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Mid-infrared Spectroscopic Imaging for disease diagnosis

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Abstract

Vibrational spectroscopy enables biochemical identification in tissue sections. Biomedical samples such as cancerous tissue are chemically heterogeneous, and bulk spectroscopy is often inadequate to ascertain the disease state in these samples. Mid-infrared spectroscopic imaging (MIRSI) is a class of technologies that combines the molecular specificity of vibrational spectroscopy with the spatial detail provided by microscopy. Traditionally, MIRSI has been performed using Fourier transform infrared (FT-IR) imaging instrumentation. The combination of machine learning and MIRSI has facilitated the identification of tissue sub-type and cancer grades in a label-free and quantitative manner. Innovations in Quantum Cascade Lasers (QCLs) have revolutionized MIRSI, and new techniques such as discrete frequency infrared (DFIR) and photothermal IR imaging have emerged recently. These technologies are more flexible, provide higher resolution, and have essential advantages over FT-IR. We will present a comparative analysis of these MIRSI technologies in the context of biomedical imaging and discuss the benefits of each technology.

Ovarian cancer is one of the deadliest cancers among women in the U.S., with over 22,000 women diagnosed with the disease every year. Early diagnosis of the disease is essential for improving survival. To automate the process of disease diagnosis, we perform MIRSI imaging followed by machine learning. However, this requires data of higher quality and resolution. We use the super-resolution capabilities of optical photothermal infrared imaging (O-PTIR) to analyze ovarian tissue and perform tissue subtype segmentation. Bone disorders such as osteosclerosis have spectroscopic signatures identified using MIRSI. We present imaging data and results of high-resolution MIRSI of bone samples. We also present the first study that uses polarization MIRSI to demonstrate the ability to spectroscopically identify thin collagen fibers (≈1μm diameter) and their orientations, which is critical for accurate grading of human bone marrow fibrosis.