

2012.7.31

第2回コンパクトERLサイエンスワークショップ@KEK

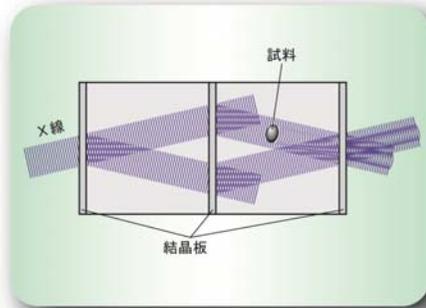
レーザーコンプトンX線への Talbot干渉計の応用

百生 敦

東北大学多元物質科学研究所

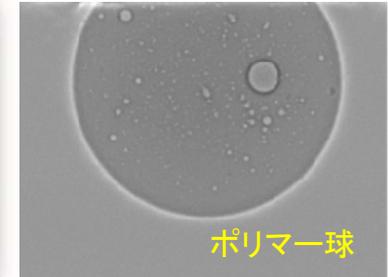
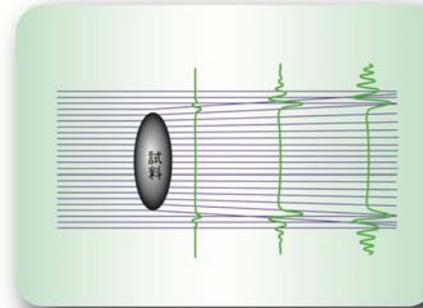
X線位相コントラスト法

Bonse-Hart X線干渉計

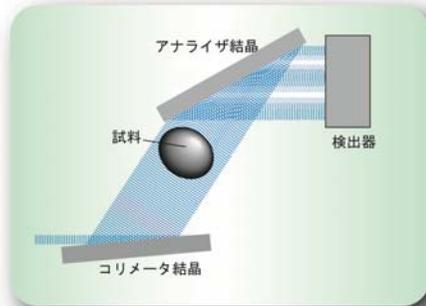


※1

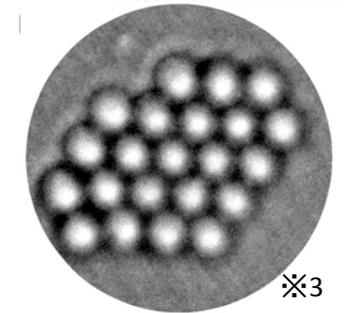
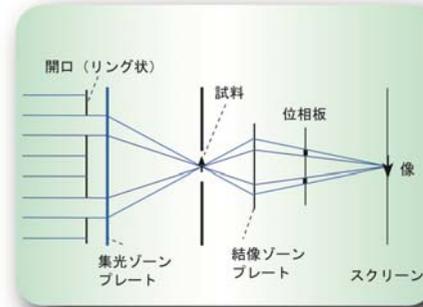
伝播法(in-line法)



DEI: Diffraction Enhanced Imaging

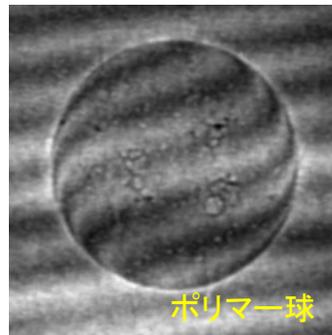
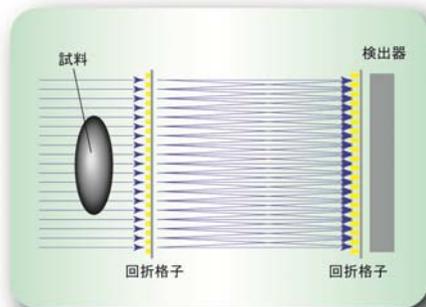


