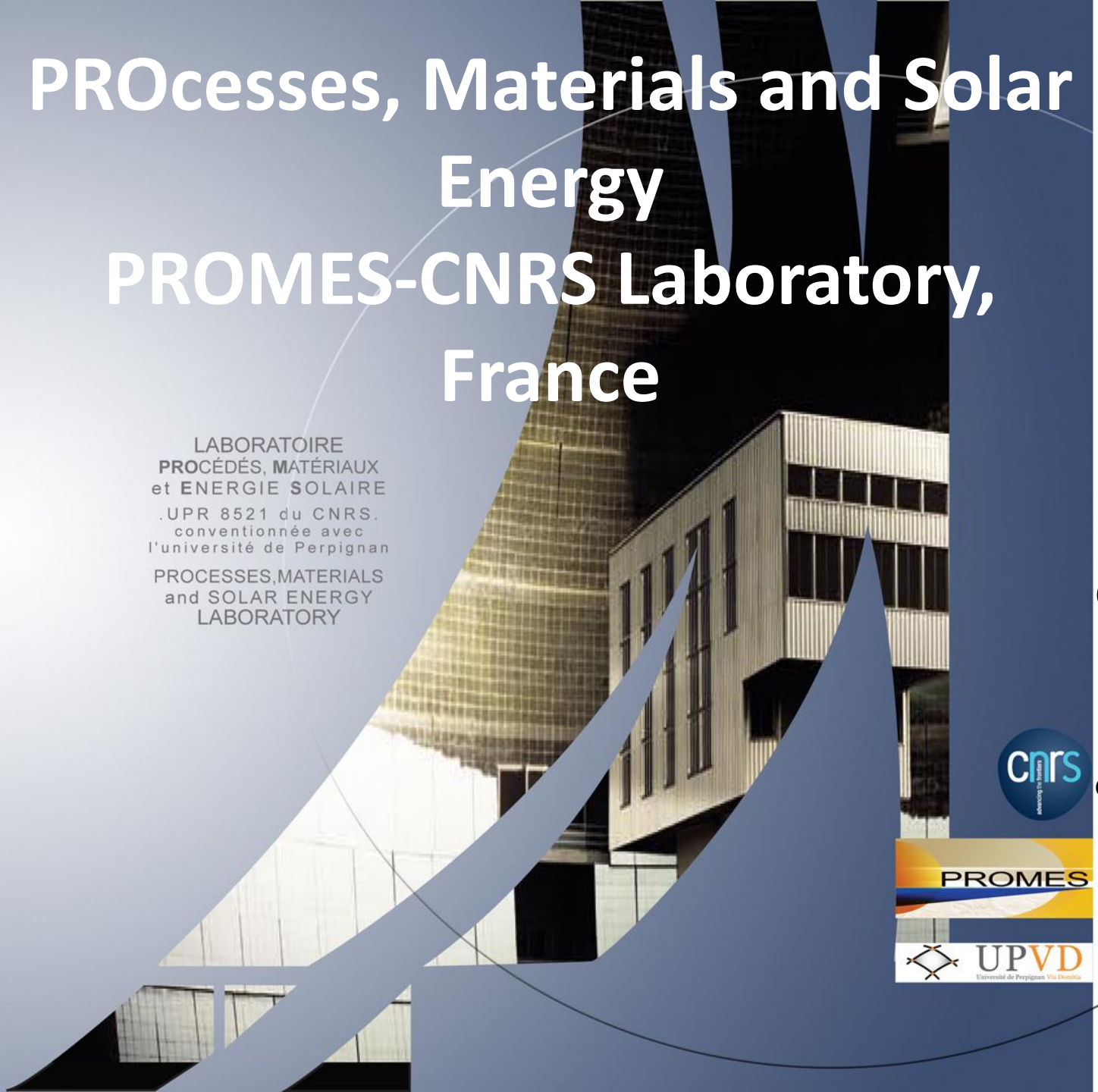
PROcesses, Materials and Solar Energy
PROMES-CNRS Laboratory, France



