Live coherent Raman imaging with inter-image wavelength switching

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We present multi-color coherent Raman imaging (CRI) with a frame rate of 8 Hz and rapid wavelength tuning within only 5 ms between successive images, enabled by a novel fiber optical parametric oscillator (FOPO). In CRI the limited tuning speed of conventional laser systems (>1 s) prevents the acquisition of successive images per second at more than one vibrational resonance and is considered as a bottleneck for multi-color assessments of rapidly evolving samples. Recent approaches to CRI with wavelength switching on a timescale of (sub-) milliseconds were based on two synchronized oscillators [1], being limited to two resonances, and parallel laser amplifiers [2] or spectral focusing techniques [3], both the latter with a limited tuning bandwidth of less than 300 cm^{-1}. In contrast, the energy difference of the pump and Stokes pulses, emitted by the here presented FOPO, is tunable across the wide spectral range between 865 and 3050 cm^{-1} within only 5 ms. Assuming an equal time span for tuning and acquisition, up to 100 user-selectable vibrational components could be imaged per second, when imaging with 100 frame/s. The rapid tuning was achieved by a novel tuning concept for OPOs, based on the dispersive matching of the repetition frequency change of the pump pulses to the associated repetition frequency change of the resonant signal pulses in the FOPO. No alteration of the FOPO, e.g., via a mechanical delay line, was required for tuning the signal wavelength and the light source could be composed of all-spliced fiber components. Compared to previously presented FOPOs, the system runs at a high repetition rate of 40 MHz. The pump and Stokes pulses exhibit equal durations of 7 ps and an average power of 500 and 200 mW, respectively. As a first proof-of concept of the CRI capabilities, Fig. 1 shows three images of a sample consisting of water, oil and beads of PMMA and PS, taken successively with an acquisition time of 125 ms for each frame, limited only by the sampling rate of our detection setup. The energy difference was tuned in a frame-by-frame manner between 2850, 2950 and 3050 cm^{-1} in a time of 5 ms, a negligible time span compared to the acquisition time.

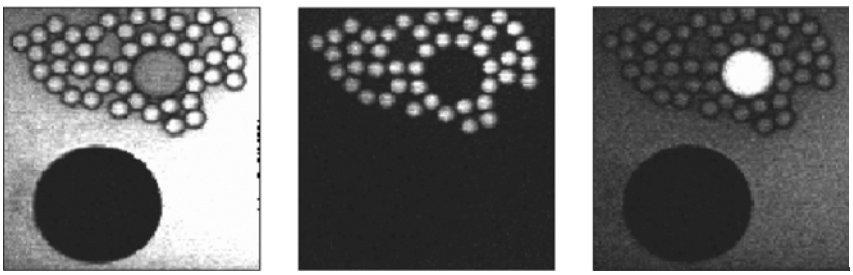

Fig. 1: CRI images of a sample consisting of water, oil and beads of PMMA and PS, each taken with an acquisition time of 125 ms. The energy difference of the excitation pulses was tuned to (a) 2850 cm^{-1}, highlighting oil, (b) 2950 cm^{-1}, highlighting PMMA, (c) 3050 cm^{-1}, highlighting PS.

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