Highly Sensitive Miniature Sensors thanks to Quantum Effects in Atomic Vapors

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The understanding and applying of physical laws in the microscopic realm, which resulted in ground-breaking inventions such as the transistor and the laser, was coined the first quantum revolution. Today, the ability to manipulate quantum effects in customized systems and materials is enabling the second quantum revolution. As a project under the Quantum Technologies (QT) Flagship of the European Commission, macQsimal is at the forefront of European efforts to push the boundaries for this new technology. The project, coordinated by CSEM, will help pave the way for transformative advancements in the domain of quantum sensing and metrology. In this area of research, macQsimal is working with atomic sensors as a new and improved interface between the physical and the digital world for enhanced applications in various fields such as navigation and medical imaging.

In macQsimal[1] CSEM designs, develops, miniaturizes and integrates advanced quantum-enabled sensors with outstanding sensitivity, to measure physical observables in five key areas: magnetic fields, time, rotation, electro-magnetic radiation and gas concentration. The common core technology platform for these diverse sensors is formed by atomic vapor cells realized as integrated micro-electro-mechanical systems (MEMS) fabricated at the wafer level.

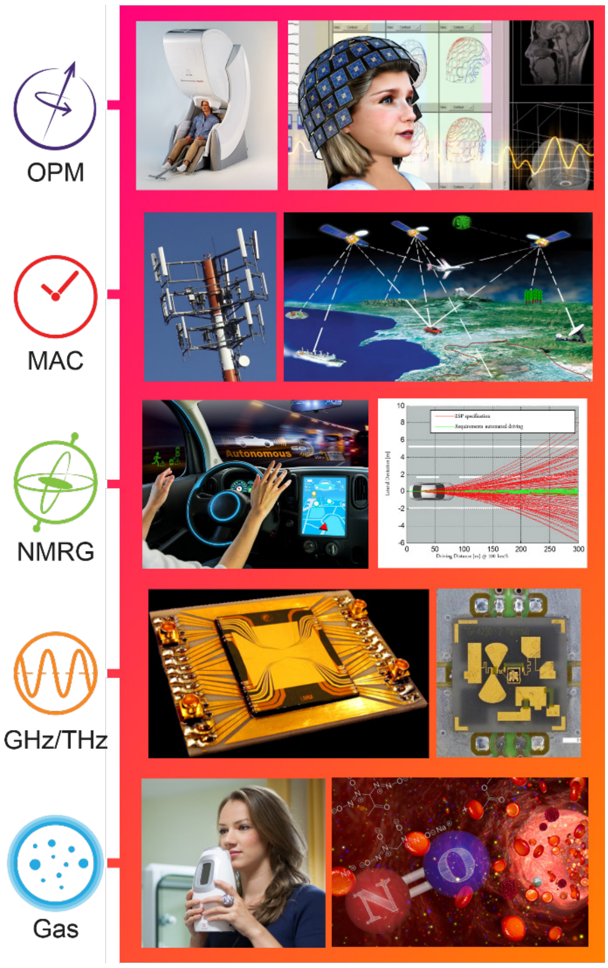

Figure 1: Miniature quantum sensor prototypes will be developed for five key applications: OPM, MAC, NMRG, GHz/THz and gas sensors.

Coordinated by CSEM, the project consortium includes leading research groups and companies who have been pioneering many of the recent advances in the field of atomic sensing and has been assembled to cover the entire knowledge chain from basic science to industrial deployment. The main objective of macQsimal is to develop five different types of miniaturized quantum sensor prototypes (Figure 1): optically pumped magnetometers (OPM) for brain activity imaging, atomic clocks (MAC) for networks synchronization, nuclear magnetic resonance gyroscopes (NMRG) for autonomous cars, atomic GHz/THz sensors and imagers, and lastly, Rydberg-based gas sensors. It is the ultimate goal of macQsimal to develop scientific breakthroughs for atomic quantum metrology and sensing which will establish European leadership in the industry and drive excellence in quantum technologies.

macQsimal will contribute to the strategic objectives of the Quantum Technologies Flagship in the sub-domain of Sensing and Metrology. The choice of atomic vapor cells makes coherent quantum processes available to applications: advanced cell-based sensors optimally exploit single-particle coherence, with the potential to harness also multi-particle quantum coherence for even greater sensitivity. Fabricating such MEMS atomic vapor cells (Figure 2) at the wafer level[2] will allow for high-volume, high-reliability and low-cost deployment of miniaturized and integrated sensors, critical to wide-spread adoption.

Figure 2: MEMS atomic vapor cell fabrication at the wafer lever in CSEM's clean room facilities.

Through its balanced basic and applied research concept, macQsimal will address the fundamental questions of quantum-enhancement techniques such as squeezing, entanglement and quantum non-demolition measures to form a basis for scientific breakthroughs for future applications.

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[1] www.macQsimal.eu

[2] CSEM patent n°US8906470 (B2).