SOLARPACES GUIDELINE FOR HELIOSTAT PERFORMANCE TESTING - RELEASE V1.0

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SolarPACES Conference, Sydney, Australia, Oct. 10-13, 2023

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Preface

The SolarPACES Task III Heliostat Working Group currently works on three guidelines:

- Heliostat Wind Load Design Guideline
  to improve and unify heliostat wind load design methods as a basis for a heliostat specific engineering code
- Heliostat Field Acceptance Guideline
  to measure the performance of an industrial-sized field
- **Heliostat Performance Testing Guideline**

⇒ In review
(Task III heliostat group)

⇒ **More details now**

Motivation
for SolarPACES Task III Heliostat Working Group

- The heliostat field is a **significant investment factor**
- It is a **long-term investment**
- It is of **big extent** and any correction or malfunctioning is expensive
- It is a **crucial component** in the energy conversion chain
- Yearly **plant output** strongly depends on its **optical quality**
- **Quality assurance and final acceptance tests** of heliostats and fields are necessary for control of subcontractors and **warranty claims**

1. Objective
Heliostat Performance Testing Guideline

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Objective of Guideline

- Enable **comparison** of *single* heliostats on an **objective, scientific, but practical** level
- **Homogenize** content of **test certificates** of different qualification centers
- **Facilitate bankability** of heliostats

Content of Guideline

- **Parameter list** with definitions to describe heliostats and their performance
- **Measurement techniques** to derive the parameters

SolarPACES

Solar Power and Chemical Energy Systems
IEA Technology Collaboration Programme

SolarPACES Guideline
for Heliostat Performance Testing

Draft Version 1.0
26.04.23

Edited by Marc Röger
DLR, Institute of Solar Research

2. History and Status of Guideline

- 2008: **First national drafts**
- From 2012: **International input** as part of SolarPACES Task III meetings
- From 2012: **Dissemination** to Task-III heliostat working group (actual almost 60 members)
- From 2012: **Review** feedback from
  - more than 14 international institutions
  - more than 30 scientists
- From 2018 First **draft releases** and **applications in R&D and industry:**
  - RELEASE_v0991: 22.08.18
  - RELEASE_v0995: 09.10.20
  - **RELEASE_v1.0: 30.05.23**
- Currently being put into the **IEC-TC-117 62862-4-3** technical committee

Thank you to all actively participating institutions, scientists and industrial engineers.

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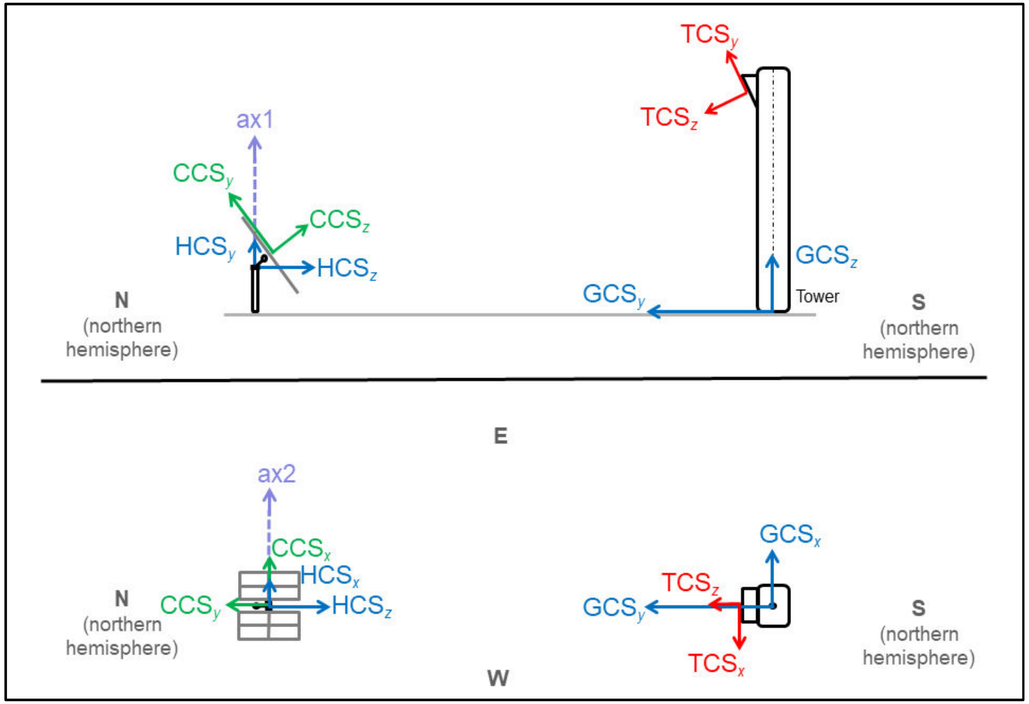
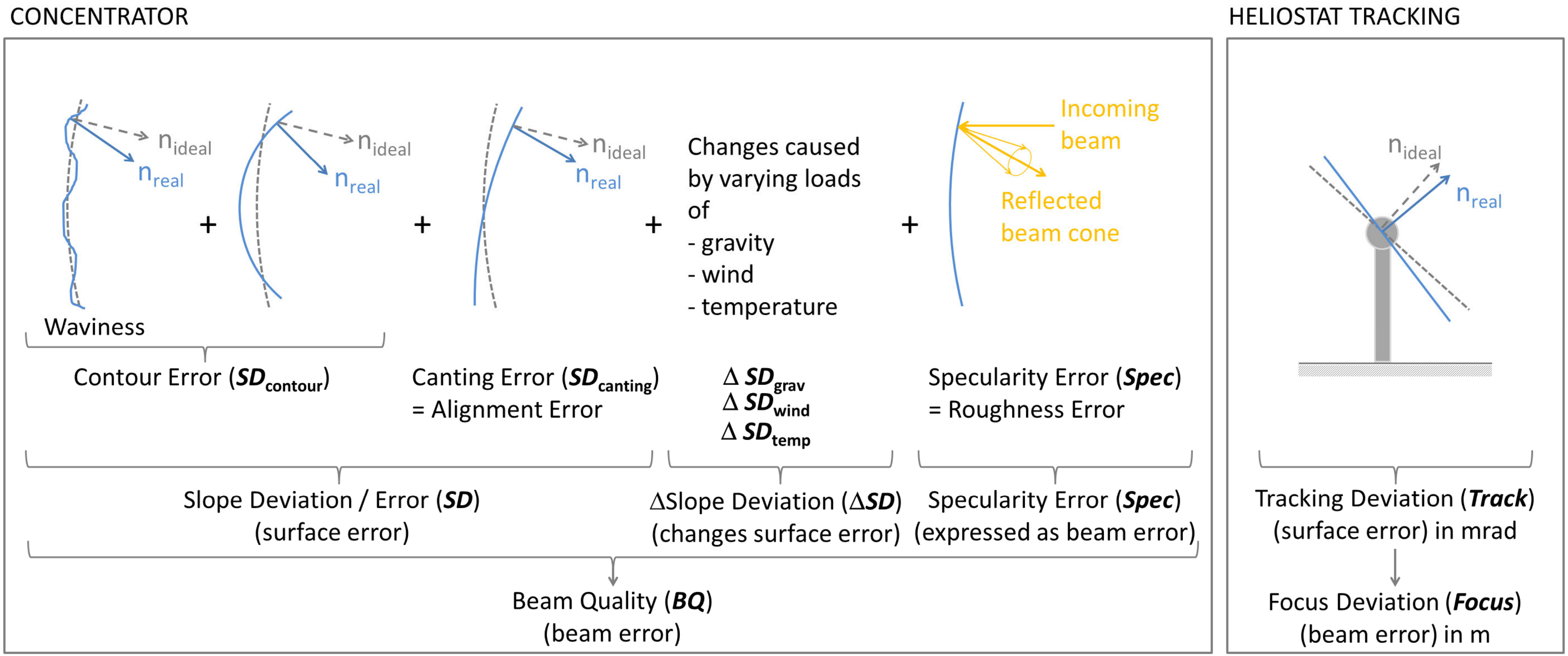
3. Definitions

