DOE/NV/25946--1443

Radiography and Image Processing

Stephen E. Mitchell, Principal Scientist

National Security Technologies, LLC

mitchese@nv.doe.gov

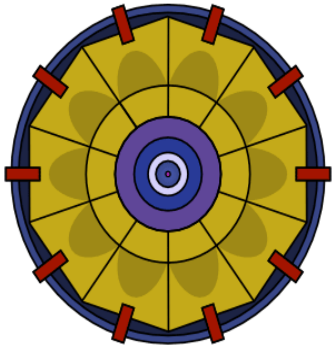
702-295-3065

This work was done by National Security Technologies, LLC, under Contract No. DE-AC52-06NA25946 with the U.S. Department of Energy and supported by the Site-Directed Research and Development Program.

Outline

- Introduction
  - ✓ What? Why? Etc.
- Pulsed Power
- Diode Physics
- Radiography ABC's
- Challenges

Introduction

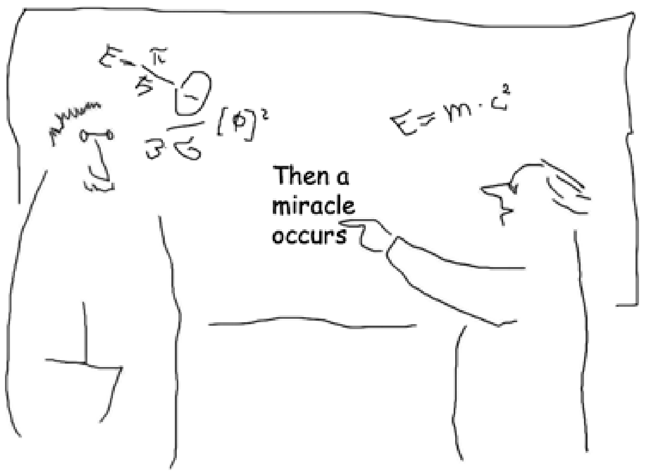


➢Subcritical Experiment (SCE) program initiated after 1992 moratorium on underground nuclear testing in support of stockpile stewardship

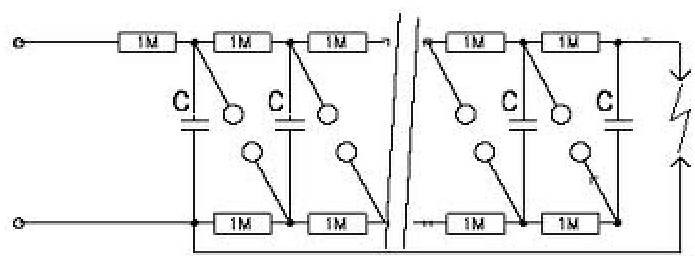
➢High energy radiography was developed over the years to complement existing surface diagnostics (i.e. Photon Doppler Velocimetry [PDV], velocity interferometer system for any reflector [VISAR])

➢Material science: Provides spatial view, internal density measurement

Pulsed Power

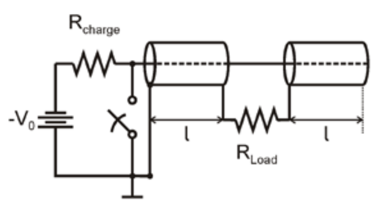


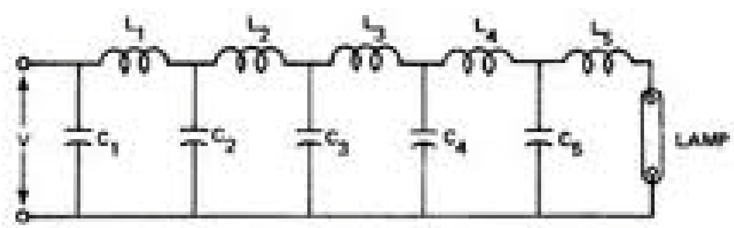
"I think you should be more explicit here in step two."



