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Development and applications of nonlinear optical spectroscopy: 10th ECONOS/30th ECW meeting in Enschede, The Netherlands†

The joint conference of the European Conference on Nonlinear Optical Spectroscopy (ECONOS) and European CARS Workshop (ECW) covers all theoretical and experimental aspects of nonlinear optical spectroscopy and microscopy. Topics include Coherent anti-Stokes Raman scattering (CARS) spectroscopy and microscopy and other forms of coherent Raman scattering, other approaches to the detection of nonlinear optical responses in time and frequency domain, and investigations of the physical and chemical processes defining the spectral signatures in different nonlinear media. Also emerging analytical techniques and their applications in biomedical research, material science, and engineering are discussed. The tenth ECONOS conference and 30th CARS workshop were held at the University of Twente in Enschede, the Netherlands on 23–25 May 2011. Altogether, 103 participants shared their research in invited sessions and poster sessions. In addition, the meeting included a session on industrial applications of nonlinear optical spectroscopy. This special issue of the *Journal of Raman Spectroscopy* presents 14 papers from that meeting. The papers reflect some general directions in which the field of nonlinear spectroscopy is developing. There are four papers on high-precision analysis of gas temperatures, three papers discuss new analysis methods of measurements, three papers discuss medical applications, and four papers discuss new developments in technology.

Coherent anti-Stokes Raman scattering offers the possibility of stand-off temperature measurements in the harshest of environments such as combustion chambers or jet engines. Hence, the use of CARS for thermometry has been developed over many years already. Increasingly complex mixtures are tackled and the precision is increased. Four papers focus on these issues.

Marrocco *et al*. and Bohlin *et al*.[1–3] investigate the Herman–Wallis corrections for different species. This interaction between the rotational and vibrational motions causes changes in the detected line shapes that can give rise to incorrect estimations of the relative concentrations or temperatures. Choosing the correct model for these corrections is essential when trying to measure minority species of a few per cent.

Bohlin *et al*.[3] experimentally explore the use of rotational CARS within one vibrational state to perform thermometry of N_2O and achieve a high degree of precision in the thermometry.

Intensity limits that can be applied to high temperature flames before saturation and broadening effects reduce the accuracy are determined by Magnotti *et al*.[4]

It is often advantageous to combine several forms of analysis or different techniques to extract more information from a sample and reach a higher accuracy. Such an approach is applied by Marrocco[5] using time-resolved CARS and the dependence of the rotational–vibrational coupling to reach better accuracy. Rodriguez[6] reports on the combination of different types of scattering to obtain more structural information.

Sometimes more information can be extracted by a more careful analysis of the data rather than a different technique. In Cicerone *et al*.,[7] the data analysis is improved to extract more detail from broadband CARS data.

For various applications, it is often advantageous to optimize a specific variation of existing techniques. A wide-field CARS arrangement capable of generating CARS images in a single shot is demonstrated.[8] This is a feature that is particularly useful in the imaging of fast-moving components in living cells. The application of broadband CARS by scanning the wavelength to obtain broadband data for chemical identification is explored in Garbacik *et al*.[9] The rapid scanning allows the use of selected wavelengths over a broad range without the need to obtain full spectra.

One of the frontiers of all types of imaging is to beat the diffraction limit. This is particularly vexing in CARS where the coherent nature of the interaction precludes the use of an equivalent stimulated emission depletion scheme. The diffraction limit can be broken however by the introduction of perturbations such as a sharp tip. The tip can simultaneously enhance the signal which is important given the small sampled volume. Furusawa *et al*.[10] show some of the latest developments in this direction.

Because CARS is coming of age, the applications are getting a wider attention, but with this attention, the need for user-friendly dedicated setups becomes apparent. Kumar *et al*.[11] highlight recent advances toward all fiber systems that aim to remove much of the required optical complexity by providing a robust turn-key system.

Applications also highlight the need for careful analysis and the opportunities available for analysis of different nonlinear processes that tend to happen simultaneously when using high intensity beams. Moger *et al*.[12] shows how stimulated Raman scattering (SRS) and photo-thermal imaging can be used simultaneously and how different contributions can be separated. The use of second harmonic generation (SHG) and CARS to image collagen production for tissue regeneration is demonstrated in a further contribution.[13] Garrett *et al*.[14] show the use of SRS for nanomedicine and fully exploit the advantages that label-free imaging has to offer.

This special issue of JRS shows the continuous progress in nonlinear optical spectroscopy and imaging in both fundamental aspects and in promising applications. The necessary technology is maturing but many new possibilities are discovered every day. We are confident that future ECONOS meetings will again bring new insights, new advances in technology, and more applications.

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