- Definition of coordinate systems
- General Definitions
  - Mirror Panel
  - Concentrator
  - Heliostat
  - Concentrator Surface Normal (=given in CCS), also called Heliostat Normal (=given in HCS or GCS)
  - Concentrator Elevation and Azimuth
- Definitions of Angular Deviations
- Naming Convention for Angular Deviations



3. Definitions
Angular Errors/Deviations



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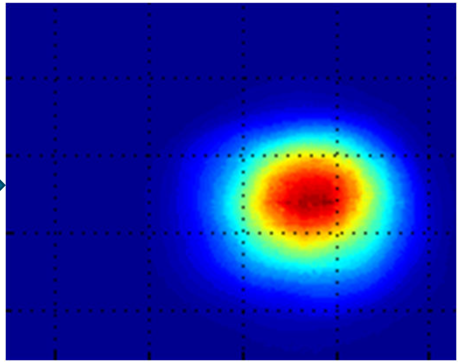
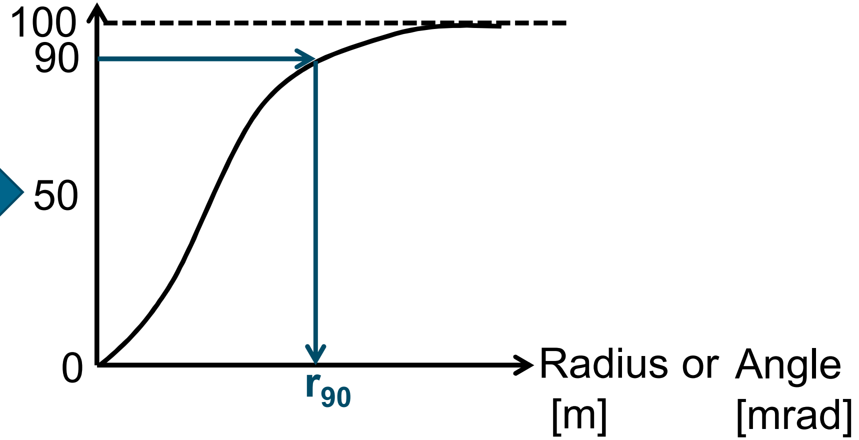
4. Methodology
OLD METHOD: Measure Beam Shape/Quality with BCS system

Beam on Target


Flux Distribution on Target W/m²



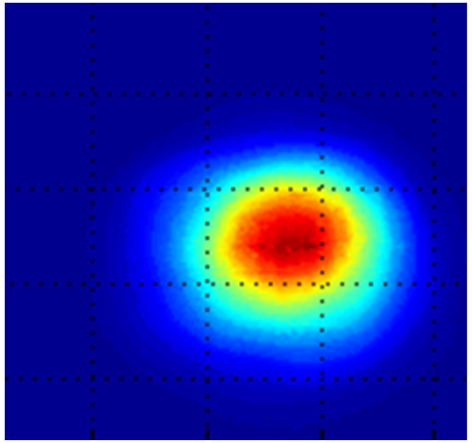
We get values like

- Total Beam Dispersion $\sigma_{TotBeamDisp}$
- “90°-cone power angle”
- Flux profiles
- Etc.

4. Methodology
OLD METHOD: Measure Beam Shape/Quality with BCS system

The Total Beam Dispersion $\sigma_{TotBeamDisp}$ as measured on target

- does not describe the heliostat properties properly,
- because it depends on
  - Astigmatism,... (day of time / year / location of heliostat)
  - Meteorological parameters (sunshape, scattering)



We would need the beam quality σ_{BQ}

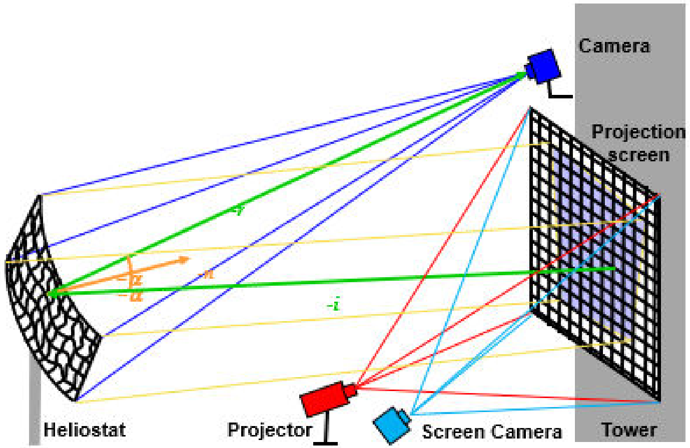
$$\sigma_{BQ} \approx \sqrt{\sigma^2_{TotBeamDisp} - \sigma^2_{sun} - \sigma^2_{astigm}}$$

