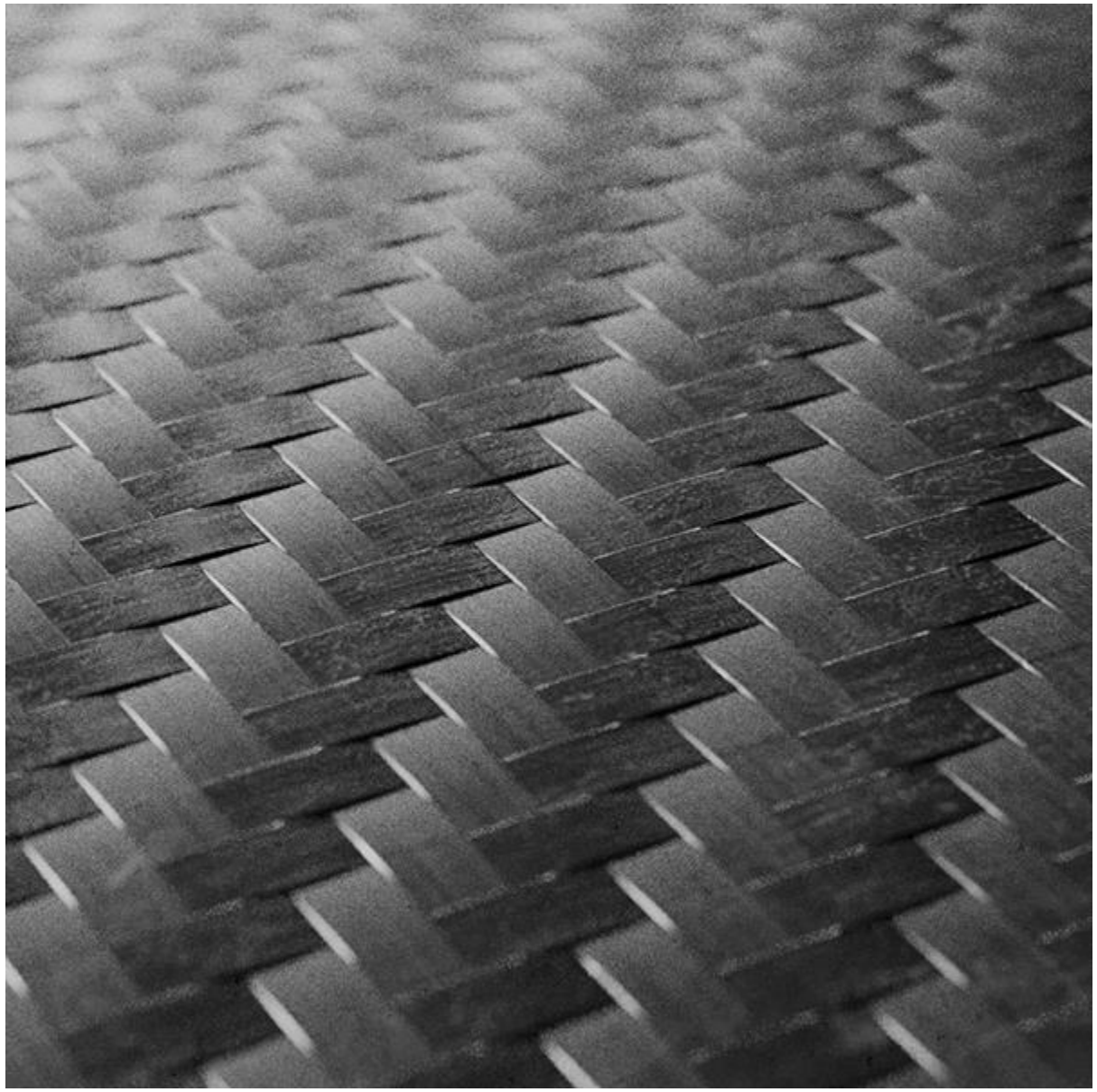
Microscale mechanics in engineering:

Big impact from small length scales

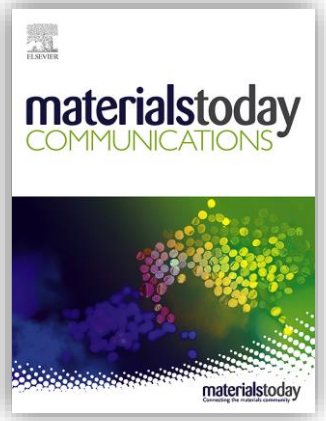
Dr Alexander Lunt

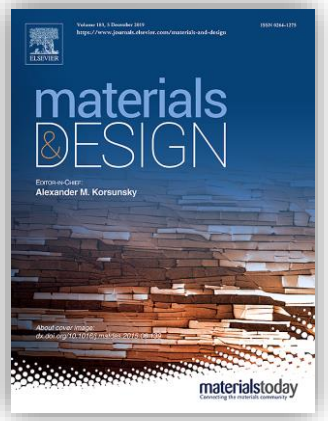


Self introduction

- PhD + Lectureship at Christ Church, Oxford 2008-2016
- Senior fellow at CERN, 2016-2019
- Started at Bath in January 2019
- 60 peer review articles (8 since starting at Bath)
- Editor for Materials Today Communications

