

Fusion

BUSINESS

Inside..

- Fusion-Industry Link on Dust Technologies
- Conference Report
- Spectroscopic Key to Nuclear Fusion
- New Jet Agreements

SPIN-OFF SUCCESS FOR FUSION

A diagnostics system developed by UKAEA Fusion scientists has been purchased by researchers for use in astrophysical plasma research.

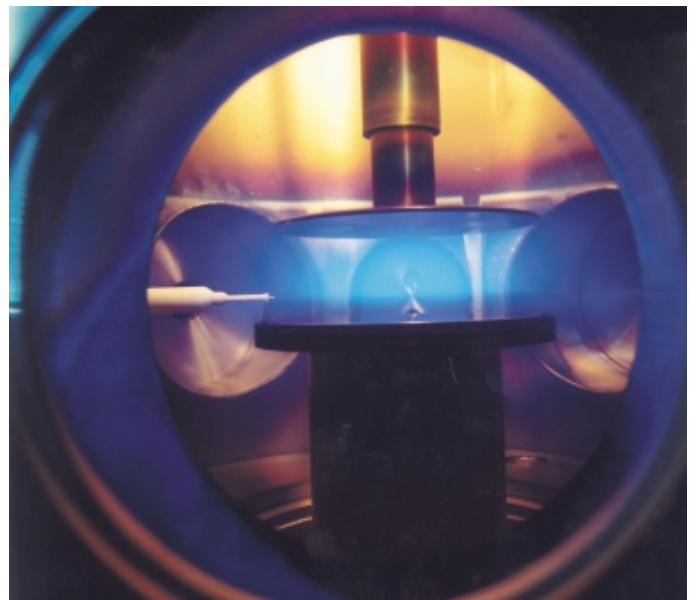
UKAEA is about to complete the order to supply a PlasmaProbe to the Max Planck Institute for Extraterrestrial Physics in Garching, Germany. Researchers there will use the probe to characterise the plasma in dusty plasma experiments.

The probe was developed using UKAEA Fusion's expertise in the diagnosis and analysis of the cool tokamak edge plasma and plasma-material interactions.

In the early 1990s this expertise led to the development, in conjunction with VG Quadrupoles Ltd. (later Fisons Instruments), of a fully automated Langmuir probe system suitable for use in a wide variety of low temperature plasmas (such as those used in the semiconductor processing industry).

It provided rapid, robust determination of plasma parameters, such as potential, temperature and density, as well as more sophisticated characteristics, such as the electron energy distribution function. The system was sold by Fisons Instruments (and later Lucas Laboratories in the USA)

to a wide variety of customers world-wide, but mostly in the semiconductor industry (IBM, Spire Corp. and others) and university labs working on plasma processing. Although the system is no longer sold commercially on our behalf, UKAEA Fusion retains the IPR on the instrument.



A PlasmaProbe head inserted into a parallel plate plasma etcher

Typically, the PlasmaProbe has been applied, often at the R&D stage, to diagnose plasmas used for etching (such as reactive ion etching), coating (such as plasma assisted chemical vapour deposition), and surface modification (such as ion implantation). However, in principle, the system is suitable for any low temperature plasma application.

Dr. Beatrice Maria Annaratone at the Max Planck Institute for Extraterrestrial Physics says: "I have used other diagnostics before but believe the UKAEA instrument is the best available for our purposes because it is customer friendly and, most importantly, is based on correct theory."

YOUR COMMENTS

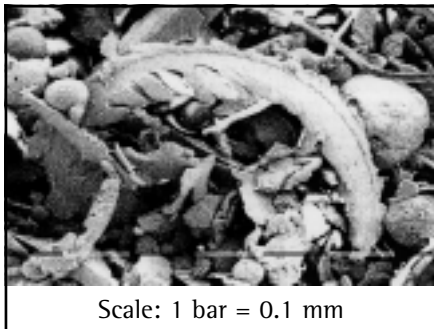
This edition of Fusion Business focuses on the issue of diagnostics in fusion, explaining the role of plasma diagnostics and featuring some of the latest work being done in this area.

