First chip-scale broadband optical system that can sense molecules in the mid-IR

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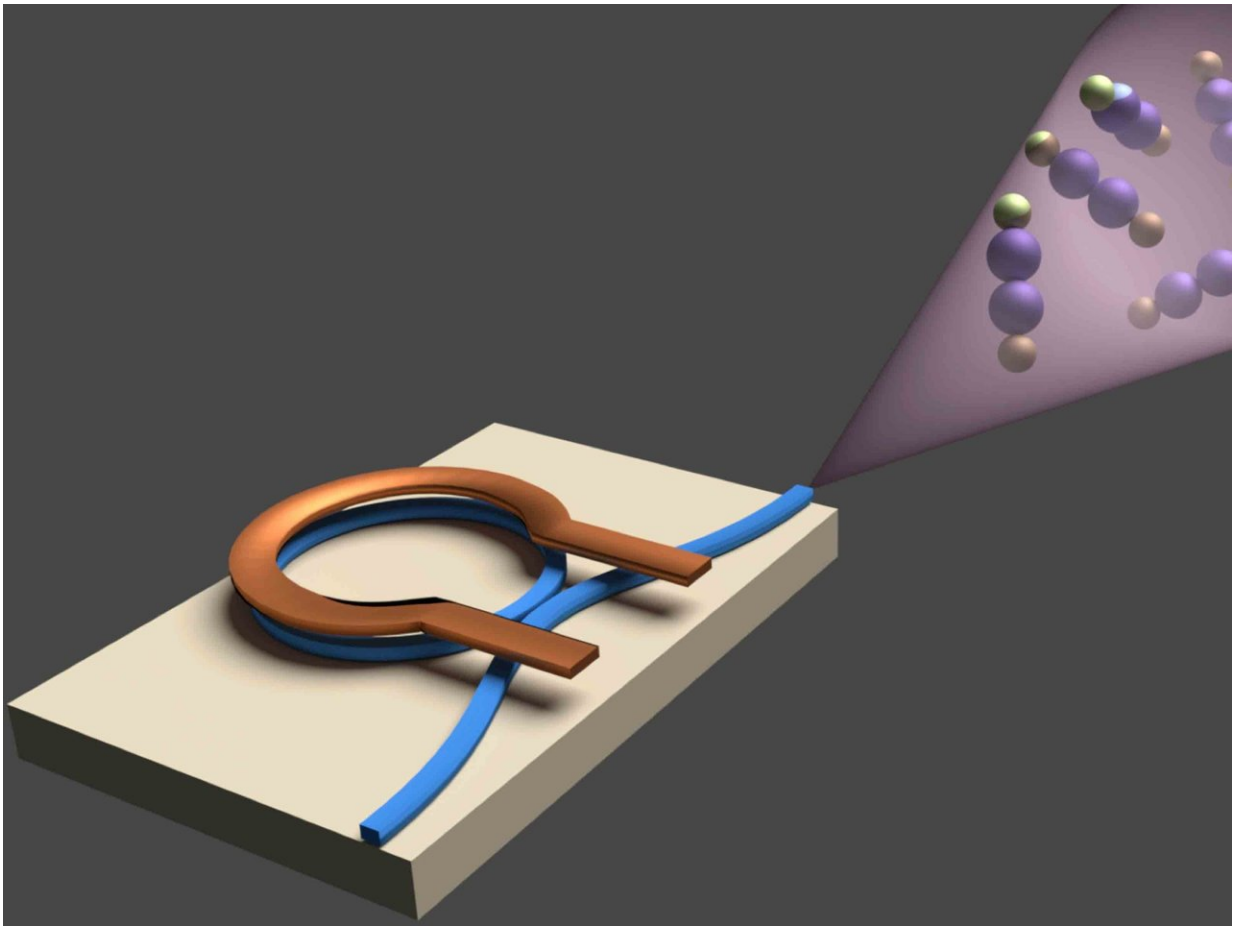

Schematic of silicon microresonator generating a frequency comb that samples molecules for chemical identification. Credit: Alexander Gaeta/Columbia Engineering

Researchers at Columbia Engineering have demonstrated, for the first time, a chip-based dual-comb spectrometer in the mid-infrared range, that requires no moving parts and can acquire spectra in less than 2 microseconds. The system, which consists of two mutually coherent, low-noise, microresonator-based frequency combs spanning 2600 nm to 4100 nm, could lead to the development of a spectroscopy lab-on-a-chip for real-time sensing on the nanosecond time scale.

"Our results show the broadest optical bandwidth demonstrated for dual-comb spectroscopy on an integrated platform," said Alexander Gaeta, David M. Rickey Professor of Applied Physics and of Materials Science and senior author of the study, published May 14 in *Nature Communications*.

Creating a spectroscopic sensing device on a chip that can realize real-time, high-throughput detection of trace molecules has been challenging. A few months ago, teams led by Gaeta and Michal Lipson, Higgins Professor of Electrical Engineering, were the first to miniaturize dual-frequency combs by putting two frequency comb generators on a single millimeter-sized chip. They have been working on broadening the frequency span of the dual combs, and on increasing the resolution of the spectrometer by tuning the lines of the comb.

In this current study, the researchers focused on the mid-infrared (mid-IR) range, which, because its strong molecular absorption is typically 10 to 1,000 times greater than those in the visible or near-infrared, is ideal for detecting trace molecules. The mid-IR range effectively covers the "fingerprint" of many molecules.

The team performed mid-IR dual-comb spectroscopy using two silicon nanophotonic devices as microresonators. Their integrated devices enabled the direct generation of broadband mid-infrared light and fast acquisition speeds for characterizing molecular absorption.

"Our work is a critical advance for chip-based dual-comb spectroscopy for liquid/solid phase studies," said Mengjie Yu, lead author of the paper and a Ph.D. student in Gaeta's lab. "Our chip-scale broadband optical system, essentially a photonic lab-on-a-chip, is well-suited for identification of chemical species and could find a wide range of applications in chemistry, biomedicine, material science, and industrial process control."

The study is titled "Silicon-chip-based mid-infrared dual-comb spectroscopy."

More information: Mengjie Yu et al, Silicon-chip-based mid-infrared dual-comb spectroscopy, *Nature Communications* (2018). DOI: 10.1038/s41467-018-04350-1

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