Marx

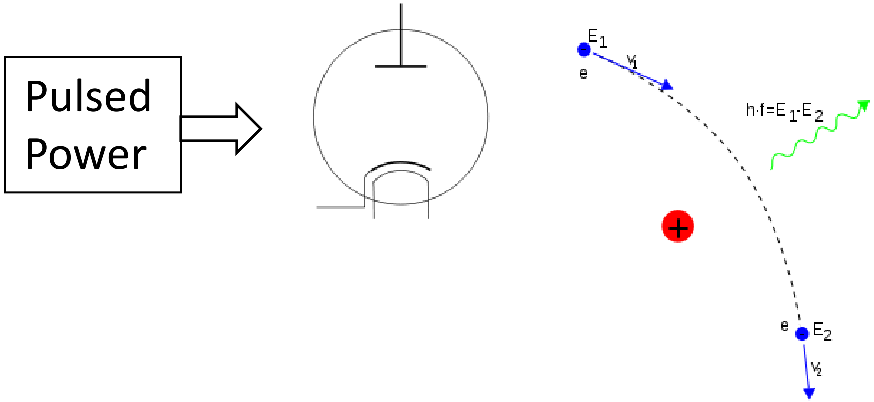
Blumlein

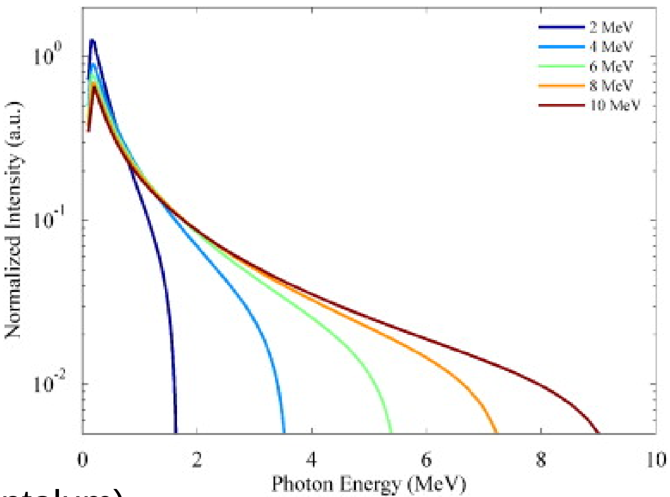




PFL

Diode Physics





•Hi-Z, TTB, electron ⇒photon converter (e.g. Tungsten or Tantalum)
•Bremsstrahlung photon flux, Φ(E), goes as ≈ (7.5E-4)•(Z)•($KE_{electron}$) in a TTB target

- Diode current may be space charge limited (SCL) in hi impedance configuration

$$I_{SCL} \propto \left(\frac{L_{eff}}{r_a f(\ln\left(\frac{r_c}{r_a}\right))} \right) V^{3/2}$$

- Diode current may be magnetically limited (ML) in lo impedance configuration

$$I_{ML} \propto \frac{\left(\gamma^2 - 1\right)^{1/2}}{\ln\left(\frac{r_c}{r_a}\right)}$$

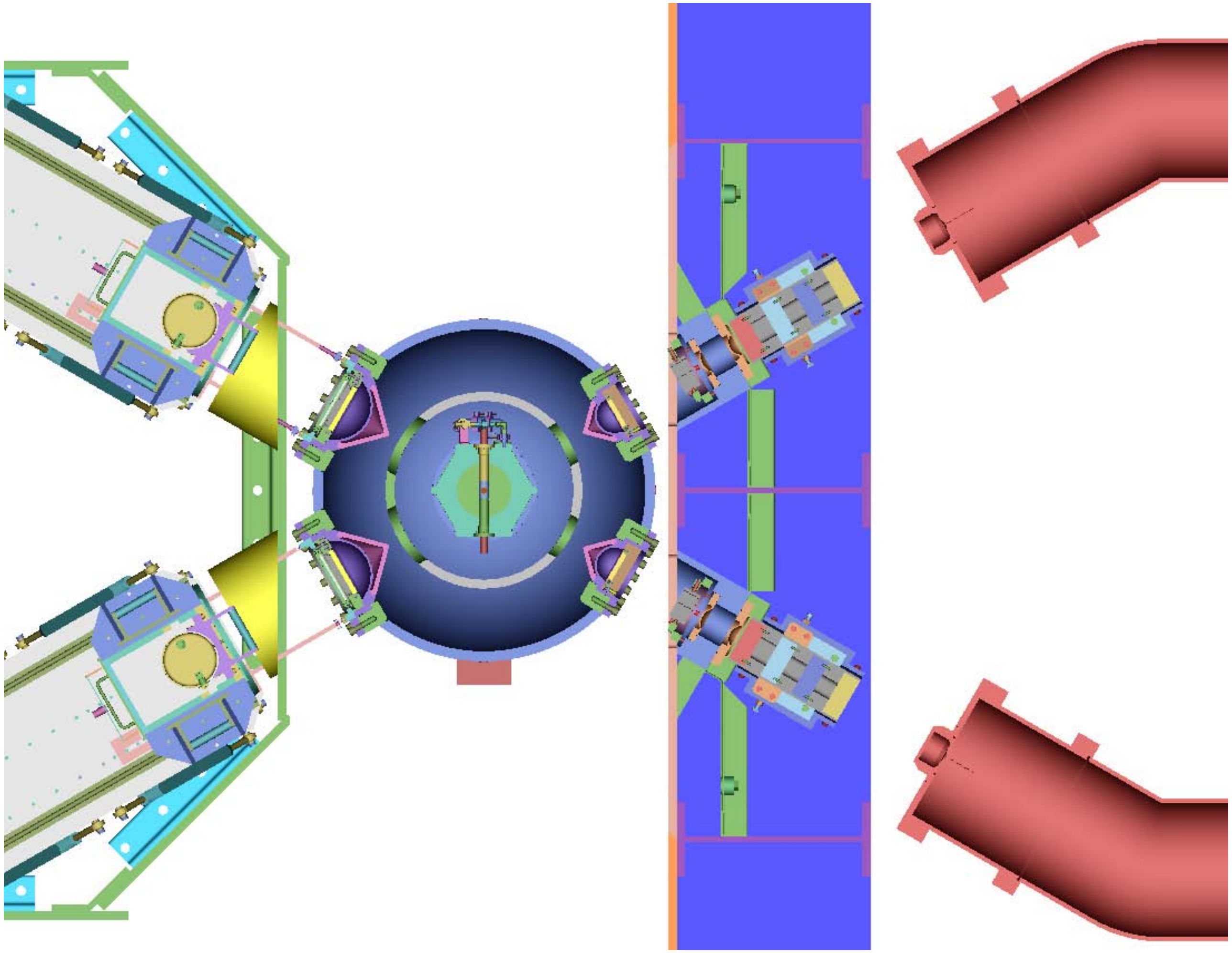
where

$$\gamma = \frac{qV}{mc^2} + 1$$

- G. Cooperstein, et. al., "Theoretical Modeling and Experimental Characterization of a Rod-Pinch Diode", Physics of Plasma, Vol 8, Num 10, 10/2001

