Adaptive Multi-Electrode Positioning (AMEP) System For Chronic Extracellular Recording In Awake Behaving Primates

Dirk Hoehl[1], Uwe Thomas[1], Alexander Gail[2]

[1]Thomas RECORDING GmbH, Giessen, GERMANY
[2]German Primate Center, Goettingen, GERMANY

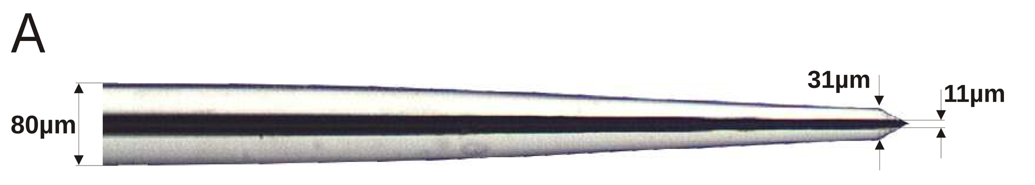
Bernstein Conference, Munich, Germany, September 12 - 14

Abstract:

Long-term extracellular recordings in awake behaving animals with implanted multielectrode devices are used for many years in neurophysiological research [1]. We have developed an chronic, yet adaptive electrode array that consists of a reuseable chamber insert and a xyz-manipulator (AMEP). The recording chamber insert uses 16 independent quartz glass insulated platinum-tungsten microelectrodes [2], which are well suited for chronic long term recordings [3]. The interelectrode spacing in the prototype is 1.5mm, smaller spacings resulting in a higher spacial resolutions are possible. Advantages over other multielectrode implant systems are that the AMEP xyz-manipulator allows a bi-directional microelectrode movements in depths with high mechanical precision and a total electrode travel distance of approx. 8-10mm. Further, the AEMP chamber insert has an integrated 16-channel preamplifier and a metal housing working as a Faraday cage that avoids electrical noise pickup from the laboratory environment. A good biocompatibility of our microelectrode technique reduces the risk of tissue damage and a gliosis around the electrode tip. The use of a secure electromechanical connection between the microelectrodes and the preamplifier input guarantees a low noise signal transmission.
A prototype of the AMEP has been successfullly used for transdural extracellular recordings in the cerebral cortex of awake behaving rhesus monkeys.

IMPLANTABLE ELECTRODES AND RECORDING CHAMBER INSERT

The AMEP chamber insert is equipped with up to 16 single-core microelectrodes as shown in figure 1, which are well suited for transdural extracellular recording. After Swadlow et al. [3] the quartzglass insulated platinum tungsten microelectrodes have a number of characteristics that make them very well suited for neural long-term recordings. The authors reported, that the platinum-tungsten alloy core has excellent recording characteristics and is virtually inert. The quartz insulation is very tough and, relative to other glasses, is very stable. And the very fine maximal outer diameter of these electrodes allow them to be funneled down very fine-diameter guide tubes for close electrode spacing, yet their stiffness generates a straight and predictable electrode trajectory.



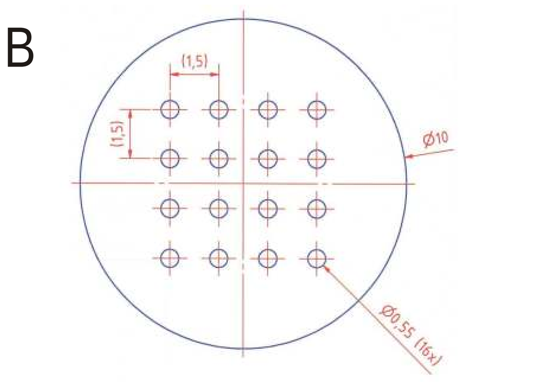


Figure 1: A) Quartz glass insultated platinum/tungsten microelectrode tip. An electrode with the above shown tip shape and dimensions has an electrode/tissue impedance of app. 2MOhm at f=1kHz. For details see Reitboeck, 1983. B) Drawing of the microelectrode array dimensions of the recording chamber insert. All dimensions are in millimeters. The electrode to electrode spacing is 1.5mm.

