A simple, robust, low-cost respiratory trigger unit for imaging rodents in whole body clinical scanners

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1 Introduction

Animal experiments are a fundamental and increasingly important aspect of modern pharmacological and disease related research. The rodents are usually anaesthetized by, e.g., isoflurane but are still spontaneously breathing which can cause severe motion artifacts.

To suppress these artifacts from periodic motions, usually trigger systems (ECG, breath belt) are used. However, for small rodents the respiratory detection system with clinical human whole body MR scanners is usually too insensitive and an alternate motion detection and trigger generation unit is necessary. Instead of electromagnetic sensitive piezo detectors [1] or mechanically difficult setups like in [2] we decided to construct a felxible optical sensor to monitor respiratory motion without any electronics inside the scanner RF cabin. This avoids all RF and gradient related interference as well as image degradation due to RF emission caused by analog-digital converters.

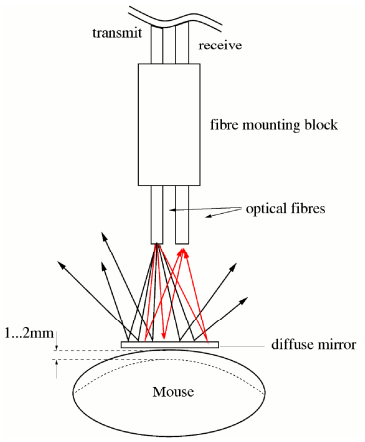

Figure 1: Optical motion detector: Light from the transmit fiber is reflected on a diffuse mirror. The light intensity coupling into the receiving fiber depends on the distance between fiber and mirror.

2 Material and Methods

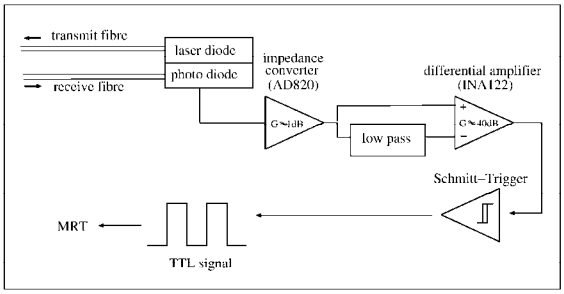

Figure 2: Detector circuitry outside the RF cabin.

The main components of the motion detection sensor are displayed in Fig. 1: Visible light (655nm) from a laser diode is coupled into a glass fiber which leads to the animal in the scanner. A small mirror with a diffuse reflective surface is glued onto a moving animal part to reflect the light back to a second, identical, receiving fiber which guides the light back outside the RF cabin to the receiver circuit. A photo diode converts the light into an electrical signal. This signal is stabilized by an impedance converter and the overlaying small offsets and slow signal drifts are suppressed by the difference amplifier (see Fig. 2). The Schmitt-trigger then generates the TTL signal for the MR scanner.

The motion detector has an additional connector prior to the Schmitt-Trigger which can be used in conjunction with an oscilloscope for biomonitoring the respiration of small rodents under anaesthesia.

3 Results

The motion detection sensor works in a distance range up to 5 mm between the mirror and the optical fibers and is very sensitive even to submillimeter motion. First in-vivo experiments in a 3T clinical whole body scanner with mice demonstrated that the trigger strongly improves image quality (see Fig. 3) of abdominal MR images by suppressing effectively respiratory related motion artifacts. Cine-series resolving the motion phases are also possible (not shown).

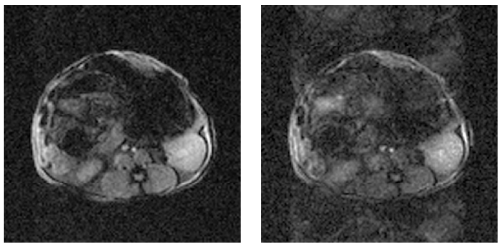

Figure 3: FLASH 2D gradient echo sequence with triggering (left), and without trigger (right). The imaging parameters are kept the same to achieve a comparable contrast: TR$\approx$ 500 ms, TE=15 ms, voxel size 0.31 mm $\times$ 0.31 mm $\times$ 2 mm.

4 Discussion

Separation of the trigger device into a purely optical sensor inside the scanner and a robust analog circuit outside the RF cabin prevents image degradation as well as RF and gradient influence on the motion signal. The optical motion sensor has to be placed very close ($\approx$ 2 mm) to the object, which can be easily achieved with a small flexible arm (goose neck) which also protects the sensitive fibers. Due to the high motion sensitivity even the tail base of a mouse, which is easily accessible in a dedicated tubular mouse coil, induces enough signal for successful triggering. Any singular motion events or changes in lighting will be compensated by the drift compensation.

In summary, sensitive optical motion detection is possible with the presented system. The electronic circuit is very simple and robust and the output trigger signal can be used with any trigger-enabled sequence on the scanner.

[1] Sato, S., et al. *Med Biol Eng Comput*, 2006. 44(5):353–362.

[2] Fishbein, K. W., et al. *Magn Reson Imaging*, Jul 2001. 19(6):881–889.