Preparation of Single Mode Optical Fibers for Application in 3D Interferometry

Applicant: XXXX

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Faculty Member: XXXXX

Department: Physics

Statement of problem/topic of the research or creative work:

My UROP proposal objective is to develop the capability to properly create single mode optic fiber with properly formed ends that will be useful in 3D Interferometry measurements. I will be working under the supervision of Professor XXXXX of the Department of Physics and Astronomy. Interferometry is a process in which a laser beam is split into two separate light paths. The beams are then brought together again with a beam-splitter, which allows the two beams to interfere on a photo-detector. If the path length difference of the two separate paths is the same or equal to the integer number of wavelengths, they will interfere constructively, producing a larger detected power. (4) If the beam paths are different by half of the light wavelength (or an integer number of half wavelengths), then the detected power is small. By this method, the power in the detector rises and falls each time the path length difference changes by the wavelength. Since the wavelength of the laser light is known with high accuracy, distance changes can be measured very accurately, even down to 1 nanometer. A "fringe" is the distance corresponding to a change in path length of one wavelength or cycle of constructive and destructive interference. (3) In the experiments proposed in XXXXX's lab, this method will be used to detect the position of a moving object in real time, by adding up all the fringes (cycles) that have been detected, and calculating the total distance the object has moved compared to a reference position.

The most commonly used interferometer type is called a "Michelson Interferometer". (9) It uses mirrors and a single beam of light. We will be incorporating the use of fiber optics and we will manipulate them to create several light beams that interfere with each other. Currently 1D laser interferometers are being utilized to measure coordinates in a single direction, or by combining linear measurements, 3D measurements can be made. This type of technology is used in the automotive industry in which computer controlled milling machines (CNC) are programmed to cut metal pieces in 3D shapes. 3D interferometry could lead to the circumvention of 1D and 2D measurements. It instead will directly measure 3D motion. Currently, the Williams lab is focusing on creating a new methodology for direct 3D measurements, allowing for more precise and quicker results in creating high precision products.

Research Background:

The first interferometer was created by Albert Michelson in the late 19th century. Interferometry is used in physics and engineering. Its initial use was to investigate a substance called Luminiferious Aether. (9) It has now been developed to detect light, measure wavelengths and distance. (3) There have been several different models that have been created such as the Mach-Zehnder Interferometer that combines two separate beams rather than just splitting one beam and then redirecting the two towards each other. Another widely known one is the Sagnac Interferometer, in which one light source is reflected on several mirrors in a ring path that allows for the measurement of rotational motion, for example the Earth revolving around its axis. The properties of light that have been discovered and used in interferometry in order to measure many difficult processes with great precision and accuracy. (6)

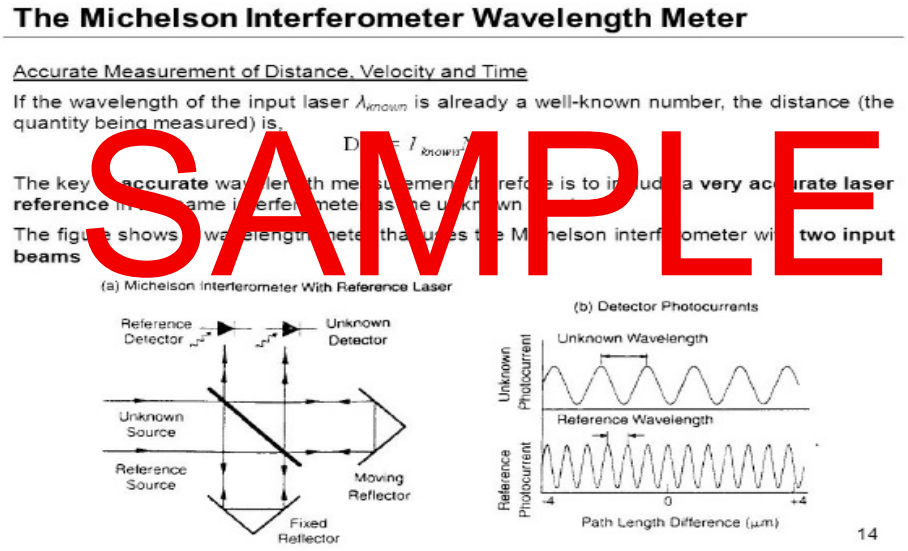

Figure 1: Explanation and example of how the Michelson Interferometer works (3)

