Production of hydrogen, carbon monoxide or other chemical commodities at demonstrator scale using tailored concentrated photon fluxes

Michael Wullenkord[1], Kai Risthaus[2]

Background and motivation

- The defossilisation of the chemical industry and the transport sector represents an important but just as much difficult task on the path towards effective greenhouse gas emission reductions.
- Photoelectrochemical, photocatalytic or plasmonic systems driven by concentrated photon fluxes are ecologically and economically promising options to allow sunlight-powered production of chemical commodities and solar fuels from water and carbon dioxide for carbon-neutral economies.
- The use of concentrated sunlight allows compact systems, which are potentially more cost-efficient than alternative approaches and facilitate product gas collection.

Methodology

- The solar input for these systems needs to be tailored depending on the specific requirements.
- A detailed experimental assessment of these systems in practical application environments and under varying operation conditions, such as concentration ratio, is necessary to realistically determine system characteristics, explore performance limits, identify bottlenecks, derive optimisation options, and finally to promote complete exploitation of the potential of systems and their components.
- Our unique solar test facilities deliver concentrated natural or artificial sunlight at different scales – see Fig. 1. They cover a wide range of (adaptable) solar concentration ratios (from 1 to > 1000) and possible receiver / reactor sizes.
- We design comprehensive experimental set-ups including suitable secondary optics and means of photon management as well as powerful data acquisition and control systems for the production of chemical commodities and solar fuels.

Project examples

- In *FlowPhotoChem,* a system, that comprises a photo-electrochemical (PEC), a photocatalytic (PC), and an electrochemical (EC) reactor module, for the production of diverse hydrocarbons, in particular ethylene, from water, carbon dioxide, and sunlight, is being developed. The experimental assessment takes place in DLR's High Flux Solar Simulator – see Fig. 2.
- *SPOTLIGHT* develops a photonic device that converts carbon dioxide and hydrogen into methane or carbon monoxide using a plasmonic catalyst. Tests with the device under concentrated sunlight are conducted in DLR's Solar Furnace with an appropriate interface to the solar input – see Fig. 3 – as well as to an LED light source.
- *PECDEMO* delivered a hybrid photoelectrochemical-photovoltaic tandem device for light-driven water splitting, which was demonstrated on DLR's solar concentrator facility SoCRatus – see Fig. 4.

