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Designing of gold Squarial nanoptenna for quantum communication

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ABSTRACT

This paper focuses on the designing and analysis of nanoptenna for quantum communication. The shape chosen here is spiral in the form of square and hence termed as squarials. Conventional microstrip antenna can work efficiently for wireless communication but cannot be used for quantum communication purposes. This created a need for designing a device at nanoscale called nanoptenna which is a nanosized antenna working at optical frequencies. In normal digital communication process, only two bits i.e. '0' and '1' is used but in quantum communication bits combination of these bits i.e. qubits can be used. This makes the communication more efficient, faster and secure.

1. Introduction

Nanoptennas are nanosized antennas designed for operations at optical frequencies. These are often known as nanoantennas or optical antennas, but the conventional antenna theories and principles do not apply at nanoscale. In order to remove the confusion between general antennas and these nanodevices, a new term is created i.e. "Nanoptenna", which is derived from three terminologies nano + optical + antenna. These are the optical or visible spectrum substitutes of microwave or RF antennas. These have the advantage of complete utilization of EM spectrum in optical communications and wider bandwidth (THz as in optical frequency > > GHz as in wireless communication) than the conventional antennas. These work on the concept of localized surface plasmon resonance (LSPR), a collective oscillation of free electrons in noble metals.

In this paper nanoptennas are designed for quantum communication where a bit of data is represented by a single atom that is in one of two states denoted by $|0>$ and $|1>$. A single bit of this form is known as a qubit. A single qubit could represent more than two states at a time i.e. the superposition of conventional single zero and one state.

A physical implementation of a qubit could use the two energy levels of an atom as shown [1] below in Fig. 1. An excited state representing $|1>$ and a ground state representing $|0>$. When the light is incident on nanoptenna, the incident photon will excite the ground state electrons to the excited state. In other words, it will change the quantum state from $|0>$ to $|1>$. In other words, it represents photon- electron interaction which enhances the computing performance. Photons interacts very weakly with each other, but electrons interactions are stronger than photons. Therefore, photons i.e. light is used to transmit information through optical fibres as it will travel straight from source to destination and electrons are used for computing information due to their interaction power. So, it is very clear that this photon electron interaction will lead to enhance quantum communication making the computing platform more secure. The enhanced field is equivalent to a strong light spot which can lead to manifold increased data rates than the present wireless technologies, thus increasing the optical data storage capacity [2].

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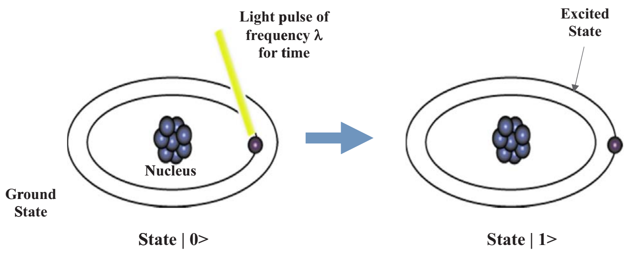

Fig. 1. Physical implementation of qubits.

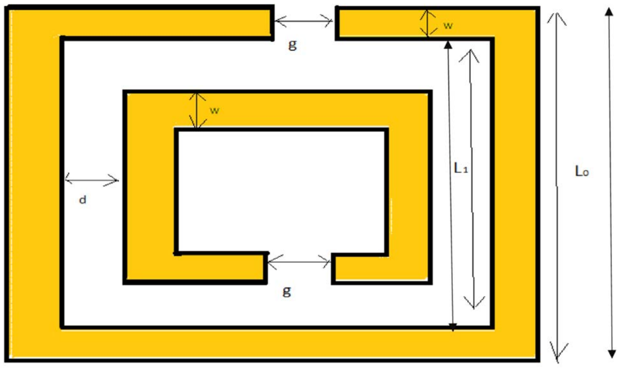

Fig. 2. Dimensions of the design.

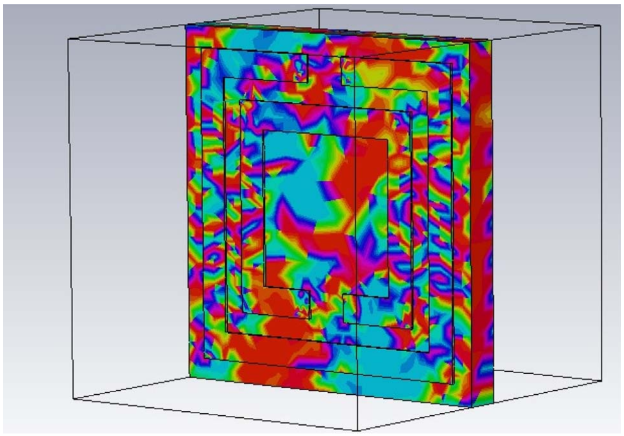

Fig. 3. Electric fields across the model upon excitation.

2. Designing and modelling of Squarials

For designing of squarials CST Microwave Studio was used in frequency domain solver. Dimensions was set in nm and frequency range in THz. The designing was based on a logic that increase in length of outer square will lead to decrease in minimum frequency and increase in length of Inner Square will lead to decrease in maximum frequency. So accordingly, frequency range was set between 300 THz and 110 THz (min-max frequency) and dimensions of structure are as follows: gap (g) is set to 30 nm, outer square length (L_0) is set to 220 nm, and inner square length (L_1) is set to 150 nm with width of 50 nm and distance between two squares is set at 20 nm as shown in Fig. 2. The structure is illuminated from below perpendicular to the long axis through waveguide mode selection. Practically plasmonic waveguides could also be useful for the excitation of these nanodevices. Finally using frequency domain solver model was simulated to obtain the results.

3. Results and discussion

The varying electric fields across the device is shown in the Fig. 3. It clearly indicates that red spots are more near the gaps and their ability to amplify light in the gap generates from the fact that kinetic energy of the oscillating electron outweighs the magnetic