Gilles Flamant

Director

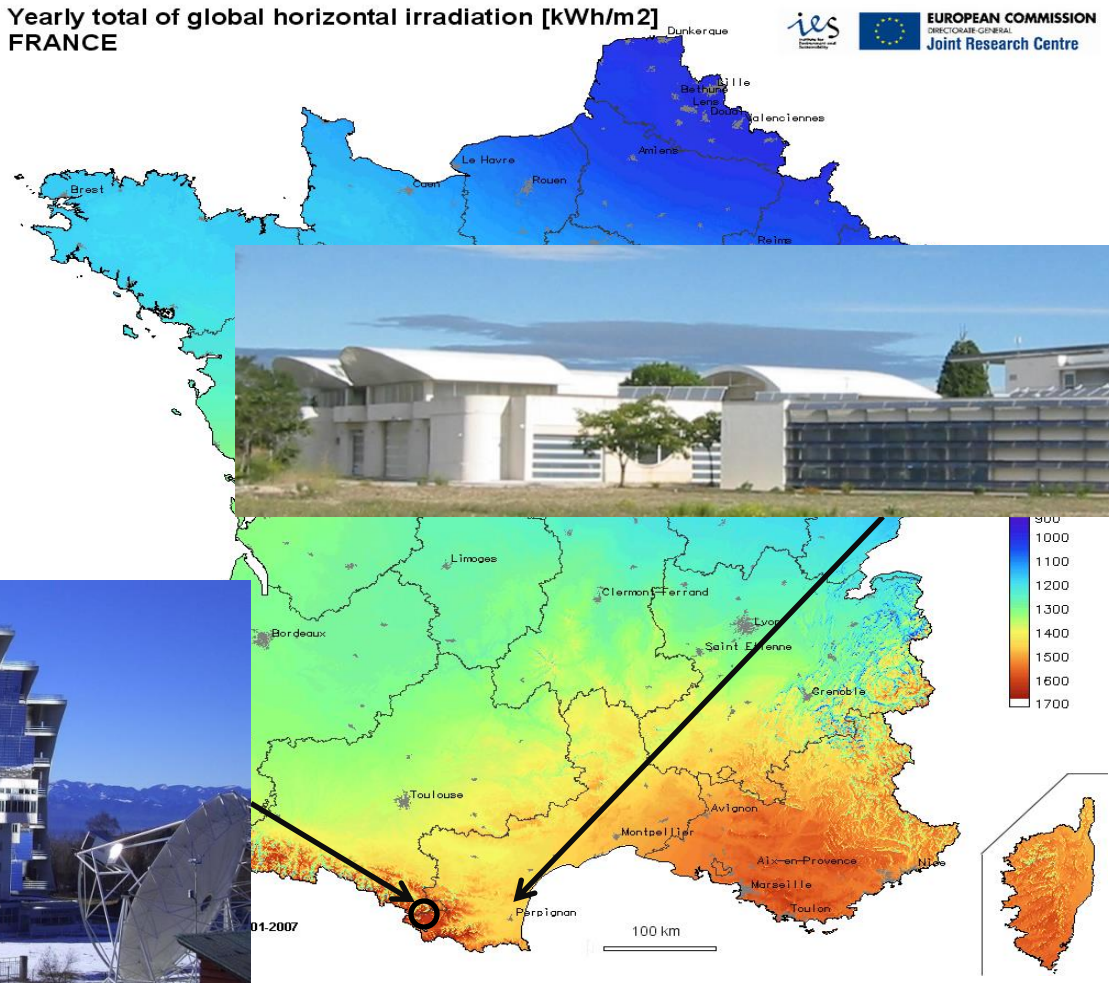
Gilles.flamant@promes.cnrs.fr

Content

PROMES Laboratory

1. Introduction
2. Mission of PROMES
3. PROMES Main Facilities
4. Research Groups
5. Examples of results

PROMES Locations



PROMES-Overview

CNRS
Institute for Engineering and Systems Sciences (INSIS)

- Two locations: Perpignan and Odeillo
- About **160** people, permanent staff: **90**
- Original equipments: Solar Furnaces (from **1.5 kW** to **1 MW**) and solar tower (**5 MW**)
- Selected for two « Projects of Excellence » of the French governement
- « European Infrastructure » in the EC-FP7 « **SFERA2** Project »

PROMES-Overview

Large projects

- National Laboratory of Excellence in Solar Energy: « SOLSTICE »
- National Equipement of Excellence in Concentrated Solar Energy: « SOCRATE »
- European Infrastructure « SFERA2 » and large EC project « STAGE-STE »

SOLSTICE

SOCRATE

SFERA

Solar Facilities for the European Research Area

Mission of PROMES

To develop Science and Technology related to solar energy applications, mainly **concentrated solar energy**, in the field of:

- ***Thermal conversion***: building heating and cooling
- ***Concentrated Solar thermal***: heat, power and fuel production
- ***Photovoltaic conversion***: new PV material processing and concentrated PV (CPV)
- ***High temperature materials testing and evaluation***

R&D at PROMES

Researches in the field of concentrated solar power and fuels:

- Optics of reflectors and solar absorber surfaces, radiation heat transfer
- High temperature solar receivers (particularly air receivers)
- New heat transfer fluid (suspension of particles)
- High temperature heat storage
- Materials ageing
- Thermochemical cycles for H_2 and CO production
- CSP system analysis and control
- High concentration PV