We would welcome any suggestions for areas or issues to focus on in future editions, along with any other comments or suggestions for articles. Please email: miriam.mason@ukaea.org.uk or call 01235 464104

FUSION-INDUSTRY LINK ON DUST TECHNOLOGIES

UKAEA scientists are working with university and industry specialists to tackle an issue facing the fusion community - dealing with dust which will be generated in future devices.

Debris, such as dust particles and flakes (see picture), is produced in fusion experiments when the hot plasma interacts with the inner surface of the vacuum vessel. This dust can reduce the effectiveness of the fusion experiments and needs to be removed and handled safely.



UKAEA is looking at UK and world industries where dust is an issue, to find the best technologies available in three key areas: cleansing mechanisms to remove dust, diagnostics to monitor dust and construction materials to minimise the production of dust.

For example, one technology being considered for cleansing dust out of fusion facilities is the vibratory conveyor used in the pharmaceutical and cement industries. This needs adapting for fusion application because of the large magnetic fields used to contain the plasma.

Other cleansing candidates include the non-solvent based mechanisms being developed by the aerospace industry for cleaning fighter jets. These include laser or ultra-bright light source systems which break up contaminating materials without damaging the underlying structure. These systems have never been used in a vacuum before so UKAEA is working with UK and US universities to test them in fusion-like environments.

To diagnose the build up of dust, it has been established that quartz crystal based systems used in other industries for measuring dust accumulation could be adapted for fusion and a ceramic-based microbalance is now being developed in partnership with industry in Germany.

Further suggestions on this issue would be very welcome. Contact miriam.mason@ukaea.org.uk

FUSION AND INDUSTRY: CONFERENCE & EVENTS DIARY

March 27-30 Plasma Physics Conference (part of the IOP Physics Congress), Brighton.

April 26-30 2nd International Conference on Atomic & Molecular Data & their Applications (including fusion), Oxford.

May 22-26 - 14th International Conference on Plasma Surface Interactions in Controlled Fusion Devices, Rosenheim, Germany.

May 22-28 - 7th Conference on Intersections between Particle and Nuclear Physics, Quebec City, Canada.

June 6-9 19th Symposium on Plasma Physics & Technology, Prague, Czech Republic.

June 12-16 - 27th EPS Conference on Controlled Fusion and Plasma Physics, Budapest, Hungary.

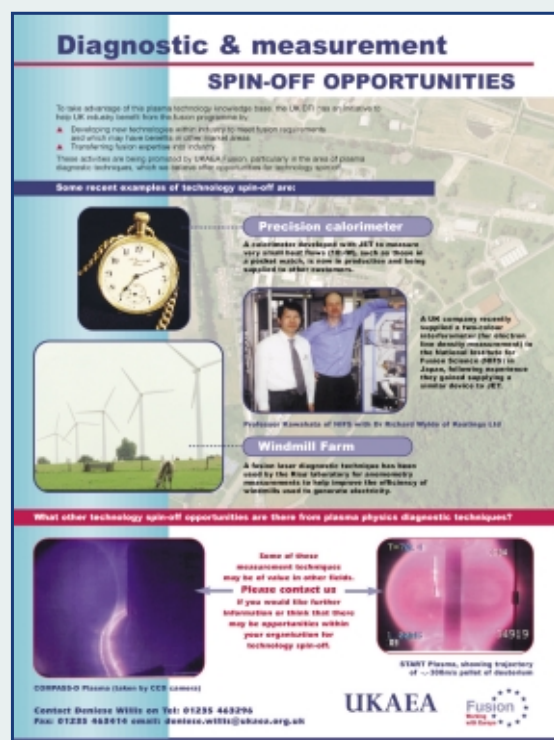
June 18-22 13th Topical Conference on High-Temperature Plasma Diagnostics, Tucson, Arizona.

September 4-8 - 21st Symposium on Fusion Technology (SOFT), Madrid, Spain.

October 4-10 - 18th IAEA Fusion Energy Conference, Italy.

CONFERENCE REPORT

The Industry Programme made a number of new contacts among delegates visiting our exhibition at the National Measurements Conference in Brighton (1-4 November 1999). These contacts, with government offices, other energy research organisations and scientific associations, are now being followed up by Industry Programme staff.



