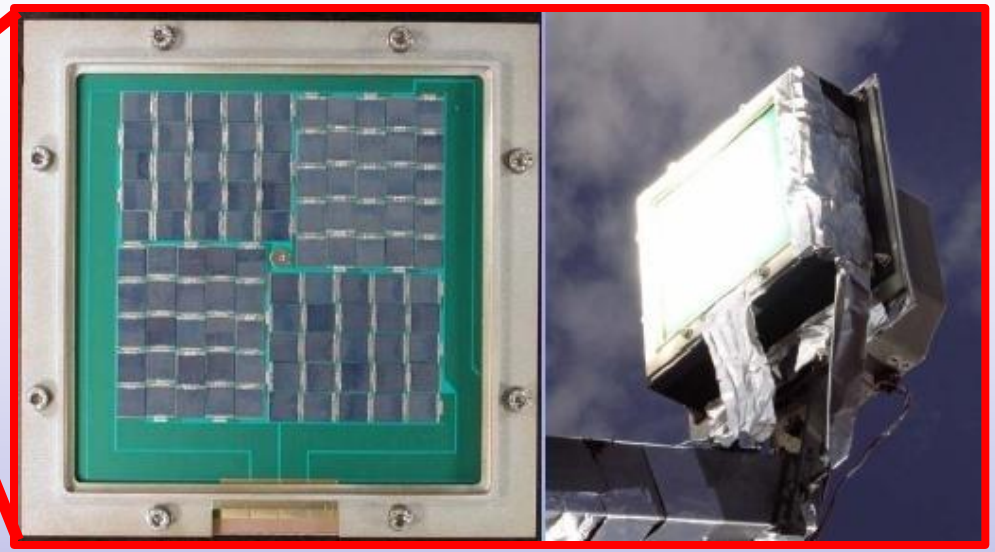


The final cost of the solar panel is **0.7 €/W**

The availability of Si is not a bottleneck even at the TW scale, while Silver – used in front contacts – will present shortage issues

Concentrating Photovoltaic Systems


Active cooling
Solar collector
(lenses or mirrors)
2-axes sun
tracking
High efficiency
solar cells

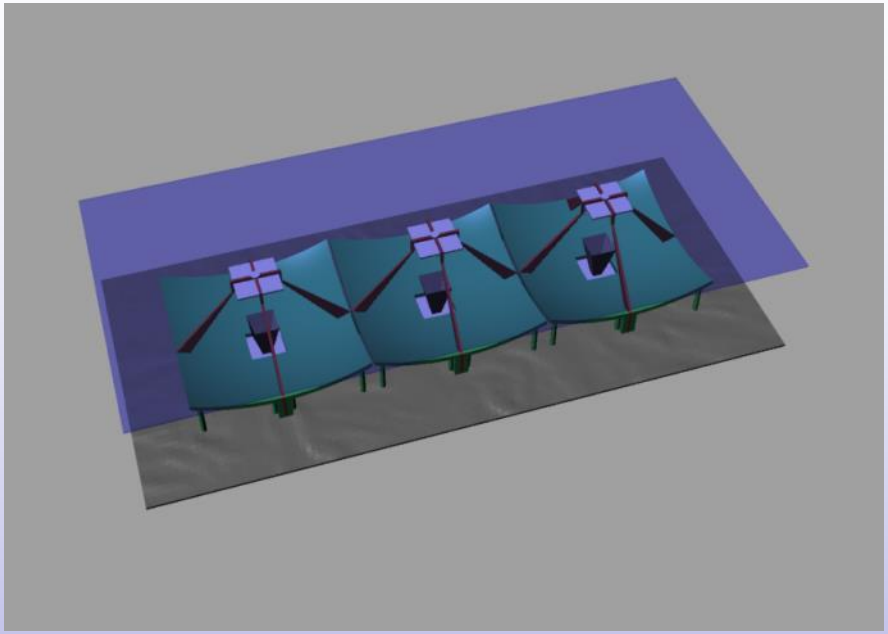


10 cm

Example of solar concentrator with flat facets.
(collection area 2.5 m^2, concentration factor 100x)

Modular Concentrator

Development of a Cassegrain Solar Concentrator



Modular system with metal-coated mirrors.

High concentration ratio and high efficiency

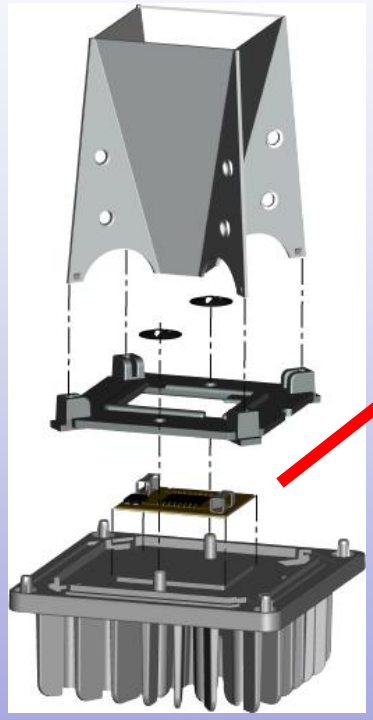
Use of optical components with large industrial availability

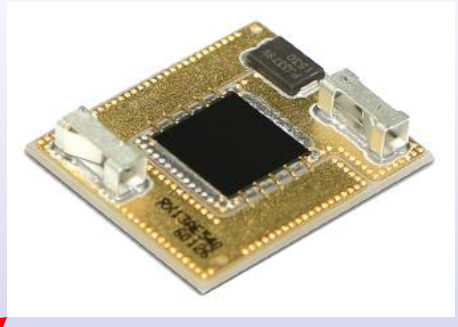
27th EU PVSEC

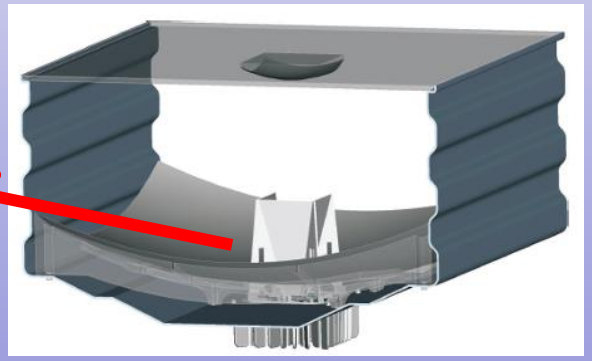
A Novel Cassegrain-type Concentrator Photovoltaic Module: Design, Prototyping and Characterization

L. Pozzetti, M. Musio, D. Vincenzi, C. Musio, S. Baricordi, A. Damiano

The GPS600 high concentration module







The multi-junction cells of GPS600 has been designed for concentration factors of 1000x and operate at 60% of their capacity to guarantee a life time even higher.

Fully automatic assembling line in Bologna (IT)

Engineering with regional companies

Dubai, September 2013

Presentation of the GPS600 solar concentrator developed in collaboration GPIII Project Srl

Test field sponsored by Hera in Forlì.

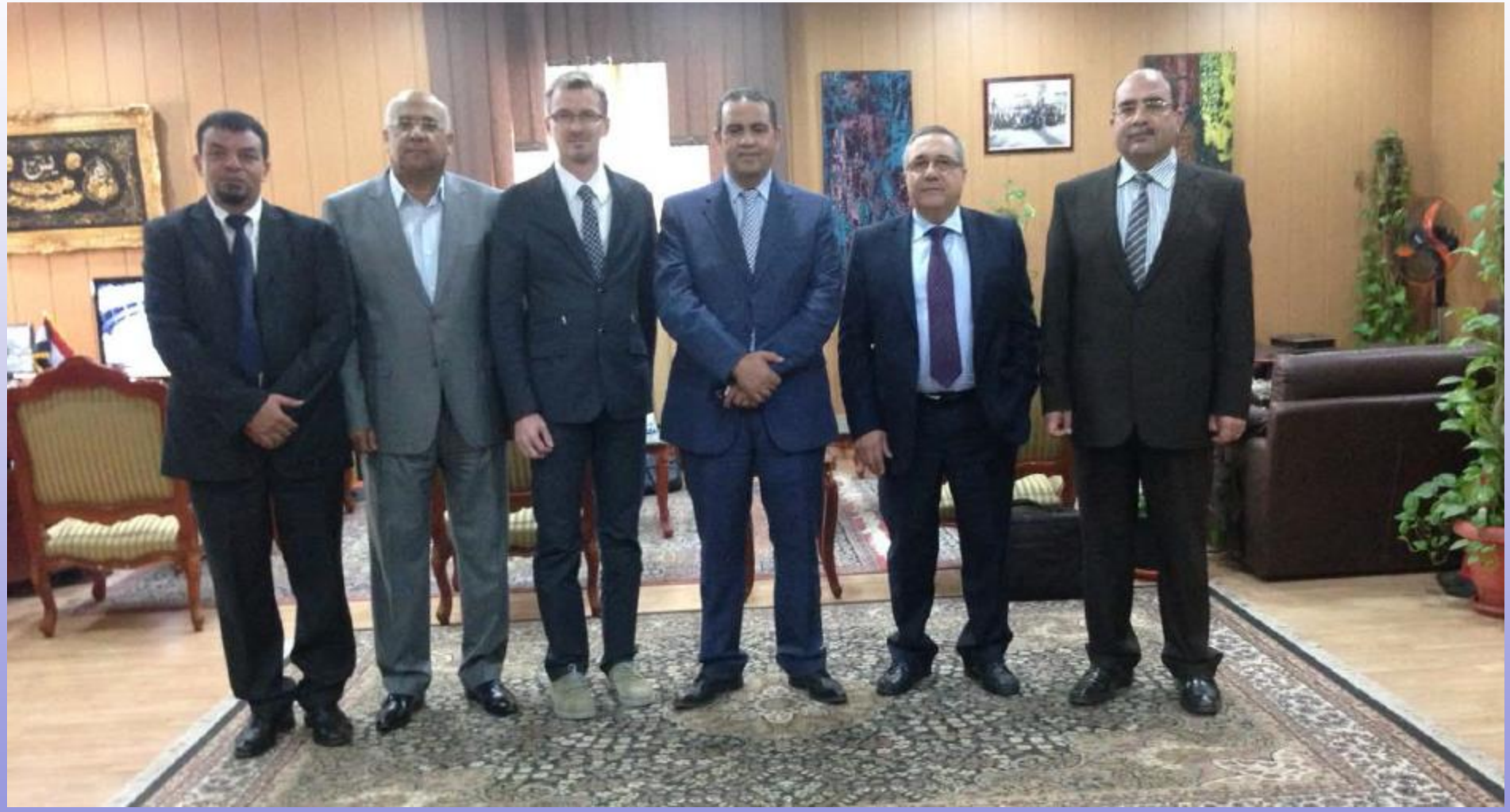
World Future Energy Summit 2015
Abu Dhabi (UAE)