PROMES Main Facilities

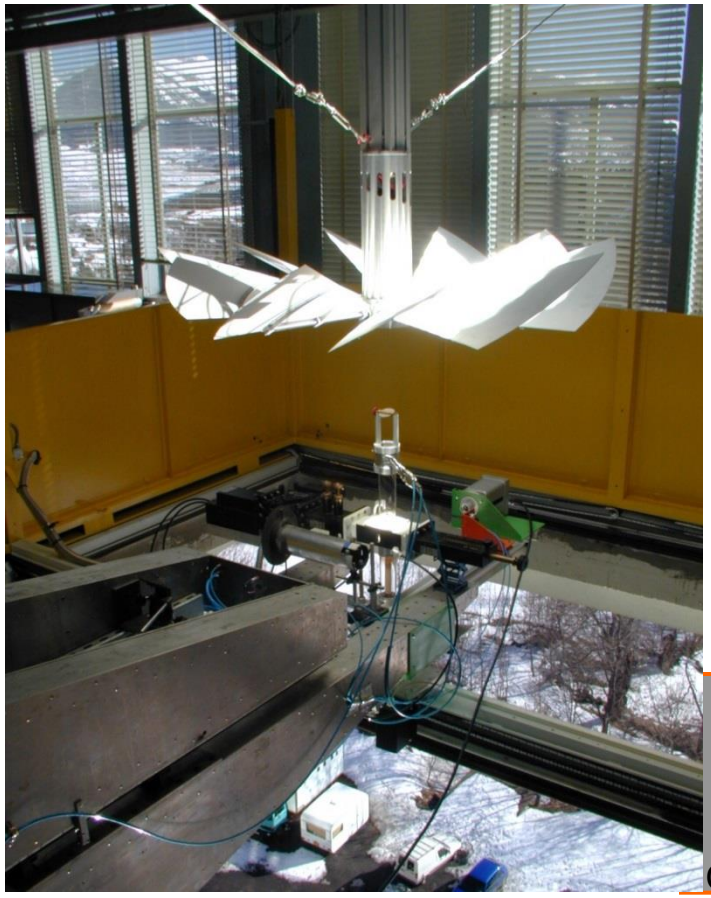
14 Solar Facilities

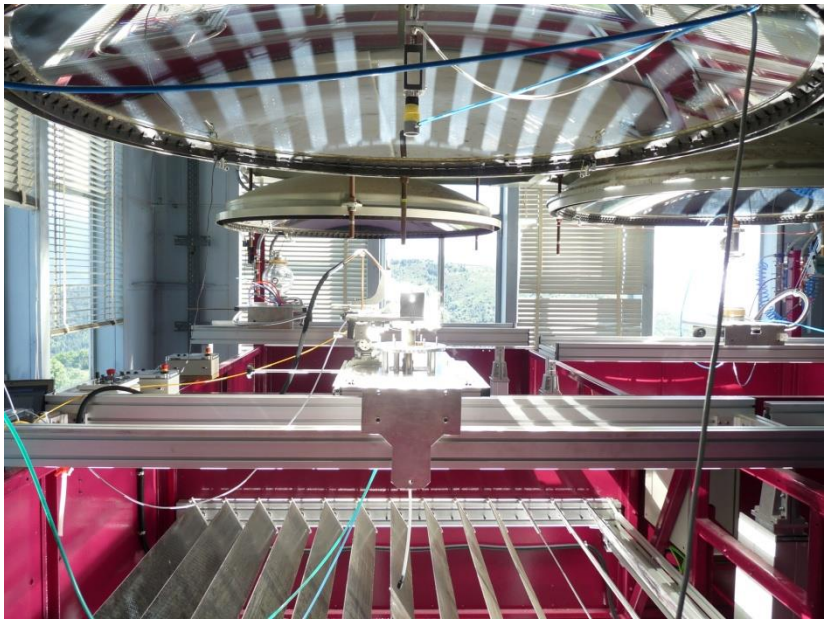
- **12 Solar Furnaces (two reflections)**
- **1 Dish 50 kW (one reflection)**
- **1 Solar Tower, 5 MW (one reflection)**

P = 1000 kW
63 Heliostats, Parabola 53x40m,
Concentration ~ 10 000

PROMES Main Facilities

Small Solar Furnaces 6 kW, 2 kW and 1.5 kW





P=6kW
Spherical mirrors
D= 4m, S=12.5m²
f= 3.75m, d=5cm
Concentration ~ 6 000

P=2 & 1.5kW
Single mirror parabola
6 Units: D=2m, f=.85m, d=0.5-1cm
4 Units: D=1.5m, f= .65m, d=0.5-1cm
Concentration ~ 17 000

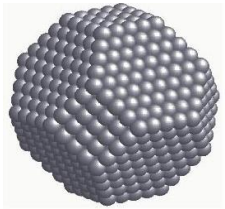
PROMES Main Facilities

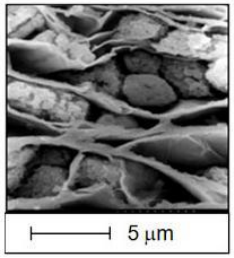
THEMIS tower and heliostat field

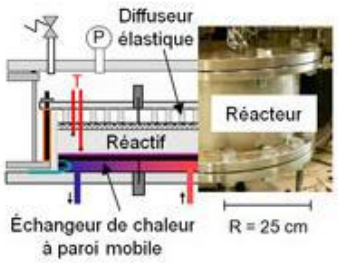
107 heliostats 54 m², 5 MW_{th}

Research Fields

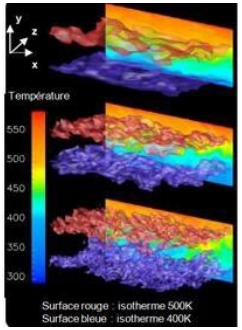
From nanoscale to plant scale, 2 Research Fields, 8 Researh Groups







10^{-9} m 10^{-6} m 10^{-3} m 1 m 100 m



Research Groups

AXIS 1: Materials and extreme conditions

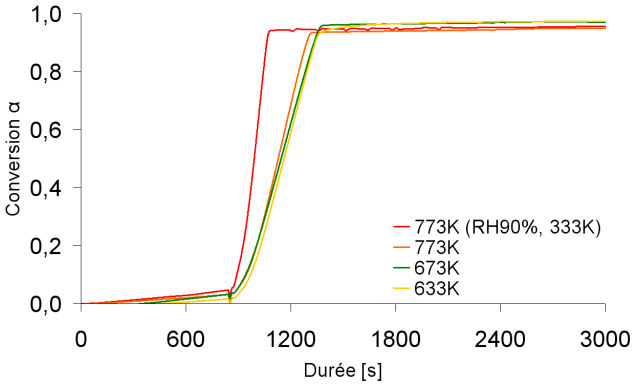
- High temperature materials and solar fuels
  Responsible : Marianne Balat-Pichelin