The microelectordes are arranged in a 4x4 array with an interelectrode spacing of 1.5mm. Each of the electrode moves bi-directional and independently in its own guide tube. The signals recorded with the microelectrodes are transmitted to the preamplifier input via a newly designed slip contact.

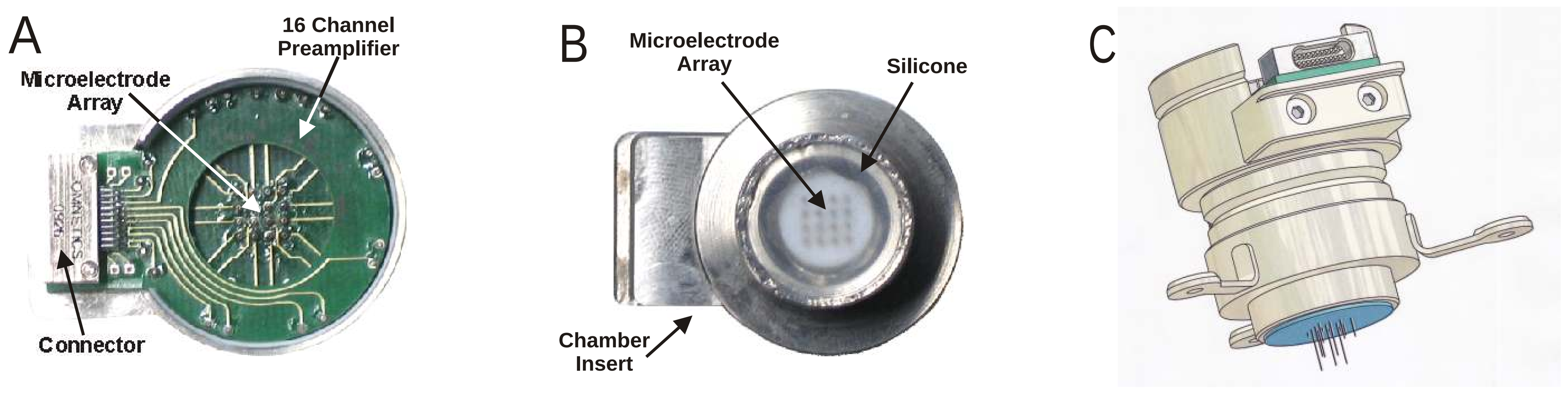


Figure 2: A) Top view on the recording chamber insert unit with integrated 16 channel electrode array and low noise preamplifier. B) Bottom view on the recording chamber insert. The insert is made of stainless steel. C) Recording chamber insert introduced in the stainless steel recording chamber.

