Low-Noise Optical Parametric Amplifier Source for Stimulated Raman Scattering Imaging

I. Martin[1,2], Y. Ahmad[2], S. Bux[1], T. Sylvestre[3], S. Metais[2], H. Rigneault[2], N. Forget[1,2]

1. Fastlite by Amplitude, 165 route des Cistes, 06600 Antibes, France

2. Aix Marseille Univ, CNRS, Centrale Met, Institut Fresnel, 13013 Marseille, France

3. Institut FEMTO-ST, Université Marie et Louis Pasteur, CNRS, 25030 Besançon, France

4. INPHYNI, Université Côte d'Azur, CNRS, 06200 Nice, France

nicolas.forget@univ-cotedazur.fr

Oral/Poster contribution

Stimulated Raman Scattering (SRS) [1] is a nonlinear microscopy technique that does not require staining or labeling to map the distribution of chemical bonds in three-dimensional space and real time. SRS typically uses two synchronized pulsed lasers, one known as the pump beam and the other as the Stokes beam, to coherently excite the selected molecular vibration. In SRS microscopy, both laser beams are spatially and temporally overlapped, and focused collinearly into a diffraction limit spot inside the sample. SRS signal is usually detected as a relative intensity change of one of the incident laser beams. However, as this intensity change is very weak, achieving a high signal-to-noise ratio (SNR) in SRS requires light sources with ultra-low noise levels [2]. Currently, optical parametric oscillators (OPOs) are the most commonly used sources for SRS microscopy. However, their complexity, cost and slow tunability speed impose significant limitations, especially when several molecular vibrations are to be sequentially imaged (hyperspectral imaging).

In this work, we propose and demonstrate an alternative and simplified femtosecond source for SRS imaging: a low-noise, supercontinuum-seeded optical parametric amplifier (OPA) with a high repetition rate (40 MHz) and high average power (0.5-1 W). We first generate a supercontinuum (SC) in a polarization-maintaining all-normal-dispersion photonic crystal fiber [3] with a 40-MHz Kerr-lens mode-locked Ytterbium shot-noise laser (Flint, Light Conversion, sub-150 fs, 20 W, 1.03 µm). The SC is then used as a seed for a tunable OPA pumped by the second harmonic of the same pump laser. In single-pass, the OPA stage delivers up to 1 W of average power over 0.78-0.95 µm with sub-100-fs pulse durations (Fig.1, left). The relative intensity noise (RIN) was measured for the pump, fiber and OPA outputs and they all reach the shot-noise floor above ~3 MHz (for photocurrents of ~5mA).

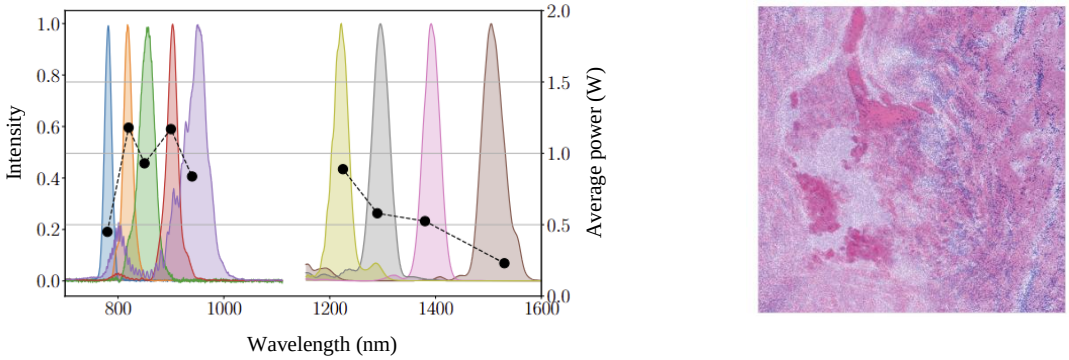

Figure 1. Left: Output wavelength and average power of the OPA. Right: experimental SRS image of mouse bone.

Finally, SRS images were acquired with this source (pump: tunable output of the OPA < 1 µm, Stokes: 1.03 µm) by using a scanning microscope and a lock-in detection at 20 MHz. A sample of mouse bone was placed in the microscope, and the CH_2 bonds (lipids) and CH_3 bonds (protein) were selectively imaged. Image of of 512 × 152 pixels were acquired at a frame rate of 0.17 Hz with a pixel integration time of 10 µs. Images were then processed using a recoloring algorithm to reconstruct a histologic virtual image, by combining the CH_2 and CH_3 contributions (Fig.1, right).

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References

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