Queen Mary
University of London
Science and Engineering

Detector Development Group Meeting

Radiation Damage in Optical Materials

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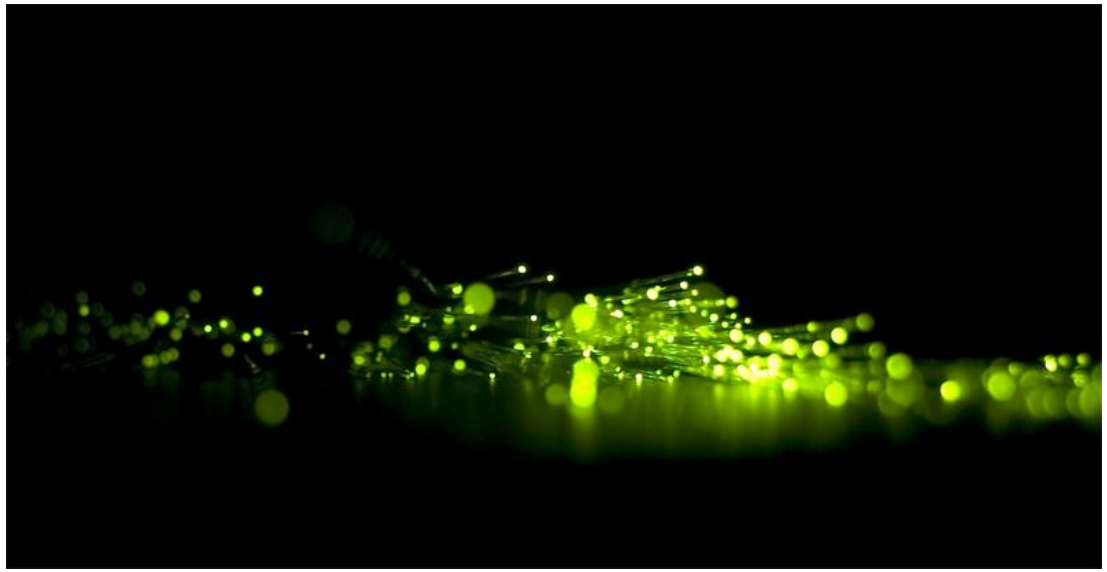
Outline

Radiation damage to optical materials is a critical limiting factor in many sensors systems. I will discuss radiation-induced absorption in scintillators and fluorescent wavelength shifters and also in materials, primarily glasses, used as faceplates in photomultiplier tubes and in camera lenses.

I will use examples from Particle Physics and Space Science and discuss the use of optical ray tracing simulations in the design of instrumentation to measure these effects.

I have carried out radiation damage studies and developed radiation tolerant sensors, for experiments at CERN, NASA and a number of UK and international companies.

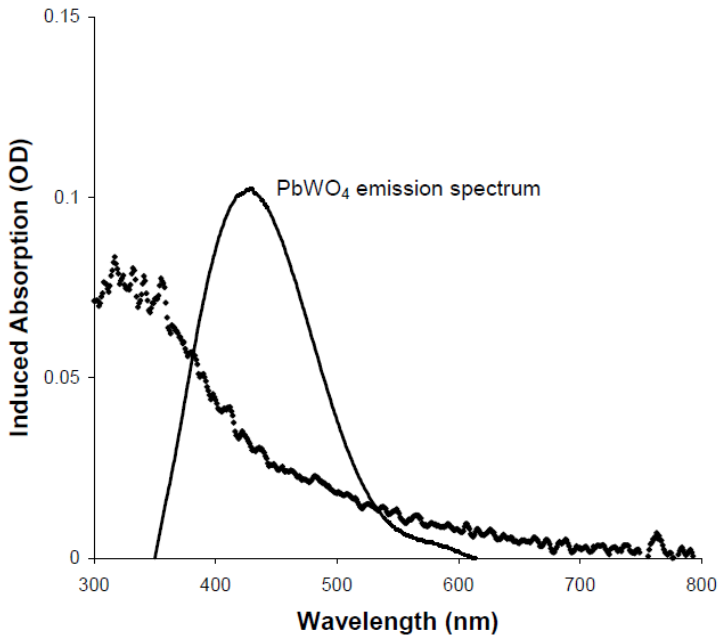


UV induced fluorescence in scintillating fibres (MICE tracker)

