Optical photothermal infrared spectroscopy

Prater CB[(1)*], Kansiz M[(1)], Kjoller K[(1)]

(1) Photothermal Spectroscopy Corp, Santa Barbara CA USA

*Corresponding author's email: craig@photothermal.com

Background – Optical Photothermal Infrared (O-PTIR) spectroscopy[1-6][7] is an emerging yet rapidly growing technique for performing infrared chemical analysis with >10X better spatial resolution than conventional infrared spectroscopy. Infrared spectroscopy is arguably one of the most widely used techniques for performing chemical characterization of samples, but fundamental limits due to optical diffraction constrains the spatial resolution of conventional Fourier Transform Infrared (FT-IR) spectroscopy to the range of 3-30 µm, significantly limiting its applicability for many microscopic applications. The O-PTIR technique leverages a photothermal detection technique using a tightly focused visible probe beam to achieve spatial resolution an order of magnitude better than the limits set by optical diffraction at infrared wavelengths.

Methods – Fig. 1 shows an illustration of the O-PTIR technique. A sample is first illuminated by a beam of radiation from a tuneable infrared laser source. When the IR laser is tuned to a wavelength corresponding to a molecular bond vibration in the sample, the sample will absorb IR light and heat up locally, creating a photothermal modulation in the sample for each IR light pulse. This photothermal modulation is detected with a visible probe beam that is focused to a much smaller spot than the IR beam, thus achieving higher spatial resolution. Infrared absorption spectra can be obtained by measuring the photothermal modulation amplitude as a function of IR wavelength and infrared chemical images can be obtained by measuring the photothermal modulation for one or more IR absorption bands overarangeofdifferentpositionsonthesample. ThevisibleprobebeamusedtomeasureIRabsorption can also be used to perform simultaneous co-located Raman spectroscopy, thus enabling multimodal chemical analysis using two complementary vibrational spectroscopy techniques.

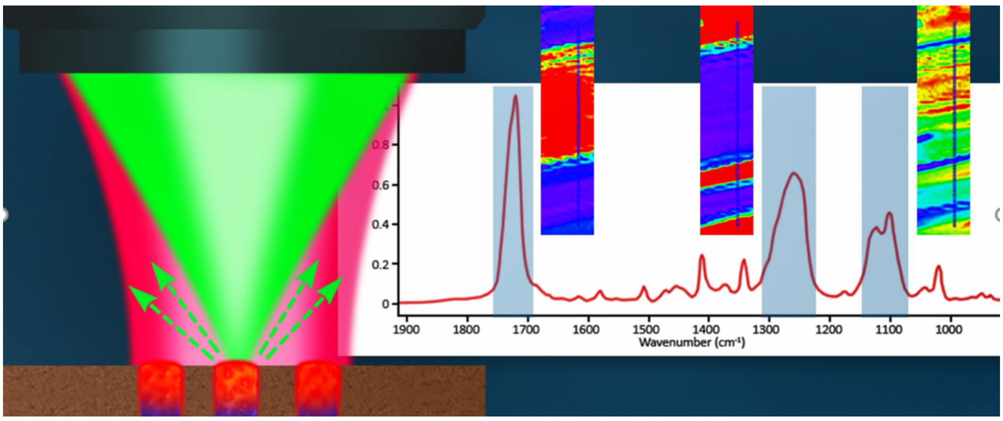

Fig. 1. Optical photothermal infrared (O-PTIR) is an optical microscope based chemical analysis technique where a tightly focused visible probe beam (green) is used to measure photothermal modulation in a sample due to absorption of infrared (IR) radiation. Infrared spectra and chemical images can be obtained with sub-500 nm spatial resolution.

This contribution will review the underlying technology of the O-PTIR approach and discuss various applications including spectroscopic analysis and chemical imaging of in application areas including life sciences, microplastics/microparticulates, polymer sciences, defect identification, and cultural heritage.

