Development of X-ray phase imaging method using a compact high-brightness X-ray generator

Sub-theme: Evaluation of the Gratings using Monochromatic X-rays

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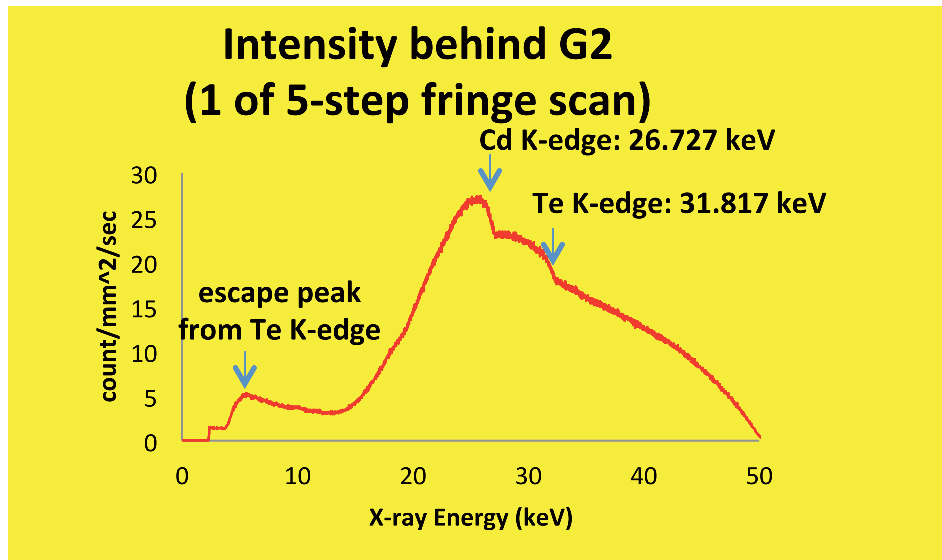
Purpose and Motivation of this work

Using polychromatic X-rays, the obtained optimum X-ray energy of the XTLI (in which there is maximum Moiré fringe visibility) was 25 keV. The Moiré fringe visibility was calculated via 5-step fringe scanning, in which the X-ray intensity behind G2 was measured using an energy-resolving detector with a CdTe diode (AMPTEK).

Unfortunately, Cd and Te have K-line absorption edges at 26.727 keV and 31.817 keV, respectively which are manifested in the measurement as shown in Figure 1. The “missing counts” are found as escape peaks at lower energies. By curve fitting and extrapolations (using AMPTEK guide) the correct intensity curve could be retrieved.

However, the curve fitting and extrapolation procedure can result to errors which affect the calculation of the moiré fringe visibility and the determination of the optimum X-ray energy for the grating interferometer.

Hence, we use monochromatic X-rays to validate the results obtained with polychromatic X-rays in the laboratory in which the optimum X-ray energy of the grating interferometer was 25 keV.

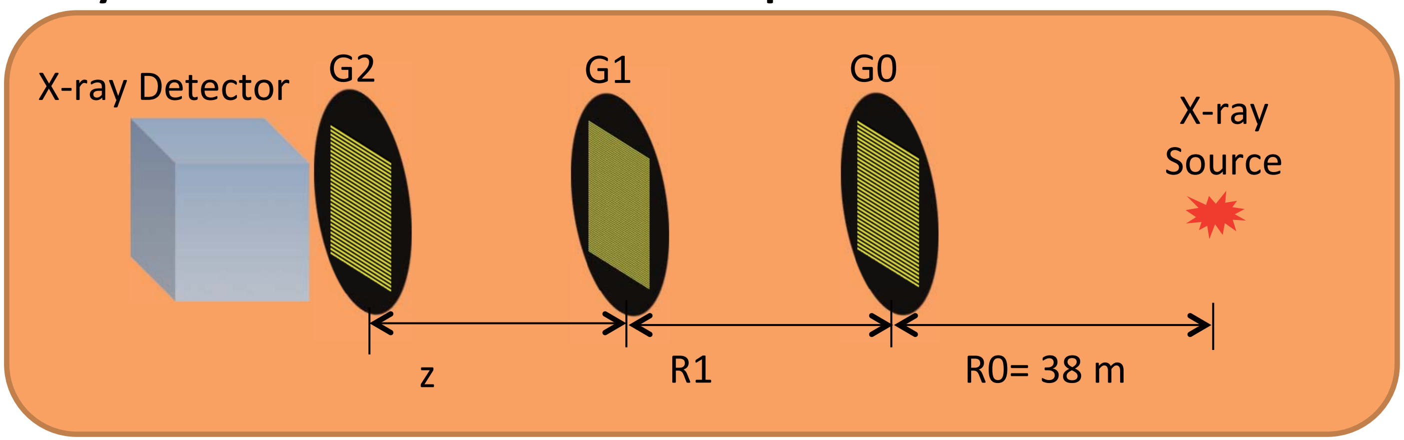


*escape peak from Cd K-edge occur at lower energy.

