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Evaluation of a gamma camera system for the RITS-6 accelerator using the self-magnetic pinch diode

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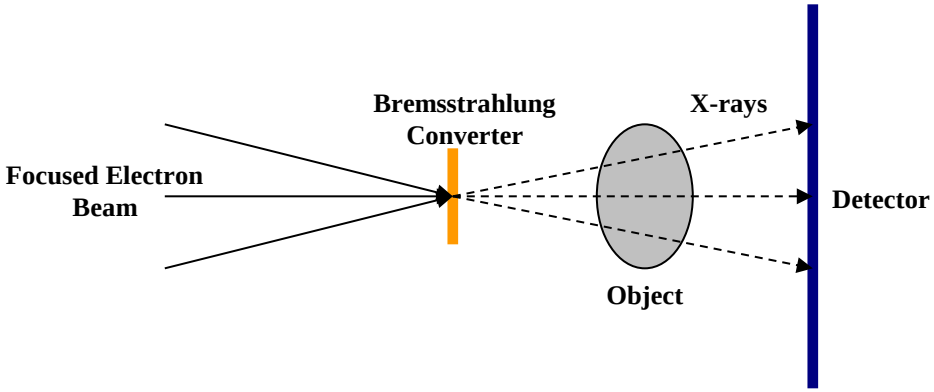
Abstract

The self-magnetic pinch (SMP) diode is an intense radiographic source fielded on the Radiographic Integrated Test Stand (RITS-6) accelerator at Sandia National Laboratories in Albuquerque, NM. The accelerator is an inductive voltage adder (IVA) that can operate from 2-10 MV with currents up to 160 kA (at 7 MV). The SMP diode consists of an annular cathode separated from a flat anode, holding the bremsstrahlung conversion target, by a vacuum gap. Until recently the primary imaging diagnostic utilized image plates (storage phosphors) which has generally low DQE at these photon energies along with other problems. The benefits of using image plates include a high-dynamic range, good spatial resolution, and ease of use. A scintillator-based X-ray imaging system or “gamma camera” has been fielded in front of RITS and the SMP diode which has been able to provide vastly superior images in terms of signal-to-noise with similar resolution and acceptable dynamic range.

