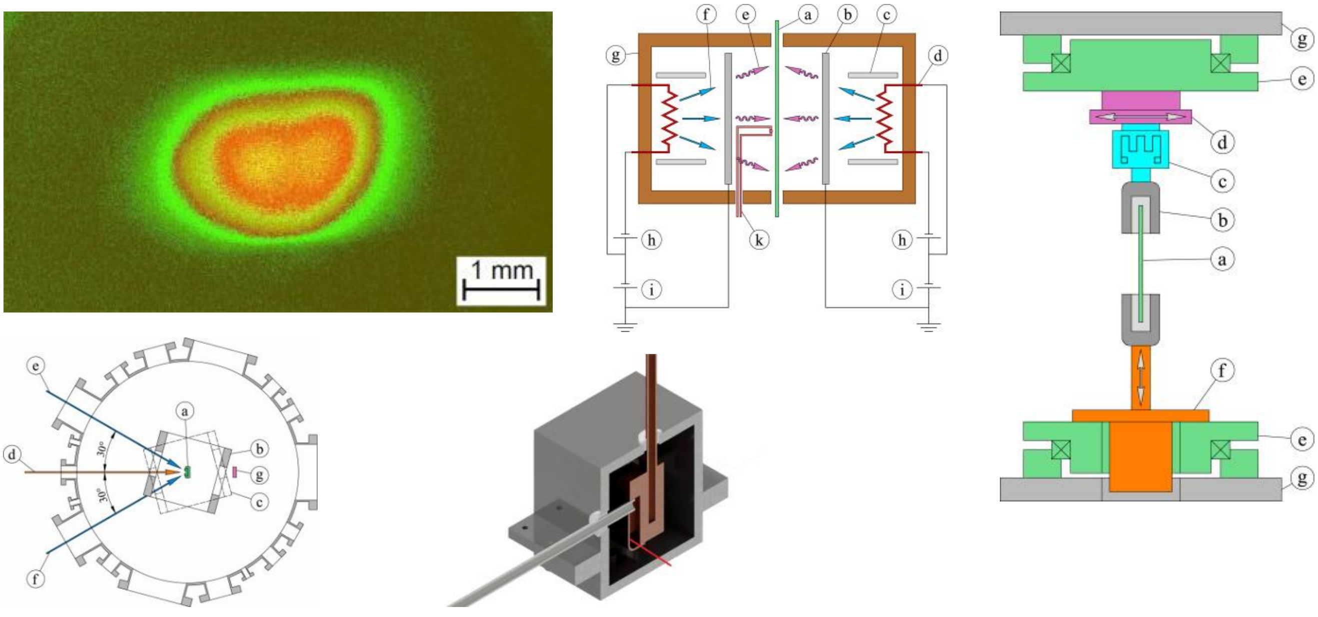
General-Purpose Irradiated Fiber and Foil Experiment (GIRAFFE)

The offered technology involves a simulator, testing machine as well as the data and knowledge acquired with this set-up regarding the behaviour of metallic components in the high temperature, high stress, high radiation environment of a fusion reactor. The analysis method targets in particular the creep behaviour under high irradiation at relatively low temperature.

Description of the technology

The tendency of metals to undergo steady viscoplastic deformation when subjected to mechanical stress at elevated temperatures, known as creep, is of pivotal significance to the structural integrity of a reactor. The analysis quantitatively modelled a non-linear high-dose radiation mediated microstructure evolution effect that facilitates fast stress relaxation in the most challenging low-temperature limit. In situ experiments on a tensioned tungsten wire exposed to a high-energy ion beam demonstrate that internal stresses of up to 2 GPa relax within minutes, in agreement with predictions from a parameter-free multiscale model constrained by atomistic simulations. In the GIRAFFE set-up, a high-precision tensile testing machine is installed in a particle accelerator beamline so that thin wires and foils can be loaded mechanically while being irradiated with high-energy ions and, where required, implanted with hydrogen and helium ions under controlled temperature conditions. Relaxation of the stress under influence of irradiation also implies weakening of the material, possibly leading to failure. The test machine can analyse and indicate such failure modes, thereby helping to improve design of reactor components and other systems under similar load or in other radiationintensive environments. The analysis set-up offers an innovative approach for the development and qualification of new materials and supports the development of lifetime prediction models under combined irradiation, thermal and mechanical loads. The GIRAFFE project and its associated multiscale modelling framework won second prize in the 2024 SOFT Innovation Prize of the European Commission.



EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

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Innovation and advantages of the offer

The behaviour of the microstructure evolution of surfaces under high temperature, mechanical and irradiation loads was not very well studied and few datasets were available for verification and testing. The GIRAFFE test machine, analysis and published data significantly reduce this gap in knowledge and can assist during the analysis and design of similar high-load mechanical structures.

Non-fusion Applications

Specialized materials laboratories, R&D centres, investigative institutions such as forensic labs or certification authorities; and on radiation-hard metallic materials for space, aerospace and other environments where components are exposed to combined irradiation, mechanical load and elevated temperature.

EUROfusion Heritage

The GIRAFFE system was developed at the Max Planck Institute for Plasma Physics (IPP) in Garching, major parts of it within the EUROfusion Consortium to test metallic fibres and foils under fusion-relevant thermo-mechanical and irradiation loads.

Key contributions come from Dr. Alexander Feichtmayer (IPP/EUROfusion), whose team combined the experiment with advanced multiscale modelling of low-temperature irradiation creep. The work has been carried out and funded in the framework of EUROfusion and the Euratom Research and Training Programme and was recognised with the 2024 SOFT Innovation Prize of the European Commission. Key scientific results and the technical description of the facility are documented in:

- *Feichtmayer, A., Boleininger, M., Riesch, J. et al. Fast low-temperature irradiation creep driven by athermal defect dynamics. Commun Mater 5, 218 (2024).* https://doi.org/10.1038/s43246-024-00655-5

- *and Feichtmayer, A., Riesch, J., Curzadd, B., Höschen, T., Schwarz-Selinger, T., Appel, M., Colson, R., Estermann, S., Lürbke, R., Neu, R.The General-Purpose Irradiated Fiber and Foil Experiment for material characterization under fusion-relevant loads.Fusion Engineering and Design 217 (2025) 115114.* https://doi.org/10.1016/j.fusengdes.2025.115114.

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