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(G*) An Enhanced Nickel Opto-Magnetic Interference Sensor (ENOMIS) for Time-Resolved Magnetic Field Measurements of Transcranial Magnetic Stimulation (TMS) Coils

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A magnetometer that has a high temporal (≤1 ns) and a high spatial (≤1 mm) resolution, a large magnetic field range (0–0.5 T), and that does not perturb the magnetic field requires an innovative and unprecedented design. Such a magnetometer is key, for example, to measure magnetic fields produced by transcranial magnetic stimulation (TMS) coils used to neuromodulate the brain in the treatment of various psychological and neurological disorders, such as major depressive disorder, Parkinson's disease, etc. TMS coils placed against the head of a patient produce rapid and intense magnetic field pulses that induce electric fields in the brain, stimulating or inhibiting neural activity for therapeutic applications. With time-resolved magnetic field measurements, time resolved electric fields can be calculated. Various TMS studies investigate the therapeutic impact of varying the frequency, intensity, and burst count of the pulse, but are limited in studying the time-resolved pulse shape and its ability to neuromodulate. To date, only peak electric fields generated by the coils are measured. Electric field or magnetic field pulse shape can be inferred from the current applied but have not been verified. Since neuron action potentials have temporal pulse shapes unique to their neural task, an important but unanswered question in TMS research to date is how the TMS temporal pulse shape impacts the efficacy of the therapy.

In this work, we present the design and construction of a fiber-based magnetometer (ENOMIS) based on the magneto-optic Kerr effect and Fabry-Perot interferometry. Our solution is based on a nickel and dielectric material multilayer deposited onto the tip of an optical fiber. Kerr rotation of 0.4° typical of air-nickel interfaces does not provide a significant SNR for resolving the typical 1-µs-wide TMS pulses in a single acquisition. Our results show that the Fabry-Perot nanoscale multilayer cavity theoretically can increase the Kerr rotation by over 1000 times. Other studies achieve good SNR at fast and ultrafast time scales, but are limited to small magnetic field ranges, unlike the 0 –0.5 T range presented in this work. Temporal resolution of ˜1 ns is limited by instrumentation used here, whereas the theoretical limit of the sensor is ˜100 ps. This work compares modeled enhancement results to the experimental prototype results.

Keyword-1

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Keyword-2

TMS

Keyword-3

Fiber Optic Sensors

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