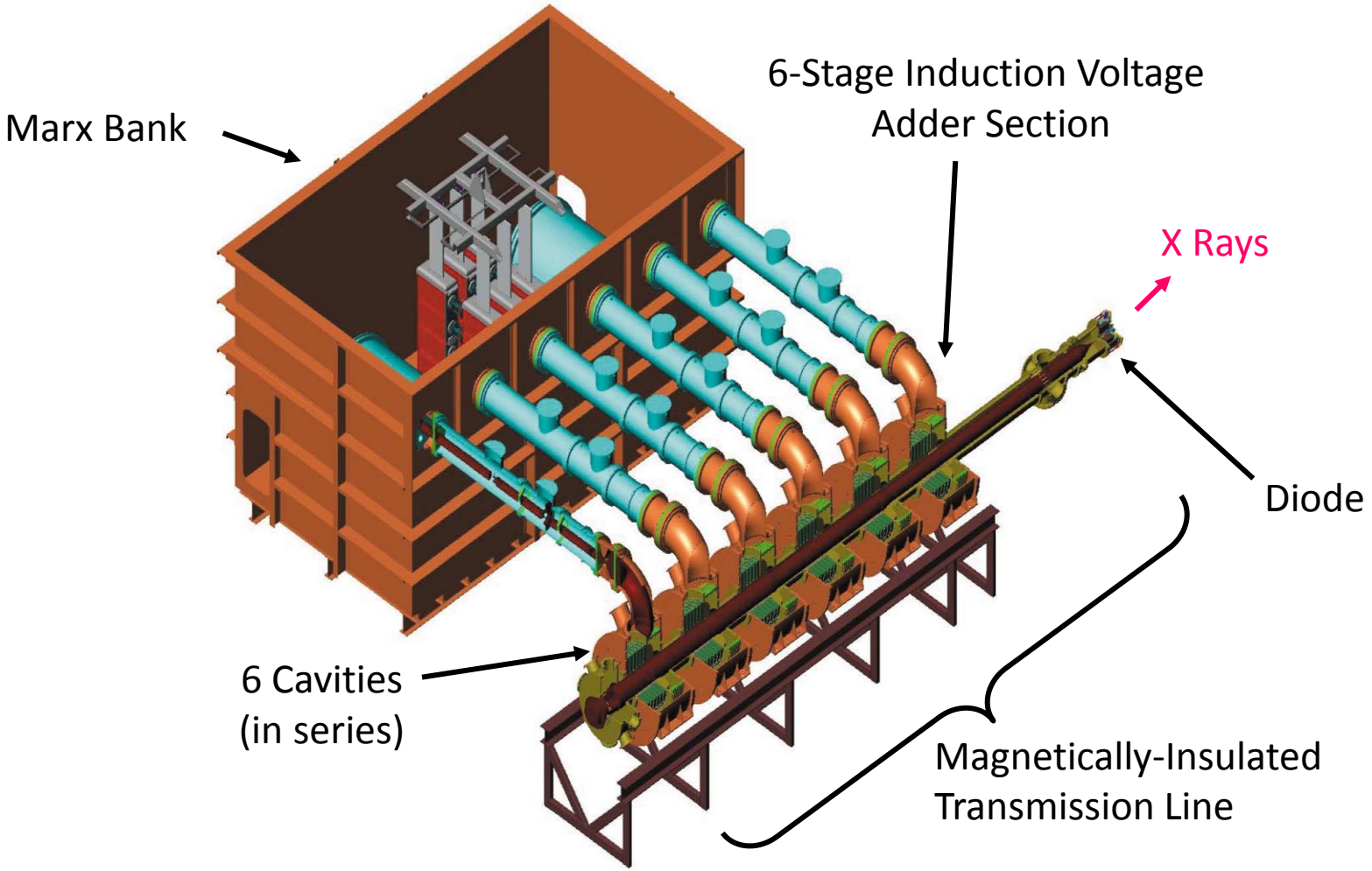
X-Ray Radiographic Source Properties



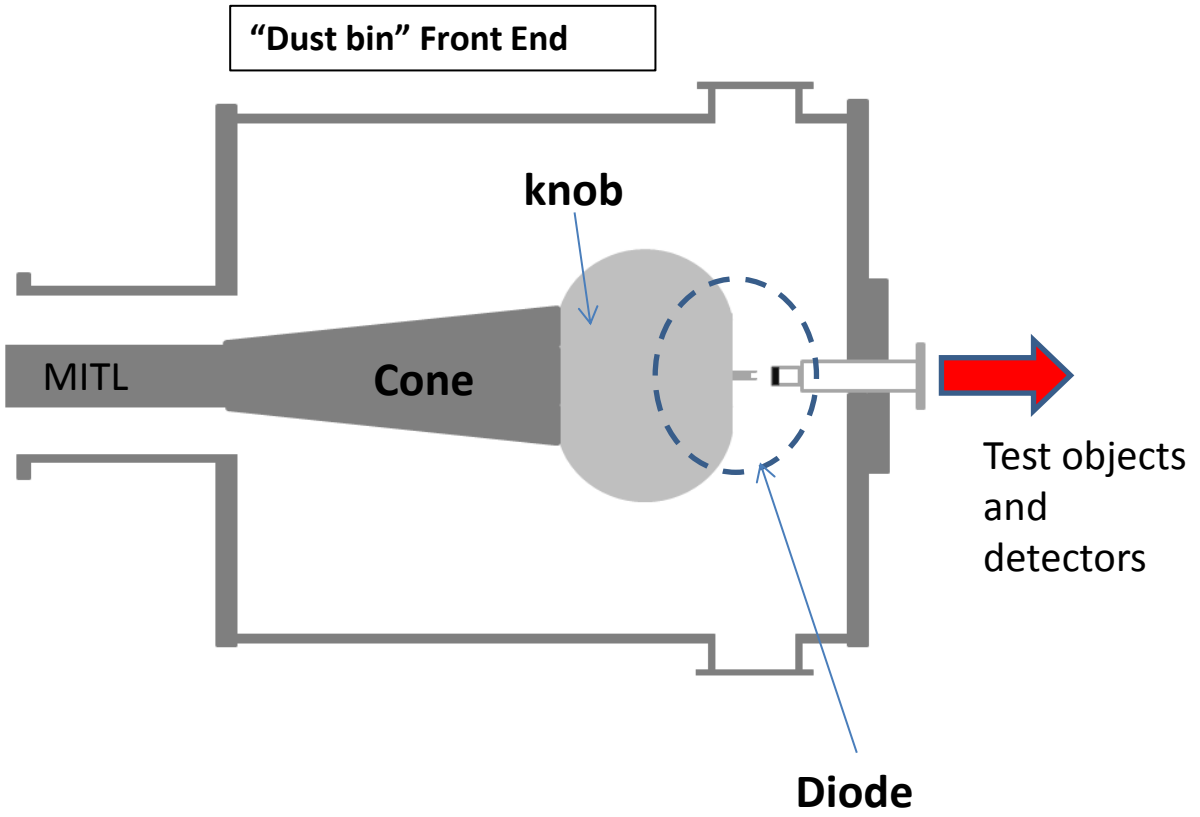
Radiographic Source Characteristics	Affect on radiograph or analysis
Dose	Signal-to-noise ratio (SNR)
Spot size	Resolution
Energy Spectrum	X-ray penetration and contrast
Flat field (beam uniformity)	Areal density reconstruction
Spot position	Spatial correlation of objects
Pulse width	*Degree of motion blur in dynamic objects*
Multi-pulse	*Time evolution of dynamic objects*
Multi-axis	*Three dimensional features of object(s)*

SMP diode research has been conducted on the RITS-6^2 pulsed-power accelerator

Radiographic Integrated Test Stand (RITS-6)

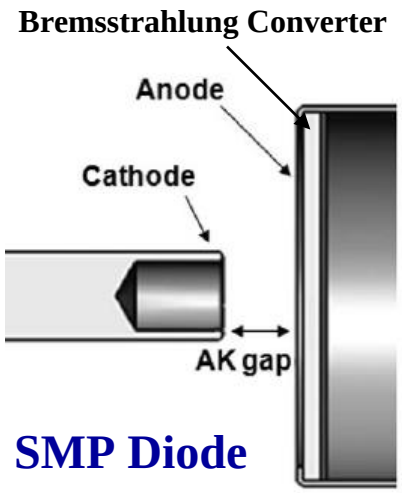


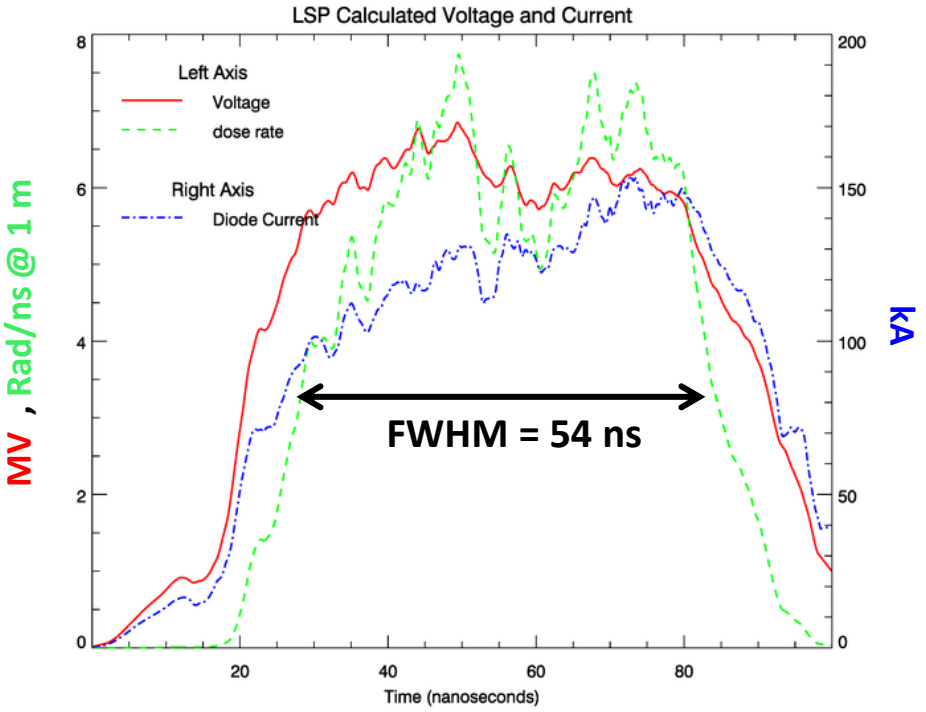
RITS-6 is a 8-12* MV Marx driven six-stage Inductive Voltage Adder (IVA) capable of driving a variety of flash x-ray radiography diode configurations (by my count around half-dozen different "diodes")