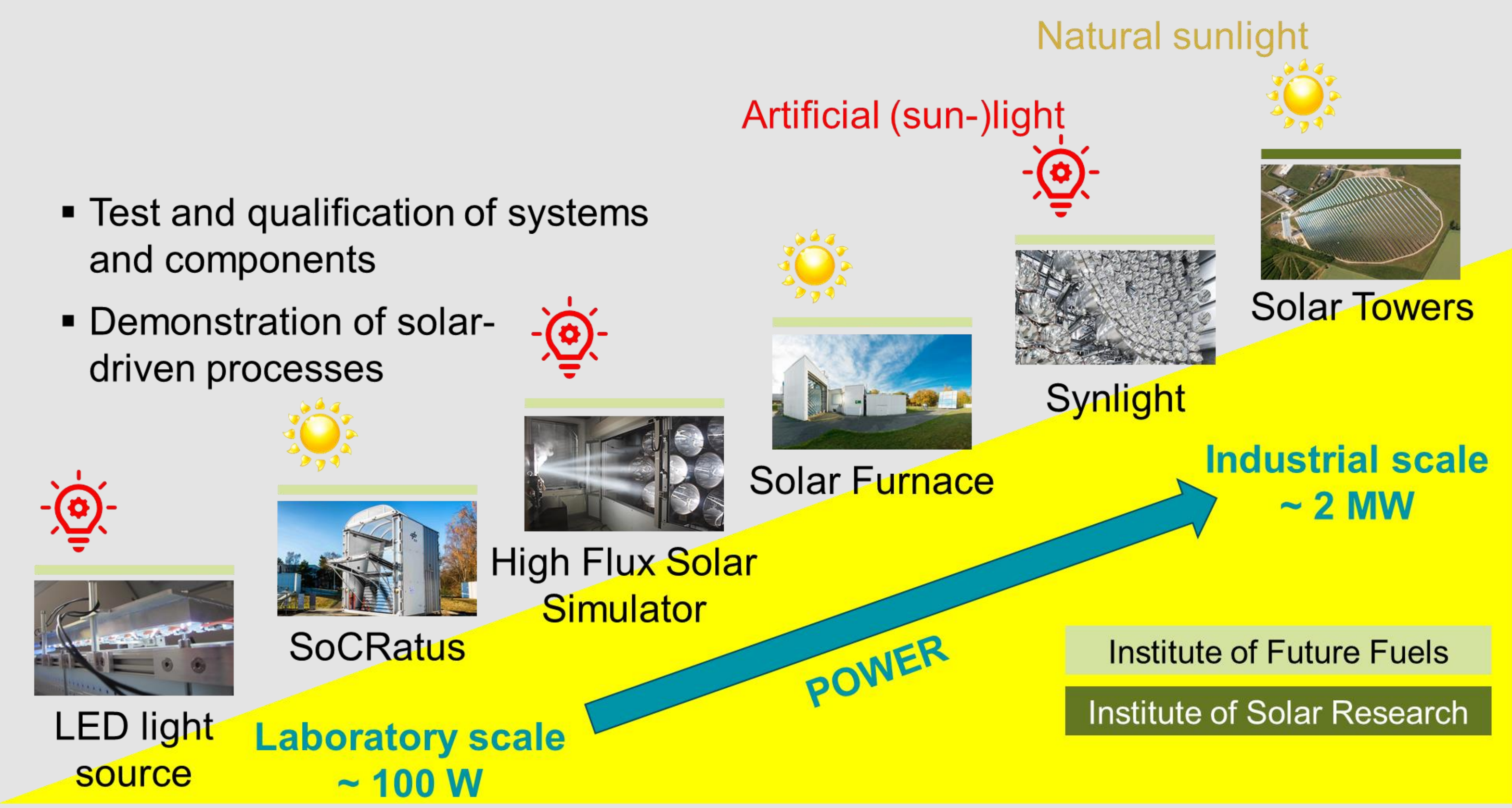

Fig. 1: DLR's solar test facilities, which provide concentrated natural or artificial sunlight at different scales

