SPEAKER ABSTRACTS

YORK

Monday 20th June

Howard Wilson, University of York
Fusion Energy: the conditions & approaches

This presentation will introduce the background to fusion energy and the conditions required to produce it. The basic fusion process will be described, focussing mainly on the reaction between two heavy forms of hydrogen – deuterium (D) and tritium (T). The so-called “triple product” will be motivated and defined as the quantity that characterises the proximity of the DT fuel conditions to those required for a commercially viable fusion power plant. These include a temperature about ten times hotter than at the centre of the sun, and requires a sufficiently effective system to confine the DT fuel at this temperature. The fuel is then in a state called plasma, which will be defined and characterised. Two broad approaches are being explored to access fusion energy conditions – inertial confinement and magnetic confinement, which will be described. Some of the different fusion concepts in each scheme will be discussed. The presentation will close with a discussion of the large breadth of science and technology that must be brought together to realise a commercially viable fusion power plant, signposting the topics to be covered in the subsequent lectures of the school.

Nick Walkden, Frazer Nash
Plasma Physics for Fusion Industry

At the heart of all fusion power plant designs sits a plasma. Plasmas exhibit a wide range of complex phenomena that must be understood to design and predict the behaviour of fusion powerplants, ultimately providing the conditions for fusion to occur and setting the power output of the device. This talk will introduce the basics of plasma physics, and explain how key concepts such as plasma drifts, instabilities, turbulence, and equilibria, affect the performance and viability of fusion devices. It will describe techniques deployed to understand the physics of fusion plasmas and outline recent key developments in the field, to provide a comprehensive and understandable overview of fusion plasma physics.

Tuesday 21st June

Garry Voss, UKAEA

The Tokamak

The Tokamak configuration for magnetic confinement of plasma was first proposed in Russia in the 1950's and has been adopted by most magnetically confined fusion research bodies as the preferred configuration. The geometry and terminology used to define the Tokamak will be introduced including the differences between the conventional Tokamaks (like JET and ITER) and the spherical Tokamak (like MAST-U and STEP).

The main components of a Tokamak and their functions will be outlined including:

Toroidal field coils: These produce a magnetic field in the toroidal direction and are either formed from copper conductors or from superconductors which offer no resistive power loss.

Poloidal field coils: These produce a magnetic field in the poloidal direction. This combines with the toroidal field to form an efficient plasma confinement and shaping system.

The 1st wall: This faces the plasma and is subjected to high thermal loads due to radiation and particle flux as well as a volumetric heating due to neutron irradiation in fusion conditions. Materials such as graphite and tungsten are often used here.

The blanket: This is needed to breed the tritium fuel for the fusion reaction. It is located directly behind the 1st wall and contains lithium in the form of a ceramic, liquid metal or salt, which produces tritium when subjected to a neutron flux. A multiplier such as beryllium or lead is often included in the blanket to increase the number of neutrons and hence tritium breeding.

Divertor: The level of impurities and helium particles in the plasma needs to be controlled by allowing them to pass outwards to a scrape-off-layer which surrounds the plasma. This is then diverted to target plates at the top and/or at the bottom of the plasma. The heat loads and erosion rates on these target plates can be very high and their design often limits the size and power of the Tokamak.

Main support structure/cryostat: This reacts the loads induced on the coils, 1 st wall and blanket structures and so holds the device together.

Other Tokamak systems: These include active and passive vertical stabilisation coils which prevent the plasma moving up or down, gas feeds and pellet injectors for fueling the plasma, heating and current drive systems using neutral particle beams and/or RF systems, shielding to limit irradiation of components and structures, diagnostics for plasma position sensing and measuring its parameters.

Nigel Woolsey, University of York & Nick Hawker CEO, First Light Fusion

Inertial Confinement Fusion

Inertial confinement fusion or ICF is an exciting approach to fusion energy production that uses a powerful driver to compress a small sphere of frozen deuterium and tritium fuel to immense pressures and heat a fraction of the assembled fuel starting fusion reactions. Once the thermonuclear conditions are assembled, heating by these nuclear reactions increases the temperature and nuclear reaction rate to ignite the fuel at which point fusion burn rapidly consumes the fuel. Energy is release as an intense, short lived pulse. The ICF approach was validated in an experiment in August last year using the National Ignition Facility, the world's largest laser. This laser delivers 1.9 million Joules across 192 laser beams to compress a single 2 millimetre diameter sphere containing deuterium and tritium. Within 10 nanoseconds (10 billionths of a second) the diameter was reduced to less than 0.1 millimetres and in less than 0.1 nanosecond produced 1.3 million Joules of fusion energy. This was just short of gain 1. Here, I will introduce the basics ideas that underpin the ICF approach, discuss the significance of National Ignition Facility result and reflect on current research into laser-driven inertial confinement fusion and whether this is a future energy source.

Steve Cowley, PPPL (US)

International Fusion Landscape

Fusion research is truly international and progress has come from collaborations that stretch across the globe. The ITER project is perhaps the emblem of this approach. However, as private companies enter the race for the first fusion electricity strategies for success are changing. I will describe efforts in the US to accelerate fusion delivery through public-private partnerships and their relationship to the international public sector programs. I will also give a perspective on the technical challenges ahead.

