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Vibrational Spectroscopy and Imaging

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A molecule's nuclei are not at rest, but rather they oscillate around their equilibrium positions within the molecule. This so-called molecular vibration leads to an oscillatory change in the permanent and/or induced dipole moment.

On the one hand, the oscillation of the permanent dipole moment can be detected by means of infrared radiation. A glowing bar ("Global"), a quantum cascade laser, or a synchrotron may act as a light source in the infrared. On the other hand, the oscillatory change in the induced dipole moment, i.e. polarizability, is monitored by means of the Raman effect. Many variants of the Raman effect, such as stimulated Raman scattering (SRS), coherent anti-Stokes Raman scattering (CARS), or surface-enhanced Raman scattering (SERS) have been researched in order to enhance signal, lower detection limit, target specific changes, and shorten measurement times.

Since the signal frequencies depend on the specific molecular vibration, which is a function of the chemical composition, the molecules' identities can be derived from the multiple peaks observed in the corresponding spectra. The biomedical application of infrared or Raman spectroscopy is summarized as "biomedical vibrational spectroscopy."

Recent technical advances have led to a strong increase in the interest of vibrational spectroscopy and imaging in the context of biomedical applications. The 11 papers in this special section cover the range from basic research in oncology to questions arising from envisioned day-to-day clinical applications.

Hormone-mediated lipogenesis is investigated in breast and prostate cancer cell lines by [Potcoava et al.](#) The authors show that hormone-treated cancer cells may have an increased number and size of intracellular lipid droplets and a higher degree of saturation than untreated cells. Raman spectroscopy is used by [Ding et al.](#) in order to reveal compositional changes in breast cancer-induced bone metastasis in a mouse model. [Buckley et al.](#) assess the chemical composition of human as well as animal cortical bone, showing that the

mineral-to-collagen ratio as well as the phosphate-to-carbonate ratio decrease at the end of the tibia. Synchrotron-based infrared imaging helps to elucidate the impact of the aging on human fibrosarcoma cells as reported by [Guilbert et al.](#) Continuous monitoring of morphological changes in a non-transformed small intestinal cell line are presented by [Zilbershtein et al.](#) on the basis of a novel surface plasmon biosensor design. [Drutis et al.](#) extend the use of stimulated Raman imaging to three dimensions, thus enabling the acquisition of structural and chemical three-dimensional images of native skin.

The overall turn-around time from sample taking through measurement and analysis to reporting of the result constitutes a further crucial success factor for an efficient and effective translation of biomedical vibrational spectroscopy into clinical practice. Measurement times as low as 2 seconds are achieved for the SERS-based detection of molecules by [Li et al.](#) by means of nanoporous gold disk arrays. [Strola et al.](#) report a method to shorten the time needed for Raman-based identification of a single bacterium. Raman spectroscopy may also speed up the assessment of the skin's health status in terms of transepidermal water loss, hydration, pH, relative amount of ceramides, fatty acids, and cholesterol content, according to [Vymvuhore et al.](#) Furthermore, the recent availability of tunable midinfrared lasers may help shorten the measurement process: in the work by [Kröger et al.](#) a mouse jejunum thin section is used to show that the combination of a quantum cascade laser illumination with a microbolometer array can reduce the measurement time per unit area and wavenumber interval by approximately three orders of magnitude. Finally, the ambient light background may impose a severe hurdle for practical applicability of Raman spectroscopy in a clinical setting. [Zhao et al.](#) investigated the ambient light properties and propose appropriately filtered LED illumination.

In sum, the special section provides a cross section of current research in vibrational spectroscopy and imaging,

from benchtop research to operating rooms, from classical Raman spectroscopy to quantum cascade laser-based imaging, and from model fluids to cancerous tissue.

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Wolfgang Petrich works as head of engineering at Roche Diagnostics GmbH, Mannheim, Germany, where he also is a senior project manager in the field of innovation management. In addition, he heads the biophotonics team at the Kirchhoff-Institute for Physics at Heidelberg University. He is also a member of the University's Faculty for Physics and Astronomy. His key interests are biomedical optics and biospectroscopy.