

A New Optical Fiber-Based Sensor for Concentrated Solar Flux Monitoring in Concentrated Solar Power Plants

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Concentrated Solar
Flux Measurement:
Up to 1.5MW/m²



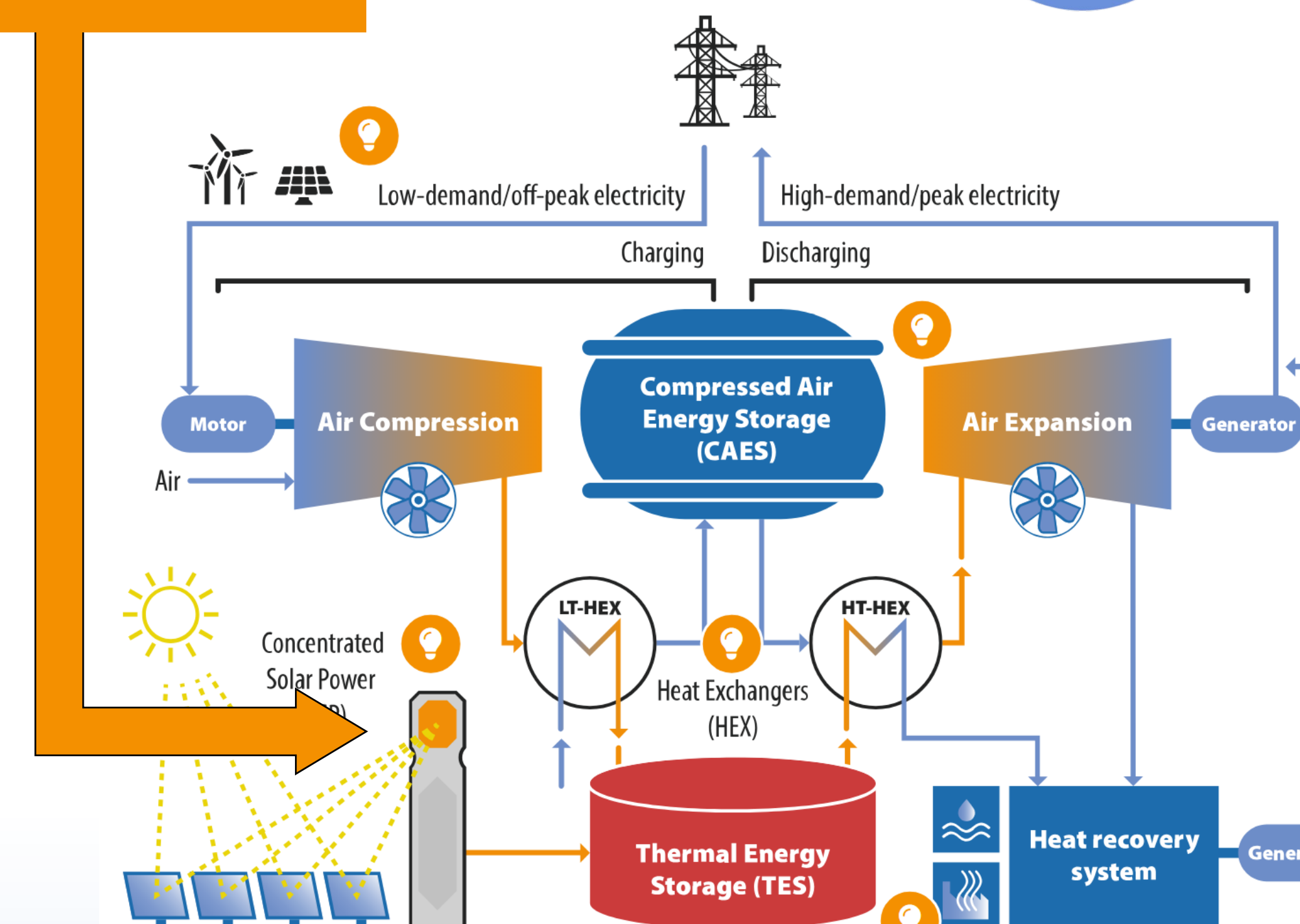
INTRODUCTION

Why measuring concentrated solar flux?