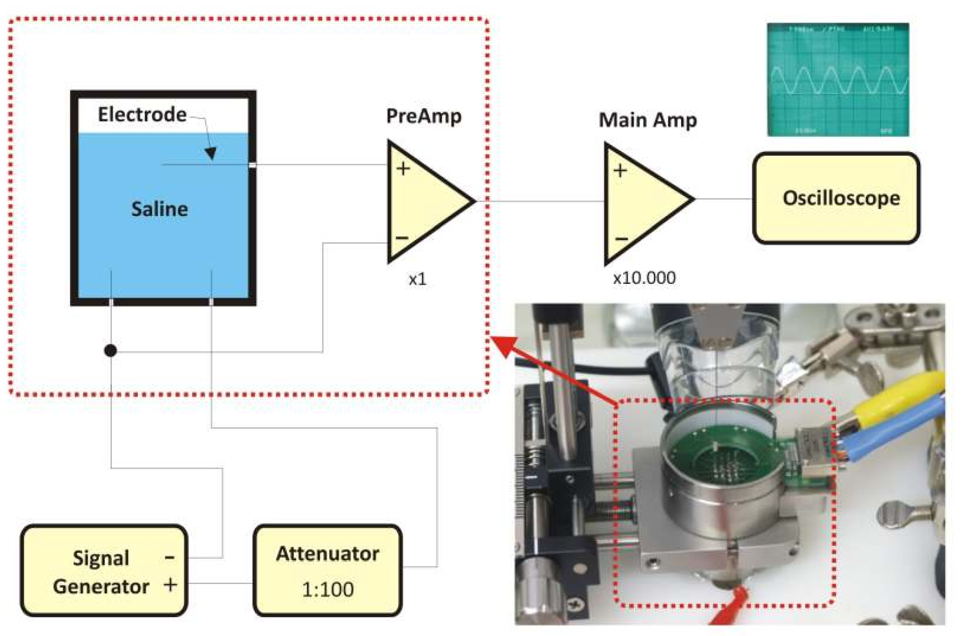
A 16 channel low noise preamplifier is integrated in the chamber insert. If the cover of the chamber insert is closed we have a complete metal shield around the electrode array and the high impedance input of the preamplifier. This avoids pickup of electrica noise from the laboratory environment and guarantees an optimal signal to noise ratio.

Figure 3: Size comparison of the recording chamber insert with a AAA size battery

The recording chamber insert is designed to be as small and lightweight as possible. Figure 3 shows a size comparison of the AMEP recording chamber insert with a AAA size battery. The weight of the chamber insert with cover and preamplifier is approximately 50g. The used materials guarantee a high reusability of this recording device.

The travel distance of each microelectrode is app. 8-10mm. The microelectrodes pass a thin sheet of medical grade silicone before they penetrate through the intact primate dura. The silicone seals the microelectrode shaft and avoids that fluids like liquor cerebrospinalis or blood enter the electrode guide tubes and the bottom of the chamber insert. The silicone sheet together with the dura serve also to stabilize the microelectrode in their vertical position after penetration.

Figure 4: Test of the recording chamber insert under real test conditions. We have used an electrolytic trough setup to test the recording performance of the chamber insert unit. This test showed, that the slip contact of the microelectrodes guaranteed a very good signal transmission between the electrode and the preamplifier input. The output connector exiting the chamber insert provides access to the low impedance signal output of the unity gain preamplifiers. The resulting low source impedance signals are connected to the following main amplifier provided off the animal. The seal on the bottom of the chamber insert is achieved with a medical grade silicone sheet. The microelectrodes penetrated this silicone sheet without problem. The microelectrodes are stiff enough to penetrate the intact dura of a monkey, if the dura is freshly prepared or kept soft by regular scraping.



MOTORIZED XYZ-MANIPULATOR

For a bi-directional independent repositioning of individual microelectrodes the AMEP is equipped with a newly developed motorized xyz-manipulator (Figure 5). The manipulator can be removed from the chamber and when electrodes are not moved.