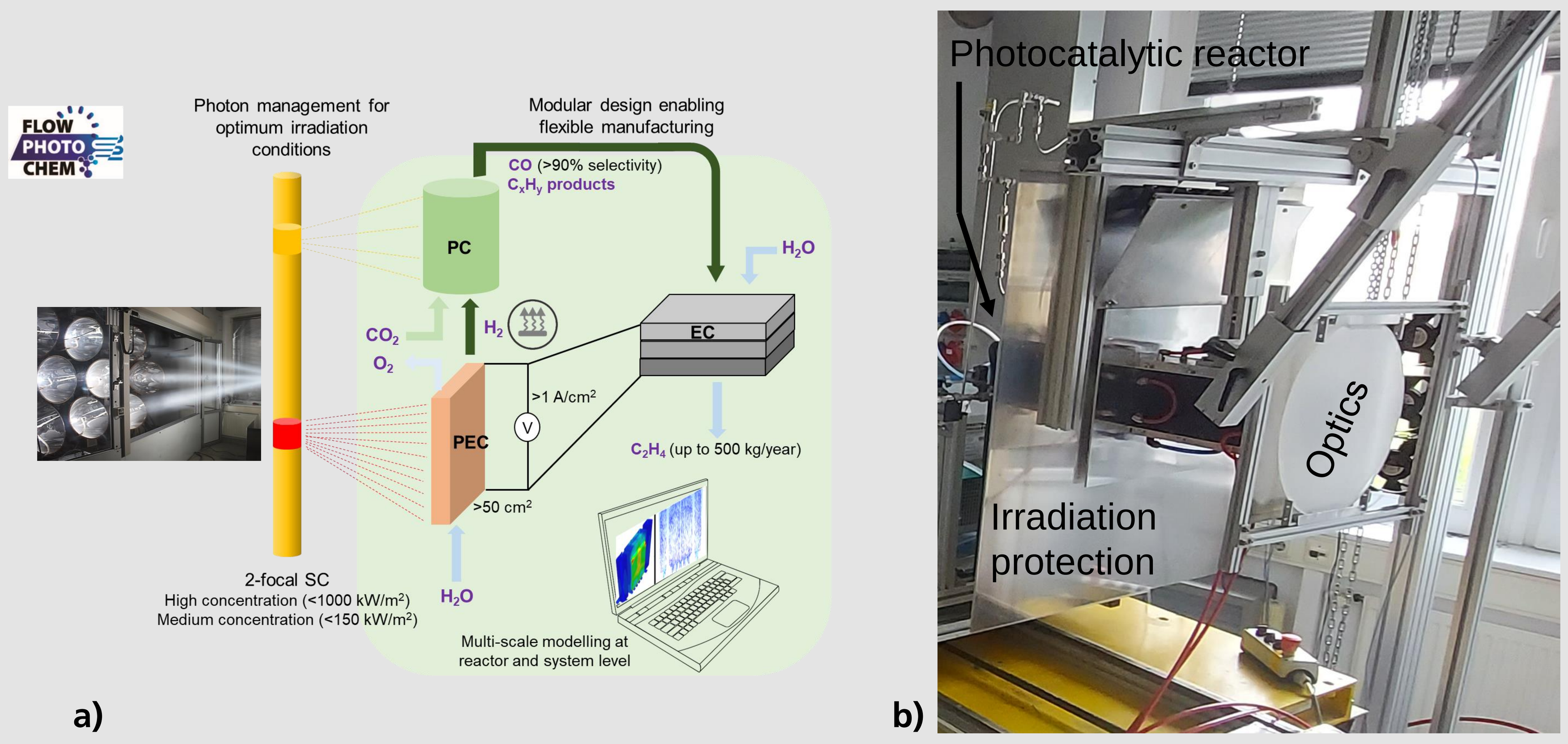

Fig. 2: a) The *FlowPhotoChem* concept with three modular reactors (SC = Solar Concentrator) and b) experimental set-up including optical components in DLR's High Flux Solar Simulator to test a photocatalytic reactor for carbon monoxide production under up to 100 kW/m² concentrated artificial sunlight