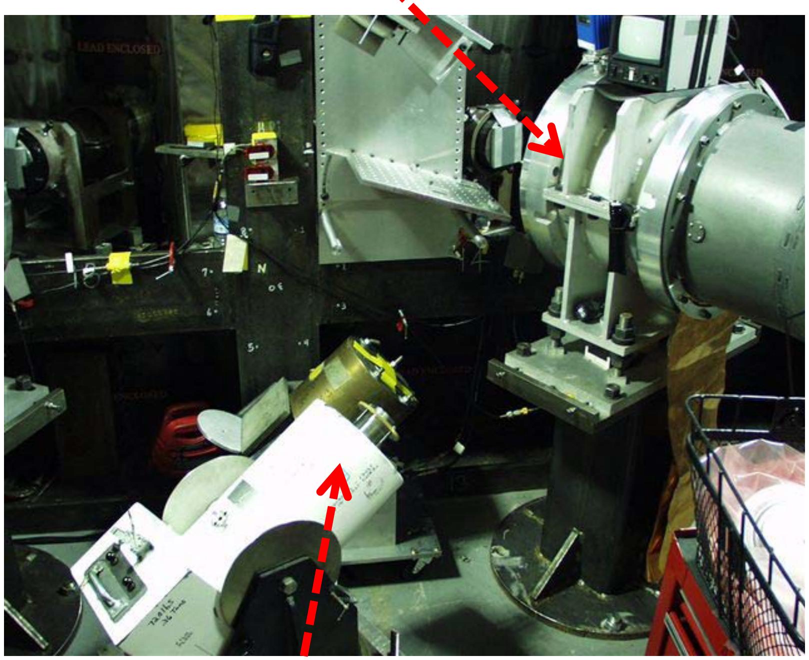
Example Radiographic Setup

Dual Radiographic Configuration Produces Two Time-Separated Radiographs of Equivalent Views - Example



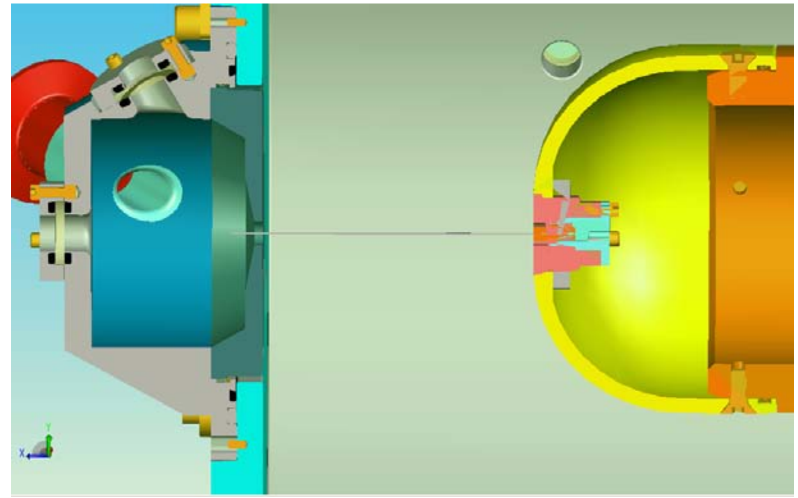
Diagnostics on Radiographic System

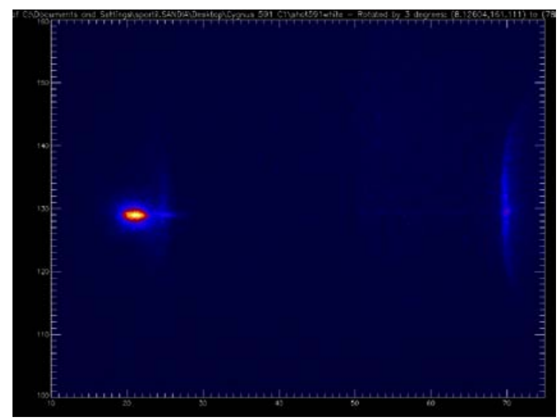
Diode Assy.



