

DALTON CUMBRIAN FACILITY FACILITY OVERVIEW

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Ion beam & gamma irradiation, material modification & characterisation, analytical techniques.



The ion accelerators at DCF

5MV tandem ion accelerator delivering M^{z+} ions with energy $5(Z+1)$ MeV:

- High current TORVIS source providing 10 MeV $^1H^{+1}$ at up to 100 μA , 15 MeV $^4He^{+2}$ up to 15 μA .
- Multi-cathode source of negative ions by caesium sputtering (MC-SNICS) for the production of heavy ion beams (up to 35 MeV), provides up to 50 hours of continuous beam at constant current with 20 cathodes per wheel for quick changeover.

Four standalone end-stations, plus two shared with the 2.5 MV accelerator, each with unique capability:

Line 1 terminates in a hotcell so that high damage studies (utilising protons up to 100 μA at 10 MeV) can be performed. Line 2 incorporates fast reaction valves (35 ms response) for direct coupling to liquid or gas filled enclosures relevant to in-situ corrosion studies, or simulation of radiation chemistry in deep-space ice cores. This beamline allows users to supply and connect their own end stations.

Line 3 is dedicated to low dose rate (few nA), high energy irradiations for radiation chemistry. A collimator and exit window allow for ex-vacuum studies on liquid or biological samples.

Line 7 is dedicated to ion beam analysis. An NEC RC43 end-station incorporates PIXE (Particle Induced X-ray Emission), RBS (Rutherford Backscattering Spectroscopy), ERD (Elastic Recoil Detection) and NRA (Nuclear Reaction Analysis).

The 2.5 MV Pelletron (model 7.5SH-2 from NEC) is a source of high current (100 μA) proton or helium ion beams, and other noble gas ion beams e.g. krypton and xenon.

It shares its two end-stations with two from the larger accelerator:

Line 5/A: Single or dual beam radiation damage, using either in-house sample stages, or users own special stage. Line 6/B: Single or dual beam radiation damage with built in SIMS and HR-EELS analysis.

Dual ion beam capability currently under development (estimated completion Summer 2023) allows for creation of radiation damage effects whilst simultaneously maintaining a radiation rich field.



Cobalt-60 irradiator

Foss Therapy Model 812 ⁶⁰Co self contained high dose rate gamma irradiator:

- Triple source rod assemblies
- Flexible absorbed dose rate capability from around 25 kGy/hr to <100 Gy/hr
- Two turntable positions centred at 10 or 15cm from the source
- Attenuators provide up to x32 reduction in dose rates
- 9 litre sample chamber (20 x 25 x 27cm)

X-Ray Irradiator (MR350 cabinet irradiator manufactured by Precision X-Ray Irradiation)

- Maximum dose rate 24 Gy/min
- Broad X-ray energy spectrum provided by Bremsstrahlung, after accelerating an electron beam onto a tungsten plate
- Peak x-ray energies are approximately 10 – 115 keV (electron acceleration voltage 30 – 350 keV)
- Electron current of 0.1 – 30 mA (maximum total power is 4 kW)
- Irradiation chamber measures 41 x 88 x 58

Materials Characterisation:

- Scanning electron microscopy (Quanta 250 FEG ESEM) with EBSD, EDX, WDS detectors
- X-Ray diffraction with Pixcel 2D detector (reflection/transmission mode; 2D XRD; powder, thin film, microbeam texture analysis, non-ambient, capillary stage available)
- Imaging a range of low density materials using the X-Ray cabinet: Ultrafocus 100 (Faxitron) provides energies from 10-100 kV)
- Helium pycnometry for volume and density measurements

Spectroscopy:

- FT-IR & FT Raman (Bruker Vertex series FTIR coupled with RAM II)
- Raman microscope with choice of 3 lasers
- UV-VIS-nIR spectrometer
- EPR X-band spectrometer for studying paramagnetic molecules such as free radicals and transition metal ions
- Fluorescence spectrometer with liquid, powder and monolith sample holders

Chromatography:

- Gas chromatography with flame ionisation, thermal conductivity and electron capture detectors. PAL3 autosampler
- Ion chromatography - ICS1600 and ICS2100
- High performance liquid chromatography

We also provide a range of high quality and high precision equipment for sample preparation, plus TGA/DSC, Spark Plasma Sintering and a range of 3D printing capabilities

FUTURE PLANS

- Electron Energy Loss Spectroscopy (EELS) will provide detailed information for determining radiation effects on chemical composition & electronic structure of samples before & after irradiation.
- Dissolved gas sensor array: will detect radiolytic gas products in aqueous solution, thereby informing understanding of the formation of corrosive products able to act at liquid-solid interfaces.
- Biomaterials irradiation assaying equipment: will examine down-stream effects of radiation and material products thereof on soft matter, polymers, DNA and biological cells.
- Minirad micro irradiators: creating flexible low dose-rate systems able to perform small-sample low dose rate experiments with higher throughput.
- Secondary Ion Mass Spectrometer (SIMS) will facilitate unprecedented before, during and after studies of damage at or below material surfaces subjected to radiation by the DCF ion-beams.
- Ion beam irradiation cell: will enable ion irradiations of a wide range of structural alloys under PWR operating conditions, helping to get insight into the mechanisms of radiation-induced corrosion

NATIONAL PROGRAMMES

The DCF is a component of 3 strategically important national programmes designed to support access by researchers from academia and industry to high-end experimental equipment.

- The Henry Royce Institute – the UK's national institute for materials science research and innovation, covering both academia and industry,
- The EPSRC UK National Ion Beam Centre – a partnership with the universities of Surrey and Huddersfield providing a mechanism for academic access to the UK's ion accelerator facilities,
- The National Nuclear User Facility – ensuring key nuclear sector relevant experimental capabilities are strategically developed and relevant user access mechanisms available.

USER INTERFACE

In the first instance a discussion of the intended research project can be held with the DCF Experimental Team by emailing dcf.experiments@manchester.ac.uk
For further information visit our website www.dalton.manchester.ac.uk

EXPERIMENTAL EXPERTISE

The DCF has a dedicated on-site team of research active expert experimentalists who are there to help the user community to design, develop and deliver experiments to a high standard and to interpret data and outcomes.

