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Fiber-Optic Pathogen Detection based on Dynamic Light Scattering

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RCEU 2023 Project Proposal

Project Title

Fiber-Optic Pathogen Detection based on Dynamic Light Scattering

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I. Project Description

Pathogen detection is critical for ensuring food safety and protecting public health. Conventional methods for detecting foodborne pathogens are based on culturing the microorganisms on agar plates followed by standard biochemical identification. These methods are laborious and time-consuming (i.e., 3~10 days). Since the majority of the samples are typically negative, it is rational to develop and employ monitoring technologies that may provide "early warnings" so as to direct efforts to further lengthy analysis on "suspicious" samples. The key attributes of such technology should be simple, low-cost, and real-time.

Optical methods have proven to be particularly attractive in this regard owing to their potential for rapid, non-destructive, online real-time measurement that requires minimal sample preparation. Dynamic light scattering (DLS), in particular, is based on optical scattering, which describes the change of light propagation when encountering spatial non-uniformities. Solid particles, oil droplets, or bacterial cells present in the liquid can scatter the incident light and cause a redistribution of the optical power along different directions. Probing such alteration of energy distribution would lend us information about these impurities.

The objective of this RCEU project is to set up a preliminary experiment and demonstrate the concept of fiber-optic DLS, with a special focus on post-measurement data processing. The project falls under the umbrella of a long-term collaborative effort between Dr. Duan and Dr. Tingting Wu (Civil and Environmental Engineering), which aims to improve the food safety of agricultural produce by using distributed optical fiber sensors (pending support from USDA).

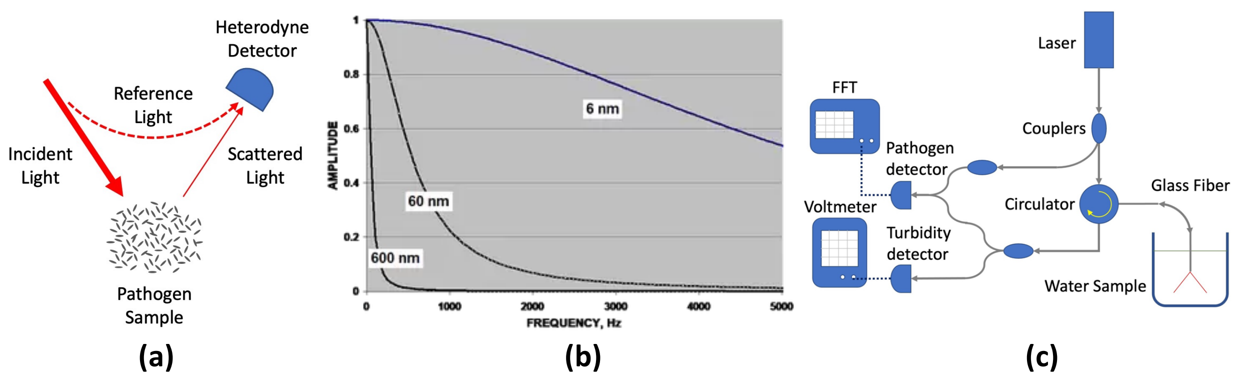

Fig. 1. (a) The basic concept of DLS; **(b)** The DLS signal linewidth is correlated to the sizes of the scattering particles; **(c)** A layout of the proposed sensing system.

Fig. 1(a) illustrates the concept of DLS. Fig. 1(b) shows a typical post-processing DLS signal, which is directly correlated to the size of the scattering particles. Since pathogens such as *E-coli* cells have well-defined sizes, the DLS signals can potentially provide early warnings about the presence of these pathogens. **Obtaining signals such as Fig. 1(b) is the immediate goal of this RCEU project.** To accomplish this goal, students need to set up a test system as shown in Fig. 1(c). They will also need to mathematically process the experimental data and analyze it against the known properties of the scattering samples.

II. Student Duties, Contributions, and Outcomes

a. Specific Student Duties

In this RCEU project, students will first set up a fiber-optic testing system (see Fig. 1(c)). Then, they will learn how to operate the optical testing instruments such as diode lasers, photodetectors and oscilloscopes so that they can independently perform the tests. Once experimental data is taken, they will learn basic data processing techniques such as denoise and FFT and use them to analyze the data. Under the guidance of the mentor, they will evaluate the processed data against the known properties of the sample and come up with strategies for optimization. This may take multiple iterations until satisfactory conclusions can be drawn.

b. Tangible Contributions by the Student to the Project *(10% of Review)*

As mentioned earlier, fiber-optic pathogen detection is the theme of a long-term collaboration between Dr. Duan and Dr. Wu, with significant implications in food safety control. **This RCEU project is the *first step* within this effort to explore the DLS technique.** It will lay down the foundation for further exploration in this field and offer valuable knowledge about the advantage and disadvantage of this technique.

c. Specific Outcomes Provided by the Project to the Student *(30% of Review)*

This RCEU project combines hands-on experiments with numerical analysis and would offer students a *complete* experience in scientific research. Experimentally, students will be exposed to basic optical research *instruments* (e.g., lasers, photodetectors, oscilloscopes, optical fibers, etc.) and *methods* (e.g., optical scattering, interferometry, heterodyne, etc.). Numerically, students will learn common data processing techniques such as fast Fourier transform (FFT), denoise, and numerical filter. The activities will allow students to gain valuable R&D experience they wouldn't acquire through regular classes or labs.

III. Student Selection Criteria

Students qualified for this project must either have taken the basic undergraduate optical courses such as OPT 341 and 342 or have prior research experience in related fields and are familiar with operating lasers.

IV. Project Mentorship *(30% of Review)*

Dr. Duan, the mentor of this project, will guide the students *step by step* throughout the process. He will personally train the students how to operate the research instruments, teach them the necessary numerical techniques, examine their research data, and proofread their research reports. He will provide his mentorship through weekly discussion sessions as well as regular lab visits.