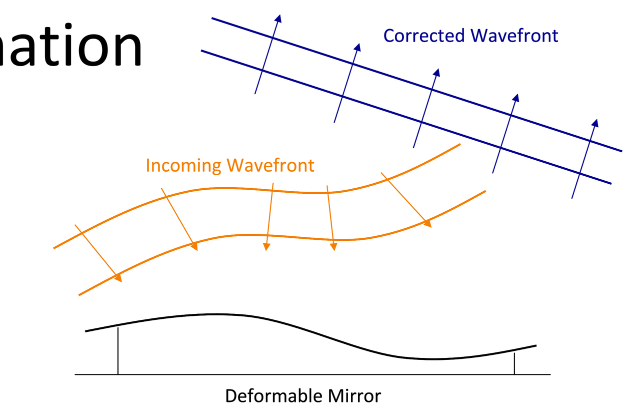
Brighter Fiber!

Designing a Multi-Mode Optical Fiber Optimization System

Michelle McMillan, *RET Teacher, Sanborn Regional Middle School* Maureen Chase, *RET Teacher, Quabbin Regional High School*
Dr. Thomas Bifano, *Photonics Center, Boston University*

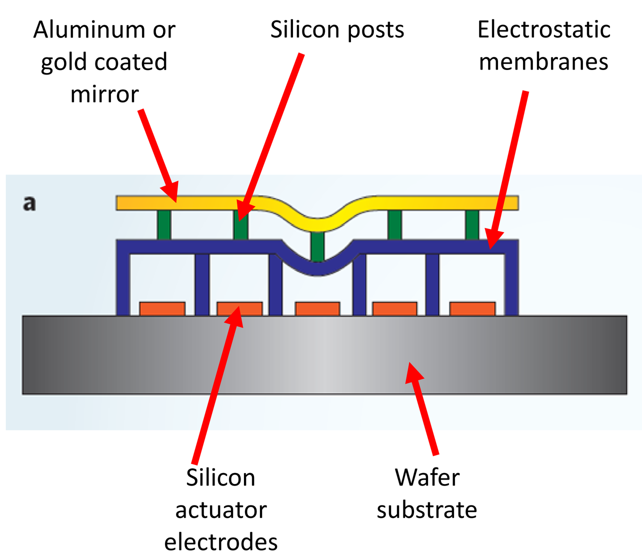
Background Information



What is a *deformable mirror?*

A deformable mirror is a mirror that can change shape.
Light traveling through a material can be distorted.
A deformable mirror fixes these distortions.

The deformable mirror we are using is a *micro-electro-mechanical system*, or a MEMS device. These are functioning machines ranging in size from 1 – 100 micrometers.

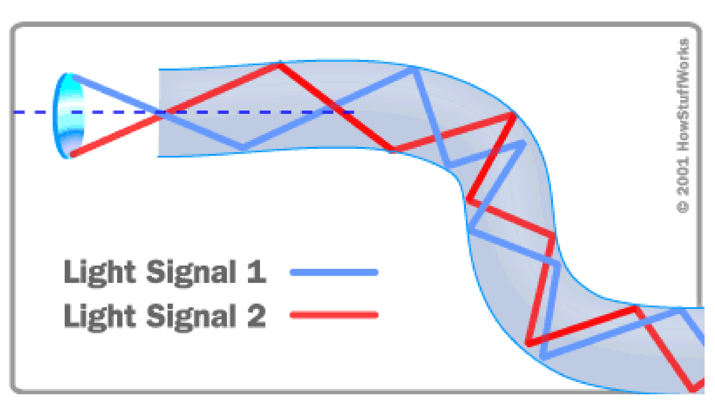


Our deformable mirror was built by Boston Micromachines Corporation. It has a grid of 140 actuators that can be moved independently. An electric charge is applied to different points behind the mirror. Like when your hair is attracted to an electrically charged balloon, an electrostatic membrane is attracted to charged electrodes. This attraction moves a segment of the mirror attached to the membrane.