Experiment Parameters

X-ray Source	Photon Factory 2.5 GeV Storage Ring, 450 mA Ring Current Vertical Wiggler at Beam Line 14-C Si (220) Double Crystal Monochromator Energy tunability: 8 – 80 keV Beam size: 6 mm (horizontal) x 20 mm (vertical)
X-ray Detector	Area Detector: 40 µm GOS scintillator connected to CCD Camera via fiber coupling (Spectral Instruments)

X-ray Talbot-Lau Interferometer Set-up



Moiré fringe visibility via fringe scanning: G2 was moved across one period d2 in steps of d2/5
Detector was located at the center of G2.

Experiment Methods

X-ray energy: 23, 24, 25, 26 and 30 keV.
G1-G2 distance, $z = \frac{p d_1^2}{\lambda} \frac{R_1}{R_1 - p d_1^2/\lambda}$ was changed by varying the fractional Talbot order p = 0.375, 0.4375, 0.5, 0.5625, 0.625, 0.75, 1.

The G0-G1 distance was adjusted in order to keep the condition for Talbot-Lau interferometer geometry: $R_1/R_2 = d_1/d_2$.

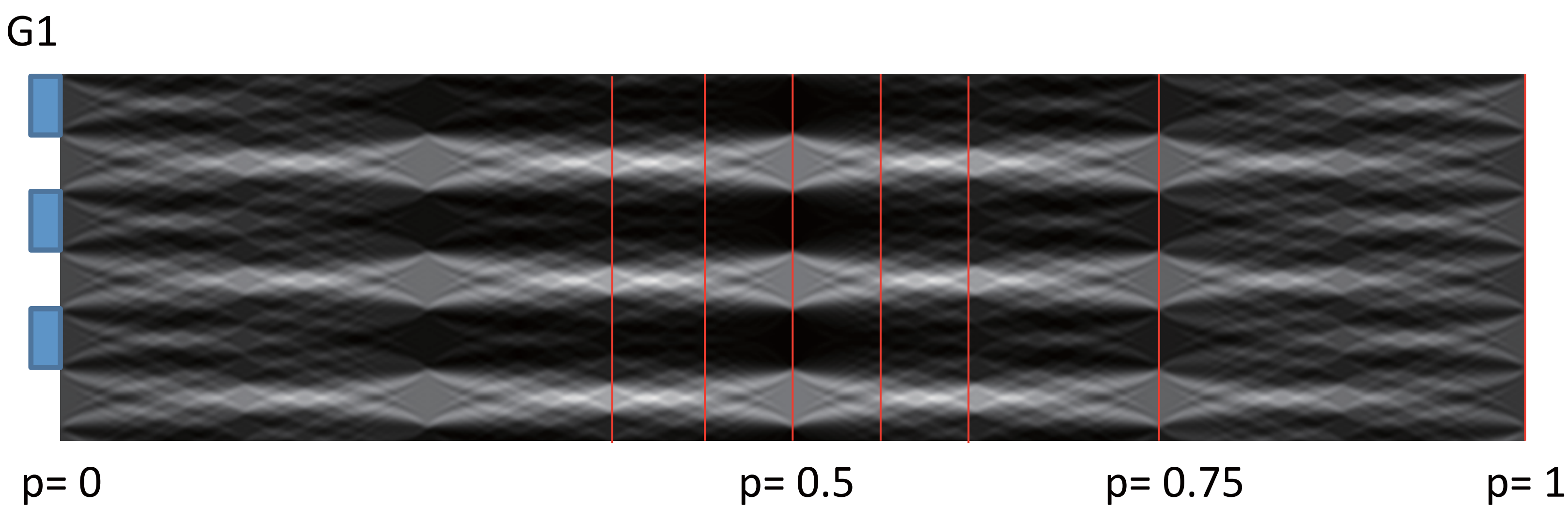
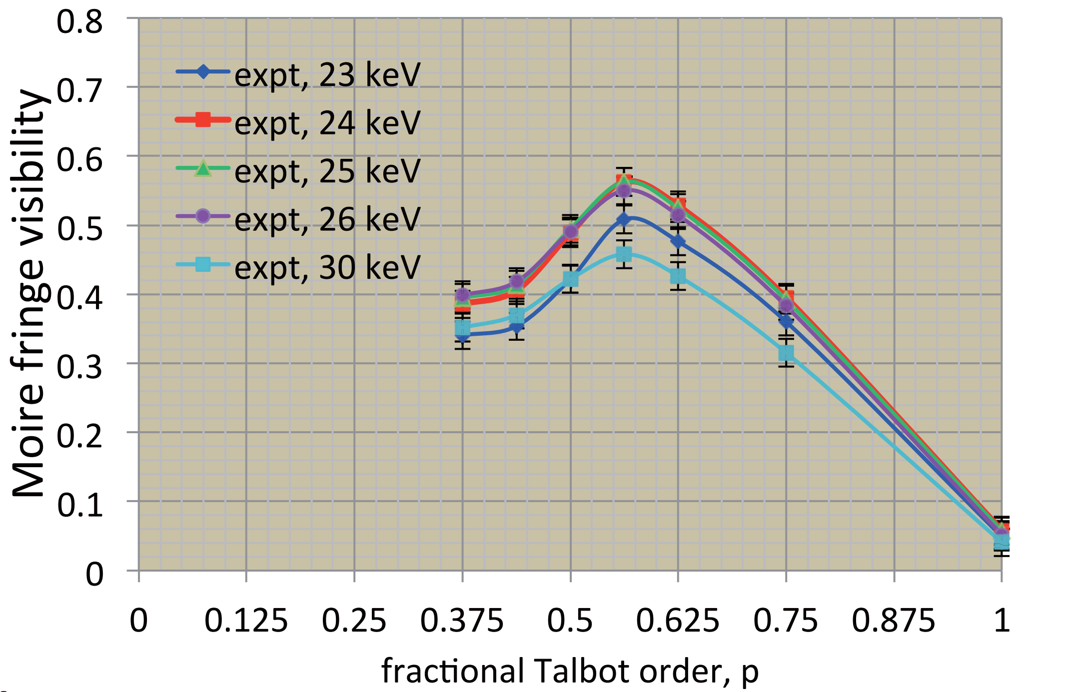


