Optical force transducer for visualizing cell mechanotransduction in 3D

PROJECT PLAN

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1 Introduction

1.1 Project statement

The project aims to collect preliminary results of a fiber-based optical force transducer that can probe forces as low as nN. One of the applications is to use it as an optical biosensor. The two-semester project will be carried out in two phases:

Phase I (Fall 2017): Model and fabricate the fiber-based force transducer
Phase II (Spring 2018): Character the force transducer and demonstrate its application in cell mechanotransduction

By connecting the nanofiber with cells and making laser going through the nanofiber, we can use a microscope to observe cells' light intensities.

1.2 purpose

Nowadays, sensors play an indispensable role in our daily life. Car, computers and mobile phones have numerous sensors, sensors can be large or small. So we start to thinking, why not design a sensor that can measure cells or even smaller things? It can contribute to the medical field, biological field, zoological field and Ecological field. Eventually, we can use these sensors to effectively measure the Human cells, animal cells and plant's cells, and observe the changes to develop new technology.

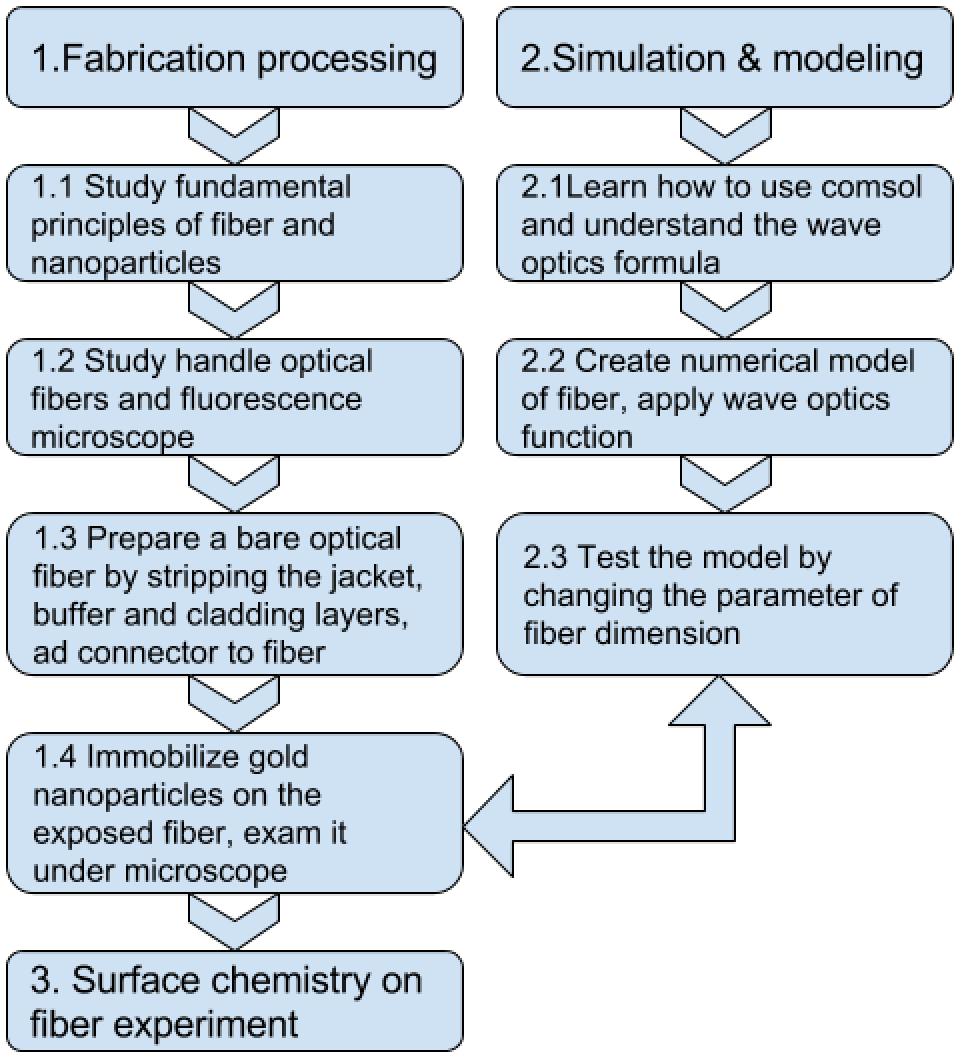
1.3 GOALS

Our goals are distributed into two semesters. In the first semester, we will learn how to handle the optical fiber and choose the best model by creating numerical simulation model. Testing parameters of optical fiber will play an important role in order to prepare the future experiment, in the mean while, we will learn how to use different simulation softwares and optical fiber equipments such as COMSOL, Solidwork equipment, fluorescence microscope, etc. We will try to find the most satisfied size of the fiber after testing the parameters.
After finishing all the parameter tests, we will start immunoassay experiment in the second semester. This means we will open the practical measurement of detecting cancer cells and healthy cells.