Bifano T, "Adaptive imaging: MEMS deformable mirrors," Nature Photonics, [5], 21-23, 2010.

What is a *fiber optic cable?*

You know from experience that light generally travels in straight lines. But what if you wanted to shine a flashlight around a corner? Follow this link to continue reading about how light is transmitted through a fiber…



What is a micrometer? 1mm=1000µm

If you look at the metric side of a classroom ruler, there are markings each centimeter. Within each *centimeter* there are ten smaller markings. These are each a *millimeter* apart. Within a millimeter, there are **1000** micrometers (aka microns)!

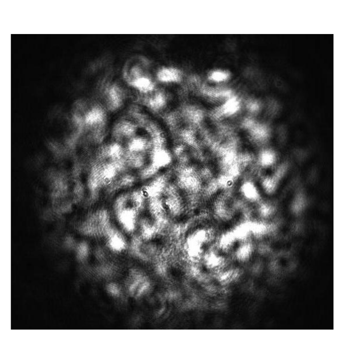
Scan this with an Apple Device to see a Powers of Ten app!

Similar to trapping light in a hallway, a fiber optic cable is a glass wire that uses a phenomenon called total internal reflection to trap the light inside the fiber. Once light has launched into the fiber, it will follow the path of the fiber. Follow this link to see a demonstration of TIR in water on my blog!

There are two types of fiber optic cables:

•*Single-mode* fibers are small in diameter; ours is around 4 micrometers across. Because the size of this fiber is close to the wavelength of light, only one mode of light can pass through. So the output of this fiber is one point of light.

• *Multi-mode* fibers are bigger in diameter. The fiber we used has a 50 micrometer diameter. Because this fiber is large compared to the wavelength of light, many *modes* of light can enter the fiber. At the other end of the fiber, these modes interfere to form a *speckle pattern* seen below. Our goal is to focus this speckle back into one point.



See the speckle pattern change as the multi-mode fiber is being moved!

What is Engineering?

(from a scientist's perspective)

Who do you think of when you read the word *Scientist*? Is the person you are thinking of on this list?

Now, picture an *Engineer*…not as easy? So if don't know an Engineer or what they do, how will you know if you would like that job? And what is engineering anyway?!

Here it is: Engineers solve problems. You need a bridge over that river, a civil engineer can design it. You need to go to the moon, hire a team of aerospace engineers and some astronauts brave enough to go. You need a phone that is as powerful as a computer, ask an electrical engineer.

In science class, we will practice engineering too. Both of these areas involve a mix of design and discovery. But if you like applying scientific knowledge to solve real world problems, then engineering might be for you.

This poster is about the engineering design project I did at the Boston University Photonics Center over the summer. Enjoy!

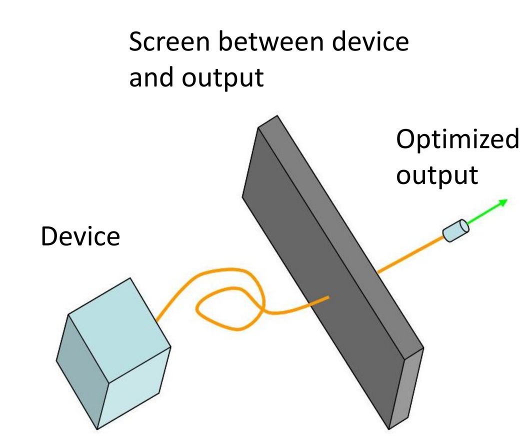
The Problem

Our problem this summer was to optimize the light coming out of a *multi-mode fiber optic cable*.

•The Requirements:

• We needed to optimize the light coming out of the fiber without being able to see the light, as if there is a wall between you and the output of the fiber.