World Future Energy Summit 2015
Abu Dhabi (UAE)

500 kW power plant in Calabria region (IT)

Agreement with the University of Mansoura (Egypt)

Characterization of CPV modules in desertic areas



Agreement with the University of Najran (Saudi Arabia)

Characterization of building integrated CPV modules

A new approach to solar concentrators: the Solar F-light module

More complete approach to architectural integration of PV modules

Shading
Electric Energy
Lighting
Thermal Energy

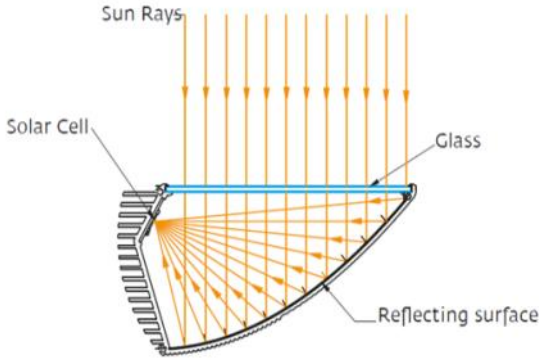
"SOLAR F-LIGHT" SYSTEMS

DAY-TIME

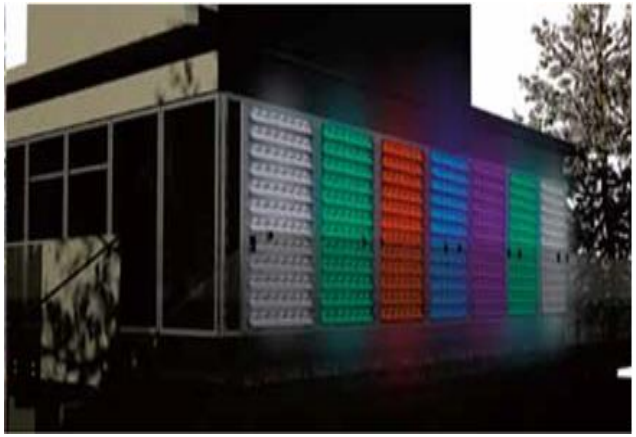
PHOTOVOLTAIC ENERGY PRODUCTION
Energy produced by high efficiency cells
With 20-suns concentration and mono-axis tracking

HEAT PRODUCTION
The same product may be used, simultaneously or alternatively, for the production of hot water

SHADING FUNCTION
Its structure is very similar to that of a sunblind flap and it lends itself to a horizontal and vertical shading function



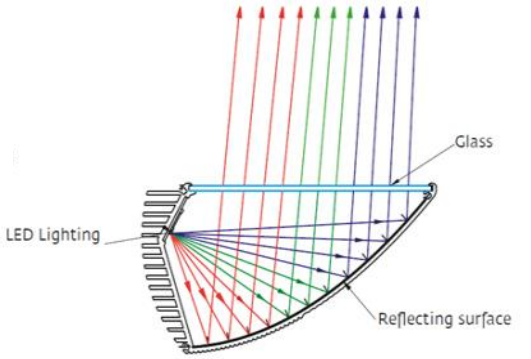
NIGHT-TIME



INTERIOR LIGHTING
Possible to set the system to light interiors throught the windows with a manual switch or PIR sensor

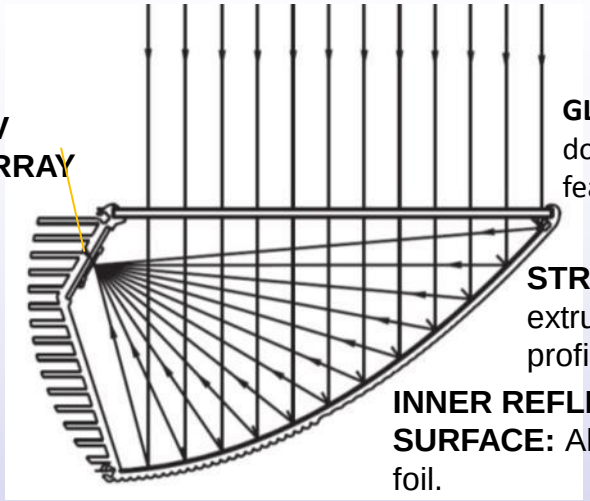
RGB FACADE LIGHTING
The facades become bright palettes where any lighting effects can be created with no limits to your immagination

ADVERTISING LIGHTING
The vertical surface with sufficient size may be use as a proper screen for advertising purposes



Low Concentrating PV module: Solar FLight® project

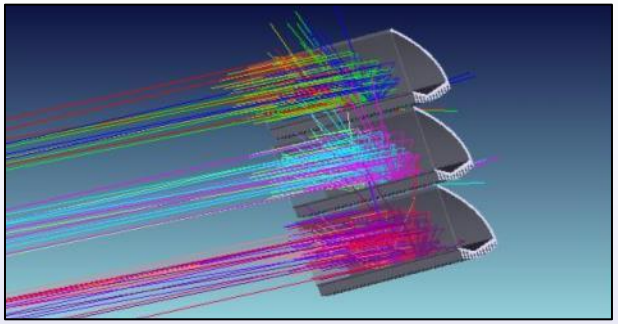
IN COLLABORATION WITH GPIII SOLAR



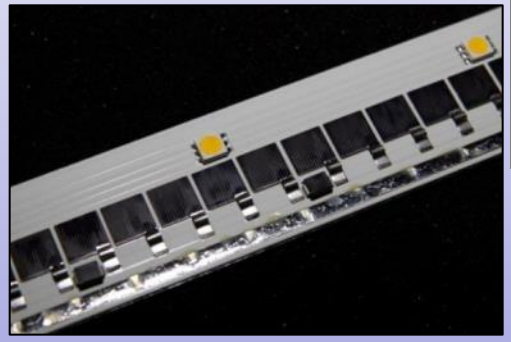
GLASS: extra-clear float glass with double antireflection coating featuring a residual reflectance of 4%

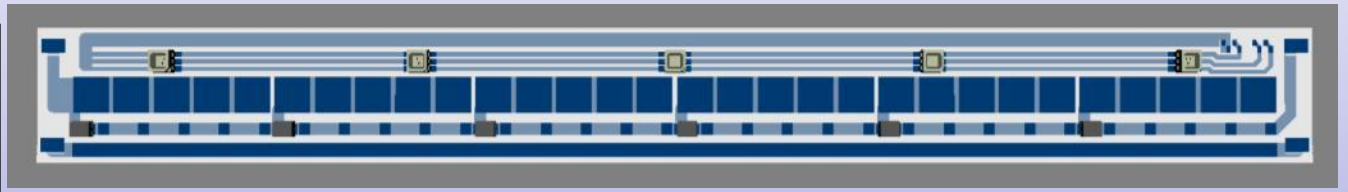
STRUCTURE: extruded aluminum profile

INNER REFLECTIVE SURFACE: Almeco Vega 98 foil.



PARABOLIC LINEAR CONCENTRATOR: concentration factor of **20 suns** optical numerical aperture of F/0.5





PHOTOVOLTAIC ARRAY: 150 Si-monocrystalline PV cells of 8x8 cm^2 surface. Overall power of 30 W at 850 W/m^2 DNI.

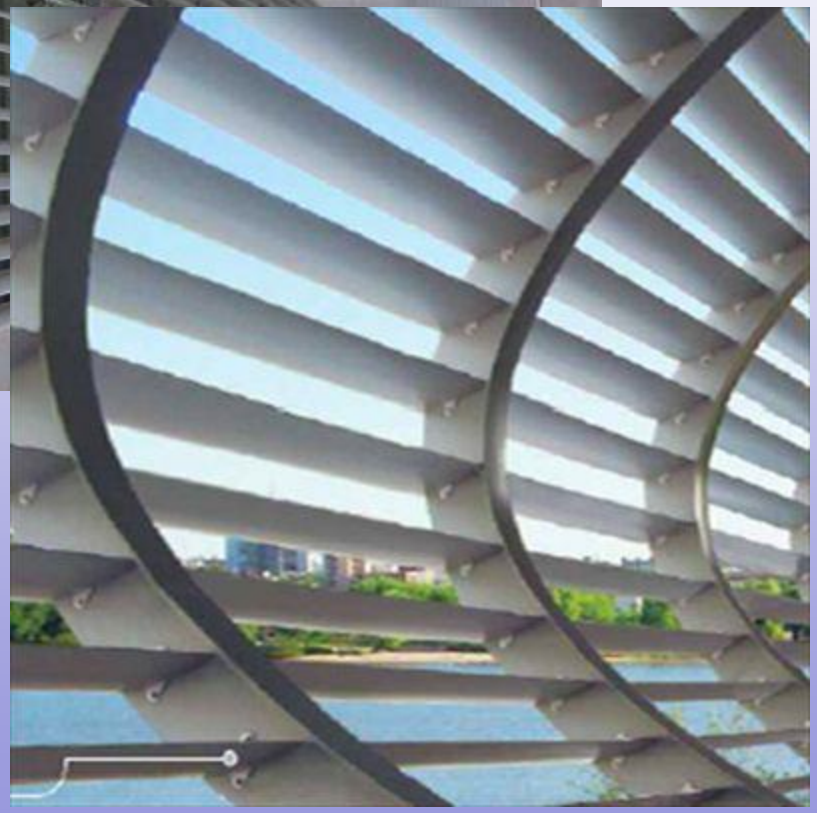
PV RECEIVER SUBSTRATE: Metal-Core printed circuit board.

LED ILLUMINATION: powerful RGB LED bar mounted in close proximity of the PV array. Luminous flux up to 1600 lux at distance of 160 cm.

MOTION: electric motors of 3 watts which can rotate up to 12 module about their axis. The tracking sensor is integrated within each module.

