UK Atomic Energy Authority

Fusion Technology Capabilities

Developing the technology for tomorrow's fusion energy machines

UKAEA's Fusion Technology team is taking the UK's fusion expertise into the age of power plant delivery. Our focus is on developing the necessary technologies to bring commercial powerplants to life. We also provide the means for industrial partners to test their components under the same conditions as operational fusion machines. Prospective suppliers can test components under conditions representative of a fusion powerplant.

Fusion Technology Capabilities

1 Radiation modelling, measurement and analysis

- Neutron and other radiation modelling and analysis – from CAD to nuclear analysis output
- Nuclear detection and measurement systems
- Independent verification of the performance of fusion machine
- Radiological assay and detection

2 Manufacturing process development, selection and qualification

- Prototype and demonstrator development
- Manufacturing supply-chain capability development
- Specialist manufacturing of dissimilar material joints
- Qualification of manufacturing process and procedure to codes and standards

3 Component performance validation and qualification

- High heat flux and magnetic field testing
- Thermal hydraulics and magneto-hydrodynamics
- Digital twins of physical components under test

4 Through-life material and component performance prediction

- Multi-scale Digital Image Correlation (DIC) strain monitoring
- High resolution DIC to support material behaviour modelling
- Small scale sample validation and standardisation

5 Whole powerplant conceptual design optimisation

- Development and use of powerplant system codes
- Fusion powerplant multi-fidelity modelling and plant integration
- Industry support through the provision of enabling codes and training

6 Fusion Technology Development

- Optimising development and testing strategy
- Exploring and developing new and adjacent technologies for use in fusion

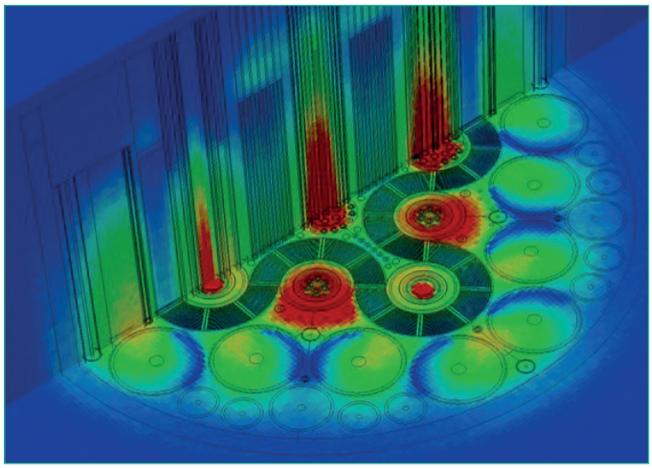
1 Radiation modelling, measurement and analysis

The Applied Radiation Technology (ART) group provides world-leading expertise and demonstrated capabilities in radiation and neutronics measurement, modelling and analysis.

Activities include:

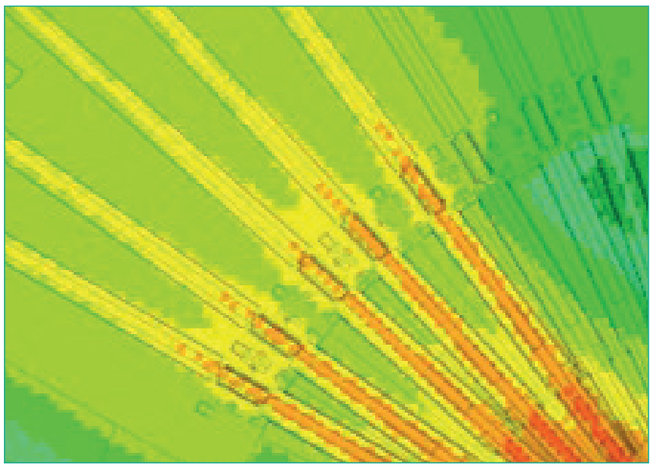
- Development of radiation transport codes and workflows
- 3D and time-dependent study of neutron populations, nuclear reactions and resultant radiation fields
- Radiological assay and detection
- Validating nuclear shielding performance

The group can perform highly detailed, accurate and reliable time-dependent simulations and modelling to support concept and detail design, safety case and operations. ART delivers work to optimise tritium breeding ratio, shielding design, divertor design, shut down dose rates and to independently verify the performance fusion machines.