Pinhole cameras

Diode Assy. Cutaway cartoon

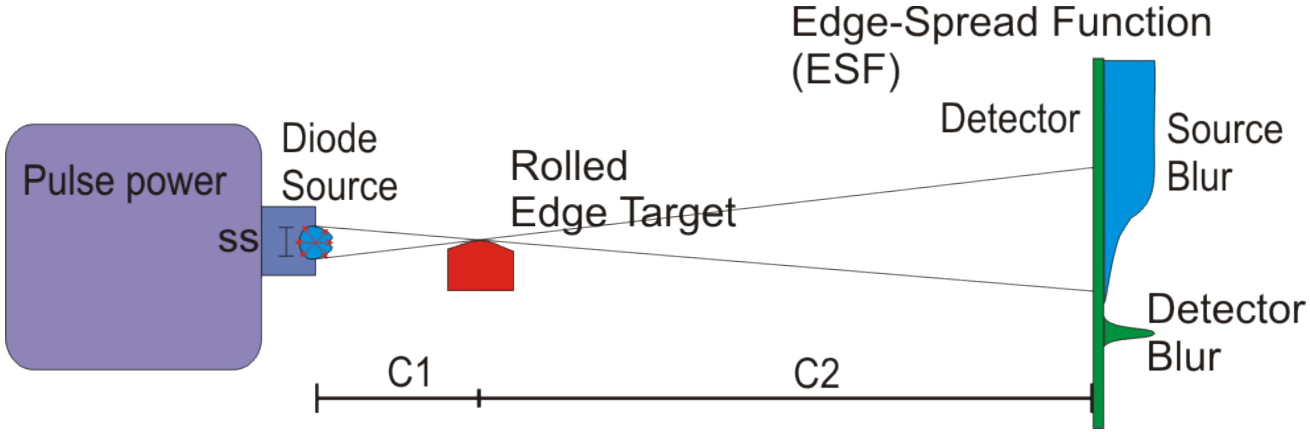




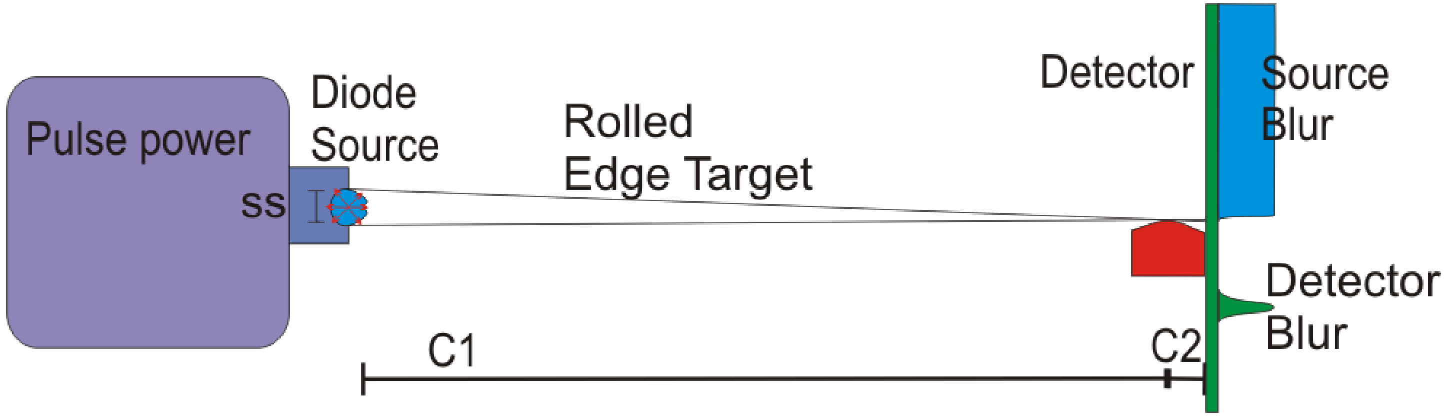
Pinhole camera radiograph

Radiography ABC's

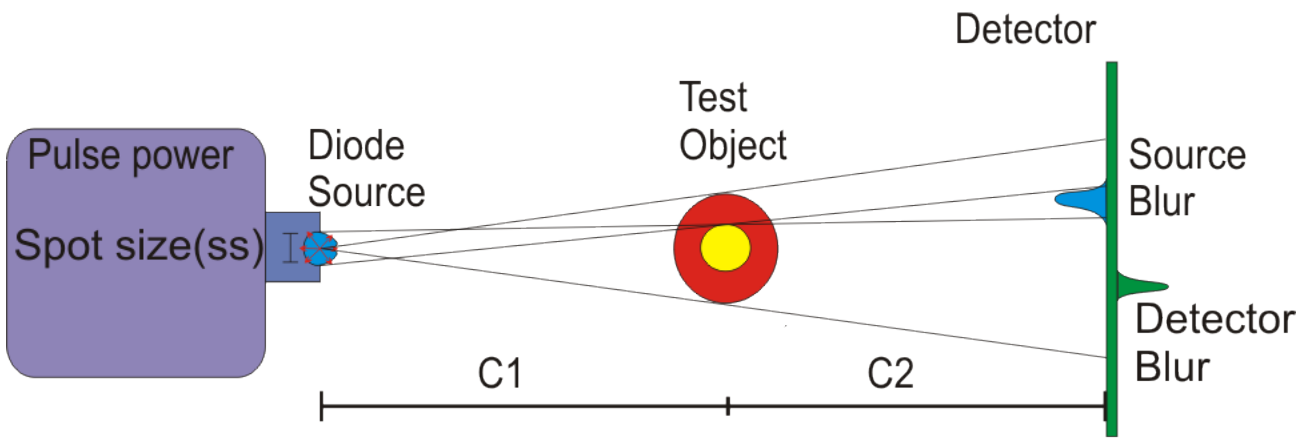
Test setup for spot-size measurement



Test setup for detector blur measurement



Radiography ABC's (Cont.)