Sun tracking
Active shading

Shading with active sun tracking

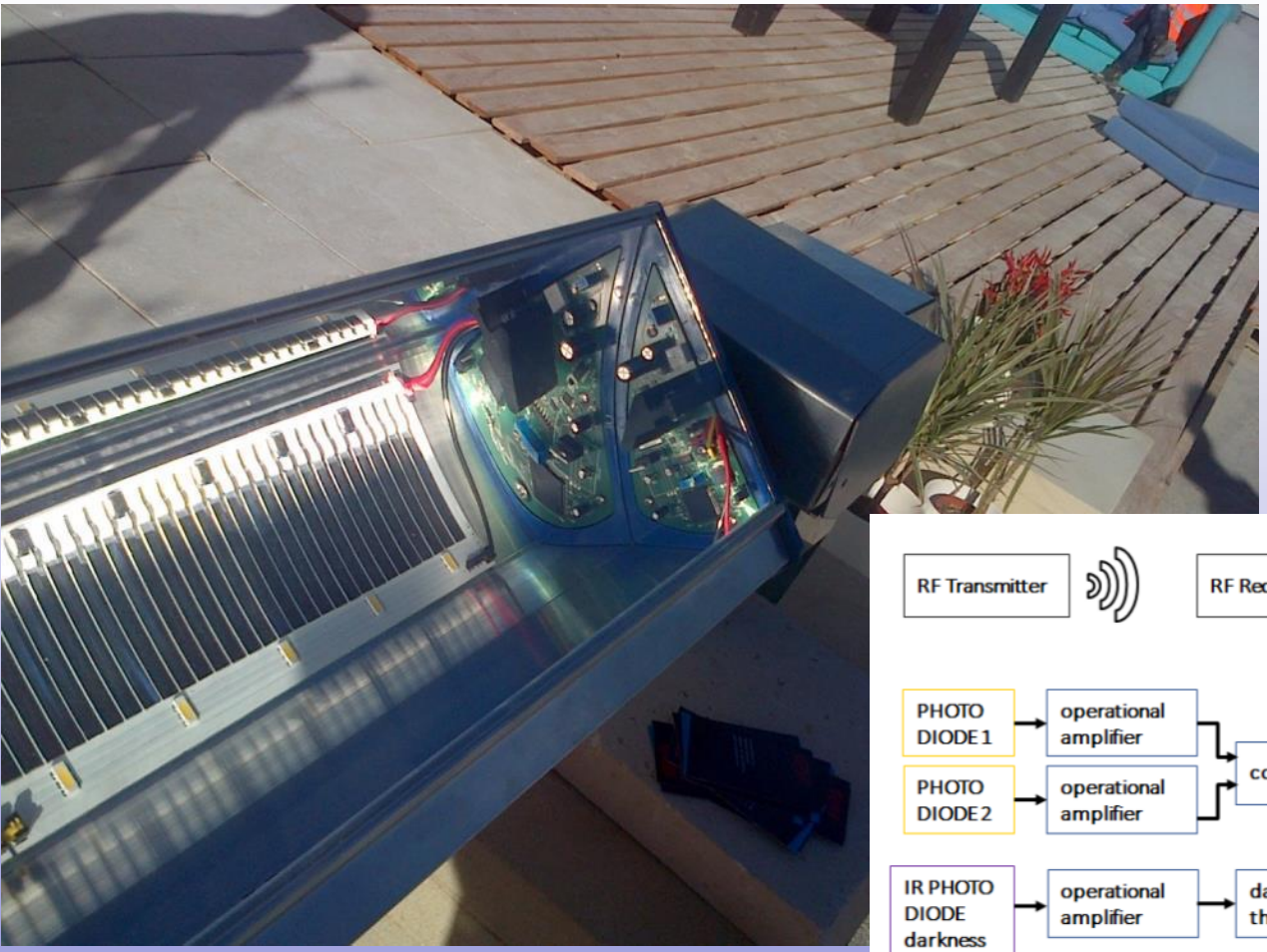


Optimization of the lighting condition inside the building thanks to active control of the louvres.

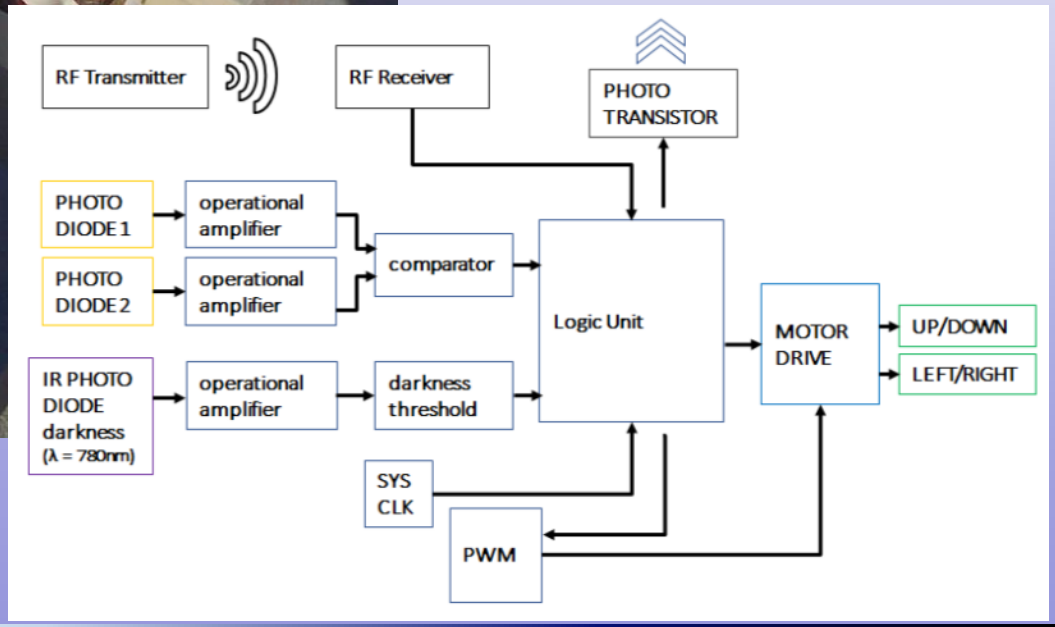
Shadowing with active control of ambient light

Interfacing with DMX or DALI light sensors to control the sun-light entering into the building

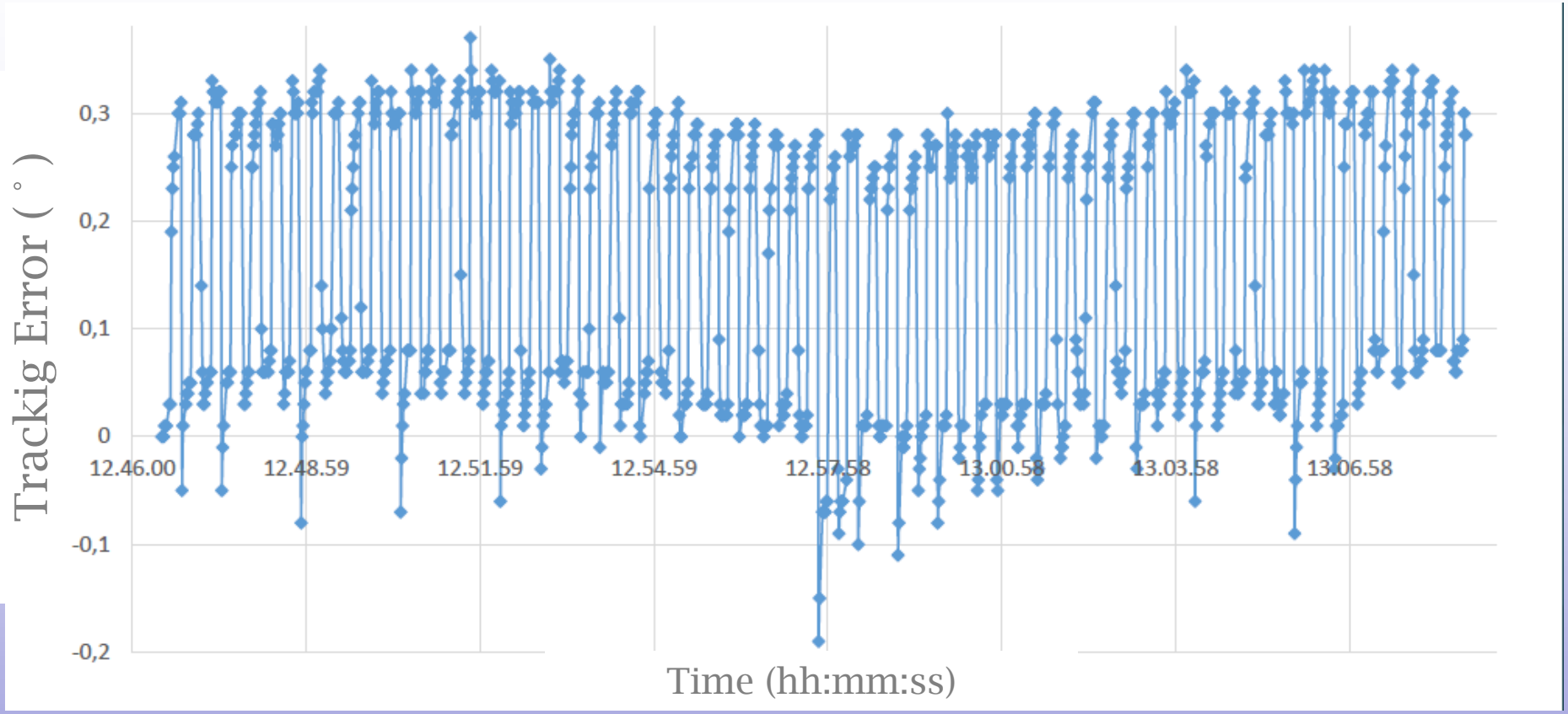
Integrated solar tracking



Automatic sun tracking and remote control of the orientation in cloudy days. Easy integration in facades of industrial buildings.

