Design and Numerical Simulation of a Quantum Graphene Gyroscope

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Today, most personal navigation devices rely on the Global Positioning System (GPS). This system is quite accurate under open sky, but this accuracy can be significantly degraded when satellite signals are blocked by terrain or buildings, or when the receiver is indoors or underground. In everyday situations these issues are mostly a minor inconvenience, but they can become critical in situations such as disaster relief or medical emergencies.

For this reason, there is a need for personal location and navigation systems that do not rely exclusively on GPS signals. Such a system can be constructed with a combination of accelerometers and gyroscopes – by tracking changes in velocity and in orientation, this would provide accurate location information from a known starting point. This system would also ideally be lightweight, compact, robust, low power, and highly accurate, making it practical for personal handheld devices. The goal of our current research is to develop a gyroscope based on graphene that meets all of these requirements.

In this talk, I will present an analysis of graphene gyroscopes that can detect rotation through purely electrical means. This is accomplished via the Sagnac effect, which is a quantum mechanical effect where angular rotation induces quantum interference that results in a modulation of current through a ring structure. This is analogous to the Aharonov-Bohm effect in electrically conductive systems, with angular momentum replacing the magnetic field, and can be implemented in both optically and electronically.

The optical Sagnac effect has been used for decades in aerial navigation, but these optical gyroscopes tend to be quite bulky and heavy. This arises from the tautological fact that light moves at the speed of light, and thus very large optical path lengths are required for the gyroscope to be sufficiently sensitive to rotation. In contrast, electrons in solids move much more slowly, allowing for much smaller structures and potentially enabling their incorporation into handheld devices.

We use a combination of numerical simulations and device modeling to design and evaluate the sensitivity of gyroscopes based on the electrical Sagnac effect in graphene. Our numerical simulations are carried out using the *Kwant* and *pybinding* simulation packages. We find that a gyroscope based on a simple graphene ring structure requires extremely demanding criteria to reach the sensitivity needed for handheld applications. We will discuss the criteria that must be met, and offer a perspective on the practicality of such a gyroscope design. Time permitting, we will then describe alternate designs that appear to be much more promising.