Radiation tolerant glass development & evaluation

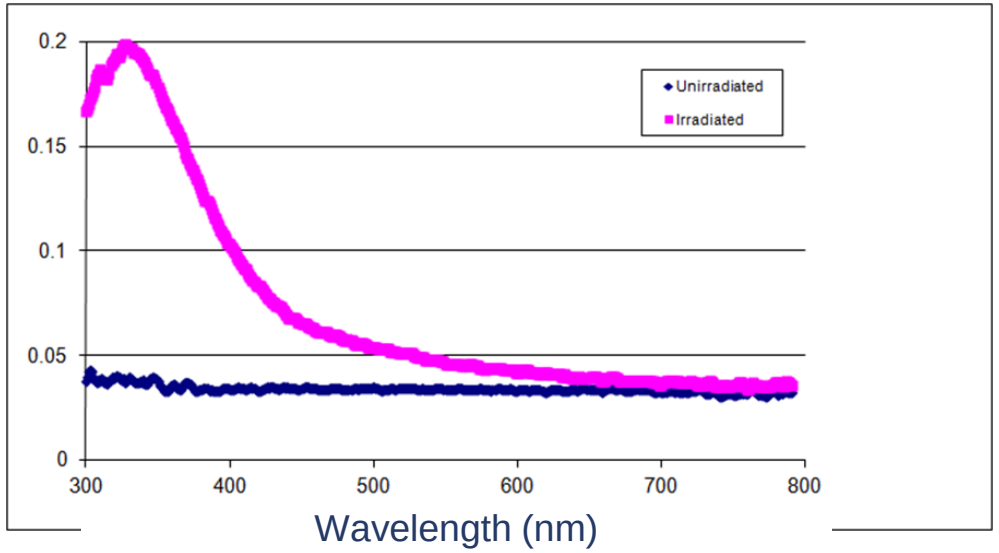
Developed, with industry involvement (Johnson Matthey, CEZUS (Jarrie)), glasses based on heavy-metal (Hf, Ba) fluorides. These, when doped with Ce^{3+} scintillate, with indium doping they are also highly tolerant of ionising radiation.

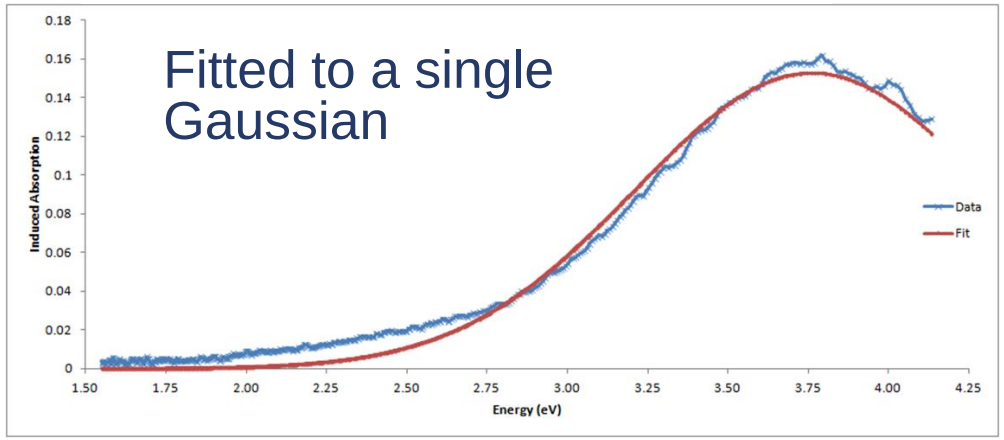
Evaluation of industrially produced borosilicate UV glasses as radiation tolerant windows for photomultiplier tubes.

