UK Plasma Physics News – Autumn 2018.

Welcome to the UK IOP Plasma Physics Group (PPG) e-newsletter. If you have items for inclusion in future newsletters e.g. any meeting announcements or reports, research achievements, new appointments, facilities, projects, buildings etc. please contact: ken.mcclements@ukaea.uk.

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COMMITTEE NEWS

There has been one committee meeting since the last newsletter with no changes to the committee. Further details of committee activity and actions are available on the Group website.

RECENT MEETINGS

16th UK Technological Plasma Workshop

The 16th Technological Plasma Workshop (TPW'18) was held in Coventry alongside the Vacuum Symposium at the Vacuum Expo at the Ricoh Arena, on the 10th and 11th of October 2018. The Technological Plasma Workshop is principally a UK-based international forum in science and technology of plasmas and gas discharges. This year it was attended by 40 delegates and the conference programme consisted of 2 invited talks, 12 oral talks and many poster presentations from a mixture of UK and international institutes. TPW'18 was themed on "Plasmas for Materials Applications: Etching, Deposition and Joining Technologies" with two industrial invited talks on Challenges and Opportunities for Thermal Plasma Abatement of PFC gases by Dr Simeone Magni (Edwards Limited, Clevedon, UK) and Plasma cathode electron generators for 3D printing and welding applications by Dr Colin Ribton (TWI, Cambridge, UK). Other presentations covered diverse topics including pulsed laser deposition of metal - oxide thin films, chemical probes for plasma diagnostics, atmospheric-pressure plasmas for biomedical and environmental applications, plasma-driven organic synthesis, computational studies of pellet ablation and microthrusters.

Joint poster sessions with other meetings held as part of the Vacuum Symposium were held on both days and Alex Shaw of Loughborough University was awarded a best poster prize for his work on the fate of plasma-generated oxygen atoms in aqueous solutions. The

prize was sponsored by the IOP and Leybold UK Ltd.

A TPW AGM was held on the second day of the conference and it was agreed that TPW 2019 will be collocated with the Vacuum Symposium at the Vacuum Expo at the Ricoh Arena, Coventry.

The support of the IoP Plasma Physics Group and the Vacuum Expo subsidised the two day conference and their support is greatly appreciated. TPW and the wider Vacuum Expo were used as an opportunity to explore collaborative opportunities between the academic and industrial communities. The Ricoh Arena is an excellent venue with a large exhibitor hall and good quality rooms for oral presentations, which provided an ideal meeting place for the next generation of researchers to engage with leading researchers in both academia and in the wider plasma and vacuum based industries.

We look forward to seeing you at **TPW 2019 at the Ricoh Arena, Coventry UK on the 9th and 10th of October 2019 (www.tpw-uk.org)**.

45th IOP Plasma Physics Conference

The 45th IOP plasma physics conference took place at Queen's University Belfast from 9th-12th April 2018. Around 95 delegates attended and a total of 34 talks were given including the Rutherford Prize talk by Dr Jena Meinecke of the University of Oxford and the Culham thesis prize talk given by Dr Clare Scullion of Queen's University Belfast. The delegates enjoyed an excellent programme of talks and posters covering all aspects of plasma physics including magnetic confinement, lasers, space plasmas and technological plasmas. They also had the opportunity to enjoy an excursion to the historic Titanic museum and a conference dinner held in the rather splendid Edwardian surroundings of the City hall where they were entertained with some traditional Irish dancing. A public lecture was given on the Tuesday evening by Dr Deborah O'Connell and Professor Norman Maitland from the University of York, with the title "It's a matter of life and death: when plasma physics meets systems biology". This was well attended and extremely well received. The conference was even mentioned on Steve Wright in the Afternoon! We thank Dave Riley (QUB), Priscilla Lim (IOP) and Marcia Reais (IOP) for all the hard work they put in to organising another very successful meeting. We are also very grateful to the IOP, CCFE, STFC and AWE for their financial support, without which the meeting could not have taken place.

FORTHCOMING MEETINGS

International Conference on High Energy Density Science (ICHED) 2019: 31 March-5 April 2019 at University College, Oxford, UK. Abstract submission deadline: 7 December 2018.

46th IOP Plasma Physics Conference: 23-26 April 2019 at Holywell Park, Loughborough, Leicestershire, UK. Abstract submission deadline: 15 January 2019.

TPW 2019: 9-10 October 2019 at Ricoh Arena, Coventry, UK. Early registration and abstract submission deadline: 1 September 2019.

