U.S. Department of Energy
HelioCon
Heliostat Consortium for
Concentrating Solar-Thermal Power

An Educational Program on Concentrated Solar Power and Heliostats for Power Generation and Industrial Process

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conceptual design • components • integration • mass production • heliostat field

An educational program has been developed by Northeastern University to expand CSP knowledge among college students as well as practicing engineers. It includes:

1. **Involvement of under-represented minority students from (LSAMP) group for summer research.**
2. **Involvement of undergraduate students in Capstone Senior Design Projects relevant to Heliostats.**
3. **Involvement of Upper-Class students in CSP Research.**
4. **Development of a four credits senior/first year graduate course.**
5. **Preparation of five short courses for industry.**
6. **Supervised a 4 credits graduate project.**

Item 1: Involvement of under-represented minority students from (LSAMP) group for summer research

The Louis Stokes Alliance for Minority Participation (LSAMP) program fostered an opportunity for two female rising seniors to conduct a research experiment in effective and efficient methods of cleaning heliostat mirrors. Their research experiment was concluded in the Fall of 2023.

Highlights

- **Hands-on, lab scale experimental design and data collection**
- **HelioCon seminar presented and published**

Item 2: Involvement of undergraduate students in Capstone Senior Design Projects relevant to Heliostats

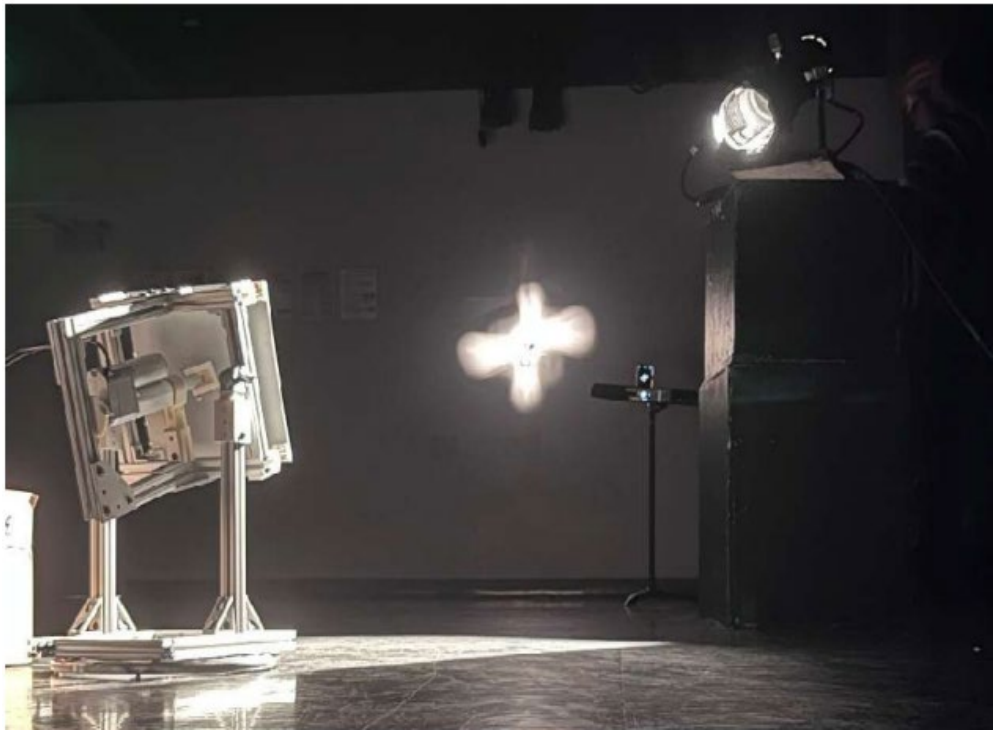

Figure 1: Deformable Heliostat Experiment setup

CSP Project #1: Deformable Heliostat

- **Objective**: to use a deformable surface to enhance the performance of a heliostat.
- **Design**: a single linear actuator and anchored to the center of a mirrored acrylic surface, pulled to create concavity.
- **Results**: light intensity at receiving surface was enhance by 7.5x, passed on to phase II capstone project.