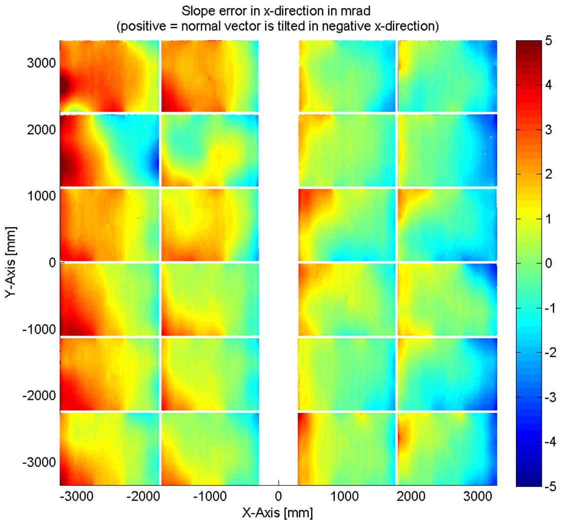
measured   not easy to account for

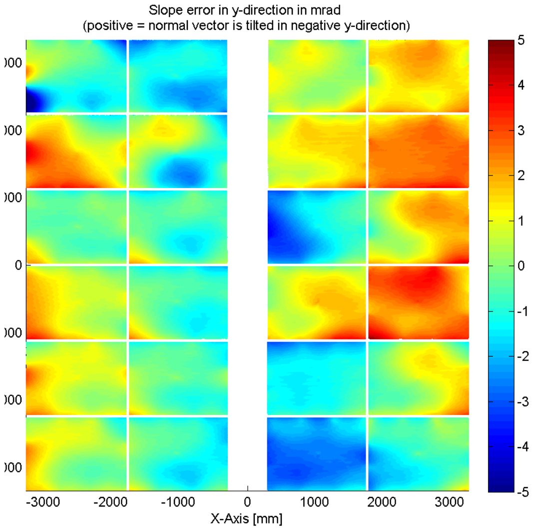
4. Methodology
Beam Quality by Shape Measurement and Raytracing

For that reason, the guideline is based on the following approach:

- Define ideal shape (paraboloidal / spherical / flat / …)
- Measure the slope deviations SD in horizontal and vertical direction, e.g. by deflectometry / photogrammetry / laser radar in one elevation. Result: SD matrices (in relation to ideal shape, 1)







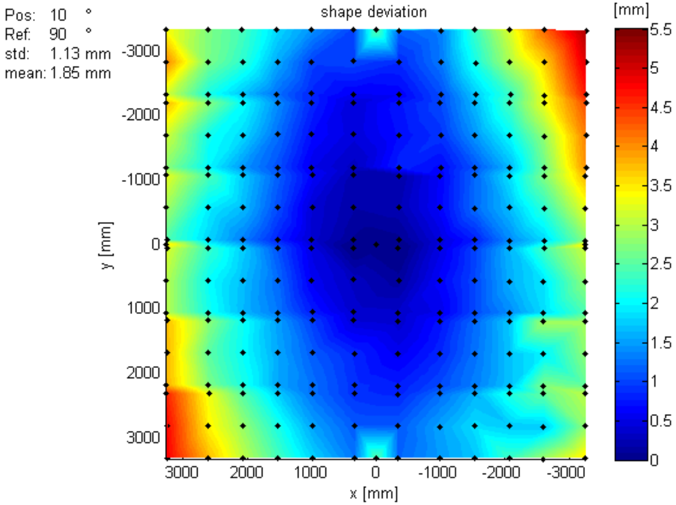
Example: Deflectometry results

4. Methodology
Beam Quality by Shape Measurement and Raytracing

For that reason, the guideline is based on the following approach:

- Define ideal shape (paraboloidal / spherical / flat / …)
- Measure the slope deviations SD in horizontal and vertical direction, e.g. by deflectometry / photogrammetry / laser radar in one elevation. Result: SD matrices (in relation to ideal shape, 1)
- Measure the shape deformation to account for deformation with different elevation angles (2) and temperatures (3) (future: wind (4)), e.g. by photogrammetry.


DLR measurement on PSA (owned by CIEMAT)



z-deviation/sag betw. 10° and 90° heliostat elevation

4. Methodology
Beam Quality by Shape Measurement and Raytracing

For that reason, the guideline is based on the following approach:

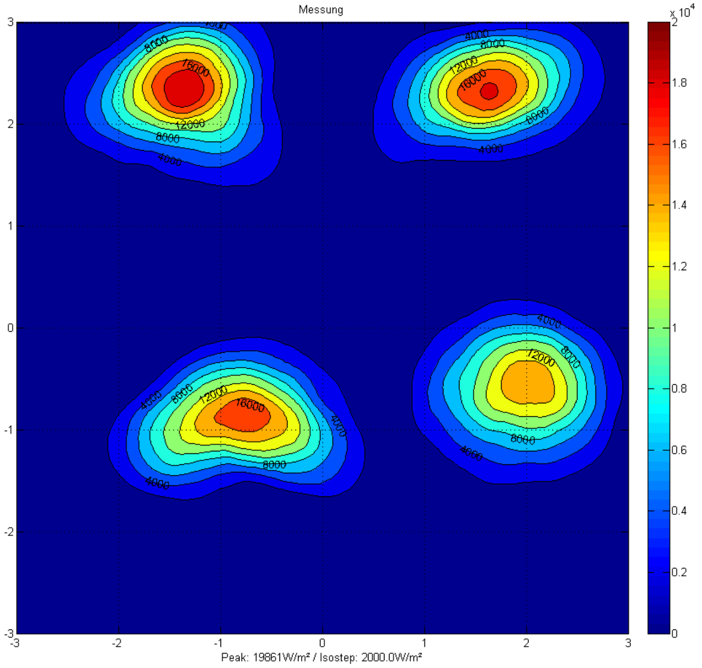
- Define ideal shape (paraboloidal / spherical / flat / …)
- Measure the slope deviations SD in horizontal and vertical direction, e.g. by deflectometry / photogrammetry / laser radar in one elevation. Result: SD matrices (in relation to ideal shape, 1)
- Measure the shape deformation to account for deformation with different elevation angles (2) and temperatures (3) (future: wind (4)), e.g. by photogrammetry.

