Plasma diagnostics

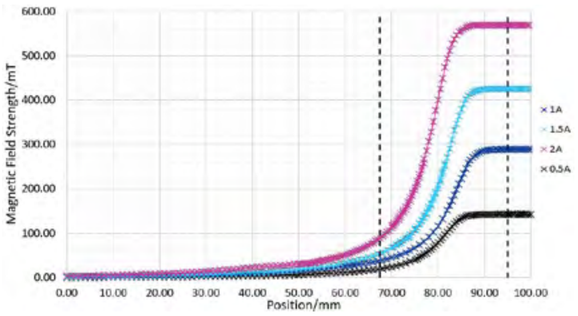
A characterisation of the Figaro electromagnet electron spectrometer

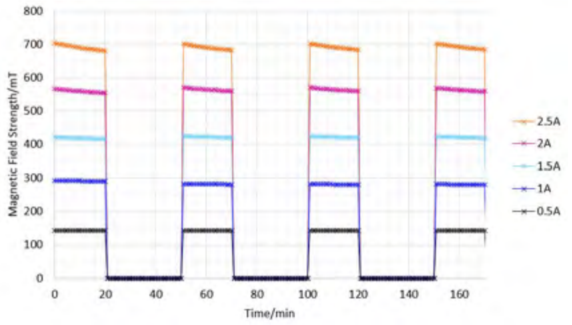
I. Gerenstein *(Department of Physics, Loughborough University, UK)*

D.C. Carroll *(Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, UK)*

The aim of this project is to characterize the magnetic field of the CLF Figaro electromagnet electron spectrometer. A Hall probe is used to map the magnetic field and how it varies spatially and temporally. The relationship between the power supply current and magnetic field was deduced, and resistive heating effects were investigated including an on-off cycle typical for a sequence of Vulcan laser shots. The magnetic field produced varies with current by the following equation: $B = 281.3I + 3.5$, where B is the magnetic field strength in mT and I is the current in A. The optimum current range to minimise decline in current due to resistive heating is between 0A and up to 2A.

Contact: I. Gerenstein (i.gerenstein-17@student.lboro.ac.uk)





Top right: Spatial measurements of the magnetic field of the spectrometer. The dashed lines represent the edge (left) and the centre (right) of the electromagnet.

Bottom right: Repeat on-off measurements of magnetic field strength with time for different electromagnet currents.

Compact scintillator – silicon photomultiplier hard X-ray detectors for laser-plasma diagnosis

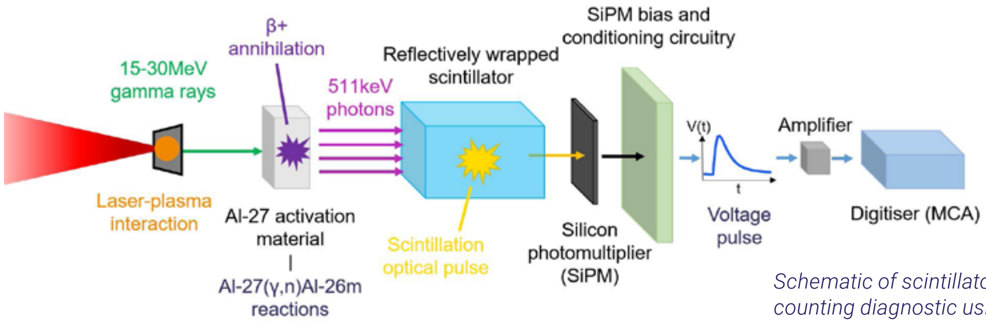
J. K. Patel *(Loughborough University, UK)*

D. Neely, C.D. Armstrong, R.J. Clarke, K. Fowell, I. Symonds *(Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, UK)*

Decaying emission of 511 keV annihilation X-rays from materials activated by >3 MeV photons can be used to diagnose laser-plasma interactions. Low-voltage operable silicon-photomultipliers (SiPM) coupled to scintillators are a favourable alternative to large, high voltage photomultiplier tube (PMT) detectors for measuring low photon numbers.

To optimise the design, the performance of scintillators of varying size is explored, and a simple model is presented which achieves good agreement with the spectra obtained from bismuth germanate (BGO) - SiPM detector combinations tested.

Contact: C.D. Armstrong (chris.armstrong@stfc.ac.uk)



Schematic of scintillator - SiPM detector for gamma counting diagnostic using activation of ^{27}Al.

