# Tracking Submicrometer Vibrations in Depth in the Glabrous Skin

Basil Duvernoy[1], Emma Kindström[1], Anders Fridberger[1] and Sarah McIntyre[1]

## I. Introduction

The perception of tactile events is a complex process. When the skin surface is mechanically deformed by an object, the deformation is transmitted through the skin to the mechanoreceptors, which facilitate mechanotransduction into the electrical spikes of the nervous system. The elicited spikes travel along the neuronal axon to the central nervous system, giving rise to tactile sensation. This work investigates the early stages of this process, the transmission and filtering of the mechanical signal that occurs in the skin.

Many studies link mechanical stimulation of the skin surface to the firing patterns of mechanoreceptive afferent neurons by using the microneurography technique to record neural spikes as they travel along the axon. Several studies have also tracked how the skin surface is deformed by mechanical stimuli. However, little is known about how deeper tissues of the skin behave in response to mechanical stimulation.

Here we present a system to track skin deformation when vibrations propagate up to $3.5\,\mathrm{mm}$ in depth in the skin. As an example, we show the result when the skin is exposed to a perceptible near-threshold $200\,\mathrm{Hz}$ sine wave vibration.

## II. Experimental Setup

The experimental setup comprises an actuator and a sensor (Fig.1a). The actuator is a vibrotactile transducer (Haptuator™ Planar, TactileLabs) capable of oscillating up to $500\,\mathrm{Hz}$. The sensor is an SD-OCT (Spectral Domain Optical Coherence Tomography) System (Thorlabs Telesto III TEL320C1) which records the optical spectrum of back-scattered light from the skin at $3.5\,\mathrm{mm}$ in depth with a high refresh rate ($10\,\mathrm{kHz}$) and a resolution of $5.5\,\mu\mathrm{m}$. A custom-made software application allows both devices to work synchronously, ensuring the capture of the pattern of oscillating deformation in the skin [1].

Since skin deformation smaller than a micrometer can be felt, we applied a phased-resolved technique to the OCT signal to measure skin deformations at this tiny scale, smaller than the size of the OCT image voxels [2].

## III. Results

Fig. 1b shows the morphological image of the area of interest, with anatomical landmarks that can indicate mechanoreceptor locations. The stimulus was an oscillation of $200\,\mathrm{Hz}$ with a peak amplitude of $2\,\mu\mathrm{m}$ lasting 1 second. It was repeated 20 times, one for each of the 20 scans shown in Fig. 1c. The 20 lines were linearly sampled from the area of interest shown in Fig. 1b.

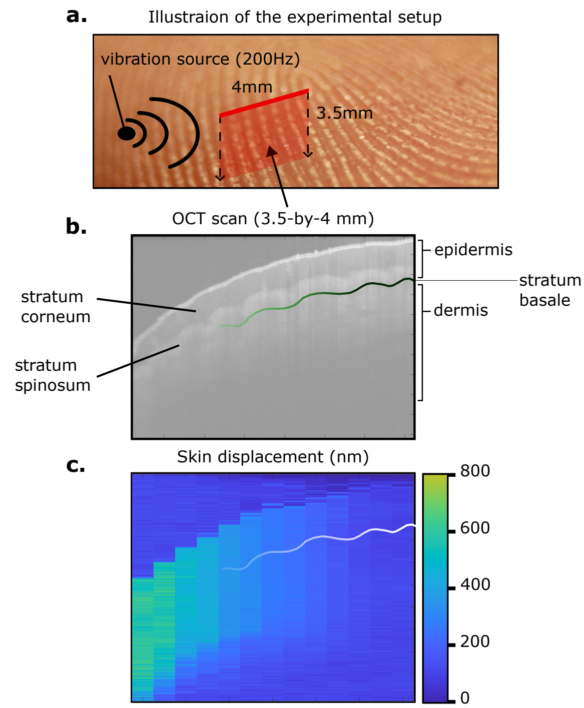


Fig. 1. From vibration actuation to skin displacement measurement: **a.** Illustration of the experimental setup; **b.** morphological OCT image of the glabrous skin; **c.** Measured displacement when the skin in *b.* is exposed to a $200\,\mathrm{Hz}$ sine wave vibration (the stratum basale has been drawn on top of the results).

## IV. Discussion

With this method, it is possible to track in-depth skin deformation that is smaller than what is perceptible [3]. This provides a potential estimation method for the skin transfer function at the limits of human perception, and in relation to the mechanoreceptors' location.

## References

[1] G. W. Burwood, A. Fridberger, R. K. Wang, and A. L. Nuttall, "Revealing the morphology and function of the cochlea and middle ear with optical coherence tomography," *Quantitative Imaging in Medicine and Surgery*, vol. 9, no. 5, pp. 858–881, 2019.

[2] B. J. Vakoc, S. H. Yun, J. F. de Boer, G. J. Tearney, and B. E. Bouma, "Phase-resolved optical frequency domain imaging," *Optics Express*, vol. 13, no. 14, p. 5483, 2005.

[3] S. J. Bolanowski, G. A. Gescheider, R. T. Verrillo, and C. M. Checkosky, "Four channels mediate the mechanical aspects of touch," *Journal of the Acoustical Society of America*, vol. 84, no. 5, pp. 1680–1694, 1988.

*Research supported by the Swedish Research Council, project grant to SM (2020-01085).

[1]B. D., E. K., A. F., and S. M. are with the Department of Biomedical and Clinical Sciences, Linköping University, SE-58183 Linköping, Sweden.