COMMUNITY NEWS

AWE

Temperature measurement in shocked materials using x-ray diffraction at the Orion laser facility

Contributors: Ashley Poole, Andrew Comley, Emma Floyd, Steven Rothman, John Foster, Colin Danson, Justin Wark, David McGonegle, Caroline Lumsdon, Anthony Meadowcroft, Andrew Higginbotham.

Temperature measurement is the 'elephant in the room' for work on laser compressed solids. Very few in-situ nanosecond temperature measurement techniques currently exist, and those that do either fail at the modest temperatures reached in dynamic compression (e.g. pyrometry) or show large error bars, often of order 50% (e.g. EXAFS). As a result, the temperature of shocked condensed matter is generally inferred from theory. This experiment, led by University of York alongside collaborators from University of Oxford and AWE PLC, was designed to bridge this gap in capability by analysing the change in x-ray diffraction patterns resulting from temperature. If successful, this technique would enjoy deployment on future experiments and next generation facilities such as NIF and the European XFEL.

Laser-plasma based X-ray diffraction techniques have traditionally focused on structural determination of high pressure phases. For example, some pioneering work studied the change in diffraction pattern of iron due to the body centred cubic to hexagonal close packed (the so called α-ε phase transition). Studies of this type rely solely on the change in angular position and number of diffraction peaks observed. However, given that the crystal is simply a 3D diffraction grating it is quickly realized that disordering of the sample away from its ideal structure, for example by thermal vibration, will play a role in coherence of scattered light, and thus in the relative brightness of the regions of coherence (the diffraction peaks). This is known as the Debye-Waller effect, and allows a route to temperature determination by making use of the often ignored intensity information in the various diffraction peaks.

For a convincing thermometry technique, a very bright x-ray source is desirable. In order to achieve this a new diagnostic configuration was designed by AWE PLC and fielded at the Orion laser facility. This new configuration demonstrates a marked improvement in capability; when coupled with a new laser pulse spatial-shaping strategy (the inclusion of phase plates rather than beam defocus), an increase in x-ray photon yield of an order of magnitude was observed over previous experiments. This new configuration also unlocks higher atomic number x-ray backlighter materials never before fielded on the Orion laser facility, allowing higher energy x-ray sources for future campaigns.

As a result of these capability improvements it was possible to gather high quality data at various pressures up to approximately 80 GPa. An example x-ray diffraction image from compressed niobium to about 25 GPa is given in *figure 1*. The blue lines on the image indicate the diffraction from the material before the shock wave has arrived. The red lines coincide with the diffraction from the material after the shock has hit; the change in position of these diffraction lines is evidence of the material compression by the shock wave. The spottiness of the diffraction lines indicate the preferred orientation of crystal grains in our material.

Measuring temperature from these images is contingent on thorough post-processing. A full analysis requires careful consideration of a number of geometrical factors including polarisation effects on scattered radiation, sample attenuation, filter attenuation, and texture effects of the sample itself. It is thought that these intensity corrections will be readily applicable. Analysis of the data is ongoing, but it is clear this technique has significant promise.

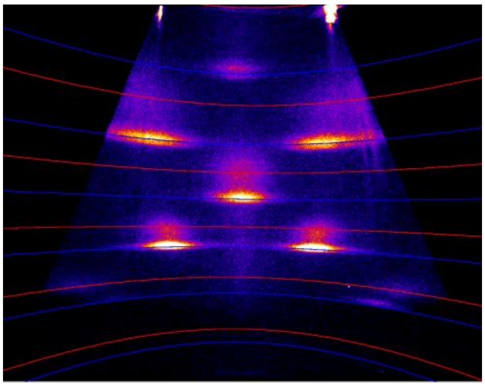


Figure 1: An example of diffraction data gathered on this experiment. The x-ray backlighter was a Zn foil, and the probed material was a Nb foil. The x-rays generated by Zn resulted in many diffraction lines, a boon for this technique. The material to be investigated, Nb, was chosen due to its compatibility with this thermometry technique.

IOP/IMA Reaccreditation of the AWE Graduate Training Scheme

On the 1st May Orion hosted an assessment visit of AWE's Graduate Training Scheme by the IOP (Institute of Physics), IMA (Institute of Mathematics and its Applications) and OR (Operational Research Society) professional bodies.

