EPSRC CENTRE FOR DOCTORAL TRAINING
NEW AND SUSTAINABLE
PHOTOVOLTAICS

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CDT-PV Student Handbook

2017 - 2018 C4

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1. Introduction

Welcome to the Centre for Doctoral Training in New and Sustainable Photovoltaics. You are embarking on a unique PhD programme and by the time you attain your degree after four years you will have received bespoke training from seven of the UK's leading PV research groups, engaged with a very wide range of academic and industry experts within the field and formed an extensive network of colleagues and research contacts. Photovoltaics is currently undergoing a rapid expansion in the UK and following the attainment of your PhD you will be extremely well placed to begin a very rewarding career in this field should you choose continue in it.

This handbook contains essential information about the CDT and lets you know what to expect once you begin your studies. It should be used in conjunction with your own institution's guidelines for PhD candidates. Up to date information about the CDT will also be available on the CDT website www.cdt-pv.org.

PhD students carry out a vast amount of original research in the UK and we wish you well on your journey into training and discovery with the CDT-PV.

2. About the CDT

This Centre for Doctoral training is part of a much broader UK research initiative funded by the Engineering and Physical Sciences Research Council (EPSRC). In total the EPSRC, in conjunction with University and Industry partners, has invested over £950m in 115 separate Centres with research focusses that included Advanced Materials, Energy, Healthcare and Manufacturing.

This CDT constitutes an investment of £8m which will fund a total of 65 students spread across 5 distinct cohorts, the first of which started in 2014. This represents an unprecedented dedication to graduate training and the generation of new research within the field of photovoltaics.

2.1 Aims and Objectives

The overriding aim of the centre is to provide an enhanced and highly specialised training programme for doctoral students in the field of photovoltaics. More specific objectives include:

- Providing a new and supportive environment for PhD research programmes in PV in the UK.
- Further improving the PhD experience through a cohort-based approach to student training .
- Exposing doctoral students to state of the art facilities and laboratories across the UK and encouraging the development of multi-institutional collaborative research.
- Creating future leaders within the next generation of scientists and engineers in the field of photovoltaics.
- Enhancing the mobility of researchers moving between academia and industry to promote the transfer of new knowledge and enable greater innovation in the economy.
- Delivering research that enables the UK economy to develop and adopt sustainable, resource-efficient, low-carbon, low pollution and low-waste technologies.

2.2 Project Partners

The CDT in New and Sustainable Photovoltaics is a multi-centre project that will operate across 7 universities: Bath, Cambridge, Loughborough, Liverpool, Oxford, Sheffield and Southampton. Funding for the CDT is also coupled with industry support which will allow the centre's research outputs to have a direct impact on the skills and knowledge base of the energy sector. To date, the consortium of companies involved in the centre includes BAE Systems, Eight19, Echerkon, LSA Ltd, SiliconCPV, Ossila, Oxford PV, PowerVision, M-Solv, McCamley Middle East Ltd and Taylor Hobson.

3. The CDT PhD Package

The most important part of any PhD is the research project itself. It is the intention of the CDT to provide a higher level of networking support, training and infrastructure to enhance your PhD. This generates additional opportunities and resources but also comes with

additional responsibilities and commitments for which you are funded for a total of 4 years rather than the usual 3.5.

In particular, you will be engaged with your PhD project for the very outset making this CDT different from many others which dedicate a full year to training. Our training model is to interleave 7 x 2 week intensive courses with your training in year 1. We have found that this preparation actually accelerates the research output of the CDT's PhD students towards the end of their first year.

All CDT students are required to attend CDT training events and our annual Showcase as these are what makes participation in the CDT distinctive. It is a particular feature of CDTs that the students are partners in developing and shaping their training environment. Your constructive feedback and suggestions will be actively sought frequently during your four years and we have mechanisms in place to make continual adjustments. Of course, your performance in the taught modules will be assessed and while there are one or two written tests most of the assessment will revolve around the outcomes of group activities.

Most importantly, by being a part of this CDT you will automatically be part of a wide network of researchers within universities and industry that will set you apart from your peers. Overall, you can be assured of the goodwill and support of all those involved in the CDT and we wish you well in your studies.

