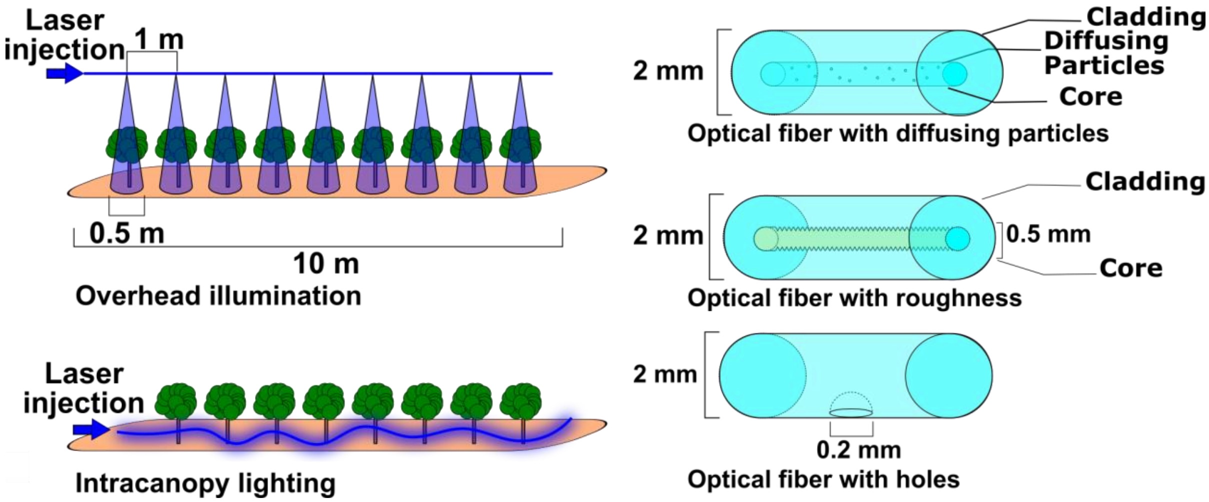
Sponsor
The **Solid State Lighting & Energy Electronics Center (SSLEEC)** at the University of California, Santa Barbara is a collaborative center which partners key industry leaders and UCSB researchers to advance solid-state lighting, display technology, and energy efficient power switching using wide band-gap semiconductors. The objective of the SSLEEC is to provide a forum for its members - key industry partners and the faculty and student researchers at the University of California, Santa Barbara - to work in collaboration and across scientific disciplines to address the most challenging problems in these important and timely areas of research. Research in SSLEEC is application driven and covers development of epitaxy and devices in gallium nitride (GaN) based light emitting diodes and lasers spanning the spectrum from UV to infra-red, and ranging in size down to micro-LEDs, nano-LEDs, and vertical cavity surface emitting lasers. SSLEEC research also includes work on AlGaN/GaN RF and power electronics. ssleec.ucsb.edu

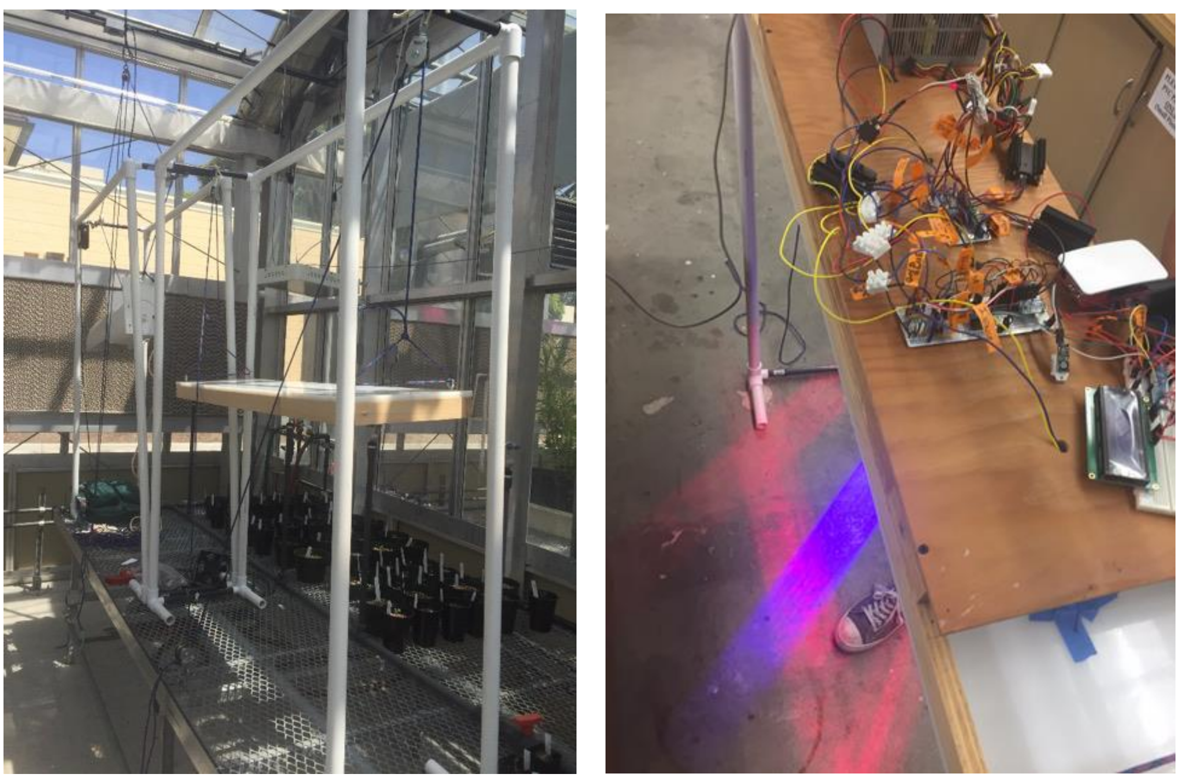
Background
LEDs have been used for horticultural lighting for several years alongside other lighting technologies such as high-pressure sodium (HPS) lamps. However, comparative studies of the impacts of various kinds of light on plant characteristics are rare. The distinguishing feature of this proposed research will come from the use of laser diodes (LDs) as the illumination source and its comparison with widely used LED lights. LDs provide orders of magnitude higher brightness than LEDs, and have a smaller form factor, enabling reduced system cost at higher illuminance, since fewer light sources are involved.

