Image Plate and Scanner Characterisation

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Introduction

Image Plate and the associated scanning machine FLA5000[1] are regularly used at the Central Laser Facility (CLF) to record and read data from high power laser interaction experiments. The image plates (IP) available (MS, SR, TR types) are all sensitive in varying degrees to ionising radiation – x-rays, electrons, protons for example and are used to detect and record information while the scanner is used to read and digitize it.

Investigations have taken place to verify linearity of response, resolution limits and noise levels of the combination of MS, SR and TR-type IP and FLA5000 scanner at the CLF. This report details the tests carried out and results.

Scanner and IP testing

A variety of tests were conducted using MS, SR and TR type IP in combination with the CLF scanner. To do these tests the IP was exposed in varying amounts to the output of an Fe^{55} radioactive source, or left to cosmic background with a combination of filtering and or resolution test objects. The activity of the source used was 1.85MBq, dose is 3.2×10^4 photons /sec/steradian ±20%.

The Fe^{55} source, was held in position 50mm above a sample IP surrounded by an Aluminium shield that had internal diameter hole of 25mm and external diameter of 50mm. The source is a 12.5 mm Copper disc coated with Fe^{55}, sealed with Nickel and gives out Mn $K\alpha_1$ x-rays at 5.89KeV.

Scanning was conducted at 25µm or 10µm scanner resolution (which is an extrapolation from the 25µm limit of the scanner)

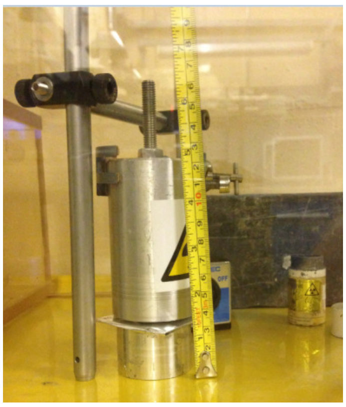


Fig. 1 picture showing the set up of the Fe55 source and IP

All tests were conducted with the IP wrapped in a 13µm thick layer of Aluminium foil to ensure light tightness.

Tests conducted were as follows:

1. *Identify how background accumulates on plates over different periods accumulate*

IP was left for differing periods of time to cosmic background. Levels were then scanned to determine how much noise was present.

2. *Identify how low signals compared to noise accumulate*

To see if low signals accumulate or are not detected when background is of a similar level. An IP was left to accumulate cosmic background for three days, irradiated with an Fe^{55} source for one day and then immediately scanned. The reverse test, irradiated by Fe^{55} for one day, left for three days to cosmic background was also conducted. This tests the response to signal accumulation.

3. *Linearity of the IP combined with scanner*

A graduated filter made up of layers of Al foil at 26µm intervals was placed on top of an IP giving 10 sections of variable transmission. This enabled a range from 1 to 1/32th in transmission (see Fig 2). The Fe^{55} source was used to irradiate the IP through this filter for a set duration and then scanned.

Fig. 2 Filter pack used to create 10 zones of filtration each layer is 26µm thick Aluminium foil.

4. *Resolution test of the IP combined with scanner*

An IP was irradiated by the Fe^{55} source with a pinhole array attached to the surface enabling the source to imprint through the pinholes. The IP was also wrapped in 13µm Al foil as a light tight cover. The pinhole array contained pinhole sizes of 200, 150, 100, 50, 35, 20 and 12.5 microns diameter. There was also a gold MTF grid present when testing the TR and SR plates. These objects were attached to the IP via electrical tape of 177µm thickness.

Results

Cosmic ray (noise) levels resulting from a 3 day and 15 day exposure on MS plate is shown in Fig 3 (graph). The results show that the background levels are around 0.01 PSL from 15 days or 0.0015 PSL from 3 days of being left.