Diagnostic & measurement SPIN-OFF OPPORTUNITIES

To take advantage of the plasma technology knowledge base, the UKAEA has a number of help UK industry benefit from the fusion programme by:

- Developing new technologies either for use in fusion or for other applications
- Providing test facilities for other industries
- Transferring fusion expertise to other industries

These activities are being promoted by UKAEA Fusion, particularly in the area of plasma diagnostic techniques, which are often the source of technology spin-off.

Some recent examples of technology spin-off are:

- Precision calorimeter**
A calorimeter developed with JET to measure very small heat flows (10-100 mW) such as those in a nuclear reactor, is now in production and being supplied to other customers.
- Windmill Farm**
A laser laser diagnostic technique has been used by the Blue Laboratory for aerodynamic measurements to help improve the efficiency of windmills used to generate electricity.

Other technology spin-off opportunities are there from plasma physics diagnostic techniques?

Some of these measurement techniques may be of value to other fields. Please contact us if you would like further information or think that there may be opportunities within your organisation for technology spin-off.

STMP Plasma, showing a jet of ~1000°C plasma

Contact Denise Willis on Tel: 01235 443266 Fax: 01235 443010 email: denise.willis@ukaea.org.uk

UKAEA Fusion

If you would like an A4 copy of the posters we presented at the conference, please email denise.willis@ukaea.org.uk

MAST FIRST

The first spherical tokamak plasmas were produced on MAST (Mega Amp Spherical Tokamak), the new magnetic fusion facility at the Culham Science Centre, in the last few days of the millennium.

This is an extremely encouraging start to the programme of work on what is the world's largest spherical tokamak, producing plasmas of more than 3 metres in diameter. Initiation and production of toroidal plasmas for a wide range of aspect ratios (the ratio of major to minor radius) and with currents up to 330kA were achieved and the first additional heating experiments have begun.

The many diagnostic systems on the machine are already allowing us to identify the nature of these spherical plasmas and assess how they scale from the previous much smaller, but very successful, START (Small Tight Aspect Ratio Tokamak) experiment at Culham, which led the world in this new area of fusion research.



Some members of the MAST team assembled on the vessel top plate

Culham scientists are looking forward to a productive work programme on this innovative approach to magnetic fusion, which is attracting increasing worldwide interest.

SPECTROSCOPIC "KEY" TO NUCLEAR FUSION

Scientists at UKAEA Culham Science Centre are investigating spectroscopic techniques which could be crucial to the eventual commercialisation of nuclear fusion as an energy source.

Spectroscopic diagnostic techniques developed at Culham are an important ingredient in actively optimising the plasma required for nuclear fusion (see Guide to Fusion page four). Head of the spectroscopic diagnostics research group, Dr. Patrick Carolan, says: "The more impurities you have, the more energy you need to put into the fusion vessel to combat them, effectively reducing the energy productivity of the plasma. Diluting the plasma by as little as 20% can reduce the reaction rate dramatically by up to 40%." Spectroscopic diagnostics have been fundamental to selecting materials for the vessel walls.

"Given the extreme temperatures generated during fusion, the vessel wall has to be protected. We used to carbonise the walls, producing a hard diamond-like layer, but by switching to boronisation instead there's been a dramatic effect on the level of impurities. Oxygen contamination has been reduced by a factor of five and metallics (iron/nickel/chromium) by a factor of ten or more," notes Carolan. However, it is from the area of 'active' spectroscopy that the greatest advances in plasma stability have recently been made.

For example, by injecting neutral atoms such as hydrogen in a high-energy beam (50–100kV) into the fusion vessel, it is possible to measure the plasma's magnetic field and direction. Using this technique it was demonstrated experimentally that the pitch of the helical magnetic field is an important parameter in plasma stability. Carolan explains: "If the shear in the pitch of magnetic field lines is increased, then the confinement time is improved, allowing the plasma performance to be 'tuned'. As a result a doubling of the plasma confinement time has been achieved."