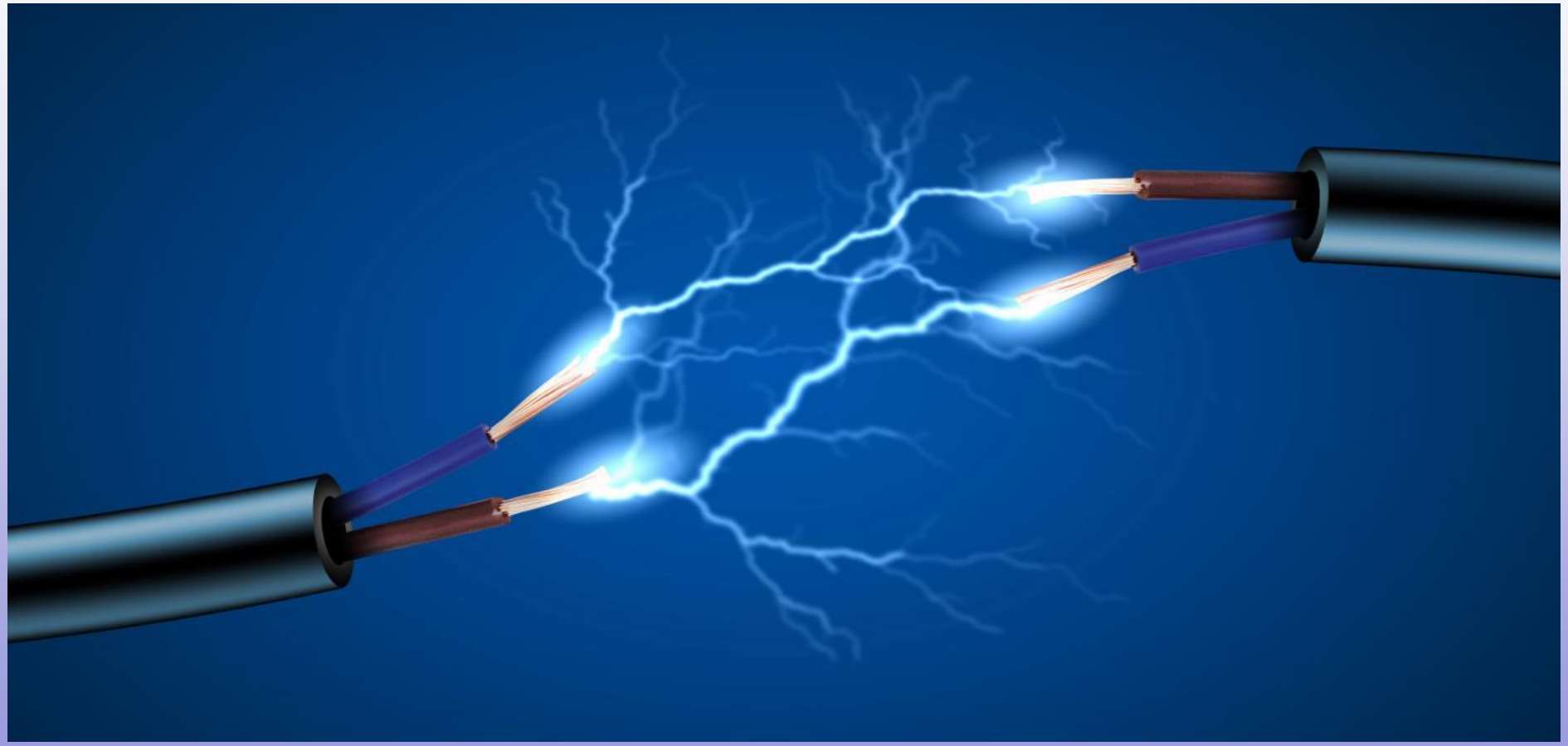


Sun tracking accuracy

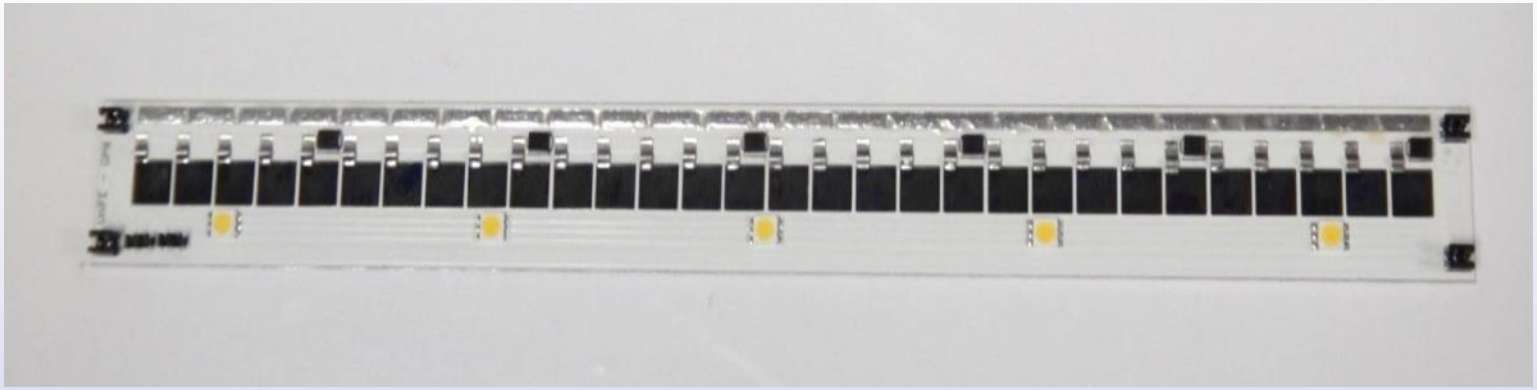


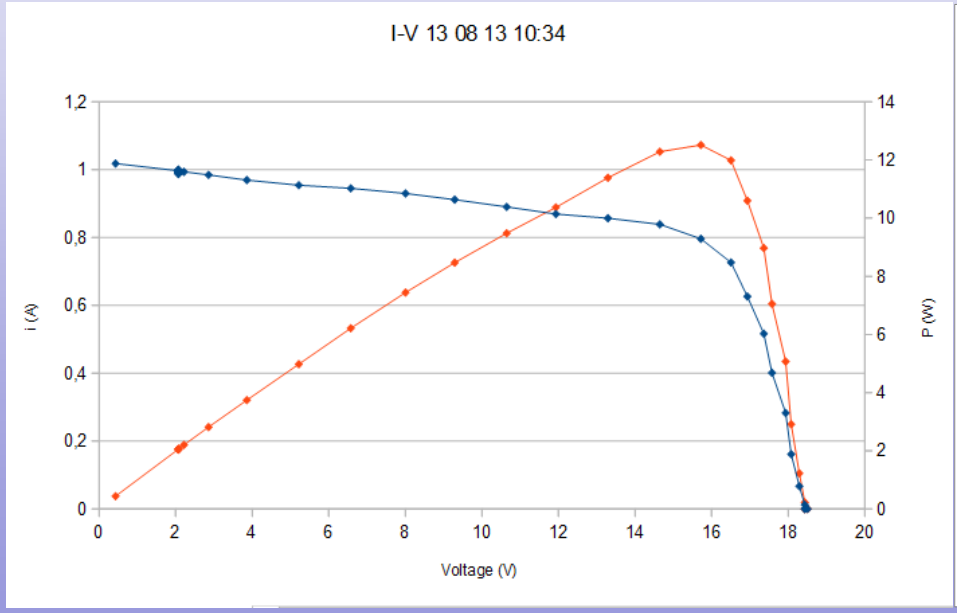
The typical sun tracking error is lower than ±0.15° even in condition of partially cloudy sky.

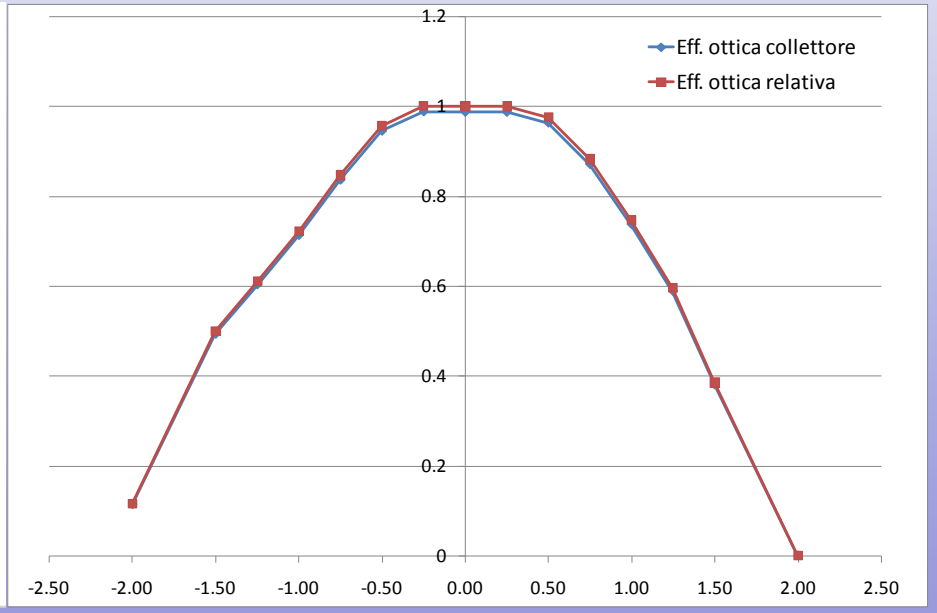
Electricity Generation



The photovoltaic receiver







Thermal energy Harvesting

Thermal energy harvesting

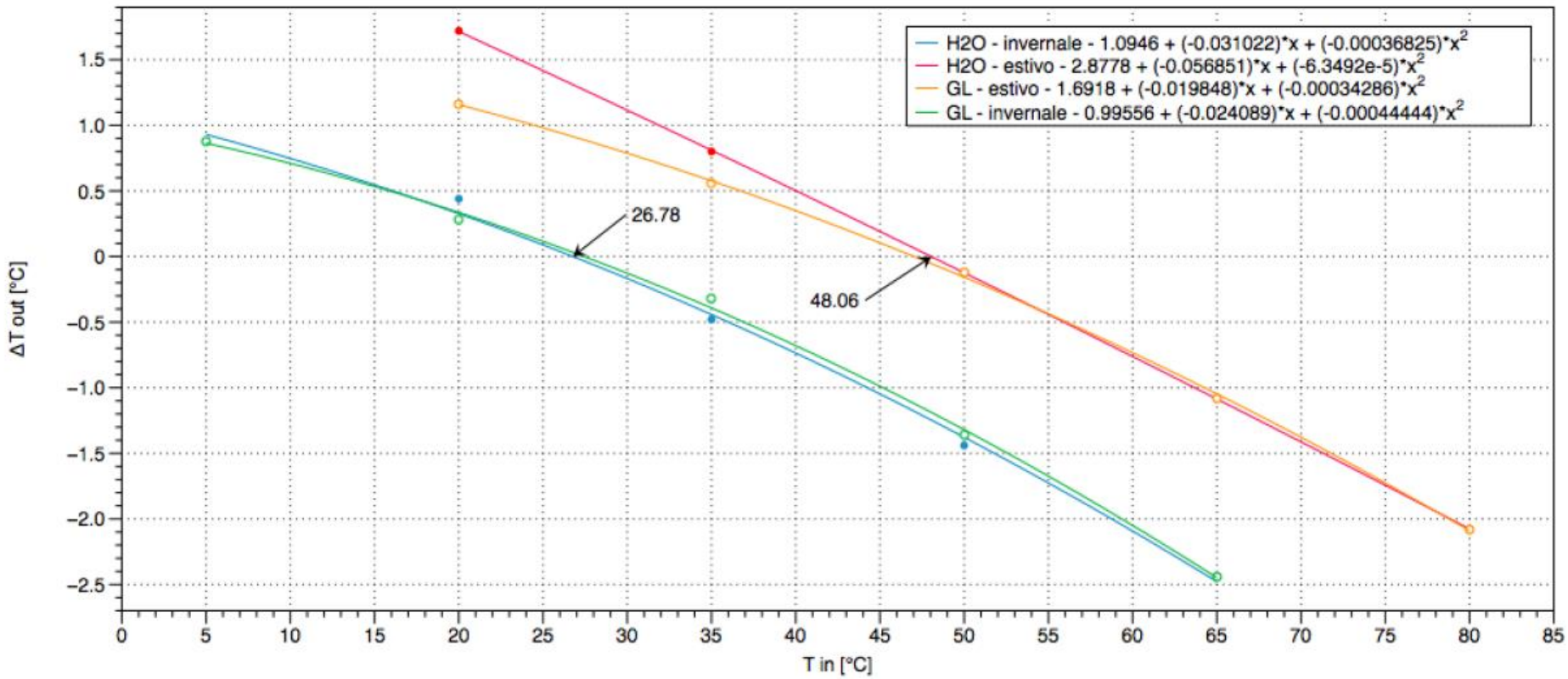
(a) Ibrido

(b) Termico

The extruded aluminum beam has a fluidic channel running behind the solar receiver which can drain the excess heat from the solar cells.