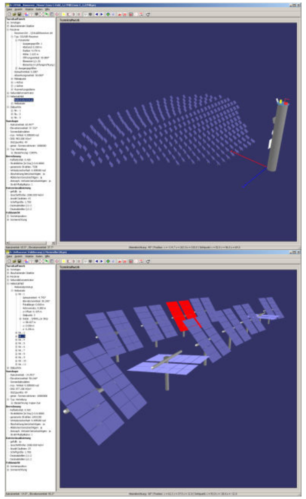
$$SD^{sum}_{x/y,mat}(az, el, \bar{u}_{10m}, \bar{\alpha}, \bar{\beta}, z_0, \rho, T) = \underbrace{SD_{x/y,mat}\Big|_{\substack{el,ref\\ az,ref\\ \bar{u}_{10m},ref\approx 0\\ T,ref}}}_{1} + \underbrace{\Delta SD^{grav}_{x/y,mat}\Big|_{\substack{(el-el,ref)\\ (az-az,ref)}}}_{2} + \underbrace{\left(\Delta SD^{temp}_{x/y,mat}/\Delta T\right)\cdot\left(T-T_{ref}\right)}_{3} + \underbrace{\Delta SD^{wind}_{x/y,mat}\Big|_{\substack{\bar{u}_{10m}\\ \bar{\alpha},\bar{\beta}\\ z_0\\ \rho}}}_{4}$$

- High-fidelity raytracers provide any other parameter (e.g. $\sigma_{TotBeamDisp}$, σ_{BQ}, flux profiles, 90deg-cone power angle, etc.)

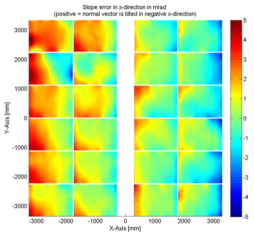
4. Methodology
Beam Quality by Shape Measurement and Raytracing

