



Infrared Frequency Comb Measures Biological Signatures

An international team of researchers from NIST, ICFO, University of Campinas and BAE Systems has demonstrated a compact frequency comb device that measures the entire infrared band of light at video rates to detect biological, chemical, and physical properties of matter

June 07, 2019

Optical frequency combs measure exact frequencies, or colors, of light. Various comb designs have enabled the development of next-generation atomic clocks and show promise for environmental applications such as detecting methane leaks. Biological applications have been slower to develop, in part because it has been hard to directly generate and measure the relevant infrared light.

Mid-infrared light is an especially useful research probe because molecules usually rotate and vibrate at these frequencies. Until now however, it's been difficult to probe this region due to a lack of broadband or tunable light sources and efficient detectors such as those

available for visible and near-infrared light, the part of the infrared spectrum closest to visible light.

In a recent study published in *Science Advances*, researchers at the National Institute of Standards and Technology (NIST) and collaborators from ICFO, the University of Campinas and BAE Systems have demonstrated a compact frequency comb apparatus that rapidly measures the entire infrared band of light to detect biological, chemical, and physical properties of matter.

Focusing on biological applications, the team used the new apparatus to detect fingerprints of NIST's monoclonal antibody reference material, a protein made of more than 20,000 atoms that is used by the biopharmaceutical industry to ensure the quality of treatments. For this, they used simple fiber lasers that generate light spanning the entire range used to identify molecules—that is, mid-infrared to far-infrared wavelengths of 2–27 micrometers (frequencies of approximately 10–100 terahertz). The amounts of light absorbed at specific frequencies provide a unique signature of a molecule. The new system is innovative in detecting the electric fields of the absorbed light using photodiodes (light detectors) operating in the near-infrared range.

In their experiment, the researchers were able to detect signature vibrations of three bands of amides (chemical groups containing carbon, oxygen, nitrogen, and hydrogen) in the monoclonal antibody reference material. Amide bands in proteins are used to determine the folding, unfolding, and aggregating mechanisms. Specific features of the detected bands indicated that the protein has a sheet structure, agreeing with previous studies. Sheets connect chemical groups in a flat arrangement.

Potential uses for this device may include the detection of interactions between infrared light and condensed matter for quantum computing approaches that store data in molecular vibrations or rotations. Likewise, potentially when combined with novel imaging techniques, the tabletop system could obtain nanometer-scale images of samples that currently require the use of a much larger synchrotron facility.

The results of the study have proven that, aside from using the setup for biological applications, it could also be used for applications regarding disease diagnosis, identification of chemicals used in manufacturing, or even biomass energy harvesting.

ICREA Prof. at ICFO Dr. Jens Biegert comments, "I am extremely excited at this development since we could overcome one of the biggest hurdles for mid-IR science, which is the efficient detection of the radiation. We now have an all-fiber mid-IR light source which

h can measure molecular fingerprints through electric-field sampling without any moving parts at video rates.



NIST's tabletop frequency comb apparatus (foreground) can quickly identify molecules based on their absorption of infrared light. Credit: NIST