Pre-heating for industrial processes or water for civil use.

Thermal energy harvesting

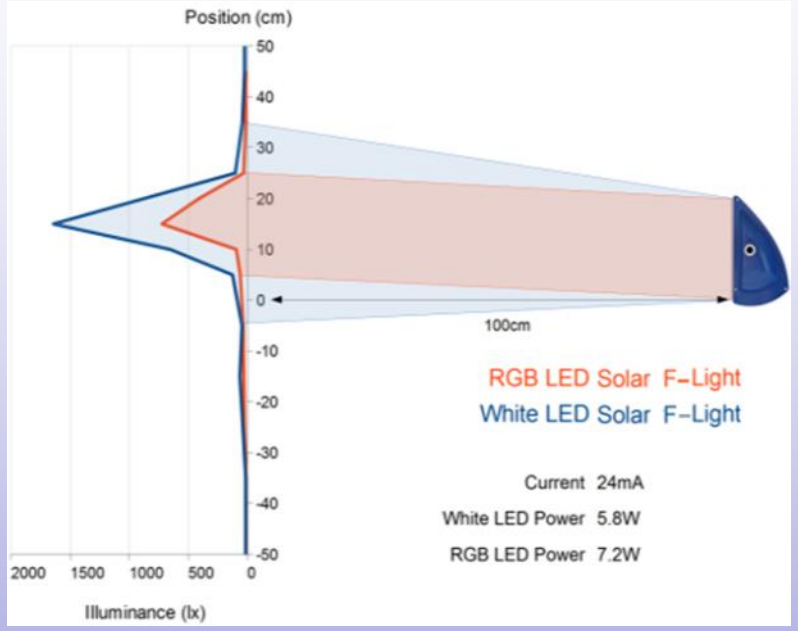


Summer-time equilibrium temperature is 48°C
Winter-time equilibrium temperature is 27°C

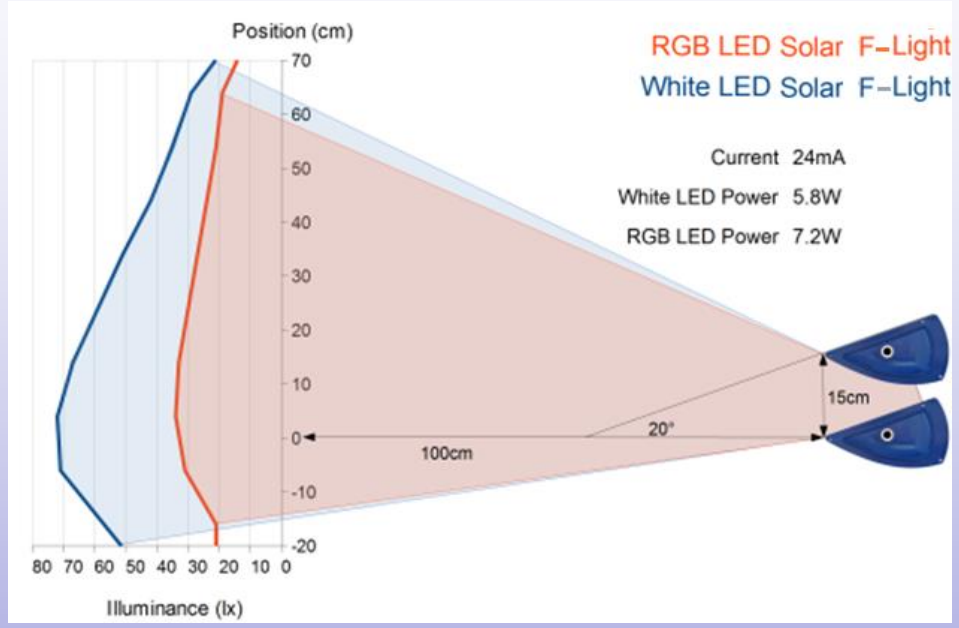
Architectural lighting

Illuminazione integrata

Illuminazione Diretta



Illuminazione Diffusa

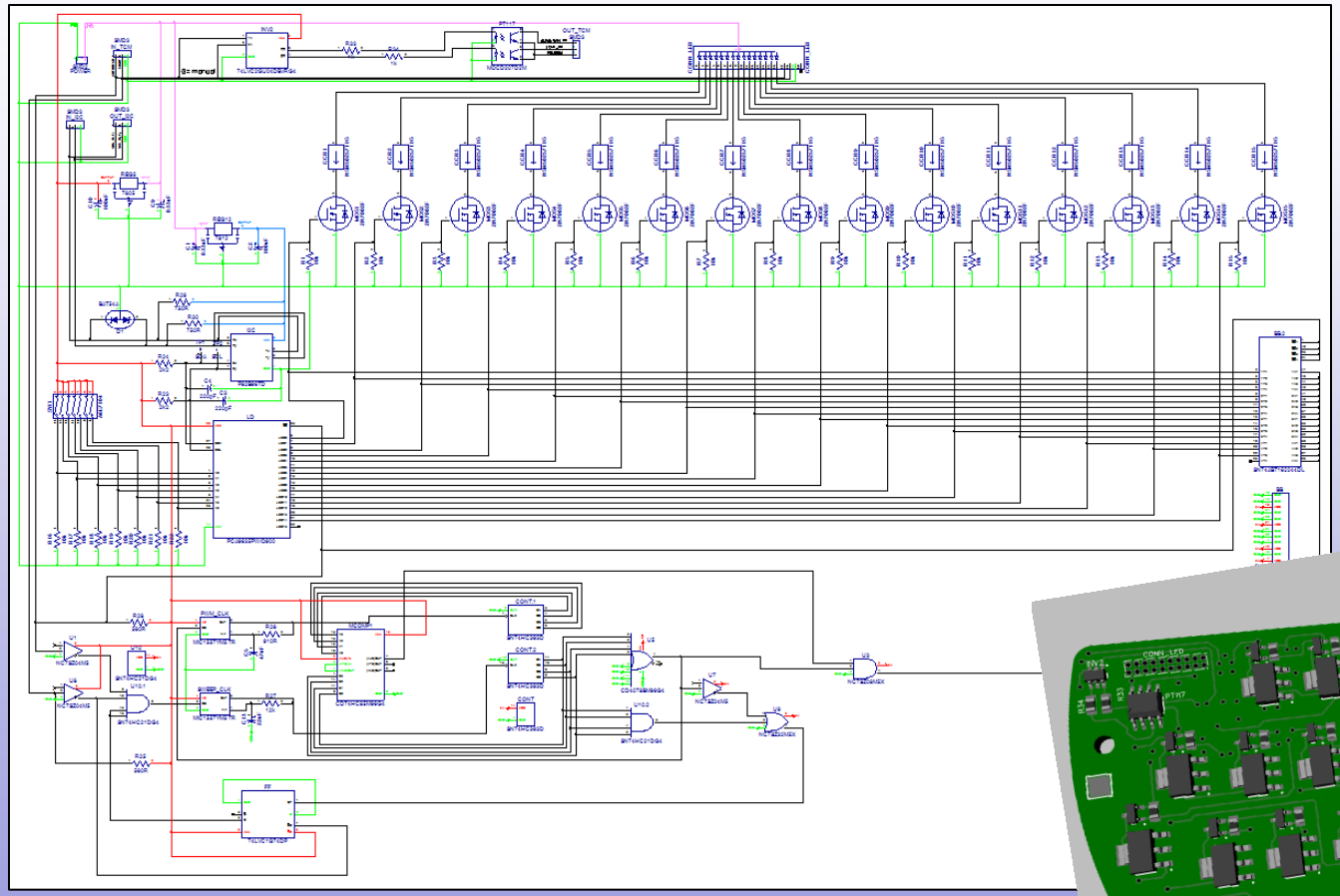


Le esigenze di illuminazione architetturale e ambientale possono essere entrambe soddisfatte dal modulo Solar Flight

Low Concentrating PV module: Solar FLight® project

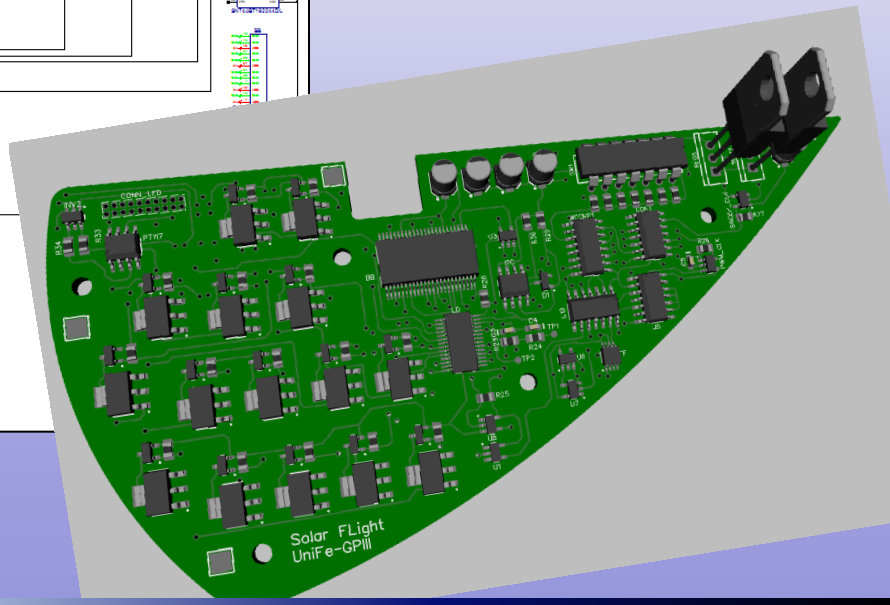
IN COLLABORATION WITH GPIII SOLAR

ELECTRONIC CIRCUIT BOARDS: LED LIGHTING CONTROL



Led Driver PCB Schematic

Led Driver PCB mounted on Solar FLight



Low Concentrating PV module: Solar FLight® project

IN COLLABORATION WITH

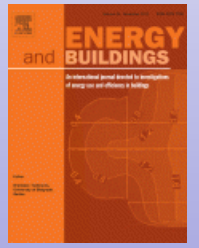
BUILDING INTEGRATION

Low-concentration solar louvers for building integration

CPV-9

F. Aldegheri, S. Baricordi, P. Bernardoni, G. Calabrese, V. Guidi, L. Pozzetti, D. Vincenzi

A low concentration building integrated solar system for a self-sustainable mediterranean house: the ASTONYSHINE house