Currently interferometry and the utilization of fiber optics has been of great interest. The discovery in 1870 by John Tyndall that light could reflect internally and follow a specific path allowed for further development of how light could be trapped in optical fibers. Actual fibers where not made until the 1950's. In 1957, optic fibers were made from glass but still not sophisticated enough as they were unable to send the light signal over large distances. The discovery of lasers in 1960 allowed for further development of fiber optics based on their ability to send intense laser light sources. (1) Now fiber optic technology has changed the face of the

world. From commercial use in internet speed to military in improving tactical systems. (8) 3D interferometry could potentially be used in the future for programmed technology to process light signals and create machines capable of instant 3D motion.

Proposed Research:

Specific activities to be undertaken and a timeline allotted for each activity:

<u>Activity 1: Developing a methodology to polish the ends of optical fibers and testing them</u>

For the beginning process, I will be using fiber optic tools to create high polished optic fiber ends. This is necessary for the 3D fiber optic interferometer. The setup requires careful preparation and the connection of optical fibers to fitted tubes, called ferrules. The most important steps are making sure that there is an equal distribution of epoxy in the ferrule and making sure there is additional epoxy on the end of the ferrule in order to have a buffer region during the next process of polishing the fiber in the ferrule tip. (2) Use of 5 μm, 3 μm, 1 μm, .3 μm, and .1 μm polishing films will be used for the polishing of each ferrule/fiber combination. The focus is to make sure that each ferrule/fiber is properly polished, resulting in the extra epoxy polished off, and that the fiber surface is optically even and smooth. I will inspect each fiber using a high magnification optical microscope (Olympus). Once I have perfected the method using sample fibers, I will then move on using the real single mode fibers (125 μm diameter) that will be used for the 3D interferometer. Once I have the methodology developed for fabrication of the ends of the single mode fibers, I will then move on with Professor Williams in testing the fibers and seeing how efficient they are in being able to measure distance.

Secondly, I will focus on how to use the methodology to connectorize single mode fiber ends. Once this has been set up and trials are conducted, I will be able to see whether the fibers are properly fabricated by connecting two fibers together and testing if the transmission of signals is reliable. If the data is considerably sound in displaying the precision and effectiveness in using optical fibers, it will be a significant step towards developing an actual model for a 3D interferometer.

The process of creating a ferrule is shown below:

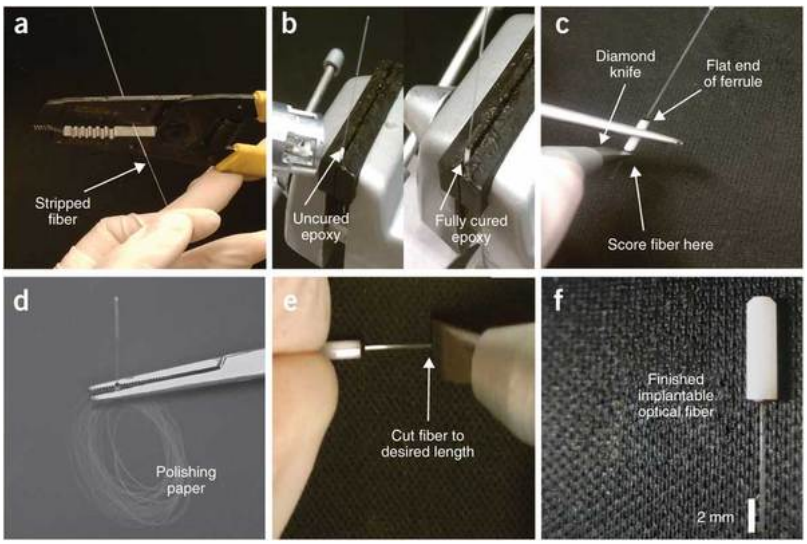

Figure 2: methodology of creating a fiber/ferrule combination (7)

Timeline: October - November 2016

Activity 2: Creation of a rotator to prevent signal loss

Once the fibers have been created and tested for light signal and strength I will move on and start working with a graduate student in building a rotator for pointing the fiber in a particular direction, which is necessary for the operation of the 3D interferometer. I will be helping to create a rotator that will direct light beams from two fibers so that they are directed toward one another not matter how they are angled from each other. This will help in the performance of 3D measurements.