Item 2: Involvement of undergraduate students in Capstone Senior Design Projects relevant to Heliostats

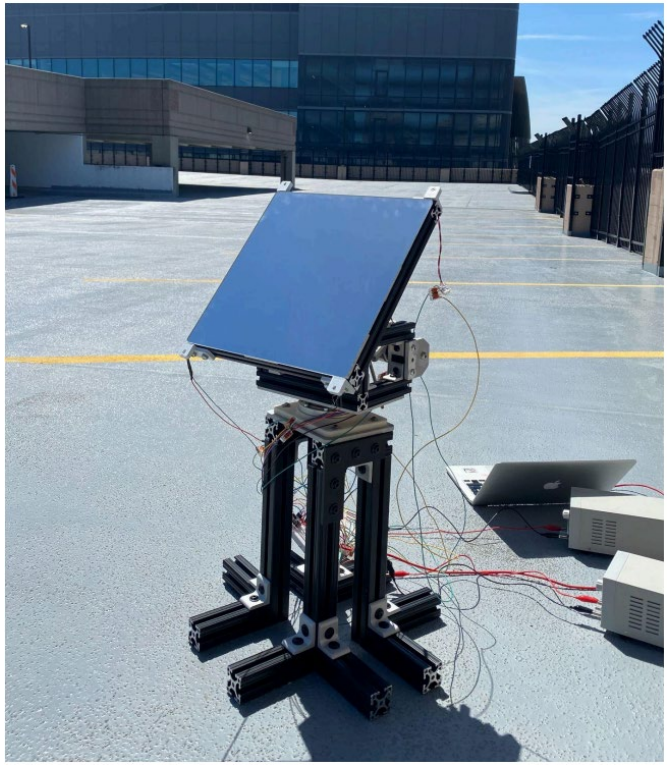

Figure 2: Solar Tracker prototype

CSP Project #2: Solar Tracking Heliostat

- **Objective**: to create a closed-loop solar tracking design to address issues associated with open-loop solar tracking setups
- **Design**: 4 light-dependent resistors on target to determine light intensity with stepper motors used to adjust elevation and azimuthal angles of heliostat
- **Results**: successful tracking of a collimated light source using the closed-loop design

Item 2: Involvement of undergraduate students in Capstone Senior Design Projects relevant to Heliostats

Figure 3: Solar Pyrolizer Dish testing

CSP Project #3: Solar Pyrolizer Dish (Phase II)

- **Objective**: to update the feeding system and solar tracking capabilities of a solar pyrolizer dish meant to turn dried pine needles into biochar
- **Design**: redesigned hardware and circuitry; advanced auger feeding system used to control pine needle flow rate
- **Results**: preliminary testing showed temperatures of 550 degrees Celsius reached – continued testing needed for auger system

Item 3: Involvement of Upper-Class students in CSP Research.

One upper-class student joined faculty in completing a three-month Fall 2023 research co-op opportunity as a joint venture between Northeastern University and the National Renewable Energy Laboratory. During this time, a solar receiver was researched and designed to improve light concentration at the receiver between 40-80%. A provisional patent application was filed with the university for further development.