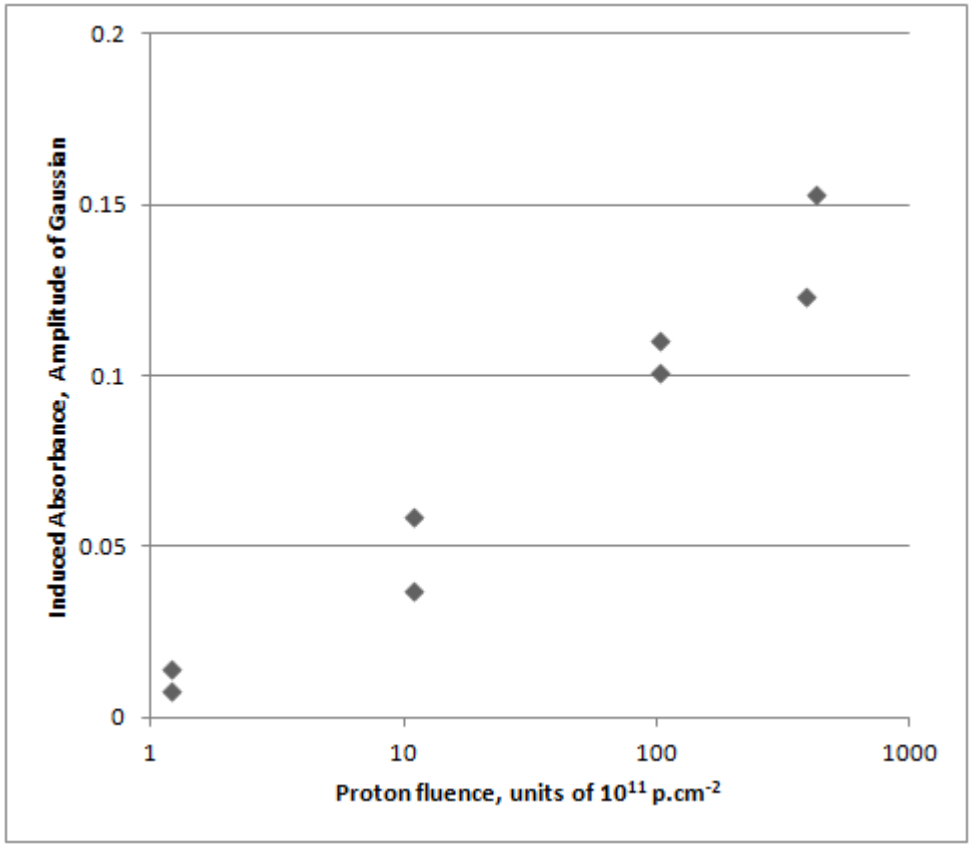


Induced optical absorbance of a vacuum phototriode face-plate after 19.3 kGy of ^{60}Co gamma irradiation. The emission spectrum of a lead tungstate crystal is shown for reference.