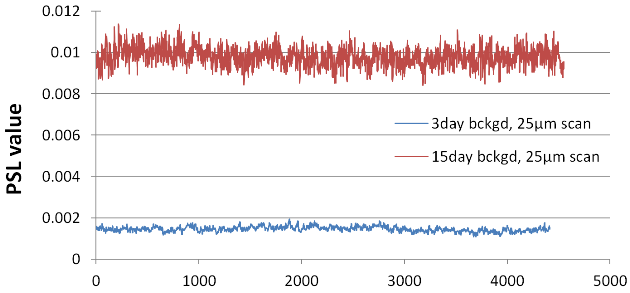


Fig. 3 Graph showing typical background attained from leaving plates for 3 and 15 days to accumulate. The data is averaged and for MS type IP scanned at 25µm

A further test to see how plate accumulation might be affected by background shows no difference at least for the exposures involved in this test – Fig 4 shows the result. This data was taken using a filter pack (shown in Fig 2) and has the noise data shown for comparison on the same graph – in this case it looks to be that data accumulation is linear in that it is additive so it doesn't make any difference if noise is added to signal or the other way round. If it had been a long 15 day exposure with a short Fe^{55} irradiation the noise would have swamped the signal in the low signal (more heavily filtered) zones however so highlighting that it is important to make sure that plates are wiped prior to use especially if expecting low signal.

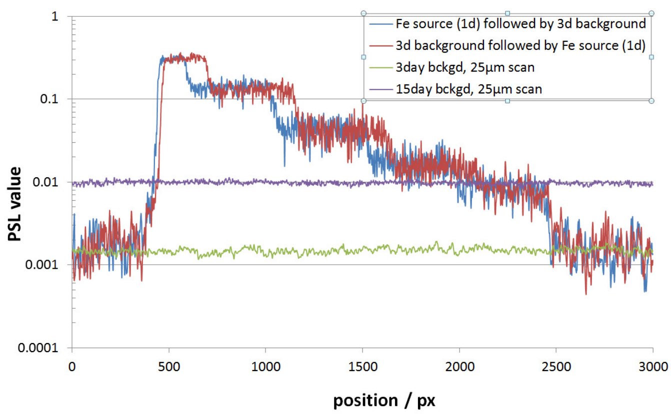
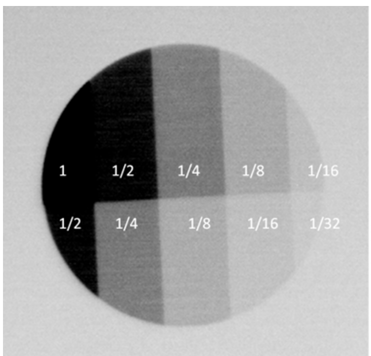


Fig. 4 Graph showing accumulation of data for MS type IP scanned at 25µm

Scanner linearity was tested using the same filter pack shown in Fig 2. The zones of transmission can be seen in Fig 5 and the transmission of the thicknesses of aluminium used is also shown in a table next to this. There are repeat levels to enable comparisons across the plate.

The zone labelled 1 relates to an area with no filter from the pack, but the IP had 13µm Al around it to make it light tight, so there is 13µm thickness base line then plus 26µm for each step.



Thickness/ µm	%T of Aluminium @5.8keV
13	0.66
26	0.44
39	0.29
52	0.20
65	0.13
78	0.09
91	0.06
104	0.04
117	0.03
130	0.02
143	0.01

Fig. 5 Image of filter step with zones (above left) and table of transmission of 5.89keV x-rays through a variety of thicknesses of Aluminium.

The linearity of the IP scanner combination for this test using MS plate is shown in Fig 6 which shows the PSL values from each zone against the expected transmission through the thickness of aluminium The response to input signal at the levels of exposure that were used looks to be very matched to a linear response.

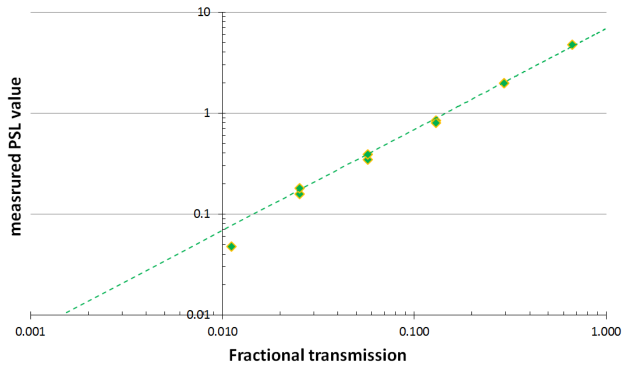


Fig. 6 Graph showing the linearity of response to input signal of x-rays

Resolution testing with a pinhole array was conducted on all types of plate. Exposure to the plate was for ~8 days in each case. In order to ascertain resolution the peak transmission through each pinhole was compared to the average peak value outside of the substrate, with background subtracted. Fig 7 shows the transmissions of pinholes 200 – 50µm in diameter for TR plate. Those smaller than 50µm were not resolvable.

