Designing a Coupled Common-Mode OCT Probe with a Voltage Electrode for Simultaneous Intracochlear Motion and Voltage Measurements in Guinea Pig

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Abstract

Background: Two of the most valuable data types for understanding cochlear mechanics in response to sound stimuli are motions of structures in the cochlea and outer hair cell (OHC) transduction currents and voltages. Optical coherence tomography (OCT) provides the ability to image and measure motion of structures within the organ of Corti complex (OCC) in vivo. There are physical, optical, and practical limitations currently preventing simultaneous motion and voltage data from being taken at the same location. We propose a coupled fiber optic/electrode probe that simultaneously records voltage and OCT-measured motion.

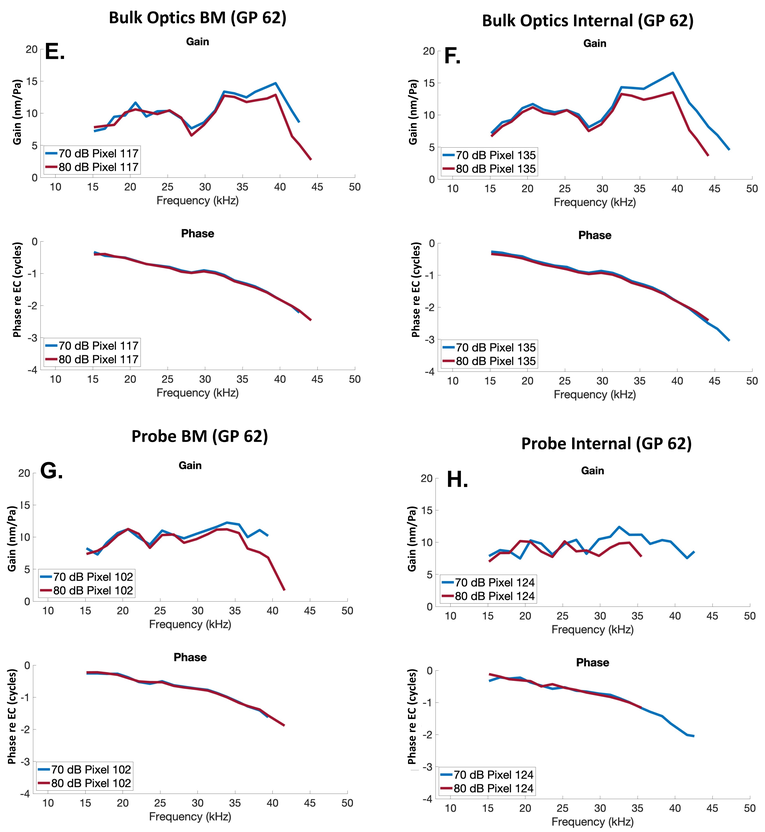
Methods: The proposed device consists of an insulated tungsten electrode glued to an OCT probe previously developed by our lab that has been adapted to use a common-path setup. This dual probe utilizes a fiber optic cable with a Graded Index (GRIN) lens (focal length of 325 µm in water) which is attached to a scanning piezoelectric bimorph. The distance between the fiber tip and the electrode tip is approximately 300 µm. To record data, the dual probe is situated in the scala tympani perilymph, scans above the basilar membrane, and records images and motion data of the basal Guinea Pig OCC in vivo. Motion and voltage data are taken with the scanner off.

Results: A prototype probe without an electrode imaged the base of the Guinea Pig OCC. Prototypes have also successfully combined the fiber and electrode; ex vivo experiments have shown that the presence of the electrode does not interfere with the imaging or scanning functionality of the piezoelectric bimorph.

Conclusions: The coupling of voltage and motion measurements this probe provides can offer insight into the intricacies of cochlear mechanics. By using the imaging capabilities, the electrode can be positioned at a precise and effective recording location close to the Basilar Membrane (BM) in the OHC region to measure local cochlear microphonic. Simultaneous motion and voltage data from the same location can offer insight into the feedback relationship between mechanical and electrical changes in the OCC.

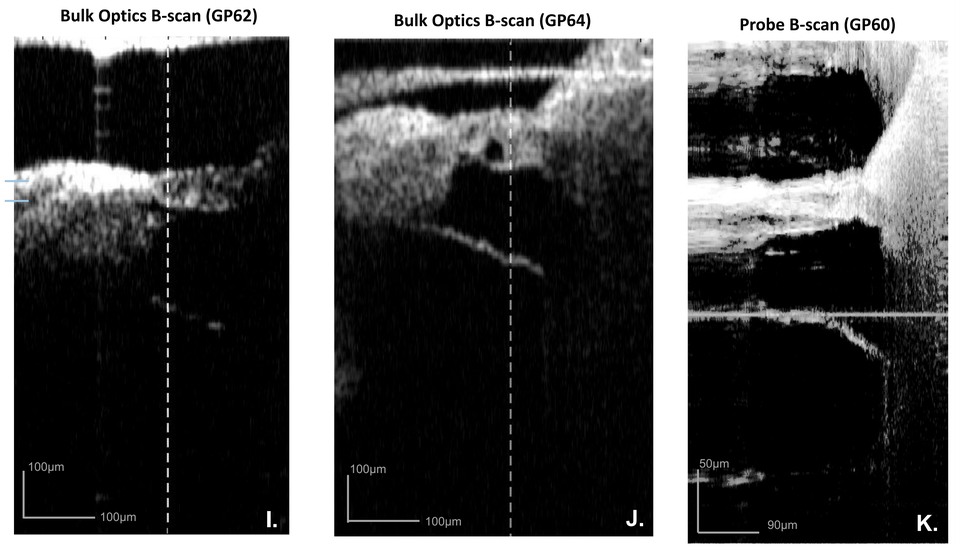
Motion Results:

