SHOT NOISE LIMITED TWO PICOSECOND FIBER LASER BASED LIGHT SOURCE FOR COHERENT RAMAN MICROSCOPY

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Fast and sensitive imaging with Coherent Raman Scattering microscopy requires pulses at two wavelengths perfectly synchronized in time and space, ideally as picosecond pulse trains with around 100 MHz repetition rate. The energy difference between the two wavelengths needs to be tuneable to match the vibrational bands under investigation. Synchronously pumped Optical Parametric Oscillators pumped by solid state lasers such as Nd:YVO have proven their capability and reliability as shot noise limited light sources in CRS microscopy. However, their pulse length is typically in the range of 5-6 ps. To match the vibrational bandwidth of Raman lines of >= 10 cm^{-1} pulses with 1 – 2 ps length would be ideal.
Here we present a shot noise limited Yb-fiber laser driven OPO light source with < 10 cm^{-1} bandwidth and pulse length of only 1.8 ps for both 1032 nm Stokes and Pump pulses. The Pump pulses (OPO Signal) are tuneable from 690 to 991 nm (400 – 4800 cm^{-1}) covering the entire fingerprint region.
The relative intensity noise, see Fig.1, is shot noise limited with -161 dBc/Hz for the tuneable Pump pulses (OPO Signal) and only 4 dBc/Hz above shot noise limit for the 1032 nm Stokes pulses above 10 MHz. Modulating the Stokes beam with 20 MHz thus allows SRS imaging with classical lock-in techniques avoiding balanced detection, necessary for other fiber laser based CRS light sources [1]. Video rate SRS images of HeLa cells at 2940 cm^{-1} were recorded with a pixel dwell time as low as 120 ns.
Direct comparison with a 6 ps solid state laser pumped OPO was performed. It shows an increase of a factor 10 in CARS signal and a factor of 2.5 in both SRS intensity and signal-to-noise ratio, close to the theoretical predicted factors. These short picosecond pulses even allow SRS imaging in the fingerprint region, as shown on HeLa cells, see Fig. 2.
The light source (picoEmerald S) is completely hands-free and computer controlled. Fast wavelength scanning is achieved with a settle time of 5 s for each wavelength step. To compensate the microscope dispersion the delay between pump and stokes is automatically corrected for each tuning step to ensure perfect temporal overlap at the sample site.

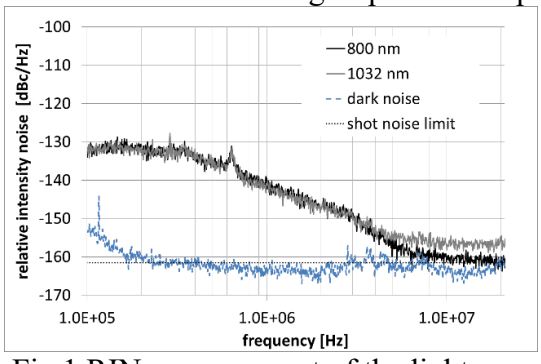

Fig.1 RIN measurement of the light source

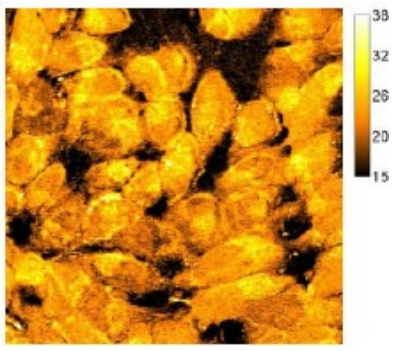

Fig. 2 SRS image of a HeLa cell at 1455 cm^{-1}

[1] C.W. Freudiger et al., "Stimulated Raman scattering microscopy with a robust fiber laser source," *Nature Photonics* 8, 153-159 (2014).