BCS measurement on target with 4 heliostats

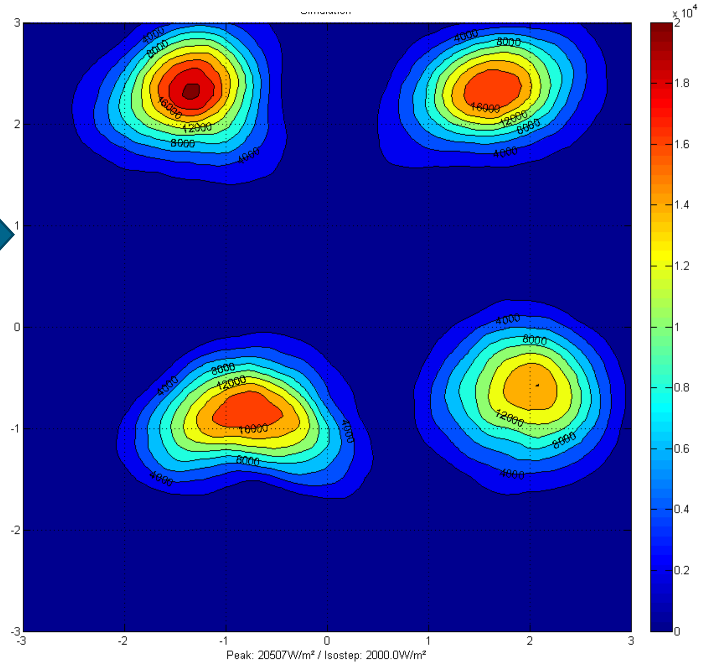




SD input

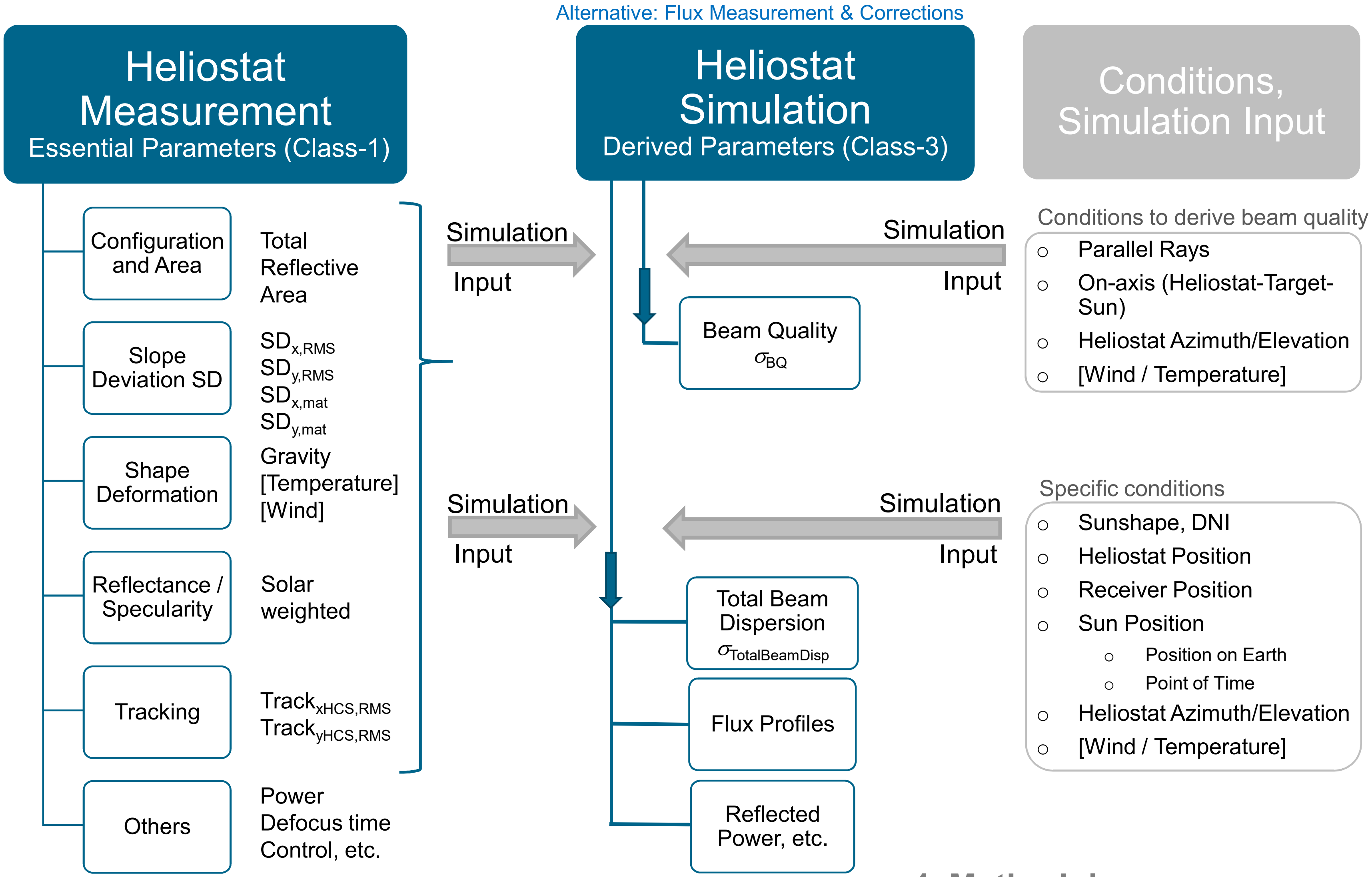


Raytracer simulation results with same 4 heliostats



Detailed Simulation of Solar Flux Possible by Using Deflectometry Data

See. e.g. Belhomme, B., Pitz-Paal, R., Schwarzbözl, P., and Ulmer, S. (June 10, 2009). "A New Fast Ray Tracing Tool for High-Precision Simulation of Heliostat Fields." ASME. *J. Sol. Energy Eng*. August 2009; 131(3): 031002. https://doi.org/10.1115/1.3139139



4. Methodology

Beam Quality by Shape Measurement and Raytracing

4. Methodology
Beam Quality by Shape Measurement and Raytracing

Heliostat Measurement
Essential Parameters (Class-1)

The essential parameters (class-1) are *mandatory* to describe heliostat performance according to this guideline. In general, all these parameters must be given for comprehensive description of the heliostat performance.
70 parameters

Additional
Additional descriptive parameters (Class-2)

Additional descriptive parameters (class-2) as part of an *extended list* deliver additional, but not essential information. They may be additionally given.
84 parameters

Heliostat Simulation
Derived Parameters (Class-3)

Only valid for specific Conditions, Simulation Input

Beam shape parameters (class-3) can be derived from class-1 parameters by *raytracing*, or are *not easily measurable under defined conditions* in industrial practice. Essential parameters should be preferred to define heliostat performance instead. However, beam shape parameters can be additionally used for their *illustrative character*.
21 parameters

Total 175 parameters, but only 70 parameters needed

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Appendix A: Heliostat Performance Parameters: Terms/Definitions and Measurement

A.1 Essential Parameters (class-1)

n	Parameter Name (Symbol)	Value Example	Unit	Variable Type	Typical Range	Definition	Technique for Derivation of Parameter	Provided by (Lab/Man)
						HELIOSTAT CONFIGURATION		
1	HelioConfig.CoordinateSys.GCS *GCS*	*(x_{GCS}, y_{GCS}, z_{GCS})*	-	string	-	Please describe the global coordinate system in the measurement report in detail. Usually it is defined like that: Right-handed coordinate system describing positions of tower, receiver and heliostats, with *x* being oriented east, *y* north and *z* vertical up for the northern hemisphere, and *x* being oriented west, *y* south and *z* vertical up. The origin has to be defined. Usually the origin is on the north-south symmetry plane of the solar field at tower ground level, either in the aperture plane of the receiver or in the case of a cylindrical receiver in its central axis at ground level.	-	IQual
2	HelioConfig.CoordinateSys.HCS *HCS*	*(x_{HCS}, y_{HCS}, z_{HCS})*	-	string	-	Please describe the heliostat coordinate system in the measurement report in detail. Usually it is defined like that: Right-handed local cartesian coordinate system defined for each heliostat which does not move with the concentrator movement, with *z* being the vector pointing south for the northern hemisphere (*z* pointing north for the southern hemisphere) or, alternatively, pointing to the tower (must be defined!), and *y* being the vertical axis. The origin could be the intersection of the two tracking axes.	-	IQual
3	HelioConfig.CoordinateSys.CCS *CCS*	*(x_{CCS}, y_{CCS}, z_{CCS})*	-	string	-	Please describe the concentrator coordinate system in the measurement report in detail. Usually it is defined like that: Right-handed local cartesian coordinate system on the concentrator which moves with concentrator elevation and azimuth with *z* being the concentrator surface normal pointing away from the mirror surface and *y* being the vertical axis projected into the concentrator plane (for elevations in the range between 0 and <90°). The origin has to be defined. It should be on the concentrator central axis so that the lowest *z* value of the reflective surface is close to zero and the rest of the *z* values are positive. For other concentrator shapes (e.g. rotation symmetric) differing systems, e.g. polar coordinates, using the index CCS can be used.	-	IQual
4	HelioConfig.CoordinateSys.AS *AS*	*(ax1, ax2)*	-	string	-	Please describe the concentrator coordinate system in the measurement report in detail. Usually it is defined like that: Coordinate system on the heliostat which moves with the concentrator (tracking axis 1 and tracking axis 2) as system axes. For perfectly mounted T-type heliostats, *ax1* corresponds to the azimuth (y_{HCS}), and *ax2* to the elevation (x_{CCS}) which moves with the rotation around ax1. The axes are not necessarily perpendicular.	-	IQual
5	HelioConfig.General.Type	*T-shape*	-	string	-	Construction principle [T-shape / carousel / sloped axes heliostat /steel frame / bubble enclosed / rotating field / ganged heliostats (multiple mirror panels) / venetian blinds / yoke / shared support / dual module drive / etc.]	specified by manufacturer	Man/IQual
6	HelioConfig.Conc.Outline	*rectang.*	-	string	-	Outline of concentrator [rectangular / round / pentagonal / hexagonal / etc.]	specified by manufacturer	Man/IQual
7	HelioConfig.Conc.Dimension	*[6.6; 6.7]*	m	single vector	0 to 100	Concentrator size in [*x*; *y*] direction (rectangular outline) or diameter (round outline) or [min; max] diameter (rotationally symmetric outline) or other description via edge lengths (other outlines)	(Laser) distance meter, tape measure, etc.	Man/IQual
8	HelioConfig.Conc.ReflectiveArea	*40.1*	m²	single	0 to 250	Reflective aperture area of concentrator (excluding gaps between mirror panels)	(Laser) distance meter, tape measure, etc.	Man/IQual
9	HelioConfig.Panel.Outline	*rectang.*	-	string	-	Outline of reflective mirror panel [rectangular / round / triangular / pentagonal / hexagonal / etc.]	specified by manufacturer	Man/IQual

