Performing Deep Brain Stimulation and neural recordings at the same target from awake animals: a new bidirectional wireless device

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1. Rational

Although deep brain stimulation (DBS) has been proven to be an effective treatment for several neurological and psychiatric disorders, including Parkinson's disease (PD), dystonia, epilepsy, depression, and obsessive-compulsive disorder, the underlying mechanisms are still unknown. This lack of knowledge could be surmounted e.g. by employment of a suitable micro-stimulation system adapted for chronic DBS in small laboratory animals. Conventional neural recording systems restrict behavioral experiments to a flat indoor environment compatible with the cable that tethers the subject to the recording instruments. To overcome these constraints, we developed a wireless multi-channel system for brain stimulation and neuronal activity recording in freely behaving small animals.

2. Technology

The wireless technology consists of special implantable microelectrodes, an implantation technique and a wireless stimulation and recording device hard- and software.

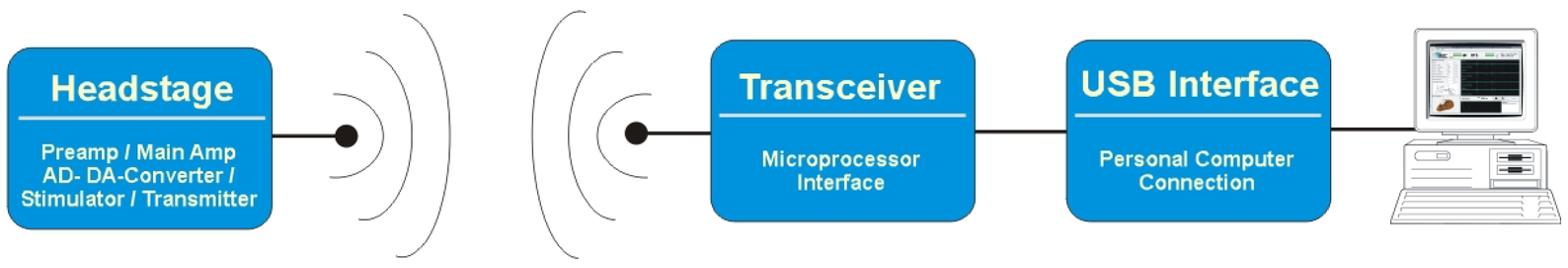


Fig. 1: Block diagramm of the wireless recording/stimulation system

Fig. 2: Headstage of the wireless system

The wireless headstage (see figure 2) contains a 4 channel pre- and main amplifier with software programmable gain selection (x200, x400, x800, x1600, x3200, x6400, x12800) and an analog to digital converter that digitizes the recorded data. The system is available with a fixed filter setting for LFP or spike recordings. The stimulator circuit has a maximum output current of 1250µA. The constant-current stimulator output is software configurable (e.g. biphasic or monophasic pulses, pule timing, constant current value, etc.). The transceiver is connected to a PC USB-port and receives the recorded data from the headstage and sends it to the data acquisition software. The transceiver sends the data from the stimulator software to the constant current stimulator in the headstage.

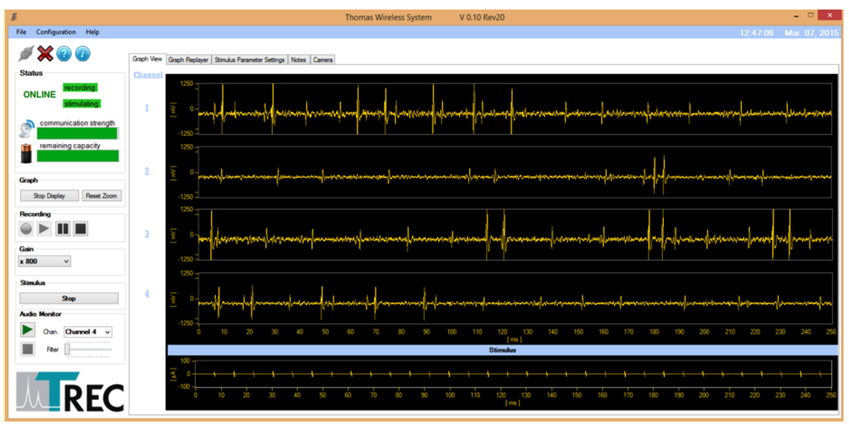


Fig. 3: Graphical User Interface of the wireless system control software

The graphical user interface of the wireless system control software allows a complete configuration of the stimulation signal. We have designed this interface so that all parameters of a stimulus pulse can be changed. The stimulation parameters can be changed while the animal is moving in the cage. This is helpful if the optimal stimulation parameters (e.g. threshold) have to be determined. The system allows biphasic or monophasic constant current stimulation with up to +/- 625µA. Complete pulse trains can be configured.

