Introduction

We are a research group working on theoretical and experimental studies of quantum optics and quantum information. Our research concerns

1) nonlocality and entanglement for complex systems,

2) the quantum aspect of surface plasmon to investigate the capabilities conventional photonics cannot achieve,

3) the development of quantum algorithms by quantum learning machine to extend the notion of machine learning into the quantum domain and apply it to quantum information processing,

4) quantum effects in biology, particularly photosynthesis to explore the high efficiency of many key biological processes that may be originated from the exploition of non-classical.

Research

Quantum Information Science is nestled at the intersection where information science, nanotechnology, chemistry, computer science, mathematics and physics meet. Rapid experimental developments stimulated by new probing techniques offer many opportunities of working on new problems and impact both theoretical and experimental studies.

We are interested in various problems in quantum information theory and quantum foundations. In particular, we tend to focus on:

1) Nonlocality. The study of nonlocality includes such questions as : At which limit quantum nonlocality is valid? And, how can we exploit nonlocality for quantum information processing?

2) Quantum Effects in Biological Systems. The ability of photosynthetic plants, algae and bacteria to efficiently harvest sunlight has attracted much research interest, since both experimental and theoretical research offer the evidence that the high efficiency of many key biological processes may be originated from the exploition of non-classical processes. Our group is invetigating the potential role of quantum coherent effects in biological systems and its applications to various artificial physical systems.

3) Quantum Learning Machine. We explore the possiblity of extending the notion of machine learning into the quantum domain and attempt to apply it to quantum information processing.

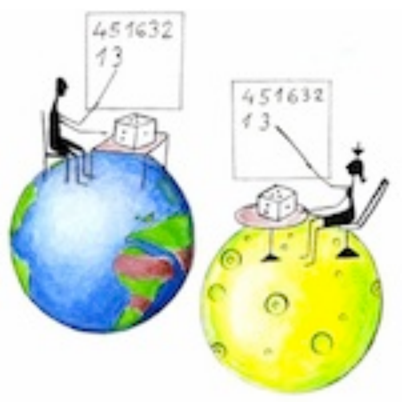
4) Quantum Plasmonics. Metal nanoparticle plasmonics is a fast-growing field of research due to significant advances in both experimental techniques and theoretical understanding of the underlying phenomena. It shows great possibility for their use in quantum control applications. We have studied the benefits of using nanophotonic systems for quantum plasmonic applications, like quantum communication.

In the following we summarize the works carried out for the last six years.

Experimental Study of Nonclassicality using single photon

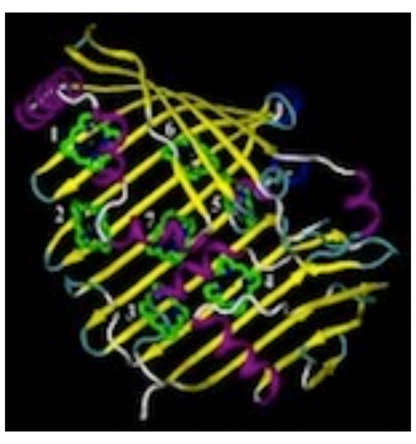
Our goal is to develop algorithm faster than the known classical algorithms using quantum superposition for certain problems. For it, we will experimentally implement the algorithm we develop and prove the the validity of the algorithm. We are also interested in how to increase learning efficiency of Machine Learning using superposition. For this study, we will develop the experimental technique of controlling single photon to generate photon anti-bunching.

Nonlocality



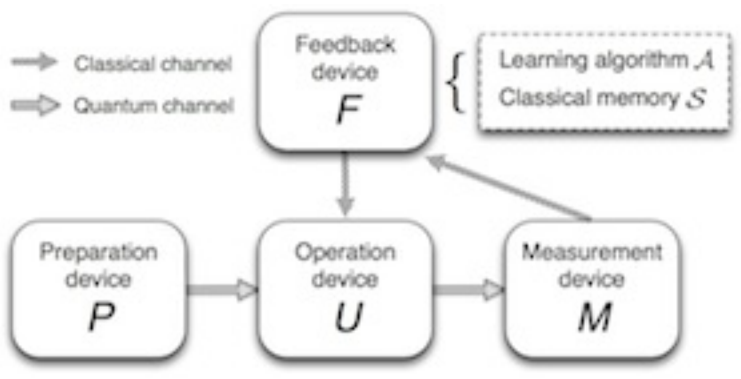
(Image from : http://www.phy.bris.ac.uk/groups/theory/index.html) Nonlocality is the most significant evidence of physical observations that cannot be explained by theories based on local realism, which is one of the major principles in our understanding of Nature. Realism means that measurement results are predetermined before observations. Locality refers to the notion that the results of obervations are independent of any action at space-like separations. Since Bell showed with his famous Bell inequality that the theories based on local realism make predictions that are different from those of quantum mechanics and therefore provided a way of falsifying either quantum mechanics or theories based on local realism, Bell's thorem has been studied in various aspects. Our group has concentrated on the generalization of nonlocality test including Bell's inequality to multipartite, multi-setting and high-dimensional systems. Nonlocality is not only of importance for fundamental research of quantum mechanics, but also in the context of quantum information processing (QIP), in that it provides a good measure of computational power of QIP.

Quantum Effects in Biological Systems



Recently there has been experimental evidence to suggest that photosynthetic complexes support and sustain quantum mechanical effects, despite the extreme conditions imposed on them by their background environment. A major question being asked in this context is whether or not biological systems actually use such quantum effects for enhancing their functional processes. We are interested in studying the potential role of quantum coherent effects in biological systems and its applications, such as the design and engineering of novel energy transport techniques in disordered artificial nanostructures.

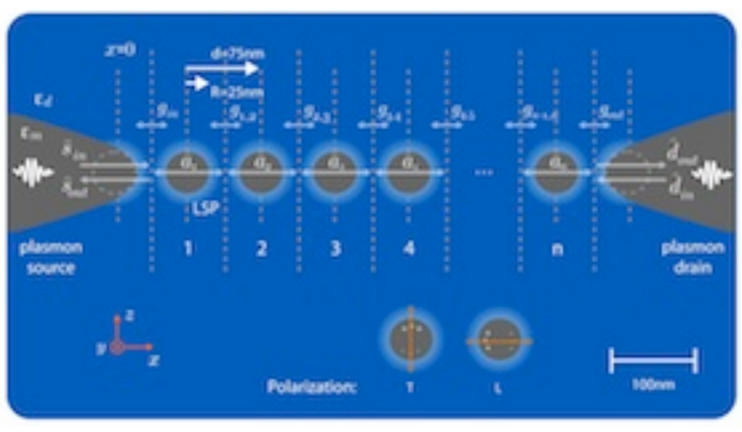
Quantum Learning Machine



Our primary goal is to extend the notion of machine learning into the quantum domain and apply to quantum information processing. For the goal, we should answer the following important questions: Can a quantum-mechanical machine or computer be designed to learn a given task by itself? Is it faster than the classical? If so, what are the key resources?

Quantum Plasmonics

(collaborated with Dr. Changhyoup Lee at KIT)



(Image from Phys. Rev. A 85 063823 (2012)) With the advancement of nano fabrication techniques, metallic nanoparticles have been attracting significant attention due to their novel capabilities offering the prospects of miniaturization, scalability, and strong coherent coupling to single-emitters that conventional photonics cannot achieve. This study assists the further theoretical and experimental studies of plasmonic nanostructures for quantum control applications and probing nanoscale optical phenomena.