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Effect of geometrical misalignment on the MTF measurement

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Background

- The modulation transfer function (MTF) has been widely used to characterize the spatial resolution of x-ray imaging systems. The MTF can be obtained from the Fourier transform of line-spread function (LSF) of the x-ray imaging system with a slit-camera
- Geometrical misalignment of the slit camera with respect to the beam geometry can distort the measured LSF and the resulting MTF
- This error can occur vulnerably in the magnification imaging

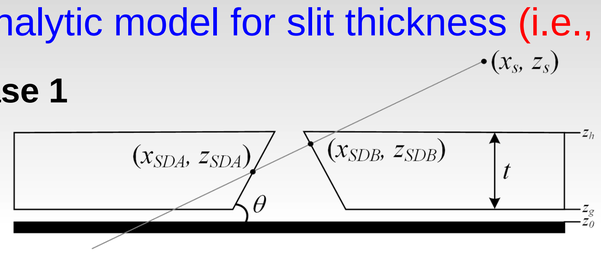
Research Objective

- We investigate experimentally the effects of geometrical misalignments on the MTF
  - Tilt-angle
  - Magnification
  - Application

Materials and Methods

- Analytic model for slit thickness (i.e., l)

Case 1

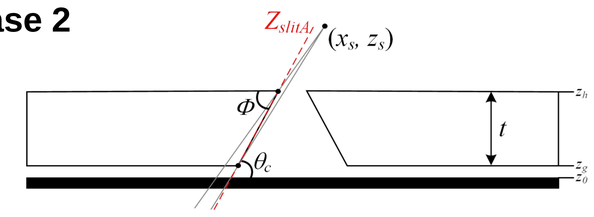


$$l_1 = \sqrt{\left(\left(\frac{(z_g - z_s)}{\tan\theta} + x_s - x_{SDA}\right)^2 + (z_{SDA} - z_g)^2\right)}$$

$$l = l_1 + l_2$$

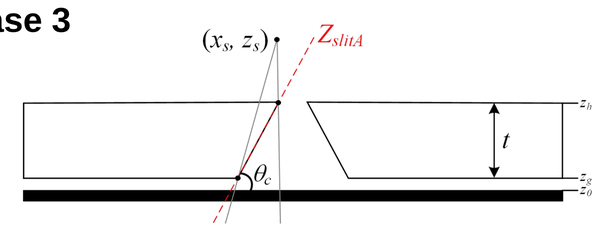
$$l_2 = \sqrt{\left(\left(\frac{(z_h - z_s)}{\tan\theta} + x_s - x_{SDB}\right)^2 + (z_{SDB} - z_s)^2\right)}$$

Case 2



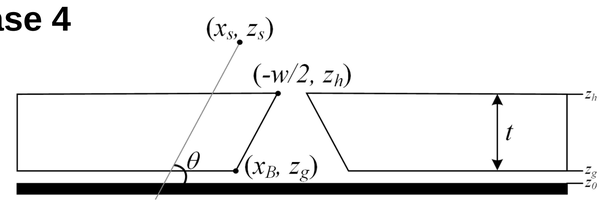
$$l = \sqrt{\left(\left(\frac{(z_g - z_s)}{\tan\theta} + x_s - x_{SDA}\right)^2 + (z_{SDA} - z_g)^2\right)}$$

Case 3



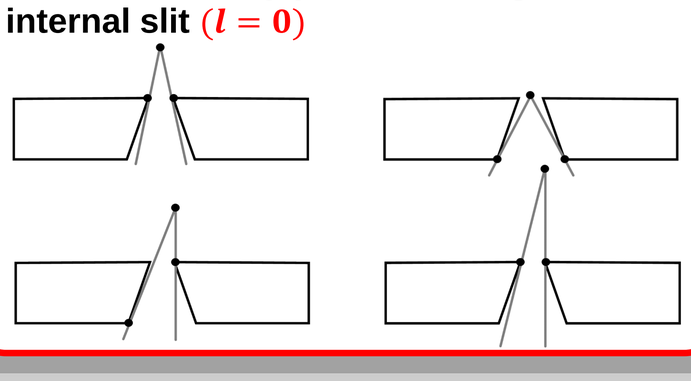
$$l = \sqrt{\left(\left(\frac{(z_h - z_s)}{\tan\theta} + x_s - x_{SDA}\right)^2 + (z_{SDA} + z_s)^2\right)}$$

