Undergraduate Program in Nanoscience and Nanoengineering: 5 Years after the NSF Grant

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Abstract: 41 students completed a multidisciplinary nanoscience/nanoengineering undergraduate education program at the University of Rochester, initially supported by NSF. It comprises a required Nanometrology Laboratory class, additional two classes and one semester research/design project on nanotechnology.

1. Introduction

The institutionalization and sustainability of the successful project at the University of Rochester (UR) after ending of the US National Science Foundation (NSF) grant support will be described here. This project addresses one of the most important concepts of modern engineering education geared towards increasingly important multidisciplinary technological problems. Nanotechnology has the undisputed potential for creating many new materials and devices with wide-ranging applications. It is important to enable the future workforce to further develop these new ideas, as well as to provide students with hands-on experience in nanotechnology methods and tools for today's jobs. Modern students should be (1) fluent in nanoscience and nanotechnology terminology, (2) able to define nanoscience, nanotechnology, and nanodevices, (3) able to develop nanotechnology questions and propose strategies to answer them, (4) able to operate some nanotechnology characterization tools (STEM majors), and (5) choose a research career in nanoscience/nanotechnology (STEM majors) [1].

2. Program Requirements

Educational program of the UR in Nanoscience and Nanoengineering based on the Institute of Optics and Integrated Nanosystems Center (URNano) resources was developed in 2014-2016 years and supported by NSF grant for the project "NUE: Development of Multidisciplinary Nanotechnology Undergraduate Education Program at the University of Rochester Integrated Nanosystems Center" [1]. Currently the Institute of Optics administration, Dean's office of Hajim School of Engineering and Applied Sciences supports this program financially (paying URNano fees, materials' cost and adjunct instructors' and teaching assistants' salaries).

Since 2015, 41 undergraduate students from different UR departments (mostly from Optics) completed this program by May 2021. 32 of them completed this program after ending the NSF grant. The program has following requirements for its completion (see Figure 1):

1. A required 4 credit hour laboratory course OPT 254/PHY 371 "Nanometrology Laboratory". This new course started in Spring 2015 was specially prepared for this program.
2. On students' selection, two other courses containing nanotechnology content (see the list of some possible courses in a diagram of Figure 1).
3. A full semester research or design project connected with nanoscience or nanotechnology.

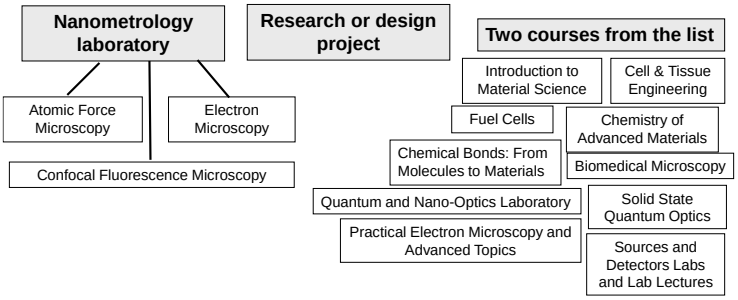

Figure 1. Required courses for completion the program in Nanoengineering and Nanoscience.

As suggested in the NSF project, after completion of this program students were awarded the Certificate in Nanoscience and Nanoengineering.

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3. Required Class on Nanometrology Laboratory

The required for this program a Nanometrology Laboratory class OPT 254/PHY 371 became very popular: we extended a maximum number of students in this class from 6 to 8-9 students. This unique class without teaching assistants (instructors, experts in the fields, spend the whole lab time with the students instructing them how to work on very expensive equipment). This course contains three modules: (1) electron microscopy (SEM and TEM) – taught by McIntyre (URNano), (2) optical microscopy (wide-field and confocal fluorescence microscopy of single nanoemitters) and nanoobjects/nanoengineering – taught by Lukishova (Optics), (3) atomic force microscopy (AFM) - taught by Lukishova (Optics). Even during a Pandemic of 2020-2021 this class was offered in Spring semesters and taught in a hybrid manner. A requirement of a social distance permitted only two persons (one student and a professor) to be in one laboratory room simultaneously. Three "in person" scheduled lab attendants worked 1/3 of each lab time (usually 3 hours) in the lab and 2/3 of each lab time remotely through a Zoom video conferencing software. Figure 2 shows a lecture (left) and a lab session (right) through Zoom.

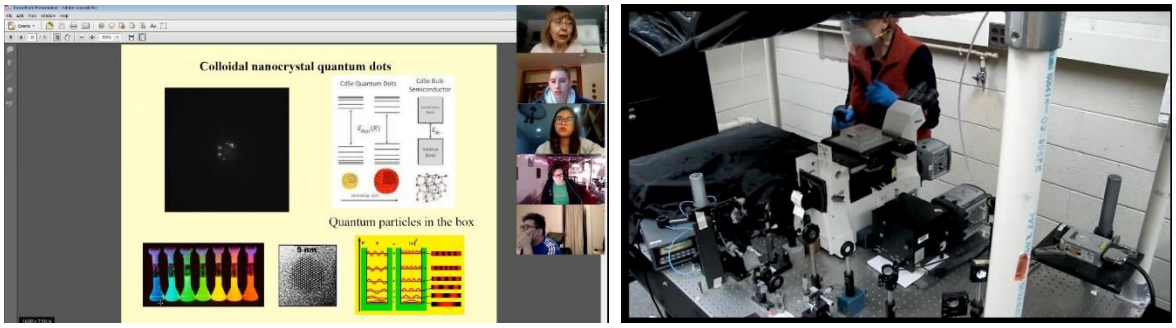

Figure 2. Screen shots from Zoom videos of a Nanometrology Lab class of the lecture (left) and a lab session (right).

4. Research and Design Projects

A very important part of the program is at least one semester research or design project (for some company) related with nanoscience and nanoengineering. Some recent students' research/design projects for the program are:

- Confocal Microscopy (Carney's lab, Optics);
- Characterizing Surface Contamination in Diffraction Gratings for the Omega Laser (Shestopalov's lab, Chemical Engineering);
- Plasmonic Nanostructures for Single Photon Source Applications (Lukishova's lab, Optics);
- Photoluminescence Spikes from Colloidal Silver Nanocubes (Lukishova's lab, Optics);
- Plasmonic Nanoantenna Array Metasurfaces and Colloidal Nanoparticles for Single-Photon Source Applications (Lukishova's lab, Optics);
- Optically Detected Magnetic Resonance Signals from Nitrogen-Vacancy Centers in Diamonds (Vamivakas's lab, Optics);
- DESIGN: Nanostructure Anti-Reflective Coating Characteristics (design for ASML, Kelkar; UR advisor: Oliver, Laboratory for Laser Energetics);
- Single Nano-emitter Fluorescence (Lukishova's lab, Optics);
- Plasmonic Nanopatch Antennas with Single-NV-Center Nanodiamonds (Lukishova's lab, Optics);
- DESIGN: A Quantum Key Distribution System (using waveguides and their nanometrology) (design for Harris, Buckley; UR advisor: Lukishova, Optics).

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References:

1. S.G. Lukishova, N.P. Bigelow, P.D. D'Alessandris, "Development of multidisciplinary nanotechnology undergraduate education program at the University of Rochester Integrated Nanosystems Center", paper 100-184, 14th International Conference on Education and Training in Optics & Photonics (ETOP), May 29-31, 2017, Hangzhou, China.