$$\text{Radiographic Magnification} = \frac{C1 + C2}{C1}$$

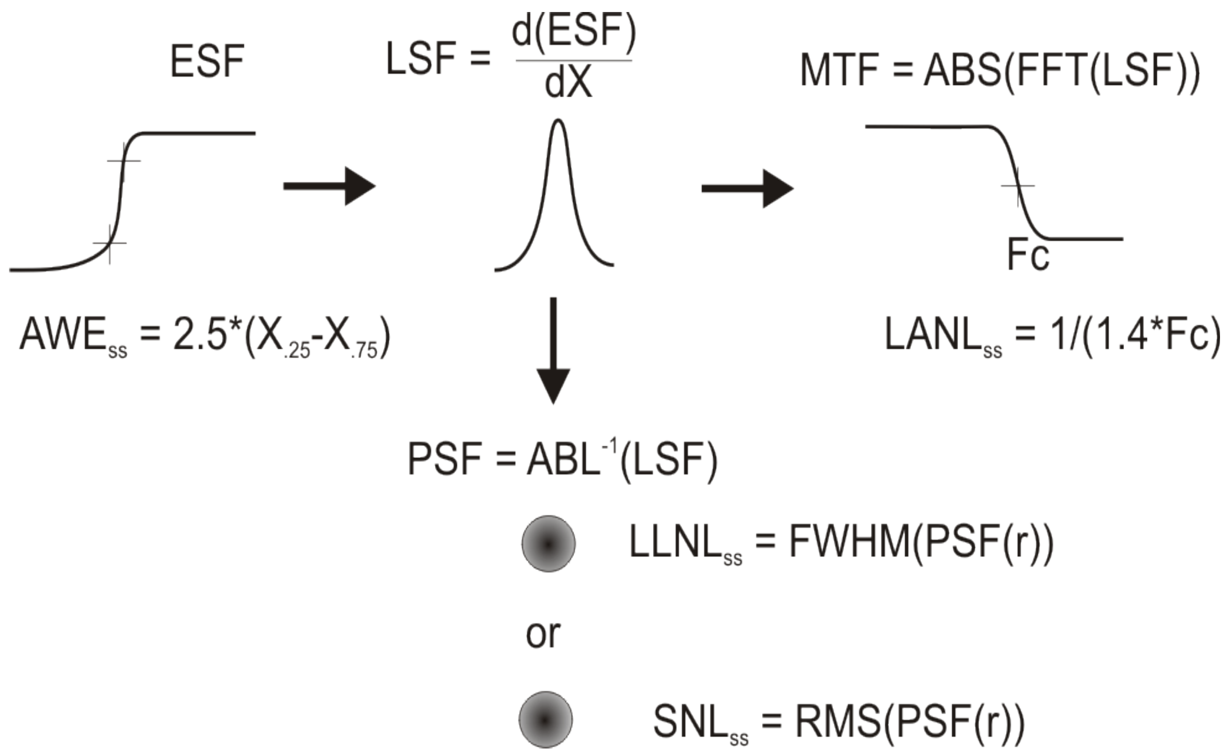
$$\text{Source Magnification} = \frac{C2}{C1}$$

System Resolution =

Radiographic Magnification

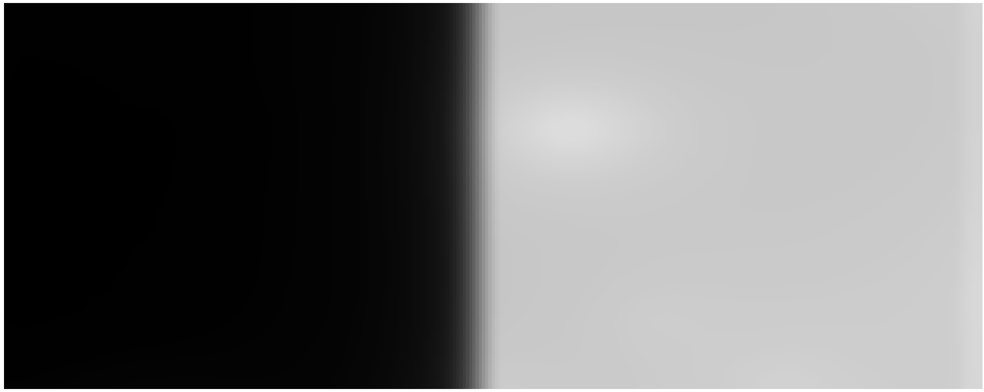
Radiography ABC's (Cont.)