5.+6. Heliostat Performance Parameters and their Measurement

Appendix A: Heliostat Performance Parameters: Terms/Definitions and Measurement

A.1 Essential Parameters (class-1)

n	Parameter Name (Symbol)	Value Example	Unit	Variable Type	Typical Range	Definition	Technique for Derivation of Parameter	Provided by (Lab/Man)
						HELIOSTAT CONFIGURATION		
1	HelioConfig.CoordinateSys.GCS *GCS*	(x_{GCS} z_{GCS})				Please describe the global coordinate system in the measurement report in detail.		
2	HelioConfig.CoordinateSys.HCS *HCS*	(x_{HCS} z_{HCS})						
3	HelioConfig.CoordinateSys.CCS *CCS*	(x_{CCS}				… can be used.		
4	HelioConfig.CoordinateSys.AS *AS*	*(ax1, ax2)*	-	string	-	Please describe the concentrator coordinate system in the measurement report in detail. Usually it is defined like that: Coordinate system on the heliostat which moves with the concentrator (tracking axis 1 and tracking axis 2) as system axes. For perfectly mounted T-type heliostats, *ax1* corresponds to the azimuth (y_{HCS}), and *ax2* …	-	IQual
5								Man/IQual
6	HelioConfig.Conc.Outline	*rectang.*	-	string		Outline of concentrator [rectangular / round / pentagonal / hexagonal / etc.]	specified by manufacturer	Man/IQual
7	HelioConfig.Conc.Dimension	*[6.6; 6.7]*	m	single vector	0 to 100	Concentrator size in [x; y] direction (rectangular outline) or diameter (round outline) or [min; max] diameter (rotationally symmetric outline) or other description via edge lengths (other outlines)	(Laser) distance meter, tape measure, etc.	Man/IQual
8	HelioConfig.Conc.ReflectiveArea	*40.1*	m²	single	0 to 250	Reflective aperture area of concentrator (excluding gaps between mirror panels)	(Laser) distance meter, tape measure, etc.	Man/IQual
9	HelioConfig.Panel.Outline	*rectang.*	-	string	-	Outline of reflective mirror panel [rectangular / round / triangular / pentagonal / hexagonal / etc.]	specified by manufacturer	Man/IQual

Definition of parameter
Concentrator size in [x; y] direction (rectangular outline) or diameter (round outline) or [min; max] diameter (rotationally symmetric outline) or other description via edge lengths (other outlines)

Technique for derivation of parameter
(Laser) distance meter, tape measure, etc.

Provided by whom?
IQual. and Man.

IQual. = Independent Qualification
Man. = manufacturer

Parameter Name
HelioConfig.Conc.Dimension

Value Example
[6.6; 6.7]

Unit
m

Variable Type
Single vector

Typical Range
0-100

5.+6. Heliostat Performance Parameters and their Measurement

n	Parameter Name (Symbol)	Value Example	Unit	Variable Type	Typical Range	Definition	Technique for Derivation of Parameter	Provided by (Lab/Man)
⋮								
20	Optics.Conc.NominalShape	*parabolic*	-	string	-	Design target curvature shape of complete concentrator including canting information [flat / parabolic / spherical / special heliostat canting (if e.g. yearly energy output computer-optimized canting)]. Numeric values are given in Optics.Conc.NominalShapeNumericValue.	specified by manufacturer	Man
21	Optics.Conc. NominalShapeNumericValue	*[55] or [25;1500] or matrices*	m	single vector, matrix	0 to 9999 or NaN (flat)	Design target curvature radius in case of spherical, focal length in case of parabolic, NaN in case of flat; for a conc. with adjustable focus give [min; max] range; for special heliostat canting ideal shape should be described by matrices *x*[m;n], *y*[m;n], *z*[m;n]	specified by manufacturer	Man
22	Optics.Conc. HelioRefOrientationTemp	*[az=0°; el=30°; T=20°C]*	-	string	-	Azimuth / elevation angle and heliostat temperature for which the SD data is valid; measurement without significant wind influences. In case, there are no limitations, [*az*=0°; *el*=30°; *T*~20°C] should be used. In case azimuth angle has no influence of shape (standard T-heliostat), the azimuth value can be omitted.	Inclinometer, protractor	IQual
23	Optics.Conc.SD_SamplingRate	*1000*	value s/m2	single	>100	Average sampling Rate used for the slope deviation measurement. Must be higher than 100 data points/m2.	Divide total number of measurement points by total measured surface; the measurement should be homogeneously distributed on the measured surface	IQual
24	Optics.Conc.SD_ShareEvalSurf	*97*	%	single	95-100%	Share of evaluated surface of total reflective surface; must be higher than 95%.	Area in which the surface error is evaluated (see Optics.Conc.SD_2D) divided by total HelioConfig.Conc.ReflectiveArea	IQual
25	Optics.Conc.SD_2D *SD_{2D}*	sR: 1.46 RMS: 2.06 (100%)	mrad	string	<3 mrad	Rayleigh Parameter sR and RMS for 2D slope deviations of real concentrator compared to surface generated using the Optics.Conc.NominalShape for whole measured surface, applying over the whole heliostat surface a ROBUST least squares optimization for the orientation of measured data to the nominal geometry. Minimum recommend resolution 100 data points/m2; minimum evaluated surface (> 95%); Low wind speeds (<NormalOperation) and no excessive temperature gradients. The measurement uncertainty of the slope deviation-RMS value has to be given (should be below 0.2 mrad). Definition of slope deviations, see SolarPACES draft guideline "Measurement and Assessment of Mirror Shape for Concentrating Solar Collectors". Give values for whole measured surface. Write in parentheses "100%", that means that all measured values (not necessarily whole reflective surface) are considered for the RMS (sR) value. Coordinate System: CCS.	The heliostat surface slopes can be measured directly by deflectometry or by measuring 3-D coordinates of the heliostat surface, using photogrammetry, laser radars, etc. While deflectometry directly gives slopes as a result, the 3-D measurement technique results have to be processed via tringualation and calculation of normal vectors. Slope deviations are calculated in reference to the nominal normal vectors defined in parameters Optics.Conc.NominalShape and Optics.Conc.NominalShapeNumericValue while orienting the two data clouds with a ROBUST least square method or similar. The minimum recommend resolution is 100 data points/m2 for photogrammetry, the other techniques should use their potential for higher resolution. The minimum evaluated surface must be higher than > 95% of the heliostat surface. The measurement uncertainty of the slope deviation matrix entries has to be given. Locally, they should be below 0.5 mrad. The uncertainties for the RMS of the slope deviation of the whole concentrator should be below 0.2 mrad. A separate measurement report must be created where all the necessary details of the measurement procedure, evaluation and accuracies is given. Note: $SD_{2D,sR}$=1/sqrt(2)*$SD_{2D,RMS}$. Note: The parameter $SD_{2D,RMS}$ can be	IQual