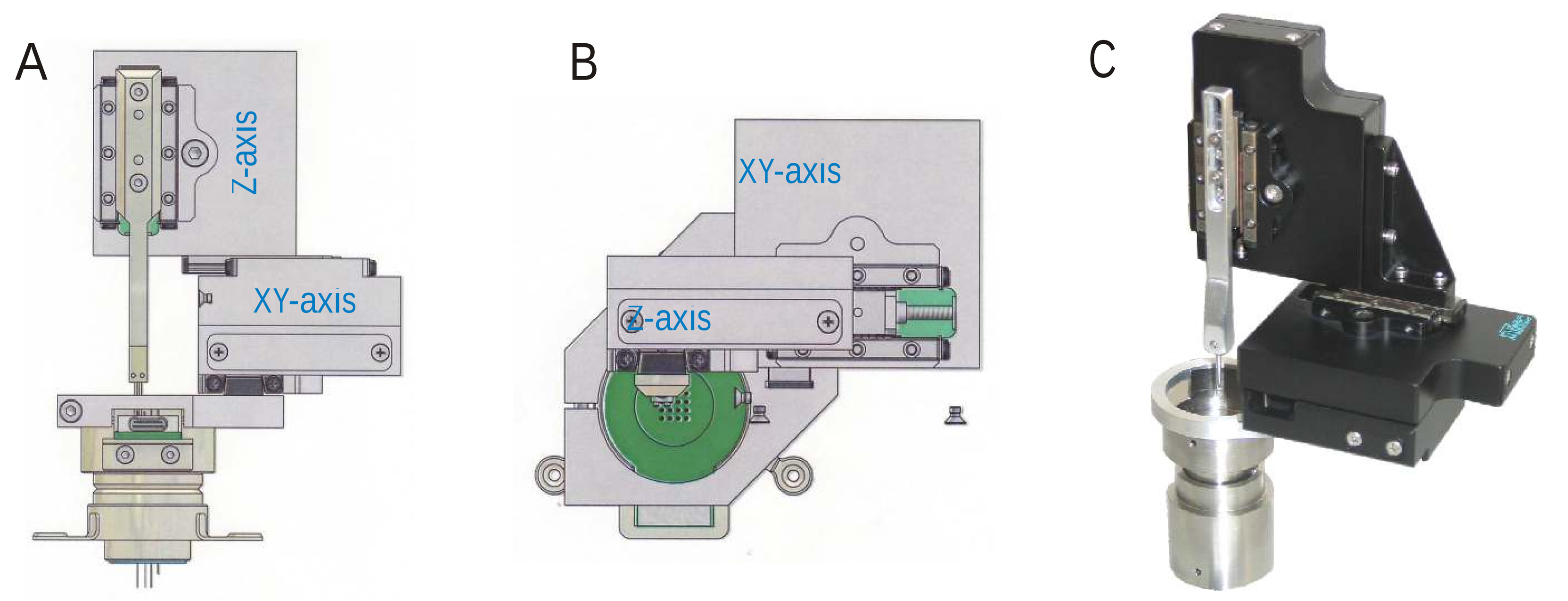


Figure 5: Overview drawing of the AEMP xyz-manipulator A) side view of the xyz maniuplator mounted to the AEMP chamber insert. B) top view of the drawing in A). C) shows a photo of the motorized xyz-manipulator prototype that is able to reposition each of the 16 microelectrodes in two directions (up and down) along the z-axis.

Precision positioning testing of the motorized xyz-manipulator was conducted using different standard test methods. Positioning tests showed an accuracy of better than 5µm for each motorized axis in the test setup.