- **Operational control:** Real-time monitoring of flux distribution enables adaptive control of heliostat fields and supports safe, reliable plant operation.
- **Performance optimization:** Measuring concentrated solar flux ensures accurate alignment of heliostats and receivers, maximizing efficiency and energy output.
- **Thermal safety:** Flux mapping prevents overheating and material damage in receivers, protecting equipment and extending its lifetime.

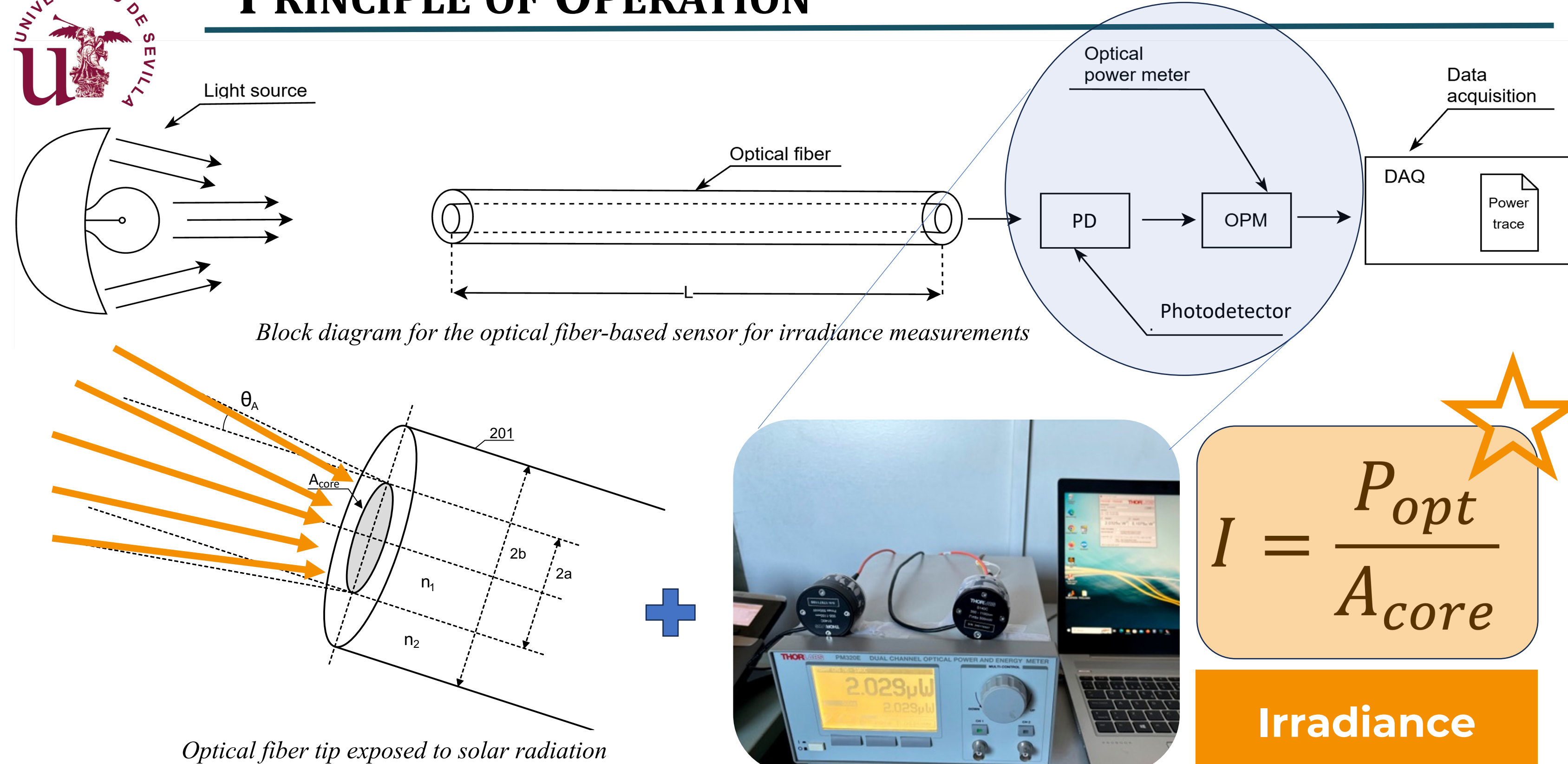
Why optical fibers?

