Optical Quantum Sensors Based on Exciton-Polariton Interferometers

DESCRIPTION FOR THE GENERAL PUBLIC

The project aims to develop innovative optical sensors that operate in the quantum domain. It uses a combination of physical sensors, specially designed waveguides, and artificial neural networks. A schematic of such a system is shown below. Its functioning can be described as follows: light transferring quantum information interacts with the sensor, driving it into an activated state, resulting in the propagation of pulses in the sensor. In each arm of the sensor, these pulses are mixed and interact, simultaneously undergoing a complex evolution. After it travels through the sensor arms and analyses the signal provides valuable information about the quantum nature of light incident on the sensor. A neural network specially trained for this purpose will then analyse this information. The accuracy of the quantum sensor is a direct result of the material's properties from which it is made. This material is selected to allow the arising of optical excitation of quantum quasiparticles known as exciton-polaritons, the presence of which helps effective detection of the quantum nature of the analysed light. Exciton-polaritons (shortly polaritons) are quantum quasiparticles typically observed in specially designed semiconductor structures. They are formed by the strong coupling of photons with excitons (particles consisting of an electron and a so-called "hole".) Polaritons are like the famous "Schrodinger's cat" state, which can be both alive or dead. The analogy in the case of a polariton refers to the presence of an exciton or photon in the system. Because of their quantum and nonlinear nature, polaritons provide an ideal platform for studying the properties of quantum states. Such sensors could find applications in new quantum computing, quantum metrology, LIDAR technologies and quantum imaging. It is worth mentioning that these applications play an essential role in the development of quantum technologies, the demand for which is becoming higher every year. The latest financial forecasts predict that the global market for quantum sensors in 2033 will reach at least $1,170.81 million US dollars.

The project involves three research tasks. The first task involves developing a theoretical model of a polariton quantum sensor. Detailed numerical simulations will be carried out based on advanced quantum computing methods to describe its operation accurately. The second task will focus on optimising the sensor to perform specific tasks, such as detecting quantum entanglement or determining quantum features of incident light. The third task deals with the designed device while considering a number of necessary experimental details that should have been considered in the initial analysis stage. The present project combines condensed matter physics with the application of neuromorphic computing systems, i.e. real computing devices (electronic or photonic) that operate on the analogy of biological neural networks. This interdisciplinary project may contribute to developing a new class of detectors operating in the quantum domain, which supports the development of fields such as quantum computing or quantum machine learning.