Engineering and Erection of a 300kW High-Flux Solar Simulator

Kai Wieghardt[1], Dmitrij Laaber[1], Patrick Hilger[2], Volkmar Dohmen[1], Karl-Heinz Funken[3], Bernhard Hoffschmidt[3]

[1] *DLR, Institute of Solar Research, Karl-Heinz-Beckurts-Straße 13, 52428 Jülich, Germany, kai.wieghardt@dlr.de.*
[2] *phinnova, Fähnrichstüttem 1, 51688 Wipperfürth, Germany.*
[3] *DLR, Institute of Solar Research, Linder Höhe, 51147 Köln, Germany.*

Abstract. German Aerospace Center (DLR) is currently constructing a new high-flux solar simulator **synlight** which shall be commissioned in late 2016. The new facility will provide three separately operated experimental spaces with expected radiant powers of about 300kW / 240kW / 240kW respectively.
synlight was presented to the public for the first time at SolarPACES 2015 [1]. Its engineering and erection is running according to plan. The current presentation reports about the engineering and the ongoing erection of the novel facility, and gives an outlook on its new level of possibilities for solar testing and qualification.

THE VISION: A NEW LEVEL OF SOLAR TESTING POSSIBILITIES

The step from laboratory scale to full-scale demonstration is a crucial point in nearly every technical development. In the case of highly loaded CSP components and of solar-chemical processes this step has a considerable distance until now:

The laboratory scale is represented by electrically driven high-flux solar simulators (HFSS). They offer precisely controllable and reproducible solar radiation, however, at a limited level of solar radiation power. One of the largest HFSS with 20 kW [2] [3] is successfully operated by DLR since 2007.

The next largest test opportunities are usually research platforms on solar towers. An example is that on DLR's Solar Tower in Jülich [4]. With a maximum power of about 1MW this research platform is typical for its class and emerged to an essential test facility. However, the use of the natural sunlight results in weather dependency and limited availability, and the high focal length effects in restricted precision and flux density.

As a consequence DLR is currently erecting a test facility which shall fill the performance gap and combine the best of both worlds: **synlight** will be a very large HFSS for precisely predictable and weather-independent solar radiation. It will have three independently operable test chambers which will receive a solar irradiance up to a power of 300kW to 400kW. In addition, the available solar power shall enable higher flux densities and so increase the possible temperature level. Synlight is still under construction in an own building close to the Solar Tower (see **FIGURE 1**).

Table 1 shows a comparison of all existing HFSS with a point focusing radiation power above 10kW, as far as known by the authors. All of these facilities use Xenon short-arc lamps; column 4 shows their number and size. The table illustrates the future exceptional position of **synlight** amongst the HFSS facilities: Each of its test chambers might receive a radiation exceeding the entire global HFSS capacity of today.

Therefore, **synlight** will open up a new quality and quantity of testing and qualification possibilities for DLR and the entire solar research community.

FIGURE 1. Near-completed synlight building and Solar Power Tower Jülich

TABLE 1. synlight in comparison with all known HFSS with point-focussing solar radiant powers >10kW ([1], updated)

Operator and facility	**Start-up**	**Solar power [kW]**	**Electric power [kW]**	**Focal length [m]**	**Peak flux [MW/m²]**
DLR, **synlight**, Jülich	2016	300* (400*) 240* (320*) 240* (320*)	149 x 7 (149 x 10)	8.0	>11.0*
PSI, Zürich [5]	2005	50	10 x 15	3.0	11.0
Niigata University [6][7]	2013	33	19 x 5	1.6	3.2
DLR, HLS, Cologne [2][3]	2007	20	10 x 6	3.0	4.2
Aristotle Univ., Thessaloniki [8]	2013	20	11 x 6	3.0	4.8
KTH Stockholm, Solar Lab [9]	2014	20	12 x 7	1.5	6.7
NCEPU, Beijing [10]	2015	20	7 x 10	2.1	4.0
Australian Nat. University [11]	2015	15*	18 x 2.5	1.9	9.5*
EPFL Lausanne, LRESE [11]	2015	15*	18 x 2.5	1.9	9.5*
University of Florida [12]	2011	14	7 x 6	2.0	5.0
IMDEA, Madrid [13]	2013	14	7 x 6	2.5	3.6
University of Minnesota [14]	2010	11	7 x 6.5	2.3	8.5

* Predicted values. Values in brackets () exceed the current standard and can be realised with additional effort.