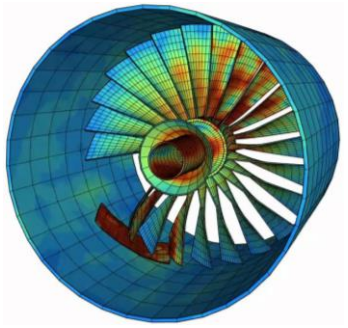
  & Journal of Materials and Design





Micromechanics

- **Materials engineer – structural mechanics**
- **Mechanics – forces & displacements**
- **Why microscale?**
  - Advanced materials (composites, additively manufactured)
  - Failure & defects (voids, inclusions, precipitates)
  - Microscale structures (thin films, lithography)
- **Emerging field – availability of new techniques + equipment**



Simulation

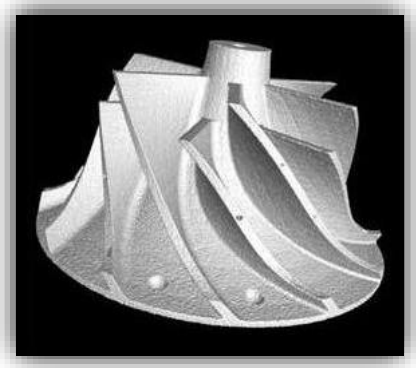
Characterisation

Manufacture

Final product

Experimental methods

- **Experimentalist**
- **Work is ‘query’ driven - toolbox**
- **Applicable to many engineering fields**
- **Collaborative research (industry, academics & research institutes)**
- **Two main analysis types:**
  - Non-destructive (X-ray diffraction & neutrons)
  - Microscopy & microscale actuation (nanoindentation)



Non-destructive methods

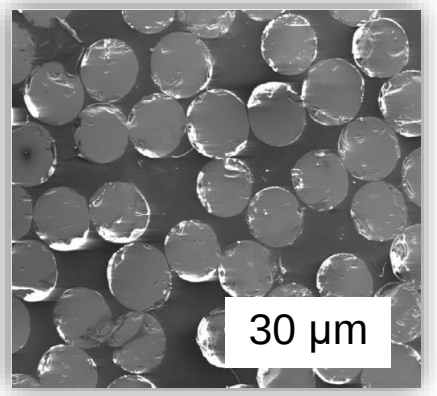
- Synchrotron X-ray and neutron facilities
- High energy beam of photons/particles
- Focus onto sample – observe interaction
- Diffraction, fluorescence, tomography, …
- Competitive application process (£21k+ per day)
- 5 experiments (21 days) awarded so far

diamond

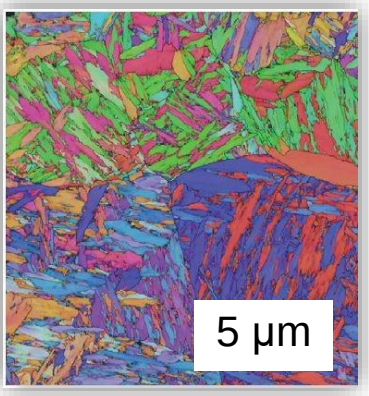
Science & Technology Facilities Council
ISIS

Microscopy and microscale actuation

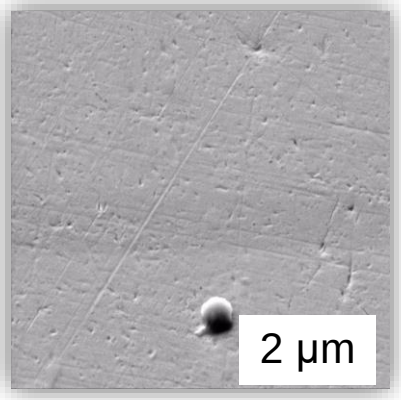
- **Electron microscopy - SEM, TEM**
  - Imaging
  - Interaction – EBSD, EDS, spectrometry
- **Focused ion beam milling**
  - Residual stress analysis
  - Microscale machining – test geometries
- **Nanoindentation**
  - Force application and measurement
  - Displacement and strain characterisation



