Instrument control and ns-synchronization in a total internal reflection microscope with coils: towards optically detected magnetic resonance of spins within fluorescent proteins

Summary of a Nanoscience project conducted at the Quantum Biology Technology (QuBiT) Lab at the University of California Los Angeles, by Milan Liepelt, November 2022

The Quantum Biology Technology (QuBiT) Lab was founded by Prof. Clarice Aiello, and is still very young. Its main purpose is to build instruments to research how electromagnetic fields can influence the fate of living organisms, via the control of the spin states of radical pairs. As an example the quantum spin dynamics of photo-induced radical pairs in cryptochrome has been suggested as the main driver for the navigation following the Earth's magnetic field of migratory songbirds like the European robin. Radical pairs also seem to be involved in other relevant physiological processes in which weak magnetic fields have been demonstrated to influence the fate of living organisms. In test-tube chemistry, radical pairs have been unambiguously demonstrated to affect the macroscopic final products of chemical reactions. However, hypotheses to explain how the radical pair mechanism guides processes in vivo have been suggested, and supportive biochemical and behavioral animal studies have been executed. The above in vivo data, however, is correlative only – organisms react to weak magnetic fields in a way that is consistent with what would be expected by the spin model. The final proof, though, unambiguously tying spin physics to physiological function in the same experiment, is missing. The goal of the QuBiT Lab is to build state-of-the-art scientific instruments that can prove or refute the influence of radical pairs on living organisms. A total internal reflection (TIRF) microscope with a vector magnetic field, a single photon avalanche detector, and fluorescence microscopy capabilities is presently being constructed to provide the confirmation or refutal (down to a quantifiable noise level) that spins in biological matter affect physiology. Synchronizing all these devices with nanosecond precision demands a sophisticated computer control system

The goal of my internship was to develop the foundation of such an experimental control system with the open-source framework labscript suite. This computer control system has been set up and successfully tested with a small experimental setup. In particular, we demonstrated how the software automates the calibration of a magnetic field source. The calibration of a vector field magnet is an important milestone on the path toward the completion and characterization of the scientific instrument. Different magnetic field sensor types complete the setup and one of those was formally not supported by labscript. Its implementation and documentation serve as an example of how to integrate future hardware into the labscript computer control system.

Since the beginning of my Nanoscience studies, I was interested in quantum biology. After some media coverage of this topic from Jim Al-Khalili, one of the authors of the famous (at least in the quantum biology community) book "Life on the Edge", the topic vanished from the radar of the public again. Just in time, when I explored the possibilities to go abroad for my Masters to conduct a Nanoscience project, a link of an interview with Clarice Aiello about quantum biology was posted on Reddit. I watched the YouTube video and was instantly hooked. I wrote an email to Clarice, introduced myself, my know how and interests, and offered my skills. After one reminder email, she offered a zoom call and we talked. This ended up in her starting the Visa process to bring me in to the US, to participate in building up quantum biology instruments. My trip to Los Angeles was a life-changing experience. Not only, I met many new people who became new friends. But also, I was able to reach more personal goals and surfed almost every day. I was the driving force that introduced my peers to surf. On the other side, they helped me to advance my skills in experimental quantum biology. I conclude, professionally and personally, that my project in Los Angeles was a full success.