2 Deliverables

To meet the goal, the team should handle the optical fiber carefully, striping the out layer without breaking the optical fiber, striping the cladding layer clear enough to operate the following experiment. The surface chemistry of optical fiber will be testing on the attachment of nanoparticles on the fiber to prove whether optical fiber have been handled correctly. At the end of this semester, our team will demonstrate the images of gold nanoparticles adsorbed on the surface of a single mode fiber.

3 Design

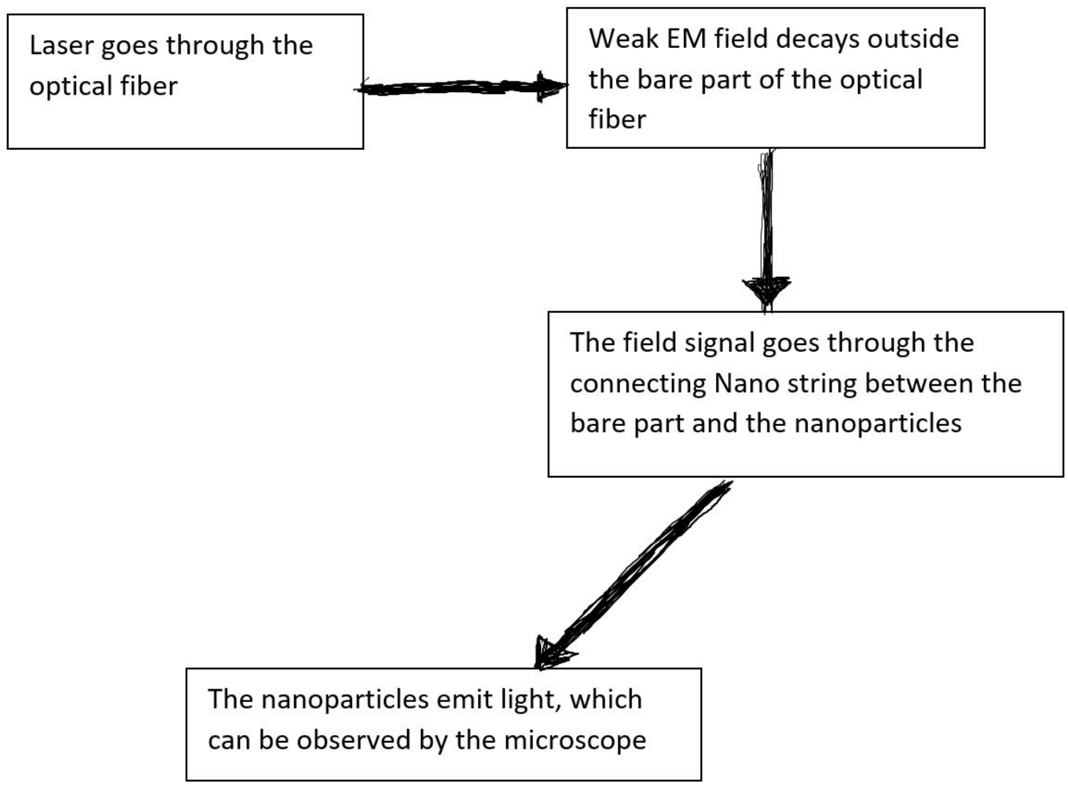


The flowchart shown above is showing the stages of the experiment for the first semester. We will start with fabrication processing of optical fiber, at the same time, we will learn how to use simulation software to create numerical simulation to select the best parameter of optical fiber. After we finished handling the optical fiber, we will work on surface chemistry to attach the nanoparticles on the optical fiber. All the stabilization tool will be made by our teammates using Solidwork.

3.1 Previous work/literature

In the research paper, they found a method to “determine mechanical force as well as its changes with single-particle dark-field spectral microscopy by using single plasmonic nanospring as a mechanical sensor”, it could transfer the force-induced molecular compression which will help our project to accomplish our goal(Xiong, B., Huang, Z., Zou, H., Qiao, C., He, Y., & Yeung, E. S., 2017).