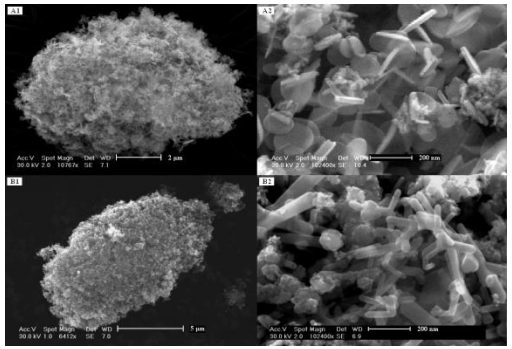
- Photovoltaics, Plasmas and Thin Films
  Responsible : Françoise Massines

- Nanoscale spin systems
  Responsible : Hamid Kachkachi

Example of Results

Solar Fuels

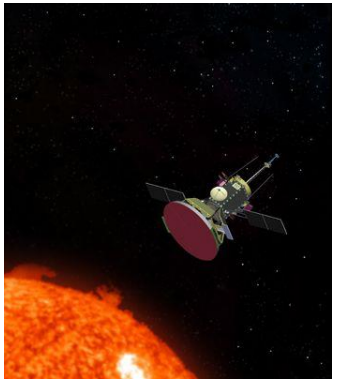


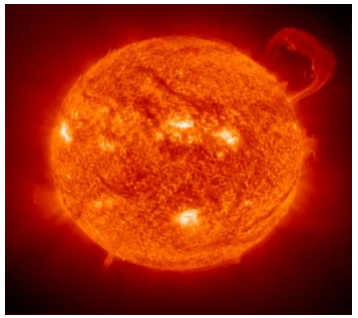


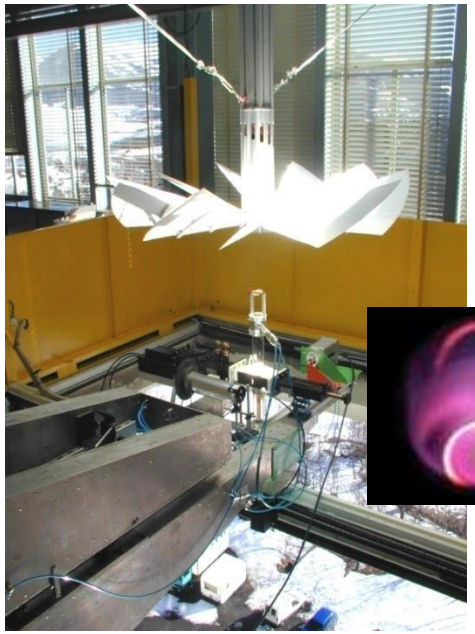
- ✓ Oxide thermochemical cycles to produce hydrogen and syngas
  ZnO/Zn, SnO_2/SnO, CeO_2/Ce_2O_3
  $M_xO_y \rightarrow M_xO_{y-1} + ½\ O_2$
  $M_xO_{y-1} + H_2O/CO_2 \rightarrow M_xO_y + H_2/CO$
- ✓ Solar up-grading of biomass and carbonaceous wastes