Spot-Size (blur) Measurement Algorithms and Metrics



De-Blurring (De-convolution)

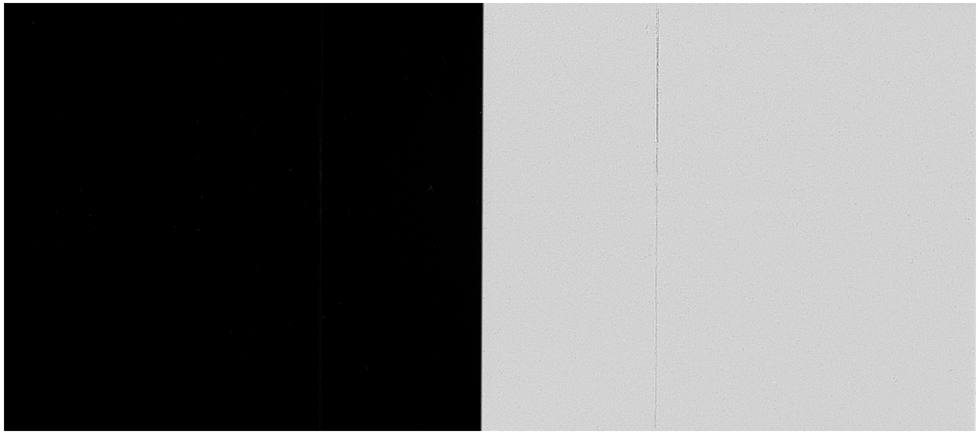
Observed "blurred" Image



Reverse

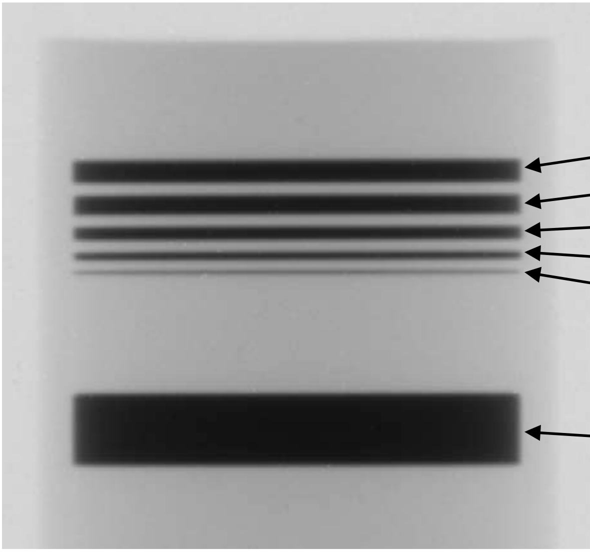
De-convolved with proper PSF…

Forward



De-blurred Image

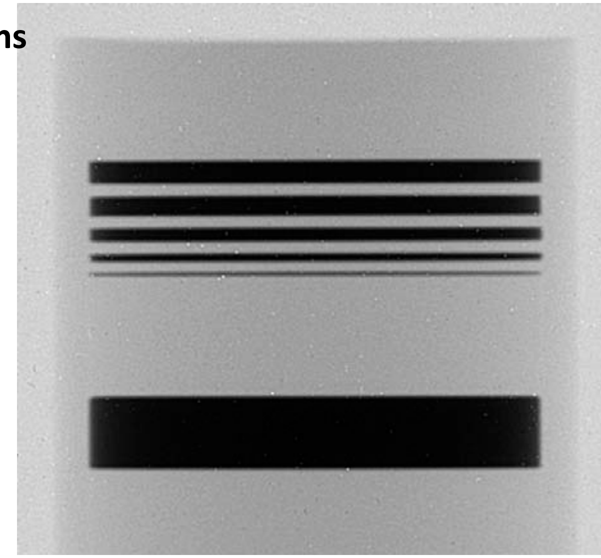
Raw and De-blurred Scatter Test Object

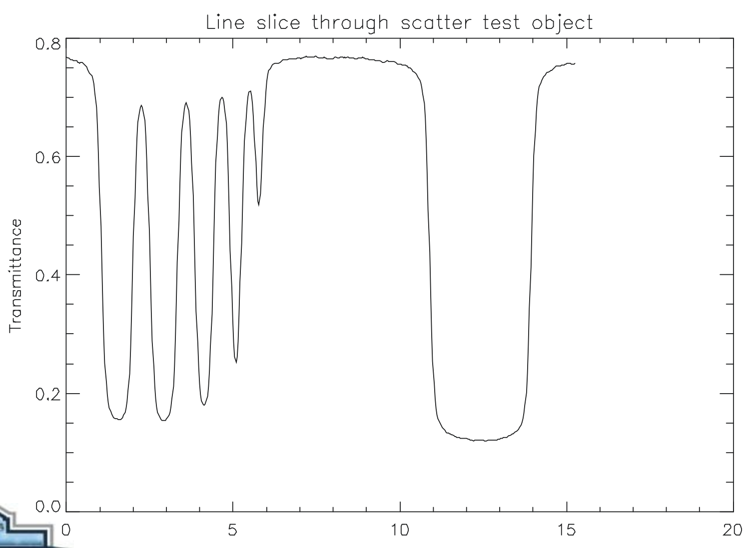


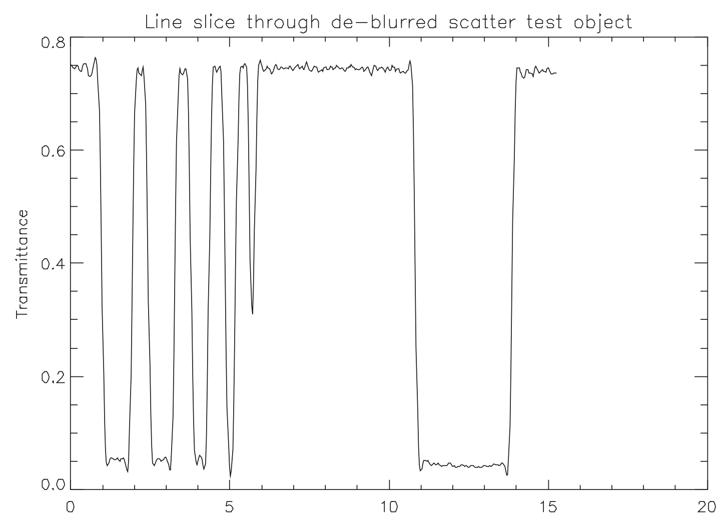
18 mm dia. Ta Shims
Thickness (mm)