4. You and Your Supervisor

The student-supervisor relationship is a key element in your success as a PhD student. It is important that both you and your supervisor make sufficient effort to maintain a good relationship throughout your studies. Here is a list of guidelines as to what you can expect from your supervisor and in turn what your supervisor can expect from you. The supervisor's defined role will vary between institutions and remember that the relationship between you and your supervisor will be unique.

4.1 What you can expect from your supervisor

a) **Regular contact:** You can expect either formal or informal interaction with your supervisor on a regular basis, e.g. this varies, but at least weekly contact is normal.

b) **Guidance:** When you start your PhD your supervisor should give you a good idea as to how you should initially proceed with your project. After this, your supervisor should provide further guidance as and when required. However, do not expect to receive a list of instructions on what to do for the whole four years on a day to day basis - that's very much up to you.

c) **Feedback:** It is important that you receive feedback on how you are progressing with your project. Any work that you present to your supervisor in the form of a presentation or report should receive some response in the form of verbal or written comments. Some supervisors request reports at regular intervals throughout your studies, other are happy to receive verbal or written updates at intervals dictated by you (within reason - daily is too often, annually is not often enough).

If there is a problem, if you are blocked or stuck in your work, if you have lost confidence, if you are experiencing domestic troubles of whatever kind, or if anything else at all is interfering with the continuation of your work, then do let your supervisors know about it. They will be able to help.

4.2 What your supervisor can expect from you

a) **Regular contact:** Even if a supervisor does not request formal meetings with you on a regular basis then you should still touch base with them frequently and let them know what you're up to. Remember, supervisors are experienced - if you actively avoid your supervisor for weeks on end because you've hit a snag and can't present them with new results then they will know something's up. Always be honest with your supervisor. Most will be acutely aware of the ups and downs of a PhD - they've had to do one too!

b) **Independence and Initiative:** Your supervisor will expect you to be able to make decisions based on your own judgement, e.g. What temperature range should I investigate? How many samples should I make? ... etc. Also, if you ever have to ask yourself "what should I do now?", then don't be afraid to act on your own ideas. If you wander too far off track your supervisor will tell you so the next time you discuss your work.

c) **Enthusiasm:** If *you* are not excited about your research who else will be? When postgraduates are really excited about what they are doing, it stimulates those around them. Excitement is infectious, and an enthusiastic student can provide a shot in the arm for even

a well established research group. All projects within the CDT have been selected by the academic partners for their high potential impact within the field of PV. This means that any new research generated by you will be highly significant to a wide community of scientists and industries.

4.3 Your second supervisor

If you have not been appointed a second supervisor before the start of your project then you should request that your supervisor find one for you from the date you start. Your second supervisor has an important role: they may bring additional expertise to your supervisory team. They should be there to give help and advice when your first supervisor is unavailable, and should also be able to provide further feedback on your progress. A second supervisor is not some passive entity that only exists to satisfy the paperwork, don't be afraid to approach them with questions of either a technical or pastoral nature if you feel the need. Very often, a second supervisor will mediate should the relationship between a student and their first supervisor become fraught. It sometimes happens that a student's first and second supervisors swap roles during a project or for the second supervisor to find the student a new first supervisor.

5. Progression, assessment and examination of your first year training and PhD

Ultimately, your PhD will be awarded on the basis of your performance in writing a thesis and a PhD viva by your university (further details may be obtained from your own institution). In addition, your institution will evaluate your performance annually and registration from one year to the next will have to be confirmed by your Department. Progression from the first year to the second year of your PhD is particularly significant and is subject to more rigorous assessment than for the other years. Typically, your institution will ask you to write a formal report and perhaps do a viva. The timing of this progression assessment depends on your university and it could take place as late as the end of your second year.There are two implications for 1st year progression for CDT PhD students:

i) You will have been assessed on your performance in the core-level modules which is a mandatory requirement of participation in the CDT. However, it is your university, not the

CDT, that will decide on your progression to the second or third year. Hence at the end of the first year, the CDT Academic Director will send a letter to your university (confirming your attendance and pass status in the CDT courses) to help inform its decision.

ii) Since the CDT funding and training is for 4 rather than the 3.5 years, your work in the first year will differ to that of traditional PhD students (and, indeed, compared to many other CDTs which take the full first year for training). In the CDT-PV you will know your project title from the outset but will also do 14 weeks of specific training. This is well understood and is taken into account by your supervisor and your department in its first year progression procedures.

