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Title

Near-infrared detection of correlated activity in the brain

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near the back focal plane of lens f2. The first relay lens f2 forms an image of the fiber facet at the back focal plane of the second relay lens f3, which recollimates the beam onto the objective. The objective is a distance f3 from the second relay lens such that the scanned beam pivots about the center of the objective. The objective is a 30x, 0.9 NA water immersion objective designed for NIR wavelengths with a working distance of 1.3 mm.

The reference arm uses a reflective geometry grating phase delay line. The beam from the fiber collimator is directed onto a 36.152 1/mm grating which diffracts the beam onto a $f = 5$ cm curved mirror, one focal length from the grating. The curved mirror, in turn focuses the spectrally dispersed beam back onto a 12 mm width galvanometer controlled mirror which is displaced in the horizontal direction. The galvo mirror can be tilted to produce an inclined phase versus wavelength in the focal plane of the spectrally dispersed beam.

The pivot axis of the mirror can be offset to produce independent control of phase and group delay and is set to produce a phase modulation only. The mirror angle is scanned with a triangle waveform at 500 Hz to provide 1000 forward and backward scans per second and a phase ramp modulation corresponding to a 900 kHz heterodyne frequency.

The XY galvo mirrors in the hand held probe are scanned in a raster pattern. The fast axis mirror is also scanned at 500 Hz and synchronized with the phase modulation scan. The slow axis mirror is scanned at 2 to 4 frames per second to acquire 500 to 250 image lines. The output of the interferometer is detected and demodulated with a log demodulator similar to that used in OCT. The demodulated output is digitized with a 5 MHz, 12 bit A/D converter and displayed on the computer. The images can be saved in digital form as well as in video using an S-VHS recorder.

Results

Figure 2 shows en face OCM images where the reference arm group delay is set to match the confocal plane of the imaging probe. The resolution of the system was tested by imaging an Air Force resolution chart (Fig. 2a) and a 300 lp/mm diffraction grating (Fig. 2b). The system could resolve the smallest 4.4 μ m elements of the chart and diffraction grating lines of 3.3 μ m. Furthermore, it was possible to resolve smaller surface features on the targets, demonstrating transverse image resolutions better than 3.3 μ m. The field of view is approximately 130 μ m by 140 μ m and the image plane was relatively flat over this range.

CWC2 Fig. 2. Examples of optical coherence microscopy en face images of an Air Force resolution chart (A) and a diffraction grating (B). The images are 130 μ m by 140 μ m and demonstrate a transverse resolution of better than 3.3 μ m.

To investigate imaging in a biological system, *in vivo* OCM imaging was performed on an African frog tadpole (*Xenopus laevis*). The tadpole was imaged from the dorsal side with 1375 $\times$ 500 and 1375 $\times$ 250 pixel resolutions at 2 to 4 frames per second, respectively (Fig. 3). Cellular structure was clearly visible at multiple en face imaging depths. The cell nuclei and cell borders appear highly scattering. In addition, circulatory flow in a large vessel was also visible in sequential images or video. To demonstrate materials imaging, OCM imaging was performed on laser fabricated optical waveguides in glass. The waveguides are inside the glass and normally require phase contrast microscopy for visualization.

Preliminary studies have also been performed at 800 nm and the phase modulation has been demonstrated with over 130 nm of bandwidth. This paper will report high resolution, high speed OCM imaging results at both 1300 nm and 800 nm wavelengths.

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CWC2 Fig. 3. OCM en face images taken of *Xenopus laevis* tadpole and of a laser-fabricated waveguide embedded in glass (C). Images A, D-E are 1375 $\times$ 250 pixels taken at 4 frames per second, while images B and C are 1375 $\times$ 500 pixels taken at 2 frames per second. The field of view in the images is 130 μ m $\times$ 140 μ m.

compression of ultrashort optical pulses," *Opt. Lett.* 18, 1651–1653 (1993).

CWC3

Invited

3:00 pm

Near-Infrared Detection of Correlated Activity in the Brain

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Since the introduction of the fMRI technique few years ago functional studies of the brain capable of good localization are now relatively common. One major drawback of the fMRI method is that the BOLD effect, which is at the basis of the method, is sensitive to changes in blood flow and volume rather than to neuronal activity. Furthermore, fMRI has not yet reached the necessary temporal resolution to follow the rapid changes due to neuronal activation. Near-ir light can pass through the skull and reach the surface of the brain. It is well established in exposed cortex experiments that brain activity changes the brain surface optical properties in the near-ir, due both to changes in blood flow and to scattering from the brain cells. Several researches have proposed optical methods and the near-ir spectral region to measure brain function non-invasively with high temporal resolution and good localization. While the detection of slow (in the second time scale) changes of blood flow by the near-ir method is well-proven, the detection of optical changes associated with fast (in the 10–100 ms) neuronal signal has been a relatively small field practiced by few experts. Our research has shown that it is possible to increase by at least one order of magnitude the detection of the small changes associated with neuronal activity. Our technical developments and a new sensor could make this optical technique widely available and complementary to fMRI.

CWC4

3:30 pm

Polarization-gated Imaging Techniques Based on Time-resolved Stokes Vectors for Filament Tissues

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Biomedical imaging operation based on snake photons via time gating techniques, combined with polarization discrimination, has been proved useful for medical diagnosis. The polarization discrimination method is usually quite effective in tissues of statistically isotropic structures, which cause strong depolarization effects.