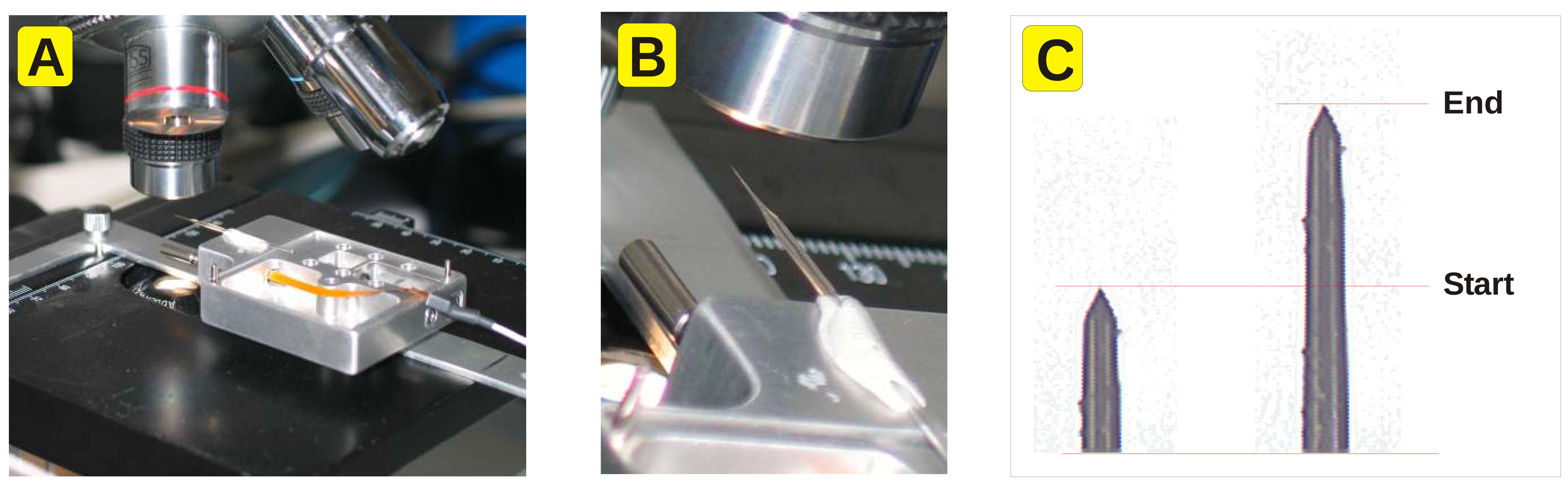


Figure 6: Positioning accuracy test A) The positionig accuracy of each axis of the xyz manipulator was tested under microscopic control. B) The tip of an electrode was used to measure the axis position with the microscope. C) Start and end position of the electrode tip was measured with the help of a software tool.

EXAMPLE RECORDING IN AWAKE MONKEY

Example of multi-unit broad band data recorded with AMEP in an awake monkey with a previously implanted conventional recording chamber. A simple k-means cluster algorithm demonstrates well-isolated single unit recordings.

