Stimulated Raman Scattering CMOS Image Sensor with In-Pixel Double Modulation Technique

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Stimulated Raman scattering (SRS) is an optical microscopy known as a label-free, noninvasive imaging technique to observe the dynamic process of biological events and vibrational properties of gases, liquids, and solids. Typical SRS microscopy uses two synchronized high-frequency laser pulse trains denoted by its angular frequency, the pump, (ω_P) and the Stokes, (ω_S) [1]. SRS signal is produced when the optical angular frequency difference between the pump and the Stokes laser resonates with the sample vibrational frequency, as shown in Fig. 1. The interference would annihilate the pump while the Stokes intensify. However, the SRS signal produced is small, where it is in the range of 10^{-5} to 10^{-4} on top of a very large offset, and difficult to digitize [2].

In this work, a technique utilizing CMOS lock-in pixel for SRS signal detection is developed. Fig. 2 shows a block diagram to represent the principle of SRS signal acquisition. The lock-in pixel demodulates the resulting signal, where the L1 branch handles the signal marked in blue, and the L2 branch handles the signal marked in red. S/H ensures both L1 and L2 signals reach the integrator simultaneously while maintaining the overall gain. S/H is developed using a switched capacitor, whereas the integrator is a fully differential folded-cascode amplifier. The amplified SRS signal from Fig. 2 may contain residue offset and suffer from low-frequency noise. As the dynamic range of imaging systems is limited by output offset and low-frequency noise, the chopping technique is adopted to perform the double modulation mechanism. Fig. 3 shows the block diagram of the double modulation technique.

The simulation results for the proposed circuit is as shown in Fig. 4. Fig. 4 (a) shows the output with the amplified SRS signal. Sampling 2 represents the result after double modulation as described in Fig. 3. As for comparison, when there is no SRS signal present, the circuit will not produce any differential output, as shown in Fig. 4 (b). From the simulation result, the SRS signal can be acquired successfully. With an additional double modulation technique, the low-frequency noise can be cancelled.

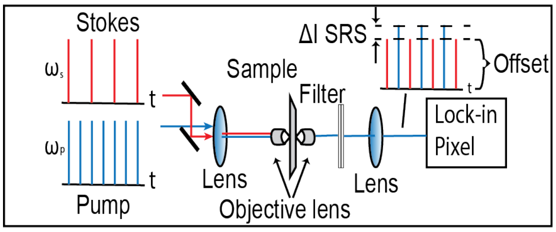


Fig. 1. The principle of SRS detection.

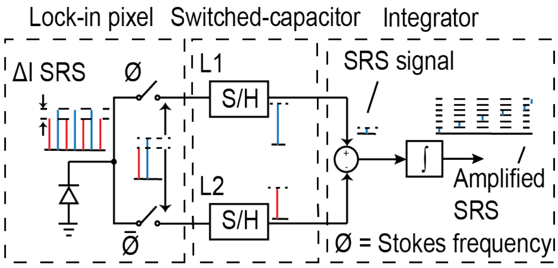


Fig. 2. SRS signal acquisition.

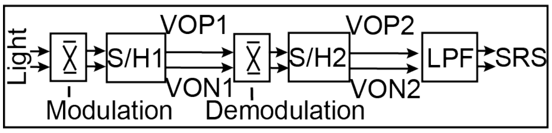
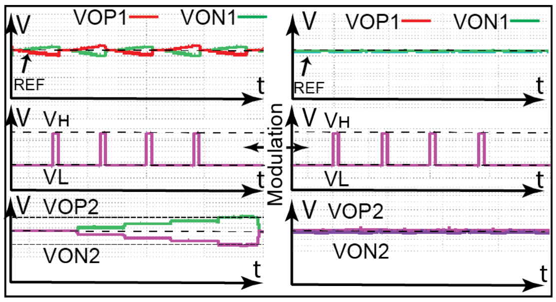


Fig. 3. SRS signal acquisition with double modulation technique.



(a) (b)

Fig. 4. (a) SRS output. (b) No SRS presents.

References:
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