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QC laser sweeps frequency in nanoseconds

At the heart of a high-resolution infrared-absorption spectrometer developed by researchers at the University of Strathclyde (Glasgow, Scotland) is a pulsed quantum-cascade (QC) laser operating at 10.25 µm. The laser and instrument operate at room temperature and require only a small amount of electronics, making the system very compact. The spectrometer has been used to measure the spectra of gases such as carbonyl fluoride and 1,1 difluoroethylene, and to detect carbon dioxide and water in a laboratory atmosphere.

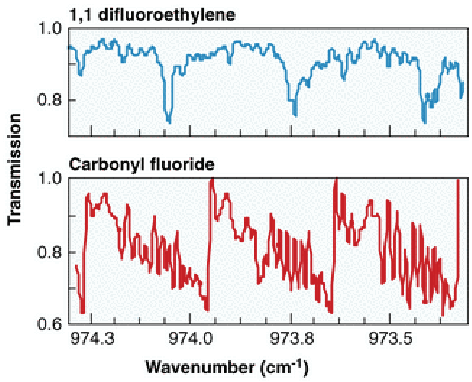
The laser itself has a distributed-feedback structure and is mounted in an airtight chamber with an antireflection-coated zinc selenide window. The laser substrate is temperature-stabilized to 0.01°C and can be varied between -40°C and +40°C. A custom-designed pulsed electrical source produces tophat-shaped current pulses lasting from 40 to 300 ns and repeating at rates to 100 kHz. The QC laser has a current threshold of 3.2 A at 0°C and is driven at a peak current of up to 6 A. When driven at a pulse amplitude of 5 A and varying the temperature of the substrate, the laser can be frequency down-chirped in an almost linear fashion at a rate of 2.3 GHz/K over a spectral range of up to 75 K.

The laser has been used with a Fourier-transform spectrometer. Because the system's spectral linewidth is determined by the spectrometer's instrument function, the laser linewidth must be narrower than 45 MHz to function with a time-integration detection.

In a version of the instrument meant for real-time use, a telescope containing off-axis parabolic germanium mirrors collects and collimates the light from the QC laser, resulting in a 3-mm-diameter beam that makes multiple (up to 202) passes through a cell containing the gas mixture to be analyzed. The light then strikes a high-speed mercury cadmium telluride detector; a digital oscilloscope produces a spectral trace in real time.

The detector amplifier has a 1.1-GHz bandwidth, producing an overall system bandwidth of greater than 400 MHz, for a temporal resolution of 1.35-ns. The instrument has been absolutely calibrated using 1,1 difluoroethylene absorption lines in the 973- to 974-cm^{-1} wavenumber region.

Spectroscopic detection of many gases in the atmosphere must be done within the atmosphere's transmissive spectral "microwindows," which range in size from 1 to 50 cm-1, with many falling between 1 and 3 cm^{-1}. The University of Strathclyde spectrometer can sweep across 2.5 cm^{-1}; its advantage over many other tunable systems is that step tuning is not necessary.



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Spectra of 1,1 difluoroethylene (top) and carbonyl fluoride (bottom) were measured with an infrared-absorption spectrometer containing a frequency-swept quantum-cascade laser operating at 10.25 µm. The spectrometer sweeps across a 2.5 cm^{-1} wavenumber range on a nanosecond time scale.

The instrument measured spectra of 1,1 difluoroethylene and carbonyl fluoride to a resolution of 0.015 cm^{-1} (see figure). In addition, the spectrometer detected water and carbon dioxide in samples of laboratory air at a 200-Torr pressure. Because the forbidden transition of carbon dioxide makes the gas difficult to detect, these results show that nitrous oxide, with an absorption-line intensity 2500 times stronger, should be sensitively detected by the room-temperature QC-laser-based spectrometer. The technique is being adapted for use in an airplane for atmospheric detection, according to Geoffrey Duxbury, one of the researchers.

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