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Detecting Spin States of Nitrogen-Vacancy Defects in Diamond Via Electron Spin Resonance and Optical Spectroscopy for Quantum Computing Applications

Abstract

OVERVIEW: Quantum computing is an emerging technology that relies on the manipulation of the spin states of electrons to represent data—instead of voltage levels, as in a traditional computer. At the level of the electron, quantum effects dominate and information can take the form of not only ones and zeros, but also a superposition of both states. This third possible state allows for applications of quantum cryptography, quantum teleportation and an exponential increase in computational speeds (e.g. rapid factorization of large numbers, search algorithms and simulations of quantum systems).

Especially important is the possibility of quantum cryptography, which promises to be—by the very laws of nature—impossible to break. Present-day cryptography relies on mathematical algorithms with a complexity that assures a reasonable level of security—but inherent in the mathematics is the possibility of cracking the encryption scheme. Such a secure system would vastly enhance the security protocols employed by the United States in the Department of Defense and Homeland Security.

STUDENT PROJECT: Currently, research is being done using nitrogen-vacancy (NV) centers in a diamond substrate as the building block of a qubit, or a quantum of information (similar to a bit in traditional computers). In order to observe the state of the electron spin, a microwave pulse with a frequency of 2.88GHz is applied to the NV center in the diamond and both Electron Spin Resonance (ESR) imaging and optical means are used to

measure the state of the electron. Microwave circuits were needed to apply the pulses to the NV centers, and software was needed to control the ESR imaging equipment.

Stripline microwave circuits were designed and then fabricated using etching techniques, which would serve as an interface to a microwave circuit embedded on the diamond substrate using Electron Beam Lithography (EBL). The connection between these two circuits is in the form of a pair of 25 micron diameter wire bonds. Additionally, software was written in LabVIEW to control a Spincore PulseBlaster card, which feeds TTL pulses to a microwave switch, and to also control a Multi-Scaler card, which serves as the data acquisition unit for the ESR measurements.