Master in Photonics – "PHOTONICS BCN"
Master ERASMUS Mundus "EuroPhotonics"

MASTER THESIS PROPOSAL

Dates: April 2025 – July or September 2025

Laboratory: Atomic Quantum Optics (Mitchell group)
Institution: ICFO
City, Country: Barcelona, Spain

Title of the master thesis: Atomic quantum sensing

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Keywords: Quantum sensing, atomic physics, quantum optics

Summary of the subject (maximum 1 page):

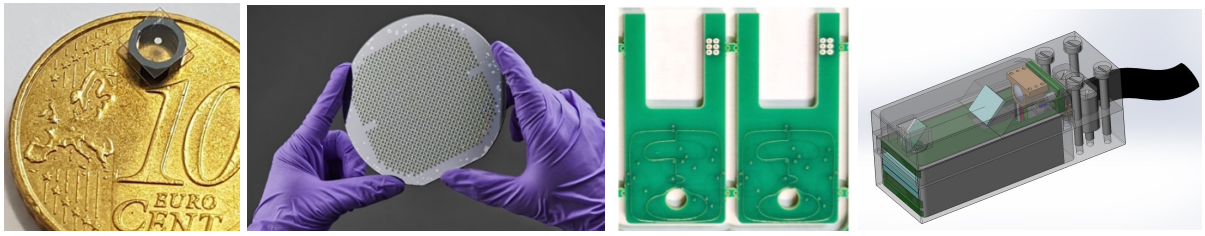

Figure 1 Elements of miniaturized atomic sensor technology. Far left: micro-fabricated vapor cell (one cell). Mid-left: a wafer of hundreds of cells. Mid-right: planar, "self-cancelling" field coils to produce a uniform field in the vapor cell but very little field in other regions. Far right: integrated sensor incorporating lasers, detectors, atoms, polarizers, focusing optics and electronics in a single package with centimetre dimensions.

We use atoms, manipulated and detected with lasers, to make extremely sensitive magnetic field detectors (magnetometers). All of these methods use atomic vapors, which have very attractive properties for sensing (adjustable densities up to 10^{15} atoms per cubic centimetre, coherence times up to minutes, strong optical transitions) combined with the possibility of

miniaturization to make small, “chip-scale” atomic devices based on small, micro-fabricated vapor cells, VCSEL lasers, micro-optics, and integrated electronics. See Figure 1.
Field amplitude (fT)

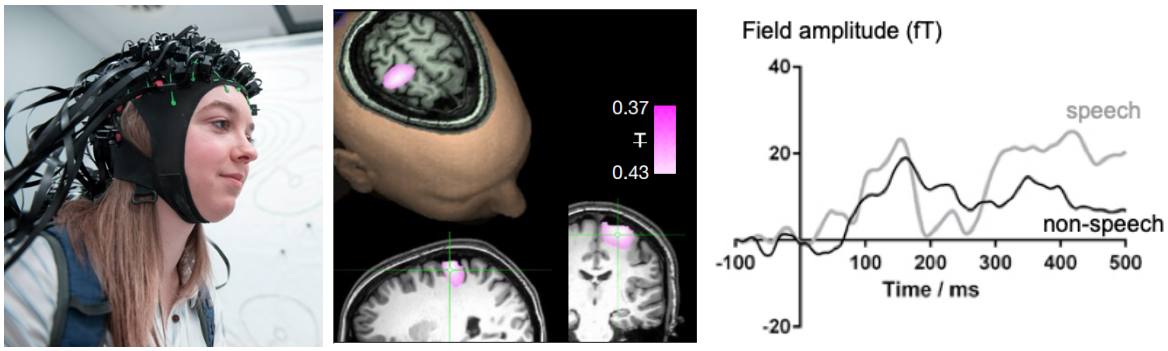

Figure 2 Use of miniaturized atomic sensors for magnetoencephalography (MEG). Left: a cap or helmet holds tens or hundreds of sensors around the subject’s head. These detect with millisecond resolution the magnetic fields produced by the brain. Center: a computer then reconstructs the current distribution inside the head. Right: signals showing brain activity in response to speech-like sounds and non-speech sounds in a severely autistic child.

These miniaturized sensors have applications ranging from magnetic brain and heart imaging to studies of reaction pathways in solar energy harvesting, to searches for physics beyond the Standard Model. Our group works on 1) development of these sensors, for example developing a new high-performance sensor for magnetoencephalography in the MACQSIMAL project:

https://www.youtube.com/channel/UCYw3Cshd_0bc5NI07MQhMKg

We also work on developing new applications, for example performing nuclear magnetic resonance and magnetic resonance imaging without powerful magnets. A topic we are looking at, in collaboration with other ICFO groups, is the study of reaction pathways in solar devices.

Objectives:

As in any laboratory, there are many things to be done. We have ideas for projects ranging from A) purpose-built semiconductor lasers to improve sensor performance, in collaboration with a commercial laser manufacturer, to B) development of new control routines and control firmware to optimally control the magnetometers in real-world environments, to C) development of magnetometers that operate beyond the shot noise limit. Please come to talk with us so we can see if your skills and interests match our project needs.

Additional information (if needed):
* Required skills: Experimental experience is desirable but not absolutely required. Hard working, good knowledge of optics and laser physics, some knowledge of atomic physics.
* Miscellaneous: Project will be done at ICFO.