ACTION–Technologies for Cochlear Implants

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The aim of the project is to develop a novel type of cochlear implant. This is a medical device used to restore auditory sensations for hearing-impaired listeners. We use tiny laser diodes to generate soundwaves inside the fluids of the cochlea. Hair cells register these vibrations and send electric signal to the brain.

ACTION is a European Project combining the knowledge and experience of seven companies and research institutions in the fields of lasers, optics, electronics, medicine, biology, chemistry, implant technology and packaging. Such a wide spread of expertise is required to address all the challenges in developing long-term implantable devices. For example, lasers are delicate semiconductor devices. Exposing the lasers to the aggressive fluids of the body would destroy them long before the anticipated end of life of a cochlear implant (CI). Vice versa, the laser contains substances toxic to the human body. A biocompatible package is therefore mandatory. But, as every foreign body is slowly being encapsulated by fibrous tissue, the surface of the package has to be modified to slow down and minimize tissue encapsulation. Otherwise, the laser light will be absorbed by the encapsulation, reducing the efficiency of the implant over the course of several weeks, potentially to a level where the device becomes insufficient to generate hearing.

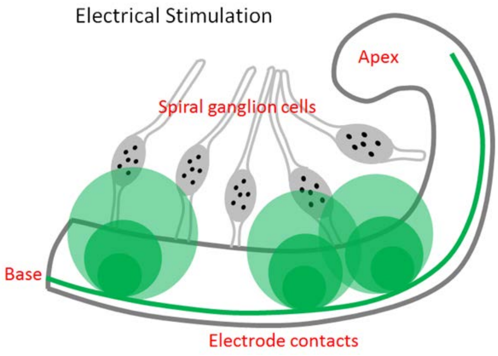

Figure 1: Schematic representation of a cochlear implant. The generated electric fields are depicted with green discs. The spreading of the fields leads to excitation of unwanted sound or tones.

Understanding the principles involved in optoacoustic stimulation helps appreciate the challenges involved. State-of-the-art cochlear implants use small electrodes placed inside the cochlea to electrically stimulate the (spiral ganglion) nerve cells, bypassing the hair cells (Figure 2). Patients suffering from severe hearing loss might not have these hair cells, but electrical stimulation might restore some hearing. Optoacoustic stimulation, on the other hand, relies on 'mechanically' stimulating the hair cells, which need to be present and functional. A focused burst of light from a laser was previously proven to generate sound waves in the cochlea fluids [1]. The sound wave, eventually, causes the hair cells to move, which sets in motion the process of generating and propagating electric signals to the brain (also referred to as Compound Action Potentials, or CAP). This sequence of events is identical to normal hearing. The condition, as above mentioned, is the presence of healthy hair cells. Consequently, a cochlear implant based on the optoacoustic effect cannot be a replacement for current cochlear implants. But they might be used in combination: Some CI users retain hearing in the low frequency region and can use a special speech processor including a hearing aid. However, this requires an earmould to be used, which is not always acceptable to the recipient. Use of the implantable laser developed in this project will allow sound transmission without an earmould.

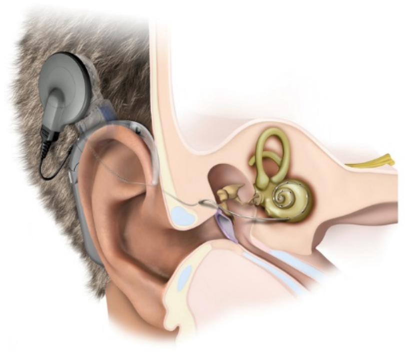

Figure 2: Conventional cochlear implant. Courtesy of MED-EL GmbH.

Optoacoustically generating CAPS depends on the system's ability to create soundwaves powerful enough to move the hair cells sufficiently. The amplitude of the sound wave is expected to increase monotonously with the laser intensity. Unfortunately, the current cannot be ramped up arbitrarily. The laser and the electric wires might heat, damaging neighbouring tissue. The laser might also get damaged by overheating. Combining the right materials and stimulation patterns, we recently managed to produce a CAP generated by specially designed VCSELS and microlenses [2].

This project helped CSEM to further its expertise in medical packaging with a focus on miniaturized devices. The technology is not limited to the cochlea, but can be used in all applications requiring miniscule biocompatible packages.

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[1] ACTION consortium, "Periodic Report Year 2" (website: www.action-project.eu).

[2] ACTION consortium, "First oaCAP Measurements" (website: www.action-project.eu).