- Responses measured with probe are like those measured with bulk optics



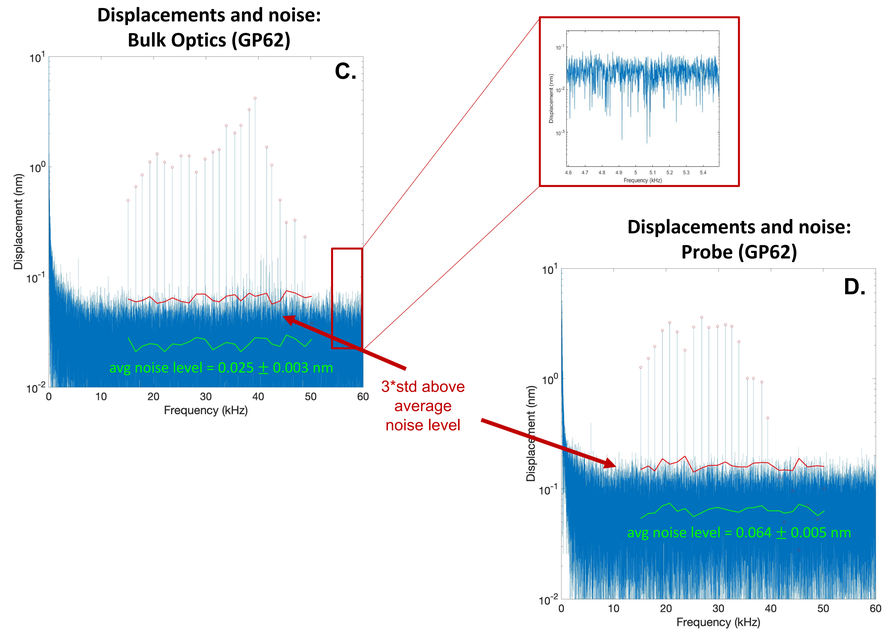
Imaging Results:

- Probe can image with scanning widths approximately 250-300 µm wide
- Probe scanning width calibrated by measuring bimorph displacement using Ronchi Rulers
- Depth in the image is also distance from probe tip to tissue
- Preliminary tests with voltage electrode have shown the electrode does not interfere with scanning/image

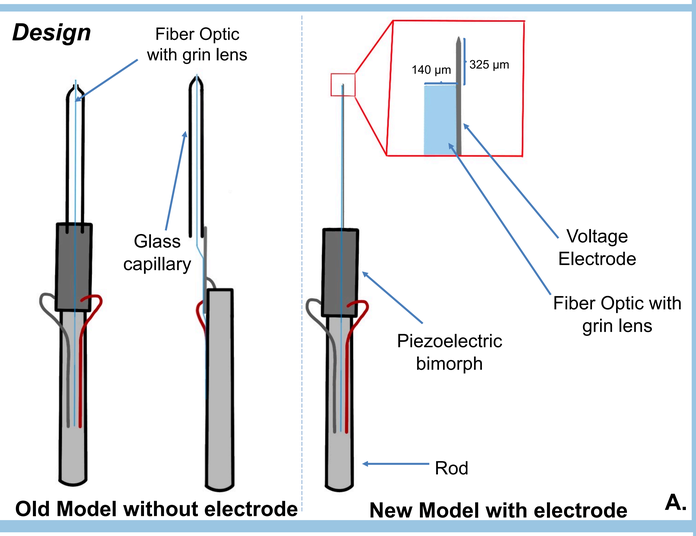


SNR Results:

- Prototype probe used for these measurements was constructed without voltage electrode
- Probe has been used to image and record motion through the round window membrane (RWM) in the Guinea Pig (GP) Cochlea
- Probe can record displacements which are out of the noise (> 3*std of the average noise)

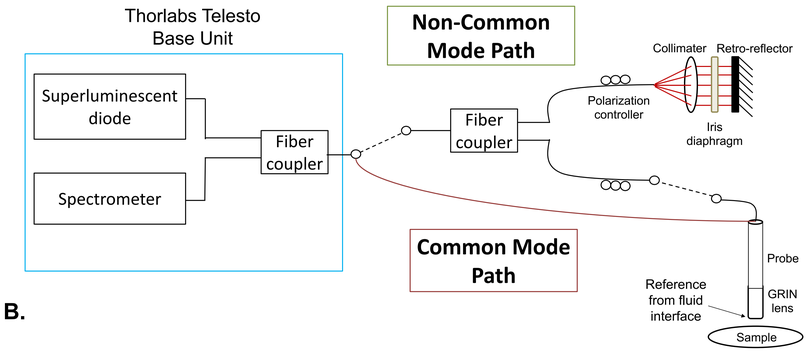


Design



Hardware

- OCT probe design (Lin 2019) utilizing only common-mode path for reference beam. Common Mode design uses reflection from the probe fiber/fluid interface as reference beam
- Voltage electrode offset in front of fiber optic by fibers' focal length in water (325 µm)
- Fiber utilizes Grated-Index (GRIN) lens to focus optical beam
- Non-common mode path is more complicated and found to be unnecessary



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References:

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