Radiation tolerant glass development & evaluation

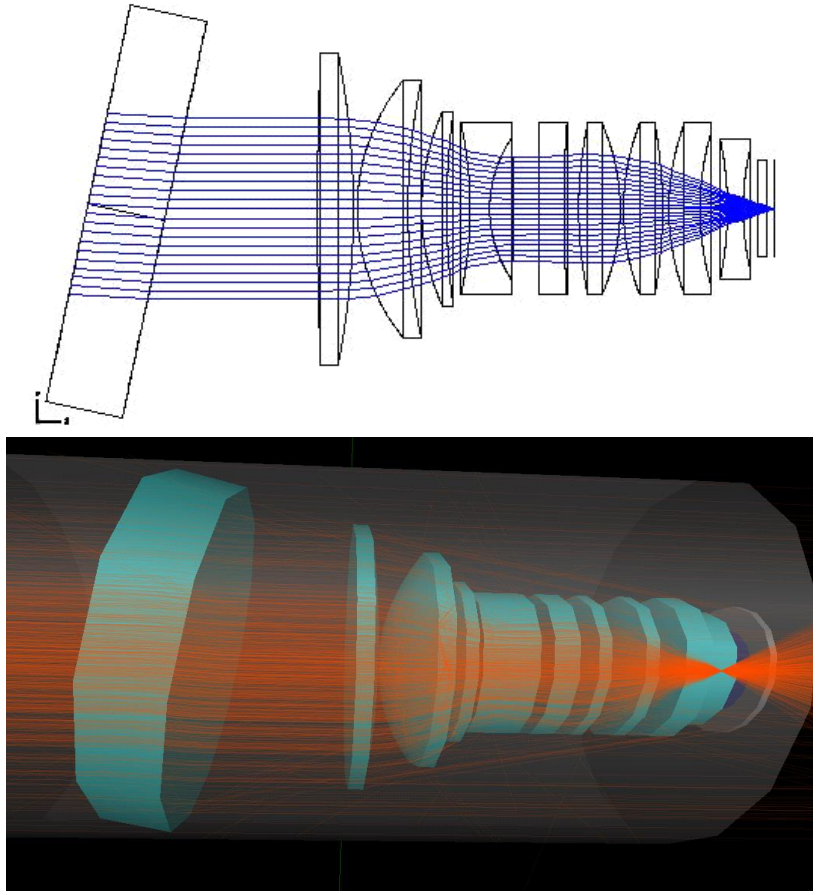




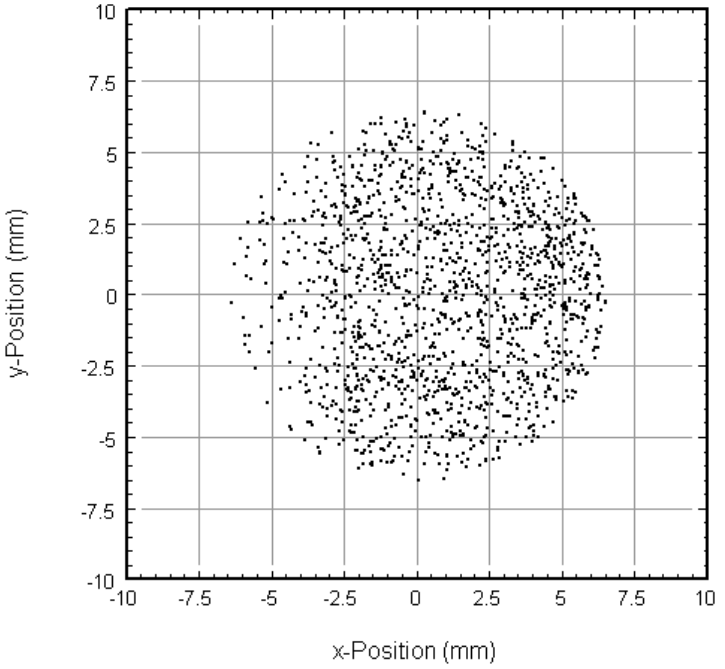


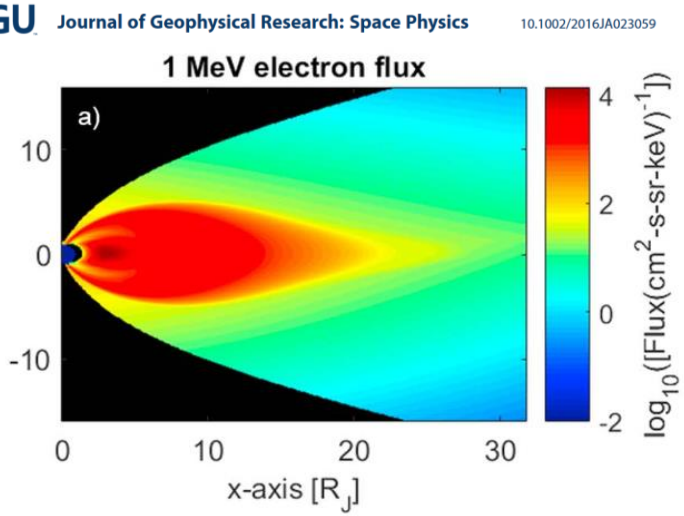
Proton irradiated (at CERN) glass faceplates. Induced absorbance vs fluence.

Star Tracker simulations for a company working with NASA on the Juno mission.



