HSTD11 & SOIPIX2017 2017.12.11-15 @OIST, Okinawa

Improvements of Grating-based X-ray Phase Contrast Imaging with a Microfocus X-ray Source by a SOI Pixel Detector, SOPHIAS

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Introduction

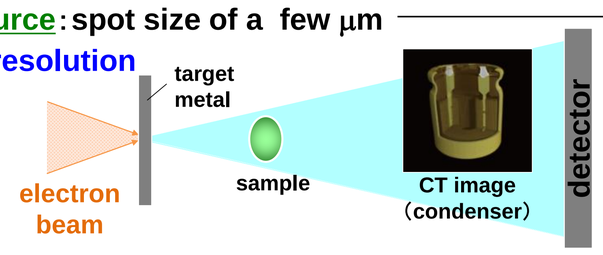
X-ray radiography

industrial application, materials science, and biology…

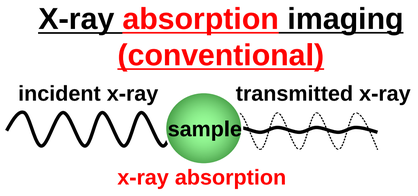
Microfocus x-ray source : spot size of a few μm

⇒ High spatial resolution

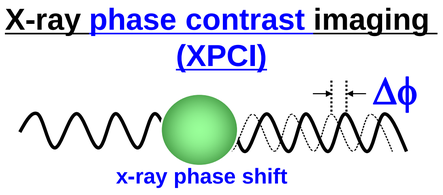
(SHIMADZU Co.)



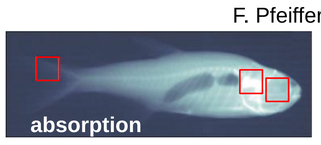
X-ray absorption imaging (conventional)

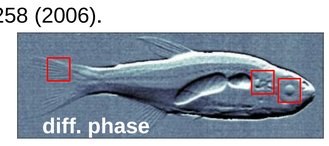


X-ray phase contrast imaging (XPCI)



F. Pfeiffer *et al*., Nat. Phys. 2, 258 (2006).





× Insufficient sensitivity to light element materials

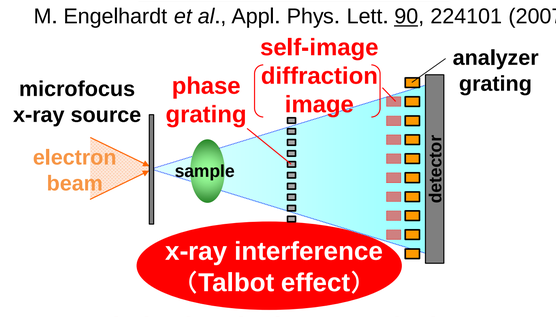
○ High sensitivity to weakly absorbing objects

XPCI with a microfocus x-ray source

XPCI methods with a microfocus x-ray source

Talbot interferometer

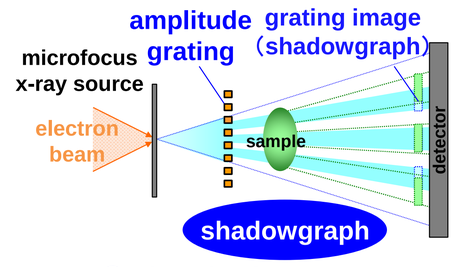
M. Engelhardt *et al*., Appl. Phys. Lett. 90, 224101 (2007).



× Limit of optical system design (total length, grating pitch, source size…)

× Only single wavelength shooting

XPCI using single amplitude grating



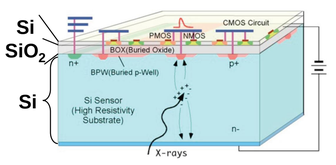
○ Flexible placement (independent of x-ray energy)

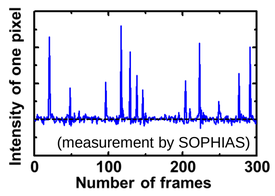
○ Multi-wavelength shooting ⇒ Substance identification

SOI (Silicon On Insulator) pixel detector

Y Arai, *et al*., Nucl. Instrum. Methods Phys. Res., Sec. A, 636 , S31-S36 (2011).

