

## PROJECT SUMMARY

### **Collaborative Research - CCLI Phase II: Diverse Partnership for Teaching Quantum Mechanics and Modern Physics with Photon Counting Instrumentation**

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Recent developments in quantum optics and quantum information physics along with the associated progress in photon-counting instrumentation has opened the opportunity of introducing the most difficult concepts in quantum mechanics to a much broader audience than previously. Undergraduates from a variety of majors and even the general public are fascinated by news of quantum computing and "quantum weirdness." These sophisticated concepts can be clearly and dramatically demonstrated by means of a series of experiments.

This proposed CCLI Phase II project is built on a smaller project lead by the University of Rochester CCLI Phase I that has produced promising results. Using this DUE award four teaching experiments on photon quantum mechanics were developed and taught as a laboratory course (see course website <http://www.optics.rochester.edu/workgroups/lukishova/QuantumOpticsLab>). We have adapted to the main challenge (the lack of space in the curriculum) by developing a series of modular experiments and demonstrations based on technical elective laboratory that can be incorporated into a number of courses ranging from freshman to senior level, in both physics and engineering. Both formative and summative evaluation showed this project's success. A special symposium-workshop with an associated teaching lab demonstration was organized for high school, community college and university faculty during the 2008 Annual Meeting of the Optical Society of America. A series of public lectures that we have given in a number of cities around the country has enhanced general awareness and stimulated interest in the field.

The goal of this project is to develop and test various versions of teaching experiments and supporting materials to facilitate understanding of the concepts of superposition, interference, complementarity and non-locality in quantum mechanics by students with diverse backgrounds. A further goal is to acquaint the students with these concepts using the recently developed instrumentation of quantum information technology which can be used in other areas (e.g., in nanotechnology or biomedicine). Collaboration by a diverse group of schools (universities, community and liberal art women colleges and a technical institute) will develop a combination of lecture courses on modern physics, quantum mechanics and nanotechnology with experimental demonstration and hand-on experiments for undergraduates down to and including freshmen. New compact equipment (e.g., a single photon source coupled with optical fibers) will be developed for sharing among institutions in a quantum optics teaching network.

Both external and internal evaluators will be used to evaluate the project's success. Student assessment methods will include written/oral examinations, essays, reports, questionnaires, and presentations. Gains in student performance will be evaluated throughout the four-year project.

**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 widely used in many technological areas (e.g., nanotechnology and biomedicine).

**Broader impact:** The project directly impacts a variety of science and engineering students with diverse backgrounds including under-represented groups. Dissemination of the results will be by a constant development of a project website, building a national network with 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 REU and RET programs and interactive workshops will provide students and teachers from other institutions with an opportunity to either learn about teaching experiments or loan compact equipment from Rochester. A book on quantum optical teaching experiments will be prepared for publication.