RamanFest 2023
Paris FRANCE

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A pixel-by-pixel correcting autobalanced detector for SRS microscopy

Stimulated Raman scattering (SRS) microscopy is a powerful tool in biological and medical research due to the chemically-selective and label-free nature of the Raman process. However, excess noise of the used light source limits the achievable signal-to-noise ratio (SNR) below the SNR given by the shot-noise limit [1,2].

In this submission we present an easy to use, compact, and modular autobalanced detector capable of up to 60 dB correlated noise suppression, 110 ° possible phase compensation at 20 MHz, and 300 ns PID settling time allowing for true pixel-by-pixel sample absorption compensation for pixel scanning rates of up to 3 MHz. Our autobalanced detector is able to provide an SRS image which is absorption compensated as well as shot-noise limited for photocurrents above 2 mA. As a novel addition, a noise-suppressed absorption image of the sample is simultaneously provided, allowing for combined SRS and absorption imaging. Our autobalanced detector was applied to a home-build SRS microscope setup utilizing a fiber-based dual-color picosecond light source with a 40 MHz Stokes and 20 MHz pump repetition rate, detecting a 20 MHz modulation on the Stokes beam. A special high dynamic range photodetector was developed, suppressing the 40 MHz repetition rate signal of the Stokes beam by up to 80 dB before transimpedance conversion, allowing for sensitive and saturation-free detection even for photocurrents above 10 mA. The image improvement by using our autobalanced detector is demonstrated in Fig. 1(a)-(b) for red onion skin. Only after enabling autobalancing the distribution of cellulose in the cell membrane became visible. Fig. 1(c) shows that this was due to high absorption in the membrane, suppressing the SRS signal to the level of the non-resonant background, which was then compensated for by the autobalancer circuit in Fig. 1(b). The SNR was increased by a factor of 1.5, however, the increase in SNR was limited only by shot-noise due to the available laser power of 10 mW per detector as well as the already low excess noise of the used light source.

References

[1] C. W. Freudiger, W. Yang, G. R.Holtom, N. Peyghambarian, X. S. Xie, K. Q. Kieu,, Nature Photon., 153 (2014) 8
[2] H. Ni, P. Lin, Y. Zhu, M. Zhang, Y. Tan, Y. Zhan, J. Cheng, Anal. Chem., 15703 (2021) 93

Figures

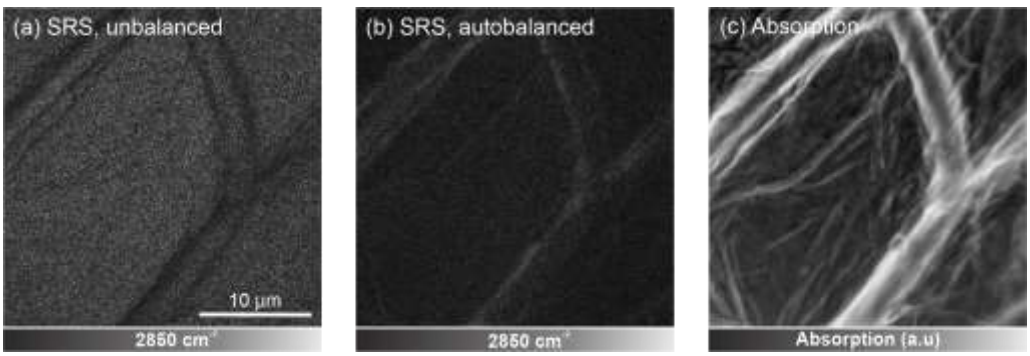

Figure 1: (a)-(b) SRS image of cellulose in red onion skin, (c) absorption image of red onion skin. All images consist of 512 x 512 pixels and were acquired with a pixel dwell time of 10 µs and a mean photocurrent of 5 mA. Image (c) was simultaneously acquired with image (b).