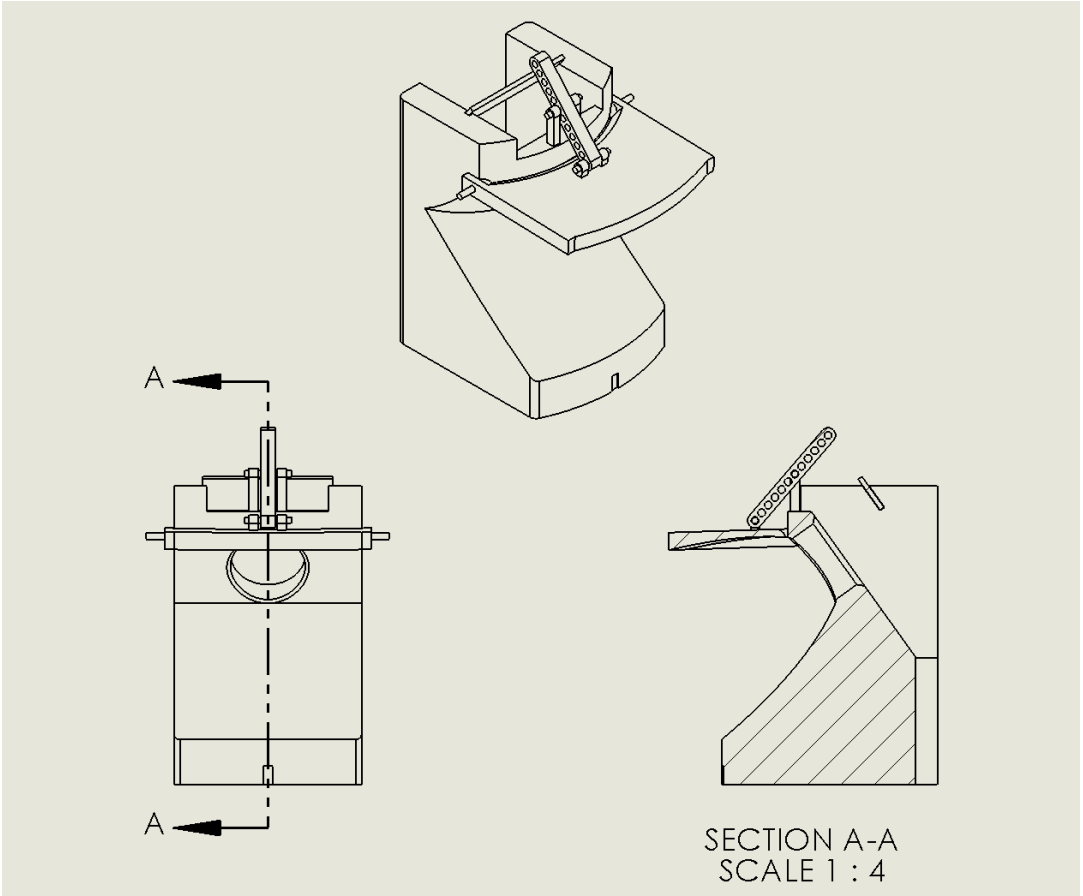

Figure 4: CAD Drawing of initial prototype and cross sections

Item 4: Development of a four-credit senior/first year graduate course.

Special Topics Course: **ME 5374** "APPLICATIONS OF CONCENTRATING SOLAR THERMAL TECHNOLOGIES"

Spring 2024 at Northeastern University, Department of Mechanical and Industrial Engineering

Textbook: "Concentrating Solar Thermal Energy: Fundamentals and Applications", Gilles Flamant, Wiley, 2022, ISBN:9781789450798 |Online ISBN:9781394169702|DOI:10.1002/9781394169702

Developed by Gregory J Kowalski

Item 4: Development of a four-credit senior/first year graduate course.

Course Objectives:

1. Understand the difference between power and energy performance measures and their differences as related to the supply and load views

2. Determine the benefits of CSP as related to power producing or manufacturing capabilities related to the high temperatures achieved in these systems

3. Predict incident solar radiation at a CSP site

4. Simulate the geometric optics to determine the incident radiation on the tower receiver

5. Predict performance measures of the heliostat fields

6. Predict the thermal performance of the receiver

7. Predict performance of Thermal Storage as it relates to the performance measures

8. Understand the economics of CSP system, including storage

9. Sustainability issues relating to the second law and thermo-economic considerations

Item 4: Development of a four-credit senior/first year graduate course.

Topics Covered

Textbook: "Concentrating Solar Thermal Energy: Fundamentals and Applications", Gilles Flamant, Wiley, 2022, ISBN:9781789450798 |Online ISBN:9781394169702

1. Chapter 1: Solar Power Plants: State of the Art
2. Chapter 2: Solar Resource Management, Assessment and Forecasting
3. Chapter 3: Optics of Concentrating Systems
4. Chapter 4: Solar Receivers
5. Chapter 5: Heat Transfer Fluids for Solar Power Plants
6. Simulation, need for numerical methods (Material Similar to Chapter 6)
7. Chapter 7: Materials for Concentrated Solar Power
8. Chapter 8: Thermal Energy Storage (Simulation)
9. Chapter 10: Synthetic Fuels from Hydrocarbon Resources
10. Chapter 11: Solar Fuel Production by Thermochemical Dissociation of Water and Carbon Dioxide
11. Microeconomics and thermo-economics
12. Manufacturing Potential of Concentrating Solar Power

Item 4: Development of a four-credit senior/first year graduate course.

As the course was offered as a Special Topics course, it was conducted in a seminar manner with weekly assigned reading and research topics. The course met remotely once a week, where:

- Questions from the readings and assignments were addressed
- An open discussion of the readings occurred
- Short lecture material were presented to provide clarity for the assigned readings
- Occasionally, a student was asked to present their work and facilitate a discussion surrounding it. The student was forewarned before the class.

Item 4: Development of a four-credit senior/first year graduate course.

Grading Policy

Class Participation	25%
Homework	25%
Exams (take home)	25%
Final Exam (take home)	25%, [Hand out last class, 5 days]

All exams were take-home and were returned at the stated due date. Independent work on exams was expected. All course related activities were expected to be conducted according to the Northeastern University Honor Code.

Item 4: Development of a four-credit senior/first year graduate course.

There were 13 students enrolled in both the in-person and online sections of the course. The students were mainly from a Mechanical Engineering background (12) and one from Chemical Engineering. The course offering provided feedback as to course content and what background topics needed to be emphasized more. The course also provided a framework for developing topics and five short courses for those practicing Concentrating Solar Power technologies.

The course has been approved and is entered in the course catalogue at Northeastern University. Further refinement will be an ongoing process as course results are evaluate and student weaknesses are revealed.

Item 5: Preparation of five short courses for industry.

These industry short courses are designed to introduce CSP to those seeking to enter the field or bolster the background of professionals with varying levels of experience in the field.

The courses will be offered as live, online sessions in a split morning/afternoon session format, and there will be five courses offered in total depending on the level of experience and familiarity of the individual seeking to participate.