6. Interruptions to your studies

Normally, short periods of illness are absorbed into a PhD schedule without having a great impact. If you miss some time please keep your supervisor informed and follow the local procedures of your university. If illness prevents you attending any of your first year CDT-PV training then you must notify the Academic Director.

For extended absences or more significant changes in your personal circumstances more formal support may need to be extended to you by both your university and the CDT. For example, depending on the circumstances, it may be possible to temporarily suspend your studies. Should anything unexpected happen to you, or your circumstances change, please be assured that the CDT and your university will give you as much support and advice as possible to help you, but the onus will be on you to keep the proper people informed.

7. Your Cohort

It is a significant advantage of the CDT that you will be part of a larger group of PhD students rather than studying alone. There will always be a group of like-minded individuals on hand to discuss your work and problems with. A vital objective of the CDT is that a high level of communication is maintained amongst the cohorts. You, your colleagues and those who follow will share in a lot of your experiences and will be able to provide support if and when you need it. Remember, this support is a two way street and all cohort members have a responsibility to help ensure the wellbeing of their fellow students.

7.1 The Role of the Cohort

Since you are part of a group of PhD students working on solar PV, you will enjoy some advantages over those in smaller groups doing PhDs in the traditional setting. Such advantages include:

a) Help solving technical troubles: It is likely that any technical problems you encounter will also be experienced, and perhaps even already be solved, by other members of the cohort. This is especially true for day to day ‘nitty gritty’ lab problems – you can save a lot of time by asking friends how to solve them. The cohort acts as an open technical forum and can be a terrific resource for problem solving. Note that this will be facilitated by the cohort network that will operate through the www.cdt-pv.org website and the CDT-PV slack group (www.cdt-pv.slack.com).

b) Comparing experience with colleagues: You will have plenty of opportunities to present your work to your cohort and engage in detailed technical discussions during more informal seminar events. Your peers within the cohort will be able to provide honest and constructive feedback on your work and will expect you to provide them with the same. This type of group feedback often picks up on aspects of your work that has been overlooked or sometimes misinterpreted by a supervisor and can be extremely useful.

c) Research collaboration: Each of the University Groups associated with the centre have a distinct set of capabilities, e.g. specific characterisation or deposition equipment, computing resources, etc. Students within the CDT are encouraged to visit cohort members at other institutions in order to engage in collaboration on an informal basis. This allows students the opportunity to greatly strengthen their own research and encourages knowledge transfer between the CDT's research groups.

7.2 Cohort Parenting

As a new PhD student it is valuable to get the experience of those who went before you – and if you’re an old hand it's fun to help and welcome the newcomers. Every new student will be assigned an ‘academic parent’ from an earlier cohort. The idea is for everyone to help one another and for it to be fun too.

8 .Your PhD Timetable Year by Year

8.1 Year 1 – Starting your project and doing the Core training

A significant portion of your first year of study (14 weeks between November and June) will be taken up by the CDT training programme. This programme will involve travelling to each of the partner institutions in turn and spending up to two weeks at each location. You will also attend several showcase, seminar and industrial events throughout the year. When you are not away from your host university you should work on your research project. In your first year, starting in the first month or so, expect to do a lot of reading. You will need to get up to speed on the literature relevant to your project and get to grips with any bits of physics or chemistry required for you to form a critical appreciation of other people's work within the field. Progression to Year 2 is determined by your University, not the CDT – please see Section 5 for details.

8.2 Year 2 – Your research project accelerates

In your second year of study you will really get to grips with your project. It is likely that you will start to plan and perform extended experiments and make deep investigations into your topic of study. You will still attend frequent training events organised by the CDT and will be required to travel to the partner institutions, however these events will be less intensive and less frequent compared to those within the first year training programme and you should expect to spend no more than a few nights away from your host university each time. You might also want to think about attending national conferences and workshops to present your work – the CDT will pay for this. Conferences are a great way to build your list of academic contacts and to put yourself on the map within the field of PV. An updated list of upcoming PV events will be maintained at cdt-pv.org. Conferences sometimes organise researcher workshops that are usually immediately before or after the main conference. Attending these events is a great way to meet other PhD students and form further collaborations at institutions outside the CDT.