REALISATION OF A MODULAR SIMULATOR DESIGN

The new facility is characterized by a strictly modular arrangement of 149 equal Xenon block units. Each of these modules is individually and computer controlled three-axially movable, in horizontal, azimuth and elevation directions. Due to a suitable definition of their movement axes, the module allocate just small honeycombed design and movement spaces.

synlight takes significant advantage from the operational experience with DLR's existing HFSS. Proven features like the reflector design and aluminum coating were adopted as well as the Xenon lamp equipment. Conventional cinema lamps with an electric power of about 7kW were chosen as they seem to represent the current economical optimum for the generation of concentrated artificial sunlight. However, the electrical equipment and the cooling is designed for special lamps up to 10kW which could be easily installed if required.

The module development was supported by a prototype (see **FIGURE 1**) for an instant testing design concepts and technical solutions. Due to the strict modularity of **synlight**, the gained experience could be transferred to the whole facility from an early stage of engineering. This gave a proper control over costs and risks and enabled predictions of performance and functionality. The current erection of synlight is predominantly a replication of the known prototype module.

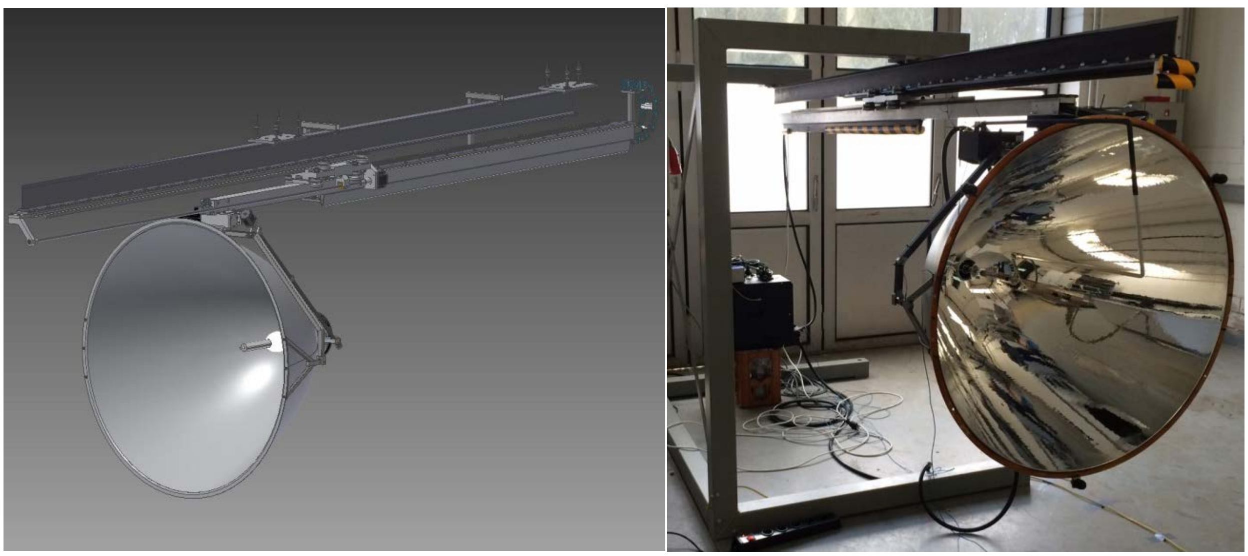


FIGURE 1. synlight module in CAD and as prototype

The 149 modules are mounted on a 14m high platform in a beehive-shaped arrangement (see **FIGURE 2**, left). One of the key ideas of synlight is to share the facility resources by multiple experiments as the test installations normally consume much more time than the pure testing. The independent computer-based movability of the modules will reach this objective perfectly as the focused light can be freely distributed amongst the three test chambers (see **FIGURE 3**, left). Equally, nearly all kinds of specially or timely functions of the solar radiation shall be realized on the apertures.

The **synlight** project started about two years ago, in mid-2014. The building was commissioned by DLR and its local partner Technologiezentrum Jülich and is nearly finished for delivery. Development, design, engineering and procurement of the facility as well as its project management were executed by DLR. The nearly 100 kinds of components and assemblies were sources from domestic and European suppliers.

Likewise, the current erection is carried out by DLR. **FIGURE 2** (right) and **FIGURE 3** (right) shall illustrate the present status. The project is still within its time and budget plan.

According to this plan, the facility shall start its operation with a DLR experiment in the fourth quarter 2016. As announced in [1] the facility shall be open for cooperative research partners from early 2017 onwards.