- **Required Functions for XPCI**
  - ✓ Noise free
  - ✓ Energy resolution
  - ✓ Small pixel size
- **Monolithic Pixel Detector (based on SOIPIX technology)**



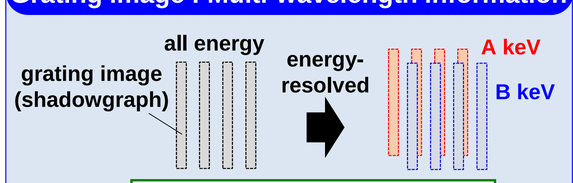


High spatial resolution & spectro-imaging detection

Purpose of this work

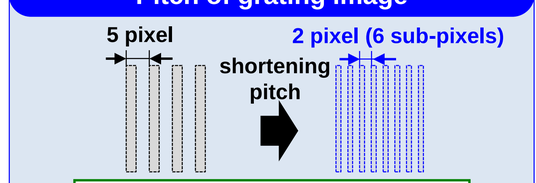
Application of "SOI pixel detector" to "XPCI using single amplitude grating"

① Energy resolution
Grating image : Multi-wavelength information

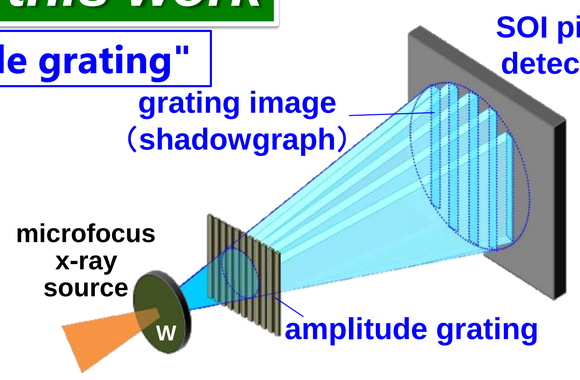


1shot energy-resolved XPCI

② Spatial resolution (sub-pixel analysis)
Pitch of grating image



High spatial resolution images

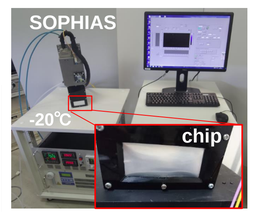


RIKEN : SOPHIAS (for SACLA/SPring-8)

T. Hatsui, Proc. Int. Image Sensor Workshop 3.05, (2013).

○ Wide dynamic range
○ Large detection area

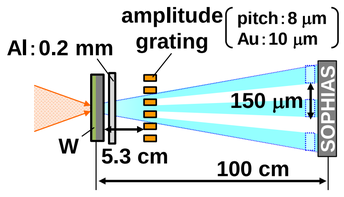
- pixel size : 30 μm
- detection area : 64.8 × 26.7 mm
- energy resolution: 3.2, 4.0 keV FWHM (7, 12 keV)

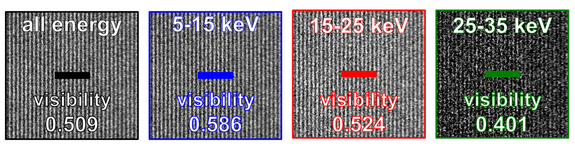


Experimental Result & Discussion

① 1shot energy-resolved XPCI

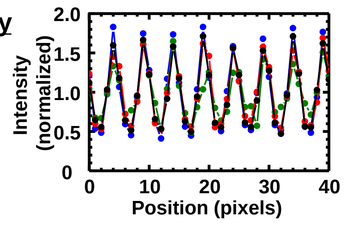
Energy-resolved shadowgraphs of grating





40 kV / 10 μA / 16.6 s (8.3 ms 2000frm)