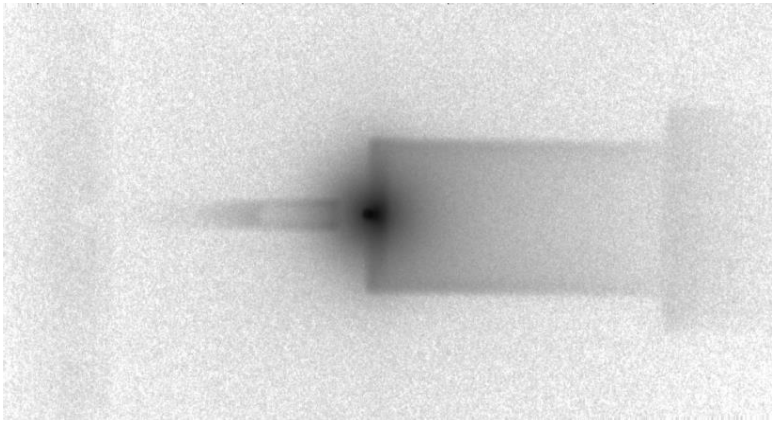


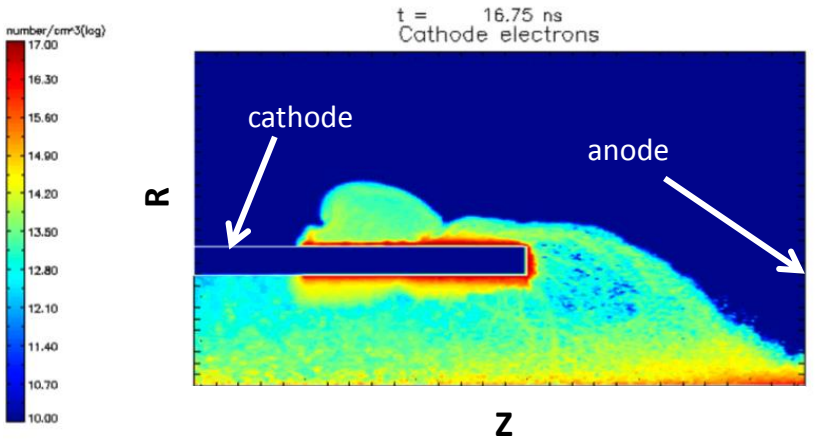
*Traditionally the maximum voltage is changed by changing the MITL inner conductor. Over the last six months we have operated the machine as low as 2 MV by different operating points on the Marx generator and PFLs.