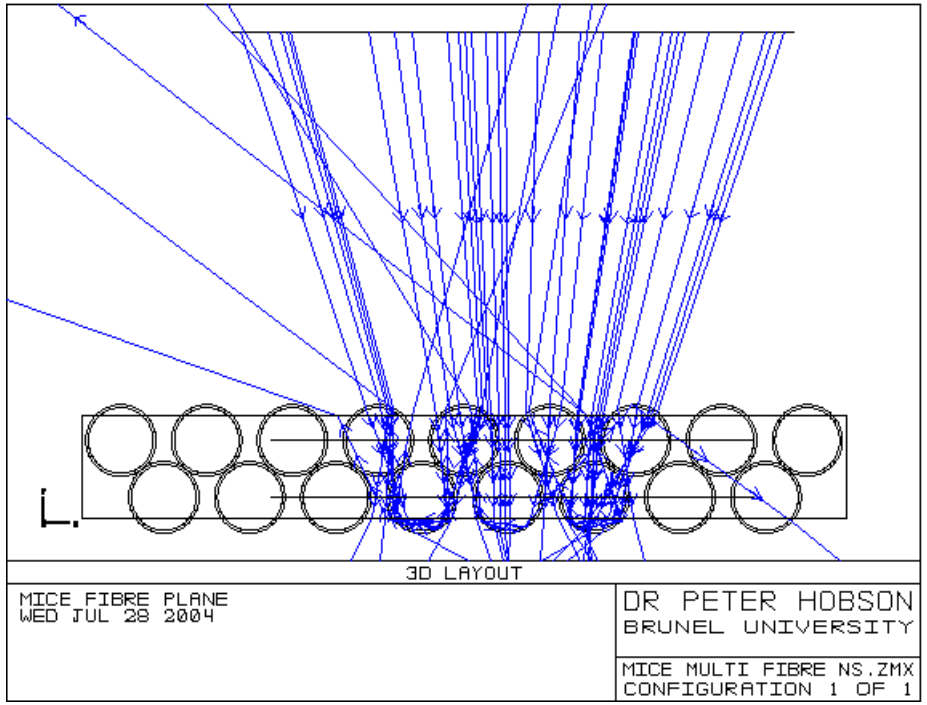
Comparing ZEMAX and CyberRay

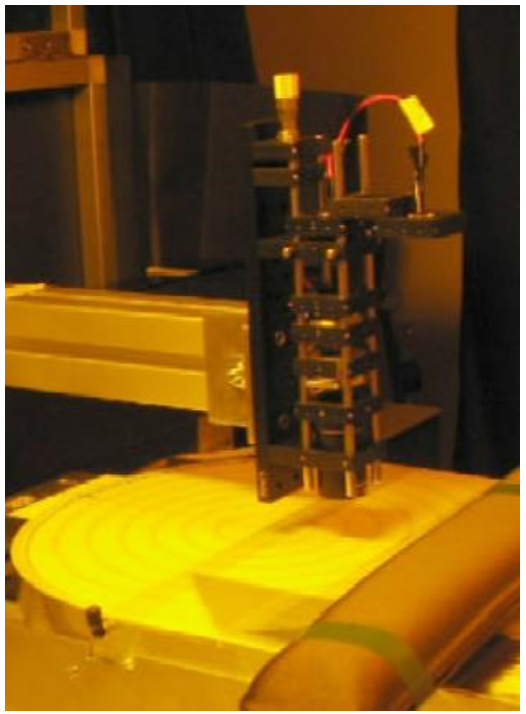


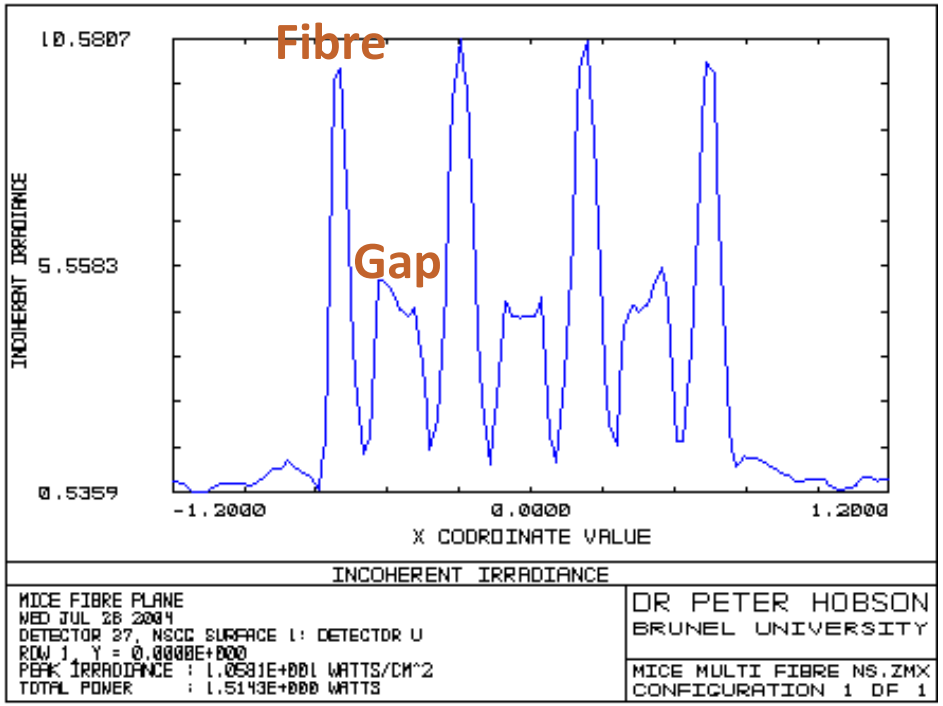


CCD hits for 200 keV electrons (close to the Cherenkov threshold of 190 keV) at 10° to the optical axis. There were 300000 electrons in the primary beam.