Assessing collection efficiency for a scintillator-based high repetition radiography detector

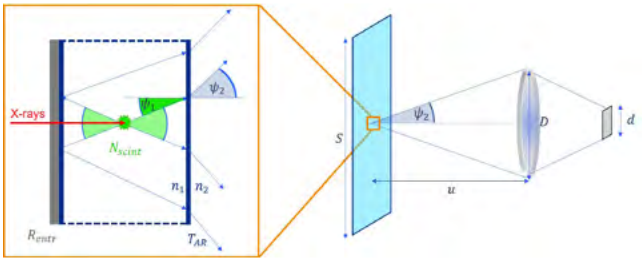
J.K. Patel *(Loughborough University, Loughborough, UK)*

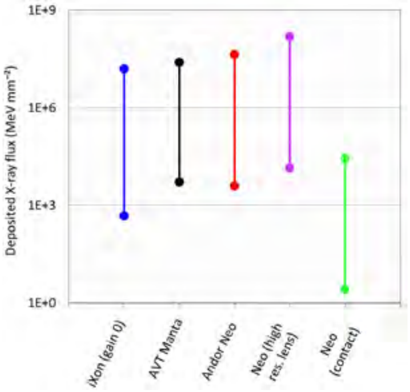
C.D. Armstrong, D. Neely *(Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, UK)*

Next generation high repetition laser driven sources offer advancements for industrial and medical radiography applications, including techniques like Computed Tomography (CT) which requires 100s to 1000s of images. Optical imaging of slab or pixelated scintillators offers a solution for a high repetition detector to pair with these sources. To this end, analytical models for the collection efficiency of camera and lens systems at high and low magnification, have been developed.

Application of the models predicts the sensitivity and dynamic range of several proposed configurations with respect to X-ray deposition. As a result, the suitability of a detector specification with a source of given flux and spectral shape can be assessed. In addition, it is shown that pixelated scintillator arrays are better suited to a set up with high geometrical magnification, where the detector plane is at a significant distance from a sample object and a point-like source. A figure of merit has also been established to compare potential X-ray scintillator candidates based on the relevant properties; light yield, density, and refractive index.

Contact: C.D. Armstrong (chris.armstrong@stfc.ac.uk)





Top: Scintillator imaging diagram on the right-hand side illustrating geometry of lens collection, and blown up cross section of modelled isotropic scintillation event, with relevant angles for calculating lens collection efficiency based on Snell's law and solid angles. Reflected rear cone and refractive indices of the scintillator and air (or alternate immersion medium) are also shown.

Bottom: The model predicted dynamic ranges of various camera and lens or contact optical couplings of a slab LYSO scintillator detector. Given in deposited energy per scintillator area, the model can be used to predict the suitability of a given imaging system with a source of given flux and spectral shape.

Improving collimation of optical flux emission from scintillator crystals

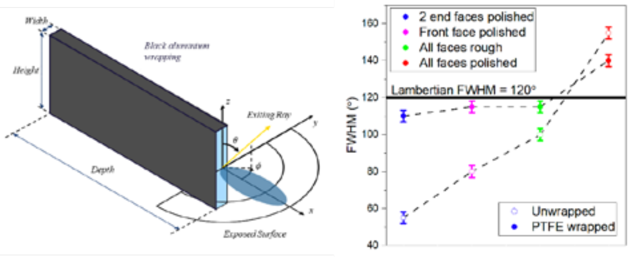
J.K. Patel *(Loughborough University, UK)*

D. Neely, C.D. Armstrong, R.J. Clarke *(Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, UK)*

A linear array of scintillator crystals can be used to characterise a hard X-ray spectrum. Reflective PTFE wrapping of individual crystals improves the incident signal onto a lens coupled detector. Increasing the collimation of scintillator emission will enable further improved yield in the angular range close to the normal to the front crystal face, for better quality electron temperature measurements on laser-plasma experiments.

Using the inherent phosphorescence of LYSO and scintillation from an X-ray source, an investigation of the impact that the surface finish and width of scintillator crystals has on the angular flux distribution, with and without PTFE wrapping, is reported here.

Contact: C.D. Armstrong (chris.armstrong@stfc.ac.uk)



Left: Crystal schematic showing the angle, between the normal to the exposed front face and the line to the centre of the camera sensor, which is varied. Anodised aluminium wrapping was used to prevent light transmitted from the other faces from falling on the sensor. Crystal depth and height dimensions used were 30 x 12 mm, and the widths were varied between 1, 2 and 5 mm.

Right: FWHM for each surface finish, with and without PTFE wrapping.

