Solar Facilities and Associated Instruments Department

Identity

Composition of the team
Team leader: E. Guillot (Odeillo’s site), A. Ferrière (Targassonne’s site)
Permanent personnel: W. Baltus (T. CNRS), N. Boullet (Al CNRS), A. Ferrière (CR1 CNRS, 50%), E. Guillot (IR2 CNRS), A. Pérez (Al CNRS, 50%), R. Rodriguez (T CNRS), J.-L. Sans (IR1 CNRS), M. Tessonneaud (T CNRS).

Not permanent personnel:

Keywords
Solar furnace, solar tower, trough, instrumentation, characterisation thermo-optic, solar resource, temperature, radiometry.

Topics
The solar facilities of the laboratory
Specific instrumentation for the solar facilities

Collaborations
National
- M. Huger, T. Chotard : UNILIM ; N. Sonneck-Museux : DGA;
International
- C. Guemyard : Solar Consulting Services ; J. Ballestrin : CIEMAT ; M. Röger, C. Willsch : DLR ; I. Alxneit, C. Wieckert : PSI ; M. Montecchi : ENEA.

Contracts
- SFERA2
- EU-SOLARIS
- CNIM

Large equipment
- Odeillo’s Big Solar Furnace (Grand Four) — jouvence via Equipex SOCRATE 850k€.
- MiniTrough — Equipex SOCRATE 1600 k€.
- THEMIS Solar Tower (locataire avec équipements CNRS).
- 9 solar furnaces “Verticales”.
- 2 solar furnaces “Bastion”.
- Euro Dish Stirling
- Spectrometer — SFERA2 114 k€.
- Weather station.
Scientific report

INTRODUCTION

The laboratory operates a world unique set of solar facilities with unrivalled range and capacities, with Odeillo’s Big Solar furnace as spearhead. These large sized facilities cover the entire spectrum for concentrated solar researches:

- From low to high power: from 0,8 kWth to more than 4500 kWth.
- From low to high power density: from 25 kW/m² to more than 16000 kW/m².

The Solar Facilities and Associated Instruments Department (Service des Installations Solaires et Instruments Associés — SISIA) has 3 main missions:

- Guarantee the operation of the laboratory’s solar facilities: organisation, maintenance.
- Identify the potential of the laboratory’s solar facilities: all performances measurement.
- Develop the capacities of the laboratory’s solar facilities: information, conception.

In addition, the SISIA handles 2 related missions:

- Provide the interface between the facilities, their associated instruments and equipment, and the users, internal form the laboratory or external from all over the World: training, participation to research project, general public communication.
- Develop special instruments and equipment specific to solar facilities: design, metrology.

To achieve its missions, the SISIA is organized per site:

- Odeillo’s site: Big Solar Furnace, MiniTrough, EuroDish, the 9 solar furnaces “Verticales”, the 2 solar furnaces “Bastion”, optical temperature measurements developments, thermo-radiative characterisation developments, concentrated solar flux measurement developments, solar resource measurements.
1. **Solar Facilities**

1.1. **Odeillo’s Big Solar Furnace (Grand Four Solaire) (Manager: J-L Sans)**

Odeillo’s Big Solar Furnace (or MegaWatt Solar Furnace, MWSF), commissioned in 1972, uses 63 heliostats which collect the solar energy to send it toward the parabola on the laboratory’s main building which then concentrates it on the experiment where up to 1 MWth and 10000 kW/m² are available with a wide range of levels and distribution.

This facility is mainly used for researches concerning materials science and to test new process to harness the solar energy typically planned for the next generations of solar towers:
- Contracts by the local team MHCTS with CNES, ESA, NASA.
- Projects by different local or hosted teams, department’s contracts: PartiSun, CSP2, Solar2Zinc, SFERA2.

This facility is the most overbooked at the laboratory: the waiting list is about 1 to 1,5 year long, with each experimental campaign during typically between 2 to 16 weeks.

Lastly, the Equipex SOCRATE has allowed to carry own the rejuvenation of the Big Solar Furnace:

- Renovation of the 63 heliostats to improve the possibilities to modulate the power and the power density and also the reliability: new motorisation, new communication and energy networks, new control and tuning software. The new system has been used for the first experiments since mid April 2016, at reduced and increasing capacity.

- Creation of a new close loop watercooling system to reduce the water bill.

![Figure 1: Odeillo's Big Solar Furnace and some of its 63 heliostats.](image)

1.2. **Thémis Solar Tower (Manager: A. Ferrière)**

The laboratory is the sole user of the solar tower Thémis (inaugurated in 1983), and uses 110 heliostats after having renovated them both on the mechanical and control side from 2006: new or updated electronics, new or updated control software. The heliostats collect the solar energy to focus it at the top of the 100 m high tower, either on the original experimental area that will be used for the PEGASE project, or on the new experimental area Mini-Pégase. (Figure 2).

Since its renovation by the laboratory, this facility has been used to test next generation processes to generate electricity: innovating solar receivers, solarized turbine, control and maintenance of heliostats fields.
1.3. MicroSol-R Solar Parabolic Trough (Manager: N. Boullet)

The MicroSol-R facility is the latest addition to the laboratory facilities thanks to the French funded Equipex SOCRATE (commissioning started in December 2015). It consists of 3 linear solar parabolic troughs with the 2 different orientations and a complete thermal oil based process to generate steam with 2 different heat storage systems and an ORC system to generate electricity.