The Self-Magnetic Pinch Diode

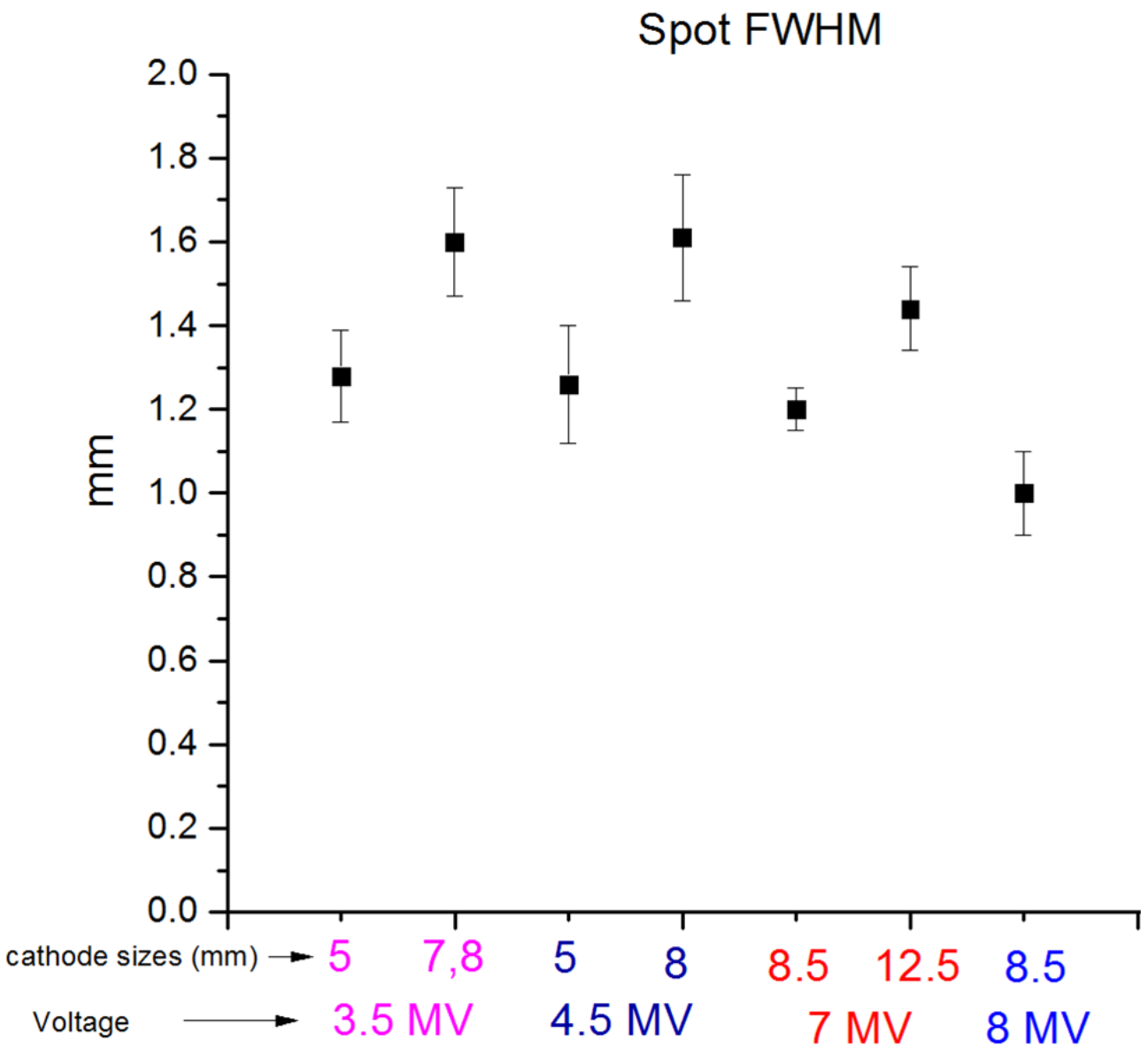




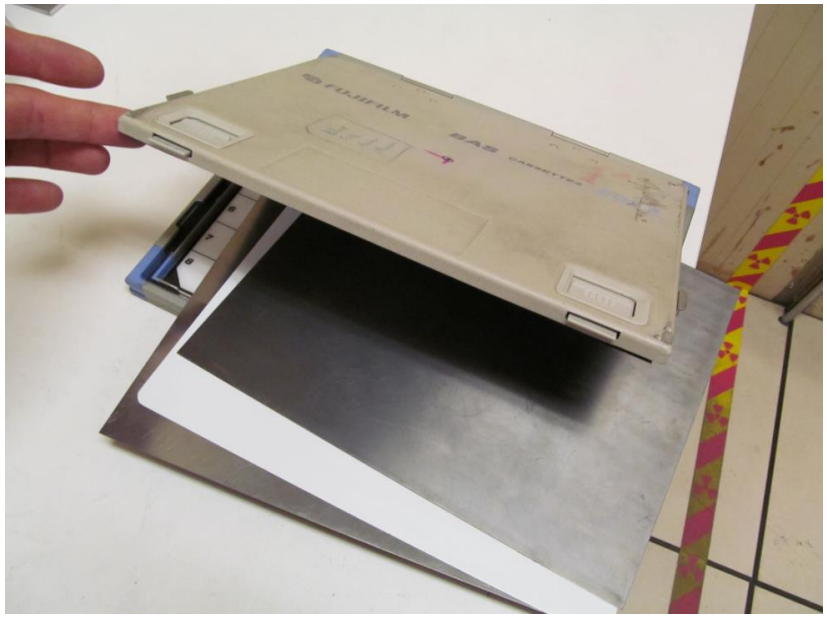




OUO


Spot FWHM
mm
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
cathode sizes (mm) →
5
7,8
5
8
8.5
12.5
8.5
Voltage →
3.5 MV
4.5 MV
7 MV
8 MV

We have typically used “storage phosphors” or image plates for routine imaging purposes.



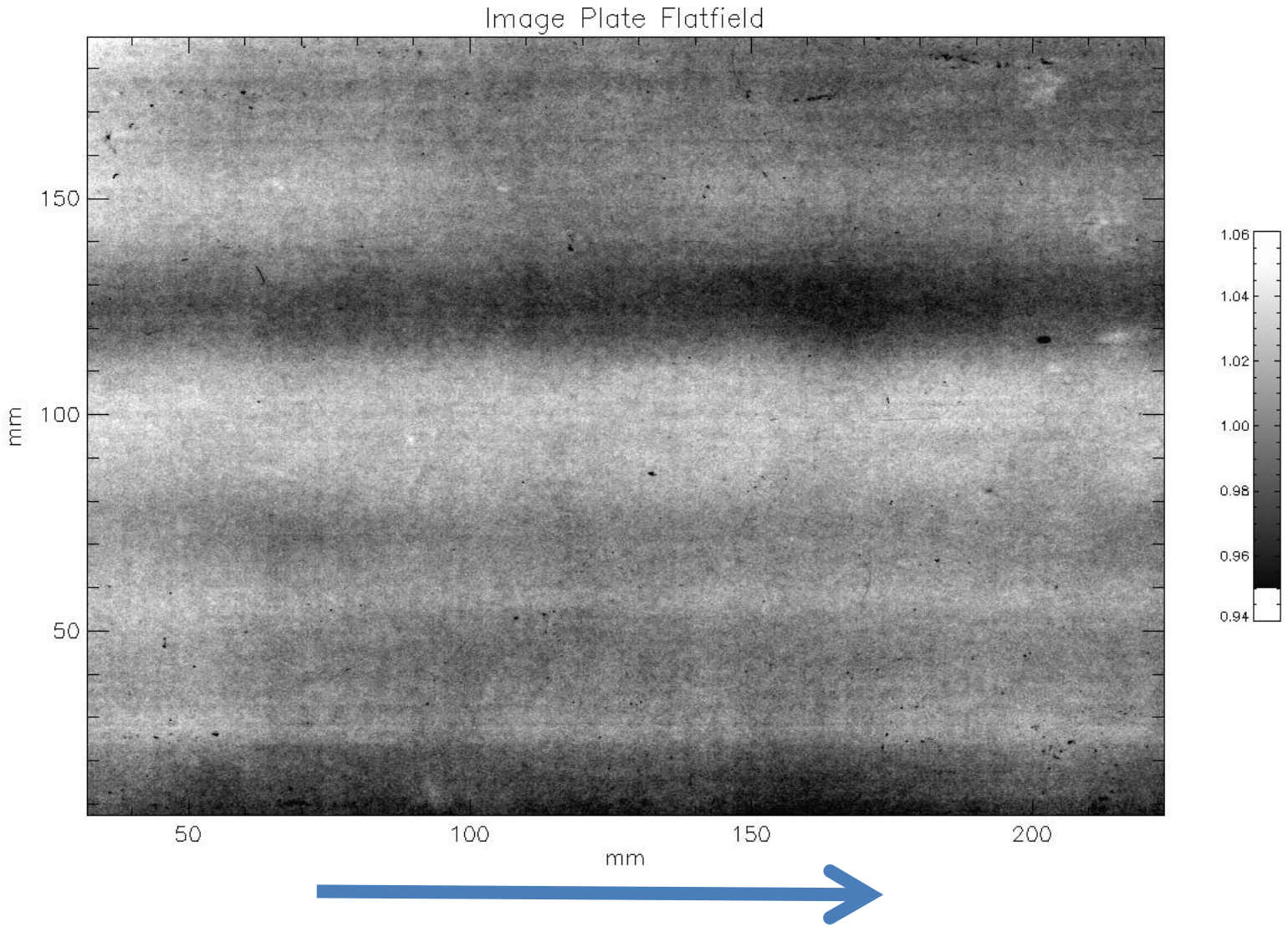
Advantages:

- Easy to field
- Reusable
- High dynamic range (10^5, < 1 mrad to > 10 rads)
- High resolution

