UROP: Undergraduate Research Opportunities Programme

A personal perspective by Emanuele Silvio Gentile

Emanuele had just completed the first year of an undergraduate degree in Physics, and embarked on an 8-weeks UROP research experience in the summer of 2016 under the supervision of Stefano Guazzotti, a Ph.D. student supervised by Prof. Ortwin Hess (Condensed Matter Theory Group, within the Department of Physics).

Placement Title: Scientific simulation of light fields interaction with nano-plasmonic structure and semiconductors applied to random laser technology

I have always been intrigued by the computer simulation of physical systems. Thanks to some Python projects carried out within first term coursework of Year 1, I was definitely sure that computational modelling would be the most suitable way for me of doing and learning science.

I found exciting to discover the behaviour of physical models with only a laptop, by altering parameters that cannot be manipulated in a real system and by properly using numerical methods to solve complicated mathematical equations. So I became determined to improve my abilities in computational physics and to really test myself on a project which would attempt to model a complex physical system. I had also the hope to understand if I would have liked pursuing an academic career after my degree. A UROP research experience was the perfect chance to fulfil all this, investing 8 weeks of the summer.

I started looking for a UROP research experience at the end of the first term, which is very early for a first year student. I was mainly interested in a computational project within “Space and Atmospheric Physics" and "Condensed Matter Theory" research fields, then I sent e-mails and I knocked on the doors of potential supervisors in the two groups.

While searching, I had a moment of hesitation. After all, I was attending the first year and I had not taken any exam yet. I wondered if Physics and computing knowledge involved in the project could turn out to be too large or too difficult to be learnt and productively tackled in 8 weeks, and I was worried about my ability to handle a role in a research project.

Fortunately, behind a door I knocked on, I met Prof. Ortwin Hess of Condensed Matter Theory group. I was extremely impressed by his deep and broad Physics knowledge as well as by his warm and respectful manners. He allowed me to attend the weekly meetings of the group he is leading where I met all researchers of the group and I could look closer at the kind of complex work involved by the scientific simulations that the researchers were conducting.

After some meetings we agreed that I could participate in a part of a project on spatio-temporal dynamics of nano-lasers and that this, although requiring a Physics background which goes far beyond the one of a first year student, could be feasible for me thanks to the guidance of Stefano Guazzotti, a very expert and friendly PhD student who would have shortly become my supervisor. The most passionate aspect of this research project was (and still is) for me its future industrial application for improving the life of human beings. The results of the research could lead to the fabrication of a new generation of lasers able to produce speckle-free images, crucial for medical diagnosis and for new-generation of TV screens. When Prof. Hess agreed to offer me a UROP research experience and supported me to apply for the UROP bursary, I was really keen to start working on this project and all my concerns were dispelled.

Before the project started, I undertook a specific preparation based on books and papers suggested by my supervisor. The project involved the use of Fortran and C programs for the simulation and the use of Matlab for data post-processing and visualisation. Thanks to my prior knowledge of C and Python, which is very similar to Matlab, I was mainly focused on learning Fortran techniques by studying a book and by writing and testing some algorithms for the numerical solution of Physic problems. The effort in funding application was a preparation as well, since it required the in-depth reading of papers on the latest research of the field.

When the research experience started I was welcomed by Prof. Hess and by my supervisor Guazzotti. My task consisted in using a large scale Fortran program and other numerical tools in order to study the spatio-temporal

dynamics of nano-plasmonic structures and semiconductors interacting with light fields. I dedicated the first weeks to get familiar with the physic problem and with all the numerical software and tools used in the various phases of the simulation process, from setting the input data input to post-processing, visualization and analysis of output data. In the last weeks, I could effectively work on the numerical simulations running a battery of significant test-cases and contributing to the interpretation of the results.

Throughout the research experience I was given invaluable and constant support from my supervisor Guazzotti. He guided me in learning the physical model and the related computer methods and in acquiring the capability of using the whole software simulation process. He also promoted my independence and professional development so that the meeting frequency decreased as the project went on and my autonomy at work was increasingly evident.

The research experience naturally broadened my knowledge of the theory, design and applications of semiconductors and nano-plasmonic structure. But it was also a gold mine of experiences and skills that are reusable in many other scientific research fields. I had the precious opportunity to learn Fortran 95 language, which is still a dominant programming language for large simulation of physical systems, not only for the one involved in my research experience. The chance to study the numerical methods used in the research was equally precious because I could be aware of the large class of mathematical physics problems they can be applied to. An important skill that I acquired is a greater familiarity with the practical aspects of the methodology behind a large scale scientific simulation. Some serious numerical simulations I ran took 3 days of computer elapsed-time to output the results, hence I learned how important it is to precisely set the data input setting parameters and think carefully about them before pushing the run button, otherwise you might burn a whole week of work. Another useful skill I gained is to write flexible Matlab scripts for the post-processing of output data of scientific programs.

But the most precious experience I gained was a growth of confidence in my creativity and in my independent scientific judge. You cannot acquire that studying from books or attending courses. You have to throw your hat in the ring of science and tackle the swarm of problems of different nature and complexity arising during the life cycle of a simulation process, whether they relate to some difficult data interpretation or they relate to an unexpected operative system behaviour.

The research strengthened my interest in Computational Physics and showed me the importance of acquiring more competence in Physics and in numerical methods. As a result, it will greatly influence the choice of the topic and the options courses of my degree final project. Also my point of view about the coursework has changed. Since I had personal experience of how Computational Physics bridges theory and experiment, I'm now more motivated in learning the theoretical parts of the Physics coursework and I feel myself more flexible in grasping their applicative potential.

I enjoyed a lot the research experience and the taste of a real research environment strengthened my desire to do research as part of my career. At the beginning it was a very demanding experience, but when I acquired enough independence I could feel the excitement and the great inward satisfaction of having the proper skills to work on an important scientific problem.

I would like to thank all the people that made my UROP an enriching experience. I am grateful to Prof. Hess for offering me the placement, for helping me to get the UROP award and for the effort in ensuring an adequate supporting environment. I'm equally grateful to PhD student Stefano Guazzotti, because without his invaluable guidance all this would have been impossible. I would like also to thank EPSRC for funding the project.