There were presentations from: Andrew Randewich on the scope of AWE's work in physic and mathematics; Helen Smith on AWE's graduate scheme training and Colin Danson on the role of the Head of Profession for Physics and Mathematics (HoPP) in staff development. A tour of Orion during a campaign day was very well received. The representatives of the professional bodies then had the opportunity to interview mentees, mentors and line managers to judge whether the training scheme was really being delivered to its best (the OR Society were present as observers).

IOP feedback: I am writing to confirm the outcome of the assessment visit, which took place on 1st May 2018. I am delighted to say that AWE's accreditation is renewed without conditions or reservations for a further three years, for both CPhys and CEng, and extended to include IEng. Feedback from all of those involved in the assessment is overwhelmingly positive; they regard the scheme as an exemplar in its field, and it was scored at top marks for 99% of criteria. In particular, they were impressed by: the quality of the graduates, their enthusiasm for the organisation and the reasons why most of them chose to join i.e. because of the breadth and depth of physics undertaken; professional development and maintaining physics permeates the whole ethos of the organization, there is a recognition that this is the way to produce a 'better workforce' and this view is embraced by everyone we met; the flexible, tailored approach to training and to recording competencies which means that graduates are empowered to own their own development; and the expertise and commitment of scheme management.

IMA feedback: Thank you for your hospitality during the recent reaccreditation visit. I am delighted to be able to confirm that we will recommend that the AWE Graduate Training Scheme should be reaccredited for a further period of five years.

We found that the scheme was structured in a way which met the criteria of the IMA for such schemes in full. In particular, we were impressed by the Graduate Project concept. From the presentation, it was clear that AWE is committed to the scheme at the highest level. From our conversations with mentors, mentees and line managers, it was also clear that the scheme is implemented according to the documentation provided and that it is valued and supported by all groups. We therefore had no hesitation in recommending the Graduate Training Scheme for reaccreditation and will forward our report in due course. Thank you once again for your hospitality.

Representatives of the professional bodies with their hosts (from left to right): Colin Danson (HoPP), Ian Gavin Blackett (OR), John Meeson (IMA), Christopher Greenough (IMA), Stephanie Richardson (IOP), Russell Coles (IOP), Martin Fair (IOP), and Jenny Macey (Deputy HoPP).

CCFE

Duke of Cambridge's visit marks end of MAST Upgrade construction

On 18 October 2018 Prince William, Duke of Cambridge, visited the Culham Centre for Fusion Energy (CCFE) to celebrate the completion of Britain's new fusion experiment, the MAST Upgrade spherical tokamak. The Duke visited Culham for a tour of the machine and heard about the potential of fusion energy to change the world. During Green GB Week, it was a particularly fitting time to highlight research into fusion and how it could be commercialised to provide huge amounts of low-carbon electricity. The Duke heard about the five-year project to build the tokamak and stood next to the MAST Upgrade vacuum chamber where, in a few months' time, it is hoped that temperatures of up to around 4 keV will be created – over three times hotter than the core of the Sun. He then unveiled a plaque in the control room (see photo) and pressed a button initiating a helium "glow discharge" – a low temperature plasma that cleans the inside of the machine during commissioning. Although the device is not ready for experiments yet, this was one of the first times that plasma has been put into MAST Upgrade, and represents a significant achievement. There was an agonising wait between the Duke pressing the button and the plasma glow flashing up on screens in the control room, but all went according to plan.

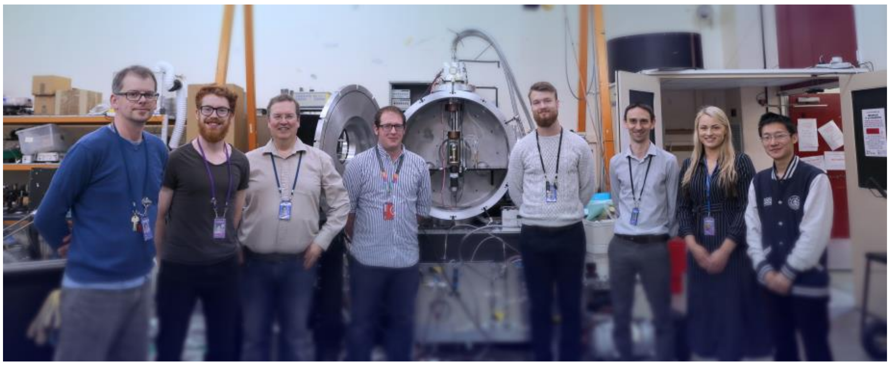
A video of the Duke's visit can be seen here: https://www.youtube.com/watch?v=SvQnHNhX4po

Update on JET

The legal basis for an extension of JET operations to 2019/2020 was adopted by the EU Council on 15 October 2018. Both the UK government and the European Commission expect that a contract for the extension will be signed before the end of 2018.