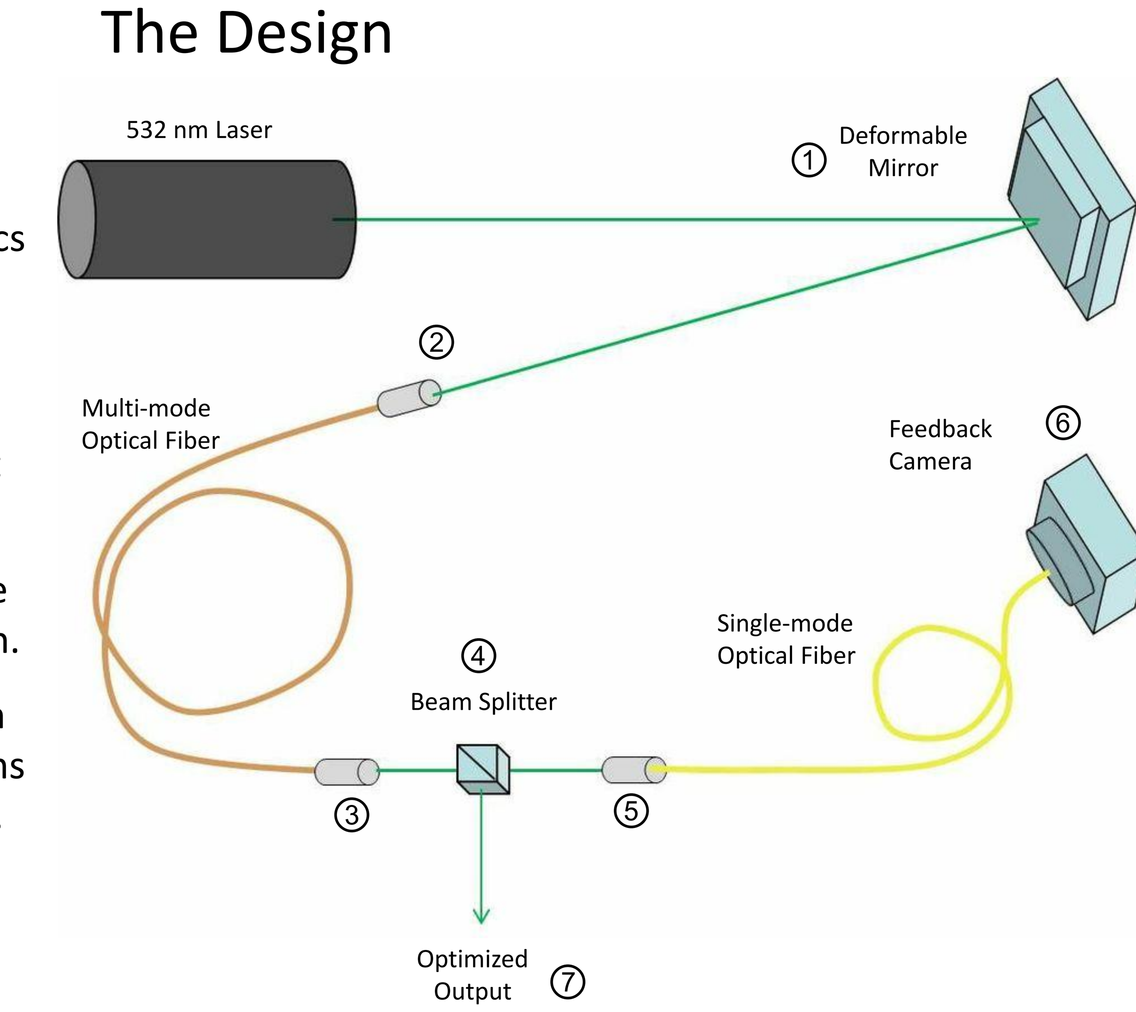
• We should be able to move the fiber - which changes the speckle pattern – and keep the output optimized.



