Detection of magnetic fields from the heart with an optical magnetometer

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The functioning of human organs such as the brain, heart and nervous system is based on conduction of electrical signals. Ionic currents in those organs generate magnetic fields which extend outside the human body. Non-invasive detection of such bio-magnetic signals with a magnetic field sensor placed outside the human body can be useful for medical diagnostics.

We have developed an optically-pumped magnetometer (OPM) based on cesium atomic vapor kept in a mm-sized paraffin-coated glass container. Our magnetometer is operated at room- or human-body temperature and is perfect for biological measurements. In one experiment, we detected the magnetic field from a nerve impulse propagating in an isolated animal nerve [1]. In a second experiment, we detected the heartbeat of an isolated guinea-pig heart. In our recordings of the magneto-cardiogram (MCG) [Fig. 1], we observe in real-time the P-wave, QRS-complex and T-wave associated with the heartbeat. Further biomedical studies will be conducted in order to determine the diagnostic value of OPMs in (fetal) cardiology.

It has recently been proposed to image the electrical conductivity of the heart with an array of OPMs [2]. This is challenging as the conductivity of the heart is low (≈ 0.2 S/m). As a step towards imaging the heart conductivity, we have imaged low-conductivity phantoms (salt-water with conductivity in the range 4-16 S/m) using a novel and highly sensitive technique based on OPMs. The long-term goal is to detect and localize conduction disturbances in the heart which is the cause of cardiac arrhythmia such as atrial fibrillation.

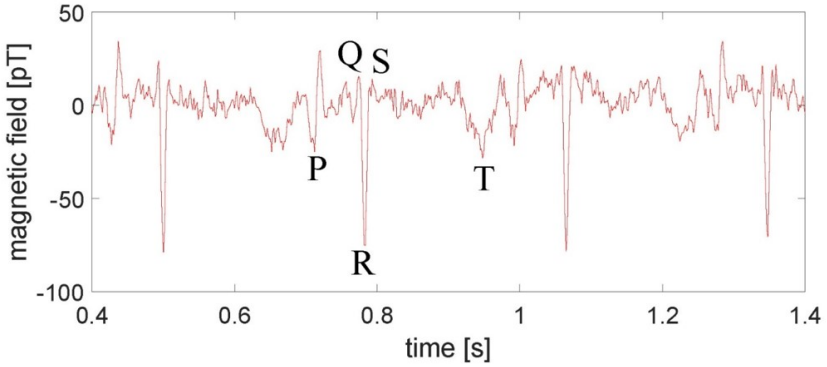

Figure 1. Real-time measurement of the magnetic field from a beating animal heart.

[1] K. Jensen et al., Non-invasive Detection of Animal Nerve Impulses with an Atomic Magnetometer Operating Near Quantum Limited Sensitivity, Scientific Reports **6**, 29638 (2016).
[2] L. Marmugi and F. Renzoni, Optical Magnetic Induction Tomography of the Heart, Scientific Reports **6**, 23962 (2016).