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Deep Learning–Optimized Ultrafast Large-Field-of-View Stimulated Raman Scattering Imaging of Living Tissue

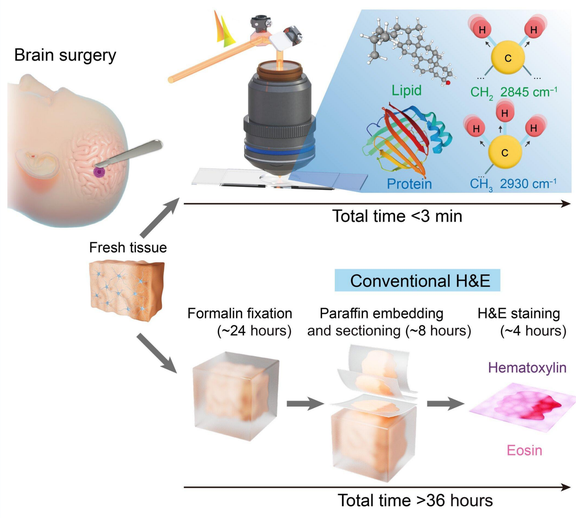
YIchuan Lan[1]，Yuhen Guo[1]，Minbiao Ji[1*]，Ying Zhang[2*]

[1]State Key Laboratory of Surface Physics, Fudan University，Shanghai 200433；
[2]The Obstetrics & Gynecology Hospital of Fudan University (Shanghai Red House Ob & Gyn Hospital)，Shanghai 200011；
Email：23110190035@m.fudan.edu.cn

Abstract

Stimulated Raman scattering (SRS) microscopy, with its label-free chemical contrast, has shown great potential in biomedical research. However, conventional point-scanning approaches based on ultrashort pulsed lasers suffer from low imaging throughput and long acquisition times, while high excitation power can induce phototoxicity, severely limiting their application in dynamic monitoring of living tissues. To address these limitations, this study proposes a low-damage, high-speed SRS imaging strategy. By introducing an ultrafast resonant galvo scanning system, tissue exposure time is significantly reduced. Combined with low-power laser excitation and deep learning–driven image enhancement algorithms, this approach effectively compensates for signal loss caused by noise reduction. The proposed strategy maintains high signal-to-noise ratio (SNR) imaging quality while substantially reducing tissue photodamage and thermal effects, providing a feasible technical pathway for label-free, large-field in vivo tissue examination and intraoperative pathological diagnosis.

Background



SRS Histology Detection

Compared with conventional histopathology or fluorescence imaging techniques that rely on exogenous staining, stimulated Raman scattering (SRS) microscopy provides label-free chemical contrast. Its minimal sample preparation requirements and low biological toxicity make it highly suitable for in vivo tissue imaging.

Result

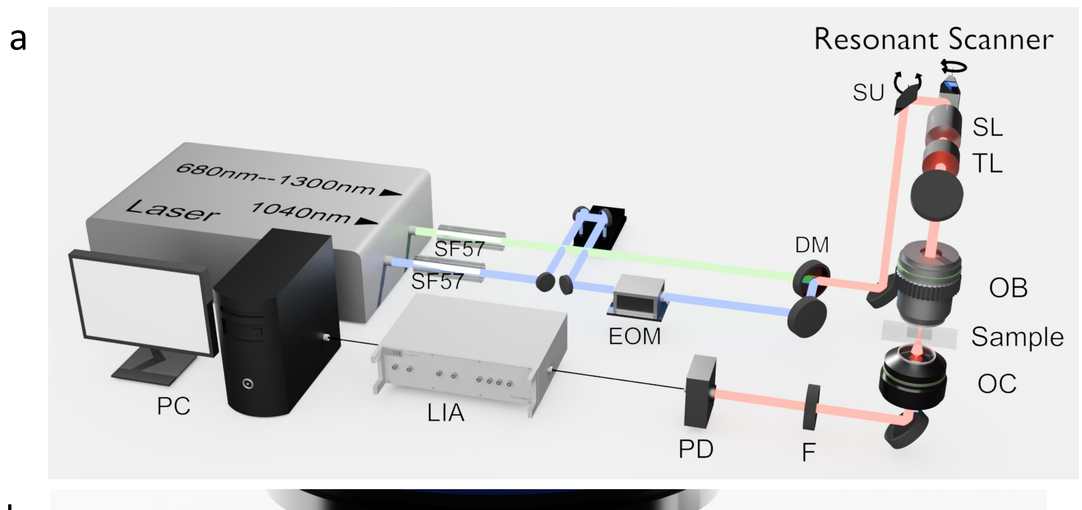


Figure 1. Schematic of the experimental system.
(a) Stimulated Raman scattering (SRS) imaging system.
(b) Image acquisition scanning strategy: the fast axis is scanned using an ultrafast resonant galvanometer to ensure high-speed image acquisition, while the slow axis is scanned with a high-precision motorized stage to enable effective large-field imaging.

