The Quest for High-Power Lasers:

Forcing Mutual Coherence in Broad Area Diode Lasers

University of New Hampshire, URC 2014

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Introduction

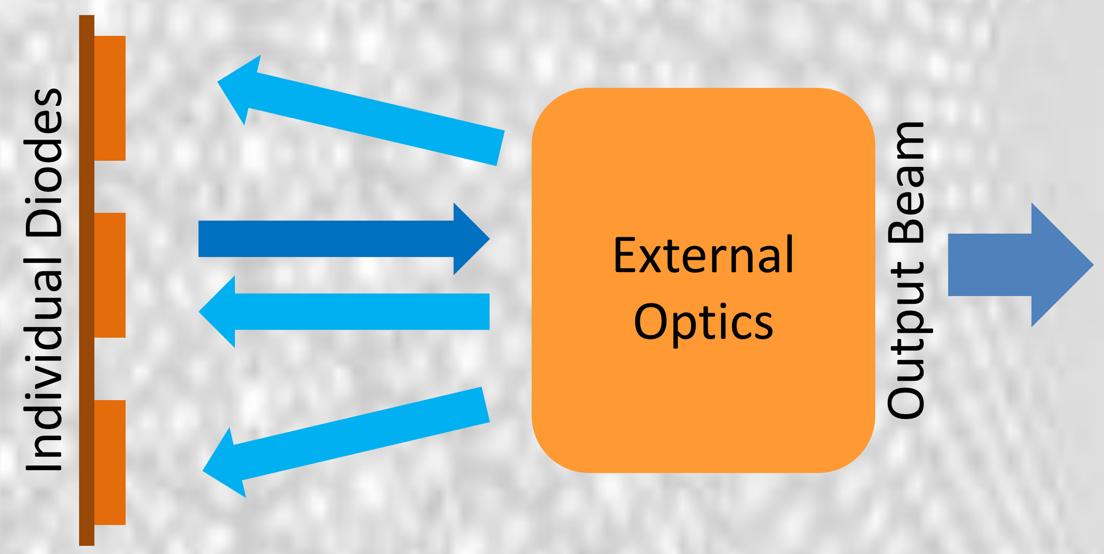
Large lasers have the advantage of being able to output a high-quality, high-power beam, but are costly and complex.

On the other hand, an ensemble of many small lasers do not have good beam quality for equivalent power, but are cheaper, simpler, and more stable.

The purpose of this project is to combine the two advantages: take many small lasers and make them act in unison like a single large laser.