F. Aldegheri, S. Baricordi, P. Bernardoni, M. Broccato, G. Calabrese, V. Guidi, L. Mondardini, L. Pozzetti, D. Vincenzi

KeyEnergy Expo Presentation – Rimini
(November 2012)

key Energy
the platform for green solutions

Solar Decathlon Europe 2012 – Madrid
(September 2012)

sd europe
SOLAR DECATHLON

Unife @ Solar Decathlon Europe

(Madrid , 14-30 September 2012)

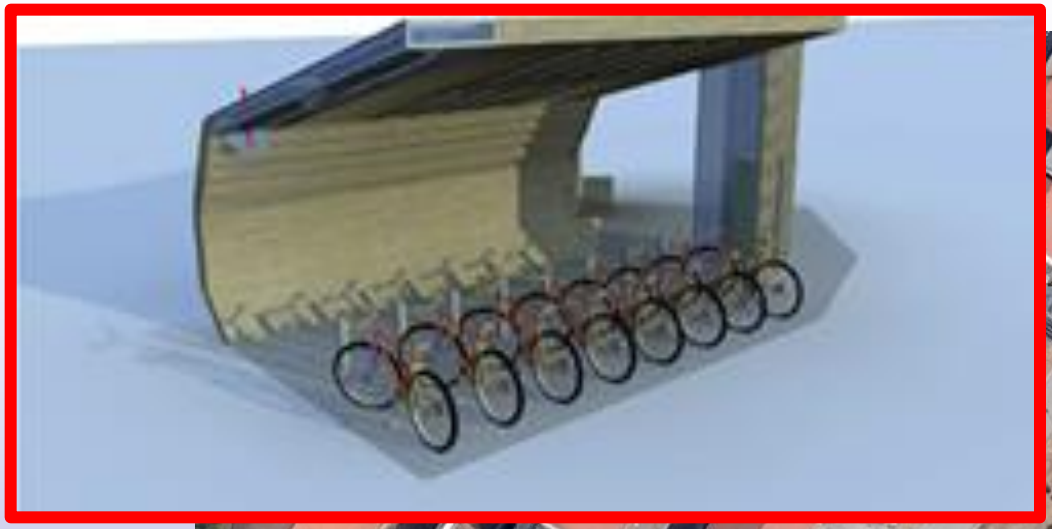
Solar Decathlon Europe 2012 , Madrid

(University of Ferrara, Ecole Nationale Superieure d'Architecture Paris-Malaquais, Ecole des Ponts ParisTech, and DICAR of the Politecnico di Bari)

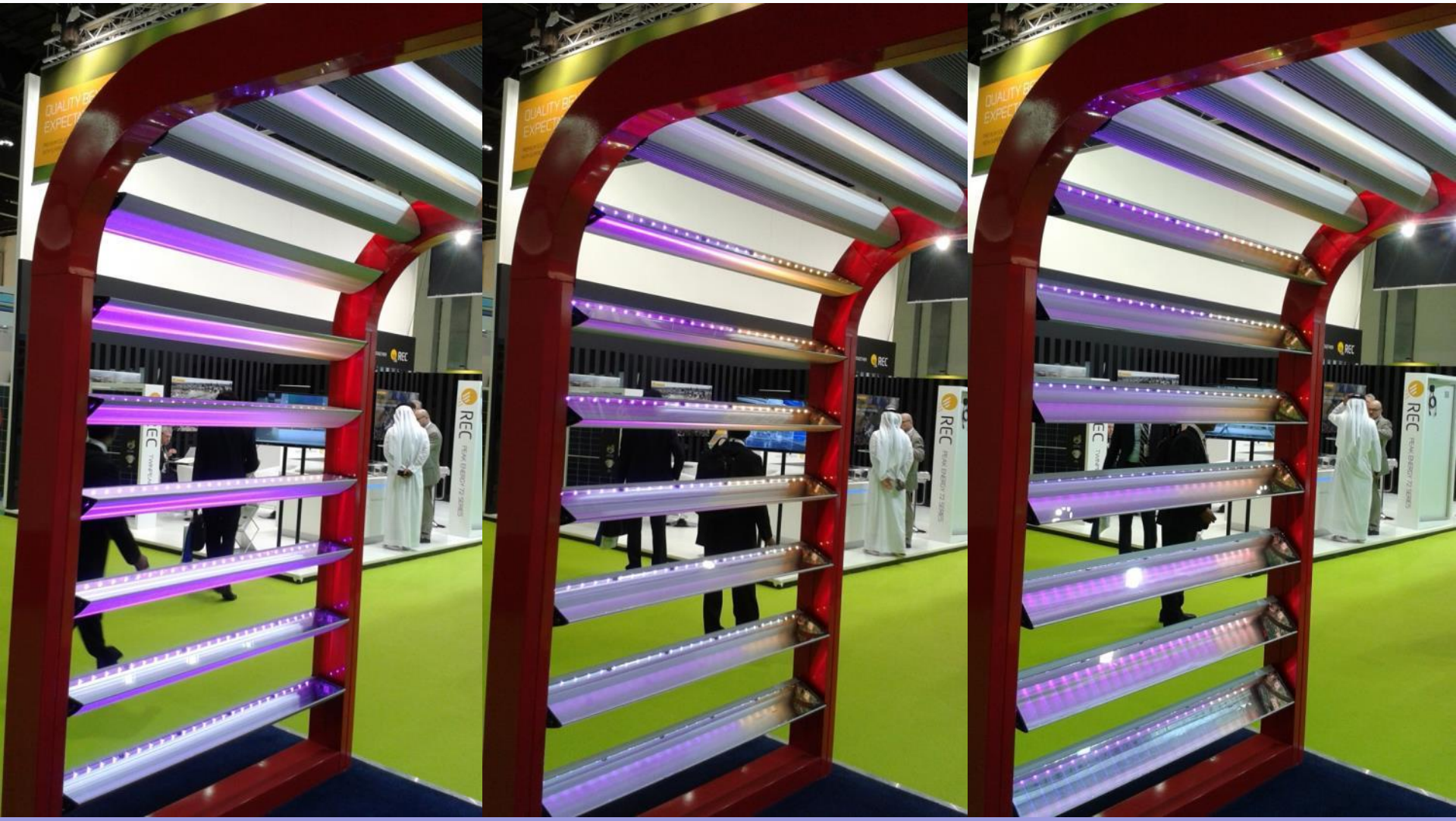
Innovation @ Solar Decathlon Europe
The Solar F-Light Module

The Solar F-Light® is a unique solar concentrator with integrated sun-tracking system, providing electricity generation, sun shading and architectural illumination.

Photovoltaic Shelter for Electric Bikes



World Future Energy Summit 2015



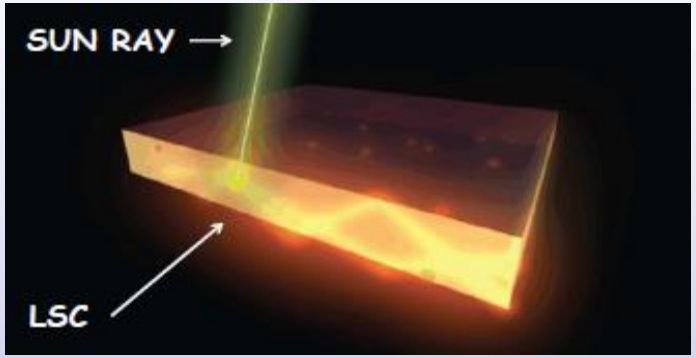
Luminescent Solar Concentrators (LSC) – Working principle

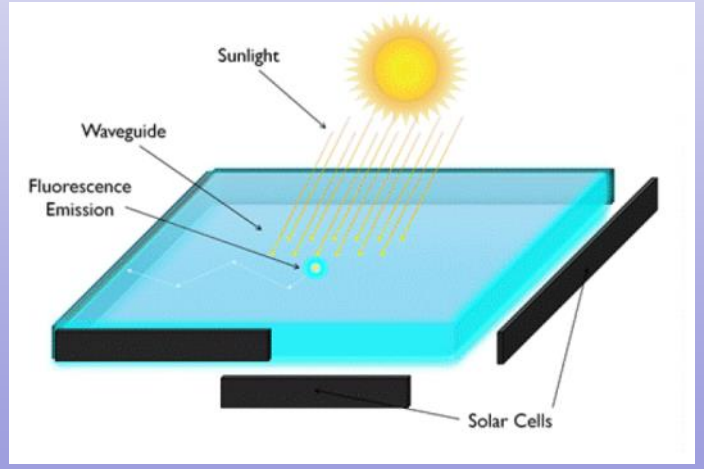
They operate according to the following working principle (three steps):

1. **the luminescent dyes absorb the incident solar radiation and isotropically re-emit photons at longer wavelength**

2. **the slab, by a process of total internal reflection (TIR), directs the radiation emitted by dyes on the PV cells arranged on the edges**