Case 4

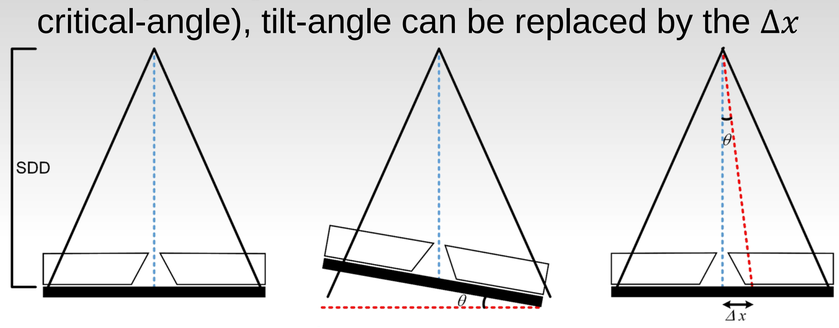


$$l = t \times \sqrt{\left(\left(\frac{1}{\tan\theta}\right)^2 + 1\right)}$$

Case of the x-ray passes through the internal slit ($l = 0$)

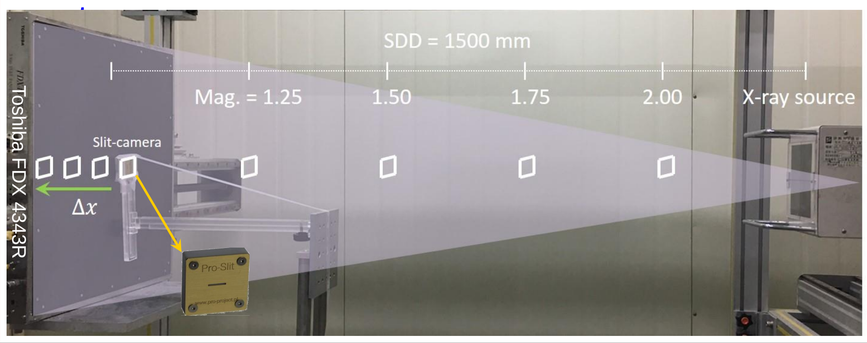


- Tilt-angle measurement (Δx)
  - When jaw-angle and tilt-angle are the same (i.e. critical-angle), tilt-angle can be replaced by the Δx



$$\tan\theta = \frac{\Delta x}{\mathrm{SDD}} \rightarrow \Delta x = \tan\theta \times \mathrm{SDD}$$

- Experimental setup

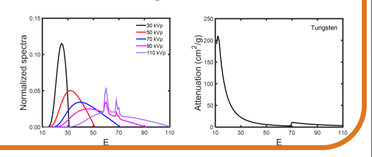


- Measurements and analysis
  - MTF
    - The MTF could be calculated by fast Fourier transforming the LSF obtained from the slit image

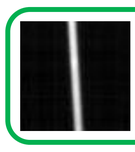
$$\mathrm{MTF}(u) = \mathrm{FT}\{\mathrm{LSF}(x)\}$$

Model

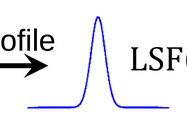
$$\mathrm{LSF}(x;\mathrm{E}) = \frac{\int S(\mathrm{E}) e^{-u(\mathrm{E})l} d\mathrm{E}}{\int S(\mathrm{E}) d\mathrm{E}}$$



Experimental

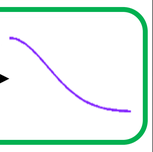


Profile



$$\mathrm{LSF}(x) = \frac{\mathrm{LSF}(x)}{\int \mathrm{LSF}(x) dx}$$

FFT



- Effective MTF

$f' = mf$
(where, m is magnification)

- Misalignment

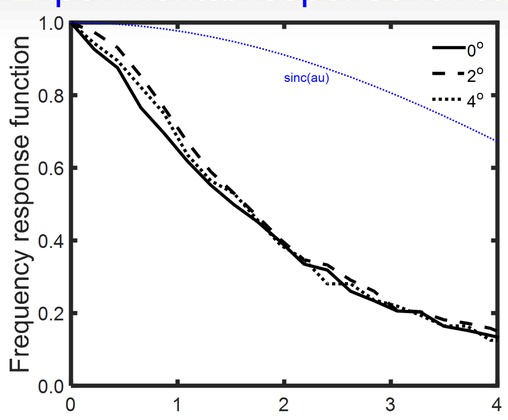
$$Misalignment = \frac{\mathrm{MTF}_{\theta^\circ}(u)}{\mathrm{MTF}_{0^\circ}(u)}$$