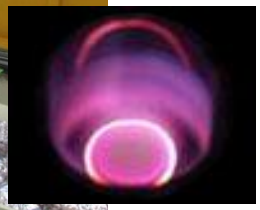
Example of Results

High Temperature Materials

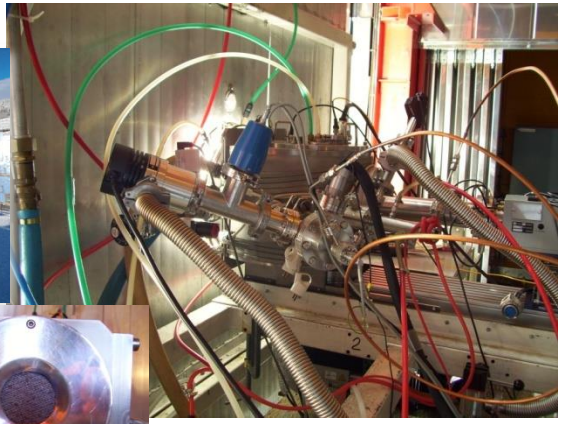








Experimental simulation tools



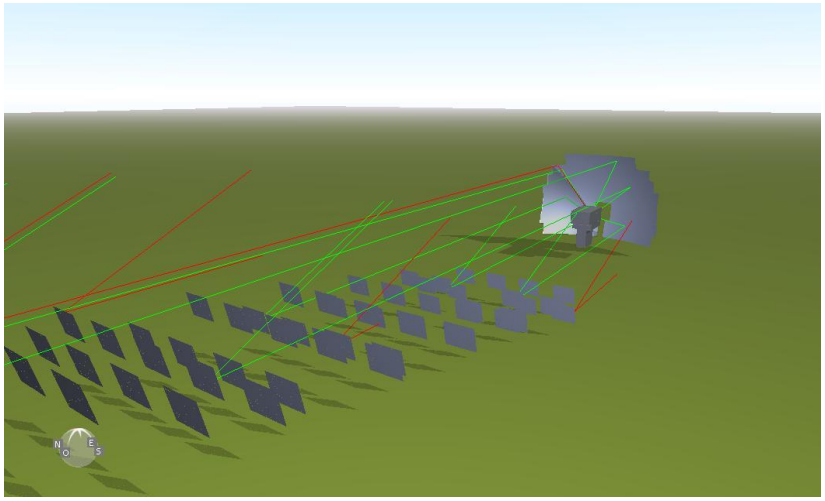
Research Groups

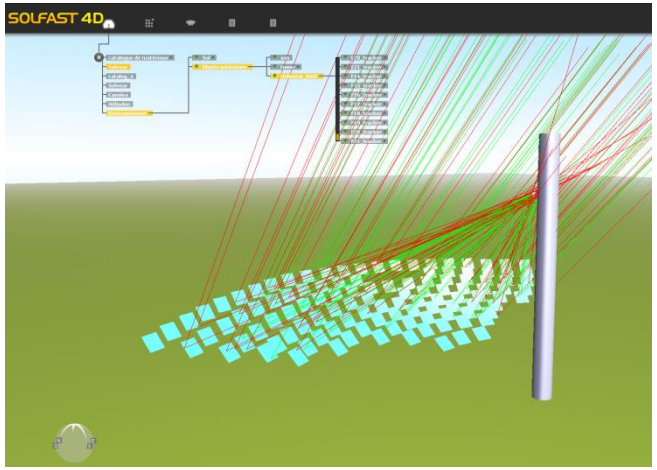
AXIS 2: Conversion, storage and transport of energy

- Radiation heat transfer and solar power plants
  Responsible : Alain Ferrière
- Thermophysics and fluid flows
  Responsible : Gabriel Olalde
- Thermodynamics, energetics and reactive systems
  Responsible : Driss Stitou
- Storage for photocatalytic and thermal solar systems
  Responsible : Vincent Goetz
- Electronics and system control
  Responsible Stéphane Grieu

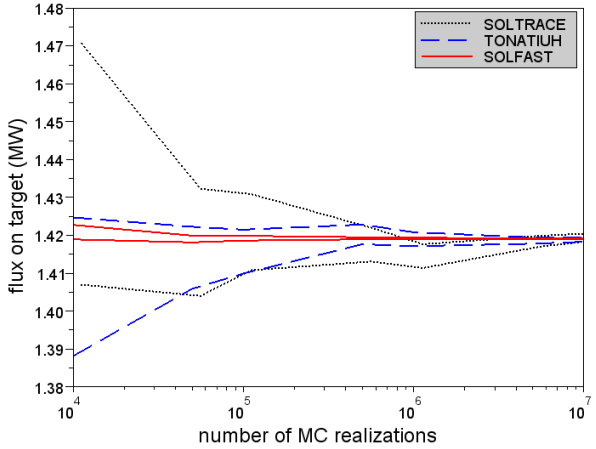
Example of Results

Simulation of Concentrating Optics





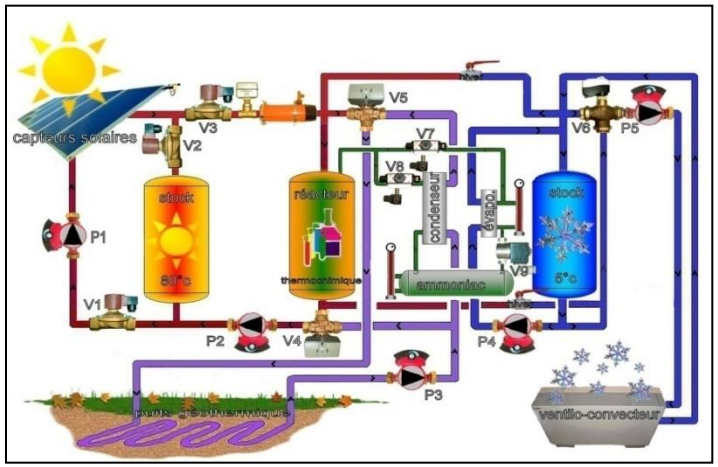
SOLFAST 4D Software,
a collaboration PROMES / HPC-SA