At the end of your second year you will be subject to a review that will be reported to the CDT board just so that we know that you're still on track. Your supervisor will be responsible for instigating this review.

8.3 Year 3 – You become an expert

Now it is likely that you will know more about the issues surrounding your specific project than anybody one else (including your supervisor). Any new research that you generate at this point will certainly be of great interest to the PV community and you should consider submitting abstracts to both national and international conferences to present your work either orally or as a poster – again, the CDT will pay for this. You will continue to perform experimental/theoretical investigations although you should be starting think about the final shape of your project and how it might look in thesis form. It is definitely recommended that you have a rough thesis plan by the end of your third year.

You should also be encouraged to formalise your work for publication in an academic journal. Writing a scientific paper is a demanding task but is an important skill to learn. If you can publish a paper in your third or fourth years then this will significantly help you when you write your thesis. Often, it is very easy to re-work a published journal article into a distinct thesis chapter.

8.4 Year 4 – Concluding your work and writing your thesis

Now is the time to start finishing off your investigations and collating your research. If you are an experimentalist, try to resist the temptation to start new experiments once you have enough for a thesis. A PhD is a finite piece of work, and one of the skills in research is knowing when you are ready to stop and write up your work. You will have plenty of opportunities to perform more experimental work if you choose to pursue an academic career. The sooner you collect your research and flesh out your thesis plan the better. It is almost certain that writing your thesis will take longer than you think – most students take about 5 months. Also, be reassured that although writing your thesis is probably one of the hardest things you will ever do, the sense of accomplishment that you get once it's completed is phenomenal.

9. First Year Training (Core Modules)

The purpose of the first year training curriculum is to provide specific training that is both relevant to your project and that will equip you with additional knowledge and skills that might not be gained through independent research and study. While the curriculum is specifically designed to address the field of Photovoltaics you will cover a wide range of subjects including: semiconductor and device physics, UK energy policy, entrepreneurship,

nanotechnology and advanced materials. It is hoped that this training, placed within the context of your own research activities, will provide you with a very broad research outlook that most PhD candidates do not get. Furthermore, the modules are designed to promote student interaction within the cohort, on both professional and social levels and it is hoped that sharing the training experience with the rest of your cohort will be an enjoyable experience.

For a full summary of your first year training modules please refer to Appendix B.

9.1 Assessment

It is important that you are assessed throughout your training and that you demonstrate to the module coordinators that your learning objectives for each module have been met.

9.1.1 Exams

For those modules that are assessed by examination, exams will typically last for 1 hour and will be sat immediately after receiving a module's lecture course. Every exam will be designated a pass mark of 50%.

9.1.2 Written Reports, Group Reports and Presentations

Written reports and Group reports will adhere to the format specified by each of the module coordinators and will be submitted either directly to the coordinator or through the student portal on the CDT website. Presentations will be given in front of the whole cohort and any other people involved with the organisation of the module. Students will receive immediate verbal feedback on their presentations from their peers within the cohort.

9.2 Requirements for Passing the First Year (See Section 5)

You will need to complete all of the first year training assessments, without exception. You can use the online tool at the www.cdt-pv.org to submit digital copies of your work for each assessment. You will also have to meet the progression requirements set by your own university - this typically involves a written report, viva or presentation. Students are required to submit all copies of institutional progression reports to the CDT-PV's Academic Manager.

9.3 Plagiarism

It is an enduring principle of scientific reporting (research papers, PhD theses and all written work) that plagiarism, i.e. direct copying or cutting and pasting of text/figures, is seen as very unsound scientific practice. The CDT strongly upholds this principle and encourages you to maintain high standards of integrity in all of your written work, including work submitted for CDT training assessments and you research outputs.

9.4 Student Feedback – What do you want the course to be like?

At the end of every module you will be given the opportunity to provide honest, constructive feedback on the training that you receive through the CDT website and can do so anonymously if you wish. Any comments, complaints, suggestions that you provide will be greatly appreciated. We particularly welcome suggestions for items that you think we can organise training on, and suggestions as to how to make things work better in the training that is provided.