Advanced fission core modelling

Compton suppression ring, comprised of NaI detectors, surrounding a high-purity germanium detector

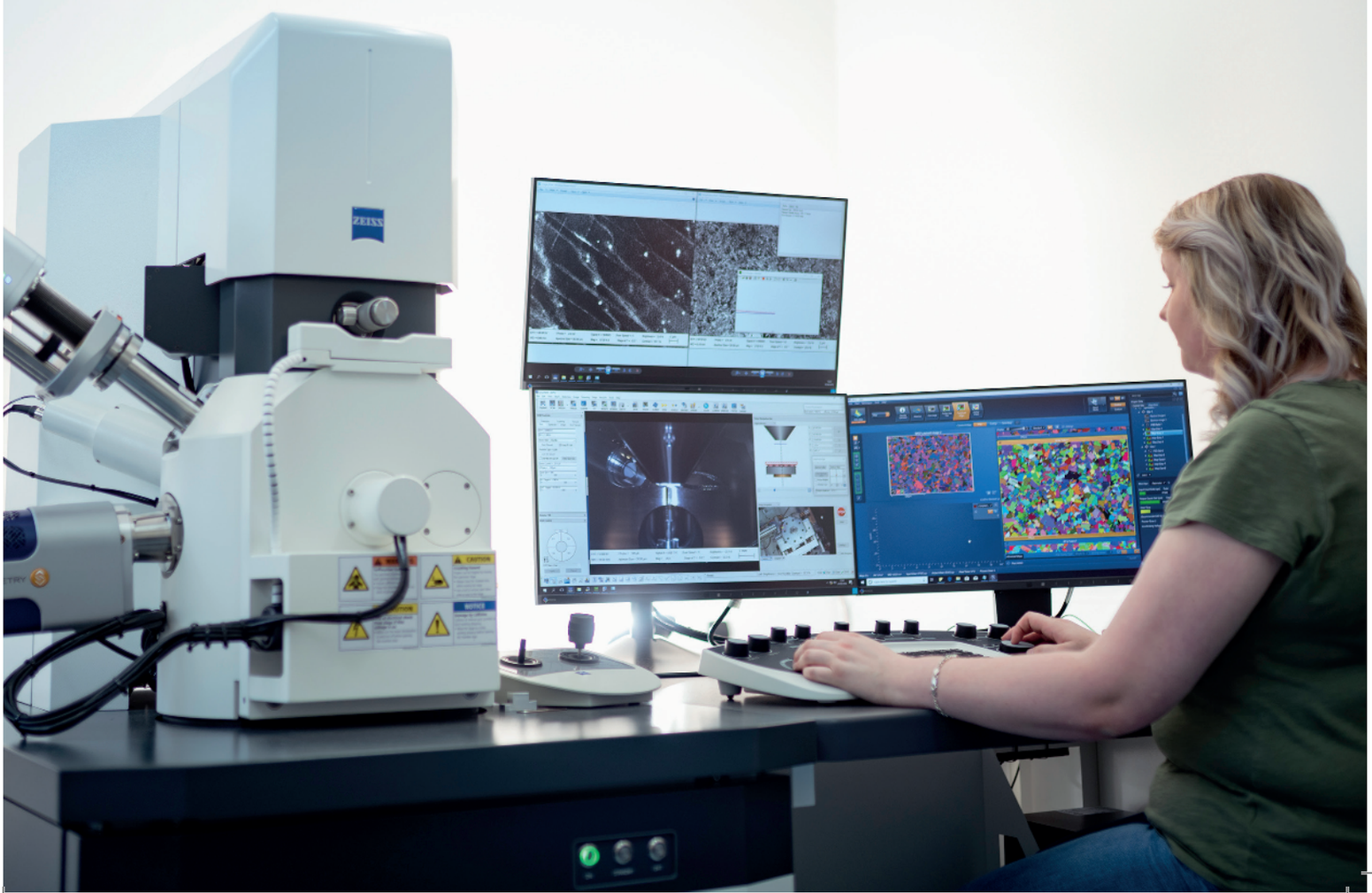


Evaluating spallation radiation fields

2 Manufacturing process development, selection and qualification

For technology requiring the development of new production routes, processes and procedures UKAEA's Manufacturing Technology and Equipment Qualification, and Special Techniques Group bring unique capability.