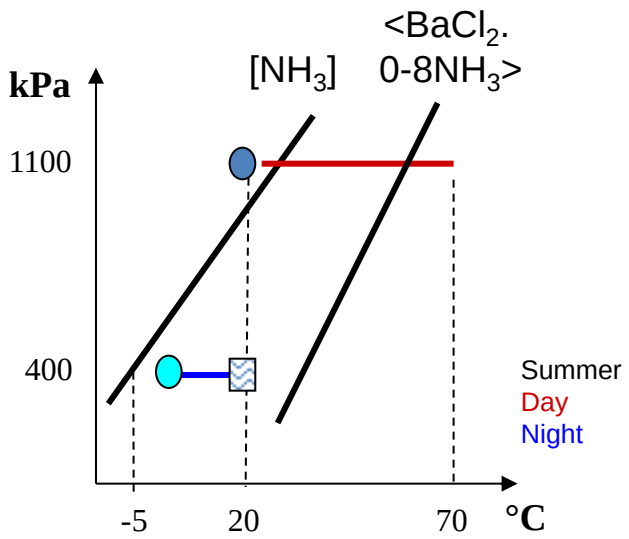


Example of Results

Researches in the field of solar thermal heating and cooling

Testing of an integrated full scale prototype



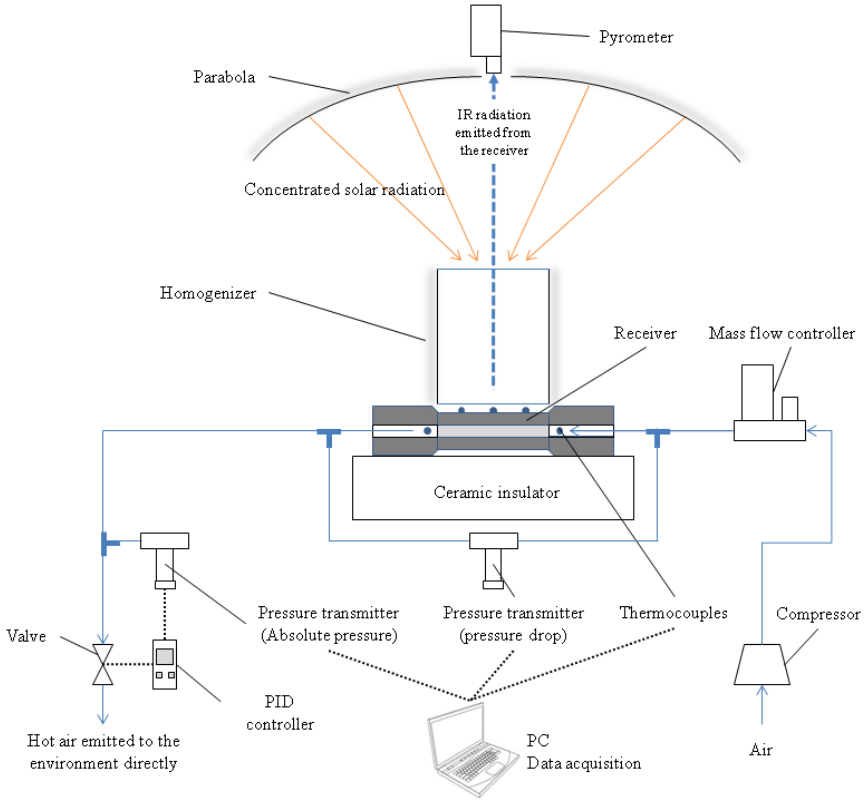


Flat solar collectors: 22 m²

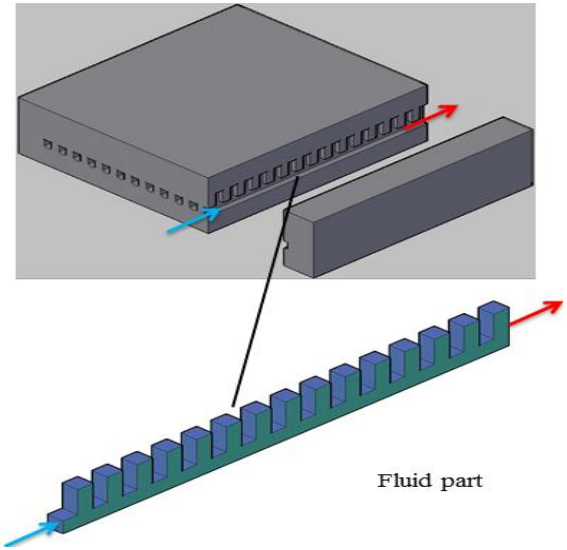
➔ **24 kWh coldness / 60 kWh heat**

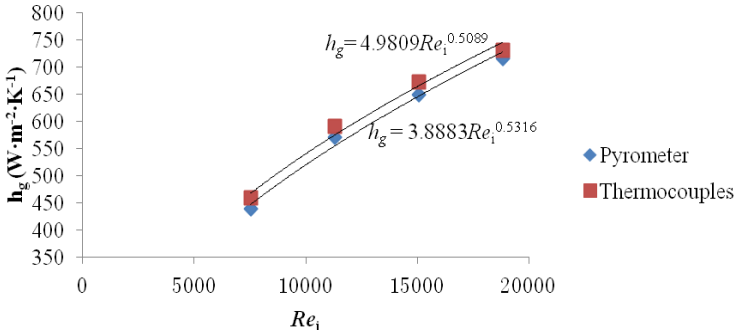
Example of Results

Compact Heat Exchanger Concept



Pressurized-Air High Temperature Solar Receiver





Example of Results

High Temperature Heat Storage

Recycling Mineral Wastes

Waste

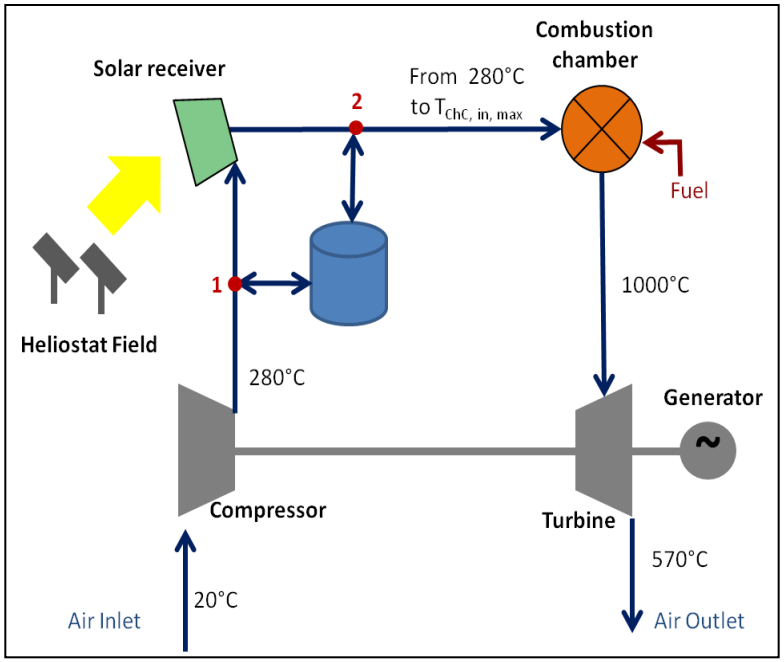
Inertization

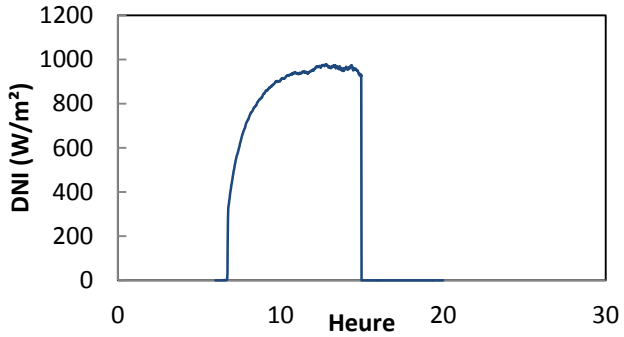
Processing of storage element

Storage tank

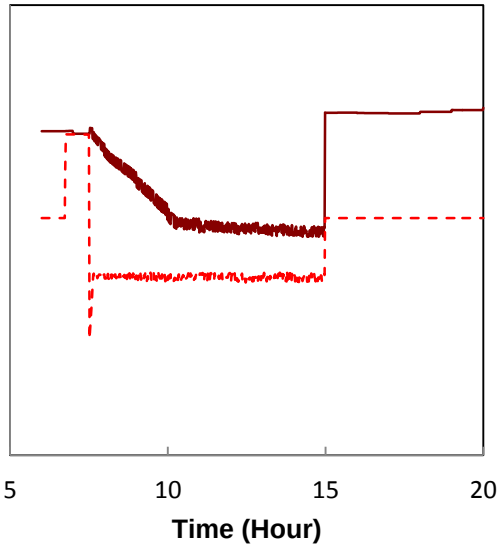
Example of Results

Solar Plant Simulation





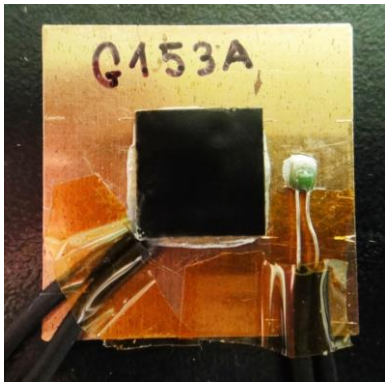
Power plant performance