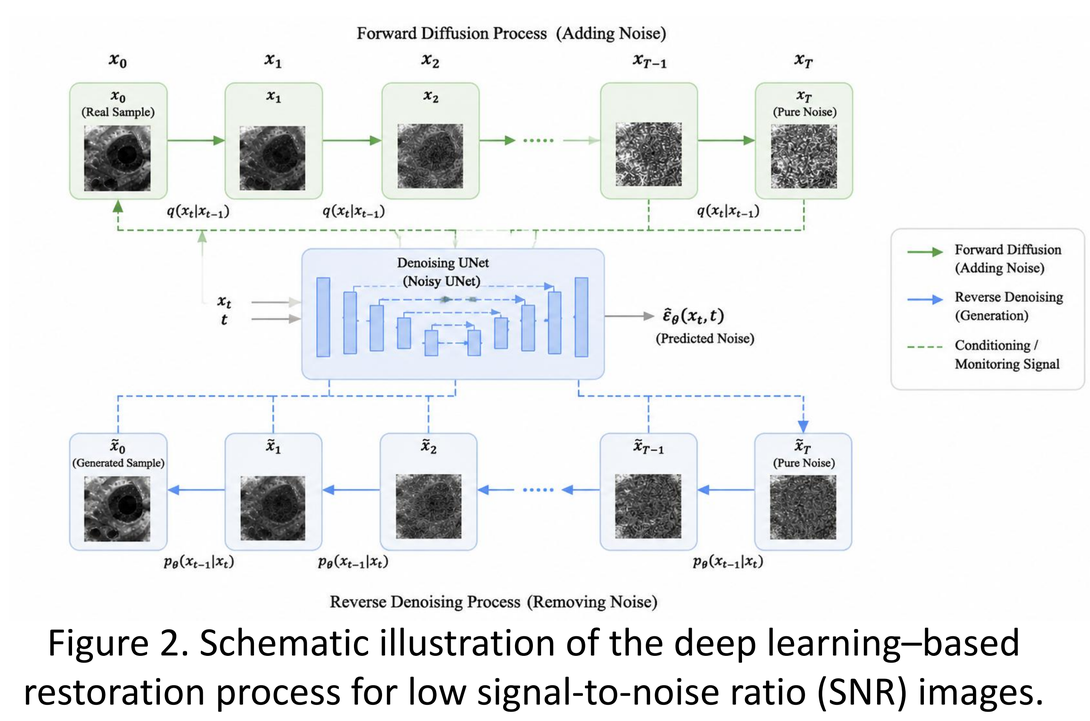


Figure 2. Schematic illustration of the deep learning–based restoration process for low signal-to-noise ratio (SNR) images.