- Design for manufacture
- Advancing the manufacturability of new component designs
- Supporting the development of commercial manufacturing routes
- Manufacturing process verification and qualification
- Derivation of qualification methodologies for manufacturing processes, materials and components to existing and new nuclear codes and standards
- First of a kind and prototyping
- High integrity bonding of ceramic materials to metals



3 Component performance validation and qualification

High Heat Flux

The HIVE facility provides the ability to test component performance under high heat flux and allows:

- Testing of cooled and un-cooled components under high heat fluxes of up to 20 MW/m^2 (geometry dependent) in a high vacuum environment
- Sample size 250 x 250 x 250mm
- Characterising high temperature behaviour of joining and coating techniques under thermal cycling
- Validating thermomechanical, thermo-fluid and control systems modelling using multi-physics virtual engineering and digital twinning technology
- Verifying concept designs which use advanced manufacturing technology, specifically to compare conventional and novel processes and materials
- Due in 2024, HIVE2 6 times greater heating and cooling power

Thermal-Hydraulics (coming soon)

The Thermal-hydraulics group is developing capabilities in high pressure water and liquid metal testing and analysis.

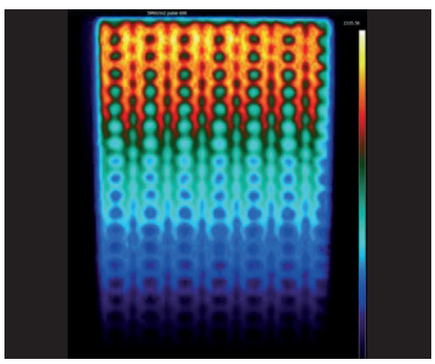
- The ANNA facility will provide a testing capability for high pressure and temperature thermal hydraulics and heat transfer in water-cooled components. It will incorporate high resolution diagnostics to generate data critical in validating the performance of simulation tools and confirming the performance of complex components.
- SmalLab will use the room-temperature liquid metal GaInSn within a closed-loop system. External magnets will create magneto hydrodynamic (MHD) effects, providing a picture of the complex MHD flow profiles within the bulk liquid metal. This data can then be used to validate predictions of the liquid metal behaviour acquired from simulations.

CHIMERA (coming soon)

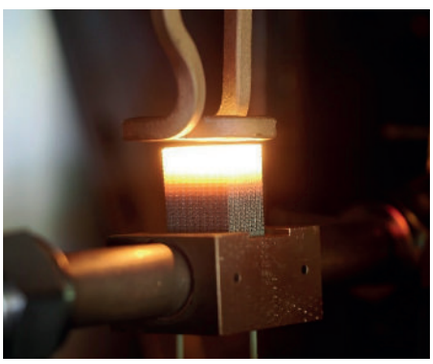
CHIMERA will test metre-scale prototype components in an environment representative of a fusion power plant. Components will be analysed to generate and synchronise component digital twins.

CHIMERA will simultaneously subject components to:

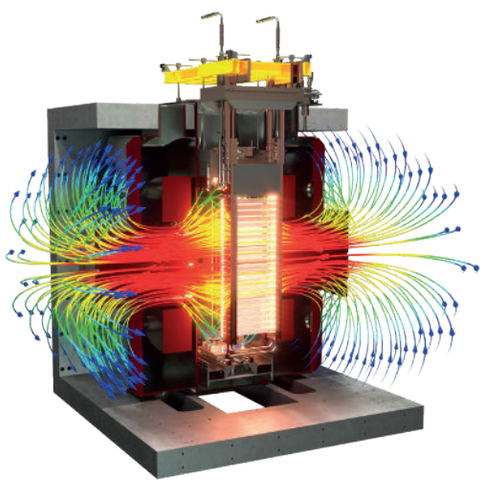
- High temperatures (bulk and surface)
- Static and pulsed magnetic loads
- Under vacuum, air or inert gas
- Connected to a high pressure/ temperature thermal hydraulics system



