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

Description of the technology

DIFFER specializes in energy-related research with the focus on fusion and solar fuels. Ion beam facility (IBF) housed by DIFFER is currently the only such device available in the Netherlands and is used in the fusion theme to analyze D retention and distribution in fusion related materials such as tungsten and liquid lithium. The 3.5 MV Singletron accelerator from HVEE is the pillar of the IBF and it can produce any gas ions with the current main usage of H, 3He and 4He. The accelerator has 7 beamlines of which 3 are in use: one is linked to MAGNUM allowing for in-situ world's highest plasma-flux exposure and ion beam analysis (IBA), the second leads to UPP allowing for in-operando IBA and mid-flux plasma exposure, and the third goes to an ex-situ IBA chamber called IBAS. Also, DIFFER hired a full-time accelerator operator to provide the ion beam as well as a full-time physicist to advise interested parties in the best solution to their research questions and perform the experiments and data analysis.

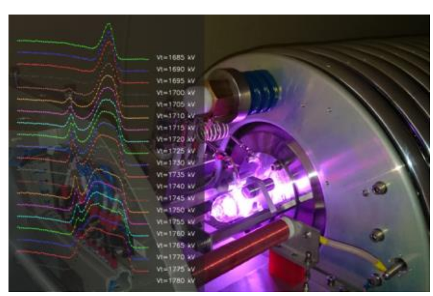
The accelerator will first be connected to DIFFER's unique facility Magnum-PSI. This unique facility is the only laboratory experiment in the world which can expose materials to the harsh plasma conditions near the walls of fusion reactors. But flexible use is already built into the facility: a switching magnet allows the operator to direct the ion beam to multiple beam lines and plans to connect the facility to solar fuels experiments and another materials research are already underway.

Technical details

By increasing the energy of the ions in the beam, the device scanned a resonance in the scattering cross-section of carbon in order to calibrate the energy of the ion beam. In this case, going from higher to lower energies, the carbon peak will develop. The highest peak can be observed by a terminal voltage of 1740 kV, in good agreement with the theoretical energy of the resonance at 1734 keV.

Other technical performance:

- Beam energy: 200 keV to 4 MeV depending on the used ions
- Ions: H, D, 3He, 4He, other gases possible
- IBA techniques: RBS, NRA, ERDA, PIXE, PIGE
- Ion-irradiation up to 150 μm, max current 80 μA



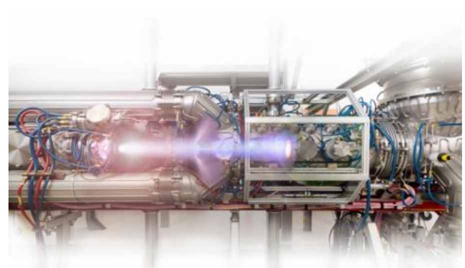


Figure 1: Magnum-PSI was designed to expose target materials to the same extreme plasma conditions

FUSION TECHNOLOGY DESCRIPTION

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

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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.

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission