Plasma diagnostics

Deconvolution of multi-Boltzmann x-ray distribution from linear absorption spectrometer via analytical parameter reduction

C.D. Armstrong, D. Neely *(Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, UK)*
D. Kumar *(Department of Radiation and Chemical Physics, Institute of Physics of the Czech Academy of Sciences, Prague, Czechia)*
P. McKenna, R.J. Gray *(SUPA Department of Physics, University of Strathclyde, Glasgow, UK)*
A.S. Pirozhkov *(Kansai Photon Science Institute, National Institutes for Quantum and Radiological Science and Technology, Kyoto, Japan)*

Accurate characterization of incident radiation is a fundamental challenge for diagnostic design. Herein, we present an efficient spectral analysis routine that is able to characterize multiple components within the spectral emission by analytically reducing the number of parameters. The technique is presented alongside the design of a hard x-ray linear absorption spectrometer using the example of multiple Boltzmann-like spectral distributions; however, it is generally applicable to all absorption based spectrometer designs and can be adapted to any incident spectral shape. This routine is demonstrated to be tolerable to experimental noise and suitable for real-time data processing at multi-Hz repetition rates.

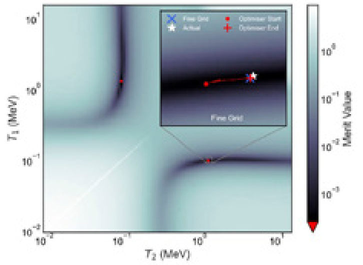


Figure 1: Example of second stage reconstruction. The inset shows the parameter space evaluated by the fine grid, and the red line shows the evaluation points for the Nelder-Mead routine—the color scale of the inset is the same as the primary figure.

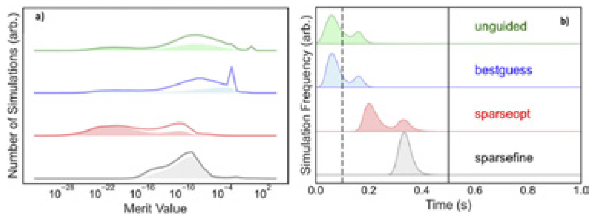


Figure 2: Averaged computation time for each methodology on a standard desktop machine. The vertical solid and dashed lines correspond to 2 and 10 Hz reconstructions, respectively

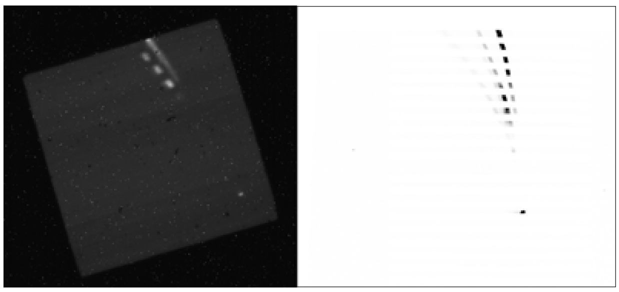
Contacts: C.D. Armstrong (chris.armstrong@stfc.ac.uk)
A.S. Pirozhkov (pirozhkov.alexander@qst.go.jp)

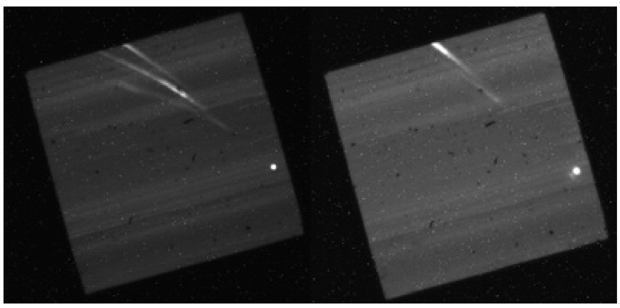
Deployment of active Thomson spectrometer at Vulcan petawatt

D. Bedilu, H. Ahmed, D.C. Carroll, R.J. Clarke *(Experimental Science Group, 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.





Top: Figure 1: Images from the slotted image plate (left) with ceramic Gadox (right) placed behind for cross-calibration

Bottom: Figure 2: Comparison between Gadox (left) and Lanex (right) scintillators

Contacts: D. Bedilu (daniel.bedilu@stfc.ac.uk)
H. Ahmed (hamad.ahmed@stfc.ac.uk)

Investigating the Working Distances of the Questar QM-1SZ Tele-Microscopes

J.J. Bush *(Physics Department, Loughborough University, UK)*

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

Tele-microscopes are an exciting new tool for the Central Laser Facility to use in the referencing of targets, helping to streamline the running of experiments. They are long range, high resolution imagers that allow for a wide or narrow field of view (FoV) from outside of the target chamber, for positional referencing of a target in 3D space.