0.89
0.71
0.51
0.30
0.10

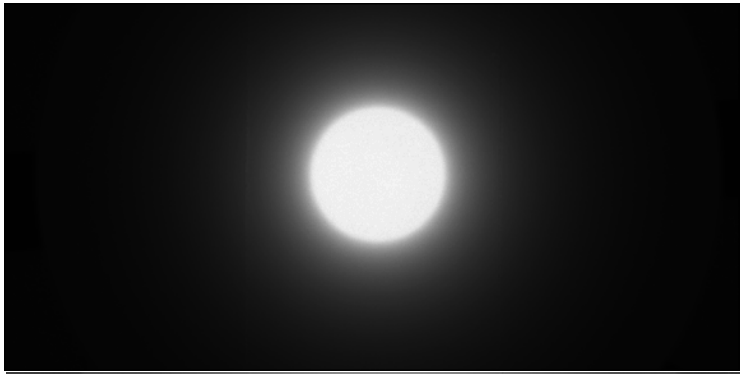
3.00





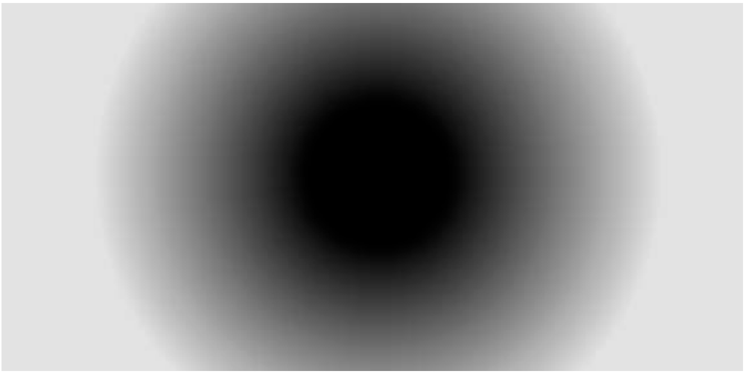


Transfer Response Relation to Areal Density



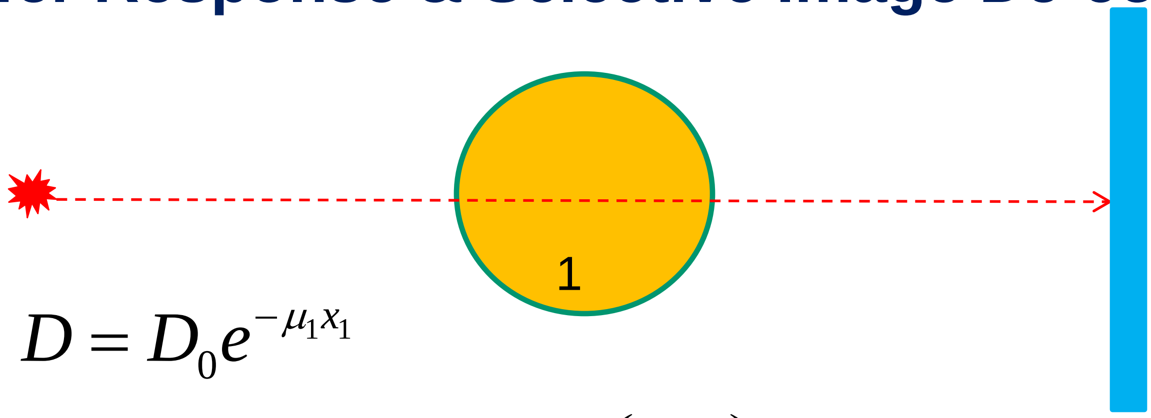
Radiograph of a graded collimator

Logarithmic ratio of Radiograph of a graded collimator to flat-field



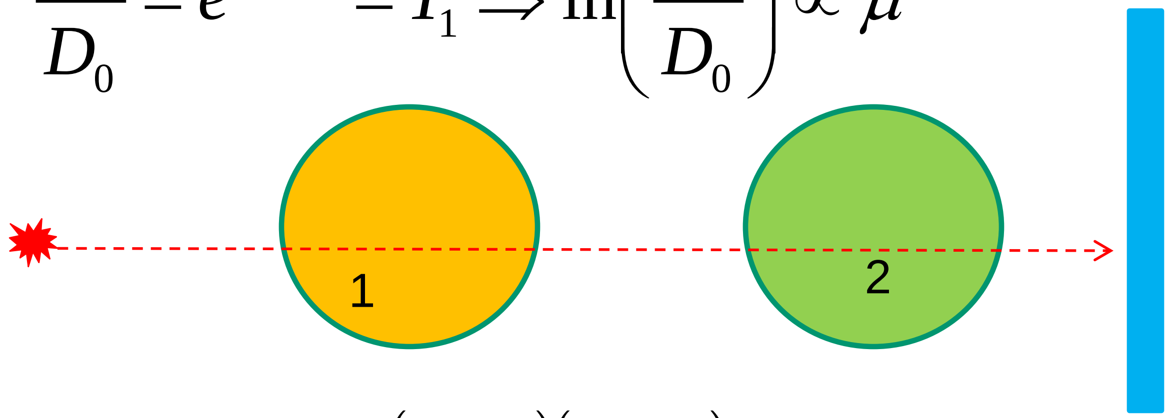
Scaled (calibrated) to yield 2-D areal density plot