QA system for MICE experiment fibre tracker







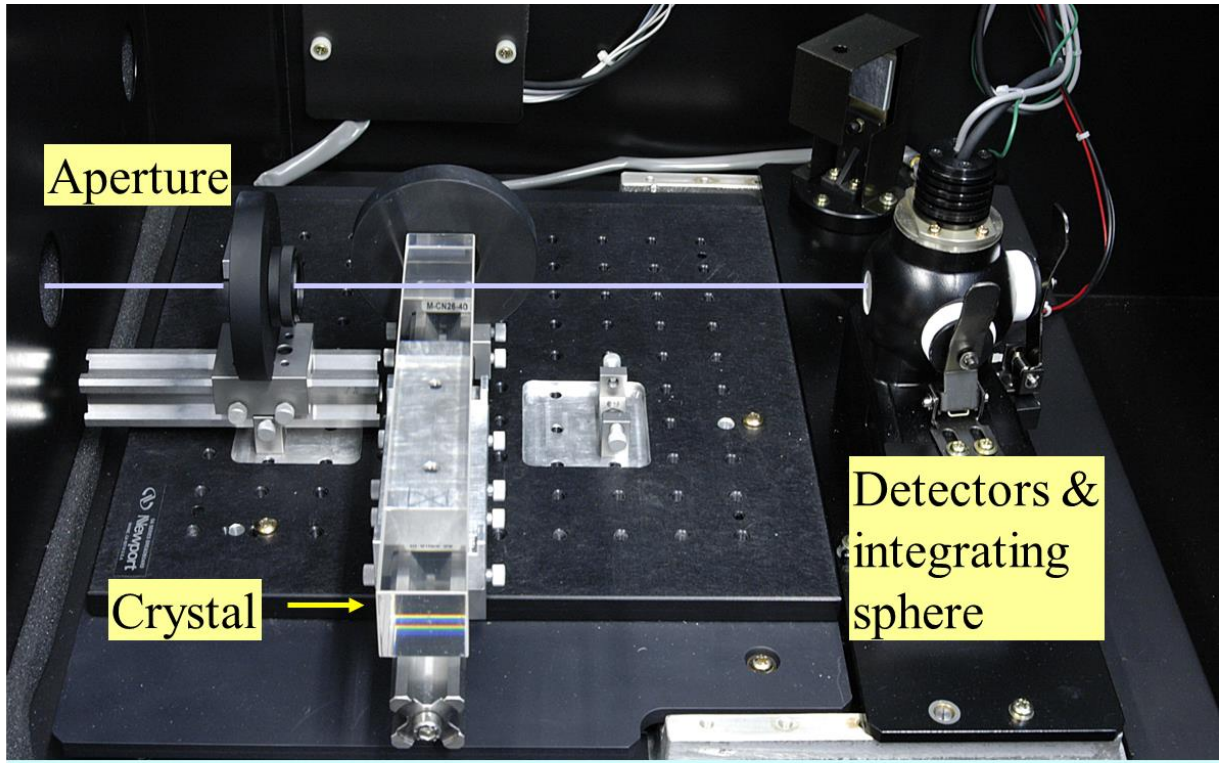
True 3D simulation (non-sequential).

Includes ray splitting, polarisation, scatter and absorption.

Horizontal lines through fibres on this view are “detector” planes Cuboid represents inter-plane glue.