- A survey has been issued to best determine the means of offering the course, prepared in collaboration with Rebecca Mitchell of NREL.

If interested, please email: gkowal@coe.neu.edu

Item 5: Preparation of five short courses for industry.

Short Course I

- Target Audience: those new to CSP with a technical background with a desire to enter the field or in a technical policy-related field

- Covers: existing facilities, general limitations; incident solar radiation; energy vs power considerations; control strategies; energy storage; economic considerations; receiver design considerations.

Item 5: Preparation of five short courses for industry.

Short Course II

- Target Audience: those recently hired in the CSP field seeking more detailed analysis, OR those who have taken Short Course I

- Covers: calculating incident solar radiation; ray tracing basics; ray tracing software; heliostat field control challenges and loss factors

Item 5: Preparation of five short courses for industry.

Short Course III

- Target Audience: those having worked in the CSP field for some time OR those who have taken Short Course II

- Covers: receiver designs and working fluids; material requirements; energy (heat) transfer basics, “element” analysis for commercial codes; working fluid requirements

Item 5: Preparation of five short courses for industry.

Short Course IV

- Target Audience: those experienced in the CSP field seeking in-depth simulation exposure for energy storage OR those who have taken Short Course III

- Covers: energy storage; integrating solar, thermal, and energy storage models; types of energy storage to respond to load demand; microeconomics and thermo-economics

Item 5: Preparation of five short courses for industry.

Short Course V

- Target audience: those experience in the CSP seeking information on manufacturing aspects OR those who have taken Short Course IV

- Covers: electrical power production; synthetic fuels from hydrocarbon resources; solar fuel production by thermochemical dissociation of water and carbon dioxide; manufacturing potential of concentrating solar power

Item 6: Supervised a 4 credits graduate project.

A graduate student completed a 4-credit graduate project in the realm of concentrated solar power. For the research project, the concentrating effects of an Axially Graded Index Lens was studied to determine the efficacy of implementing the lens on a solar receiver. The graduate project required weekly meetings, research, experiments, and data analysis to perform, which was talked about in a final presentation.

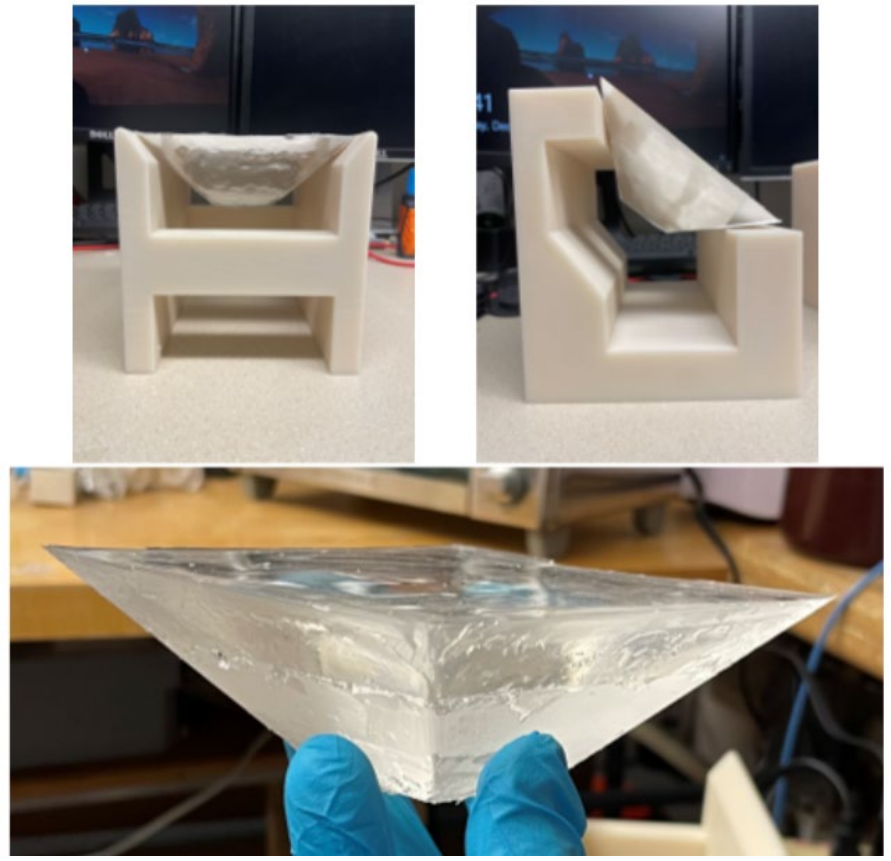

Figure 4: Axially Graded Lens Manufacturing

Questions?

www.nrel.gov **csp.sandia.gov**

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