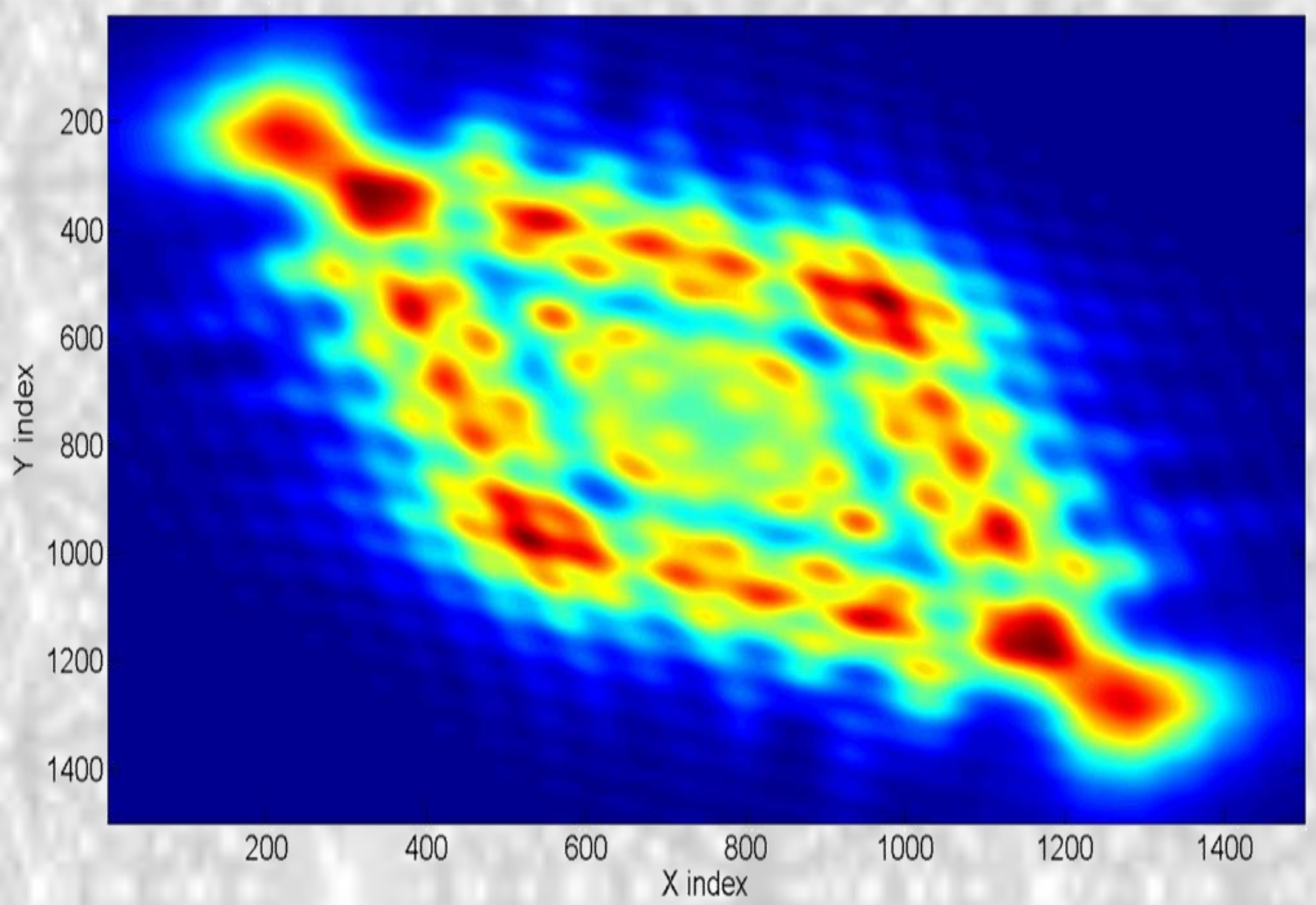
Diode lasers are used in this project because they are easy to assemble into a "diode laser stack" of 1000+ elements, each with ~1W power.

Overall Principle



Many individual laser diodes act as one single laser if each of their light outputs are correlated with each other.

Light correlation occurs when the light from one diode (dark blue) is reflected (light blue) by an optical system into adjacent diodes. This light is amplified by the adjacent diode, causing a correlation among the output light.



Propagation Matrices

The propagation of light through an optical system can be modeled discretely, using matrices and the Rayleigh-Sommerfeld approximation.

To the left is an example of a propagation matrix for an optical system. A vector of an input light pattern is multiplied to give the light pattern out of the system.

