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Author: Mr. Jaroslav Hruby
Institute for Material Research (IMO), IMOMEC, IMEC , Belgium, jaroslav.hruby@uhasselt.be

Mr. Siemen Achten
Hasselt University, Belgium, siemen.achten@student.uhasselt.be
Mr. Musa Aydogan
Hasselt University, Belgium, aydoganmusa2@gmail.com
Mr. Siemen Vandervoort
Hasselt University, Belgium, siemen.vandervoort@student.uhasselt.be
Mr. Sam Bammens
Hasselt University, Belgium, sam.bammens@student.uhasselt.be
Mrs. Boo Carmans
Hasselt University, Belgium, boocarmans@gmail.com
Mr. Jeffrey Gorissen
Hasselt University, Belgium, jeffrey.gorissen@hotmail.be
Mr. Sebastiaan Vanspauwen
Hasselt University, Belgium, vanspauwensebastiaan@gmail.com
Mr. Yarne Beerden
Hasselt University, Belgium, beerdenyarne@gmail.com
Mr. Teoman Koseoglu
Hasselt University, Belgium, teoman.koseoglu@student.uhasselt.be
Mr. Dries Hendrikx
Hasselt University, Belgium, dries.hendrikx@mail.be
Mr. Remy Vandebosch
Hasselt University, Belgium, remy.vandebosch@uhasselt.be
Mr. Jens Mannaerts
Hasselt University, Belgium, jens.mannaerts@student.uhasselt.be
Prof. Milos Nesladek
Hasselt University, Belgium, milos.nesladek@uhasselt.be

OSCAR-QUBE: INTEGRATED DIAMOND-BASED QUANTUM MAGNETIC FIELD SENSOR FOR SPACE APPLICATIONS

Abstract

The emerging field of quantum sensing has become a distinct and rapidly growing branch of quantum science and technology, opening new horizons in terms of high sensitivity, precision and enabling various measurement protocols. One of the intriguing quantum platforms nowadays is the nitrogen-vacancy (NV) center, an opto-magnetic defect located in the diamond's crystalline lattice, which can be exploited as a solid-state qubit. This atomic system can be used as a microscopic compass needle with a theoretical sensitivity below 10 femtotelsa $/\sqrt{Hz}$. The NV-based magnetometers can operate at room temperature and excel in their wide dynamic range (linear to ∼0.1T). Furthermore, the NV-centers are located along the four crystallographic axes of the diamond, allowing their utilization as vector magnetometers. By

reading out the electron spin state of negatively charged NV-centers, the magnetic field, electric field, and temperature can be measured, relying on the spin-spin interactions.

We are a team of 15 interdisciplinary students who are developing a portable diamond-based quantum magnetic field sensor within the project OSCAR-QUBE (Optical Sensors based on CARbon materials). Our project was selected in the framework of the 'Orbit Your Thesis!' programme in March 2020 by the European Space Agency to develop an experiment that will map the magnetic field of the Earth. It is expected to be launched in August 2021 and operate over the course of 4 months onboard the International Space Station.

The paper will demonstrate the device parameters and the results of the OSCAR-QUBE mission objectives, being: the feasibility of this novel technology in a space environment, the testing of measurement protocols, and the prospects of using this sensor from the spacecraft's interior. The sensor will be placed inside of the ICE Cubes Facility, in the Columbus module in a form factor of 1U, weighing slightly above 400 grams, with a power consumption of 5W. The target sensitivity for this demonstration is 1nT with a dynamic range of up to 1mT, together with pulsed measurement protocols allowing for improvements in sensitivity and unlocking the true quantum potential of the device.

The success of this mission is yet another step towards expanding the boundaries of available tools enabling the further exploration of space while widening the applicability for quantum sensing technologies. Addressing the challenges of a wide range of applications in space and on Earth, such as biosignal measurements, space weather monitoring, navigation, magnetometry, mineral exploration, or onboard sample analysis.