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TOKAMAK SOLUTIONS, OXFORD INSTRUMENTS, THE CZECH TECHNICAL UNIVERSITY IN PRAGUE AND THE INSTITUTE OF PLASMA PHYSICS OF THE ACADEMY OF SCIENCES OF THE CZECH REPUBLIC

Press Release – October 2011

World first use of high temperature superconducting magnets on a tokamak

Groundbreaking experiment leads the way to faster development of fusion.

Fusion research company Tokamak Solutions has worked with partners at Oxford Instruments, the Czech Technical University and Institute of Plasma Physics, Prague to use high temperature superconducting magnets on a tokamak for the first time. High temperature superconductors have remarkable properties: they conduct electricity with zero resistance, even with simple cooling by liquid nitrogen; they can withstand high magnetic fields and huge current densities – and we now know that they continue to be superconducting throughout the plasma pulse in a tokamak. It has long been known that high temperature superconductors could have an important role to play in the future of tokamak fusion research, but this is the first time they have actually been used for magnetic field coils on a tokamak.

In the experiment, two of the copper magnetic field coils on the Golem tokamak in Prague were replaced by high temperature superconductor in a simple cooling system known as a cryostat. Plasma pulses were then created in the normal way and the tokamak operated exactly as expected. A whole series of further experiments is now planned.

Dr Mikhail Gryaznevich, Chief Scientist of Tokamak Solutions, said “this was an important step for fusion research. We have learned a lot about the practical use of high temperature superconductors on tokamaks and these new materials are now certain to play a key role in the future of controlled fusion.”

Dr Vojtěch Svoboda of the Czech Technical University in Prague said “although Golem is just a small tokamak, we are always looking for innovative ways to improve its performance and to progress fusion research. Last year Golem became the first tokamak to be operated fully remotely via the internet. This year, thanks to a

stimulating collaboration with Tokamak Solutions and Oxford Instruments, it is the first tokamak to use high temperature superconductors."

Dr Radomír Panek of the Institute of Plasma Physics of the Academy of Sciences of the Czech Republic said "we are delighted to have supported this groundbreaking experiment. High temperature superconductors will be vital to the future of fusion research and this experiment has already provided useful data."

Jonathan Flint, Chief Executive of Oxford Instruments, said "Oxford Instruments has long established track record supplying tools and consultancy services to the fusion community and as the leading innovator in high performance magnets for scientific applications, so we were delighted to play our part in this successful collaboration."

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Editors notes

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Images available on request

1. Dr Mikhail Gryaznevich and the GOLEM Tokamak with high temperature superconducting magnetic field coils
2. Technology image – a stable fusion plasma in a small tokamak.

About Tokamak Solutions UK Ltd

Founded in 2009, Tokamak Solutions aims to commercialise spherical tokamaks as neutron sources and plasma research instruments.

The nuclear fusion reaction produces an abundance of high-energy neutrons and Tokamak Solutions has designed a super compact fusion neutron source to exploit this aspect of fusion and produce powerful neutron sources.

The applications for a powerful fusion neutron source of 14 mega electron volt neutrons include materials research, the production of isotopes for medical use and the transmutation of waste from existing nuclear power stations.

Existing designs for fusion neutron sources are expensive to build and operate and are unreliable. Tokamak Solutions has overcome these problems by designing a smaller super compact fusion neutron source with an overall diameter of two metres that can provide megawatt level neutron output while operating at modest plasma performance.

This breakthrough has been achieved by harnessing the effectiveness of beam-plasma fusion. Instead of requiring a large, ultra-hot plasma to produce fusion neutrons, the super compact fusion neutron source designed by Tokamak Solutions generates neutrons by the simpler method of injecting a high energy beam into a 'warm' plasma of modest size.

The Tokamak Solutions board is led by Dr David Kingham (CEO) who was formerly managing director of Oxford Innovation, a leading operator of business and innovation centres, investment networks and advisory programmes for entrepreneurs. Other members include Dr Mikhail Gryaznevich (chief scientist) and Alan Sykes (technical director).

The Scientific and Environmental Advisory Board is chaired by Lord Julian Hunt FRS. Other members include Sir Martin Wood FRS (co-founder of Oxford Instruments plc); Jack Connor FRS (one of the most influential theoretical plasma physicists in the international fusion programme), Professor George Smith FRS (emeritus professor of materials at the University of Oxford) and Professor Bill Lee (professor of professor of ceramic engineering at Imperial

College and Deputy Chair of the UK Government advisory Committee on Radioactive Waste Management).