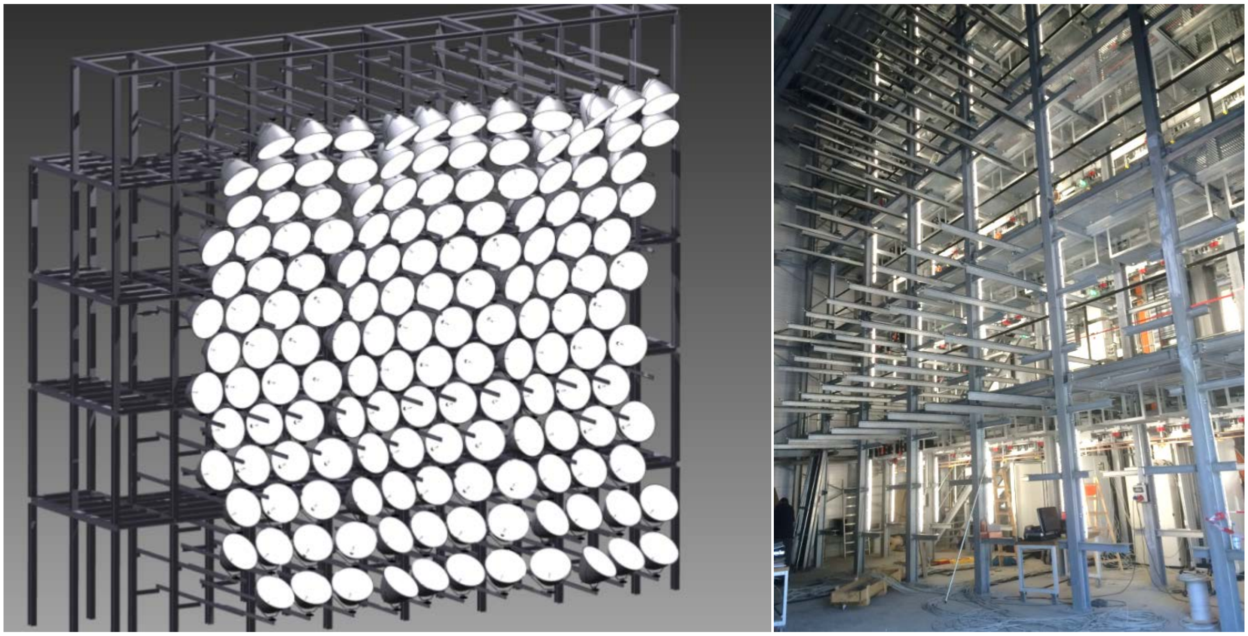


FIGURE 2. synlight facility in CAD [1] and under current construction

TECHNICAL PROFILE OF THE FACILITY

The three test chambers opposite to the platform are placed behind fire and light proof roller shutters with a size of 4m x 4m. Together with appropriate walls and the access control system, these measures will enable the chambers to be operated independently from each other. Installation and reconstruction works can be safely performed while a test is running in the adjacent chamber.

Each of the test chambers is designed and equipped for specific requirements. **TABLE 2** shows the floor plan and the main parameters.

The yellow arrows mark the positions of the focal points. The movement spaces of the modules enable 121 modules to hit this target point in the central chamber and 96 modules each in the side chambers. The given radiation powers are derived from these numbers and the prototype measured radiation powers of the standard 7kW lamps and the maximum useable 10kW lamps, including cosine effects.