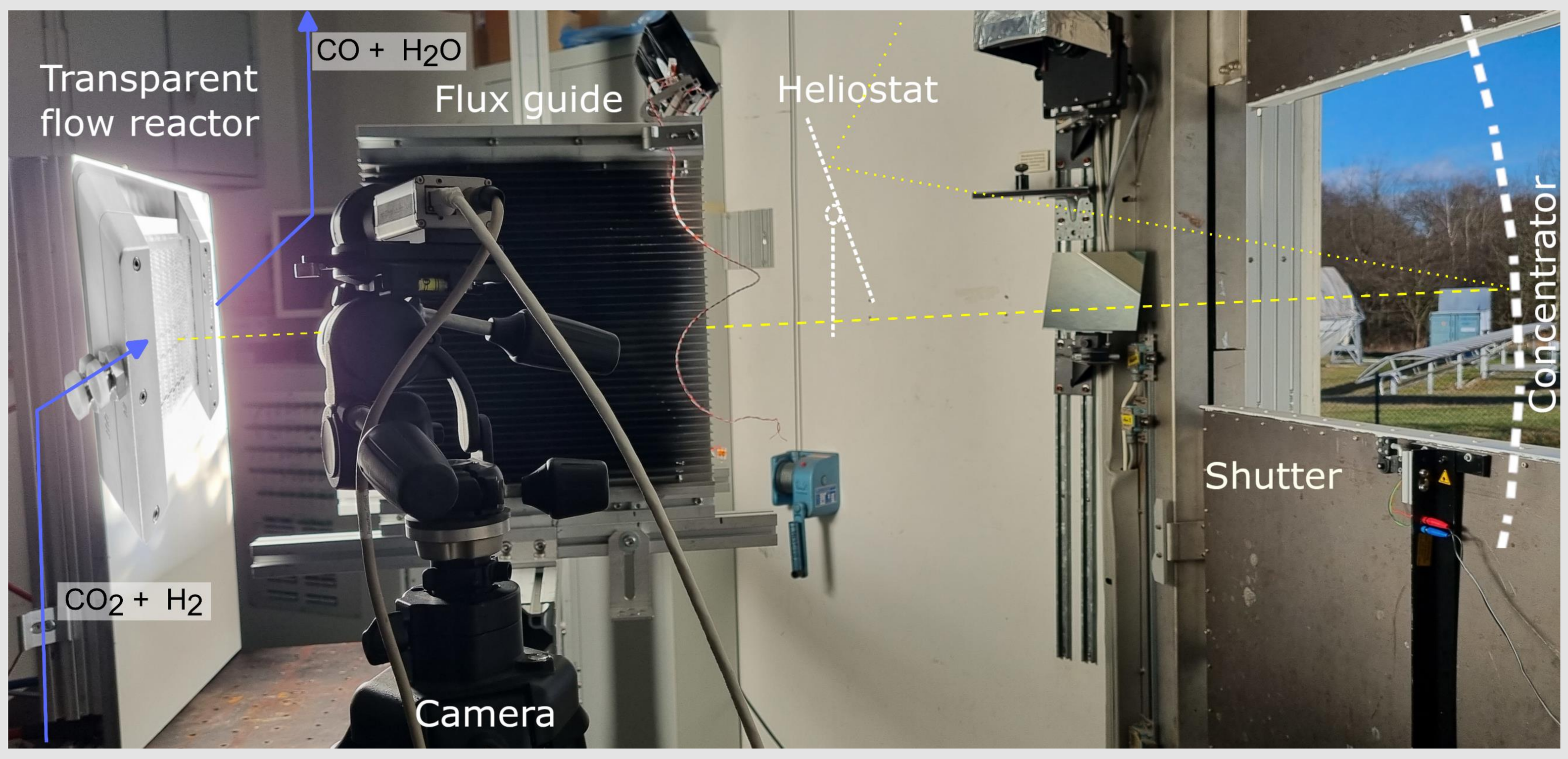

Fig. 3: Scheme of the *SPOTLIGHT* set-up at DLR's Solar Furnace. A transparent flow reactor is illuminated by up to 20-fold concentrated sunlight to enhance the reaction rate of the reverse Water-Gas-Shift reaction by plasmonic catalysis