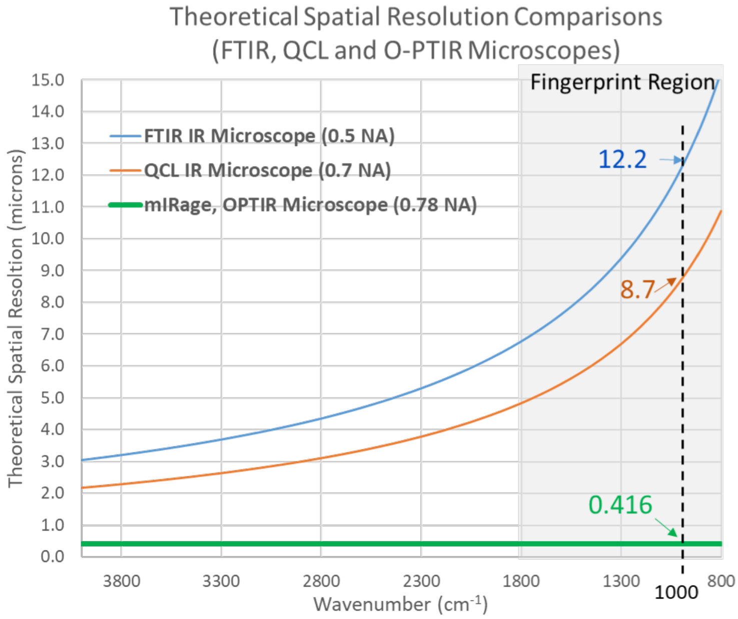

Fig. 2. Comparison of spatial resolution of O-PTIR technique versus conventional IR microscopes based on Fourier Transform Infrared (FT-IR) and quantum cascade laser (QCL) microscopes. The O-PTIR technique achieves up to 30X better spatial resolution than competing techniques and with constant spatial resolution versus wavelength.

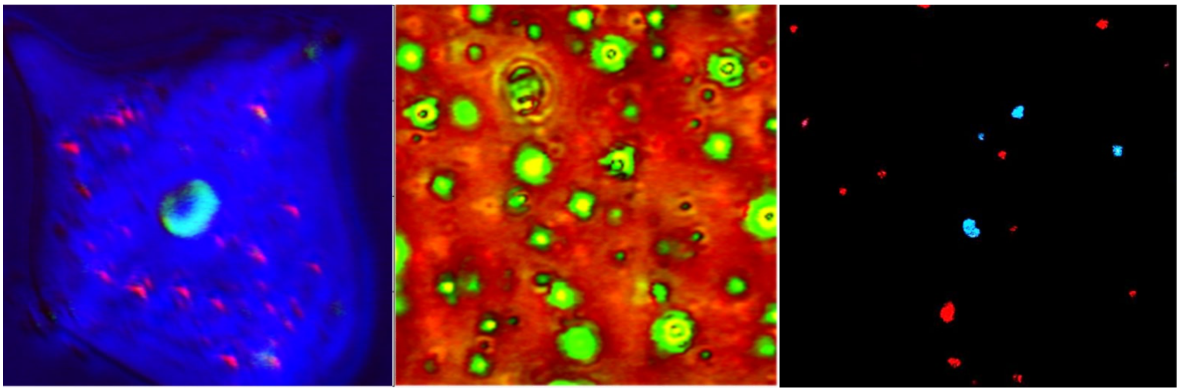

Fig. 3. Example O-PTIR chemical images of human cell (left), polymer blend (center), and microparticles (right).

References

[1] D. Zhang et al., Depth-resolved mid-infrared photothermal imaging of living cells and organisms with submicrometer spatial resolution. Science Advances 2:9 (2016) p. e1600521.

[2] R. Furstenberg et al. U.S. Patent No. US9091594 B2 (2015).

[3] Z. Li, M. Kuno, G. Hartland, Super-resolution Mid-infrared Imaging using Photothermal Microscopy. in Conference on Lasers and Electro-Optics (2016) San Jose, California: Optical Society of America.

[4] M. Kansiz et al., Optical Photothermal Infrared Microspectroscopy with Simultaneous Raman – A New Non-Contact Failure Analysis Technique for Identification of <10 µm Organic Contamination in the Hard Drive and other Electronics Industries. Microscopy Today 28:3 (2020) 26-36.

[5] M. Kansiz et al., Optical Photothermal Infrared Microspectroscopy Discriminates for the First Time Different Types of Lung Cells on Histopathology Glass Slides. Analytical Chemistry, 93:32 (2021) 11081-11088.

[6] Y. Bai, J. Yin, J.-X. Cheng, Bond-selective imaging by optically sensing the mid-infrared photothermal effect. Science Advances, 7:20 (2021) p. eabg1559.

[7] For an extensive list of O-PTIR references go to www.photothermal.com/publications.