This facility has been designed notably to work on thermal storage, the modelling of complete plant, the test of solar receivers, the training of students.

1.4. EuroDish Solar Dish (Manager: E. Guillot)

The EuroDish parabolic dish directly aims at the sun to collect 55 kWh and then to concentrate it to get up to 9500 kW/m². This dish can also be used as a 20 kWh solar furnace by borrowing a heliostat from the nearby Big Solar Furnace MWSF. The facility, first operated in 2004, includes a complete loop to generate electricity based on a Stirling engine or can be used for other experiments.

As the experiments installed at its focal point are not protected from the weather (rain, snow, hail, wind...) and the facility is currently complex to operate, it has not been operated during this report period beyond crucial maintenance.
1.5. Small parabolas at the Verticales (Manager: E. Guillot)

The Verticales solar facility use 3 heliostats to collect the solar energy and send it to 9 vertical axis parabolas and as many workplaces:

- One 4m parabola: 5.5 kWth and 5500 kW/m² with a fast solar energy modulator.
- Four 2m parabolas: each 1.5 kWth and 15000 kW/m², two have solar energy modulators SÉSAME.
- Four 1.5 m parabolas: each 0.85 kWth and 15000 kW/m², one has a solar energy modulator SÉSAME.

This facility hosts most of the research teams, either from the laboratory or from anywhere else, notably thanks to the European project SFERA2: 98 operating weeks in 2014 and 144 in 2015 for this project.

The researches at this facility cover the widest range, such as: new material synthesis, materials coatings, thermal testing, chemical conversion, electric conversion... It is also usually at this facility that we receive students or journalists to sensitize them on the potential of solar energy and the laboratory’s activities.

Figure 5 : Show of rock melting to students with one of the parabola at the “Verticales”.

1.6. Small parabolas at the Bastion (Manager: E. Guillot)

The Bastion solar facility use 2 heliostats to collect the solar energy and send it to 2 horizontal axis parabolas, each 1.5 kWth and 16000 kW/m².

The researches at this facility notably include: thermo-optical characterisation of materials, solar energy usage based on thermo-chemical cycles, development of solar pumped LASER beams.

Figure 6 : Solar directional reflectivity measurement with DISCO setup at the Bastion.
2. **INSTRUMENTATION**

Due to operating requirements (weather station) or as the solar facilities’ users have operating parameters not covered by commercial instruments, the SISIA develops original instruments and instrumentation methods.

2.1. Weather measures (Responsible: E. Guillot)

In order to assess the repeatability and the reproducibility of the solar researches at Odeillo and to determine the overall efficiency of the tested conversion processes, SISIA operates and maintain the required sensors and associated infrastructure: 4 pyrheliometers, 5 pyranometers, 3 solar trackers, dedicated computers and specially developed software, several UPS, in coordination where relevant with the IT service and electrical service. The SISIA also operates the “SAM” instrument to determine the apparent solar disk diameter (CSR) to improve the accuracy of the collected data. Current collaborations are with CIEMAT and DLR within the SFERA2 project (WP11) in order to improve calibration of these solar sensors. The third development in progress is about sky cameras to optically detect the cloud cover, forecast solar resource and determine shadow on the ground.

![Figure 7: Main weather station in Odeillo: pyrheliometers and pyranometers on the solar tracker, sky camera to track clouds.](image)

2.2. Temperature measurement (Responsible: J-L Sans)

Surface temperature measurement is critical for most solar experiments. Usual commercial devices cannot usually be used as they are disturbed by the highly concentrated solar light reflected. Several laboratory’s teams have developed since the beginning special instruments or customised commercial instruments. SISIA is now carrying on several of these developments, notably bi-color pyrometry and pyro-reflectometry. Another original technique is currently under evaluation within the SFERA2 European project with PSI (Switzerland).

![Figure 8: Testing a solarblind pyrometer prototype at the “Bastion”.](image)
2.3. Optical properties measurement (Responsible: J-L Sans)

In order to conduct optical surface temperature measurements or to assess the radiative performance of materials, the reflectivity and emissivity must be determined. SISIA is contributing in this field at the laboratory. Notably, the MEDIASE setup is currently being upgraded within the SFERA2 European project.

![Figure 9: SFERA2 funded new spectrometer being calibrated to allow emissivity measurement with MEDIASE at the MWSF.](image)

2.4. Concentrated solar flux measurements (Responsible: E. Guillot (Odeillo), A. Ferrière (Targassonne))

In order to monitor the performance of the solar facilities and to evaluate the energy delivered to the tested processes, the concentrated solar power must be measured, including its spatial distribution. No suitable device is commercially available, notably as the solar facilities set is World unique. Suitable sensors and techniques are developed since the beginning of the laboratory, now carried on by the SISIA: calorimeters, camera based flux mapping including 2 moving bars.

Some of these instruments are periodically compared to the other EU developed sensors (DLR, CIEMAT, ENEA, DGA), the next campaign is being planned within the SFERA2 European project.

![Figure 10: Concentrated solar power spatial distribution at the focus of a 2 m MSSF parabola "Verticales" with a very dirty heliostat: peak is 10551 kW/m² instead of about 15000 kW/m² nominal.](image)