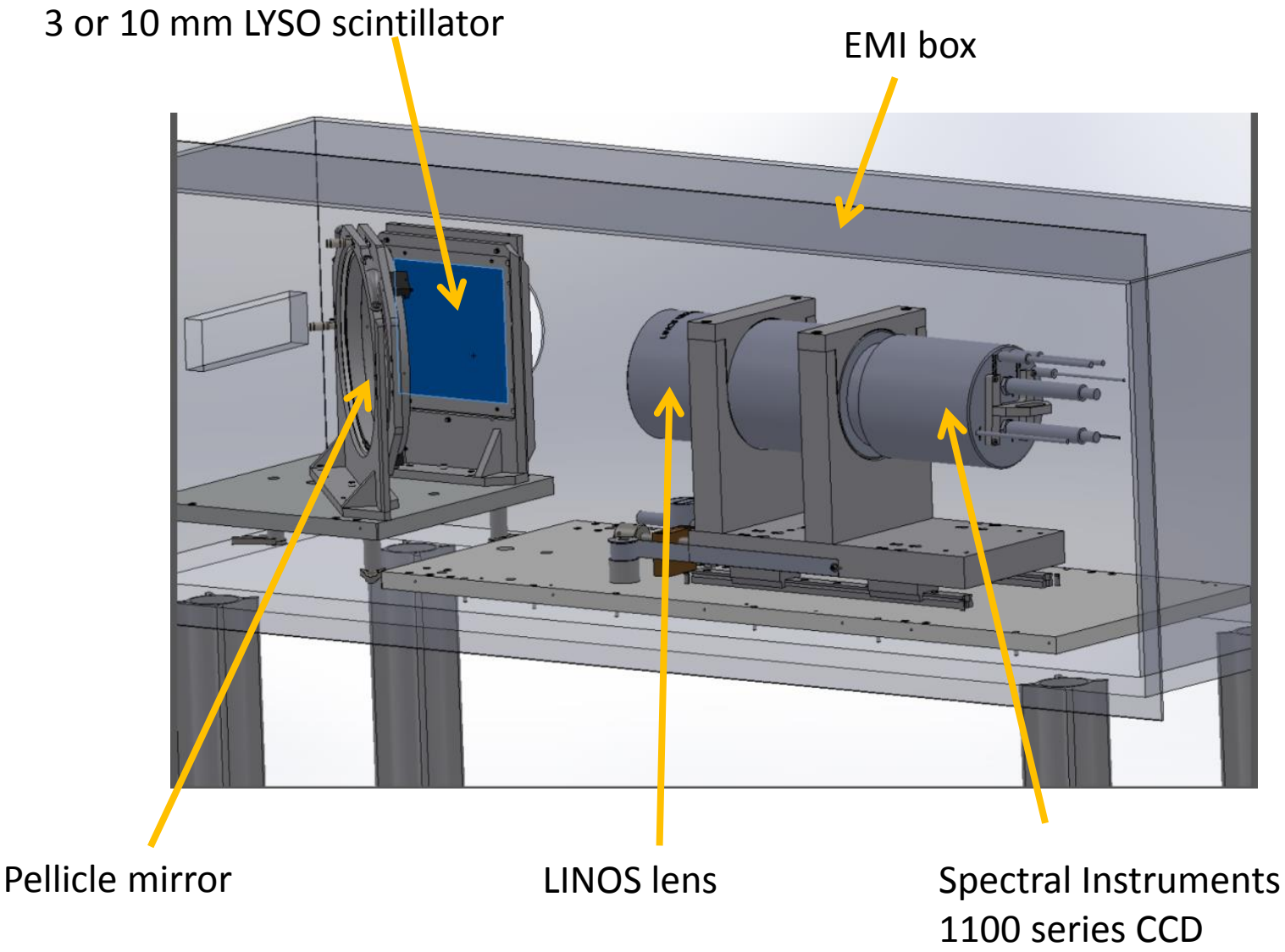
Disadvantages:

- Inefficient (low DQE)
- High fixed-pattern noise

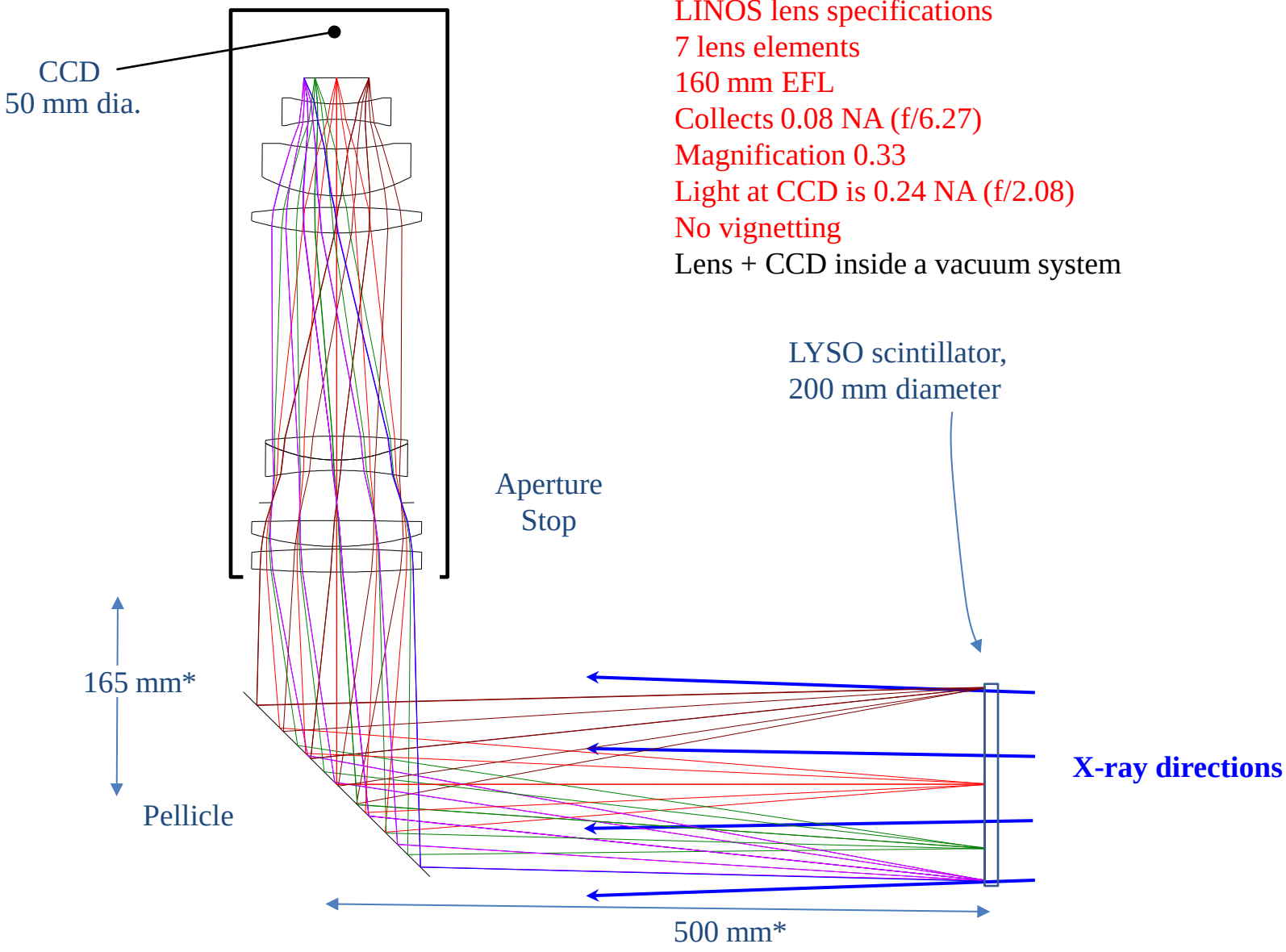
The image plate scanner may have significant fixed pattern noise.
Example here is FLA-7000 with Fuji MS plate