HIVE's infra-red camera captures the heat distribution across a sample under test



Additively manufactured lattice being inductively heated in HIVE



Magnetic fields and heating systems on CHIMERA

4 Through-life material and component performance prediction and qualification

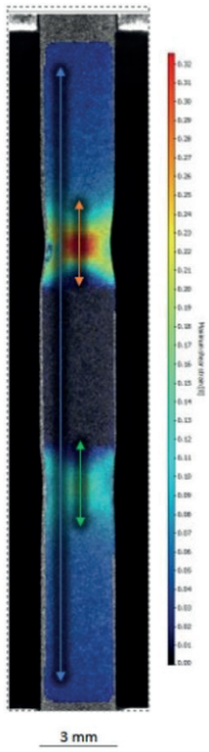
Accurate measurement of strain localisation using Digital Image Correlation (DIC).

DIC is a very powerful, non-contact tool for measuring strain in engineering materials. The Advanced Materials Technology (AMT) group has shown how accurate measurement of materials performance can be obtained post-localisation ("necking") using the technique. These results are extremely important to design engineers because the data obtained using conventional strain measurement techniques (e.g., extensometers) cannot capture the post-necking behaviour observed in lab-scale materials testing. Early results have revealed a strain rate dependency on the observed post-necking material response; work highly relevant to anyone conducting lab-scale mechanical testing of engineering materials.

High resolution DIC is also being used to support material behaviour modelling at microstructural level.

Investigation of size effects in miniature tensile testing.

The volume of material required for standard lab-scale mechanical testing is not always available. AMT is working to reduce the size of test specimens, while retaining the key information produced in traditional testing. Results will aid the development of a new set of standards for miniaturised tensile testing, which will ensure test results are credible for through-life performance assessments.



Digital image correlation gives analysts a strain map to assess complex material behaviour, not achievable with conventional strain measurement techniques

