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Mid-IR Spectrometer Incorporates Difference-Frequency

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Scientists at Istituto Nazionale di Ottica Applicata of the Consiglio Nazionale delle Ricerche in Pozzuoli, Italy, have demonstrated a 2.9- to 3.5-µm integrated cavity output spectrometer that employs a difference-frequency generator as its source. In a proof-of-principle setup incorporating an off-axis high-finesse cavity, it demonstrated the ability to detect CH_4 at a concentration of 850 parts per trillion.

The team, directed by Paolo De Natale, is working to refine the instrument for in situ trace-gas analysis of CH_4, C_2H_4, NH_3 and N_2O at minimum concentrations of hundreds of parts per trillion, with applications in the monitoring of volcanic gases.

Researchers are working to develop a compact, rugged and portable version of an integrated cavity output spectrometer with a difference-frequency generator as its 3-µm source. To date, the instrument has employed a multipass cell rather than an off-axis cavity. Courtesy of Pietro Malara.

In difference-frequency generation, the interaction of two laser beams in a nonlinear crystal yields a third beam whose optical frequency is the difference of the two. Pietro Malara, a researcher at the institute, explained that the approach has been considered as a means of accessing the 2.5- to 3.5-µm window where important C-H, N-H and O-H bonds exhibit characteristic vibrations — a window, he said, that is inaccessible to continuously tunable, single-mode, high-purity laser sources, including quantum cascade lasers. Difference-frequency generators, however, had been limited to output powers of a few hundred microwatts.

The problem, he noted, is that off-axis integrated cavity output spectroscopy, despite various

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That is no longer the case. Thanks to advances in nonlinear crystal and rare-earth-doped fiber amplifier technology, the scientists at the institute have obtained 5.5 mW of continuous-wave 2.9- to 3.5-μm radiation from their system.

The source incorporates a laser diode from Toptica Photonics AG of Munich, Germany, mounted in a Littrow external-cavity configuration and tunable from 1030 to 1070 nm. It is amplified in an ytterbium-doped fiber amplifier from IPG Fibertech srl of Legano, Italy, to deliver up to 700 mW. The other laser, a diode-pumped erbium-doped fiber laser from IPG, is tunable from 1545 to 1605 nm and offers an output power of up to 8 W. A 5-cm-long periodically poled lithium-niobate crystal is used for difference-frequency generation.

In the laboratory demonstration, a 90-cm-long stainless steel tube capped by spherical mirrors served as the off-axis high-finesse cavity with a calculated path length of 1.8 km. A thermoelectrically cooled three-stage InAs detector from Judson Technologies LLC of Montgomeryville, Pa., was used to monitor any absorption of the introduced laser radiation by the gas species of interest — CH_4 in the experiments.

The team is developing a portable version of the system for monitoring pollutants and greenhouse and volcanic gases. A particular refinement in the new system, Malara said, is the use of fiber-coupled elements prior to the nonlinear crystal to reduce misalignments in crystal injection that can produce fluctuations in the output power of the difference-frequency generator.

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