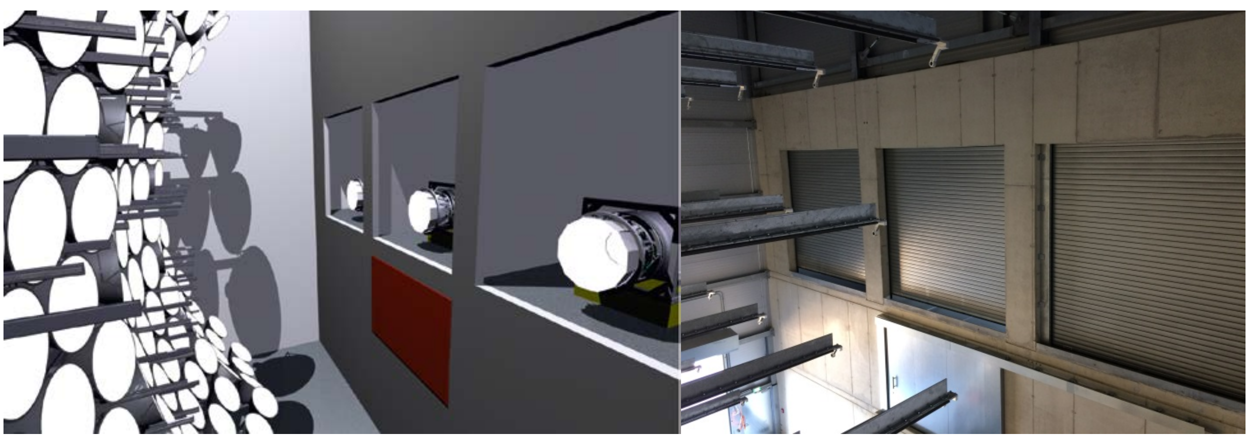
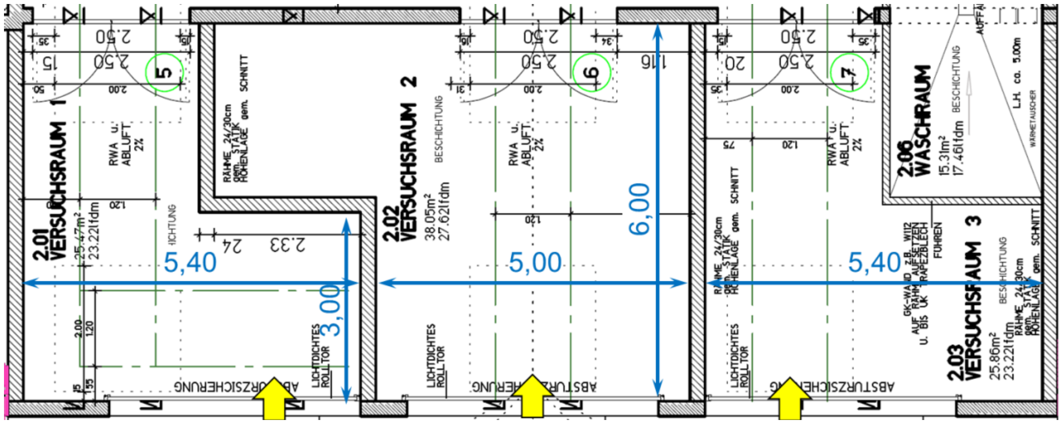


FIGURE 3. Test chambers with roller shutters in CAD [1] and current status of realization

TABLE 2. Floor plan and technical profiles of the three test chambers

	Test Chamber 1	**Test Chamber 2**	**Test Chamber 3**
Floor plan			
Max. solar power (point focussed)	240kW* (320kW*)	300kW* (400kW*)	240kW* (320kW*)
Peak flux	>8MW/m²*	>11MW/m²*	>8MW/m²*
Max. aperture (width x height)	2m x 2m (4m x 4m)		
Chamber space (area x height)	25m² x 4,5m	38m² x 4,5m	26m² x 4,5m
Max. weight of test object	2,5t (>4t)	2,5t (>6t)	2,5t (>4t)
Cooling	air cooling up to 3m³/s per chamber, additional water cooling		
Connections	440V/63A and 230V/10A, 100l/min water and Ethernet 1000Mbit/s in each chamber		
Special feature	high UV proportion	equipped for solar-chemical applications	

* Predicted values. Values in brackets () exceed the current standard and can be realised with additional effort.

A round rail transport system was adopted from production logistics. With it, test objects up to a weight of 2,5t and a size of 2m x 2m x 2m can be manually transported and positioned. Larger test systems can be lifted though the roller shutters.

The entire facility will be air cooled from the back of the building. A partial flow of 3m³/s will be guided through each active test chamber, including for explosion protection. A 2” water connection in each chamber opens additional cooling options.

The chambers 2 and 3 are preferred for solar chemical applications as they have stainless steel pipe connections to a washer room. The Xenon lamps opposite to chamber 1 will emit light with higher UV proportion and make this room particularly suitable for aerospace applications.

Each of the chambers has a separate control room in the floor below. The operation of the assigned **synlight** modules will happen from there as well as the test control and the measurement data acquisition. For this, a separate Gigabit connection to the test chamber will care for data security between different working groups.

The authors look forward excitedly to the commissioning later in 2016 and hope that this exceptional test facility will push the concentrating solar research.

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Note for the review:
The topic of this paper is a work in progress. The figures and parts of the text are planned to be updated for the final version.