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High power swept source for Optical Coherence Tomography

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Abstract

Optical Coherence Tomography (OCT) is an interferometric technique that allows non-invasive depth-resolved imaging of scattering samples, like biologic tissue. It has found many applications in medical diagnostics, especially for retinal imaging in ophthalmology. A 2D or 3D-image is composed of many adjacent depth scans (A-scans), which can be acquired in different ways. In Swept Source-OCT (SS-OCT), a tunable light source probes the spectral response of the sample. Each sweep corresponds to one A-scan. Typically, swept sources are tunable external cavity diode lasers, which can allow for very high sweep rates (hundreds of kilohertz, even megahertz). The wavelength range around 1050 nm is interesting for imaging of the posterior eye (retina and choroid) due to low absorption and dispersion in water. (The probing light has to pass the vitreous twice.) However, light source development for this wavelength range is challenging. Typical semiconductor laser gain media provide relatively low output power. Furthermore, high chromatic dispersion in optical fiber limits the performance of the so-called Fourier domain mode-locking (FDML) technique which is the key to ultra-high sweep rates. We developed a novel swept source configuration featuring a tapered amplifier as gain medium providing abundant output power. We introduced an additional gain element into the resonator, and thereby achieved stable FDML operation, exploiting the full bandwidth of the gain media despite high dispersion. The light source operates at a repetition rate of 175 kHz with an average output power in excess of 30 mW. Buffering the output enables an A-scan acquisition rate of 350 kHz and hence recording high-resolution 3D-datasets in less than 3 seconds. With a total sweep range of 70 nm, we achieved an axial resolution of 13 μm in air (<10 μm in tissue) in OCT measurements. We demonstrated the feasibility of the light source by taking images of human retina in vivo. As our work shows, tapered amplifiers are suitable gain media for swept sources at 1050 nm with increased output power, while high gain counteracts dispersion effects in an FDML laser.

Keywords: optical coherence tomography, swept source, tunable lasers, semiconductor optical amplifier

Sebastian Marschall studied physics at the Technical University of Darmstadt and received his degree “Diplom-Ingenieur der Physik” (equivalent to MSc in physics) in 2008. He conducted his final project on frequency-swept laser light sources for optical coherence tomography at the Department of Photonics Engineering of the Technical University of Denmark. In 2008 he started a Ph.D. project at the Technical University of Denmark and is currently continuing the research on swept sources.