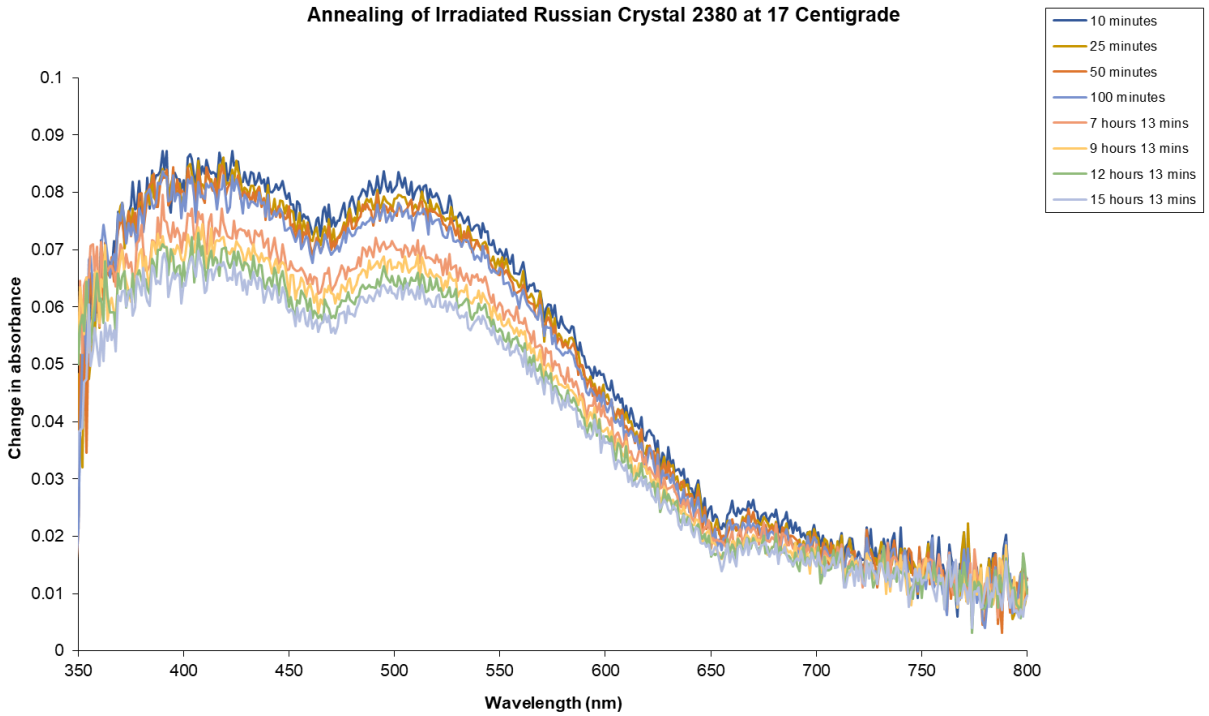
Power crossing the midline of the upper 4 fibres. Energy in gaps doesn’t excite these fibres (but does excite the 3 fibres in the bottom row)

Rapid annealing of irradiated $PbWO_4$ crystals.



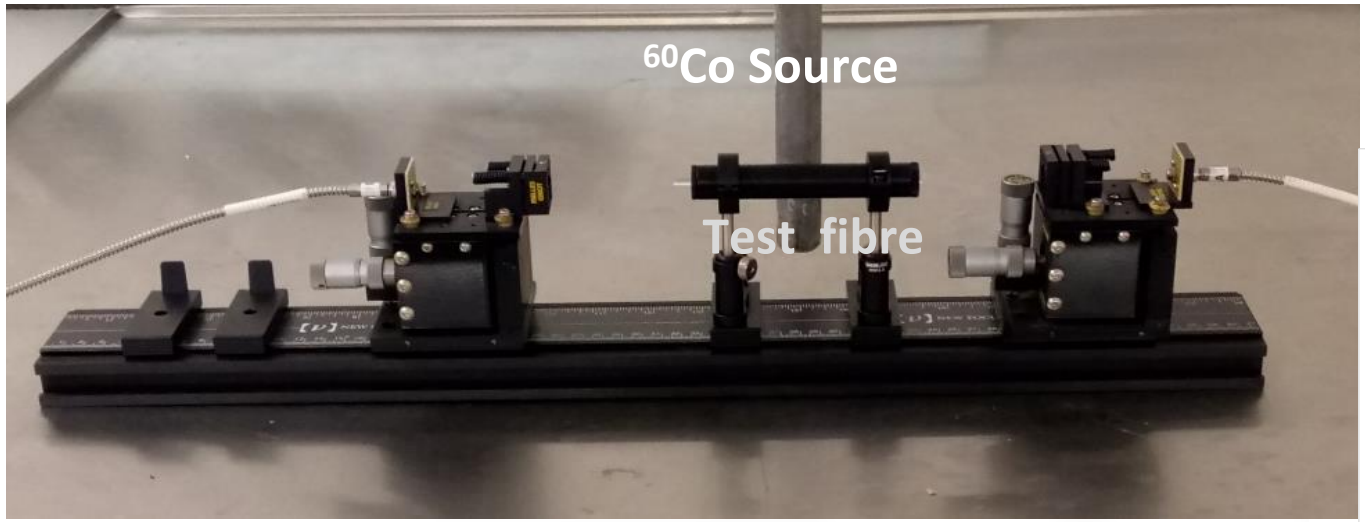
Compartment modified to take optical rails and other components

