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Development of an auto-tuned filter for low-frequency Raman spectroscopy

4th-Year Engineering Project 2024-2025

Motivation and background

Low frequency Raman (LFR) spectroscopy, a technique that probes intermolecular vibrations, finds various applications in biomedical and pharmaceutical research [1]. Examples include the characterization of drug solubilization or crystallization, intermolecular interactions between drugs and receptors, and polymorphism in pharmaceutical tablets. These studies can play a fundamental role in optimizing drug performance in various conditions and ultimately improve patient outcomes. LFR measurements involve irradiating the sample under study with a single frequency laser, collecting the scattered light, and measuring its spectral content with a spectrometer. While most photons are scattered elastically (i.e. they have the same wavelength as the incident laser), a very small fraction of the photons are scattered inelastically (i.e. they are shifted in wavelength). The latter, the Raman peaks, are the signals of interest. The wavelength shifts involved in LFR are very small; the Raman peaks can be within 1 nm of the excitation wavelength. A major challenge of this technique is thus to detect extremely small Raman peaks in the immediate spectral vicinity of the elastic scattering peak, which is typically well over a million times larger. To address this issue, the elastic scattering peak must be suppressed with an ultranarrow notch filter. Existing approaches such as volume holographic grating filters [2] have limitations with respect to how close to the pump we can measure. An alternative approach currently being investigated in the APClab consists of using a fiber Bragg grating (FBG) between the collection optics and the spectrometer such as to reflect the elastically scattered light while transmitting the LFR signals. Although preliminary results are promising, much research remains to be done. In particular, given variations in the FBG manufacturing process and an unavoidable degree of laser fluctuations, a central aspect of the proposed technology is to provide auto-tunability by implementing strain-tuning and a feedback loop.

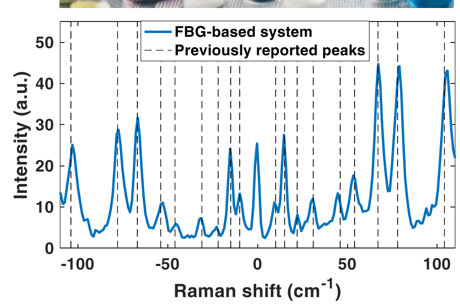
This Capstone project would be at the forefront of this new research avenue. If successful, the technologies being developed would be conducive to making LFR a wider spread technique in biomedical laboratories and supporting deployments outside research laboratories.

Project description

- Developing and demonstrating an auto-tuned ultranarrow notch filter for LFR based on a strain-tuned FBG.

Project milestones

- Determining the target specs
- Designing the optical, mechanical, and electronic systems
- Programming a feedback loop and overall control system
- Assembling, testing, and debugging the prototype
- Doing a proof-of-concept LFR pharmaceutical measurement



Required interests and skills

- Optics and sensing
- Hardware design and testing
- Data analysis and programming

[1] Bērziņš, Kārlis, Sara J. Fraser-Miller, and Keith C. Gordon. "Recent advances in low-frequency Raman spectroscopy for pharmaceutical applications." International Journal of Pharmaceutics 592 (2021): 120034.

[2] Carriere, James T., and Frank Havermeyer. "Ultra-low frequency Stokes and anti-Stokes Raman spectroscopy at 785nm with volume holographic grating filters." Biomedical Vibrational Spectroscopy V: Advances in Research and Industry. Vol. 8219. SPIE, 2012.