We have fielded a Gamma Camera which has a much better collection efficiency.

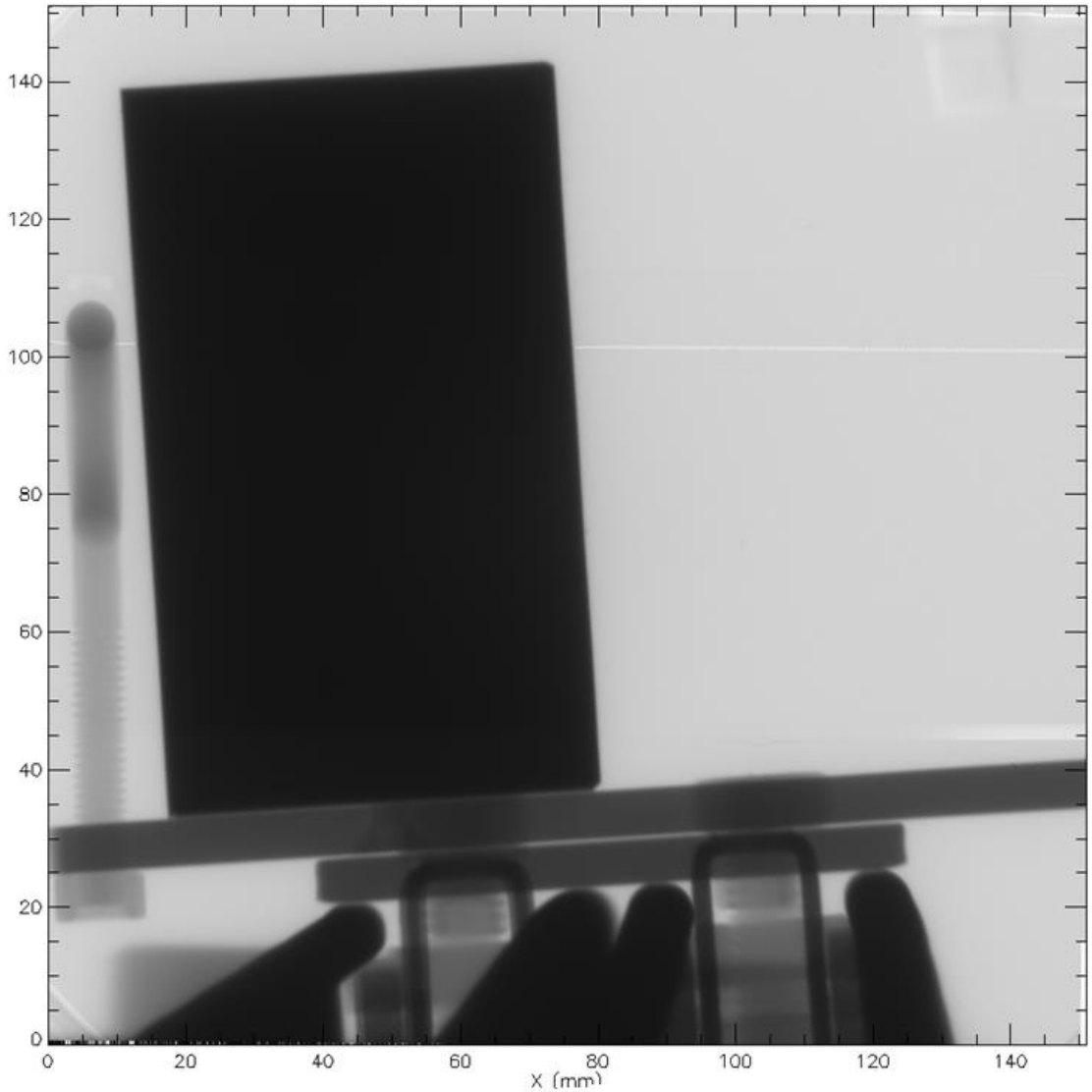


LINOS lens specifications
7 lens elements
160 mm EFL
Collects 0.08 NA (f/6.27)
Magnification 0.33
Light at CCD is 0.24 NA (f/2.08)
No vignetting
Lens + CCD inside a vacuum system