Optimising the shear allows plasma physicists to obtain an internal transport barrier (ITB), which substantially increases the thermal insulation of the hot plasma core. Similarly there is an Edge Transport Barrier (ETB) which supports steep thermal gradients. Carolan and his team are now studying the ETB and ITB in different fusion facilities at Culham.

This article is based on extracts from a feature in 'Spectroscopy Europe' September/October 1999 (see www.spectroscopyeurope.com). For further information on the techniques used by Patrick Carolan and his team call 01235 464104 or email miriam.mason@ukaea.org.uk

A Guide to Fusion – Part 7

Plasma Diagnostics

The goal of fusion research is to generate a dense, stable, high temperature plasma. Plasma diagnostics are necessary to understand and compare the performance of different types of plasma confinement experiments and to establish empirical scaling laws to allow extrapolation to larger, reactor relevant experiments.



A plasma image from the START experiment

Plasma diagnostic techniques are numerous and varied and utilise the unique properties of magnetised plasma. Fast video imaging of plasma light is helpful to monitor the shape and stability of the plasma but detailed information is obtained by measuring the effect of currents in the plasma on the local magnetic fields inside or close to the vacuum vessel.

In the hot plasma core, high power lasers, microwave and sub-mm radiation and particle beams are used to probe the plasma. Electromagnetic radiation and particle emission from the plasma in the visible, UV and X-ray spectrum can yield important information, particularly about impurities. Black body microwave emission from the plasma can also be analysed to determine the temperature of electrons. X-ray tomography is used to establish the shape and position of the hot core of the plasma and to monitor its stability.

Interactions with the material surfaces of the vacuum vessel 'wall' generate impurities and can have an important effect on the thermal isolation of the plasma. This region is relatively cool and can be diagnosed with small metallic probes. The highest points of the wall, i.e. those most likely to interact with the plasma, are known as the limiters and are often made from some form of carbon. The power lost from the plasma can give very high power loadings leading to high temperatures, localised melting and erosion of the material surface. Infra-red imaging of these surfaces and other non-contact diagnostics to measure surface temperature and erosion rates are very important in large experiments.

NEW JET AGREEMENTS MEAN CONTINUED ROLE FOR INDUSTRY

Under EFDA (the European Fusion Development Agreement), a new JET Implementing Agreement has been signed which funds the use of the JET facilities at the Culham Science Centre from January 1st 2000 until at least the end of 2002.

The planning of the JET workprogramme is now being undertaken directly by the European fusion laboratories. Around 20 scientists and engineers will be seconded to Culham for these three years to co-ordinate the programme and a similar number will assist in operations. They will be joined by up to 80 physicists from across Europe for particular experimental campaigns.

The focus of the experiments will be work towards fusion's 'next step', the proposed construction of an experimental reactor, ITER (International Thermonuclear Experimental Reactor).

The UKAEA is now responsible for the operation and maintenance of the JET facilities under a JET Operation Contract, and will play its part in the JET workprogramme as one of the European laboratories, under the co-ordination of the EFDA Associate Leader for JET.

Work for industry will come either through contracts with the UKAEA, for maintenance and operation of the JET facilities, or via the European Commission or individual national fusion associations, for work connected with the experimental programme or with enhancement of the facilities.

NEW INDUSTRY PROGRAMME MANAGER



Cleve Forty is the new Manager of the Fusion Industry Programme, replacing Tom Todd who has moved to another post within UKAEA.

Cleve joined UKAEA in 1985 working on materials science R&D, computer modelling and code writing, and theoretical physics modelling in the Materials Development Division (1985-89). He then worked with the Tetronics Research & Development Co. in Faringdon, Oxfordshire for a year in large-scale plasma arc technology R&D before returning to UKAEA in 1990. Since then he has worked in safety & environmental analysis and the development of new materials for fusion, and has been a member of the Industry Programme since its launch.

Views expressed herein do not necessarily reflect those of the EURATOM/UKAEA Fusion Association. No liability is accepted whatsoever for errors or omissions in Fusion Business. This work is funded by EURATOM and the UK Department of Trade and Industry. Please visit our web site at:

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