- **Spatial efficiency and resolution:** Minimization of the area occupied at the receiver, allowing for multiple measurement points and high spatial resolution.
- **Fast response:** Dynamics are not dependent on thermal dynamics, but light propagation.
- **Measurement decoupling:** Eliminates the necessity for active cooling, reducing operational complexity.

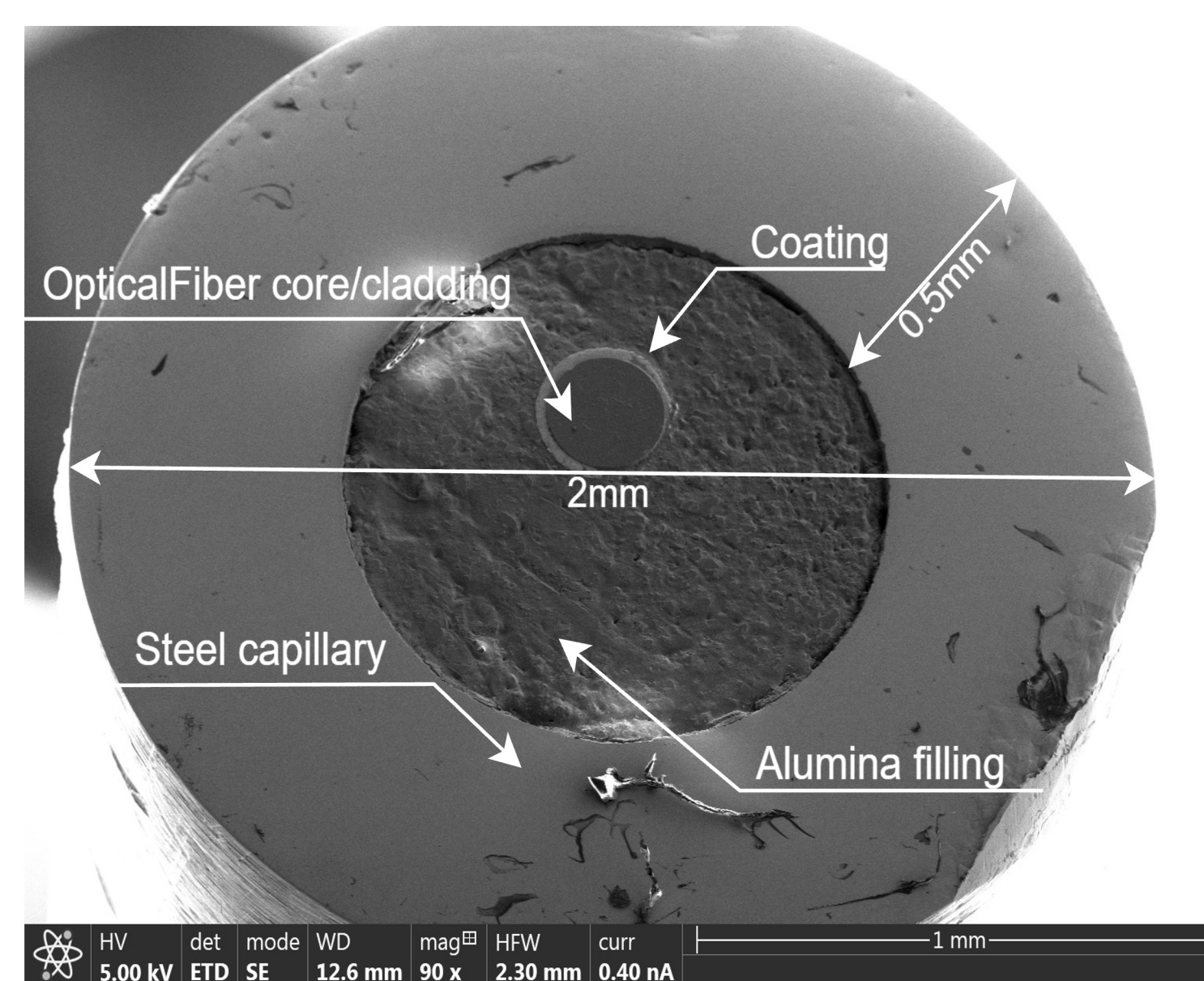


Crescent Dunes, Nevada, USA

PRINCIPLE OF OPERATION



HIGH TEMPERATURE OPTICAL FIBERS



Optical fiber were designed and manufactured by engionic Femto Grating GmbH (Goslar, Germany). Their design can be examined in adjacent figure.

They rely on:

- **High temperature coating** around optical fiber, made of either polyimide or gold.
- **Alumina filling** to prevent heat conduction.
- **Steel capillary** ensuring structural integrity.
- 0.22 numerical aperture, resulting in FoV of 25°.

This design ensures:

- Stable performance up to 700 °C.
- Withstanding peak temperatures up to 1000 °C.

PROOF OF CONCEPT (High Flux Solar Simulator)



High Flux Solar Simulator specifications

- **HFSS - KIRAN42**
- **7 Xenon lamp** housed in enclosure.
- **Ellipsoidal reflectors** focusing light outside enclosure.
- **Flux** at focal point up to **3 MW/m²**.
- **Temperatures** higher than **1000°C**.
- **3 axis positioning table**.

Experimental assembly

- **Stainless steel plate** was mounted on the positioning table.
- Fiber was exposed to radiation through a connector to align the tip of the optical fiber cable.
- **Gardon radiometer** was positioned next to the fiber tip to provide benchmarking measurements.
- Steel plate was covered with **ceramic wool** to minimize thermal influence
- A **thermocouple** was attached on the rear side for temperature monitoring.



RESULTS: CONCENTRATED FLUX MEASUREMENTS

The optical fiber utilized for the testing campaign specifications were 200 μm core diameter, 220 μm cladding diameter and gold coating.

Two **photodetectors** have been used in the Optical Power Meter:

- Thorlabs **S401C** – **Thermal** Power Sensor Head (10 μW - 1 W)
- Thorlabs **S140C** – Integrating Sphere **Photodiode** Power Sensor (1 μW - 500 mW)