10. Workshops, Conferences and the Annual CDT Showcase

PhD students normally attend conferences and workshops in the higher years of their PhDs. For CDT-PV, we write this into your training plan. The CDT website will be updated regularly with information concerning upcoming events and you will also be kept up to date via e-mail or slack. The annual CDT Showcase will normally be held in October or November each year. All cohorts, academic partners and industry partners will be invited to attend and the event will take the form of a mini conference. All students will be expected to present their work at least once at a Showcase event.

As mentioned above, you are encouraged to attend national conferences and meetings throughout your PhD. It will also be your responsibility to provide your cohort with feedback on the conferences and report on any new developments within the field. Your conference reporting needn't be too formal and you are encouraged to make good use of social media (see below) to communicate with your cohort.

The CDT is linked to the activities of the SUPERGEN PV `SuperSolar' Hub. This is the EPSRC funded project and network that promotes solar PV research in the UK. This will enable students to engage more widely with the PV research community by providing

access to further training events, national and international research conferences and industry forums.

11. Expenses while on CDT events

Every student has a daily sustenance allowance of up to £24 while attending core-level training, workshops, conferences or other related CDT-PV events. Students are not obliged to spend all of this.

We urge students to exercise common sense when spending their allowance. In the eventuality that commons sense is in short supply here are some hard and fast rules regarding expenses

- No alcohol can be claimed for under any circumstances.
- No expenses can be claimed for gifts (e.g. confectionery, flowers).
- When submitting receipts for a group meal clearly highlight your items on a copy of the receipt and write a new total at the bottom of the receipt .
- Do not buy food or drink for anyone else other than yourself, this will not be reclaimable.
- Do not splurge. Frequent grocery shops throughout your training are fine but don't try to blow all of your cumulative allowance the last day. That's not OK .

All of your claims will be subject to the scrutiny of your respective institutions each of which will have a set of slightly different set of rules regarding claims, do look these up. CDT-PV cannot enforce payment of any expenses claim.

12. Outreach

Being able to communicate the issues surrounding your field to non-academic audiences is an important skill to learn. The CDT encourages its students to maintain an active outreach profile throughout their studies and engage frequently with public groups, particularly schools. One excellent way of doing this is to become a STEM ambassador. The STEM network will provide you with plenty of opportunities within your local area to engage in outreach. For more information visit http://www.stemnet.org.uk.
Performing outreach is a rewarding experience and your input will encourage young people to consider pursuing qualifications and careers in science and engineering. It is also an

excellent opportunity for you to develop confidence and new skills that will greatly enhance your future employability.

13. Social Media

The use of social media throughout your PhD is a double edged sword. Using sites such as LinkedIn, Research Gate and Facebook can be an excellent way to develop a network of research contacts, publicise your work and establish a reputation in the field. However, remember that your attention is a limited resource, and a PhD requires that your focus your attention intensely on the problems that arise in your research and writing. This has to take priority, so be careful when investing your time and attention in social media. Make sure it does not distract you from the main task at hand - your PhD.
That said, here are a few examples of how social media can be of benefit to the CDT:

- Conference Reporting: It is impossible for the CDT to send every student to every PV conference. Using Twitter to report directly on talks that you attend during a conference mean that the rest of your cohort can share in your experience without leaving their own host institutions. Check out the Sli.Do guide to live tweeting at conferences.
- Videos and podcasts: Sometimes, describing a tricky technical process via e-mail can be difficult. Posting video or audio recordings that document technical aspects of your work can be of great benefit to other members of the cohort engaged in similar work. More general videos that provide an overall outlook on your research or a description of your group's capabilities can also greatly improve your collaboration potential.
- Feedback: Through twitter, you can provide instant feedback on your CDT experience. Your comments and suggestions will be appreciated. By following @cdtpv you can also be kept up to date with all developments within the centre.

