Magnetocardiography and magnetoencephalography as applications for OPMs

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Electrophysiological processes in the human body such as heart or brain activity lead to electrically and magnetically measurable signals. Hardware is much simpler for the recording of electric signals, but the small magnetic signals of the human body (typically 10 fT to 100 pT) contain additional information. Therefore, superconducting quantum interference devices (SQUID) have been used for the last three decades to measure patterns emanating from human electrophysiology. SQUIDs have several disadvantages such as the need for cooling, fixed multichannel layout, and large source to sensor distance. New magnetic fields sensors are constantly improving with optically pumped (atomic) magnetometers (OPM) leading the field. Two applications, magnetoencephalography (MEG) and magnetocardiography (MCG), have been experimentally demonstrated with OPMs [1]. For the investigation of brain function by MEG the advantages of OPMs appear to be almost disruptive to SQUID technology leading to high ranking scientific publications such as [2]. Irrespective of the differences between SQUIDs and OPMs the need for magnetic shielding to measure fields in the fT to pT range remains. This is visualized in Fig. 1, where the panels show MCG data measured in a two-layer Ak3b magnetically shielded room (left) and in the seven-layer BMSR2 room (right). Depending on the sensor orientation a strong slow background is observed in the Ak3b (left, lower panel), whereas the background is flat in the BMSR2 (right panels).

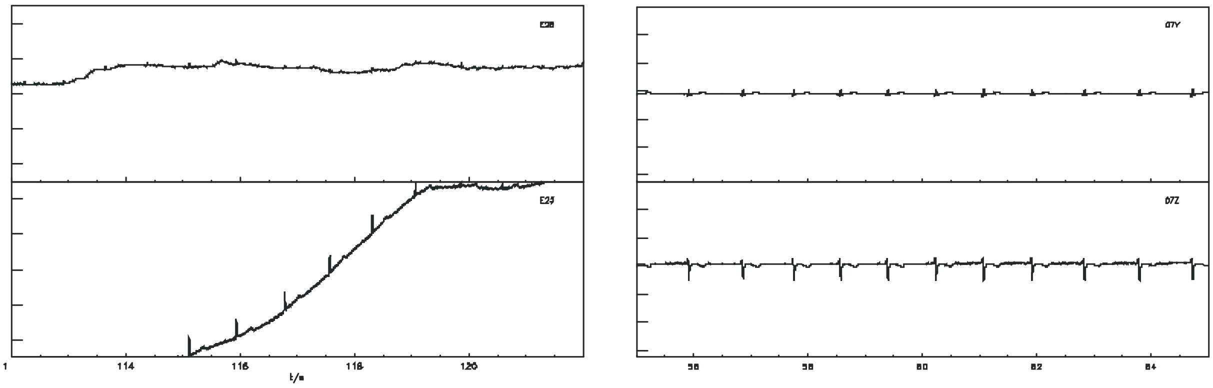

Figure 1. MCG data measured using commercial SERF OPMs in a two layer magnetically shielded room (left) and in a seven-layer room (right).

For commercial single sensor OPMs companies in the United States are clearly leading, but many unexplored sensor principles and properties allow plenty of opportunities for additional contributions to the field. Theoretical studies [3] indicate benefits if sensors are further improving to enable a SNR better than SQUIDs. Gradiometers with a balance better than 0.1 % might be part of the solution for the DARPA challenge [4], which asks for operation of OPMs in the Earth field at fT noise performance.

[1] Sander TH, Preusser J, Mhaskar R, Kitching J, Trahms L, Knappe S (2012) Magnetoencephalography with a chip-scale atomic magnetometer. Biomed Opt Express. 3: 981-90.
[2] Boto E, Holmes N, Leggett J, et al. (2018) Moving magnetoencephalography towards real-world applications with a wearable system. Nature doi:10.1038/nature26147.
[3] Iivanainen J, Stenroos M, Parkkonen L (2017) Measuring MEG closer to the brain: Performance of on-scalp sensor arrays. NeuroImage 147: 542 – 553.
[4] DARPA HR001117S0025 (2017) Atomic Magnetometer for Biological Imaging In Earth's Native Terrain (AMBIIENT). March 29, 2017 (Amendment No. 01: As amended through April 13, 2017)