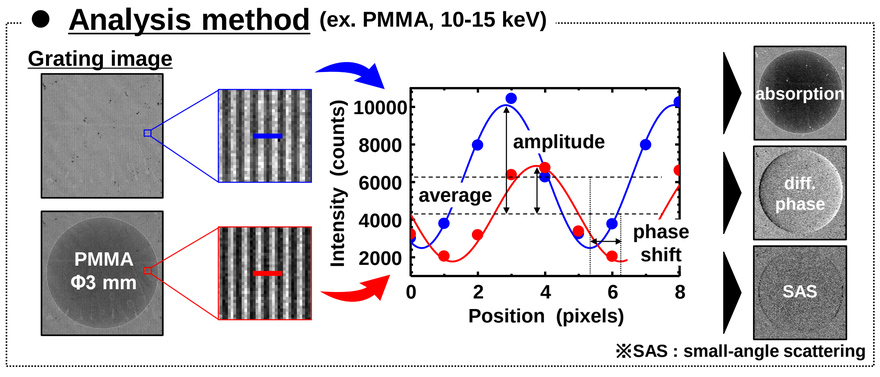
Intensity profile



Confirmation of grating image formation

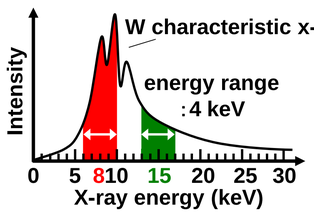
Energy-resolved x-ray imaging

- **Analysis method** (ex. PMMA, 10-15 keV)

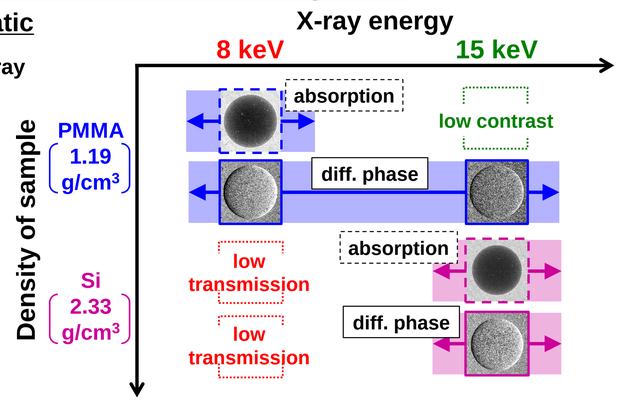


- **Imaging results : PMMA & Si spheres**

Energy spectrum schematic



tube voltage : 40 kV
tube current : 10 μA
exposure time : 249 s
(8.3 ms 30000frm)

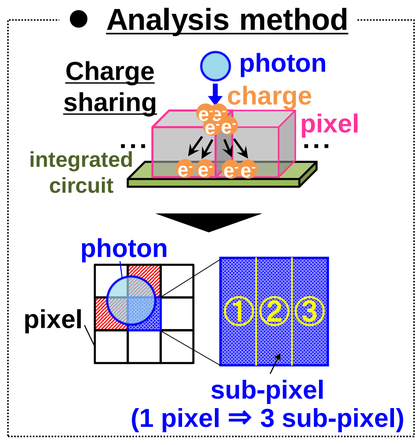


Energy-resolved images extracted after single measurement
⇒ Important for material characterization