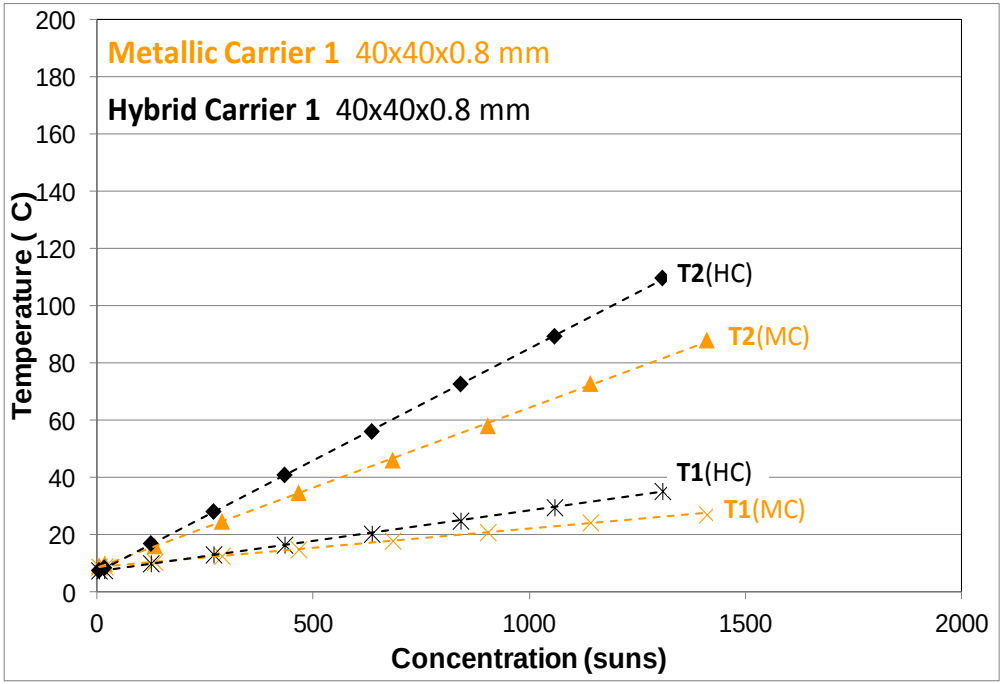
Example of Results

High concentration PV

Concentration x1000 / 5000
Theory of radiation losses
Ageing
Temperature control



Dummy cell (on Cu) with 2 resistance temperature detectors



Comparison of temperatures measured at the center of the cell (T2) and close to the cell (T1) for 2 different receivers (cell+cell carrier) of similar size but different structure (metal or metal+insulator)

Laboratory of Excellence SOLSTICE

Creation of LabEx was an initiative of the French government through « Investment for the Future » funding tool. SOLSTICE was created in 2012 (submitted 2011)

- To increase « Excellence », originality and transfer of knowledge thus increasing international position of French research
- To propose high level courses at the master and PhD levels
- To be coherent with site and University priorities