⋮

Heliostat Performance Testing Guideline

n	Parameter Name (Symbol)	Value Example	Unit	Variable Type	Typical Range	Definition	Technique for Derivation of Parameter	Provided by (Lab/Man)
⋮								
20	Optics.Conc.NominalShape: parabolic					…oncentrator including canting …cial heliostat canting (if e.g. yearly …]. Numeric values are given in	specified by manufacturer	Man
21	Optics.Conc.NominalShapeNumericValue: [55] or matrices					…case of parabolic, …x] range; for …es *x*[m;n], *y*[m;n],	specified by manufacturer	Man
22	Optics.Conc.HelioRefOrientation: [az=0°; el=30°; *T*=20°C]					…e SD data is valid; …are no limitations, …tat), the azimuth	Inclinometer, protractor	IQual
23	Optics.Conc.SD_SamplingRate: 1000 values/m^2					…. Must be higher	Divide total number of measurement points by total measured surface; the measurement should be homogeneously distributed on the measured surface	IQual
24	Optics.Conc.SD_ShareEvalSurf: 97%					…ated surface of total reflective surface; must be higher than 95%.	Area in which the surface error is evaluated (see Optics.Conc.SD_2D) divided by total HelioConfig.Conc.ReflectiveArea	IQual
25	Optics.Conc.SD_2D: sR: 1.56; RMS: 2.06 mrad (100%)					Rayleigh Parameter sR and RMS for 2D slope deviations of real concentrator compared to surface generated using the Optics.Conc.NominalShape for whole measured surface, applying over the whole heliostat surface a ROBUST least squares … geometry. …valuated surface …emperature …MS value has to be …ee SolarPACES …r Concentrating Solar Collectors". Give values for whole measured surface. Write in parentheses "100%", that means that all measured values (not necessarily whole reflective surface) are considered for the RMS (sR) value. Coordinate System: CCS.	The heliostat surface slopes can be measured directly by deflectometry or by measuring 3-D coordinates of the heliostat surface, using photogrammetry, laser radars, etc. While deflectometry directly gives slopes as a result, the 3-D measurement technique results have to be processed via tringualation and calculation of normal vectors. Slope deviations are calculated in reference to the nominal normal vectors defined in parameters Optics.Conc.NominalShape and Optics.Conc.NominalShapeNumericValue while orienting the two data clouds with a ROBUST least square method or similar. The minimum recommend resolution is 100 data points/m2 for photogrammetry, the other techniques should use their potential for higher resolution. The minimum evaluated surface must be higher than > 95% of the heliostat surface. The measurement uncertainty of the slope deviation matrix entries has to be given. Locally, they should be below 0.5 mrad. The uncertainties for the RMS of the slope deviation of the whole concentrator should be below 0.2 mrad. A separate measurement report must be created where all the necessary details of the measurement procedure, evaluation and accuracies is given. Note: $SD_{2D,sR}$=1/sqrt(2)*$SD_{2D,RMS}$. Note: The parameter $SD_{2D,RMS}$ can be …	IQual
							⋮	

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7. Reporting

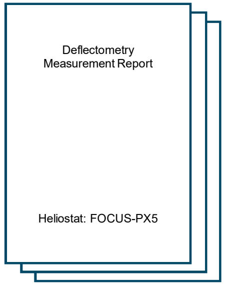
HELIOSTAT PERFORMANCE TEST	
Photo or simplified scheme of general heliostat configuration	
Heliostat manufacturer name	HeliostatFactory
Name of heliostat model	FOCUS
Serial number(s) or other identifier(s)	PX5
Total number of heliostats investigated	1
Name and address of testing laboratory	R&D Testing Center, Street Name, City, Country
Testing location	Heliostat Testing Platform, 52428 Jülich, Germany
Date of testing period	30.05.23 - 15.08.23
Date of erection of heliostat	01.04.22
Reference to guideline version	SolarPACES Heliostat Performance Guideline v1.0 from 30.05.23
Report format	This report and data CD
Date, signature and stamp of independant qualification organization/company	

