Ultrafast Optical Coherence Tomography Using Sheet Illumination

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1. Introduction
The imaging speed of OCT has improved significantly in the past two decades [1-3]. An A-line acquisition rate of 20 MHz has been reported recently. This allows an effective frame rate of 20 kHz provided that each frame is comprised of 1000 A-lines [3]. Nonetheless, a technical barrier prevents further significant improvement in the frame rate. In most existing OCT setups, A-lines are recorded sequentially when the weakly focused sample beam is shifted to scan along a transverse direction. While a galvanometer is usually employed as the scanning device, the typical resonant frequency of high-end galvanometers is a few kilohertz. It is therefore very difficult for existing OCT techniques to go beyond 20 thousand frames per second.

2. Method
Here I report a novel OCT technique that is capable of unprecedented speed to take cross-sectional images. An OCT setup based on this technique does not need a scanning mechanism for two-dimensional cross-sectional imaging. A light sheet is formed to illuminate the sample in parallel. A slit functions as a spatial filter, which is combined with coherence gating to improve the sensitivity. A two-dimensional image sensor detects the interferograms in parallel. All the necessary information is collected in a single exposure with the image sensor, much like the situation in normal photography. The image acquisition time is determined by the shutter speed of the camera or the duration of a light pulse used to illuminate the object. One-dimensional inverse Fourier transform is used to convert a raw image into the cross-sectional sample image.

3. Results
A prototype ultrafast OCT system has been built and tested. The shortest frame acquisition time is 40 microseconds, which is limited by the camera. Its sensitivity was measured around 60 dB at such a speed, while the optical power on the sample was 2 mW. This is equivalent to 89 dB in a video rate (25 frames per second) system. Another 16 dB improvement is possible by the use of better optical components and a high-quantum-efficiency camera in the system. Imaging experiments with biological samples have been conducted. The spatial resolution and imaging depth are comparable to those of conventional OCT systems.

References