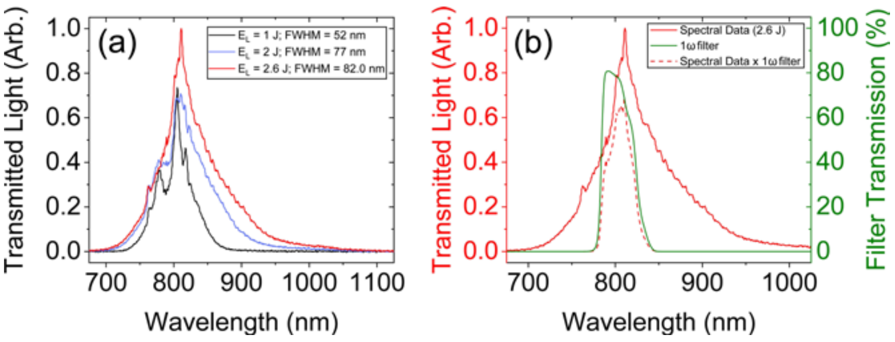
Accounting for spectral bandwidth broadening due to self-phase modulation in measurements of laser pulse transmission through a dense plasma

E.J. Dolier, R. Wilson, T. P. Frazer, J. Goodman, A. Lofrese, A. Horne, M. King, R.J. Gray, P. McKenna *(SUPA Department of Physics, University of Strathclyde, UK)*

T. Dzelzainis, D. Neely (*Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot UK)*

A method has been developed to characterise the fraction of laser energy transmitted through an initially over-dense plasma whilst accounting for broadening in the transmitted pulse spectrum. As such, this method accounts for the effect of self-phase modulation which may occur as an intense pulse propagates through beamline optics before being detected.

Contact: E.J. Dolier (ewan.dolier.2015@uni.strath.ac.uk)



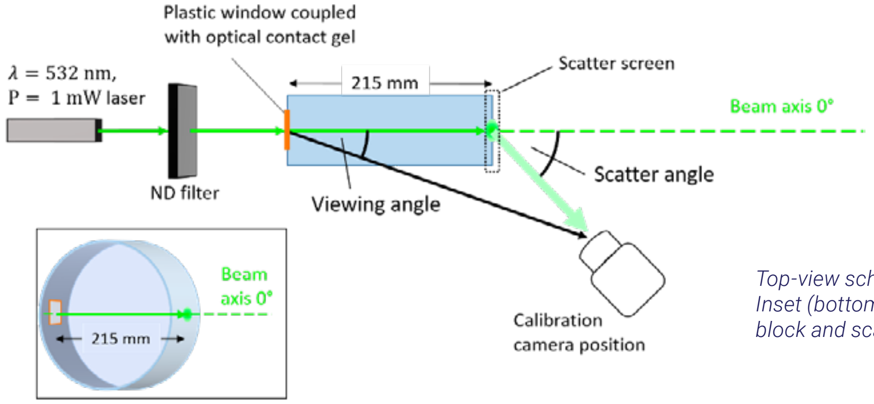
(a) Transmitted light spectra for several no target shots display increased bandwidth (FWHM) with increasing incident laser energy, suggesting SPM-induced broadening. (b) An example transmitted light spectrum (solid red) is shown for a no target shot, alongside the transmission curve of the Δλ = 40 nm interference filter placed in front of the CCD camera (green). Spectral measurements were multiplied by this transmission curve (dashed red), indicating the proportion of transmitted light which has gone undetected by the filtered camera.

Absolute Cherenkov photon measurements via angular calibration of a fused silica scatter screen

J.K. Patel *(Loughborough University, UK)*
D. Neely, C.D. Armstrong, Y. Katzir, A. Dasgupta, D. Treverrow, S. Hawkes *(Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, UK)*
E. Zemaityte, R. Gray, A. Horne, T. Frazier, P. McKenna *(University of Strathclyde, Glasgow, UK)*
S. Rozario, J. Wood, M. Backhouse *(Imperial College London, UK)*
R. Deas, H. Thomas, J. Wilkinson, S. Dorkings, R. Giordmaina, P. Dodd, J. May *(Defence Science and Technology Laboratory (Dstl), Fort Halstead, Kent, UK)*

Cherenkov radiation is the electromagnetic emission (typically of visible to ultraviolet wavelength) produced when a charged particle travels faster than the speed of light in a medium with refractive index >1. Cherenkov radiation can be used to diagnose the charge of high energy electron bunches, such as those produced in laser-plasma interactions, by placing a medium in the path of electrons. The expected light yield in photons can be derived from Cherenkov theory, which can be used to verify experimental results. Herein an absolute calibration of the scatter screen is carried out using cooled Andor NEO scientific linear CMOS cameras. The results and methods of such a calibration are reported here, for direct calibration of experimental Cherenkov measurements.

Contact: C.D. Armstrong (chris.armstrong@stfc.ac.uk)



Top-view schematic of scatter screen calibration set up. Inset (bottom-left) is side-view illustration of fused silica block and scatter surface.