Aneeqa Khan, University of Manchester, Jiangang Li, ASIPP, Alain Becoulet, ITER, Steve Cowley, PPPL (US), Hartmut Zohm, Max-Planck-Institute for Plasma Physics

Meet the Experts: International perspective

Our 'Meet the Experts' panel will be discussing international strategies, representing ITER (Alain Becoulet), Europe (Hartmut Zohm), US (Steve Cowley) and China (Jiangang Li). During this time we will have a curated discussion with the panellists, who will give the latest information and views on the international fusion landscape, as well as opportunities for questions from the conference participants.

Wednesday 22nd June

Fernanda Rimini, UKAEA
Tokamak Operational Scenarios

The talk will cover aspects of Tokamak Operations, focussing on different plasma scenarios and the implications they have for future reactor scenarios and design. We'll touch on concepts like pulsed operation, thermal confinement and H-mode, plasma instabilities and disruptive events. We will, also, introduce some of the real-time machine protection and control issues, to be elaborated further in subsequent lectures.

Hartmut Zohm, Max-Planck-Institute for Plasma Physics
Diagnostics and Control

Diagnostics for magnetically confined fusion plasmas have to provide measurements of various quantities of interest in a harsh environment. In the last decades, enormous progress has been made in this field and to date, there are measurements available of a large number of plasma parameters with high temporal and spatial resolution. In present day experiments, diagnostics are used as instruments to understand the behavior of the hot plasma, but also as sensors, to feedback control the plasma discharge. In a fusion power plant, the emphasis will mainly be on the latter aspect, but also the environment will be significantly harsher than in present day machines, so the problem of diagnostics and control remains a challenging one.

In the talk, I will first review diagnostics principles for the main plasma parameters needed for both physics understanding as well as control. This will be followed by a brief discussion of the available actuators (heating, current drive and fueling), which will be dealt with in more detail on the following day. From there, I move to describing the control challenge of tokamak plasmas, which turns out to be a multi-input multi-output problem. Strategies to cope with the challenges will be discussed as well, including the prospects for model-based control versus a pure heuristic approach.

Thursday 23rd June

Dr Elizabeth Surrey, Former Head of Technology, UKAEA

Plasma Heating and Current Drive Systems

There are four types of heating and current drive systems available for tokamaks. Three depend on radiofrequency waves over a range of frequencies, the fourth uses neutral particle beams. The uses of the four different heating and current drive systems will be briefly described with emphasis on the technical requirements imposed by tokamak-based power plants. A technical description, along with example properties (power, frequency, pulse length, etc.) of each system and its individual components will inform the discussion. The components include a wide range of power supplies both d.c. and a.c., special coatings and windows, control and instrumentation, in addition to hardware. Some particularly demanding examples will be included.

Rachel Lawless, UKAEA

Fuelling a Tokamak

Tritium and deuterium are widely considered the most viable fuels for fusion power plants. Whilst deuterium is abundant on earth and can be treated like hydrogen, tritium does not occur naturally in significant amounts and must be handled carefully due to its radioactive nature. For fusion to be viable, technologies must be developed to safely breed, extract, process, handle, and store tritium gas. This talk will outline how fusion fuel cycles are designed, and the considerations needed when handling tritium and developing tritium technologies, as well as outlining the steps required to deliver safe and efficient fusion fuel cycles in the future.

Jan Coenen, Forschungszentrum Juelich, Germany

Plasma Exhaust and divertor design in Tokamaks

One of the Crucial Points when realising fusion is the understanding of Plasma Wall Interaction and Power Exhaust. In modern Magnetic Confinement Fusion Devices such as the Tokamak exhaust is realised in a component called the Divertor. In this lecture the basics of plasma wall interaction (PWI) as well as power exhaust will be discussed . Plasma Wall interaction and Power Exhaust relate directly to two aspects of fusion devices - the plasma performance and divertor component design options. Hence after introducing the main mechanisms of basic PWI and Power exhaust we will discuss the options for modern divertors as well as potential limitations due to materials and the feedback of such interaction on the plasma system. In the lecture we will also discuss the current design option considered for the next step designs such as ITER and DEMO and highlight some path forward to more advanced setups.

Friday 24th June

Lee Packer, UKAEA
Nuclear/Neutronics Analysis of Fusion Systems

I will give a brief introduction to fusion neutronics (radiation transport simulations), covering some of the key computational methodologies and nuclear data used in this field as well as discussing elements of benchmarking and validation of results. Also aspects of neutronics relating to fusion power plant design, including evaluation of tritium breeding rates in blanket design, nuclear heating, activation and residual dose rate calculations relevant to operations and safety will be covered.

Andrew Davis, UKAEA
Digital Approaches to Design in Fusion

The process of designing fusion reactors and fusion reactor systems historically inherited much from traditional nuclear industry methods. Fusion however is a much more complex physics problem than fission systems. The fusion load case is multi-physics; large heat loads (even larger off-normal heat loads), high neutron flux, large magnetic field, complex chemistry, structural changes, and neutron flux dependent material parameters. We will cover the current set of technology issues that fusion faces, how computer based modelling will fill the gaps and what the state of the future might look like.