Broadband noise suppression for fiber-laser-based video-rate stimulated Raman scattering spectral microscopy.

°Michio Ishikawa, Naoki Kohara, Yuki Yonetani, Akira Yamamoto, Chidane Ouchi, and Masanobu Hasegawa

Canon Inc.,

E-mail: ishikawa.michio@canon.co.jp

Stimulated Raman scattering (SRS) is a nonlinear-optical microscopy technique, which provide molecular-specific images without staining bio-medical samples [1]. Unlike the CARS signals, SRS signals are free from non-resonant backgrounds thus spectra in common with well-known spontaneous Raman spectra can be obtained. Owing to 3 orders higher sensitivity than spontaneous Raman scattering, high-speed SRS images have been obtained with low-noise mode-locked solid-state lasers [1].

On the other hand, fiber-based mode-locked lasers are small, inexpensive, and stable thus they are expected to be appropriate laser light sources for SRS microscopy. Since mode-locked fiber lasers are generally noisy compared with solid-state lasers, SRS measurements with fiber lasers are performed in small frame rate such as 1 frame per second (fps) accompanied with noise suppression techniques. As the noise reduction methods, a delay and add line (DAL) [2] or a high-speed noise cancellation system based on voltage-subtraction auto-balanced detection [3] have been used.

Since high-speed data acquisition with a lock-in amplifier requires broadband signal extraction in RF frequency, In order to expand these noise suppression techniques to video-rate data acquisition, a broadband noise suppression technique is needed.

In the present paper, we demonstrate a new type of noise reduction technique (3DAL: triply blanched delay and add line), which enables broadband noise suppression for video-rate (30 fps) SRS imaging with mode-locked fiber lasers.

Figure 1 illustrates experimental setup of the 3DAL. Triply blanched light beams are merged to suppress the noise. Normalized noise spectrum is expected to be $\left|1+2e^{i2\pi f/f_{rep}}+e^{i4\pi f/f_{rep}}\right|/4$, where f and f_{rep} are RF frequency and repetition frequency, respectively.

Figure 2 shows noise suppression behaviors. The experimental result of noise suppression matches theoretical prospect of the 3DAL. The noise reduction curve is broad enough to cover RF region to be extracted with lock-in amplifier (40 +- 6.4 MHz, indicated with yellow box).

The remaining noise within the region is smaller than the noise with the DAL, indicating that broadband noise suppression is feasible with the 3DAL and it is appropriate for fiber-laser-based video-rate SRS spectral microscopy.

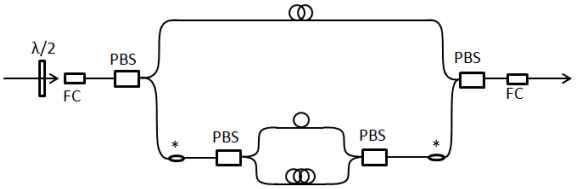

Figure 1, Experimental setup of the 3DAL. PBS: polarized beam splitter, FC: fiber collimator, *: 45 degrees twisted fusion splice.

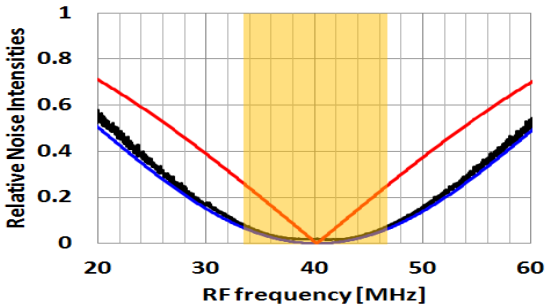

Figure 2, Noise suppression behavior. The DAL (red curve, calculation), the 3DAL (blue curve, calculation) and an experimental result of the 3DAL (black curve) are illustrated.

References

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