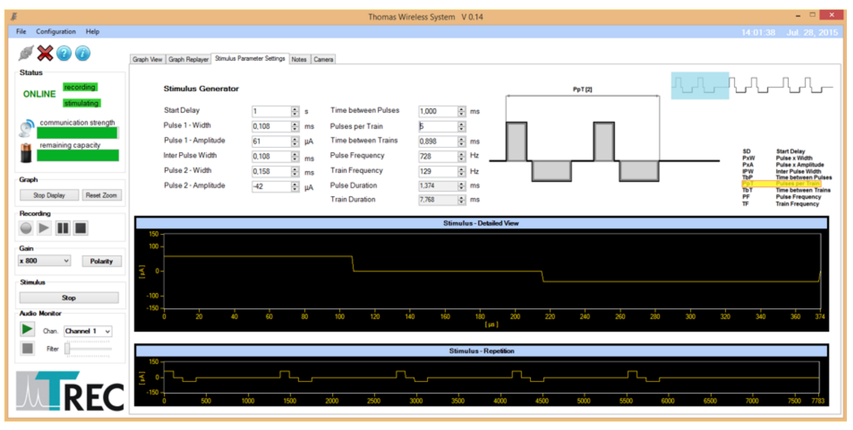


Fig. 4: Graphical User Interface of the wireless system control software: stimulation interface

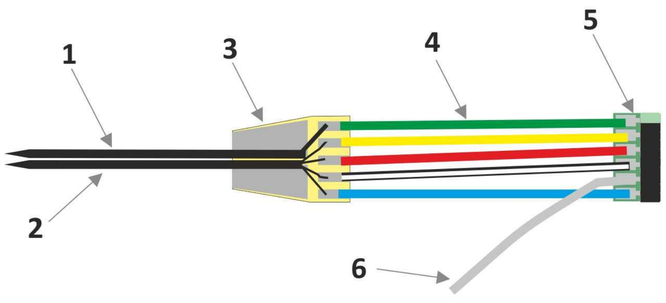
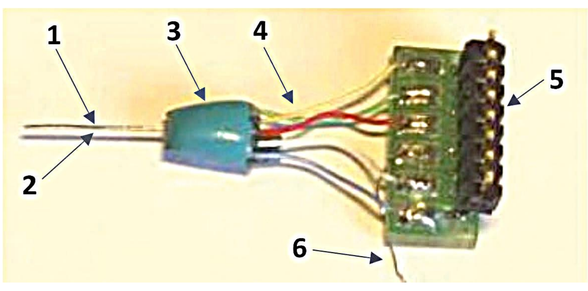


Fig. 5: Drawing (left side) and photo (right side) of an implantable Thomas microelectrode. (1) recording electrode/tetrode, (2) stimulation electrode, (3) circuit board, (4) connection cables, (5) connection board for the headstage, (6) reference wire



3. Method

The electrodes are implanted under physiological control by using a special designed preamplifier connected to a physiological recording system. When the electrodes record signals with optimal S/N the electrode unit is fixed to the skull with cement.

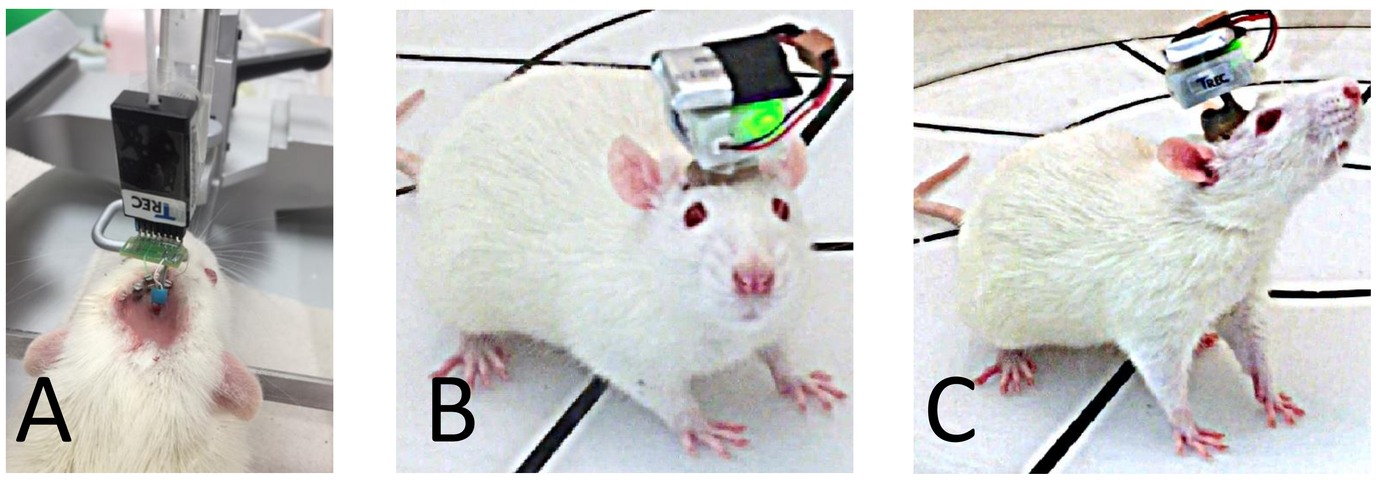


Fig. 6: (A) Implantation of the electrode unit under physiological control by using a special designed preamplifier.

(B) and **(C)** Wireless system headstage with battery pack mounted on the implanted electrode unit. The battery pack allows a continuous system operation for about one hour. The weight of the wireless headstage is 3.9g (without battery) and the size is 23x21x10 millimeters. The animals did not show problems with the weight or size of the wireless system.

4. Conclusion

- The wireless headstage works **bidirectionally**, means it can electrically stimulate neurons in the environment of the electrode and simultaneously record the neural response to the stimulus.
- The electrode unit and the implantation technique that we have developed is highly **reproducible** design and guarantees **reliable** stimulation and recording results.
- The wireless headstage is **small and lightweight** works **without cable** connection to the animal and does not influence the animal in his normal behavior
- The neural response can be recorded during presentation of acoustic, visual, olfactory, tactile stimulation or pharmacological stimulation
- The wireless system has a **wide operation** range of 5m
- Stimulus parameters can be changed “on the fly” while the headstage is connected to the animals.

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