More interestingly, LDs are among the smallest light sources available and can provide a highly luminous beam with very directional emission. As a result, lasers can be coupled into waveguides and/or fibers with minor losses (as compared to LEDs), or used in combination with scanning micro-mirrors, allowing a large amount of light to be delivered from a remote source. In this manner, light can be delivered to specific plants at desired levels with limited wasted light while the temperature at the plant is kept low, preventing plants from overheating or burning. Additionally, the remote laser source can be placed outside of the greenhouse environment, removing size-constraints on the emitter and potentially increasing source reliability.

Problem Statement and Solution Concept
The primary problem to be addressed by the project is the design for delivering the maximum light to the plant, with maximum system efficiency, while keeping the laser source outside of the greenhouse environment. Some preliminary modeling has been done around laser coupling into leaky fiber optics and into waveguides with engineered extraction elements. Fiber optic systems have the additional advantage of allowing for light delivery around the plants instead of only via top-down illumination. However, coupling high-energy laser emission into fibers without damaging the fiber tip can be problematic. To that end, a possible solution involves leveraging free space light transmission, leveraging scanning micro-mirrors to direct light to the plants.



Fiber-guided concept



First prototypes. System shown does not leverage guided light; instead the lasers are shining directly onto the plants instead of taking advantage of the remote source configuration. The spectral mix of LED-based systems is typically 2/3 red, 1/3 blue. This ratio can be duplicated in the laser system, with no need for optimization under the scope of this project.

Deliverables

The team should assemble a fully-functional growth system based on light delivery from a remote, multi-wavelength laser source. The team should conduct a basic theoretical study of the various options for light delivery before deciding on a system configuration (e.g. fiber, waveguide, free-space/mirrors, etc.), as well as a literature review of current LED-based approaches and their limitations. A report should be assembled in the Fall quarter, before any procurement of parts.

The team will have to purchase both red and blue high-power lasers for use in the prototype, as well as source any waveguides or mirrors. Leaky fibers are available, should the team choose this route.

The flux, spectrum, illumination uniformity, and temperature should all be measured at the location where the plants will eventually be placed. The system should be optimized such that there is maximum light delivered to the plant, while also maximizing uniformity and overall system efficiency (which should be calculated).

Stretch Goals

(1) Optimize the vertical density of the growth system: does a laser-based system sufficiently reduce temperature at the plant so that the light-directing element can be brought closer to the plant (essentially maximizing vertical packing density in a multi-tiered vertical farm application)

(2) Plant growth: set up a growth trial for micro-greens in an enclosed illumination system with the laser source on the outside, simulating a vertical farm

Vertical farm based on LED lighting. Can lasers enable a higher density of plants? Can lasers enable a system with fewer components?

Student Qualifications

- Interest in AgTech
- Familiarity with lasers, optics, power supplies, and circuit design
- Mechanically minded – able to work with machine shops and Innovation Workshop (makerspace)

Student Requirements

None - students are encouraged to take the idea through the TMP New Venture Competition

Resources Provided to Team

A power meter will be available for use by the team:
https://www.apogeeinstruments.com/quantum/