Results with S401C – Direct Incidence

Slow response – Low sensitivity

Gardon reference: 312 KW/m²

Fiber: 222.8 KW/m²

Results with S140C – Direct Incidence

Fast response – High sensitivity

Gardon reference: 312 KW/m²

Fiber: 222.6 KW/m²

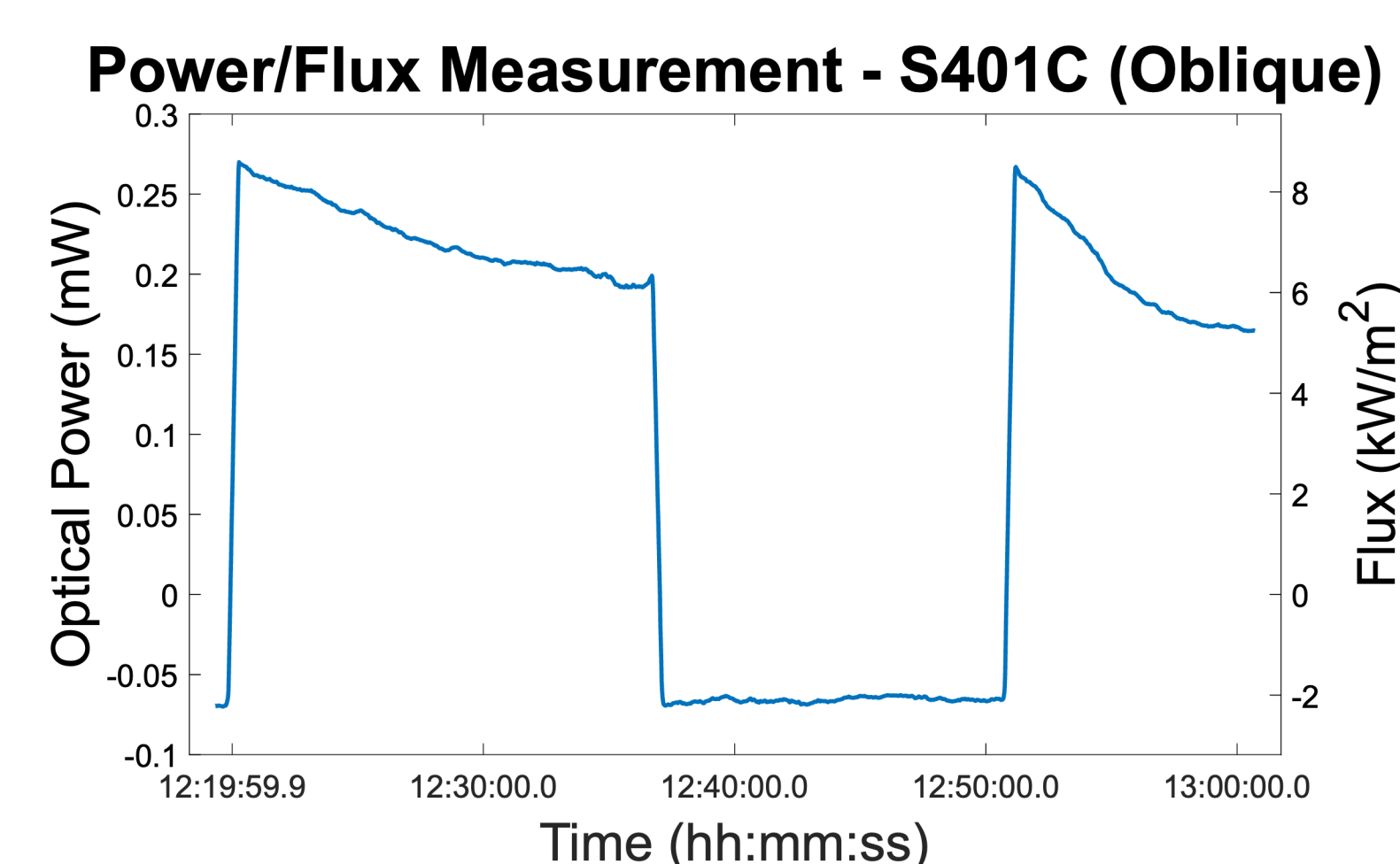
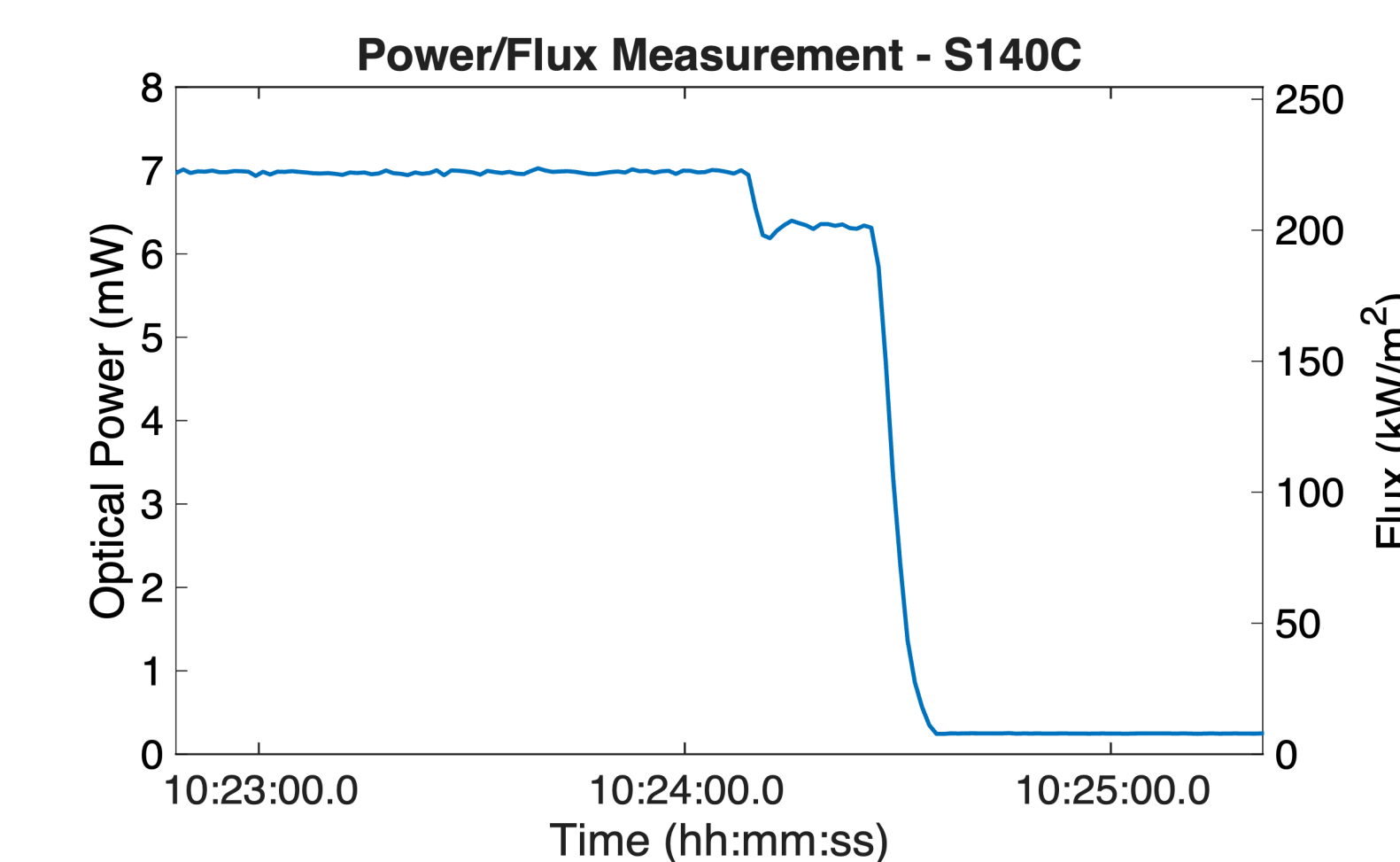
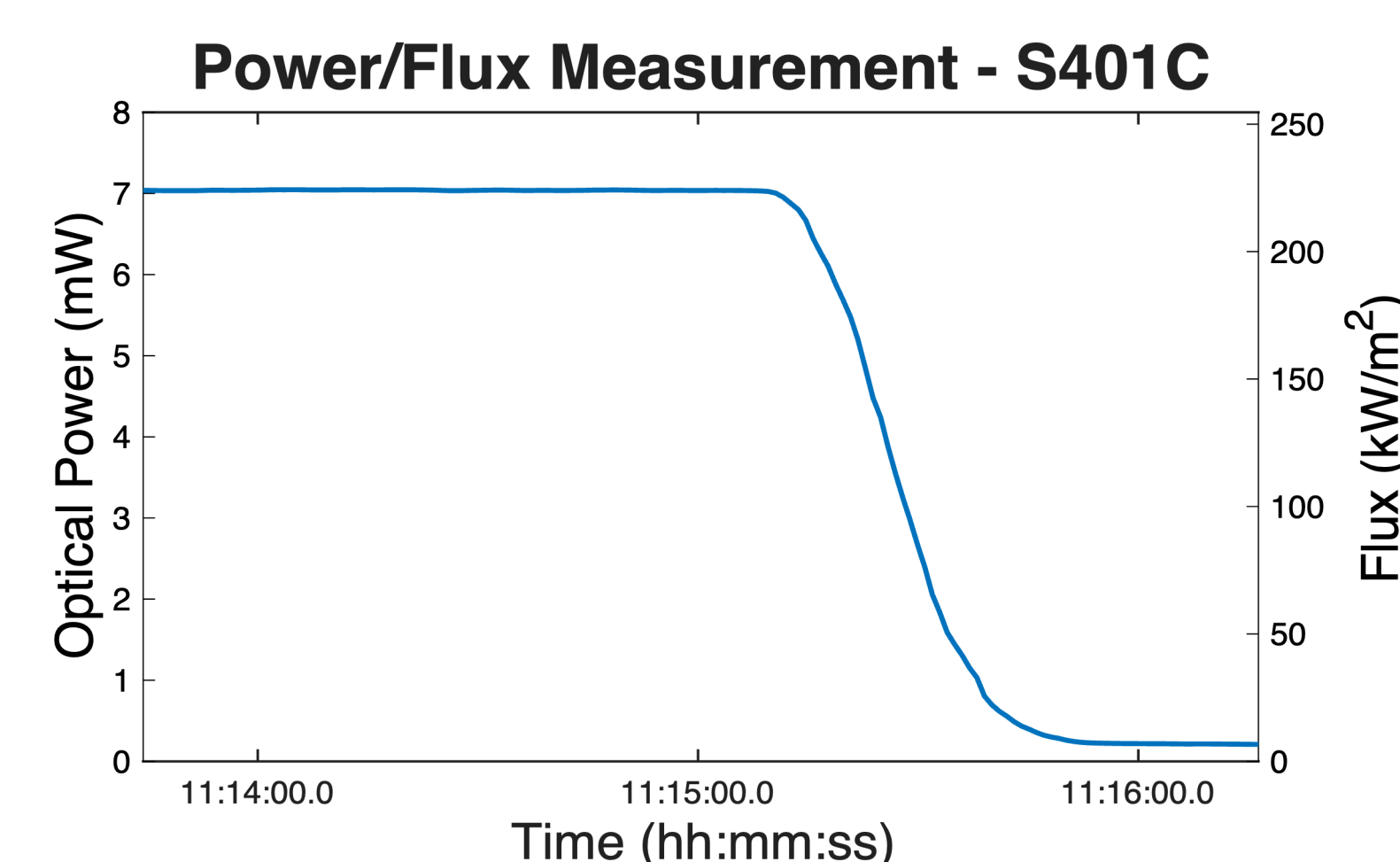
Results with S401C – Oblique Incidence

Gardon reference: 357 KW/m²

Fiber: 8.9 KW/m²

Identified Problems and current limitations

- **Damage** in the optical fiber tip exposed to high radiation.
- Limited **Field of View** due to Numerical Aperture of the optical fiber
- **Temperature dependence** of the concentrated flux measurement



CONCLUSIONS

This work demonstrates the feasibility of using optical fibers with thermal and photodiode power sensors for concentrated solar flux measurements in CSP environments. The proposal constitutes an efficient, passive, robust and low-maintenance alternative to traditional radiometers. Future optical designs will focus on widening the system's field of view and mitigating the temperature dependence of the measurements.

ACKNOWLEDGEMENTS

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REFERENCES

- [1] M. J. Blanco et al., "1 – Introduction to concentrating solar thermal (CST) technologies", in Advances in Concentrating Solar Thermal Research and Technology, United Kingdom: Woodhead Publishing, 2017, ch. 1, pp. 3-25, doi: <https://doi.org/10.1016/B978-0-08-100516-3.00001-0>.
- [2] M. Abdullah et al., "Advancements, challenges, and opportunities in the measurement of high heat flux for concentrated solar thermal systems", Solar Energy, 287, 2025, doi: <https://doi.org/10.1016/j.solener.2025.113252>