Zernike位相差顕微鏡



※3

X線Talbot干渉計

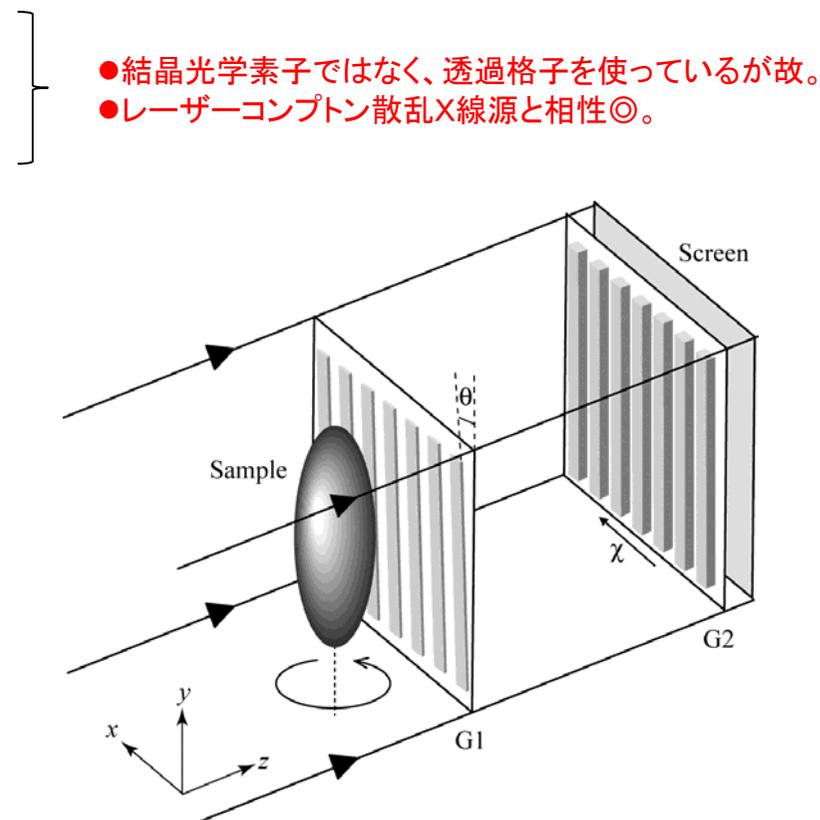


※2

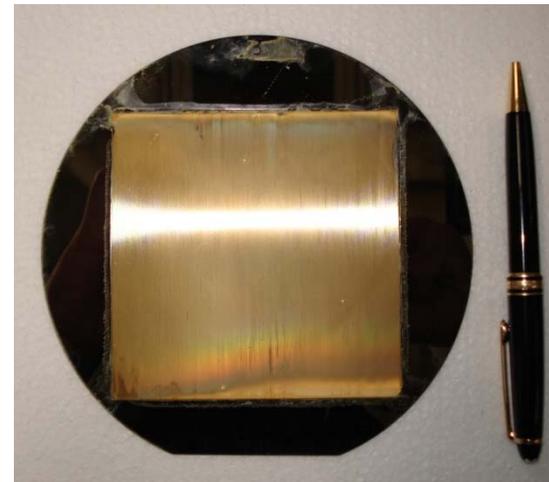
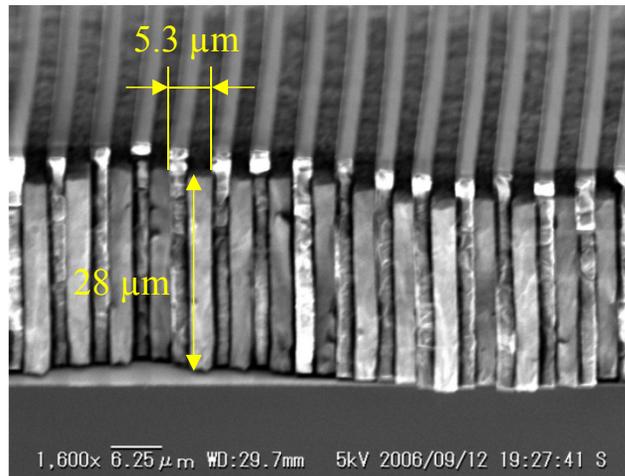
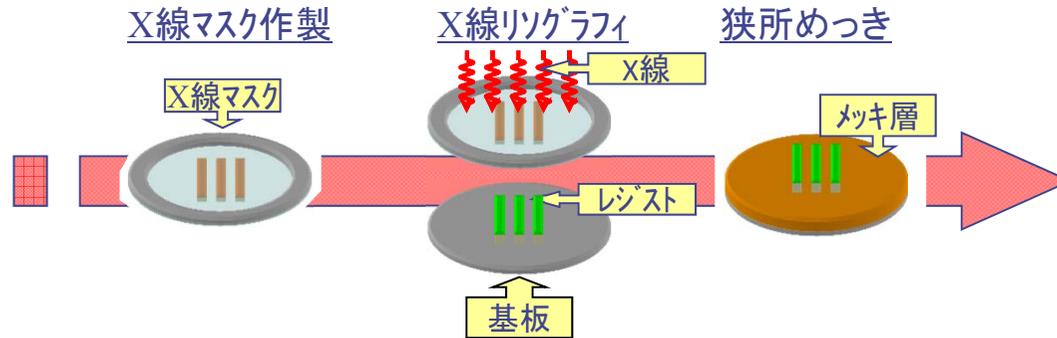
- ※1 A. Momose et al., Med. Phys. 22 (1995) 375-379
- ※2 A. Momose et al., Jpn. J. Appl. Phys. 42 (2003) L866-L868
- ※3 Y. Kagoshima et al., J. Phys IV 104 (2003) 49-52

X-ray Talbot interferometerの特徴

- ➔ 光学系が扱い易い
- ➔ 微分位相コントラストを生成
- ➔ コーンビームが使用可能
- ➔ 準単色X線 ($\Delta E/E < 0.1$) が使用可能
白色放射光でも実績あり
- ➔ シンクロトン放射光以外のコンパクトX線源で展開可能
- Ⓢ 高アスペクト比のX線透過格子の製作