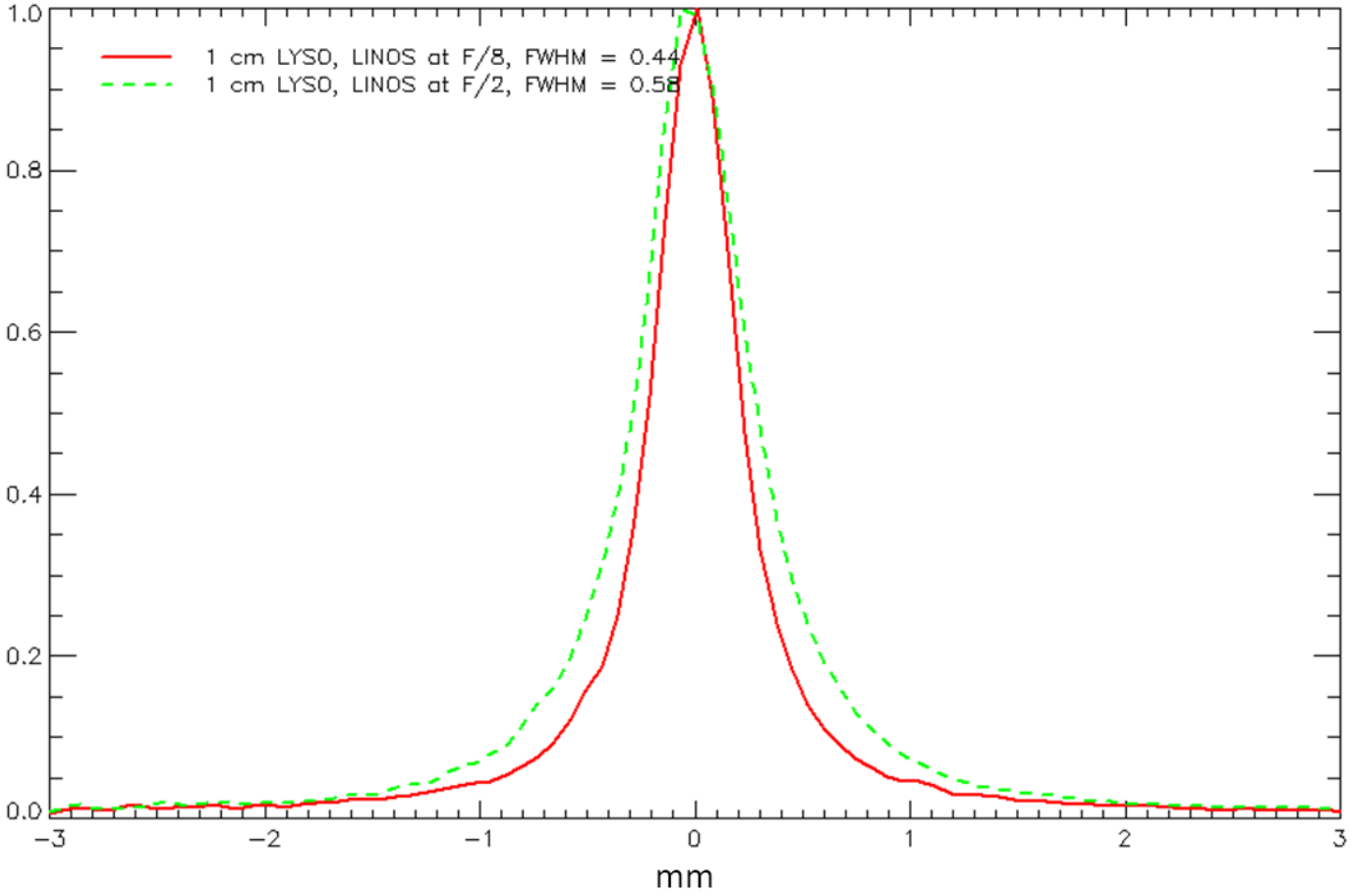
* These distances are from a similar system using the same lens (see *SPIE 2013 8844-11*). Actual distances of the RITS camera are different (e.g. lens to pellicle) though the total focus distance is the same.

Thick Tungsten "Rolled Edge" at near contact with scintillator to measure detector blur functions.