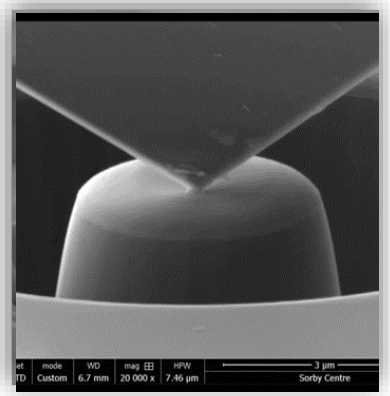
Carbon fiber



Grain orientation



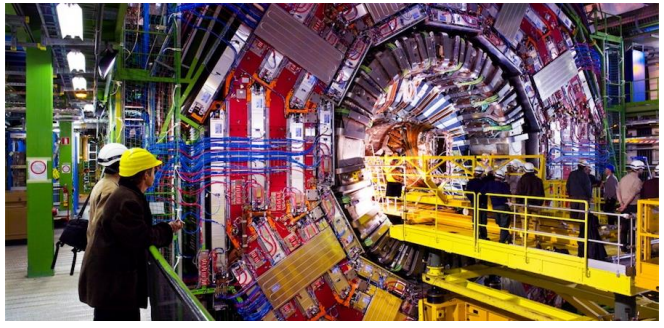
Residual stress analysis



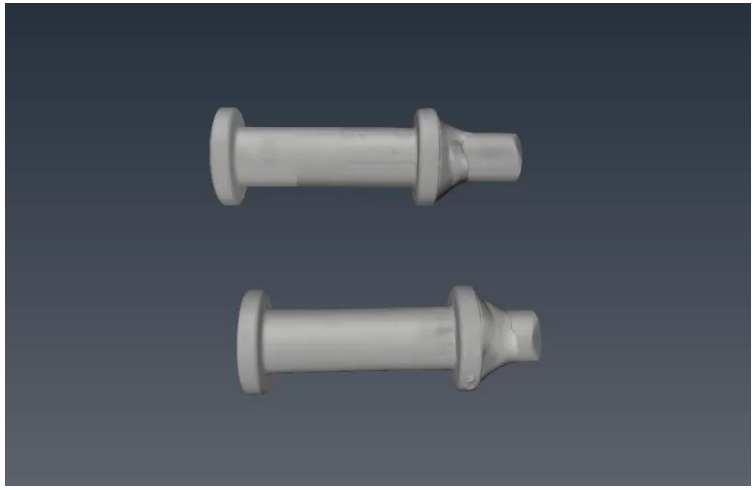
Fracture toughness

CERN/CMS affiliation

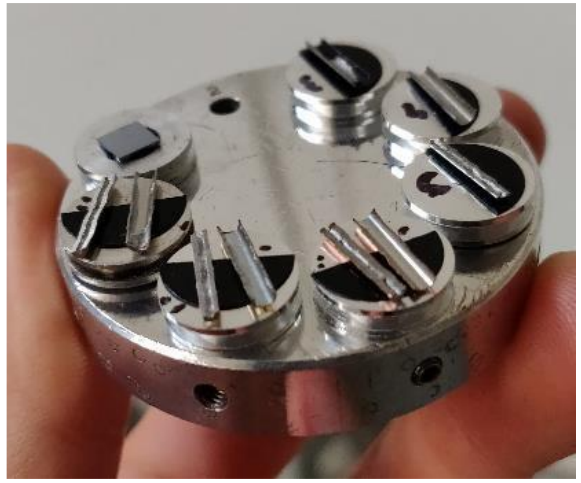
- **Faculty agreement signed in Feb 2019**
- **Diplomatic visit in Sept (VC, Dean, HoDs)**
- **Team leader role**
  - Engaging with management – find opportunities for Bath
  - Establish collaborative projects
  - Undergraduate (GBDP, FYP and placements) and PhDs



My research with CMS



- **Accelerator design – extreme engineering requirements**
  - Microscale precision required - significant stress, thermal, radiation loads
  - Microscale mechanics – crucial for many applications
- **Thin walled cooling pipes for CMS tracker upgrade**
  - PhD student started in October
  - New pipe and connection design – high pressure, low temperature CO_2
  - Microscopy, tomography, surface characterisation, residual stress analysis
  - Pressure test rig design and production
- **PhD advert – CFD of boiling CO_2 inside pipes**



Summary

- **Exciting time – enhance existing Bath research through collaboration**
- **Bring in new industrial & research partners (CMS)**
- **New equipment arriving soon**
  - Keyence 3D optical microscope, nanoindenter, AFM, FIB?
- **Enhance micromechanics capabilities at Bath**
- **Lots of new projects underway**
- **Advertising for many PhD studentships!**

Thank you!
Any questions?