SOLSTICE

INVESTISSEMENTS D'AVENIR

Laboratory of Excellence SOLSTICE

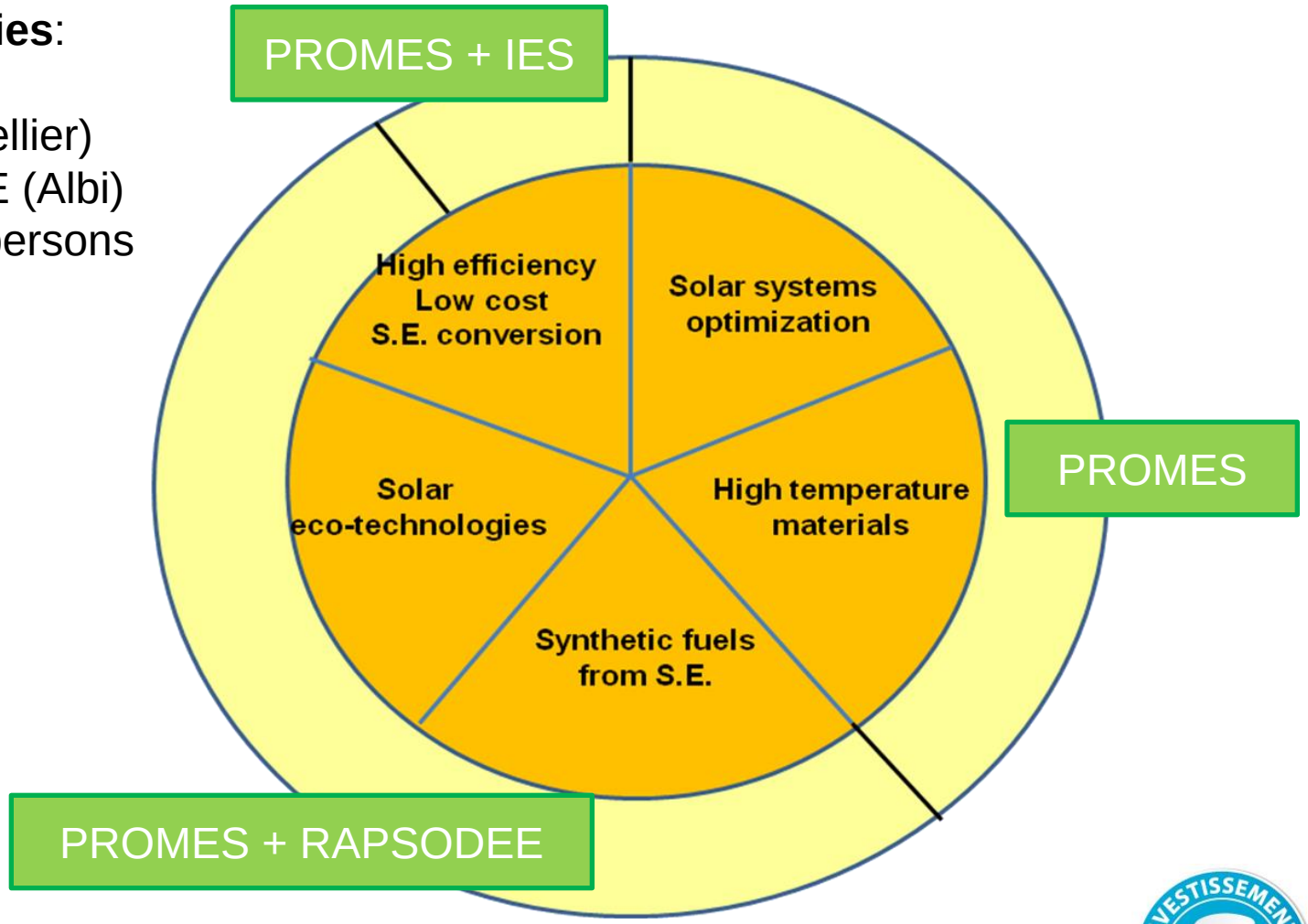
Solar energy: Science, Technology and Energy Conversion

SOLSTICE

INVESTISSEMENTS D'AVENIR

Topics and Partners of SOLSTICE

3 laboratories:
PROMES
IES (Montpellier)
RAPSODEE (Albi)
About 200 persons



SOLSTICE

INVESTISSEMENTS D'AVENIR

Scientific project of SOLSTICE

High efficiency and low cost conversion processes of solar energy: control of optical properties of solar converters, thermodynamic conversion of concentrated solar energy including thermal storage, concentrated photovoltaics (CPV), production of heat and coldness, PV materials processing.

High temperature materials for energy conversion: identification of new very high temperature materials, measurement of temperature and materials optical properties in the temperature range 300°C-3000°C, define and validate new methodologies to perform durability predictions of materials under severe conditions, investigation of physico-chemical behavior of materials, aging and degradation mechanisms.

SOLSTICE

INVESTISSEMENTS D'AVENIR

Scientific project of SOLSTICE

Synthetic fuels from solar energy: thermochemical redox systems for conversion of H_2O into H_2 and CO_2 into CO, solar chemical reactors operating up to 1800°C, thermochemical biomass valorization using concentrated solar energy.

Solar eco-technologies: detoxification of polluted water using photochemistry, thermal treatment of wastes by solar energy (valorization, stabilization, glass processing), uses of solar thermal energy in industry.

Solar systems optimization: development of algorithms for controlling solar process, optimal design approach of solar systems.

SOLSTICE

INVESTISSEMENTS D'AVENIR

SOLSTICE

Summary:

• A scientific project on solar energy, mainly solar thermal and concentrated solar
• An education project based on high level courses
• An innovation project targeting solar industry
• An ambition in the field of international collaboration
• Funding: 5 M€ up to 2020

INVESTISSEMENTS D'AVENIR

Thanks for your attention !