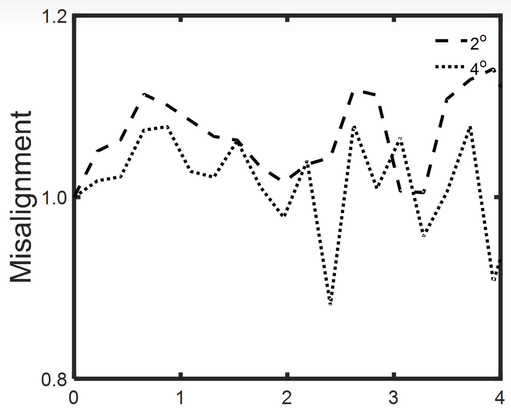
- Effective aperture

$$A_{eff}\ (mm) = \left[2\pi \int_0^\infty \mathrm{MTF}^2(u) u du\right]^{-1/2}$$

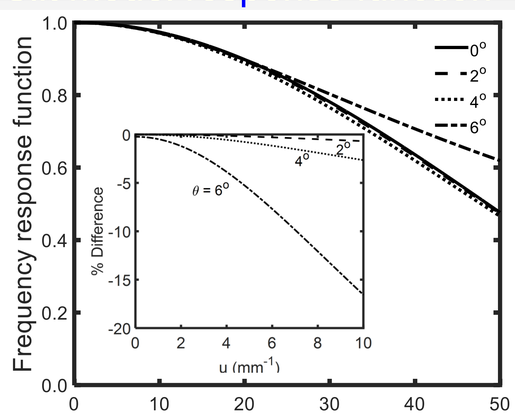
Results

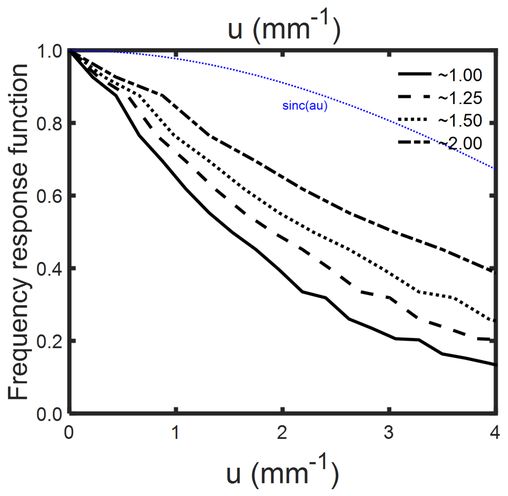
- Experimental response function

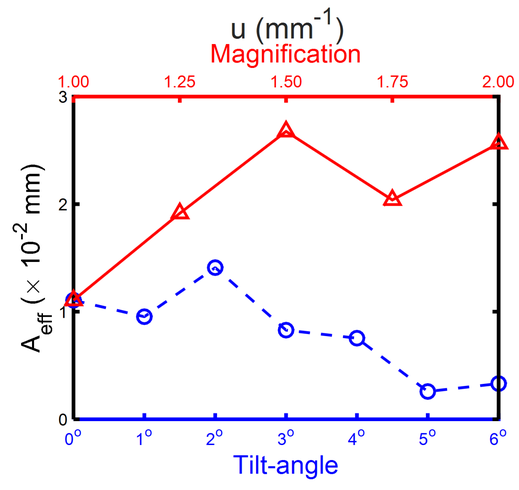


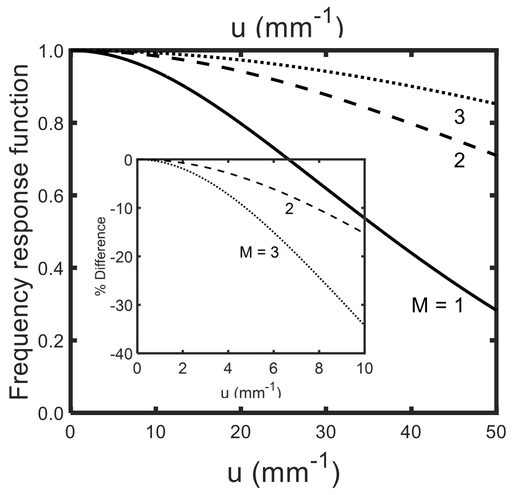


- Slit model response function









- The frequency response function is similar for the tilt-angle from 0º to 4º, but that is distorted at specific angle because the x-ray source and center of the slit have misalignment
- The spatial frequency $(f' = mf)$ is scaled by magnification. The frequency response function increases according to the magnification

Discussion & Conclusion

- The developed analytic slit-camera MTF model explains well the experimental MTF characteristic for geometrical misalignment (i.e. magnification, tilt-angle)
- The MTF for tilt-angle shows a similar tendency until critical angle $(\theta, \phi = 4°)$, but no experimental result was obtained for tilt-angle more than 5°
- Increasing of tilt-angle is followed by a misalignment and the resolution (A_{eff}) characteristic between tilt-angle and magnification in experimental results shows an opposite tendency

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