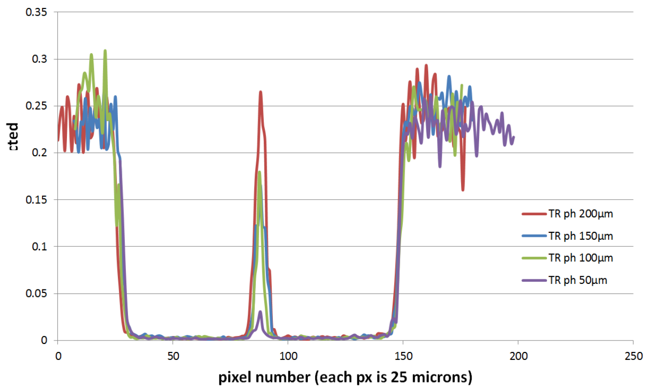


Fig. 7 Pinhole transmissions, example with TR plate, for 200µm - 50µm pinholes

Contrast of the signal is calculated as the transmission peak to outside area peak ratio. A nominal resolution limit obtained from this at the usual cut off point of 50% which is where the usual cut off for "seeing" an object is. Fig 8 shows the contrast of pinhole transmissions for all types of plate from this initial test. Errors in the data are around 10%. This would be improved by further testing and more data to collect statistics on the peak transmissions.

Taking the level of 50% contrast from the graph in Fig 8 the resolution limits can be approximated. It can be seen that the cut off resolution for MS is around 150µm (averaged from the MS data), SR 120µm and TR 80µm. These numbers for SR and TR are close to those attained in a previously published study[2] by a group from LLE using an 8keV source and knife edge technique (MS was not tested in this other study). This study found with their scanner & TR IP to be limited to 94µm and with SR IP 109µm. In both cases showing TR to have a better resolution limit in combination with a scanner than SR.

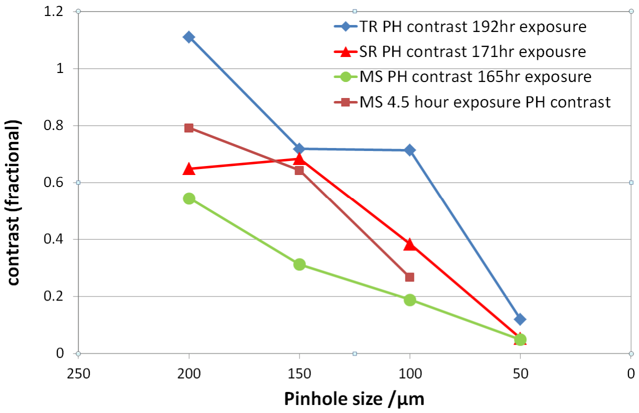


Fig. 8 Contrast of MS, SR and TR image plates from pinhole peak values

Other data collected by analyzing a test grid gives slightly different results.

The grid, made from 25µm thick Gold, had features sized from 160µm in width down to 10µm and was arranged in an MTF type format (Fig 9). Lineouts in both vertical and horizontal direction were taken from the images produced by the scanner of the grid Fig 10.

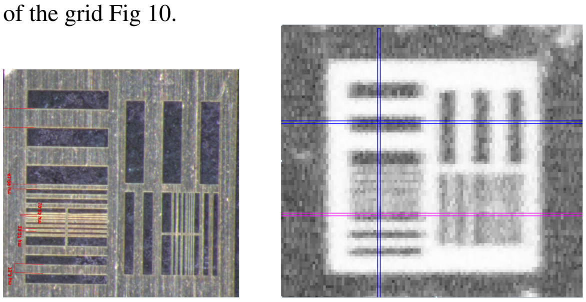


Fig. 9 MTF grid (left) made from gold 25µm thick. Features are 160, 80, 40, 20 and 10µm wide in a vertical and horizontal array. Image result (right) of irradiating Fe55 x-rays through the grid.

