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Miniaturized and Integrated Optically Pumped Magnetometer for Biomedical Applications

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We present a compact and integrated optically pumped atomic magnetometer (OPM) developed for high-sensitivity biomedical applications. This device, based on a Spin-Exchange Relaxation-Free (SERF) atomic magnetometer configuration, demonstrates a sensitivity of 20 $fT/\sqrt{Hz}$ with a bandwidth of 1 to 80 Hz. The miniaturization of the magnetometer is achieved through the integration of an elliptically polarized single-beam optical path, utilizing a 5 mm × 5 mm × 5 mm Rb vapor cell. The compact design of device, with a total volume of 0.45 cm^3, allows for flexible deployment in various biomedical scenarios, including wearable applications. In experimental setups, the device is positioned within 4 mm of the biological tissue, ensuring optimal signal acquisition.

Our system has been successfully applied to non-invasive magnetoencephalography (MEG) in small animals, detecting rat auditory evoked magnetic fields with high fidelity[1,2]. Additionally, the magnetometer has been utilized for real-time monitoring of drug-conjugated magnetic nanoparticles (Fe_3O_4) in live mice, facilitating the assessment of drug release dynamics[3,4]. This capability has proven invaluable in drug delivery research and monitoring of biophysical processes in vivo. Furthermore, our device demonstrated its potential in studying neural activity in Drosophila, detecting oscillatory brain activity associated with visual salience. Finally, we presented a brain-computer interface (BCI) approach that uses our OPMs-based MEG associated with motor imagery (MI) for the synchronous operation of a brain controlled virtual drone in three-dimensional space [5].

The compact and portable nature of the developed OPM, along with its high sensitivity and non-cryogenic operation, make it a promising tool for advancing biomedical research, including applications in neuroscience and drug monitoring. Future work will focus on optimizing the sensor array for multi-channel measurements, obtaining the complete vector information of the magnetic field and enhancing real-time data processing to accommodate dynamic biomedical environments.

References:

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