Mid-IR Spectroscopy in Medical Diagnostics Using Tunable Quantum Cascade Lasers: A Complement or a Competition to FT-IR-Spectroscopy?

Werner Mäntele

Institut für Biophysik, Fachbereich Physik,
Johann Wolfgang Goethe-Universität Frankfurt am Main,
Max-von-Laue-Straße 1, D-60438 Frankfurt am Main, Germany

For almost three decades Fourier transform infrared (FT-IR) spectrometers have proven to be the best choice for the spectroscopic analysis of body fluids, cells and tissues. Infrared lasers such as the CO or CO_2 laser, in spite of the high spectral power emission, have never played a role because of their limited tunability and insufficient stability. Tunable IR laser diodes based on Eu doped lead sulfide or lead selenide semiconductors could not be used outside the lab because of the cryogenic temperatures required for operation.

With the advent of the quantum cascade laser (QCL) in the late nineties, powerful narrow-band single wavelength IR emitters or, with an external cavity (EC), tunable EC-QCLs are now available. Their power reaches to hundreds of mW and their tunability can extend over several 100 cm^{-1}, sufficiently broad to scan the entire IR fingerprint region within some tens of msec. Probably their most pronounced advantage is their use in a pulsed mode, which makes them an ideal IR light source for photometric measurement of IR radiation absorbed in skin or tissues in combination with photoacoustic detection. A further advantage is high spatial resolution because of the possibility of small focus sizes, basically only limited by diffraction to some tens of microns. The only disadvantage at present is the price, which, for broadband tunable EC-QCLs is substantially higher than routine FT-IR instrumentation and is one of the actual obstacles for widespread biomedical applications.

The lecture presents our most recent developments in QCL applications for the measurement of skin parameters and body fluids *in vivo* in comparison with FT-IR experiments. Photoacoustic detection methods with resonance cells are described that, optimized for the small focus and the high pulse energy of QCLs, open the possibility for the analysis of even deeper skin layers that cannot be accessed by FT-IR spectroscopy because of the low spectral density.