Timeline: December – January 2016

Activity 3: Calibrate the 3D Interferometer and compare to a standard reference

After the creation of a rotation methodology, I will focus on helping another graduate student to calibrate the optic fiber interferometer to make sure that it corresponds with already proven and standard techniques. This will validate its performance. It will potentially be like a 3D version of a Michelson interferometer, the first one discovered and most widely used. I will help with the calibration measurements. If there is a big difference between the 3D interferometer measurements and standard calibration methods, a cause will be looked for. Such differences could be caused by light divergence or an environmental effect that could cause the loss of or weakening of the optical signal, such as the reflection of light waves off surroundings objects or

walls. If this happens the crucial step then will be to figure out how to prevent these effects from occurring without hindering the optical fiber interferometer potential.

Timeline: January – February 2017

Activity 4: Create a lens that will not allow the light to diverge called columniation

It may be necessary to connect a specific lens directly in front of the optical fiber end that will cause the light beam not to diverge (called collimation), so that the bean radius is not changed when increasing the distance of the two fibers away from each other. This is essential in keeping the beam strength consistent and prevent signal loss. I will develop the lens housing needed to perform the light collimation. It will be fabricated so that it can directly couple with a connectorized optical fiber (developed in activity 1). (5)

Timeline: February – March 2017

Relationship of the proposed work to the expertise of the faculty mentor:

My mentor and supervisor will be Professor XXXXX in the Physics Department. XXXXX had done research in the specific field of electronic and physical properties of nanometer devices and materials. Professor XXXXX has 15 issued patents. One of his most funded proposals was entitled "Single-Spin Tunneling Force Microscopy for characterization of paramagnetic defects in electronic materials." He has given over 50 invited talks and a multitude of funded grants and contracts over the course of his time at the University of Utah. He is a Fellow of the American Physical Society. His primary work consists of figuring out how to detect single electron spins in order to understand defects in spintronic materials and potentially create quantum spin devices. Recently, he has invented a innovative 3D interferometer concept which has been funded by the Technology Venture Commercialization office and for which 3 patents have been submitted. The 3D interferometer will likely be commercialized in the next year, after it is fully demonstrated. (10)

My main role is helping him create usable optic fibers that will be used in measuring distance in 3 dimension. My research project can be applied to several areas of physics and technology which makes his mentoring very valuable in aiding me to learn research skills and understand the new technology. I have already learned while working with him the value of independent

thinking especially while starting off with a beginning project for something that could eventually expand into many different areas of research. He aides me whenever I have questions but does not hinder my desire to try things and come up with my own ideas in solving problems that occur. This has had a great impact on me because I really feel like a researcher, not just an assistant. While working with him we discuss my progress every couple of hours and eventually as I am able to take control of the project we will discuss my progress once per week.

Relationship of the proposed work to the student's future goals:

Even though the research is mainly about Physics and technological advancements, it also has some connections with my majors, Business and Biology, which I would not have initially expected. I decided to work in a physics primarily because I have already had a Biology and Chemistry internship at the University of Utah. Through those experiences I was able not only to learn new ideas and products being created for future use in society but also how each science subject actually crosses over into many other areas of life. I wanted to have an interaction with each science and see how even if I am mainly focusing my studies on Biology, I could also utilize concepts, ideas, and technology from other areas of science. I have learned so far that some aspects of biology and chemistry are connected with my current project when dealing with ways to figuring out the use of chemicals, concepts and structures of atoms and wavelengths, and instead of going from macro to micro, I am now learning to see things the other way around in regards to how the transfer of energy can later on create products that will later on impact entire societies. Also Professor XXXXX has a great deal of experience with getting funding and creating patents for his products and inventions. I will be able to learn through this process of actually creating a methodology and then a product how to get investors to not only fund the development of the product but also its commercialization. It will be a real life experience which is unique. That is applicable for me to acquire a dual-major in Biology and Business and how I can use concepts of Business in science-related lab work.

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