New approach captures detailed mid-infrared images for medical diagnostics

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Researchers have developed a unique high-resolution imaging method that can capture mid-infrared spectral images of fast events or dynamic processes that take place on the order of milliseconds. This spectral range is used for many applications because it can reveal the detailed chemical composition of a sample.

"This novel approach could one day be used to prescreen medical biopsies to identify the ones that need closer examination," said Peter Tidemand-Lichtenberg, a member of the research team from DTU Fotonik in Denmark. "It could be used to look for the chemical signatures of cancer and other diseases in ways that would increase the accuracy and speed of diagnoses."

A multi-institutional group of researchers describe the new imaging approach in *Optica*, The Optical Society's (OSA) journal for high-impact research. They also demonstrate some of the technique's potential applications by imaging a gas flow and distinguishing cancerous and normal samples of esophageal tissue.

"Although mid-infrared spectroscopy is recognized as a powerful tool for chemical analysis, its applicability has been hampered by a lack of affordable light sources and sensitive detectors," said Tidemand-Lichtenberg. "To overcome this barrier, we used an approach that translates information from the mid-infrared region, where the chemical signatures are most distinct, to the near-infrared, where today's camera technology is most mature and sensitive."

Practical mid-infrared spectroscopy

The researchers drew on a process known as nonlinear frequency conversion in which energy is added to a photon to change its wavelength, and hence its color. Although frequency conversion, or upconversion, is often used to change the wavelength of a laser's output, the researchers from DTU Fotonik developed a detection system that could shift an entire mid-IR image into the near-infrared wavelength range while preserving all the spatial information.

The system incorporates a new mid-infrared light source developed by collaborators from The Institute of Photonic Sciences (ICFO). This single-wavelength light source can be tuned to different wavelengths and it also uses frequency conversion to generate the mid-infrared light. In fact, the researchers used the same pulsed near-infrared laser for two things: to generate the tunable mid-IR light and to achieve the image upconversion.

"This approach yields high peak power pulses in perfect synchronism, eliminating the need for sophisticated temporal control of the pulses, leading to images with a good signal-to-noise ratio," explained Tidemand-Lichtenberg. "In addition, our optical setup is designed in a way that requires very little post-processing after the images are acquired."

Imaging fast events and complex samples

The researchers demonstrated the imaging speed of their new mid-infrared upconversion spectroscopy approach by tuning the illumination laser to match the peak absorption of a gas flow and acquiring a video with 40 images per second.

They also conducted a pilot study, headed by the team members from

Exeter University, in which the system was used to evaluate cancerous and healthy esophageal tissue samples. They found that morphology and spectral classification using their system matched well with the standard stained histopathology images.

"Our upconversion imaging approach is generic and constitutes a major simplification in realizing video-frame-rate, mid-infrared monochromatic imaging," said Tidemand-Lichtenberg.

"The spectral information provided by this technique could be combined with machine learning to enable faster, and possibly more objective, medical diagnostics based on chemical signatures without the need for staining."

More information: S. Junaid et al. Video-rate, mid-infrared hyperspectral upconversion imaging, *Optica* (2019). DOI: 10.1364/OPTICA.6.000702 , www.osapublishing.org/optica/a …m?uri=optica-6-6-702

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