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Light, a layered Universe and Possums

Our physical world is composite. It consist of the world of classical mechanics where gravity pulls objects to the ground, and which we experience every day. Underlying the classical world, there is the quantum mechanical world, where physics become odd and counterintuitive.

Research in the quantum mechanical world was for decades restricted to experiments for confirming or disproving theories, but recent progress in nanofabrication has allowed for designing and implementing quantum mechanical devices, that utilize the phenomenons of quantum mechanics to solve problems considered unfeasible given the limitations of the classical world.

One such device is the quantum computer. A quantum computer will be a tool all fields in natural science can benefit from. As computers enabled scientists to solve problems with complexities beyond calculating with pen and paper, a quantum computer, harnessing the power of quantum mechanics, can solve a problem with a complexity beyond the capabilities of known supercomputers. Quantum computers could be used for simulating new materials, where the number of variations quickly would force a normal computer to give up.

The next step is then to bring these devices beyond proof-of-concept. To achieve this my ph.d. focused on developing one platform for such devices by utilizing quantum light sources. I worked on improving the efficiency of such quantum light sources. We succeeded in demonstrating a method, which makes it possible to overcome one of the most fundamental issues for the implementation of this platform.

The development of quantum light sources is of tremendous importance as currently no other known quantum particle can reliably send information over vast distances. Furthermore as global communication is based on light in optical fibers, long range distribution of quantum information using quantum light is already feasible.

Quantum computer

The foundation of a quantum computer is a quantum bit or a qubit, which is the quantum mechanical counterpart to a bit found in a normal computer. A bit and qubit have two distinct states, for instance up or down. But whereas the bit may only be either up or down, the qubit can exhibit a superposition of both up and down, where both states coexist. The coexistence of the two states facilitates the ability to handle larger complexity than a normal computer, and as in the classical computer it is the number of qubits that counts.
The challenge is therefore to generate qubits and lots of them.

Light as qubits

A flurry of platforms are vying to become the predominant quantum computing platform. An interesting frontrunner is to use single photons as carriers of information. A single photon is an indivisible particle of light, where one and only one photon is present in a single pulse of light. Single photons can carry information in their polarization and can therefore be used as a quantum bit in our quantum computer.

Using light as a quantum bit has its challenges, first of all one needs to be able to create these qubits in large quantities and with a high efficiency. Secondly, the qubits have to interact with each other in order to perform computations. Achieving interaction is challenging with light, as the interaction of light qubits with their surroundings and each other is weak.

Quantum light sources in the lab

My research at the Niels Bohr Institute has focused on developing a platform for generation of light qubits. My starting point was an interesting device called a quantum dot. A quantum dot is grown in a clean room and when illuminated by a laser it sends out light qubits. The quantum dot emits the qubits in random direction which makes collection and utilization challenging. To decrease the randomness of the qubit emission, the quantum dot is encapsulated inside a structure called a photonic crystal. The photonic part of the name stems from the fact that this crystal interacts with light (photons). The photonic crystal compels the quantum dot to emit the photons in a direction of our choice.

One of the great challenges with this method of generating qubits is that the qubits travel one at a time separated in a single channel, for instance an optical fiber. How do you enable these qubits to interact with each other so that computations can occur? We came up with a method to separate the single stream of photons into multiple streams, which allows us to manipulate the individual qubits. With the qubits separated in different channels, they can be manipulated individually. The qubits can also be brought together in a controllable manner, achieving the first building blocks of the quantum computer.

Bugs in the lab

I spent 2 months in Australia, visiting the Quantum Technology group at University of Queensland. The group in Brisbane is among the leading groups of quantum computing with light. During my time there, we worked on creating entanglement between photons. During the project we struggled tremendously with optimizing the signal to obtain the desired results. One of my last days there I recieved a phone call from my collaborator there, telling me that he found the error and asking me how come I had not noticed it. I was of course very embarrassed and I asked him to explain it to me, instead he sent a picture. The picture showed a possum sitting in the middle of our setup. During the night three possums had gotten into the lab and runned havoc. These were not the kind of “bugs” I was used to, I had just had an Australian experience.

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