The company is located at Culham Innovation Centre, Oxfordshire.

About tokamaks

A tokamak is a device that uses a magnetic field to confine a plasma in the shape of a torus (doughnut). Experimental research of tokamak systems began in 1956 in Kurchatov Institute, Moscow by a group of Soviet scientists led by Lev Artsimovich.

Tokamaks are the most promising technology for the ultimate goal of controlled fusion to produce electricity – sometimes referred to as harnessing the power of the sun on earth

In order to obtain sufficient fusion energy to exceed the power input required to create the magnetic field and heat the plasma, conventional tokamaks have to be very large. JET (Joint European Torus) at Culham, which is already close to this goal, and ITER, under construction at Cadarache, France, are huge, impressive feats of engineering.

High temperature superconductors are expected to feature in the first fusion power stations.

Details of the high temperature superconductor experiment on the Golem tokamak

In the experiment, the two copper poloidal field coils on the Golem tokamak in Prague were replaced by 6 turns of high temperature superconducting tape supplied by SuperPower Inc. The coils were wound *in-situ* by hand to avoid the need to disassemble the tokamak. The dimensions of the tape are approximately 0.1mm by 12mm with a maximum current capacity of over 300 Amps. The tape is "second generation" high temperature superconductor and the crucial material is (Re)BCO where Re is a rare earth element.

A simple cryostat was assembled and filled with liquid nitrogen to cool the tape to the critical temperature at which it becomes superconducting. In this case the critical temperature was measured at 90K, well above the boiling point of liquid nitrogen (77K). The maximum current actually carried in the tape during the experiments was just over 160 Amps, giving the target total magnetomotive force of 1000 Amp-turns from a coil with dimensions (including insulation between layers of tape) of approx 1mm by 12mm.

Plasma pulses were then created in the normal way and the tokamak operated exactly as expected. There had been concerns that the plasma pulses might cause a "quench", ie cause a sudden and potentially damaging transition from superconductor to normal conductor. However, many plasma pulses were achieved without any quenches.

A whole series of further experiments is now planned.

About Oxford Instruments plc

Oxford Instruments aims to pursue responsible development and deeper understanding of our world through science and technology. It provides high technology tools and systems for industrial and research markets, based on its ability to analyse and manipulate matter at the smallest scale. Innovation has been the driving force behind Oxford Instruments' growth and success for over 50 years, and its strategy is to effect the successful commercialisation of these ideas by bringing them to market in a timely and customer-focused fashion.

The first technology business to be spun out from Oxford University over fifty years ago, Oxford Instruments is now a global company with over 1,500 staff worldwide and a listing on the London Stock Exchange (OXIG).

Its objective is to be a leading supplier of next generation tools and systems for research and industry. This involves the combination of core technologies in areas such as low temperature and high magnetic field environments, Nuclear Magnetic Resonance, X-ray electron and optical based metrology, and advanced growth, deposition and etching. Oxford Instruments' products, expertise, and ideas address global issues such as energy, environment, and health and are part of the next generation of telecommunications, energy products, environmental measures, security devices, drug discovery and medical advances.

For more information: www.oxford-instruments.com

For more information about the Institute of Plasma Physics of the Academy of Sciences of the Czech Republic see: www.ipp.cas.cz

About the GOLEM tokamak

GOLEM is a small tokamak of circular cross-section, which can be remotely operated via internet access. It has operated routinely for nearly two years at a modest range of parameters Bt < 0.5 T, Ip < 8 kA, pulse length < 15 ms, and with a limited set of diagnostics. The device is a modification of CASTOR tokamak, which was previously operated at Institute of Plasma Physics, Czech Academy of Sciences. Then it changed its mission and became an educational device for domestic as well as for foreign students via remote participation. A wide range of tasks with varying levels of complexity covering tokamak physics, technology and operation can be studied by the fusion specialists of the future. For more details see http://golem.fjfi.cvut.cz

About the Czech Technical University in Prague

Czech Technical University in Prague (CTU, České vysoké učení technické v Praze – ČVUT in Czech) is one of the largest universities in the Czech Republic and the oldest institute of technology in Central Europe. It was established in 1707 by the Emperor Joseph I. According to the THES-QS World University Rankings for the year 2010, the CTU is the world's 121st best university in technology. The GOLEM tokamak is situated at the Faculty of Nuclear Sciences and Physical Engineering. For more details see http://www.cvut.cz