Incoherent and collective Thomson scattering as a diagnostic tool

Incoherent Thomson scattering (ITS) has been applied for decades for the determination of electron density and temperature in fusion plasmas. With the Technical University of Delft, a set-up has been realized to develop incoherent Thomson scattering for welding plasmas. The tool is intended for the application to a range of sources, including Hall thrusters, planar magnetrons and electron cyclotron resonance plasmas.

Description of the technology

Thomson scattering (TS) is basically the process of acceleration of electrons due to an electromagnetic wave and as a consequence emission of radiation with the same frequency as the incoming wave, i.e. the wave is scattered elastically. Thomson scattering is an important technique for plasma diagnostics in nuclear fusion facilities such as tokamaks and stellarators. It is used to measure both the electron temperature and density at many locations inside the plasma.The measurement is conducted using a pulsed laser, typically a Ruby laser or Nd:YAG, that generate repeated pulses that are shone into the plasma. Some of the laser light (photons) is scattered of free electrons in the plasma resulting in spectral expansion due to the Doppler effect. Avalanche photo diodes (APDs) detect the scattered photons and high-performance digitizers capture the resulting waveforms. The spectral expansion helps assess the plasma temperature whereas the number of scattered photons determine the plasma density.With the Technical University of Delft a set-up has been realized to develop incoherent Thomson scattering for welding plasmas. As a next step, the DIFFER team will develop coherent Thomson scattering for welding plasmas, with the view to study effects such as preferential sputtering during welding, and the interaction of the welding torch with the welding pool.

Innovation and advantages of the offer

This process can be applied as a non-intrusive method to determine the electron temperature and density with high accuracy and high spatial resolution. Scattering by electrons whose motions are correlated with each other can also occur; this enables fluctuation measurements (to identify turbulence) and measurements of the plasma frequency.

Non-fusion Applications

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EUROfusion Heritage

Thomson scattering is a very powerful diagnostic which is applied at nearly every magnetic confinement device. Depending on the experimental conditions different plasma parameters can be diagnosed. This work has been carried out within the framework of the EUROfusion Consortium.The Dutch Institute for Fundamental Energy Research conducts leading fundamental research in the fields of fusion energy and solar fuels, in close partnership with academia and industry to successfully transfer fundamental insights to society at large, we are actively building an energy science society through the formation of multidisciplinary networks. DIFFER is part of the institute's organisation of NWO

FUSION TECHNOLOGY DESCRIPTION

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

Ion Beam Accelerator and analysis

Connected to DIFFER's unique facility Magnum-PSI (the only laboratory experiment in the world which can expose materials to the harsh plasma conditions near the walls of fusion reactors), Ion Beam facility provide an accelerator is a high beam-stability with low ripple and high beam-current. The accelerator is used for ion beam analysis (IBA) and ion-irradiation (for defect engineering). IBA is a none-destructive, quantitative, quick, and cheap method of elemental depth profiling. IBA and ion-irradiation can be applied to a plethora of cases; e.g. elemental depth profiling in areas such as fusion and fission, solar cells, semiconductors, optoelectronics, as well as archeology and cultural heritage, meteorology, forensic, geology, and biological sciences

Innovation and advantages of the offer

Compared with other material characterization techniques such as SIMS, XTEM, SAM, GD-OES, XPS, and LA-ICP-MS, Ion Beam analysis is the only none-destructive technique with the largest depth of penetration (up to 120 µm). It requires no standards and has accuracy of 1%. The elemental sensitivity can go as low as 10 ppm and the resolution 5 nm. It requires no sample preparation and a wide range of target sizes can be investigated (mm to cm). A data spectrum can be obtained within few minutes. Proton-irradiation has the defect rate 2-3 orders of magnitude higher than neutron-irradiation allowing for quick material damaging. Single-time users have to rely on the expertise of a dedicated physicist to simulated the experiment, perform and analyse it but multi-time user can learn the basics within few weeks.

Non-fusion Applications

Ion beam radiation can be used for research on the effects of radiation on materials and in the development of applications of materials analysis. The Ion beam method can also reveal whether an article is fake or genuine; whether it has been altered in the past; what mechanisms of corrosion and deterioration have been at work; and how affected artefacts can be preserved.

IBA and ion-irradiation can be applied to a plethora of cases; e.g. elemental depth profiling in areas such as fusion and fission, solar cells, semiconductors (such as the creation of nano-fabricated structures, ion implantation); , optoelectronics, as well as archeology and cultural heritage, meteorology, forensic, geology, and biological sciences. Ion-irradiation is used to introduce defects to material and the ions act as proxy for neutron-irradiation (fusion, fission) or cosmic rays (to test FGPAs). Ions also can be used to damage DNA (instance mutagenic breeding of plants or flowers)

EUROfusion Heritage

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme and DIFFER has landed an Enabling Research grant from the Horizon2020 programme EUROfusion.

DIFFER's main experiment Magnum-PSI (Plasma Surface Interaction) was designed to be the first laboratory setup that can study how the wall of future fusion power plants will respond to the intensely hot and dense charged gas (plasma) of those artificial suns. the researchers gain a new technique to perform detailed materials research before and after plasma exposure. The 3.5 MV singletron accelerator at the heart of the Ion Beam Facility will first be connected to DIFFER's unique facility Magnum-PSI.

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