Towards MHz OCT for vocal cord imaging in the awake patient

Miroslav Zabic*,[1,2,3,4], James W. Napier[5], Lennart Müller-Wirts[2], Paul Neubronner[2], Sara Sharifpourboushehri[2], Sonja Johannsmeier[2], Walter Neu[5], Dag Heinemann[3,4,6], Alexander Heisterkamp[1], Tammo Ripken[2]

[1]*Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany*
[2]*Industrial and Biomedical Optics Department, Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany*
[3]*Institute of Horticultural Production Systems, Leibniz University Hannover, Herrenhäuser Str. 2, 30419 Hannover, Germany*
[4]*Hannover Centre for Optical Technologies (HOT), Leibniz University Hannover, Nienburger Str. 17, 30167 Hannover, Germany*
[5]*Institute for Laser and Optics, Hochschule Emden/Leer - University of Applied Sciences, Constantiaplatz 4, 26723, Emden, Germany*
[6]*PhoenixD Cluster of Excellence, Leibniz University Hannover, Welfengarten 1A, 30167 Hannover, Germany*

*E-mail: miroslav.zabic@hot.uni-hannover.de

Abstract: Laryngeal OCT imaging is challenging due to anatomy-dependent vocal cord position and motion artifacts caused by movements of patient and physician. We present a MHz OCT laryngoscope with variable working distance.

Keywords: MHz OCT, laryngoscopy

1. Introduction

There is a wide range of vocal cord disorders that require a biopsy for a definitive diagnosis since clear conclusions can often not be drawn from surface images of the diseased tissue alone. Surgical biopsy is an invasive technique that carries the risks of general anesthesia and irreversible damages of the vocal cords that can lead to permanent hoarseness and dysphonia. A noninvasive technique that has the potential to aid in diagnosing laryngeal lesions is optical coherence tomography (OCT).

Various OCT laryngoscopes have already been proposed in academic research. [1,2] A challenge that all devices have to face is the varying depth of the larynx that depends on patient anatomy and posture. In addition, involuntary movements of the patient (swallowing, breathing, head and neck tremors) and the physician (tremors of the hand holding the OCT laryngoscope) can cause image artifacts and move the vocal cords out of the OCT imaging depth. Acquiring OCT images of vibrating vocal cords can provide useful information [2,3] that can help distinguish between healthy and diseased tissue. However, these dynamic acquisitions usually also suffer from image artifacts due to the comparably slow acquisition rates of common OCT systems with maximum A-scan rates of 200 kHz.

Here we present an OCT laryngoscope system with an A-scan rate in the MHz range and a variable working distance.

2. Design of the MHz OCT Laryngoscope

Fig. 1 shows the mechano-optical layout of the curved MHz OCT laryngoscope prototype that is designed to provide optimal visibility of the vocal cords. A miniaturized camera is placed in the tip of the laryngoscope right next to the protective exit window of the OCT beam path. The curved tube, containing optical components for the OCT beam path, is 3D printed using the biocompatible printing material *PolyJet MED610* (Stratasys, Ltd., Eden Prairie, USA). It is attached to a box that contains a fiber collimator, alignment mirrors, liquid lens and galvanometer scanners. The size of the box enables easy beam alignment and cable management. Working distance adjustment is possible by varying the focus position of the OCT sample beam with the liquid lens and simultaneously adjusting the optical delay of the reference arm with a motorized stage. A FDML laser (λ_c = 1315.4 nm, $\Delta\lambda$ = 102 nm, NG-FDML, Optores GmbH, Germany) enables high-speed OCT imaging with an A-scan rate of 1.68 MHz.

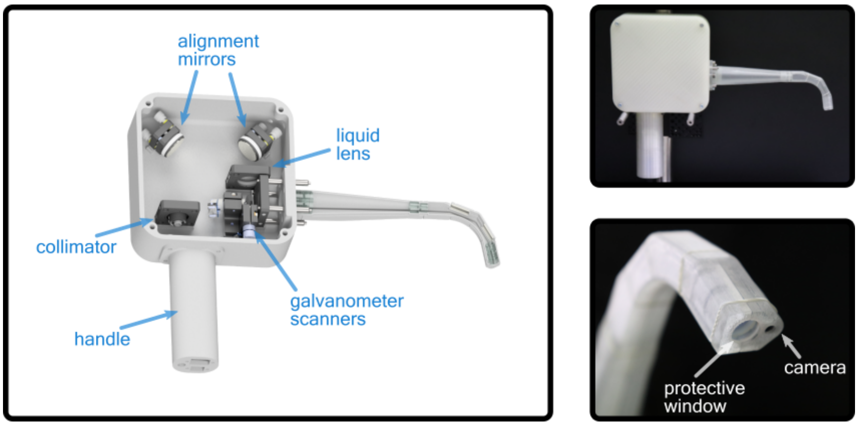

Figure 1 Left: Schematic overview of the MHz OCT laryngoscope. Upper right: A photograph of the actual laryngoscope placed on a stand. Bottom right: Close-up of the tip. The protective window is the last optical component of the OCT beam path. A miniaturized camera is placed in the tip next to the OCT beam path.

Ex vivo measurements on porcine laryngeal tissue demonstrate the system's general ability to acquire 3D OCT data as well as camera images. Fig. 2 shows OCT and camera images of a sample that was placed at a distance of 23 mm from the tip of the laryngoscope. Three-dimensional datasets are acquired at a rate of 12.8 volumes/s. By disabling the slow-axis scanner, 2D datasets can be recorded at a rate of approximately 3200 B-scans/s, which is sufficient to significantly reduce motion artifacts when capturing vibrating vocal cords.

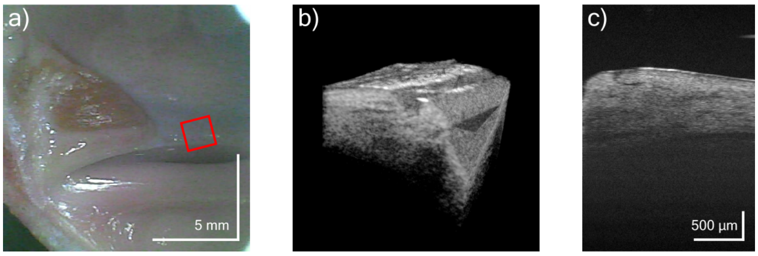

Figure 2 Ex vivo measurement of porcine laryngeal tissue with the MHz OCT laryngoscope. a) Image from the miniature camera showing the laryngeal tissue. The red square indicates the OCT scan area. b) 3D volume rendering of the acquired OCT data. c) OCT B-scan that was generated by averaging 16 adjacent B-scans from the acquired volume.

3. Conclusion and Outlook

We described a MHz OCT laryngoscope prototype that paves the way for in vivo imaging of human vocal cords. The high acquisition rate is suitable to reduce motion artifacts which makes it possible to acquire distortion free OCT images of vibrating vocal cords.

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