② High spatial resolution XPCI using sub-pixel analysis

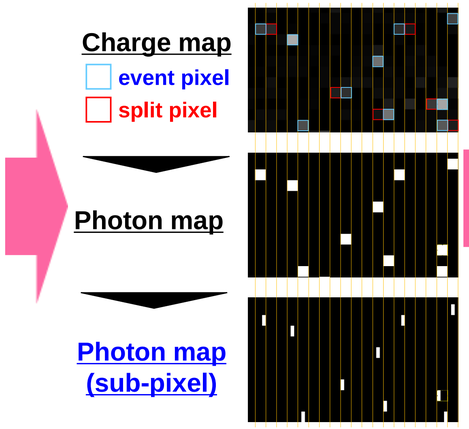
Sub-pixels analysis

- **Analysis method**



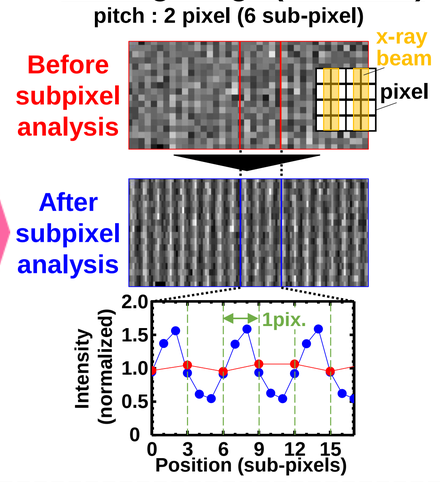
- **Photon counting image**

1 frame, w/o optical elements



- **Grating image (10-20keV)**

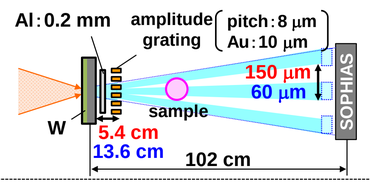
pitch : 2 pixel (6 sub-pixel)



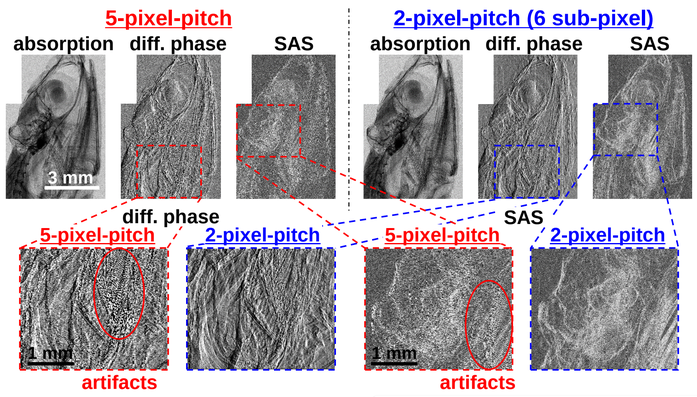
High spatial resolution XPCI

- **Setup**
  - 5-pixel-pitch
  - 2-pixel-pitch (6 sub-pixel)

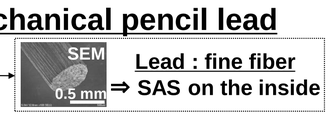
40 kV / 10 μA / 66.4 s (8.3 ms 8000frm)

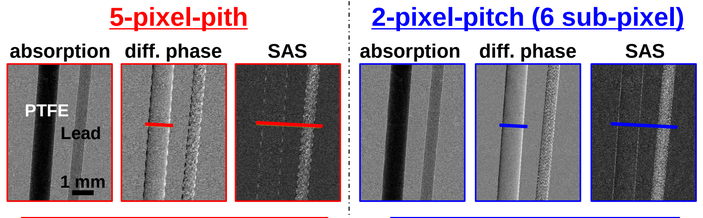


- **Small fish**



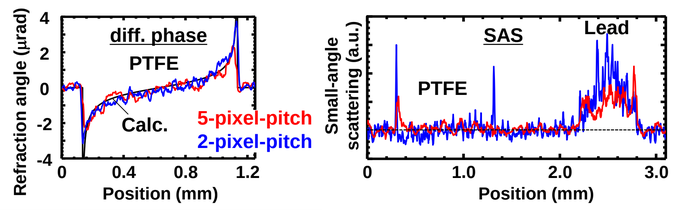
- **PTFE fiber & mechanical pencil lead**





Artifact at the edge of sample

Clear image without artifacts



Summary & Future plan

★ Energy-resolved imaging by single measurement
⇒ Important for material characterization

★ Subpixel analysis (Shortening pitch of grating image)
⇒ Improvement of spatial resolution

⇒ Energy-resolved x-ray phase tomography