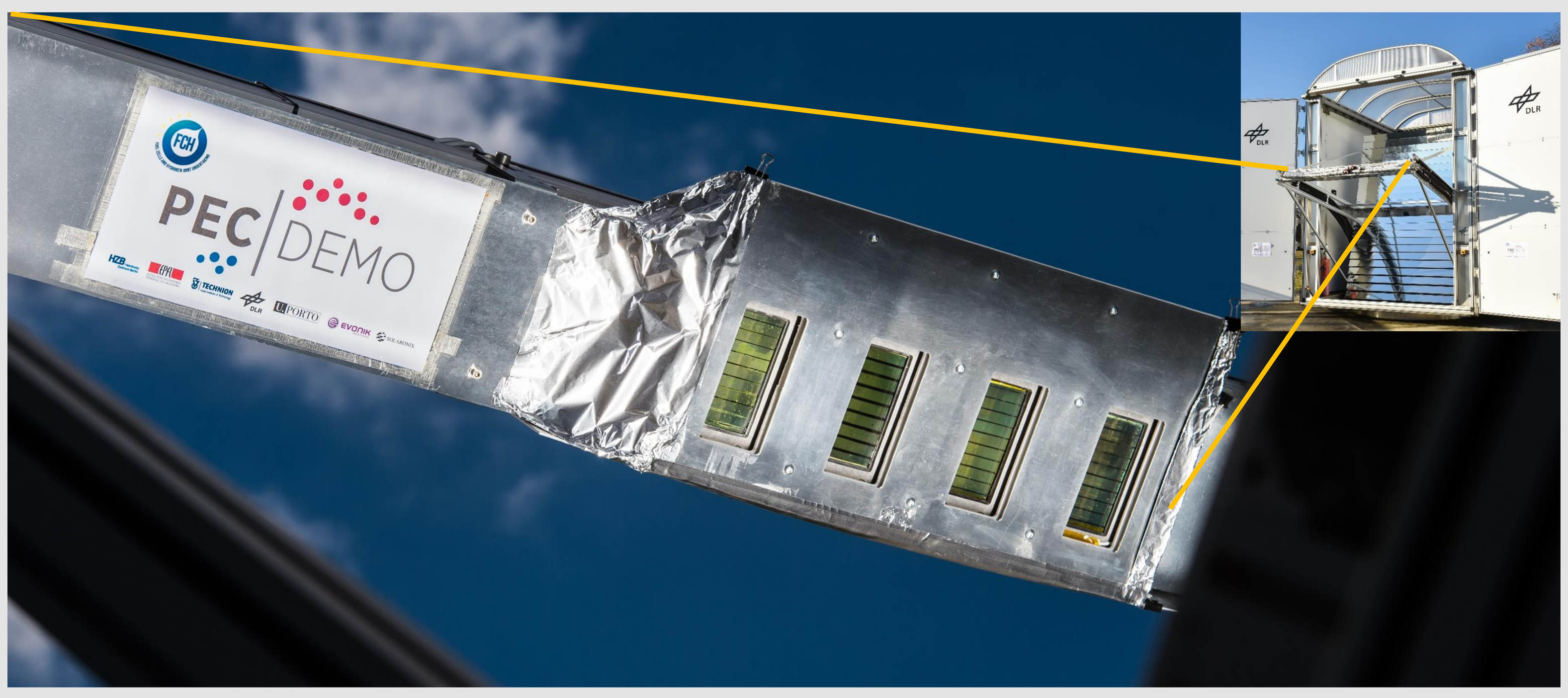

Fig. 4: *PECDEMO*'s photoelectrochemical-photovoltaic tandem device for water splitting installed in the focal plane of DLR's SoCRatus and operated under up to 17.5-fold homogeneously concentrated sunlight

[1] Chemical and Physical Fundamentals | +49 2461 93730 320 | michael.wullenkord@dlr.de
[2] Solar Process Demonstration | +49 2461 93739 316 | kai.risthaus@dlr.de

Deutsches Zentrum für Luft- und Raumfahrt

German Aerospace Center | Institute of Future Fuels
Schneiderstrasse 2 | 52428 Juelich | Germany | www.DLR.de/FF

Acknowledgements

- *FlowPhotoChem* has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 862453. The material presented and views expressed here are the responsibilities of the author(s) only. The EU Commission takes no responsibility for any use made of the information set out.
- *SPOTLIGHT* has received funding from the Photonics Public Private Partnership programme under Grant Agreement No. 101015960.
- *PECDEMO* received funding from Europe's Fuel Cell and Hydrogen Joint Undertaking (FCH JU) under Grant Agreement No. 621252.

PHOTONICS21
PHOTONICS PUBLIC PRIVATE PARTNERSHIP