Fiber Coupling Project Proposal

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1 Introduction

Fiber coupling is the problem of arranging mirrors to send light from a laser into a fiber optic cable with minimal power loss. [1] [2] Currently, this is mostly done by hand in an annoying and time consuming process. Recently, Andreww Lennman, an undergraduate student working for Professor Boris Braverman, developed a mirror mount that allows the position of the mirrors to be controlled by a computer. This opens the door to automatically optimizing the mirrors, but an algorithm is required which we will develop in this project. This type of optimization has been investigated in the past, such as in [2], but there are still many algorithms to test.

2 Project Goal

Our objective is to optimize the positions of mirrors mechanical system on an optical table system to produce the highest power transfer from a laser through an fiber optic cable.

3 Timeline

We will begin by writing the math and code for the initial version of the model. We should have a base model that we can start testing on the week of October 20th; we expect to have multiple stages of iterative testing where we update the code as required. We aspire to finish testing in a week, but are leaving ourselves some buffer room in the inevitability that we need more time. We will then spend the rest of the time writing the report.

Project start	Math and code complete	Iterative Testing	Report Complete
October 3rd	October 20th	Week of October 20th	November 30th

4 Technical Background

Our system consists of two mirrors channelling light from the a test setup into a multi-mode fiber optic cable, as shown in figure 1. We will first mathematically model the fiber coupling system to determine what general properties, such as convexity or relative peak size, the system has, and then use that information to design various optimization algorithms. Finally, we will test those algorithms to find the one that has the best convergence.

We have investigated a number of optimization methods and believe that these three are the most likely to be successful.

4.1 Method 1: Gradient descent

Gradient descent is an algorithm where by repeatedly moving in the direction of the gradient, a local extreme will eventually be reached. [3]

To calculate the gradient, we will move each degree of freedom a small amount, and measuring the change in power transfer, to approximate the partial derivative for that degree of freedom.

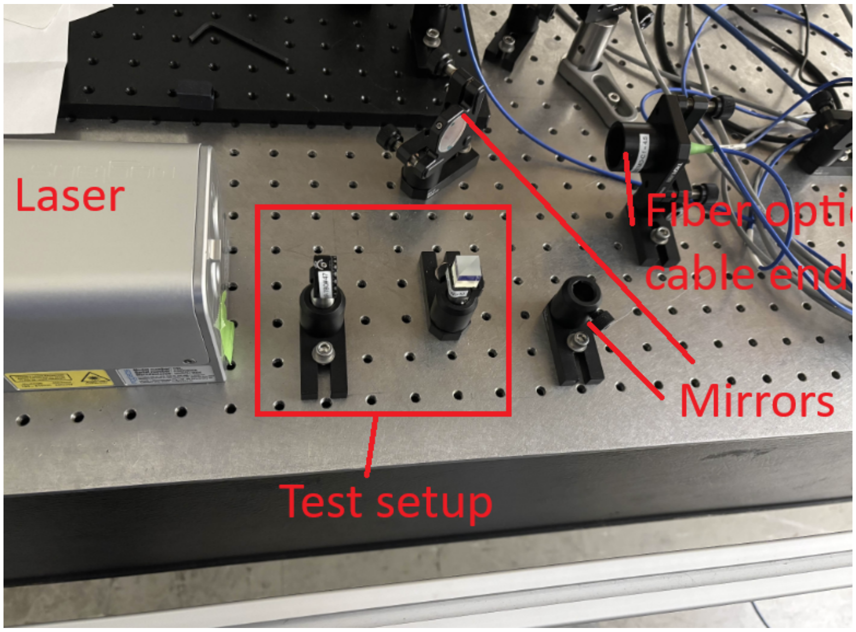

Figure 1: The current lab setup on an optical table

4.2 Method 2: Newton's Method

Newton's method is an algorithm to determine the zeros of a function. For the optimization a function, it can be used to locate the zeros of the derivative of the function, which correspond to the local minima or maxima. The main idea is to repeatedly find better guesses for the root of a function by the process $x_{n+1} = x_n - \frac{f(x)}{f'(x)}$ [4].

We would repeatedly find the root of the partial derivative of each degree of freedom until all partial derivatives are zero, approximating both the first and second partial derivative by moving the mirror a small amount. This process requires fewer steps then gradient descent, but it may be difficult to approximate the second derivative.

4.3 Method 3: Random sampling

Random sampling works by randomly sampling points around the current highest power point. If another higher power point is found, the process is repeated around that point. The benefit of this method is that it does not require finding the gradient or higher derivatives. [5] This makes random sampling more resistant to noise. However, the random nature means that it will likely take a significant amount of time to converge.

4.4 Combinations

We will also investigate combinations of the above methods. For example gradient descent for speed followed by random sampling once the gradient is too small to reliably measure. Additionally, all of the methods can fail by getting trapped in local maxima that are not the global maxima, so we will implement some method of detecting when this happens based of the results of our theoretical modelling of the system.

5 Experimental testing

We will test the various algorithms on the set up. Using the controllable mirror mounts, we will run the algorithms to determine the optimal positions for maximum power and convergence speed. We will be testing iteratively with code updates to improve our algorithms, and eventually select the most promising algorithms, meaning that our testing will run over multiple days.

References

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