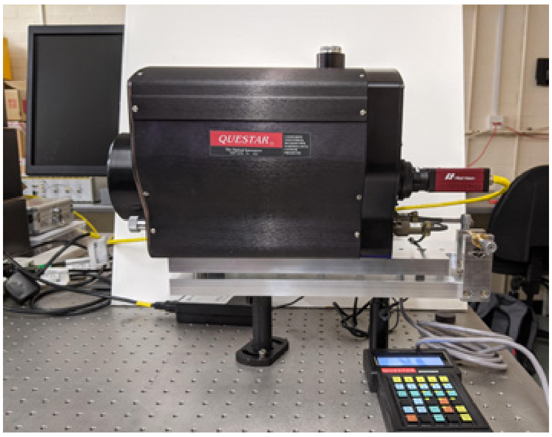
This report is a continuation of *Investigating Contrast, Resolution and Field-of-View (FoV) of the Questar QM-1SZ Tele-Microscope* by J.A. Hodson et al. [1], which looked to measure the resolution, contrast and FoV of the tele-microscopes QM-41and QM-42 (serial numbers QM110541SZ and QM110542SZ) at distances of 65 cm and 1.4 m.

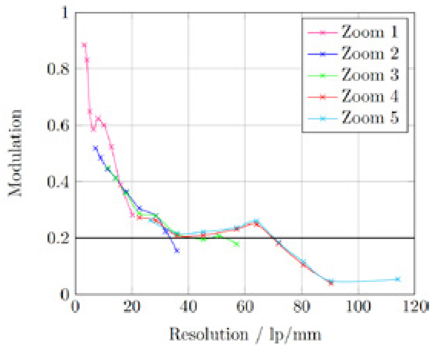
This later investigation looks into the working distance of these two tele-microscopes, as well as QM-40 and QM-43 (serial numbers QM110540SZ and QM110543SZ) that are advertised to have a much longer working distance at the cost of resolution. Measurements are taken of the resolution and FoV of the QM-40 and QM-41 at their nearest focus, 1.2 m, and at their farthest focus. The working distance stated in the specifications for the QM-41 and QM-42 was from 560 mm to 1520 mm, whereas the working distance for the QM-40 and QM-43 was from 914 mm (3 feet) to infinity. However, the effective working distance from the front plate of the tele-microscopes was found to be 621 mm to 1370 mm for the QM-41 and QM-42, while a value of 1036 mm to infinity was found for the QM-40 and QM-43. An analysis of the capabilities of a custom built adjust able stand for the tele-microscopes was also included, as well as an evaluation of the performance of these tele-microscopes as a referencing tool in the Dr G Scott experiment [2].

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

[1] J.A. Hodson et al., Investigating Contrast, Resolution and Field-of-View of the Questar QM-1SZ Tele-Microscope. Tech. rep., Central Laser Facility Annual Report 2018/19. https://www.clf.stfc.ac.uk/Gallery/45%20-%20Hodson.pdf

[2] Dr G Scott. Direct Laser Acceleration of Electrons to Superponderomotive Energies. Experiment Proposal. 2020.





Above: Figure 1: Setup of QM-41 on custom stand

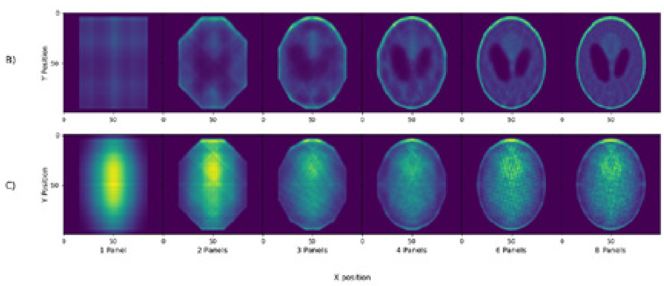
Left: Figure 2: QM-41 1.2 m Vertical Modulation

Modelling Tomographic Reconstruction using Scintillator Fibres for active proton imaging

A.R.L. Illoul *(School of Physics, University of Bristol, UK)*

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

High repetition rate laser facilities require active diagnostic systems in order to process data promptly. Current methods to image the spectral-spatial distribution of protons are incapable of this, and so novel diagnostic tools need to be developed. Here we present software as a proof-of-concept active proton imaging system, capable of measuring the spectral-spatial distribution of proton beams. This novel approach utilises tomographic reconstruction, with scintillating fibres as the medium of signal transport. We exhibit the reconstructed images as further projected angles are used, and demonstrate the necessity of correcting for light absorption within a scintillator fibre. We analytically present how the spectral resolution of such a diagnostic tool would vary as further projected angles are used.