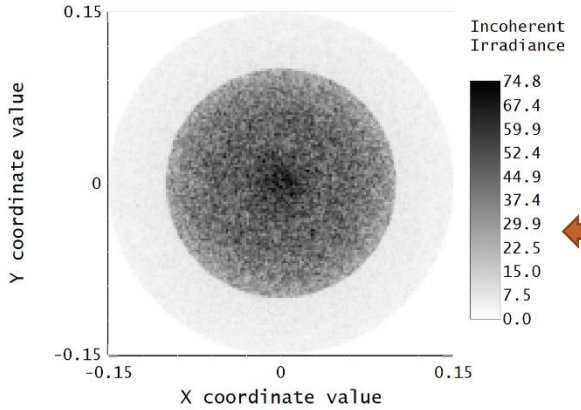
Transverse measurement of induced absorbance in UV-vis-IR sprecrophotometer



Significant short-term changes in ^{60}Co gamma induced absorbance in an irradiated crystal produced for the CMS experiment at CERN.

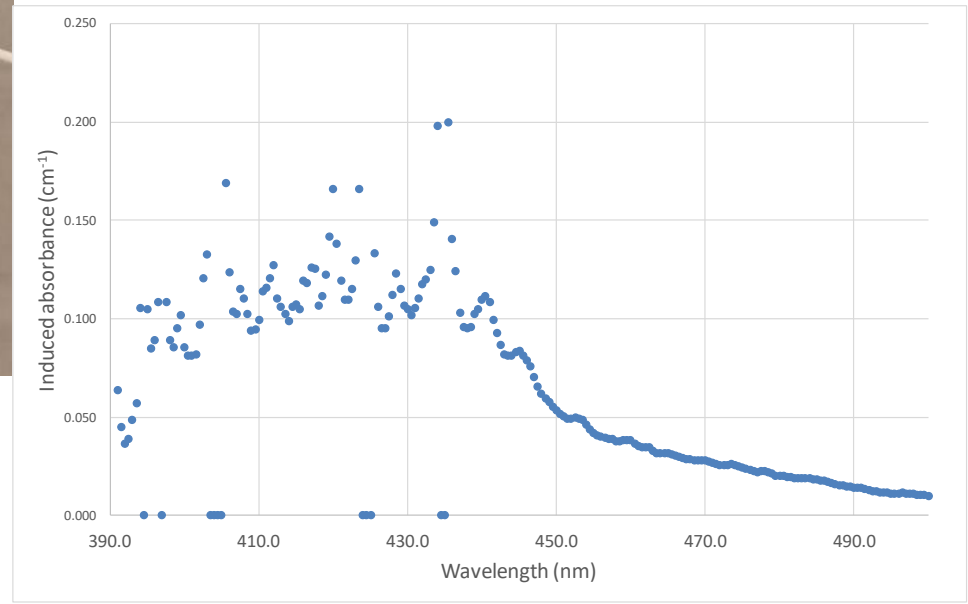
Optical Fibre Test Bench





Non-sequential ray-trace simulations using ZEMAX.

Power coupled into receiver fibre via quartz lenses and test fibre.



Induced absorbance in a PMMA rod after 10kGy.

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