Young Scientist

I wish to be a photon juggler

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Introduction

I am an experimental physicist working in the field of quantum optics. When I was asked to write an article for the "young scientist" section, the editor said that any kind of topics would be welcome. Here, I'd like to offer three topics that I hope will interest you. The first one is my brief history. In it, you will learn how a young scientist enjoyed doing basic research in a private company. The second topic is about my life at Hokkaido University. Some of the readers may have heard about the stressful life of people in Japanese metropolises, i.e. extremely crowded commuter trains. However, life in Sapporo, where Hokkaido University is located, is completely different. The third topic is our research activities relating to the quantum information technologies using photons.

My Brief History

After I finished my master's degree in low dimensional condensed matter physics at Kyoto University, I entered Mitsubishi Electric Corporation, where I wanted to do research on quantum devices.

In the company, I belonged to the Embryonic Science and Technology Department. That department was not very large, however, many interesting kinds of basic research were being conducted in the department: Research on the neural networks of sea slugs, single molecular diodes, and so on.

Mr. Maeda, the director of the department, encouraged us to be ambitious in creative work. He gave me a chance to look for a really interesting topic, and I had an opportunity to read a paper on a quantum computation algorithm proposed by Deutsch and Jozsa.

An idea struck me that an experiment demonstrating the algorithm was possible by using linear optics and single photons. Mr. Maeda advised me to propose the experiment as a PRESTO (Precursory Research for Embryonic Science and Technology) project of the Japan Science and Technology Corporation (JST).

With the financial support and encouragement by JST and Mitsubishi Electric, I devoted myself to the experiment from 1995 and succeeded in demonstrating the Deutsch-Jozsa algorithm in 1998 [1].

During that period, I also had a chance to visit Prof. Yoshihisa Yamamoto's laboratory at Stanford University for nine months. The stay there was very impressive. I worked on the development of photon detectors that had 88% quantum efficiency [2] and also the ability to distinguish the number of incident photons [3] with Dr. Jungsang Kim. The friendship I had with the group members at Stanford remains a treasured memory of mine.

During the course of these researches, I became fascinated by basics experiments in quantum optics, rather than those aiming at producing future products. Fortunately, I had a chance to move to an academic position at Hokkaido University in 1999.

Sapporo and Hokkaido University

Hokkaido is the second largest and most northern of Japan's four main islands. The capital city of Hokkaido is Sapporo with two million people living there. Hokkaido University is in the central part of Sapporo.

My house sits seven km south of the University. I usually take a subway (not crowded so much) to Sapporo station for 10 minutes each morning, and walk 15 minutes to the laboratory. I really like the passage through a grove of white birch on the university campus. In winter, everything is covered with snow, and the contrast between the blue of the sky and the white of the snow and trees in the very pure air is wonderful. However, in order to enjoy this beauty, I have to endure cold down to minus ten degrees Celsius. The temperature in summer is usually 20 to 30 degrees Celsius, and that's very comfortable.

The island is also famous for its delicious foods, beautiful nature and many Onsen (hot springs spas). Some people in our research group like hiking. This summer, we visited mount Tokachi-dake (2077m) and enjoyed its surrealistic volcano landscape and beautiful alpine plants (see picture). Needless to say,

At the starting point of the trail to Tokachi-dake: Matsuo, Ishii, Kojima, and Takeuchi. (From the left)

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we enjoyed an outdoor Japanese-style hot spa, also.

My research activity

I am interested in the quantum information technologies using photons. As we know, the true description of the nature is given not by classical (Newtonian) theory, but by quantum theory. In the field of quantum information [4], people are trying to reconstruct the information theory based on quantum physics. There are two main applications that attract people. One is quantum cryptography, which enables us to transfer a "random number key" without any possibility of its being intercepted. The other is quantum computation, which enables us to perform massive parallel data processing in extremely large Hilbert space.

Currently, we are trying to achieve quantum information processing by using photons. I demonstrated a quantum algorithm using single photons and linear optics in 1998 [1]. At that time, our method had a weak point in that the number of optical modes increased exponentially when the number of required qubits increased.

Recently, Knill, Laflamme and Milburn proposed a scheme to create a quantum computer by using linear optics, single protons, and multi-photon distinguishable detectors where the number of modes scales linearly with the number of qubits [5]. This proposal represents tremendous progress.

Based on their ideas, our research group has also suggested a more practical method for constructing both a quantum gate [6], and a quantum filter that can create entanglement between single photons [7].

Currently, our research group in Hokkaido University is also working on achieving single photon sources [8], and single photon quantum phase gates by using cavity quantum electrodynamics [9].

Conclusion

I hope you found some points of interest in this article. Your impressions, comments and questions are welcomed; please sent them to takeuchi@es.hokudai.ac.jp . You can get additional information at our website: http://optsys.es.hokudai.ac.jp/index-e.html

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