Hadamard-transform high spectral resolution and broadband stimulated Raman Scattering microspectroscopy using an acousto-optic tunable filter

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Conventional stimulated Raman scattering (SRS) microscopes perform spectral acquisitions probing one single Raman shift (wavenumber) at a time. A multiplexed approach, however, would allow to perform faster spectral acquisitions, either measuring several wavenumbers in parallel or using reconstruction techniques that increase the signal to noise ratio (SNR). While the first approach often requires the use of complex technical solutions, the latter can be implemented with minor changes to an already existing broadband setup.

We present a simple and flexible multiplexed acquisition modality based on the Hadamard transform [1] using a single detector and a single lock-in amplifier in a fingerprint-to-CH-stretch continuously tunable SRS microscope [2]. A narrowband (7 cm-1), high-speed and multichannel Acousto Optical Tunable Filter (AOTF) generates Hadamard spectral masks by turning on and off different subsets of its 8 channels, corresponding to different wavelengths available within the broad bandwidth of the tunable output of a dual-beam femtosecond laser (Fig. 1a). The SRS signal is recorded by a single photodiode and the inverse Hadamard matrix is used to retrieve the SRS spectrum. The multiplexing method reduces the additive noise affecting the SRS measurements, allowing to obtain the same SNR of spectra measured with a 4-times longer integration time using a conventional single-channel Raster acquisition (see Fig. 1b).

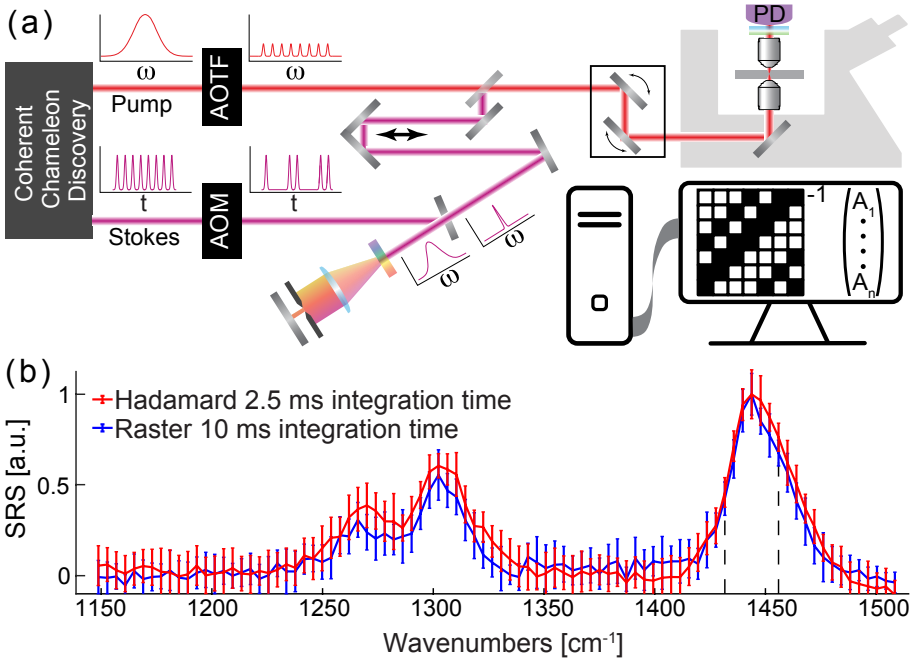

Figure 1: (a) Schematic of the SRS microscope. The AOTF creates the spectral masks with eight independent narrowband channels. AOM, acousto-optic modulator; PD, photodiode. (b) SRS spectrum of the fingerprint region of olive oil. The conventional single wavenumber scan performed with 4 times longer integration time has the same SNR of the one performed using the Hadamard transform scan.

The Hadamard-based acquisition modality here presented features high flexibility, allowing to perform seamless and fully automated acquisitions from the fingerprint to the CH-stretch spectral regions. The high spectral resolution and improved SNR make this acquisition method an ideal candidate for hyperspectral imaging and compressive sensing applications.

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[2] Laptenok, SP, Rajamanickam, VP, Genchi, L, et al. Fingerprint-to-CH stretch continuously tunable high spectral resolution stimulated Raman scattering microscope. J. Biophotonics. 2019; 12:e201900028. https://doi.org/10.1002/jbio.201900028