Illustration of Talbot carpet and location of various fractional Talbot orders.

Results and Discussion

1. The optimum fringe visibilities were obtained for 24, 25, 26 keV.

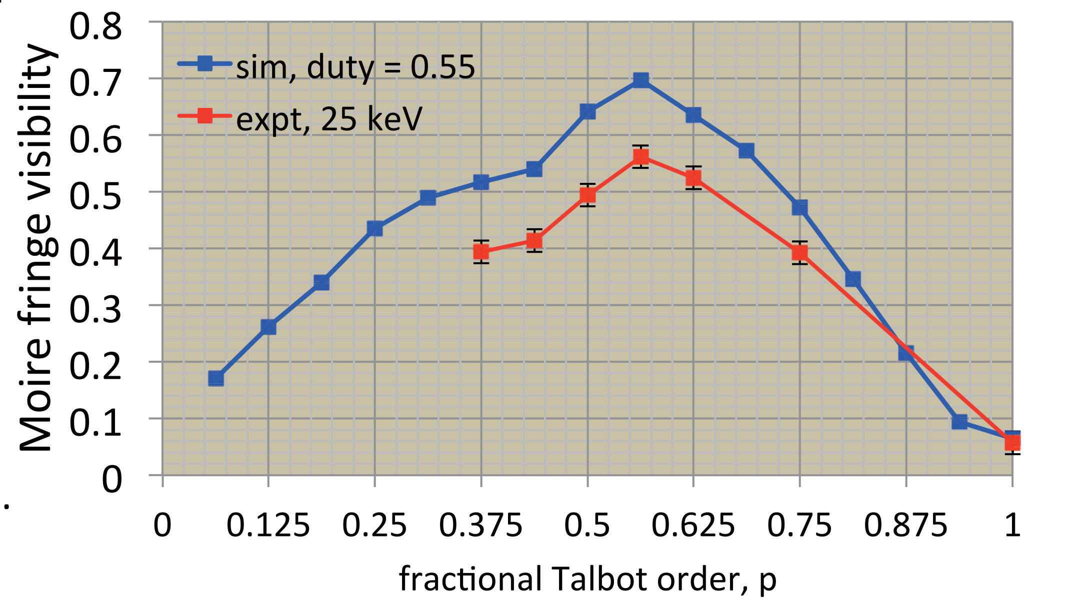
This validates the result obtained in the laboratory using polychromatic X-rays and CdTe detector.