Demonstration of reconstruction of a Shepp-Logan phantom with increasing angles, with and without accounting for attenuation of the light emission

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

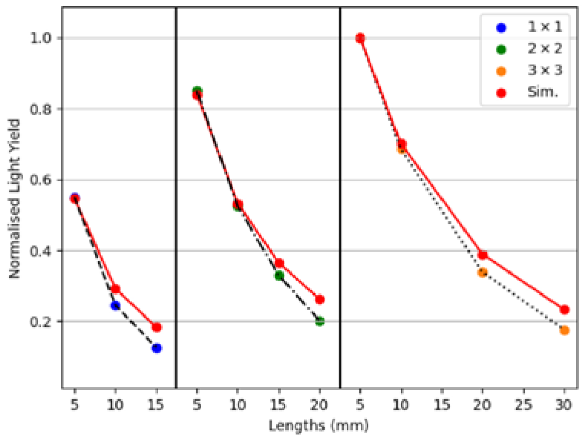
Demonstrating Light Yield and Energy Resolution trends for different sized Scintillators using Monte Carlo Simulations

A.R.L. Illoul *(School of Physics, University of Bristol, UK)*

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

Light yield loss due to larger scintillator dimensions has been documented for a number of different scintillators, and was explained using the overlap between the characteristic emission and absorption spectrum of the scintillator – causing self-absorption, an effect which rises with respect to the average photon path length. Monte Carlo simulations were used to demonstrate that the in- crease in surface area of a diffusely-reflecting surface wrapped around the scintillator will produce a similar trend, independent of self-absorption. The aspect ratio of two sides of the scintillator was varied to observe its effect on the light yield measured, showing a gradual climb in yield as the ratio increased. There is indication that the detector planes surface area is not driving this increase independently. The energy resolution of scintillators of a given length were established, producing higher resolutions at smaller scintillator lengths. Increased resolution was also found for higher reflection coefficients of the reflective wrapping. A literature comparison is also shown to demonstrate the simulations consistency.

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



Light yield from a scintillator as a function of cross-section and aspect ratio, comparing the results from Cherry et al.[1] with the presented Monte Carlo simulation

[1] S R Cherry *et al.* Collection of scintillation light from small bgo crystals. IEEE Transactions on Nuclear Science, 42(4):1058-1063, 1995

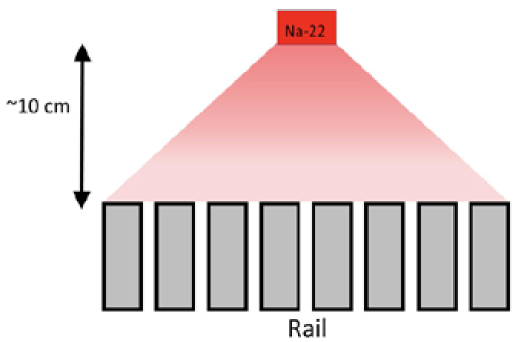
Scintillator Light Yield Variation due to the Reflective Wrapping

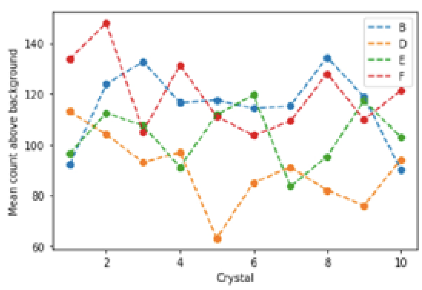
A.R.L. Illoul *(School of Physics, University of Bristol, UK)*

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

During calibration of an X-ray spectrometer composed of rails of scintillator blocks, Dasgupta *et. al.*[1] observed large discrepancies between each scintillator block's light yield when radiated by a Sodium-22 (Na-22) source. Forty individual scintillator blocks of the same shape and type collectively constituted the yield data set with a variation of 16.7%. We demonstrate, using Monte Carlo simulations of light transport in scintillators, that the cause of this high variance could be accounted for in variations of thickness of the reflective material on the scintillators' surface. Literature figures that related the number of layers of reflector tape to the reflectance coefficient were employed to then produce a distribution of reflectance coefficients, which fully justify variations in the reflectivity as the source of light yield variation.

[1] A. Dasgupta, C.D Armstrong, D.Neely, D.R. Rusby, G.G. Scott - Calibrating LYSO crystals part of a hard X-ray spectrometer CLF Annual Report 2019





Rail calibration schematic (left) and results (right) demonstrating high variability in uniform set of crystals. Subtle variation in average reflective coefficient can explain the measured variation in yield.

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