Speckle reduction by spectral compounding average in SD-OCT using tunable quasi-supercontinuum source

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Optical coherence tomography (OCT) suffers speckle noises, which arise from superposition of multiple backscattering with random phases, degrading the image contrast [1]. The quasi-supercontinuum (SC) source has tunable spectrum with different central wavelength, bandwidth, and spectral shape [2,3]. It is expected that this light source is useful to achieve speckle decorrelation on OCT imaging.

In this work, we demonstrated the speckle reduced OCT using quasi-SC source at 1700 nm spectral band. By spectral compounding average of OCT images obtained by tunable quasi-SC spectra, we confirmed the improvement of OCT image quality.

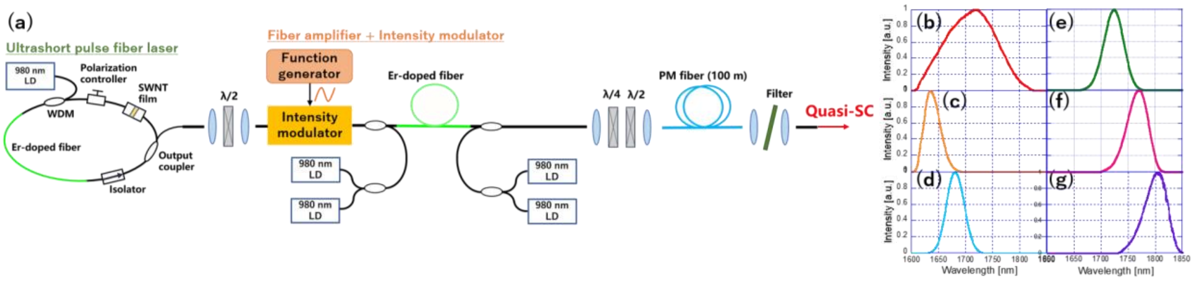

Fig.1. (a) Optical setup for 1700 nm quasi-SC laser source. (b)-(g)The spectra of tunable Gaussian-shaped quasi-SC output, (b) broad spectrum: λc = 1710 nm, △λ = 115 nm, incident power = 42.5 mW,(c) narrow spectrum: λc = 1638 nm, △λ = 34 nm, incident power = 28.1 mW,(d) narrow spectrum: λc = 1680 nm, △λ = 38 nm, incident power = 40.8 mW, (e) narrow spectrum: λc =1722 nm, △λ = 42 nm, incident power = 48.7 mW, (f) narrow spectrum: λc = 1766 nm, △λ = 46 nm, incident power = 54.8 mW, (g) narrow spectrum: λc = 1802 nm, △λ = 50 nm, incident power = 59.1 mW.).

Figure 1(a) shows the experimental setup for 1700 nm quasi-SC laser source. An ultra-fast intensity modulator was used for tunable quasi-SC generation. Here, using the modulation of programmable function, tunable Gaussian-shaped quasi-SC spectra with different central wavelength and spectral bandwidth were obtained, as shown in Figs.1(b)-(g).We introduced the above quasi-SC spectra into spectral domain (SD)-OCT system. Firstly, we examined the characteristics using a reflective mirror as a sample. The total system sensitivities of SD-OCT were all up to 100 dB. The axial resolution using the above broad spectrum was 16.2 μm in air, corresponding to 11.7 μm in biological tissue. The axial resolutions using narrow quasi-SCs were close to each other, around 32.2 μm in air (23.3 μm in biological tissue).

Figure 2(a) show OCT image of tape stack obtained by broad spectrum. The high-resolution image was obtained. Compounding average was applied to OCT images obtained by the five narrow-quasi-SCs. Speckle reduced OCT images with compounding average were shown in Fig.2. (b). From the images, we confirmed that the image contrast became better as the average numbers were increased.

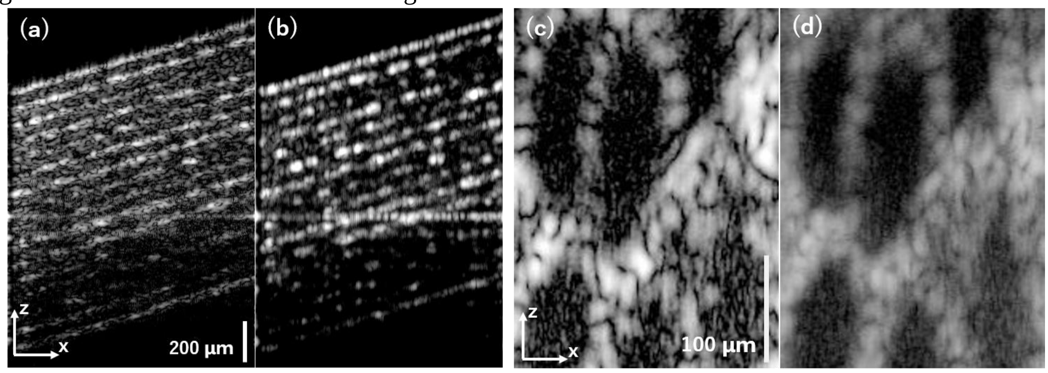

Fig.3. Cross-sectional images of tape stack (a) using broad quasi-SC and (b) by compounding average using narrow quasi-SC. OCT imaging of pig thyroid gland (c) with and (d)without speckle reduction.

Finally, we performed a pig thyroid gland imaging and applied compounding average. Figures 2(c)-(d) show the cross-sectional images of the pig thyroid gland without and with the speckle reduction method. The results clearly indicated that the structures of the samples were more clearly observed in the speckle reduced OCT image.

In conclusion, we performed 1700 nm speckle reduced SD-OCT imaging using tunable quasi-SC source and confirmed that the image contrast was clearly improved by spectral compounding average.

Reference
[1] Pircher *et al.*, *Biomed. Opt. Express* **8**, 565 (2003)
[2] Sumimura *et al.*, *Opt. Lett.* **33**, 2892 (2008)
[3] Sumimura *et al.*, *Opt. Lett.* **35**, 3631 (2010)