14. CDT-PV Equipment Pool

At each of its partner institutions the CDT-PV has been responsible for purchasing and installing characterisation equipment for free use by its students and members. The table below provides further details:

Item	**Location**	**Contact**

Cary UV-VIS-IR Spectrophotometer	Bath	Dr. Enrico Da Como (e.da.como@bath.ac.uk)
Fluorescence Spectrometer	Cambridge	Prof. Neil Greenham (ncg11@cam.ac.uk)
Non-Scanning Kelvin Probe	Oxford	Dr. Pabitra Kumar Nyak (pabitra.nayak@phisics.ox.ac.uk)
Solatron DSSC Impedance Analyser	Liverpool	Dr. Laurie Phillips (laurie.phillips@liverpool.ac.uk)
Impedance Analyser and Closed Cycle Cryostat	Loughborough	Dr. Jake Bowers (J.W. Bowers@lboro.ac.uk)
Bruker DXT Surface Profilometer	Sheffield	Dr. David Lidzey (d.g.lidzey@sheffield.ac.uk)
Bentham EQE System	Southampton	Dr. Stuart Boden (sb1@ecs.soton.ac.uk)

It is a principle of the CDT team that the universities will share access to equipment wherever it is practical to do so. Once you have identified a piece of equipment you wish to use please OK its use by asking the supervisor who has responsibility for it. Please bear in mind that this may involve the goodwill of local staff/students and perhaps require additional training.

15. Governance and Officers of the CDT

CDT Board: This is the body that holds the power to make all of the decisions for the CDT. The voting members are: one academic per partner institution, student representatives, industrial board members present. In addition, the meeting may be attended by the Academic Manager and the Quality and Education Advisor.

Director: Has overall responsibility for the CDT.

Academic Director: Has the responsibility for the academic content, monitoring and progression within the CDT.

Academic Manager: Has the responsibility for the day to day operation of the CDT.

Quality and Education Advisor: Has the responsibility for providing independent oversight of the CDT procedures.

Student Representatives: Responsible for representing the views of the whole student body on the Board.

CDT Project Selection Sub-group: Three academics advise the Board on new PhD projects to be considered for funding annually.

Industrial Advisory Board: Representatives from each industrial partner plus the Director and two other academic representatives.

Module Leaders: A named academic from each institution holds the responsibility for coordinating each taught module in the first year.

International Advisory Board: Provides external guidance on all aspects of the CDT.
Module Leaders: A named academic from each institution holds the responsibility for coordinating each taught module in the first year.

Appendix A: Finance Summary – Resources Supporting Your PhD

This summary is intended as a reference to inform you of the financial resources supporting your PhD and training.

Item	**Value**	**How Accessed**
Stipend (for a max of 4 years)	£14,553 per annum (RCUK 2016 stipend rate)	Via your university's postgraduate office. Paid quarterly.
Fees (Home and EU students, for a max of 4 years)	£4,195 per annum	Paid by CDT to your institution or paid by your institution itself as matched funding.
Research Training and Support Grant 'RTSG' (For your consumables and research travel for a max of 4 years)	£14,000 (in total)	Your supervisor holds this budget.
Module training costs (including student accommodation)	Up to £7,000 per module per cohort	Module leader issues orders for training locally. Academic Manager arranges accommodation.
Additional training costs – i.e. in addition to the Core Level training (student travel, sustenance, conference fees etc.)	£3,500 per student over 4 years.	Conference registrations handled centrally by Academic Manager. Claims for accommodation, travel and sustenance should be submitted to your local departments.

Appendix B: Core-Level Training Information

Core Level Training 2016/17

1. Important Dates and Contacts

Module	**Location**	**Dates**	**Module Leader**
1. Fundamentals of Photovoltaics	Liverpool	Oct 30 – Nov 10 2017	Prof. Ken Durose (ken.durose@liverpool.ac.uk)
2. Renewable Energy & Entrepreneurship	Cambridge	Nov 27 – Dec 08 2017	Prof. Neil Greenham (ncg11@cam.ac.uk)
3. Research Skills and PV in Action	Sheffield	Jan 08 - 19 2018	Prof. David Lidzey (d.g.lidzey@sheffield.ac.uk)
4. Mathematical Methods and Nanotechnology	Southampton	Feb 05 - Feb 16 2018	Dr. Giles Richardson (G.Richardson@soton.ac.uk)
5. Design, Fabrication and Characterisation for High Performance	Bath	Mar 05 – 16 2018	Prof. Alison Walker (a.b.walker@bath.ac.uk)
6. Advanced Sustainable Materials	Oxford	Apr 08 – 20 2018	Prof. Henry Snaith (Henry.Snaith@physics.ox.ac.uk)
7. Systems & Real PV Performance	Loughborough	May 13 – 25 2018	Dr. Jake Bowers (J.W.Bowers@lboro.ac.uk)

