High Flux Solar Simulator for the Investigation of Solar Thermochemical Cycles at Low Pressures

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Introduction

Metal/Metal oxide cycles at low pressures are a promising route to carbon neutral fuel production:

Endothermic solar step requires a high intensity source of solar radiation

Solar simulator provides a more controlled environment

Based on earlier optical design for ETH Zurich

Several design improvements

Adapted for University of Florida requirements

Currently under construction at the University of Florida

Overview

The simulator is comprised of seven, 6 kW Xe-arc lamps which closely mimic the spectral distribution of the sun.

Expected peak flux levels are 5000 kW/m², equivalent to a stagnation blackbody temperature of approximately 3000 K

Each lamp is placed at the focal point of an elliptical mirror (see figure 4)

All lamp/mirror assemblies focus the light to a common focal point

Definition

An important element of any solar system is the measurement of the input flux. Knowing the flux distribution at the aperture allows for mass and energy balances. Consequently, these values can be used to compute the effectiveness of various processes and reactor designs. To accomplish this task a flux measurement system has been developed and will be implemented on the UF solar simulator.

Calibration

At present the CCD camera, a water cooled, diffusely coated, flux target (shown below) will be placed at the focal point with a point radiometer capable of measuring flux levels up to 10 kW/m² close to the camera. A picture will be taken of the target and, knowing the flux at a specific point, gray levels in the image will be translated into a flux scale.

Design Stage

The simulator is currently under construction. Completion of the construction phase is expected in December 2010.

Specifications

The solar simulator at UF will include:

• An extruded, adjustable aluminum frame
• Seven, 6 kW lamps close-coupled to elliptical mirrors to focus the radiation
• Air cooling systems to keep the lamp and mirror assembly cool
• A power rack containing transformers and converters
• A safety wall with a retractable door (controlled from a separate room) to block radiation on the reactor until the experiment is ready to begin
• A fully controllable and customizable x-y table to mount and position experiments
• Adequate DAQ systems as required (flux measurement, thermocouples, pressure sensors, etc…)
• Comprehensive, redundant safety system.

Monte Carlo Program

A free and open source Monte Carlo ray tracing program will be used to verify the results from the flux measurement system. This program has been used extensively in the past during the optical design of the simulator.

Inverse Problem

It is crucial to know an intensity distribution at the aperture rather than a flux distribution. The intensity distribution gives a directionality that the flux map lacks. However, the intensity distribution cannot be measured directly.

A method for translating multiple flux maps at varying distances from the focal point into an intensity distribution is currently being developed. The solar simulator at UF will be used to verify the forthcoming mathematical representation of this transformation.

Conclusion

A solar simulator system is designed to provide highly concentrated radiation for the experimental investigation of high temperature solar thermal processes for the production of solar fuels, in particular metal/metal-oxide cycles at low pressures. The solar simulator provides highly controlled boundary conditions to the experiments.

Flux Mapping System

Figure 3: Three dimensional model (wire frame) of the proposed solar simulator as shown in CAD.

Figure 1: Conceptual layout of a solar thermochemical plant with low pressure solar reactor.

Figure 2: Schematic diagram of a low pressure experiment.

Figure 4: The partially assembled solar simulator at UF. The figure has been cropped and annotated in the graphic. 6 of the seven mirror assemblies have been mounted, with the seventh mirror assembly to be mounted soon. Lamps will be centered at the center of each mirror and will be supported by the link arms (visible in front of each mirror). The cooling system will also be integrated onto the frame.

Bibliography


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