Bioanalytical Infrared Spectroscopy with Quantum Cascade Lasers (QCL): Revolution or new Challenge ?

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Abstract:

Infrared spectroscopy has long been established in chemistry for the identification of molecules. For decades, dispersive instruments using prism or grating monochromators suffered from low spectral intensities, long measuring times and low signal-to-noise ratio and thus limited the application in biochemistry, biology or medicine. With the advent of Fourier transform infrared (FT-IR) technologies in the early 80's, this improved significantly due to the multiplex advantage, and IR applications for structural, functional and time-resolved studies on biopolymers, biological membranes, cells and tissues became possible. Yet, the IR sources were still thermal emitters, with low emission power and low brilliance.

There were many attempts to apply IR lasers as more powerful sources for infrared spectroscopy, such as CO, CO2 or the lead salt semiconductor lasers, but their limited emission wavelength range or their complicated handling prevented a broader use. This changed dramatically when the first quantum cascade lasers (QCL) for the mid-IR were developed and commercialized around the turn of the century.

QCLs are unipolar lasers that emit through intersubband transitions in a multiple stack of semiconductor quantum well heterostructures. They can be manufacured as DFB (distributed feedback) lasers with single-wavelength emission, as tunable lasers using an external tunable cavity (EC-QCL) or, meanwhile, as DFB laser arrays for the emission at several IR wavlengths, e.g. fro sensing multiple gases. Emission power can range from mW to W, and the small emitter sizes make beam handling easy. Applications that profitinclude gas spectroscopy, sensors, biomedical applications or applications in biotechnology. Other applications that benefit from the point-source characteristics of the QCL are e.g. infrared microscopy.

After a short introduction to bioanalytical infrared spectroscopy and the principle of QCLs, we will discuss the pro's and con's of QCLs for bioanalytical and biomedical infrared spectroscopy. Highlights as well as problems that are concomitant with this novel IR light sources will be considered. Finally, we will look at examples for the application of QCL for sensors and biomedical applications.