CLF

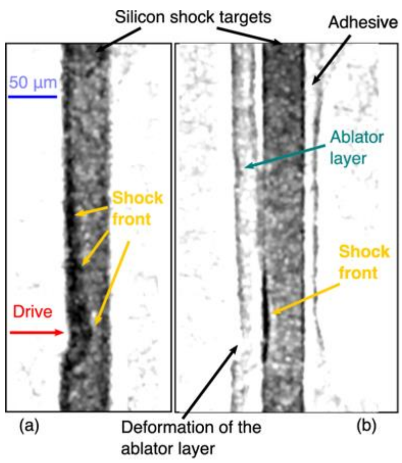
FROM ICE TO FIRE: Nanostructured cryogenic targets form relativistic plasma accelerators



How intense does a burst of energy have to be to cause a frozen object to erupt into flames? The answer, if you're hoping to achieve this quickly, is very. Now imagine that the object is cryogenically cooled to just above absolute zero, and the aim is to super-heat it to form plasma. This is what Dr Graeme Scott and his team at the CLF have recently achieved using the Vulcan petawatt laser. This feat involved the use of pioneering cryogenic targetry jointly developed by the A-SAIL consortium and the CLF and has been considered a world first in the field. The study used nanostructured cryogenic targets for laser driven particle acceleration, which has shown that deuterium beams can be accelerated in directional cones with a narrow range of kinetic energies. Ion beams with these parameters could find applications in fusion energy or healthcare and the research demonstrates a new mechanism by which ion beam properties can be controlled.

For the full story and link to the PRL publication, see here: https://www.clf.stfc.ac.uk/Pages/Nanostructured-cryogenic-targets-form-relativistic-plasma-accelerators.aspx

Using ultrashort pulsed, hard, bright X-rays to 'freeze' laser driven shock waves in silicon



For more than a decade at Imperial College London, Dr Stuart Mangles and Dr Daniel Eakins along with a research team have been developing a new type of compact accelerator called a laser wakefield accelerator. It has the capability to make ultrafast flashes of X-rays that can 'freeze' the motion of rapidly changing systems. Furthermore, the use of betatron radiation – ultrashort pulsed, hard, bright X-rays – for radiography is an enticing foray into the imaging of rapidly evolving phenomena. As it stands presently, traditional surface based measurements are proving inadequate as the subsurface interactions cannot be diagnosed directly. The result being, measurements of shock properties at the surface are potentially affected by interactions below the surface which are not being observed. The Gemini laser at the Central Laser Facility, with its two beamlines, proved invaluable as the Gemini South beam was used in the production of the betatron radiation and the Gemini North beam was used to produce the shock wave in the target. The delay between the target being hit and the betatron probe was able to be varied continuously between 0 and 12 nanoseconds allowing for snapshots to be taken of the shock wave. One benefit proposed by betatron radiation is that rapidly evolving phenomenon can be imaged without the need for larger, more expensive, light synchrotron sources.

For the full story and link to the Nature Scientific Reports publication, see here: https://www.clf.stfc.ac.uk/Pages/betatronradiation.aspx

First observation of radiation reaction: Light so intense that it can even slow matter down

Published in Physical Review Letters X, the team's results shed light on a fundamental problem in modern physics, known as radiation reaction. An accurate understanding of such a process is not only of interest for fundamental physics but is also crucial for our understanding of massive and exotic astrophysical objects, such as black holes and quasars, which are permeated by electromagnetic fields of comparable strength. Radiation reaction is the back-action on an accelerated electron from the radiation it emits. Whilst this phenomenon is well understood in the classical realm, a consensus has not yet been reached in regimes of ultra-high intensities, where a quantum approach must be adopted. In order to provide a first direct experimental evidence of the phenomenon, the team took one of the twin laser beams of Astra-Gemini and focused it at the entrance of a helium-filled gas cell. Through the principle of laser wakefield acceleration - a technique used to create an electron plasma wave from a laser pulse - the group were able to accelerate a multi-GeV electron beam. The electron beam then collided with the second laser beam of Gemini, focussed down to a size comparable to the breadth of a human hair. During collision, the electrons were observed to lose a significant fraction of their energy, in a way that defies the laws of classical physics. Upon completion of numerical simulations of the phenomenon, the team confirmed that when electrons were propagated through the short burst of intense laser light, up to 30% of their energy was lost. This effectively indicated that - at these high intensities - this tiny layer of light, the width of a human hair, was as efficient in stopping particles as half a centimetre of iron.