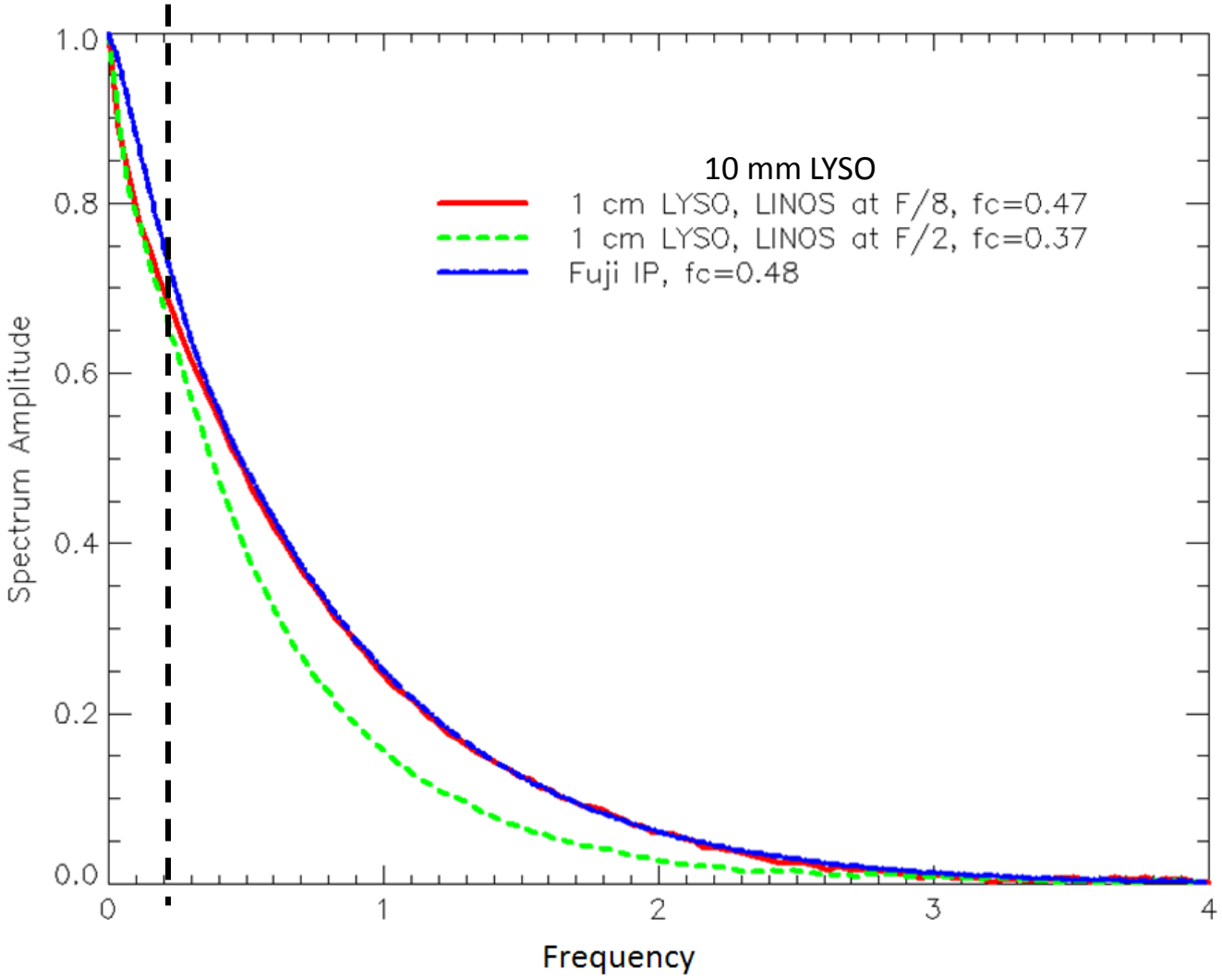


Line spread functions at different lens F-numbers show effects of optical blur presumably due to depth-of-field effects.

10 mm LYSO

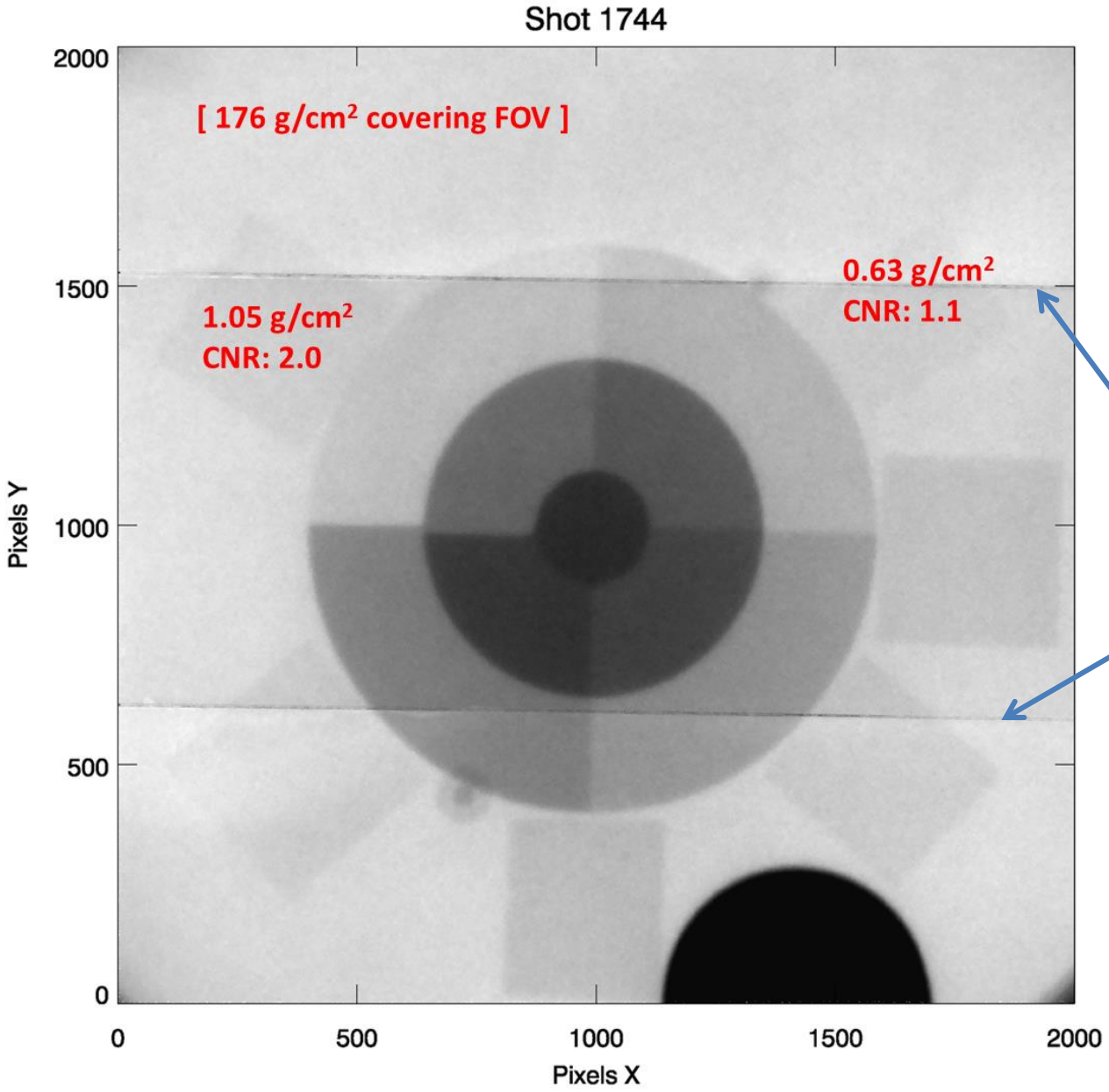


MTF: different frequency components suggest various sources of blur.



Low-frequency “tile glow” affect the scintillator similarly regardless of F-number. High frequency is affected more by optical blur which changes with F-number.

Demonstration of Areal Density Resolution using a step wedge.



Contrast to Noise Ratio:

$$CNR = \frac{|I_s - I_b|}{\sqrt{\sigma_s^2 + \sigma_b^2}} > 1$$

Scintillator tile boundaries

References

[1] Kahn, K. D. et al. “Overview of magnetically pinched-diode investigations on RITS-6.” IEEE Trans. Plasma Sci., vol. 38, no. 10, pp. 2652-2662, Oct. 2010. Davis, A. R., Bush, C., Harvey, J. C. and Foley, M. F., "Fresnel lenses in rear projection displays," SID Int. Symp. Digest Tech. Papers 32(1), 934-937 (2001).

[2] Johnson, D. L., et al., "Status of the 10 MV 120 kA RITS-6 inductive voltage adder.” Proc. 15th IEEE Int. Pulsed Power Conf., Monterrey, CA, 2005, pp. 314-317.

[3] Rowlands, J. A., “The physics of computed radiography,” Phys. Med. Biol. 47 (2002) R123–R166.

[4] Meadowcroft, A. L., Bentley, C. D., and Stott, E. N., “Evaluation of the sensitivity and fading characteristics of an image plate system for x-ray diagnostics,” Rev. Sci. Instr. 79, 113102, 2008.