• The Resources:

• A *deformable mirror* (more on that below), a multi-mode fiber optic fiber, a single-mode fiber optic fiber, and a green laser (at 532 nanometers).

The Design



1) Light from a green laser hits the deformable mirror (optics not shown).
2) Light from the deformable mirror is launched into a multi-mode fiber (optics not shown).
3) Light leaving the multi-mode fiber forms a speckle pattern.
4) Light passes through a beam splitter that forms two beams perpendicular to each other.
5) Half of the light is launched into a single-mode fiber.
6) Light leaving the single-mode fiber is view by a camera. We move the deformable mirror so as to maximize the brightness of this output.
7) As we maximize the output of the single-mode fiber, the output of the multi-mode fiber is optimized.

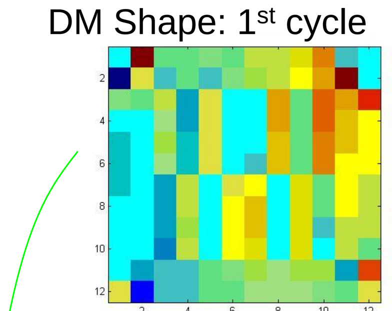
Optimization

To optimize the light exiting a multi-mode fiber, we need to figure out what shape to put on the deformable mirror. We do this using a trial-and-error method:

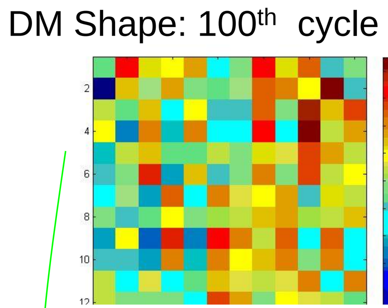
1) We create an array of 256 Hadamard shapes (an orthogonal and complete set).
2) We apply the first shape to the deformable mirror.
3) We find what amount of that shape makes output of the single-mode fiber as bright as possible.
4) We add the result to the deformable mirror and repeat with the next shape.

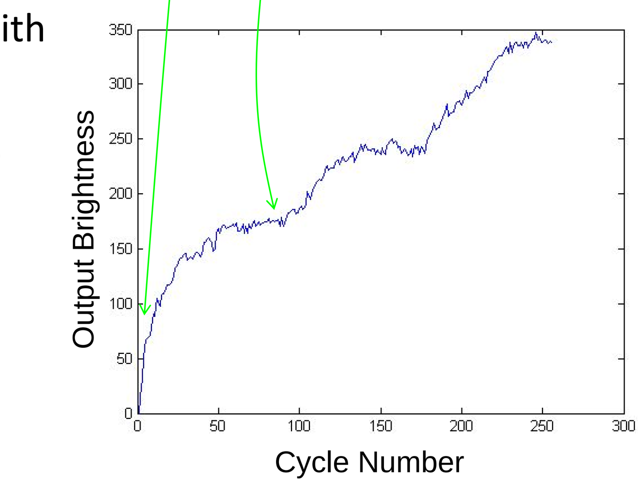
This is done in real time. As the fiber moves, new shapes are applied to keep the optimization as good as possible.

