UMSAEP UM/UWC Linkage Program: Final Report

"Curriculum Development in Materials Science at UWC"

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This final report summarizes the activities and outcomes of my visit to South Africa, sponsored by a $1,500 UMSAEP grant. The visit took place from April 1 to May 4, 2017, together with Prof. Suchi Guha from MU Physics. Our hosts were Profs. Chris Arendse, Theophilus Muller, and Dirk Knoesen from the UWC Physics department.

I. Teaching activities

During the first two weeks of this visit (April 3-14, before the Easter break), I taught two short courses at the BSc and MS level, respectively.

I.1 Electronic structure and excitations in nanomaterials (MSc nanophysics)

The Master of Science (MSc) two-year degree in Nanoscience, a unique program in South Africa, is a collaborative initiative between UWC, University of Johannesburg (UJ), University of the Free State (UFS), the Nelson Mandela Metropolitan University (NMMU) and the Department of Science and Technology. It is spearheaded by UWC (and coordinated by Prof. Dirk Knoesen). The partnership between these institutions allows students from other campuses across South Africa to take courses at UWC. This year has been one of the largest enrollments in their MSc Nanoscience program: the course was taken by 11 students; about half of these were from UWC.

Prof. Suchi Guha and I team taught the course on "Electronic Structure and Excitations in Nanomaterials" over two weeks. The course was offered every day for two hours in the afternoon (on two days there was no class, due to a holiday and due to graduation).

The aim of this survey-style course was to provide students with an appreciation and understanding of the quantum nature of electronic structure and excitation processes in nanoscience, from both an experimental and a theoretical perspective, in order to expose the students to the current forefront in materials science and nanotechnology. The topics covered were as follows:

Day 1:

- Overview of functional materials; crystal structure (Guha)
- Electronic band structure (Ullrich)

Day 2:

- Introduction to the electronic many-body problem (Ullrich)
- Interaction of light and matter (Guha)

Day 3:

- Optical constants and absorption measurements (Guha)
- Density-functional theory and modern computational materials science I (Ullrich)

Day 4:

- Excitonic effects in optical spectra (Guha)
- Density-functional theory and modern computational materials science II (Ullrich)

Day 5:

- Phonons and Raman scattering (Guha)
- Plasmonics I (Ullrich)

Day 6:

- Carbon based nanostructures – fullerenes (Guha)
- Plasmonics II (Ullrich)

Day 7:

- Plastic electronics (Guha)
- Graphene (Ullrich)

The lectures were based on presentation style with in-class discussions. Pdf copies of the powerpoint lectures were made available to the students. The students were assessed based on a written homework assignment at the end of the first week, and a short in-class test on the last day of the course. The students then received a grade. The class average was 64%, which however includes two students who missed the final exam. Without those students, the class average was 72%.

I.2 Electronics for the 21st century (BSc honors)

I also taught a two-week intensive course for BSc honors students (with materials science emphasis) in their last year. There were 17 students from UWC enrolled in this course. The aim of this course was to complement the course offering of the BSc honors program at UWC.

It turned out that the level of the students was such that I had to cover the basic concepts of condensed-matter physics first, before coming to more advanced concepts and applications of the electronics and nanoscience. Fortunately, I was able build upon a course in condensed-matter physics which I had already taught several times at MU. I adapted and streamlined this course, and added some new material, to tailor it to the 2-week intensive format. The following topics were covered:

Day 1:

- Review of quantum mechanics;
- Atomic structure
- Interatomic binding I and II
- Crystal structure I

Day 2:

- Crystal structure II
- Reciprocal lattice
- Quantized electron gas

Day 3:

- Electronic band structure
- Electronic structure of real materials
- Semiconductors I

Day 4:

- Semiconductors II
- The p-n junction
- Semiconductor heterostructures I

Day 5:

- Semiconductor heterostructures II
- Semiconductor optoelectronics

Day 6:

- Nanomaterials
- Graphene

Each class session was for 1 ½ hours in the first three days, and for 2 hours in the last three days. Pdf copies of the PowerPoint lectures were made available to the students. Notice that the students also had other courses to take during these two weeks, which explains why we only met on 6 days.

At the end of the first week, the students received a homework assignment. On the last day of classes, the students took an in-class exam. Based on these assessments, the students received a grade. The class average was 82%.

II. Other activities

During our stay at UWC, Prof. Guha and I had the opportunity to visit other research facilities: The iThemba LABS in Cape Town and NMMU in Port Elizabeth. Research activities at the IThemba LABS are based on sub-atomic particle accelerators. It also has a strong focus on materials science related research. We got an in-depth tour of their research facilities.

The visit to NNMU in Port Elizabeth was organized by Prof. Arendse and the Nanoscience program. The electron microscopy facility at NNMU is a world-class research facility and is equipped with state-of-the-art electron microscopes. We are grateful to Prof. Jan Neethling (Director of the high resolution microscopy center) and other faculty members of the physics department at NNMU for discussing their research activities and giving us a tour of their world-class research capabilities.

My own research is in theoretical and computational condensed-matter physics. Therefore, learning about ongoing experimental research at UWC, IThemba and NNMU was very interesting for me, even though it did not lead to any concrete scientific projects or collaborations, at least not at this time.

I made the observation that there is a notable absence of theoretical condensed-matter physics at UWC or, for that matter, in most of South Africa. The UWC physics department is very strong in nuclear physics and astrophysics, including theory, but there are no theorists to lend support to the materials science program, or to train their students. I believe that this would offer opportunities for future visits to UWC, either to teach or to collaborate. I would also welcome a student exchange, where students from UWC would come to MU to be trained in computational methods.

III. Acknowledgments

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