For the full story and link to the PRX publication, see here: https://www.clf.stfc.ac.uk/Pages/Light-so-intense-that-it-can-even-slow-matter-down.aspx

PRIZES AND AWARDS

Nobel Prize in Physics won by a trio of laser pioneers

Congratulations to Arthur Ashkin, Donna Strickland and Gerard Mourou for winning this year's Nobel Prize in Physics. It is especially celebratory this year in the equal recognition of Strickland for her contributions alongside Mourou. Donna is the first woman to be recognised with a Nobel Prize in Physics since Goeppert-Mayer in 1963 – ending a 55 year hiatus – and the third woman to receive one.

Arthur Ashkin invented the optical tweezers, which uses beams of light to move and manipulate tiny physical objects. These are now widely used in biological sciences to manipulate bacteria without harm. Whereas, Donna Strickland and Gerard Mourou invented the technique of Chirped Pulse Amplification (CPA), which allows high power lasers such as the Vulcan and Gemini lasers at CLF and the Orion Laser at AWE to generate petawatts of laser power enabling them to create some of the hottest, densest matter ever created on earth. CPA involves taking a very short pulse of laser light and stretching it in time, before amplifying it to high energy and then compressing it close the original pulse duration. Along with opening up the petawatt era of laser plasma physics, it is also the reason that lasers can be applied for eye surgery which has had a huge societal impact ever since.

Rutherford Prize for the Communication of Plasma Physics 2019 (sponsored by STFC)

Nominations are now open for the Rutherford Prize for the Communication of Plasma Physics 2019. Self-nominations are welcome and there's no time limit as to when the activity took place. The award recognises those who exemplify excellence in outreach to the general public through the communication of plasma physics to those that are non-experts. The prize is open to ALL members of the plasma physics community, whose application will be judged by a distinguished panel of scientists and communicators (to include one plasma physicist, one non-plasma physicist and one non-physicist). This year's winner will be announced, and the prize presented during the 2019 IOP Plasma Physics Conference (23rd-26th April, Holywell Park Conference Centre, Loughborough). The winner will receive £500 and complimentary registration to the conference and will be invited to present a short talk on their activities during the conference.

The application procedure requires evidence of excellent communication skills and discussion of the impact of **one outreach activity**. Past applications have seen examples such as creating a website, giving a talk or lecture, writing an essay or an article in a magazine, blogging or producing a podcast or video. Anything that communicates our plasma science will be considered - the more creative the better! Nominations and self-nominations are welcome, and past unsuccessful nominations can be re-submitted.

Culham Thesis Prize (sponsored by CCFE)

Nominations are now open for the Culham Thesis Prize 2019. The prize is awarded annually to the candidate who has displayed excellence in the execution of the scientific method as witnessed by the award of Doctor of Philosophy in Plasma science from a UK or Irish university. The thesis content should exhibit significant new work and originality, clearly driven by the nominee, be well explained and demonstrate a good understanding of the subject. The prize consists of £500 in cash plus an expenses paid trip (to a maximum of £500 for travel) to the annual IOP plasma physics conference, where the recipient will be asked to give an invited talk.

Malcolm Haines Prize

Thanks to a gift from his widow Polly Haines, there is a new biennial IOP Prize of £500 for early career researchers, created in honour of the late Malcolm Haines, an outstanding plasma physicist at Imperial College London. Eligible nominees are researchers working in any area of experimental or theoretical plasma physics in the UK or Ireland with less than 6 years of work experience after completing a PhD or, if they do not have a PhD, less than 10 years of work experience (not including career breaks). `Plasma physics' is defined here to include magnetically-confined and inertially-confined fusion plasmas, laser plasmas, warm dense matter, low temperature plasmas, technological plasmas, and space/astrophysical plasmas. The research must have been carried out in the UK/Ireland. Self-nominations will be accepted, but a second nomination is required from a person who is a member (in any category) of the Institute of Physics and is based at an institution other than that of the nominee. The prize will be awarded for outstanding research, leadership and/or innovation in plasma physics and nominations will open in December 2018.