A new longer-wavelength laser for more sensitive atmospheric and gas detectors has been unveiled coming up for air

November 2010 Vol. 46 No. 17

Broad appeal

Laser-based gas analysers are used in many applications in industry, environmental studies, agriculture, planetary science and for the improvement of indoor air quality. They have many advantages over other technologies including their specificity, high sensitivity, rapid response and ability to provide quantitative gas concentrations. Tunable diode laser absorption spectroscopy can determine gas concentrations by scanning the laser wavelength through an absorption feature of the target gas in a spectral range free of interferences from other species. The 3–4 μm, in the mid-infrared (IR), range is of great interest as the absorption features are often narrow and sharp. Simple gases such as hydrogen fluoride and methane usually have sharp absorption lines, requiring a narrow laser linewidth for high resolution. Singlemode lasers are particularly suitable for these gases with their continuous, mode-hop-free tuning, and distributed feedback (DFB) lasers are normally employed as they can provide a continuous tuning of about 10 nm. In this work, however, the NRC researchers sought to develop a suitable laser with broader tunability.

“A key motivation for our work is to characterise the gaseous volatile organic compounds (VOCs) that form ‘nanoaerosols’ which are ultrafine, nanometre-sized airborne particulates,” said Dr James Gupta from the Institute for Microstructural Sciences at the NRC. “These nanoaerosols contribute significantly to poor atmospheric air quality and related adverse health and environmental effects. The VOCs are often present indoors where chronic exposure presents health hazards for the occupants.”

Pushing up the wavelength

Three different types of mid-IR lasers are currently undergoing rapid development: type-I diode lasers, quantum cascade lasers (QCLs) and interband cascade lasers (ICLs). Gupta and his team chose to concentrate on the interband type-I lasers. “Although the three different types of mid-IR lasers face different challenges moving forward, my feeling is that all three have very good prospects,” Gupta commented. “The choice of laser design depends more on the background of the individual research team than on selecting a single ‘best’ technology. At the NRC, type-I diodes provided the best synergy with our other efforts.”

It is relatively straightforward to make type-I lasers in the 2–3 μm range by molecular beam epitaxy (MBE) using compressively-strained InGaAsSb quantum wells with AlGaAsSb cladding and waveguide layers on GaSb substrates. Extending the wavelength beyond 3 μm is challenging because high In contents are required, which increases the compressive strain. A previous key development in this area was the introduction of the quinary AlInGaAsSb barrier material, which provides better hole confinement, allowing better laser performance at longer wavelengths. The NRC researchers used this materials system to develop long wavelength narrow-ridge waveguide lasers which provide light output in a single spatial mode, in contrast to many exploratory reports involving broad-area, multimode waveguides. They incorporated them into an external cavity laser (ECL) configuration with broad tuning provided by an external grating and were able to achieve tunable single-wavelength operation at 3.24 μm near room temperature (10°C) suitable for spectroscopy. Work is now continuing to refine the designs and fabrication processes to enable high-performance ECLs in the 3–4 μm range for a plethora of applications including the detection of VOCs for which the broader laser tunability is ideal.

“Our nanoaerosol work is part of an initiative involving Canadian universities and other NRC institutes, in partnership with Canadian industry and environmental agencies, to develop laser-based instrumentation for studying the formation, composition, and distribution of nanoaerosols,” said Gupta. “This study will cover the entire lifecycle of nanoaerosols comprising the whole range of chemical composition and physical properties from individual molecules to single nanoparticles, both volatile and non-volatile, organic and inorganic, and soot. It is currently at the laboratory stage, but will soon progress to field studies to characterise the full range of nanoparticles emitted during hydrocarbon fuel combustion.”

Industrial opportunities

There is currently great demand for more sophisticated gas detection systems and the NRC researchers are working with ECL manufacturers to provide laser diodes above 3 μm for potential use in their future products. They are already providing antimonide DFB lasers at key wavelengths in the 2–3 μm range to manufacturers of commercial gas analysers for safety and regulatory applications in industrial environments. As part of one NRC initiative, gas analysers based on their lasers are being deployed in an intelligent building ventilation system. There is now great interest from manufacturers in the latest results from the NRC and Gupta hopes to continue to improve their laser performance and to optimise both their ECLs and DFBs for wider deployment of 3–4 μm laser gas analysers.