2. Module Summaries

Module 1: Fundamentals of Photovoltaics

Location: University of Liverpool

Module Co-ordinator: Prof. Ken Durose (ken.durose@liverpool.ac.uk)

Summary: This course is an introduction to the relevant fundamental physics required to understand the operation and characterisation of photovoltaic devices. The course is divided into several components; a lecture course (8 lectures), practical lab-work, a group project and a materials workshop. The course will also include a series of problem classes and an examination. There will also be a site visit to the Pilkington NSG float line in St. Helens if it is practical to arrange it to fit in with the plant schedule.

Training Elements:

- Lecture Course: Fundamentals of Photovoltaics
- Communicating Science: Podcasting
- Lab Taster Sessions
- Workshop: Transparent Conducting Oxides
- Team Challenge
- Tour of NSG float line, St. Helens

Assessments:

- Podcast
- Exam on lecture course
- Team challenge presentation

Module 2: Renewable Energy and Entrepreneurship

Location: University of Cambridge

Module Co-ordinator: Prof. Neil Greenham (ncg11@cam.ac.uk)

Summary: In the first half of this module you will be introduced to the technological aspects of a wide range of renewable energy technologies including wind, tidal, energy storage, as well as solar. You will receive a balanced overview of climate change science and will review global and UK energy usage/supply.

In the second half of the module you will receive an introduction to technological commercialisation and entrepreneurship. This will include an overview of entrepreneurship theory and practice, the basics of intellectual property protection and the role of IP in business/university policies and an introduction to finance and responsible business practices in the context of sustainable technology. There will also be a tour of Eight19 Ltd (printed plastic solar technology).

The module assessment will include an "open-book" examination which will occur the first Monday after the training.

Training Elements:

- Lecture Course: Renewable Energy
- Visit to Eight19
- Research Seminars
- Entrepreneurship Workshop

Assessments:

- Exam on lecture course

Module 3: Research Skills and PV in Action

Location: University of Sheffield

Module Co-ordinator: Prof. David Lidzey (d.g.lidzey@sheffield.ac.uk)

Summary: This module aims to give students a background understanding and practical experience of experimental methods and techniques used in materials research. The core of the module will be a lecture course that informs about the wide variety of thin-film deposition and characterisation techniques including UV-Vis spectroscopy, infra-red absorption spectroscopy, Raman scattering and electron microscopy.

You will also take part in a diverse programme of practical activities which will include: the deposition of thin films via spin coating, absorption and fluorescence measurements of organic semiconductors and training to use atomic force microscopy.

Training Elements:

- Literature Review
- Lecture Course: Experimental Techniques
- Lab Practicals
- Introduction to Python for Scientists
- Visit to Osilla and workshops

Assessments:

- Lab report (x2)

Module 4: Mathematical Methods and Nanotechnology

Location: University of Southampton

Module Co-ordinator: Dr. Giles Richardson (G.Richardson@soton.ac.uk)
Summary: This module will focus on Mathematical Modelling and Numerical Methods in the context of PV. You will also participate in labs on cell characterisation, clean room processing and laser physics, and a workshop on TCAD (Technology Computer Aided Design).

Assessments for the module include detailed lab reports of analysis encountered during lab practicals and a team presentation.

Training Elements:

- Lecture Course: Mathematical Methods
- Labs: Nanotechnology and the Clean Room
- Team Challenge
- TCAD Workshops

Assessments:

- Lab report
- Team challenge presentation

Module 5: Design, Fabrication and Characterisation for High Performance

Location: University of Bath

Module Co-ordinator: Prof. Alison Walker (a.b.walker@bath.ac.uk)

Summary: In this module you will receive training in electro-chemistry characterisation, electronic structure, Kinetic Monte Carlo simulations, materials characterisation for organic photovoltaic cells and fabrication methods for transparent coated oxides and thin film solar cells.

Training Elements:

- Electrochemistry Lectures and Labs
- Electronic Structure Workshop
- TCO and thin-film deposition
- Workshop: Organic PV

Assessments:

- Organic PV lab report
- KMC report

Module 6: Advanced Sustainable Materials

Location: University of Oxford

Module Co-ordinator: Prof. Henry Snaith

Summary: This module will begin with a comprehensive lecture course covering the following topics: Opto-electronic properties of organic semiconductors, carbon nano-tubes and graphene, polymer physics and the commercial development of OPV. This course will be assessed by a short examination.