Transfer Response & Selective Image De-coupling (Ideal)



$$D = D_0 e^{-\mu_1 x_1}$$

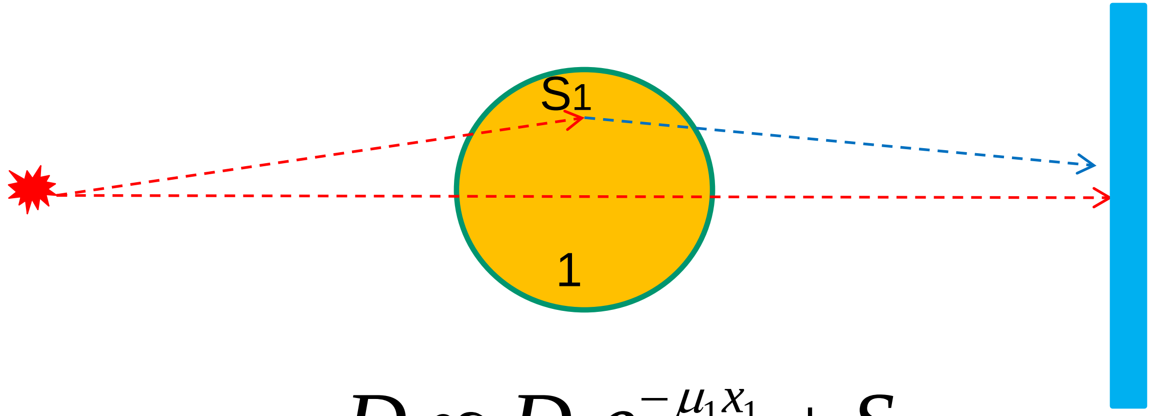
$$\frac{D}{D_0} = e^{-\mu_1 x_1} = T_1 \Rightarrow \ln\left(\frac{D}{D_0}\right) \propto \mu$$



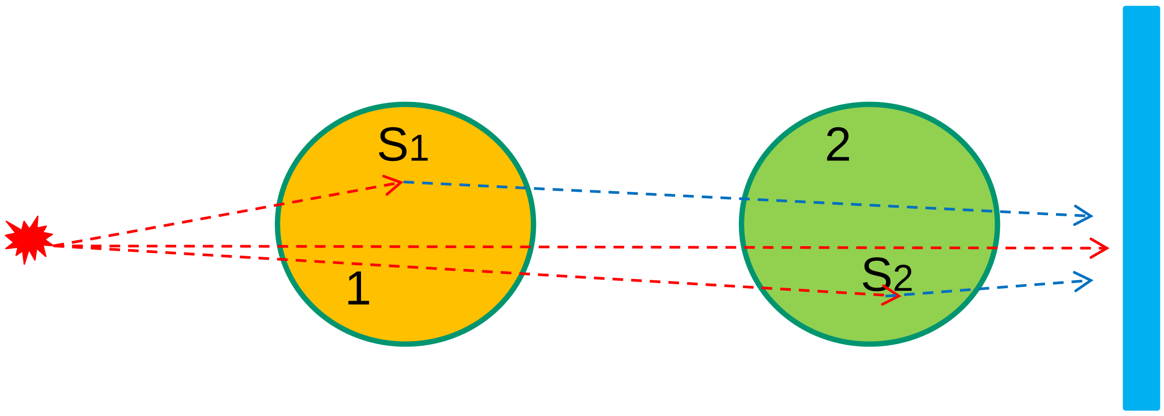
$$D = D_0 \left(e^{-\mu_1 x_1}\right)\left(e^{-\mu_2 x_2}\right)$$

$$\frac{D}{D_0} = \left(e^{-\mu_1 x_1}\right)\left(e^{-\mu_2 x_2}\right) = T_1 T_2 = \prod_n T_n$$

Scattered Field (real world)



$$D \propto D_0 e^{-\mu_1 x_1} + S_1$$



$$D \propto D_0 \left(e^{-\mu_1 x_1}\right)\left(e^{-\mu_2 x_2}\right) + S_2\left(e^{-\mu_1 x_1}\right) + S_1\left(e^{-\mu_2 x_2}\right)$$

Complications and challenges

- Bremsstrahlung source spectrum (non mono-energetic source spectrum)
- Scatter field contribution
- DOF issues; ill-defined light origin within scintillator, “fast” low F-number imaging system, light collection efficiency
- Non-symmetric objects – beyond Abel transforms toward Radon transforms with >2 line of sight views
- Normalization – flat field and dark field normalization, shot-shot variations