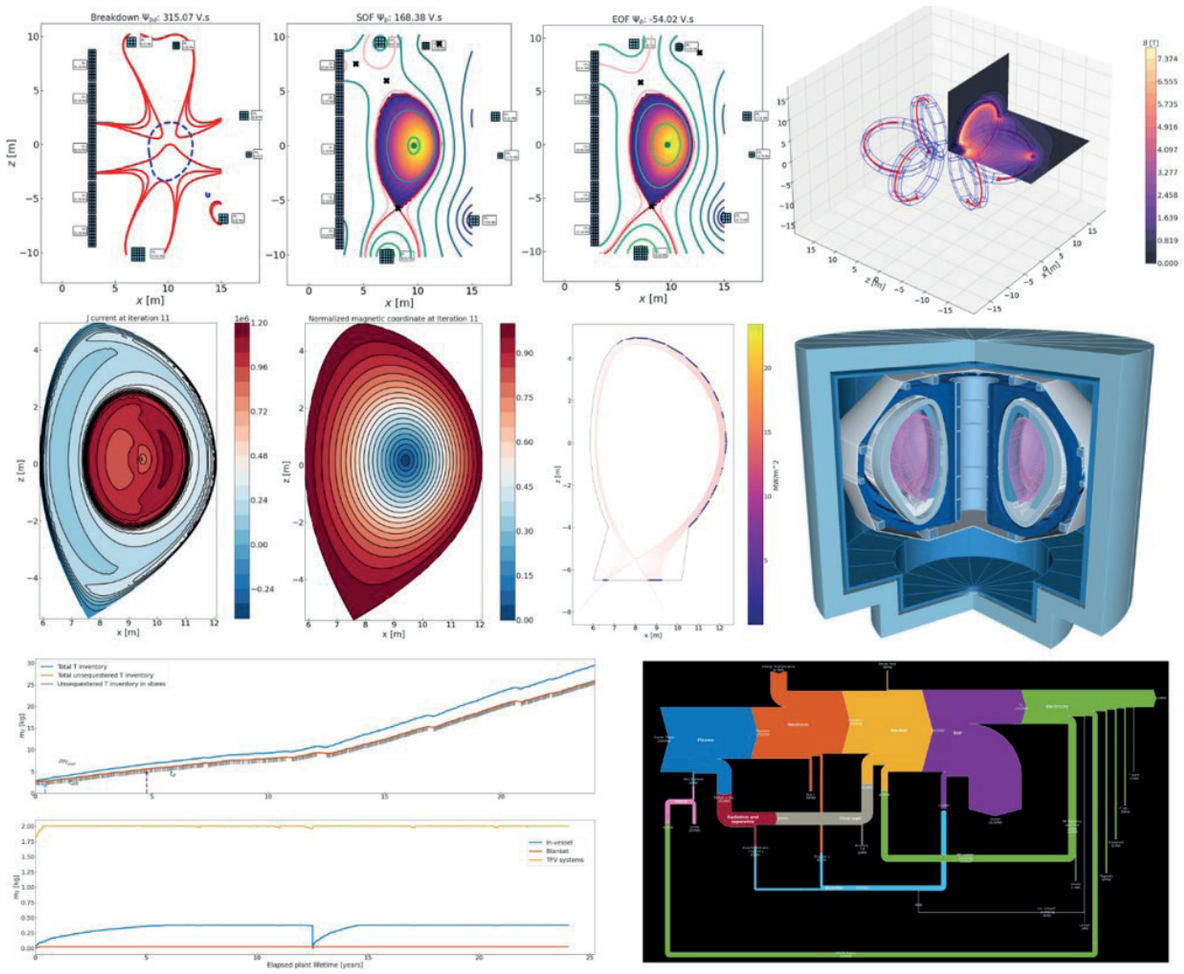
5 Whole powerplant conceptual design

The Power Plant Technology (PPT) group is active in the developing capabilities that can help optimise whole plant concept design and support critical decision making.

PPT is active in:

- Developing power plant system codes
- Fusion power plant multi-fidelity modelling and plant integration

PPT is also providing industry support through the provision of enabling codes e.g. BLUEMIRA and training in fusion power plant design and the use of these codes.



Selection of BLUEMIRA outputs

6 Fusion technology development

The Technology Development group bring best practice techniques to the maturation of technologies from proof of concept maturity through to technology demonstration.

Focusing on progression of technologies through TRL 1-6, the group develops efficient test programmes and prototyping strategies.

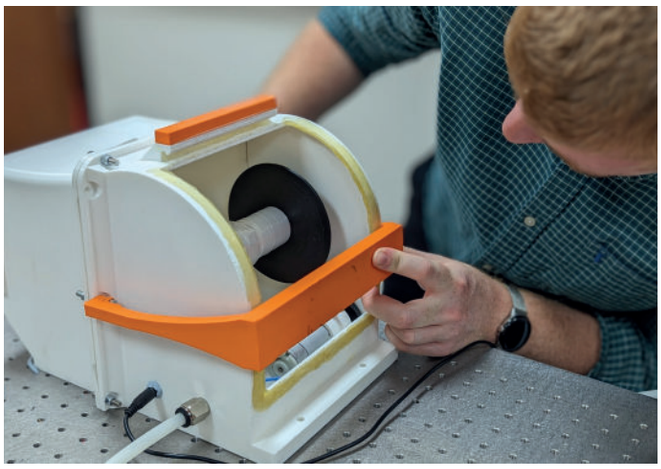
Leveraging the group's role in operating test facilities, a core capability in test programme management is offered:

- Mapping technology development requirements through to full test campaigns
- In-depth knowledge of available test facilities allows for the optimal inclusion in the test campaigns.
- Complete technology development programme delivery, including the management of test campaigns and prototyping.

Leveraging the insight acquired from managing the operation of test facilities and delivering efficient test programmes, the group provides a core capability in the development of new test rigs and facilities:

Turnkey design of small to medium scale test rigs, supported by a broad range of engineering disciplines available at UKAEA and through its partners

- The development and the management of the test facility to ensure the outcomes meet the needs of the testing programme and the operational stakeholders' requirements
- The capturing and translation of operational needs into test facility requirements
- Utilisation of operational insight to specify key test rig elements, e.g. facility integration and sensor set strategy
- Where appropriate, provision of ongoing test facility management and operation.



Preparation for benchtop testing of prototype component to deliver experimental proof of concept

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