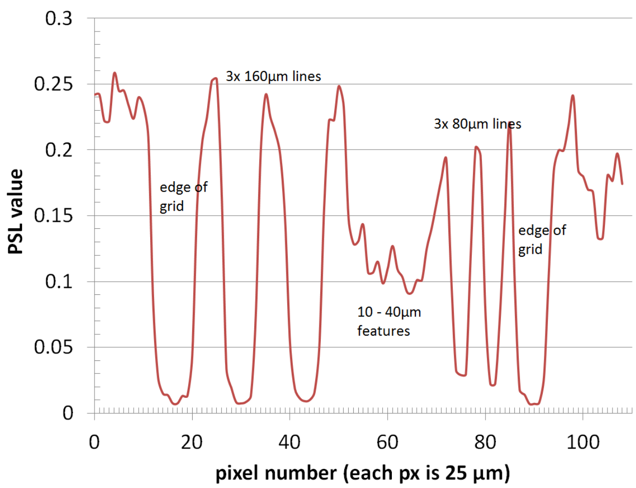


Fig. 10 Lineout example from the vertical highlighted line on the image in Fig 9

Analysis of the features was conducted via a visibility calculation where *(Imax – Imin)/ (Imax+Imin)*as shown in Fig 11. This gives the contrast in an area where the light and dark features are equivalent and take up similar fraction of area. The peak and trough values of areas were taken from lineouts such as those in Fig 10. Sections on the lineouts below have been highlighted as to where they match the image in Fig 9. It can be seen from this that the larger features 160µm, 80µm are certainly more visible than those less than this. The results of the visibility calculations can be seen in Fig 11. Standard deviation on these data are averaged at 4% for 160µm features, 30% on the 80µm features and 20% on the 40 µm features

The results show that at the 50% visibility level again, the scans orthogonal to the scanner direction have a better resolution than scan data taken in the scan direction. The MS type IP was not tested in this case – this needs to be completed in future.

The scanner IP combination that seems best is TR with an average limit of 68µm, followed by SR at 100µm. So the TR and SR result follows the pinhole data in trend although the values are slightly better in this test.

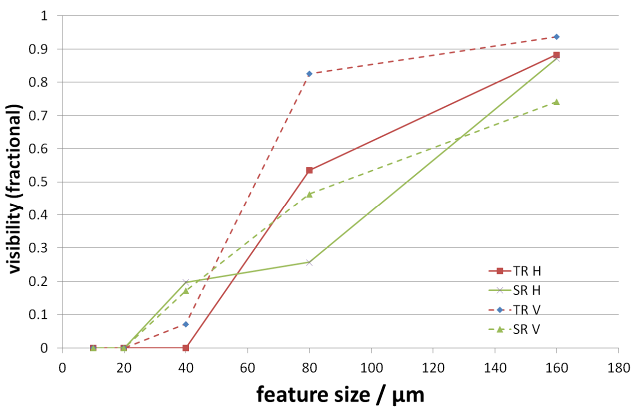


Fig. 10 Graph showing visibility / contrast of grid features also highlighting the difference in result from scan direction and orthogonal to scan direction data.

Conclusions

The scanner response is linear at least with the signal levels concerned within this report.

The resolution of the scanner in combination with different image plates is limited and appears to match data previously collected[2]. Data suggests that the resolution with TR plates is better than with SR in combination with our scanner with a best resolution of 74µm for TR and 110µm for SR (result averaged between the grid and pinhole test data). From this it seems that this system .is not able to resolve the levels quoted as options for scan resolution (in the case of the FLA5000 10, 25, 50, 100 and 200µm options are available). Also the 10µm level available on the FLA5000 scanner is purely an algorithm that extrapolates from a real scan of 25µm digital scan resolution.

When scanning plates in order to achieve this optical resolution it would be advisable to scan on the 25µm setting but there seems to be no benefit using the 10µm option.

Further testing to compare with the other scanners available would be of interest for future work and with higher dose levels to see if there is any change in the outcome.

References

1. FujiFilm products

2. G. Fiskel et al, RSI vol 83 086103 (2012) “Note: Spatial resolution of Fuji BAS-TR and BAS-SR imaging plates”