3. **the solar cells convert incident photons into electrical energy**



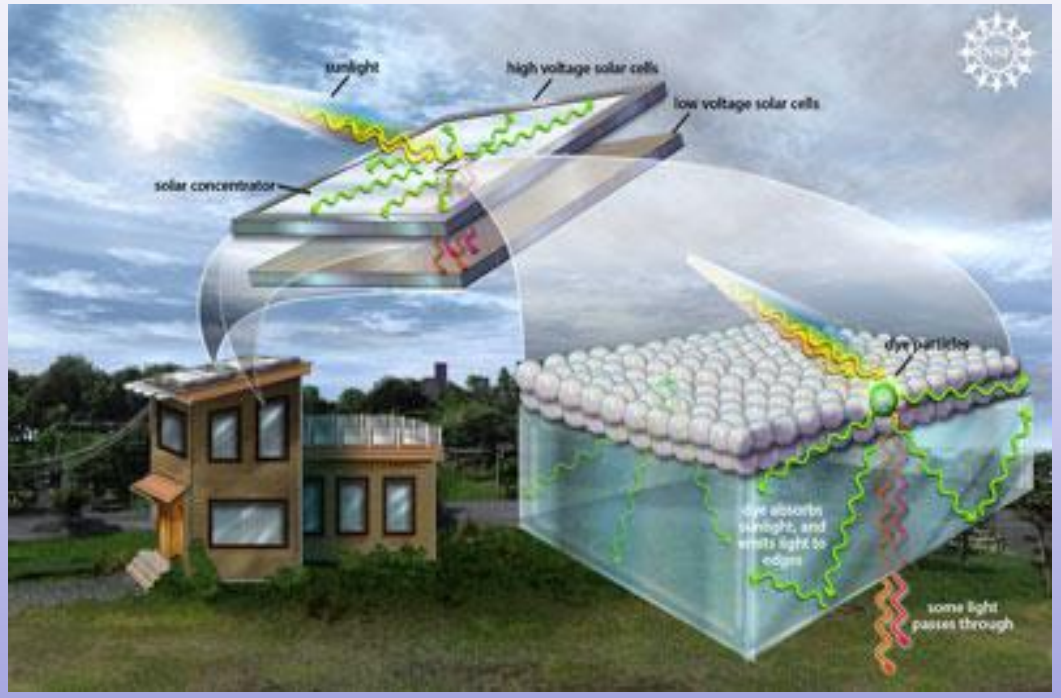


Luminescent Solar Concentrators (LSC) – Applications

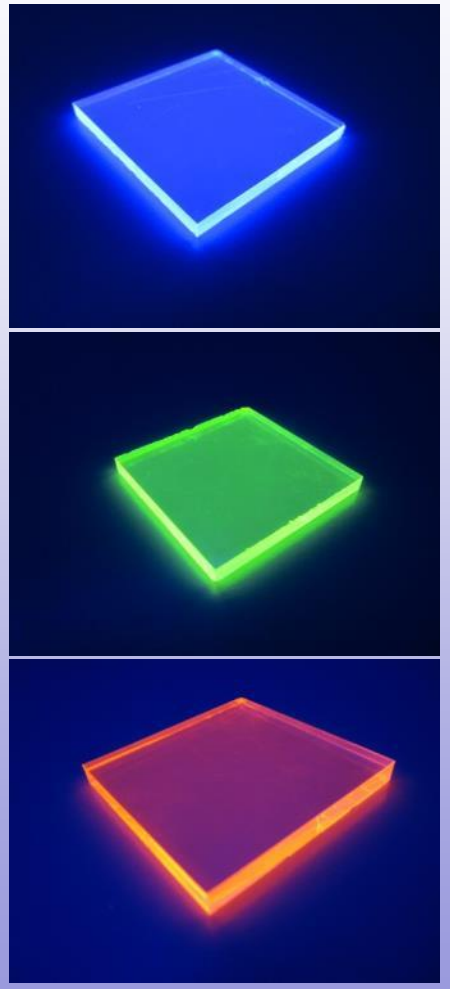
The use of LSCs is manly devoted to the Building Integrated Photovoltaic field (BIPV).

The main possible configurations are:

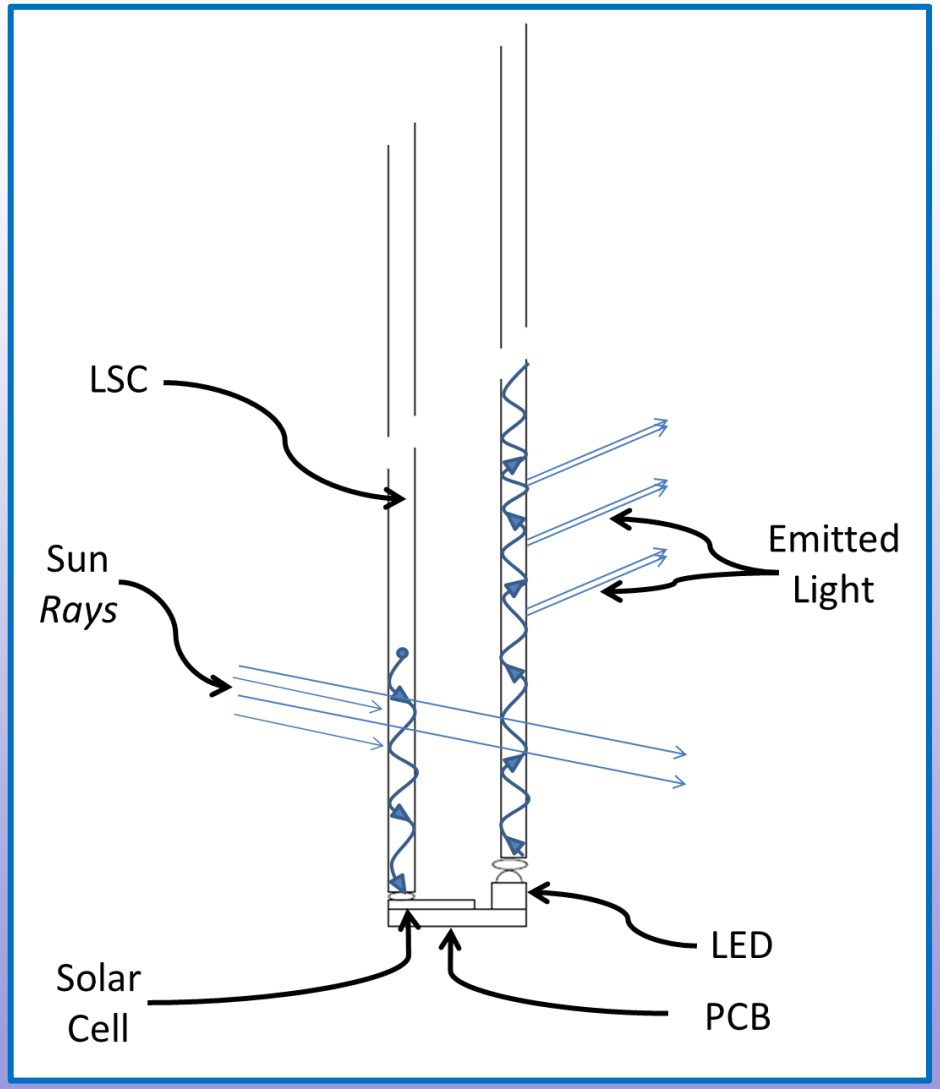
1. **Photovoltaic windows** (transparent / semi-transparent panels)
2. **Photovoltaic panels** (for the opaque parts of the building)
3. **Photovoltaic covers** of Si panels

