PROJECT SUMMARY

CCLI - Phase I: Quantum Optics Laboratory for the Undergraduate Curriculum – Teaching Quantum Mechanics with Photon Counting Instrumentation

PI – Carlos Stroud, University of Rochester; Co-PIs – Svetlana Lukishova, Wayne Knox, University of Rochester, William Mooney, Monroe Community College

The appearance of the new fields of quantum optics, quantum computation, and quantum communications and the rapid progress in photon-counting instrumentation open new opportunities for teaching the most difficult concepts of quantum mechanics by set of simple, easily understandable, and exciting experiments with single photons. Several universities both in the US and in Europe already offer quantum-optics teaching laboratory experiments for undergraduate students. A special symposium of the 2006 Annual Meeting of the Optical Society of America is scheduled to provide a forum for comparing experiences in quantum-optics-teaching experiments among these universities.

This CCLI phase I exploratory project involves an interdisciplinary Quantum Optics Laboratory for the Science/Engineering Undergraduate Curriculum. It will leverage the resources of current teaching laboratories of the Institute of Optics and Department of Physics & Astronomy with the strong research program of the Center for Quantum Information. The goal is to create experiments and supporting materials that help students better understand the superposition, interference, wave-particle duality, and nonlocality principle in quantum mechanics. The goal is further to provide them with a modern view on these issues, using the instrumentation of quantum-information technology. Major teaching experiments include (1) entanglement and Bell's inequalities; (2) single-photon interference; (3) single-photon source. Photonic based quantum computing, quantum cryptography, and quantum teleportation are to be outlined in the course text-books as possible applications of photonic quantum mechanics. Students will be exposed to cutting-edge photon-counting instrumentation and methods with rapidly growing applications ranging from quantum information and nanotechnology to biotechnology and medicine. The first two experiments will build on the experience of Colgate University and Whitman College in creating inexpensive experiments on entanglement and quantum superposition and interference. The third teaching experiment will use modules from *research* setups funded by the NSF at the University of Rochester.

The project also includes faculty from Monroe Community College providing a two-year degree program for training technicians to work in the optical industry. Photon counting instrumentation will be implemented in OPT215 Laboratory course "Electro-Optical Devices and Systems". This two-year college will also participate in interactive Workshop with college and K-12 science teachers.

Both formative and summative evaluation methods will be used in project assessment. Evaluation efforts will be coordinated by a faculty member of the graduate School of Education.

Intellectual merit: The project addresses one of the most challenging concepts of modern physics in science and engineering education that is now being applied to important technological problems. Enormously powerful computers and total communication security are the future goals of Quantum Information Technology which is emerging in the market. It is important to familiarize the future workforce with these new ideas as well as to provide them with hands-on experience in photon-counting instrumentation currently widely used in many technological areas.

Broader impact: The project directly impacts a group of students with diverse backgrounds. Dissemination includes collaborative activities with similar course instructors from other universities, presentations and publications in educational journals, and by student publication and presentations at regional and national professional-level meetings. NSF Summer Research Experience for Undergraduate and Teachers programs and an interactive Workshop will provide students and teachers from other institutions with an opportunity to either learn about inexpensive teaching experiments or to work on Rochester research modules on single-photon source generation and characterization. A book on quantum-optics teaching experiments will be prepared for Oxford University Press.