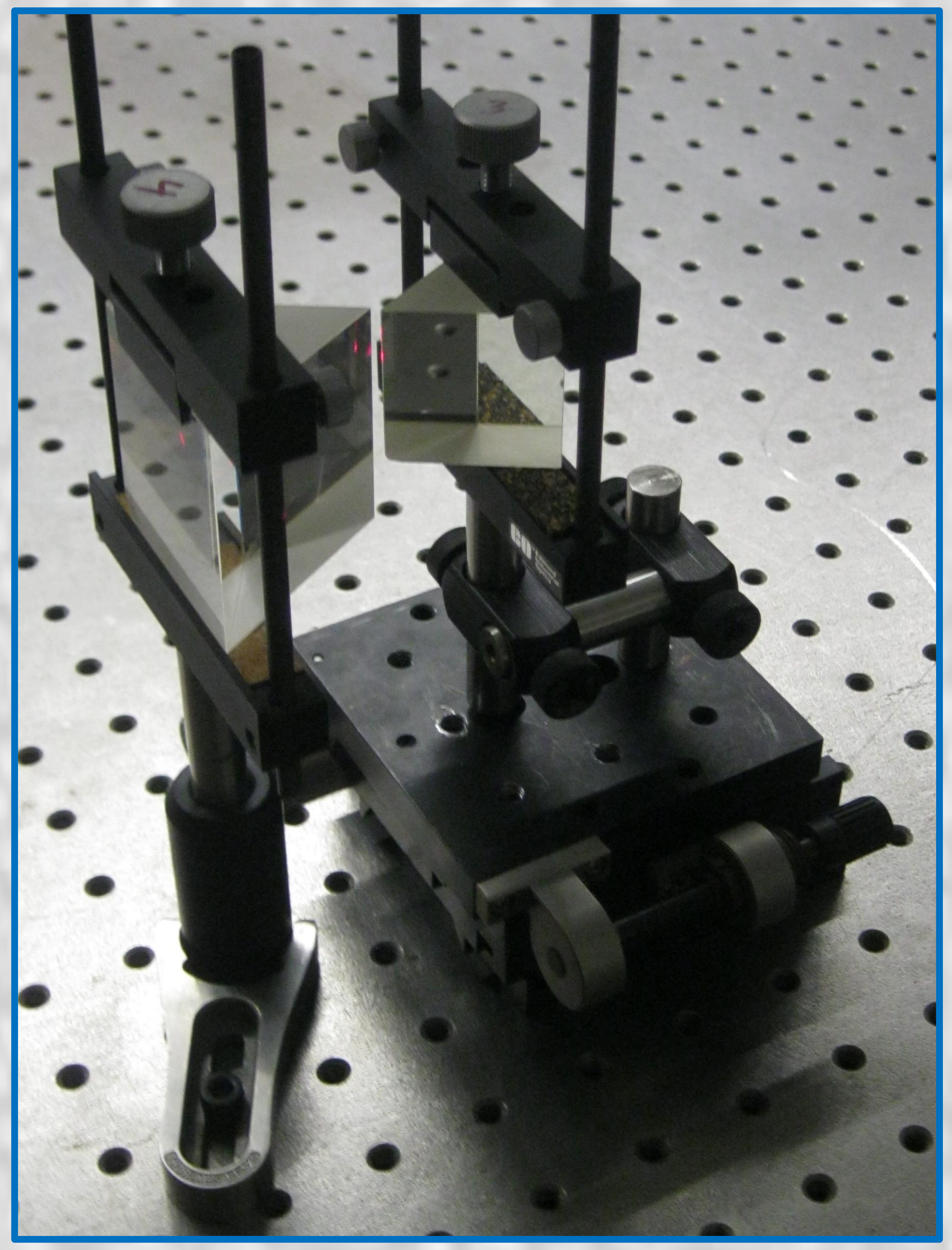
Experimental Methods

One method of creating mode locking is to use single-slit diffraction from a spatial filter (a S.F. external resonator).

- Light from one diode is diffracted and spreads to the adjacent diodes, causing mode locking.

A system is currently being assembled to demonstrate this phenomena.

- Utilizes a 100Watt, 50-element diode laser stack, and a lab-built spatial filter to create single-slit diffraction.
- Is a proof-of-concept for a scalable system (100kW+)



Above: A High-Power S.F.

The spatial filter for the prototype 100W CW laser system now in development. Glass prisms are used to "peel off" extra light, instead of a small pinhole, which would vaporize due to light intensity.

Theoretical Methods

Primary analysis uses propagation matrices to show cavity performance.

- Calculating Eigenvalues and eigenvectors for propagation matrices finds resonant modes and resonator gain, as well as frequency response.
- Results suggest very fine accuracy is required for some components of the experimental system.

Also simulating a personal idea which uses a nearfield effect based on glass reflecting on both interfaces.

Below: Simulated S.F. System

Showing the simulated propagation of a square input beam (like that of a focused laser pointer) through a 1m lens and a 250µm spatial filter. Blue is low light intensity, red is high light intensity.

What is this Background?

This background is an example of the *Talbot Effect*, which is a near-field phenomena where an infinitely periodic light pattern re-produces itself after a certain length (the Talbot Length).

This effect can be leveraged by making a *Talbot Cavity*, where the periodic structure of a diode laser stack is projected on a mirror at the Talbot length, which reflects the exact diode pattern back on itself, forcing all diodes to lock into a "supermode".