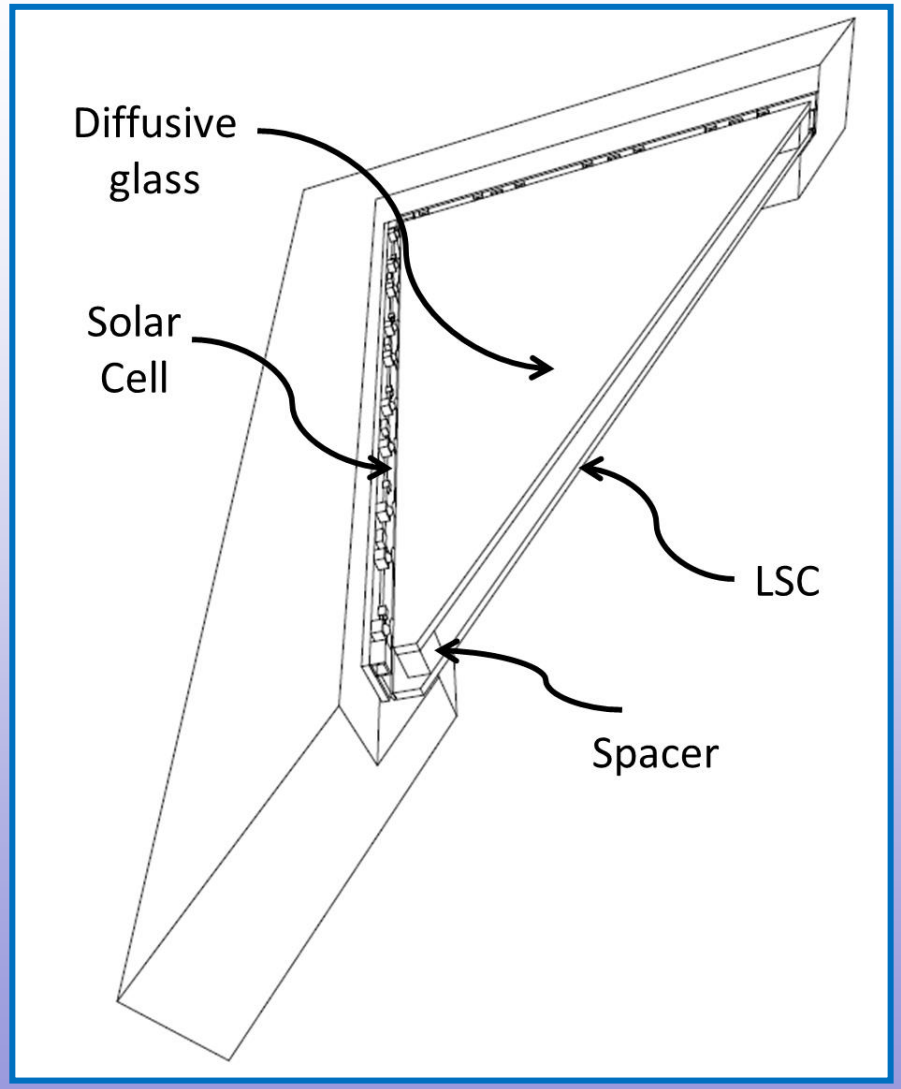


Luminescent Solar Concentrators

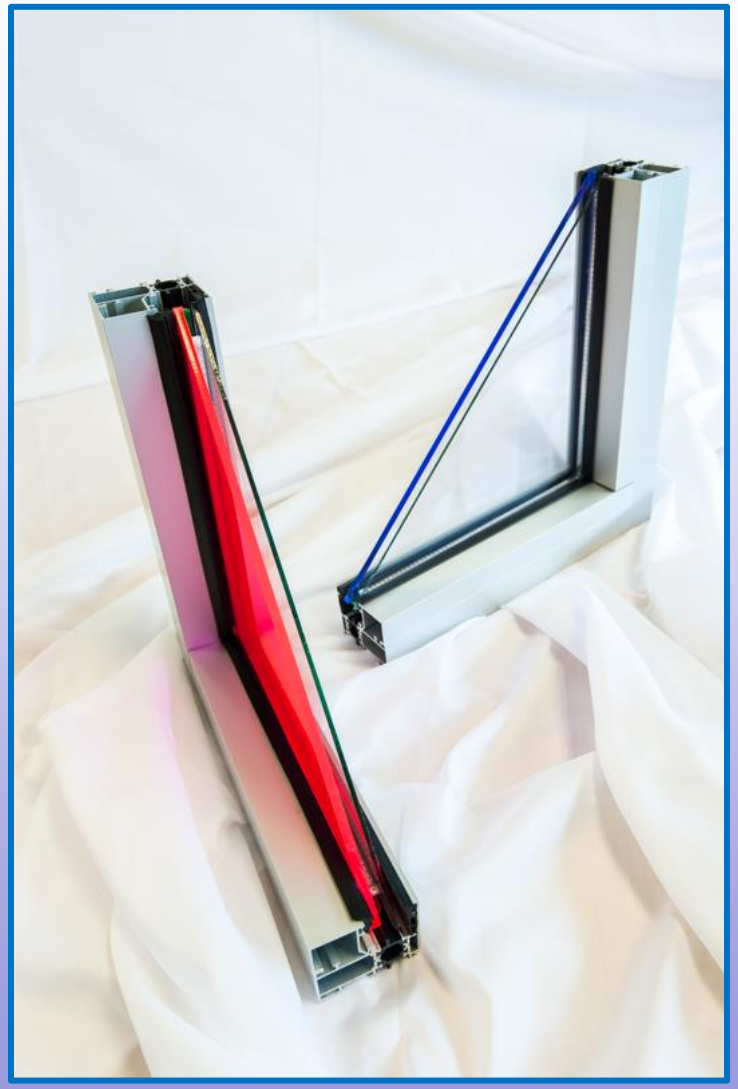


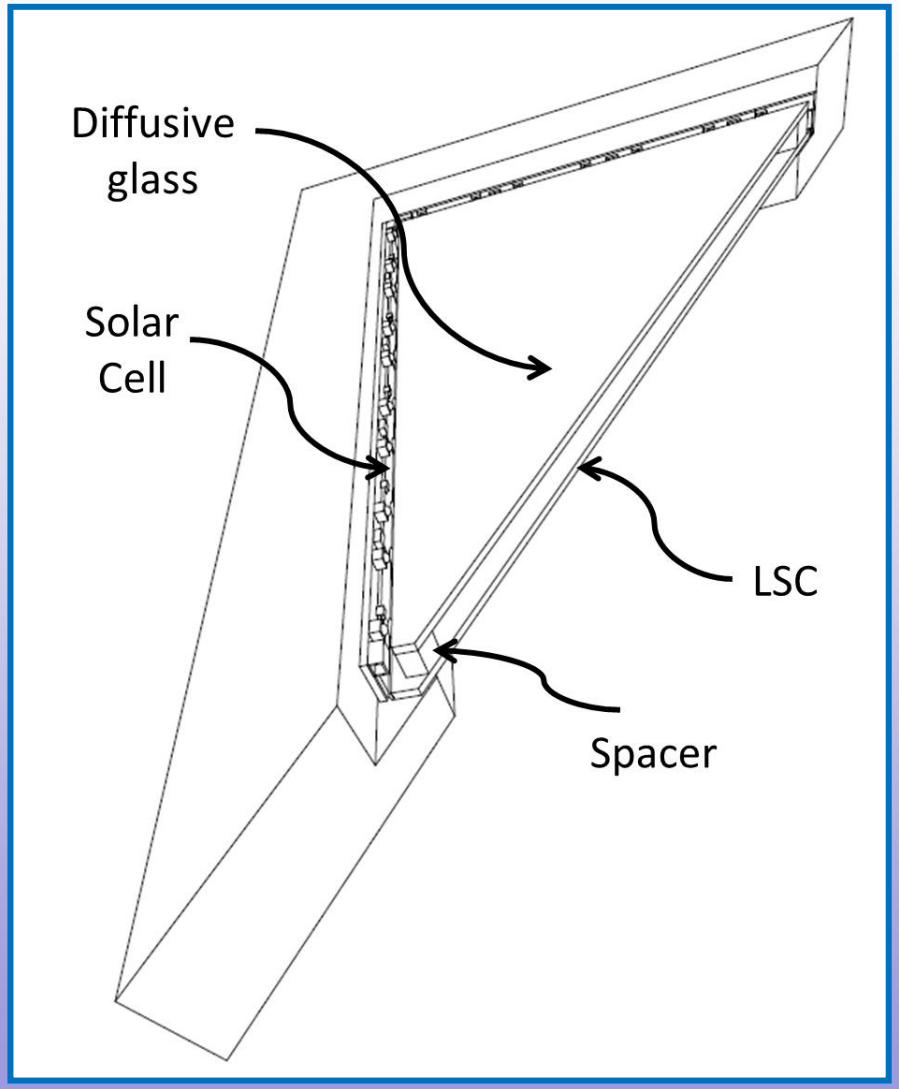
Luminescent Solar Concentrators





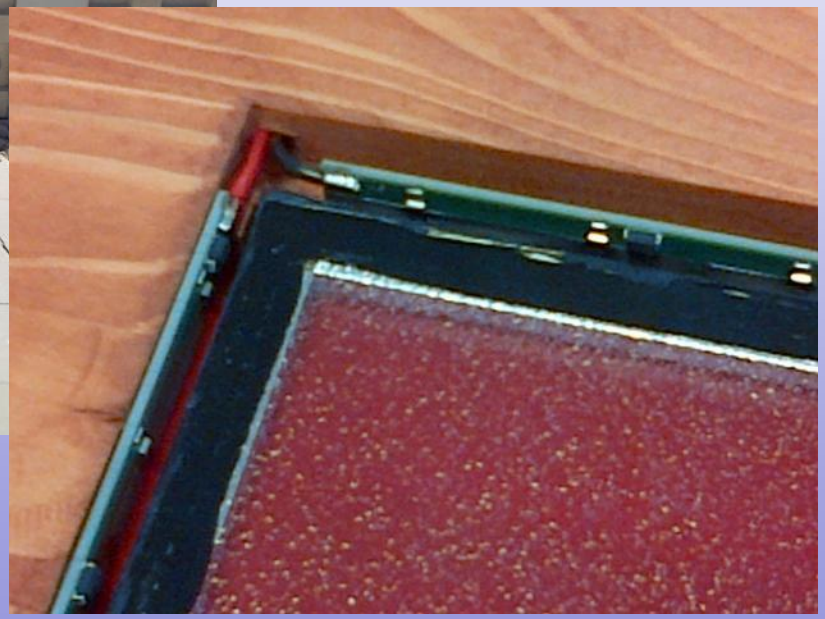
Luminescent Solar Concentrators





Innovation @ Solar Decathlon Europe 2012
Luminescent Solar Concentrators

Collaboration between University of Ferrara, University of Trento (Italy), Ecole Nationale Superiore d'Architecture (PARIS)



Double-glass stutter with integrated luminescent solar concentrator, MPPT tracking and battery charger.

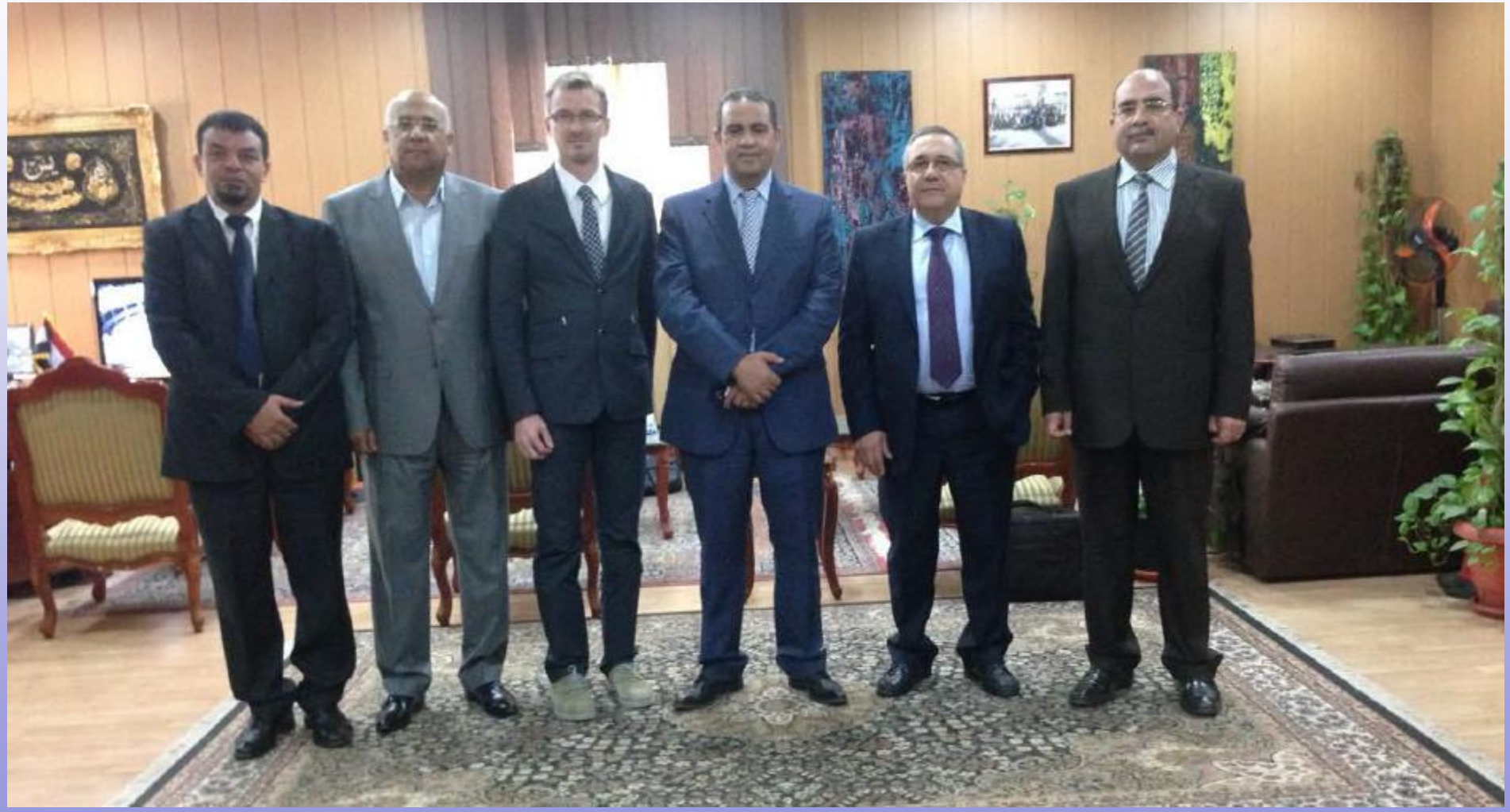
Solar Decathlon Europe 2014
Versailles (F)

Trentino Rainbow Energy

weAR

Agreement with the University of Mansoura (Egypt)

Characterization of CPV modules in desertic areas



Agreement with the University of Najran (Saudi Arabia)

Characterization of building integrated CPV modules

The Experimental Concentrating Photovoltaic plant at the Scientific and Technological campus

…the roof of the Physics and Earth Sciences Department