n	Full Parameter Name (Symbol)	Value	Unit	Meas.Technique	Measurement Report
	HELIOSTAT CONFIGURATION				
1	HelioConfig.CoordinateSys.GCS	see report	-	Laser dist.meter	Hel_Main.pdf
2	HelioConfig.CoordinateSys.HCS	see report	-	Laser dist.meter	Hel_Main.pdf
3	HelioConfig.CoordinateSys.CCS	see report	-	Laser dist.meter	Hel_Main.pdf
4	HelioConfig.CoordinateSys.AS	see report	-	Laser dist.meter	Hel_Main.pdf
5	HelioConfig.General.Type	T-shape	-	Laser dist.meter	Hel_Main.pdf
6	HelioConfig.Conc.Outline	rectang.	-	Laser dist.meter	Hel_Main.pdf
7	HelioConfig.Conc.Dimension	[6.6; 6.7]	m	Laser dist.meter	Hel_Main.pdf
8	HelioConfig.Conc.ReflectiveArea	40.1	m²	Laser dist.meter	Hel_Main.pdf
9	HelioConfig.Panel.Outline	rectang.	-	-	-
10	HelioConfig.Panel.Dimension	[3.0; 1.1]	m	Laser dist.meter	Hel_Main.pdf
11	HelioConfig.Panel.Number	[2; 6]	-	-	-
12	HelioConfig.Panel.Type	glass mirror panels	-	-	-
13	HelioConfig.Panel.Material	silver coated glass	-	-	-
14	HelioConfig.Axes.Alignment	[az. axis vert.; el. axis horiz.]	-	-	-
15	HelioConfig.Axes.HeightOfSecondaryAxis	2.14	m	Laser dist.meter	Hel_Main.pdf
16	HelioConfig.Axes.DistanceAx1Ax2	0.15	m	Laser dist.meter	Hel_Main.pdf
17	HelioConfig.Axes.DistanceConcToSecondaryAxis	0.10	m	Tape meter	Hel_Main.pdf
	HELIOSTAT OPTICS				
18	Optics.Panel.CurvatureMounted	flat	-	-	-
19	Optics.Panel.CurvatureMethod	tensionless	-	-	-
20	Optics.Conc.NominalShape	parabolic	-	-	-
21	Optics.Conc.NominalShapeNumericValue	[55] or [25;1500] or matrices	m	-	-
22	Optics.Conc.HelioRefOrientationTemp	[az=0°; el=30°; T=20°C]	-	Inclinometer, TC	Hel_Shape.pdf
23	Optics.Conc.SD_SamplingRate	1000	values/m2	-	Hel_Shape.pdf
24	Optics.Conc.SD_ShareEvalSurf	97	%	-	Hel_Shape.pdf
25	Optics.Conc.SD_2D	sR: 1.46 RMS: 2.06 (100%)	mrad	Deflectometry	Hel_Shape.pdf
26	Optics.Conc.SD_2D*	sR: 1.09 RMS: 1.54 (98%)	mrad	Deflectometry	Hel_Shape.pdf
27	Optics.Conc.SD_2DHighFraction	sR: 6.95 RMS: 9.83 (2%)	mrad	Deflectometry	Hel_Shape.pdf

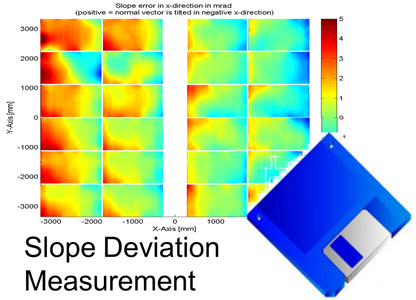
- An Excel template is part of the guideline as main test report in tabular form with links to appended data, measurement report pdfs, graphs.

Further data:

- Data format (in case of matrices, e.g.)
- Graphical form (in case of matrices, vectors, e.g.)
- Detailed measurement reports



Measurement Reports



Slope Deviation Measurement

Conclusion & Outlook

Contact: marc.roeger@dlr.de

DLR

Heliostat Performance Testing Guideline

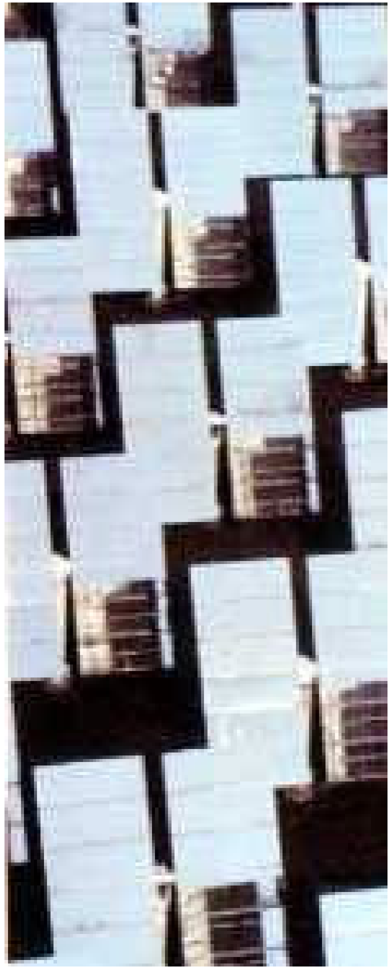
- Is focused on **prototype validation & qualification.**
- It has proven its **practicability** in several applications in R&D since 2018.
- **Version 1.0** is released.
- Currently, the content is **transferred to the IEC-TC-117-62862 Part 4-3**:
  "Technical requirements and design qualification of heliostats for solar power tower plants".
- The guideline, containing more details, **shall supplement the IEC standard**.

- A future 2nd version may include parameters and tests to describe the heliostat tracking behavior and the increase in concentrator slope deviations **under windy conditions.**

Heliostat Field Acceptance Guideline

- As national draft, is being launched into the **international review** (heliostat working group).

More details in manuscript: Röger, M., Schlichting, T., Blume, K., Guidelines for heliostat testing, Proceedings of SPIE - The International Society for Optical Engineering, 2023, to be published under https://www.spiedigitallibrary.org/



Funding Agencies

Saphir (16UM0068)
Heliodor (0324310)

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

SFERA-II (312643)
SFERA-III (823802)

SFERA
Solar Facilities for the European Research Area

EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME (Grant 823802)

AnalyzeHeliostatField

SolarPACES
Solar Power & Chemical Energy Systems

For the review and fruitful discussion, the authors thank Andreas Pfahl, Anna Heimsath, Ansgar Macke, Chuck Andraka, Daniel Benitez, De Wet van Rooyen, Felix Göhring, Finn von Reeken, Kai Regina, Lorin Vant-Hull, Markus Schramm, Norbert Geuder, Patrick Hilger, Peter Schwarzbözl, Rafael López Guerrero, Reiner Buck and Stefano Giuliano, amongst others.

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