Imaging of the Oral Cancer Tissues with Optical Coherence Tomography Using Self-Phase Modulation in Fiber for Broadband Source Generation

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Abstract

An optical coherence tomography system of 5 μm in depth resolution was built for oral cancer study. The broadband source was generated through self-phase modulation of a femtosecond Ti:sapphire laser in single-mode fiber.

I. Introduction

Optical coherence tomography (OCT) is a useful technology for noninvasive imaging of subsurface biological tissues, which may provide important information to medical diagnosis [1]. An OCT system is typically a setup of Michelson interferometer and its longitudinal resolution is equal to the width of interference fringe envelope, which is inversely proportional to the bandwidth of the light source. Therefore, generation of a stable broadband light source, either coherent or incoherent, is crucial for OCT development. Moreover, a light source with higher power may provide higher sensitivity in sample sacnning. In our experiments, we utilized the self-phase modulation and possibly other nonlinear processes in a single-mode fiber to generate broadband light source for building an OCT system, which is used to scan the human oral cancer tissues with high quality [2]. The morphological images are compared to the histology pictures.

II. Experiments

For generating the broadband light source of the OCT system, about 100 fsec pulses from a mode-locked Ti:sapphire laser were end-coupled into a single-mode fiber of about 5 m. The pulsed signal from the fiber output end was directed to a free-space OCT system.

Figure 1 shows the input and output spectra of the fiber with the coupled power at 300 and 600 mW when the central wavelength of input spectrum was 828 nm. The asymmetrically broadened output spectra may result in several possible mechanisms, including asymmetric input pulses, significant stimulated Raman scattering, and other nonlinear processes. The dependence of output spectral width on input power through 5-m fiber is shown in Fig. 2. In this figure, the circular symbols describe the full-widths-at-half-maximum (FWHM) versus input power. To see the contribution of the side-bump features, the square symbols in Fig. 2 depict the full spectral widths of one-fifth (20 %) maximum intensity (abbreviated as FWFM) with various input powers. When the power coupled into the fiber reached 600 mW, up to 81 nm FWFM could be obtained.

In the OCT system, the beam size at the focal point was estimated to be around 5 μm, which corresponded to the resolution of the lateral scan. The high lateral resolution was chosen at the expense of a short depth of focus

or depth range of scanning, which was estimated to be just a few hundreds μm. The power incident upon samples could be as high as 100 mW. The depth resolution was tested to be from 5 to 10 μm, depending on the input power to the fiber. The sensitivity was estimated to be higher than 120 dB.

We have used this system to scan various tissue samples. Figure 3 shows the OCT scan result of a piece of human oral mucosa, in which cancerous cells were identified. Many cavity structures (as a couple examples indicated with arrows), including some of them close to the surface, were supposed to be the regions of cancerous cells. For comparison, a histology picture of the same tissue sample was also shown.

Acknowledgement:

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References:

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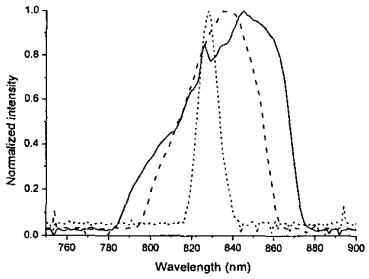

Fig. 1 Input spectrum (short-dashed curve) and output spectra of the fiber with the input power at 300 (long-dashed curve) and 600 mW (solid curve).

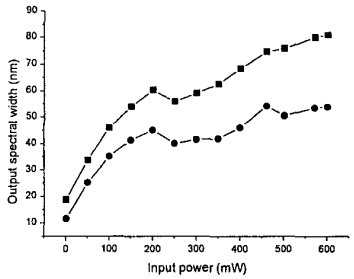

Fig. 2 Dependence of output spectral width on input power.

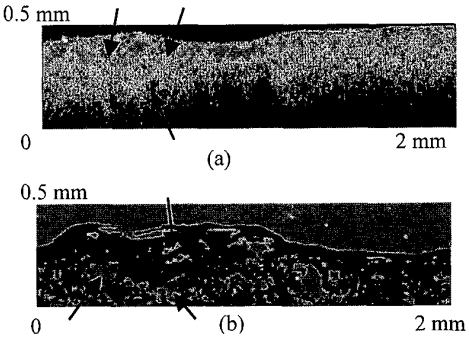

Fig. 3 (a) An OCT scan picture of a human cancerous oral mucosa sample. (b) A histology picture of the same sample.