DM Shape: 1st cycle



DM Shape: 100th cycle

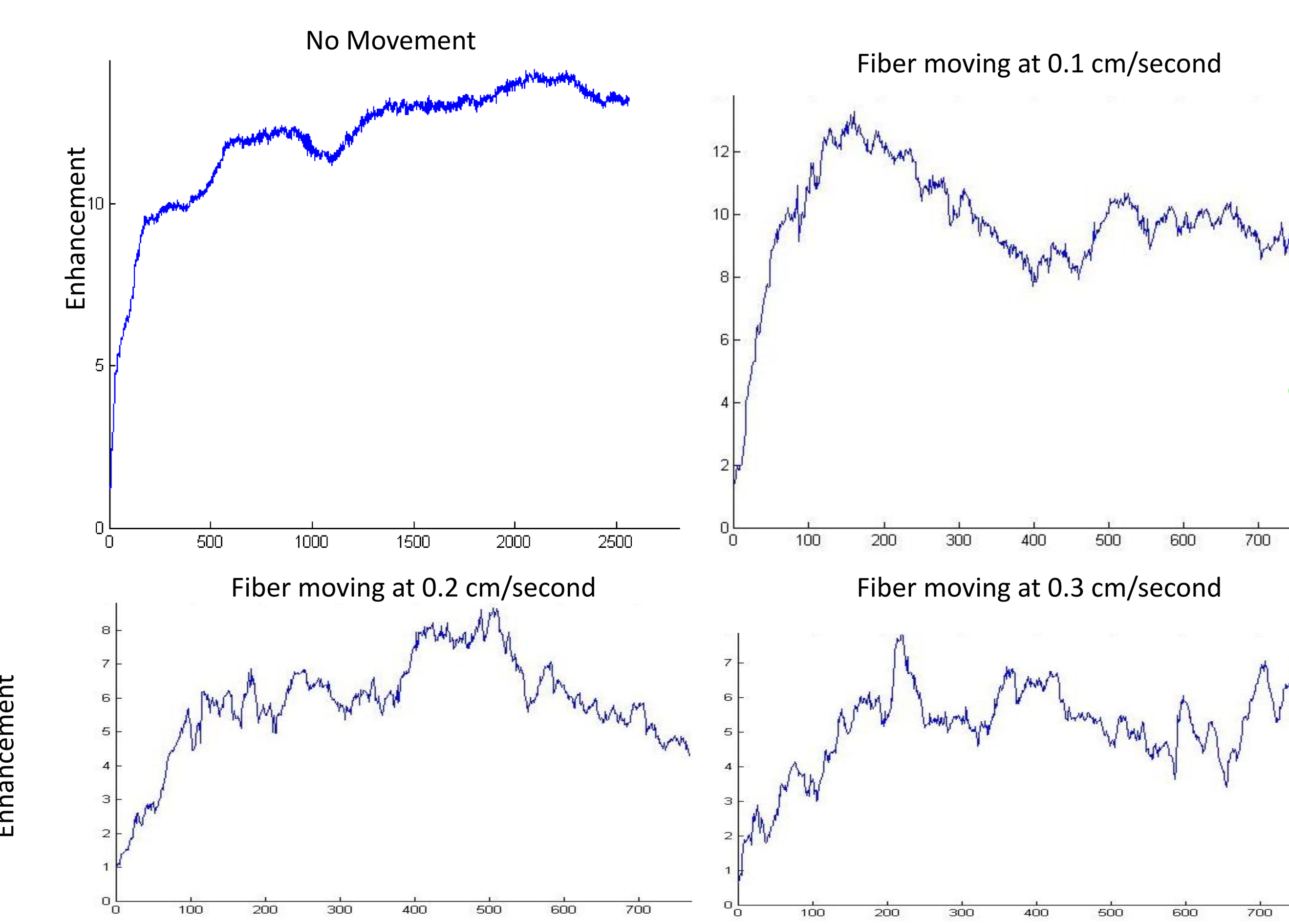




Performance

• When the multi-mode fiber is not being moved, an enhancement of about 15 can be achieved.

• When the fiber is moving, the enhancement depends on the speed of movement. Enhancements between 5 and 10 were achieved while moving the multimode fiber.



Comparison of pre- and post- optimization.

Conclusion

Using two fibers, our design is able to meet the requirements of optimizing the output of a multi-mode fiber without being able to see the output directly. However, using two fibers is not the best solution for some applications. For example, a doctor might want to send these fibers inside a patient. In that case, two fibers would be thicker – and more uncomfortable – than one. The best solution to the problem would be to optimize the output of the multi-mode fiber by looking at the reflected light through the same fiber. More tests would be needed to see if that alternate solution could meet our requirements.

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