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Miniaturized tunable QCL light source for MID-infrared spectroscopy - Rosa A Merten - Fraunhofer IPMS

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Broadband tuning of MIR-infrared radiation from 3 to 10 µm may be a very promising way for spectroscopic study of gaseous, liquid, or solid species or intermixtures. We report a quick broadband tunable IR-light source supported the mixture of a quantum-cascade-laser and micro-opto-electro-mechanical systems (MOEMS) with integrated diffractive grating. This idea unites the benefits of broadband sources with the benefits of coherent laser sources during a miniaturized setup. The grating is processed inline within the MOEMS production process by non-isotropic etching. Grove depth and thus maximum spectral diffraction efficiency is decided by lithographic mask and therefore the etch-parameters. The scanning MOEMS-grating is driven electrostatically and oscillates with high repeatability at resonance frequency of 1 kHz and up to 10° deflection, which allows scanning the whole spectral range of the QCL-chip within 500 µs. This opens the way for real-time spectroscopy within the MID-IR range. We present applications in non-contact detection of hazardous species e.g. explosives and inline-detection oil contamination in water. Interest in mid-infrared spectroscopy instrumentation beyond classical FTIR employing a thermal light has increased dramatically in recent years. Synchrotron, super continuum, and external-cavity quantum cascade laser light sources are emerging as viable alternatives to the normal thermal black-body emitter (Globar), especially for remote interrogation of samples ("stand-off" detection) and for hyper spectral imaging at diffraction-limited spatial resolution ("microspectroscopy").

It's thus timely to carefully consider the relative merits of those different light sources for such applications. We study the theoretical maximum achievable signal-to-noise (SNR) of FTIR using synchrotron or super continuum light vs. that of a tunable quantum cascade laser, by reinterpreting a crucial result that's documented in near-infrared optical coherence tomography imaging. We rigorously show that mid-infrared spectra are often acquired up to 1000 times faster-using an equivalent detected candlepower , an equivalent detector background level , and without loss of SNR-using the tunable quantum cascade laser as compared with the FTIR approach using synchrotron or supercontinuum light. We experimentally demonstrate the effect employing a novel, rapidly tunable quantum cascade laser that acquires spectra at rates of up to 400 per second. We also estimate the utmost potential spectral acquisition rate of our prototype system to be 100,000 per second.

Spectroscopy within the mid-infrared (MIR) band (3–25 µm) is understood to be a strong tool for both, qualitative and quantitative chemical analysis even in complex matrices. together with MIR transparent optical waveguides, this technology represents a reliable and sensitive real-time sensing principle with high application potential in medical sciences, long-term observation of environmental pollution and process control in industry. Evanescent wave sensors are particularly suitable for addressing organic analytes in aqueous media, especially when using appropriate polymer coatings at the waveguide surface as analyte enrichment layers.

Interest in mid-infrared spectroscopy instrumentation beyond classical FTIR employing a thermal light has increased dramatically in recent years. The suitability for such systems to work under harsh conditions was recently demonstrated with the prototype of a MIR underwater sensor system supported a Fourier transform infrared (FT-IR) spectrometer capable of tracing volatile organic compounds (VOCs) during a marine environment. The signal transduction is predicated upon attenuated total reflection (ATR), together with silver halide MIR transparent fibers representing the active sensor head. Recent developments within the field of quantum cascade lasers (QCLs) provide a viable concept of MIR laser sources, with the likelihood of tailoring the emission wavelength within a broad range of frequencies. A QCL may be a micro fabricated, compact light, with the choice of near-room temperature operation at a coffee voltage. These properties make QCLs a light-weight source with a big potential for MIR sensor technology and particularly for integration into compact, remotely operated MIR target spectrometers within the near future.

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