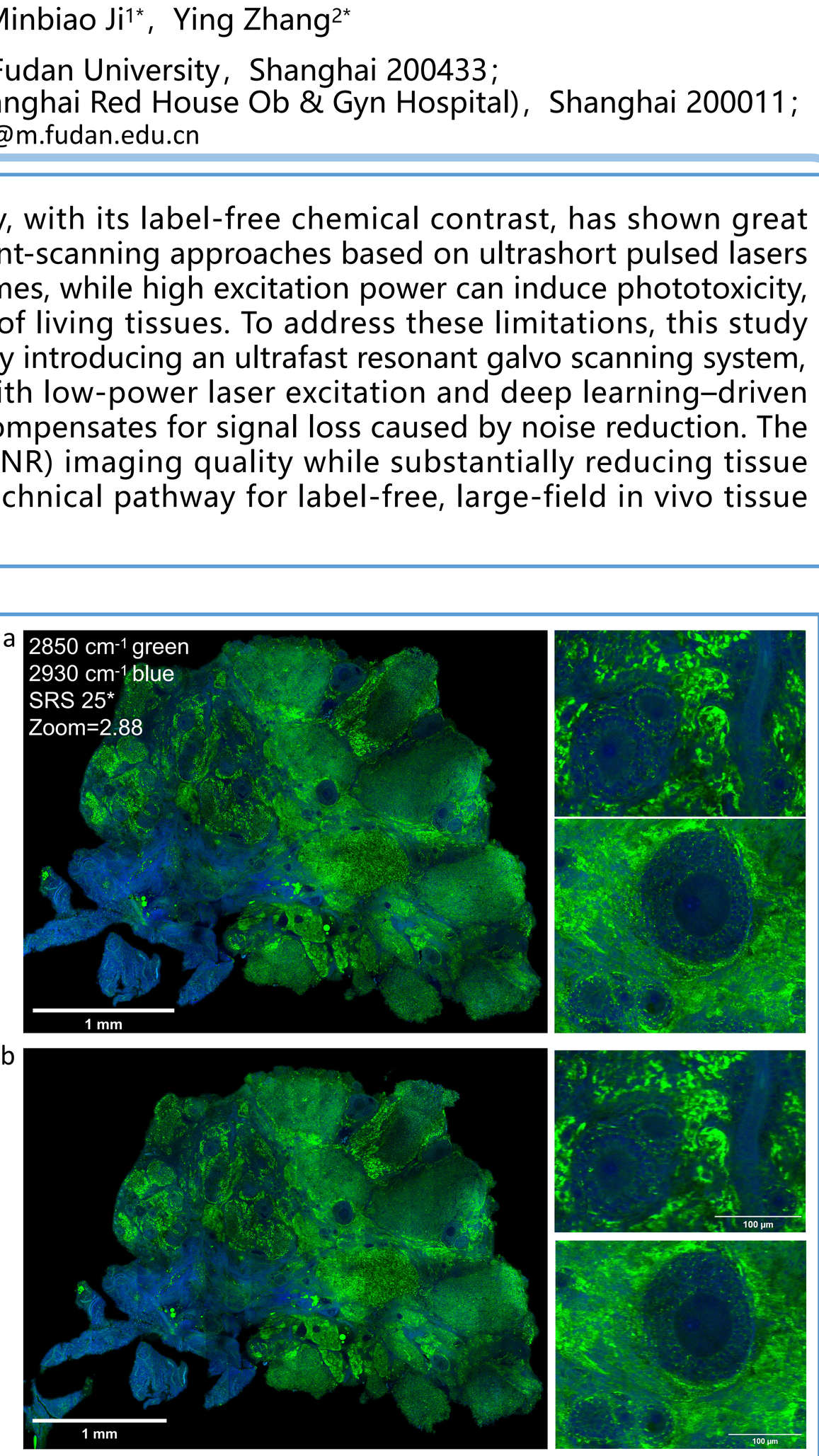


Figure 3. Dual-channel super-resolution stimulated Raman scattering (SRS) imaging results of living mouse ovarian tissue.
(a) Conventional imaging method (acquisition time: ~41 min).
(b) High-speed imaging method (acquisition time: ~90 s).

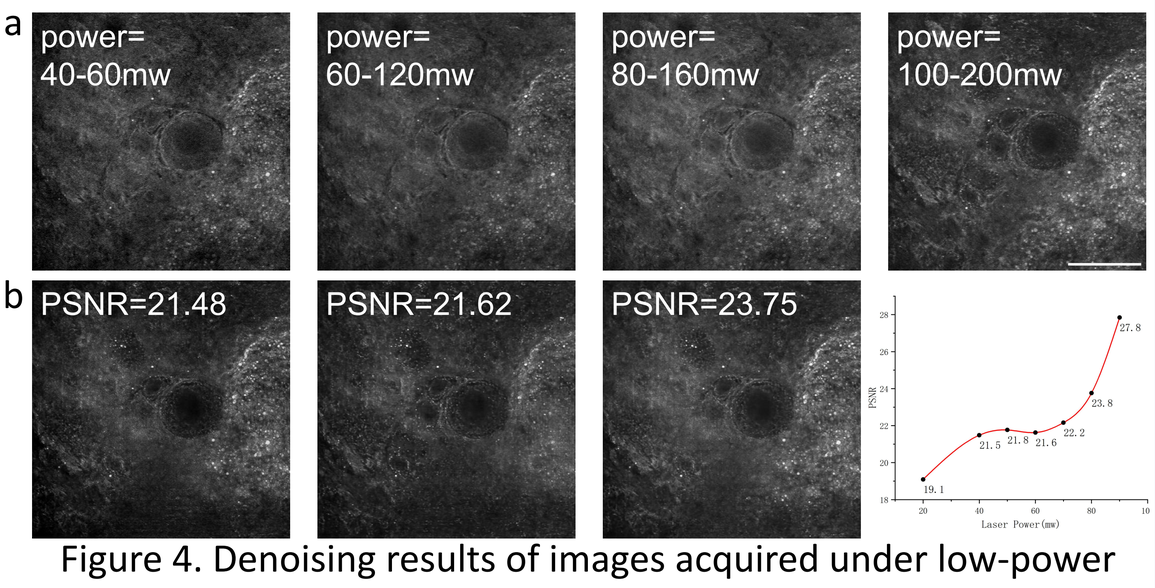


Figure 4. Denoising results of images acquired under low-power conditions. (a)Origin images (b)Denoised images (Scale Bar: 50um)

Conclusion

- An ultrafast, low-photodamage stimulated Raman scattering (SRS) imaging system was developed.
- For imaging of approximately 4*4mm FOV, the system achieved an acquisition time of less than 120 s at a high sampling density of 0.345um/pixel.
- By deep learning–based image processing, the system achieved an PSNR >20 under excitation powers <60 mW.

This work enables high-speed imaging of tissue samples on the millimeter scale (~5 mm), achieving an approximately 40times increase in imaging speed compared to conventional SRS microscopy. The illumination power is reduced to roughly 40%, effectively minimizing tissue photodamage and establishing a method for label-free in vivo tissue examination.