2. The peak fringe visibility were obtained at p = 0.5625 (instead of p = 0.5).

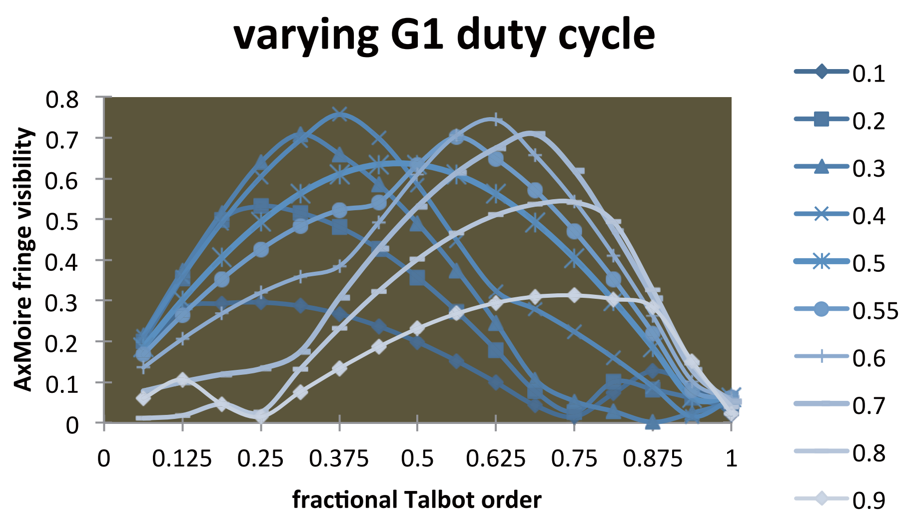
This is because the duty cycle of G1 (line width/period) = 0.56 ± 0.01 as measured by Microworks using SEM images and as confirmed by simulations (blue squares).

The simulations were performed for a Talbot interferometer hence the higher visibility values. The G2 duty cycle was 0.5.



Further Discussion

Moiré fringe visibility (25 kev) versus the fractional Talbot order for various G1 duty cycle



Note that a compact Talbot interferometer can be made by choosing a G1 duty cycle smaller than 0.5.

For example for duty cycle = 0.4, the optimum visibility is at p = 0.375, which means the interferometer can be compacted to ¾ the length when duty = 0.5 and p = 0.5. Simulation result also shows that the Moiré fringe visibility is 21% higher than when duty = 0.5 and p = 0.5.

Further simulations should be done to calculate the total Moiré fringe visibility when this configuration is used with polychromatic X-rays. Also, the effect of the G2 duty cycle should be investigated.