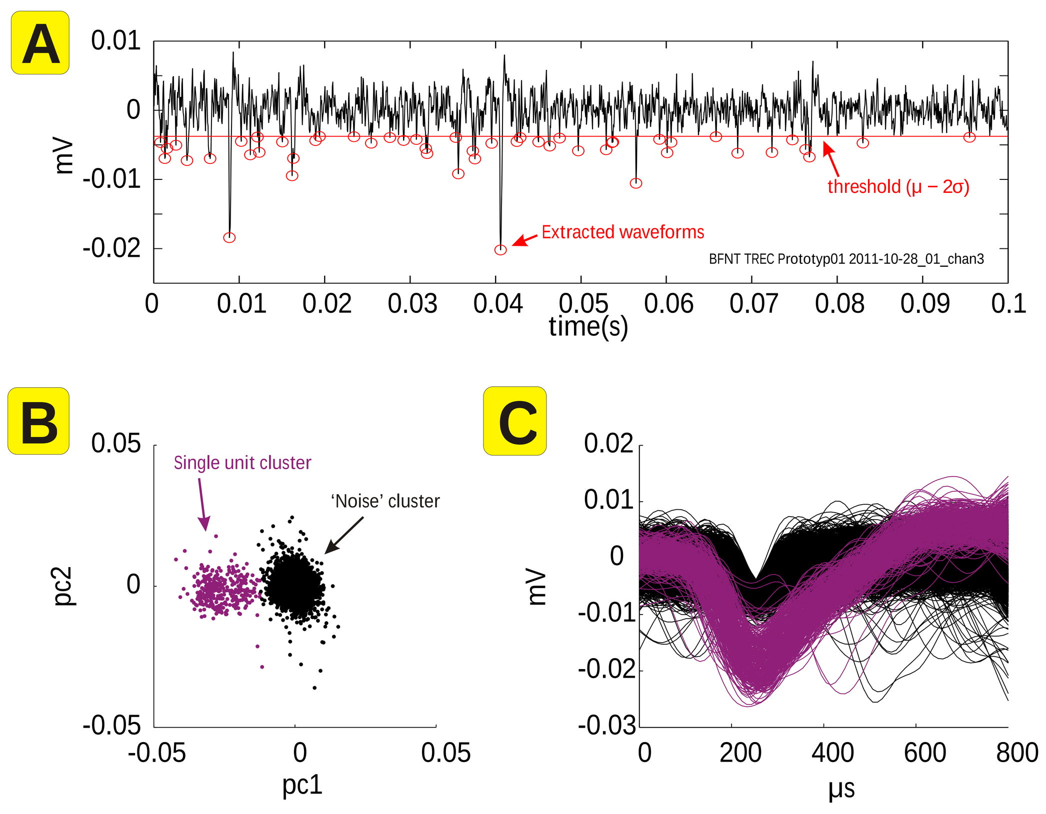


Figure 7: A) Example of broadband multi-unit (MUA) data recorded from a AMEP channel in the parietal cortex of a rhesus monkey at approx. 6mm depth below cortical surface. A amplitude threshold was applied (red line) and all signals that exceeded such a threshold were extracted and defined as events (red circles). Note that such events consisted of putative single units as well as noise. B) Each waveform extracted as above was plotted in principal component space yielding two clusters: a noise cluster (black dots) and a signal cluster (violet dots). Cluster identification and separation was achieved using the k-means algorithm. C) Once cluster separation was achieved, the corresponding waveforms could be sorted automatically as belonging to the single-unit cluster (violet) or the noise cluster.

DISCUSSION:

The AMEP is a new method for simultaneous extracellular recording of larger numbers of cortical neurons in awake behaving primates. This technique has major advantages over existing methods. Using the AMEP, it is possible to independently reposition each of the 16 microelectrodes vertically in two directions with high spatial resolution. Bi-directional movements allow implementation of automated positioning algorithms [4]. The microelectrodes have very fine tips reducing tissue damage and offering optimal recording performance. The material combination of the microelectrodes (e.g. platinum-tungsten, quartz glass) has a high biocompatibility and is therefore well suited for chronic recording applications. The chamber insert is made of stainless steel so that the noise sensitive high impedance recording front end is shielded like a Faraday cage against electrical noise pickup from the lab environment. This offers optimal signal-to-noise ratio for the extracellular recorded neural signals. A medical grade silicone sheet seals the bottom of the chamber insert so that fluids (e.g. liquor cerebrospinals, blood) cannot enter the electrode guide tubes. The chamber insert is reusable. Due to the transdural microelectrode positioning there is no need to remove the dura mater. After recording all electrodes can be withdrawn in the chamber insert so that the insert can easily be replaced by another one to reestablish recordings with a new chamber insert. The AMEP xyz-manipulator is required for initial microelectrode placement and for readjustment of the microelectrode recording position if it should be required. All components of the AMEP were verified under bench conditions. The chamber insert has been successfully applied to cortical transdural recordings in a rhesus monkey. During the recording session well isolated single units have been recorded on individual channels.

CONCLUSION:

The newly developed AMEP will allow precise microelectrode repositioning in chronic preparations with an electrode travel distance suitable for extracellular chronic recordings even from non-surface areas in the cerebral cortex of non human primates. The bi-directionality of movement opens the potential to fully automatize the electrode positioning with signal-driven control algorithms.

REFERENCES:

[1] deCharms et al. ; A multielectrode implant device for the cerebral cortex; J Neurosci Methods 93: 27-35; 1999
[2] Reitboeck, H.J.; Fiber microelectrodes for electrophysiological recordings, J Neurosci Methods 8:249-62, 1983
[3] Swadlow, H.A. et al. ; A multi-channel, implantable microdrive system for use with sharp, ultra-fine "Reitboeck" microelectrodes; J Neurophysiol 93: 2959–2965; 2005
[4] Chakrabarti, S. et al. ; Expert-like performance of an autonomous spike tracking algorithm in isolating and maintaining single units in the macaque cortex. J Neurosci Methods 205:72-85.

Acknowledgement:

This work is supported by BMBF grant 01GQ0820 to A. G. and Thomas RECORDING GmbH.