

Frequency-Modulated Portable Light Source for Coherent Raman Imaging with Enhanced Sensitivity

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We present multicolor coherent Raman imaging (CRI) with enhanced sensitivity by a novel fiber optical parametric oscillator (FOPO). The FOPO combines a rapid and wide tunability for accessing Raman bands between 700 and 3500 cm^{-1} within only 5 ms with a frequency modulation (FM) at 20 MHz for enhancing CRI sensitivity by at least two orders of magnitude.

When measuring weak concentrations of Raman scatterers, the maximum achievable sensitivity is usually limited by the non-resonant background in CARS microscopy and by cross-phase modulation in SRS microscopy. To overcome these limitations, we have implemented a frequency modulation at 20 MHz for fast switching between on- and off-resonance measurements by means of an unbalanced electro-optic delay in the feedback of the FOPO of reference [1]. The resulting two different round trip times in the FOPO together with chromatic dispersion and a fixed arrival time of the following pump pulses effectively result in two distinct wavelength filters, one on- and the other off-resonance. This FM functionality can be seamlessly integrated into the all-fiber setup. We present images and first concentration measurements of deuterated DMSO achieving two orders of magnitude higher sensitivity compared to CARS microscopy without FM. The resolvable concentration of down to 0.05% is comparable to previously reported values of FM-CARS measurements using solid-state laser systems [2,3,4], however, now realized with a robust and portable fiber-based light source. This development constitutes an important step for advancing CRI in terms of portability and sensitivity for out-of-lab applications in medical diagnostics or environmental sensing.

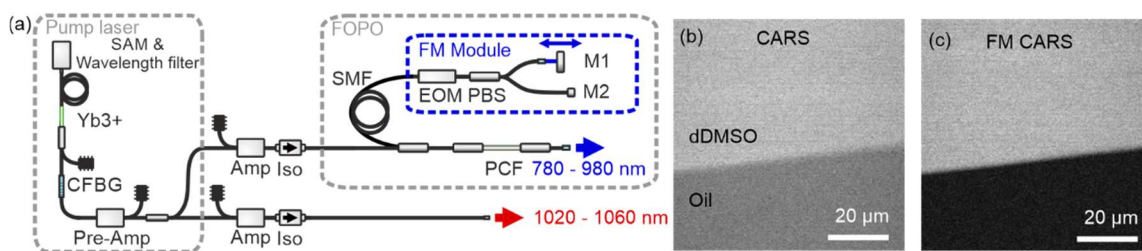


Fig. 1 (a) Schematic experimental setup of the fiber optical parametric oscillator (FOPO) with the module for frequency modulation (blue box). SAM: saturable absorber mirror; Yb3+: Yb-doped fiber; CFBG: chirped fiber Bragg grating; Amp: amplifier; SMF: single-mode fiber; PCF: photonic-crystal fiber; EOM: electro-optic modulator; PBS: polarization beam splitter. (b) Standard CARS image of an interface between deuterated DMSO and rapeseed oil measured at 2250cm^{-1} . (c) FM-CARS image of the same sample with 4-fold enhanced contrast (pixel dwell time of 1 μs).

References

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