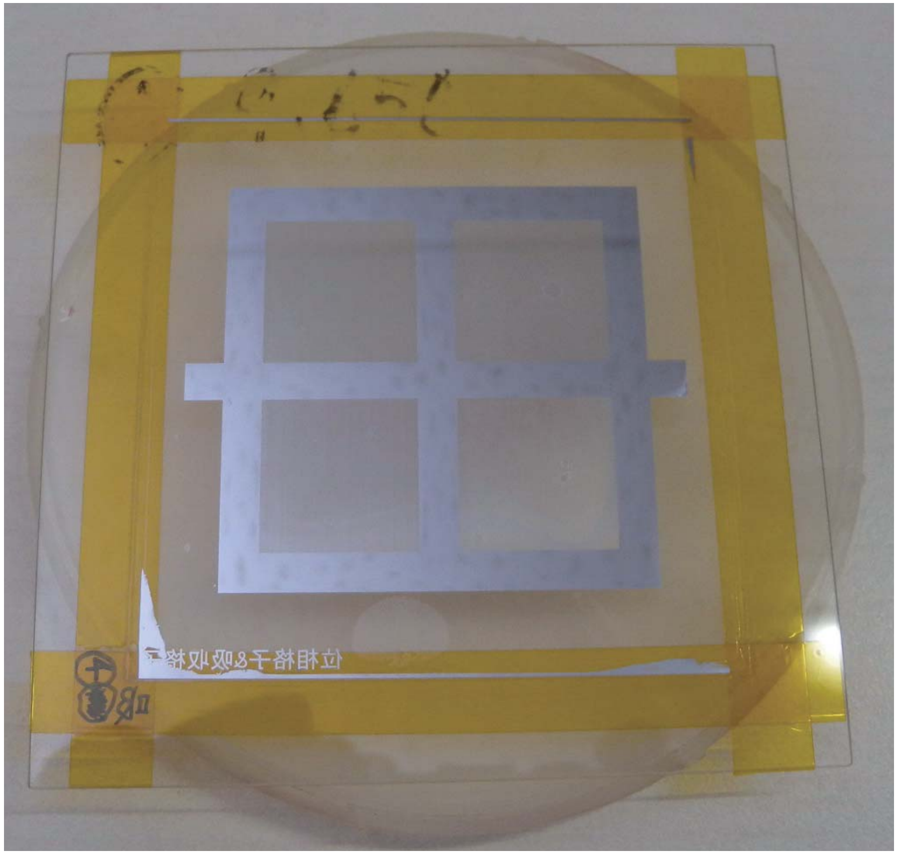
Conclusion

By using monochromatic X-rays, we were able to validate the results obtained in the laboratory that the optimum energy for the Talbot-Lau interferometer is 25 keV.

Also, the shape of the Moiré fringe visibility versus the fractional Talbot order confirmed that the duty cycle of the phase grating is about 0.55 as reported by Microworks.

Simulations show that a compact grating interferometer can be achieved by using a G1 duty cycle that is less than 0.5. Further simulations should be performed.

9keV用格子



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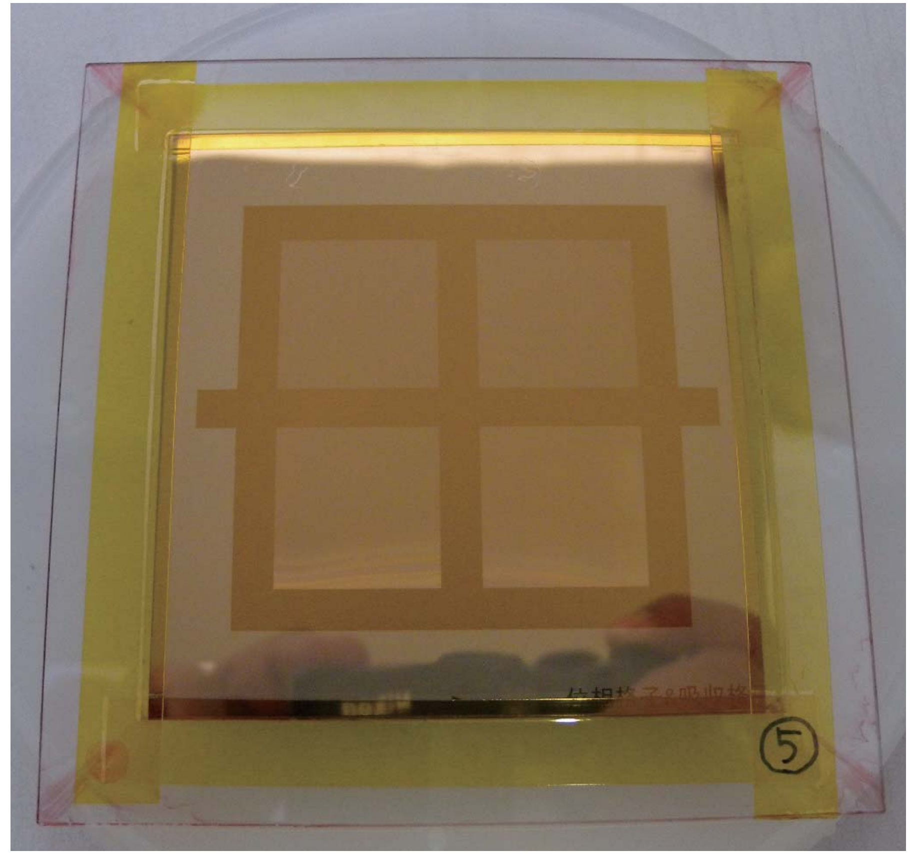

位相

基板：70umガラス（10cm角）
格子面積：2cm角
周期：6,7,8,13um