ADAPTIVE SPECTRAL FOCUSING FOR MULTIMODAL IMAGING

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We demonstrate a novel spectral focusing approach for CARS microscopy by exploiting the flexibility offered by combining a single broadband 10-fs oscillator and a pulse shaper.

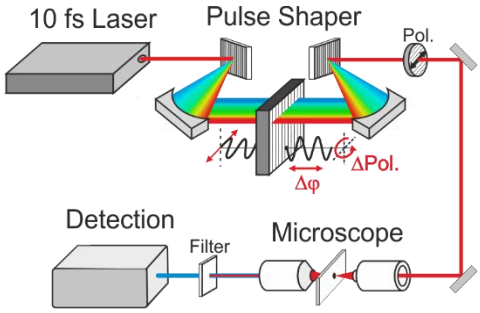

Fig. 1: Experimental setup for single-beam multimodal microscopy.

The pump and Stokes frequencies driving Raman resonances in the CARS process are equally stretched in time to achieve a constant instantaneous frequency difference that enables to select a specific resonance. In contrast to traditional spectral focusing approaches using static dispersive elements, the proposed pulse shaping scheme furthermore allows to *independently* address frequencies acting as probe. This tailored spectral focusing scheme not only makes it possible to overcome the drawback of the nonresonant background inherent to CARS microscopy but offers additional features and advantages [1]. For example, the bandwidth of the instantaneous frequency difference can be variably adjusted to the linewidth of the addressed Raman resonance in order to optimize spectral resolution and signal intensity. Delaying the probe frequencies to the end of the excitation further increases the resonant CARS signal intensity due to a longer build-up and therefore a stronger coherence at the time of probing. As shown for lipid resonances of skin tissue at 2850 cm^{-1}, intensities more than six times higher than with the usual spectral focusing approach are readily achieved [2].

By scanning the probe delay, it is not only possible to generate background-free CARS signal but to achieve contrast based on the different coherence-decay of adjacent Raman lines. Independent control over the probe frequencies furthermore makes other nonlinear signals accessible for multimodal imaging. Signal intensities of TPEF and SHG are increased significantly due to the transform-limited nature of the tailored probing region. Their simultaneous detection together with the *resonant* CARS signal is achieved as demonstrated by imaging of human skin tissue (Fig. 2).

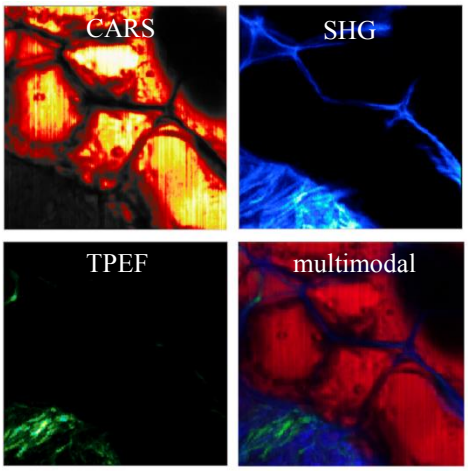

Fig. 2: With a spectral focusing phase function simultaneously measured signals from human skin tissue.

[1] L. Brückner, T. Buckup, and M. Motzkus, "Exploring the Potential of Tailored Spectral Focusing" *J. Opt. Soc. Am. B* **33**, 1482-1491 (2016)
[2] L. Brückner, T. Buckup and M. Motzkus, "Enhancement of Coherent Anti-Stokes Raman Signal via Tailored Probing in Spectral Focusing" *Opt. Lett.* **40**, 5204-5207 (2015)