Students will then engage in a programme of lab work that aims to provide training in time resolved photoluminescence, perovskite cell characterisation and LabView for PV characterisation. Further assessment will take the form of a brief written report on these activities.

The cohort's Team Challenge will consist of a presentation concerning the current status, problems and future solutions for Building Integrated Photovoltaics. The training for this module will be rounded off with a trip to Begbroke Science Park thin film coating facility where students will receive a tour and technical presentations from industry experts.

Training Elements:

- Workshop: How to Write a Paper
- Lecture Course
- Lab Practicals: Device Making and Characterisation
- Team Challenge: BIPV
- Visit to Oxford PV, Begbroke Science Park

Assessments:

- Writing a journal style article
- Team Challenge Presentation

Module 7: System and Real PV Performance

Location: University of Loughborough

Module Co-ordinator: Dr. Jake Bowers

Summary: This module aims to broaden understanding of PV from the lab scale to full scale operation of 'real world' PV modules. Students will attend a lecture course that covers module fabrication, encapsulation and interconnect design, performance characterisation and the aspects surrounding the ageing, degradation and failure of PV modules. Guest lectures from key industry members will be provided and the many aspects of commercial PV technologies discussed.

The module includes several workshops, e.g. on LabView and Matlab, aimed at providing training on useful skills for your PhD

Students will also visit the UK's largest solar farm at Wymeswold

Training Elements:

- Workshop: PVSyst
- Workshop: Matlab

- Workshop: Matlab
- Lecture Course: PV Systems
- Lab Practicals: Module Building and Testing
- Visit to Wymeswold Solar Farm

Assessments:

- Data Analysis Reporting
- Group Presentation

Appendix C: Who's Who in the CDT-PV

Person	e-mail	Role
Dr. Jake Bowers	J.W.Bowers@lboro.ac.uk	Module Leader, Loughborough CDT Board Member
Adam Brunton	Adam.Brunton@m-sovl.com	Industry Board Member M-Solv
Chris Case	Chris.case@oxfordpv.com	Industry Board Member Oxford PV
Prof. Phil Dale	phillip.dale@uni.lu	International Advisory Board Member, University of Luxembourg
Prof Ken Durose	ken.durose@liverpool.ac.uk	CDT Director CDT Board Member
Eric Don	eric.don@semimetrics.com	Industry Board Member Semimetrics
Prof. Neil Greenham	ncg11@cam.ac.uk	Module Leader, Cambridge CDT Board Member
Sajad Haq	SHAQ@qinetiq.com	Industry Board Member Qinetiq
James Kingsley	J.Kingsley@ossila.com	Industry Board Member Ossilla
Prof. David Lidzey	d.g.lidzey@sheffield.ac.uk	Module Leader, Sheffield
Dr Adam Mannis	a8mannis@liverpool.ac.uk	Quality and Education Advisor
Prof. David Mitzi	david.mitzi@duke.edu	International Advisory Board Member, Duke University
Humayun Mughal	h@siliconcpv.com	Industry Board Member Silicon CPV
Dr. Giles Richardson	G.Richardson@soton.ac.uk	Module Leader, Soton CDT Board Member
Prof. Garry Rumbles	garry_rumbles@nrel.gov	International Advisory Board Member, NREL
Prof. Henry Snaith	Henry.Snaith@physics.ox.ac.uk	Module Leader, Oxford CDT Board Member

Antulio Tarazona	Atarazona@echerkon	Industry Board Member Echerkon
	manager@cdt-pv.org	Academic Manager CDT Board Member TBA
Prof. Alison Walker	a.b.walker@bath.ac.uk	Academic Director Module Leader, Bath CDT Board Member
Paul Warren	Paul.Warren@nsg.com	Industry Board Member Pilkington NSG Ltd.
Jurjen Winkel	Jurjen.winkel@eight19.com	Industry Board Member Eight19
Lewis Wright	L.Wright2@lboro.ac.uk	C2 Student Rep
Peter Yates	sgpyates@liverpool.ac.uk	C1 Student Rep