3.2 Proposed System Block diagram



3.3 Assessment of Proposed methods

At the beginning of the project, we will buy the different size of optical fiber, and remove its outer layer and cladding layer to move on the next stage of experiment. Then we will apply surface chemistry which is the PVA-GA Surface chemistry for Amine-terminated materials to attach the nanoparticles. After applying the surface chemistry, we will Capture $-NH_2$ coated AuNPs (gold nanoparticles) and Capture -COOH coated AuNPs (gold nanoparticles). We will practice the process many times until the parameters match with the predicted result. Then the final stage would be the immunoassay test.

3.4 Validation

The experimental results will be compared to the theoretical predictions. We will use fluorescence microscope connected with computer to capture the picture of the nanoparticles on the optical fiber, this will confirm whether the optical fiber was handled correctly in the previous stages of work. At the end of the project, we will do Immunoassay experiment to observe the optical fiber to confirm the result of the project.

4 Project Requirements/Specifications

4.1 FUNCTIONAL

The functional requirement of the project are listed below:

Fiber cleave and cleaning, the fiber should be clean enough to continue the following process.

Surface chemistry experiment to attach the nanoparticles. The nanoparticles should be attached throughout the entire fiber.

Coupling of laser into the single-mode fibers.

Immunoassay development.

4.2 Non-functional

The non-functional requirements of the project is to meet the advisors on time, report any possible issues to the group member in order to find a solution. In the experiment of handling optical fiber, group members should always wear safety goggles and gloves. All the tasks assigned by the advisor in the team meetings should be finished before the deadline.

4.3 Standards

We will follow the lab safety requirement specified by the ISU EH&S department. Since in the experiment group, when optimizing the fiber, members will often handle the flame burner. So following the lsb safety instruction is necessary in the process.

5 Challenges

1. Fiber cleave and cleaning. Fiber needs to be optimized size we need. So how we well-proportioned fiber can be considered as a task in the future experiment.

2. Coupling of laser into the single-mode fibers.
3. Immunoassay development. Antibody identification is an new area for all of group, and we have never access to medical field before. So we need to find more reading material in order to learn knowledge about it.

6 Timeline

6.1 First Semester

Period	Yalun Tang & Quan Wang	Jiameng Li & Qinming Zhang
09/09 - 09/30	• Prepare a bare optical fiber (stripping the jacket, buffer, and cladding layers), add a FC/PC connector to fiber, and polish the fiber tip • Try surface chemistry to attach the gold nanoparticle on the surface of the bare part of the optical fiber	• Finish the modeling of the optical fiber with a nanoparticle in a simulation tool • Design the holder for the optical fiber
10/01 - 10/31	• Immobilize gold nanoparticles (40 nm, 60 nm, 100 nm) on the exposed	• Optimize the sensor parameters: fiber

	fiber, exam fiber under optical microscope and SEM • Characterize light scattering by the nanoparticles	diameter, nanoparticle size, DNA/PEG, and operation wavelength.
11/01 - 11/30	• Functionalize the fiber core (silica) using PEG or DNA. Test the gold nanoparticles immobilization process.	• Characterize the Figure of Merits (force sensitivity) and noise sources
12/01 - 12/14	Final presentation and Final report	

6.2 Second Semester

The second semester will mainly focus on the immunoassay test by using the optical fiber we refined. The goal is to character the force transducer and demonstrate its application in cell mechanotransduction.

7 Conclusions

In the project, we will learn how to handle the optical fiber, using the surface chemistry to develop the optical fiber, and attach the nanoparticles onto the optical fiber. Our goal is to model and fabricate the fiber-based force transducer and Character the force transducer in order to demonstrate its application in cell mechanotransduction. We will learn how to use new equipments like fluorescence microscope and simulation software and make equipment using Solidwork.

8 References

Xiong, B., Huang, Z., Zou, H., Qiao, C., He, Y., & Yeung, E. S. (2017). Single Plasmonic Nanosprings for Visualizing Reactive-Oxygen-Species-Activated Localized Mechanical Force Transduction in Live Cells. ACS Nano, 11(1), 541-548. doi:10.1021/acsnano.6b06591

Huang, Q., Lee, J., Arce, F. T., Yoon, I., Angsantikul, P., Liu, J., . . . Sirbuly, D. J. (2017). Nanofibre optic force transducers with sub-piconewton resolution via near-field plasmon–dielectric interactions. Nature Photonics, 11(6), 352-355. doi:10.1038/nphoton.2017.74