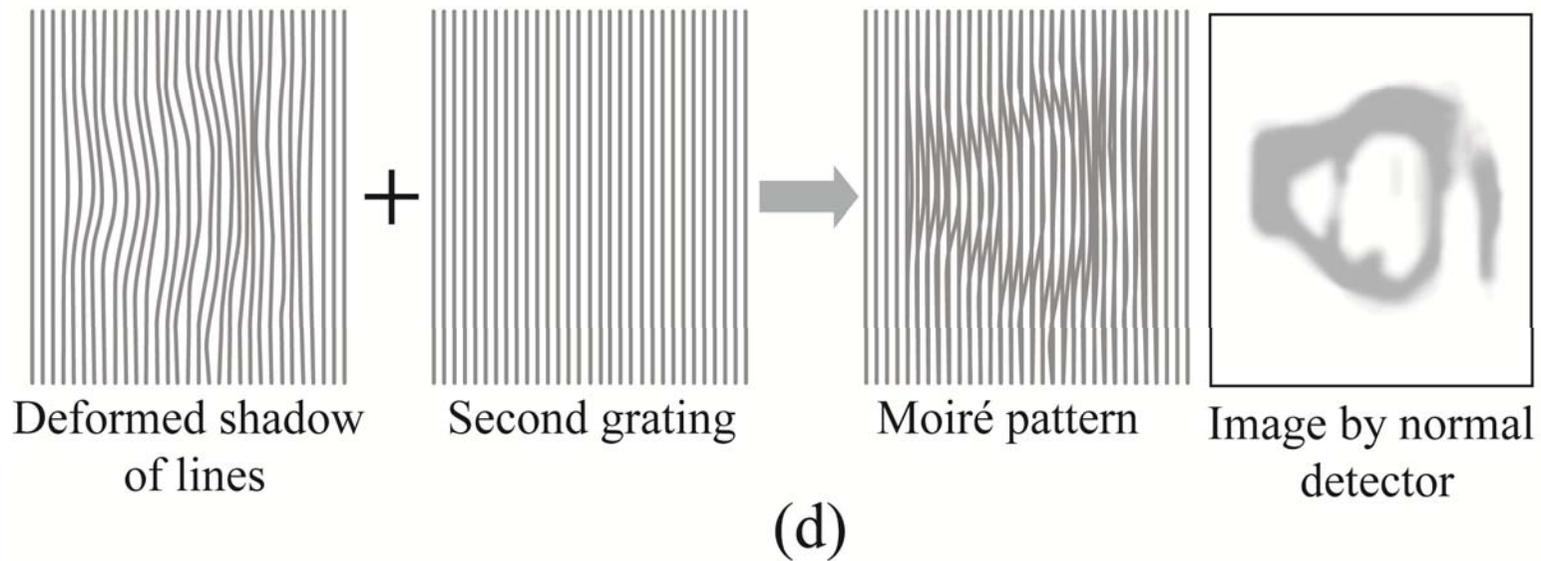
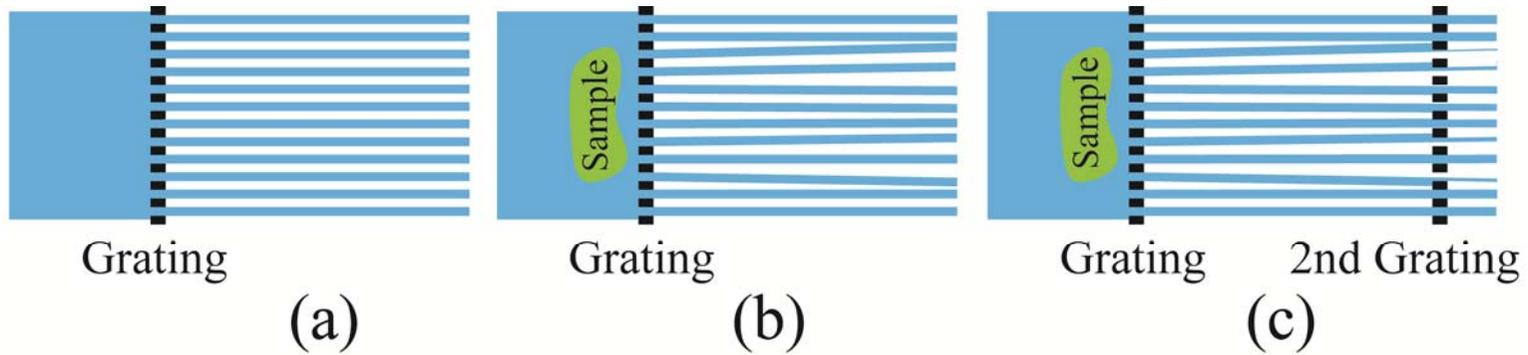


X線Talbot(-Lau)干渉計のための光学素子 —X線格子の製作—

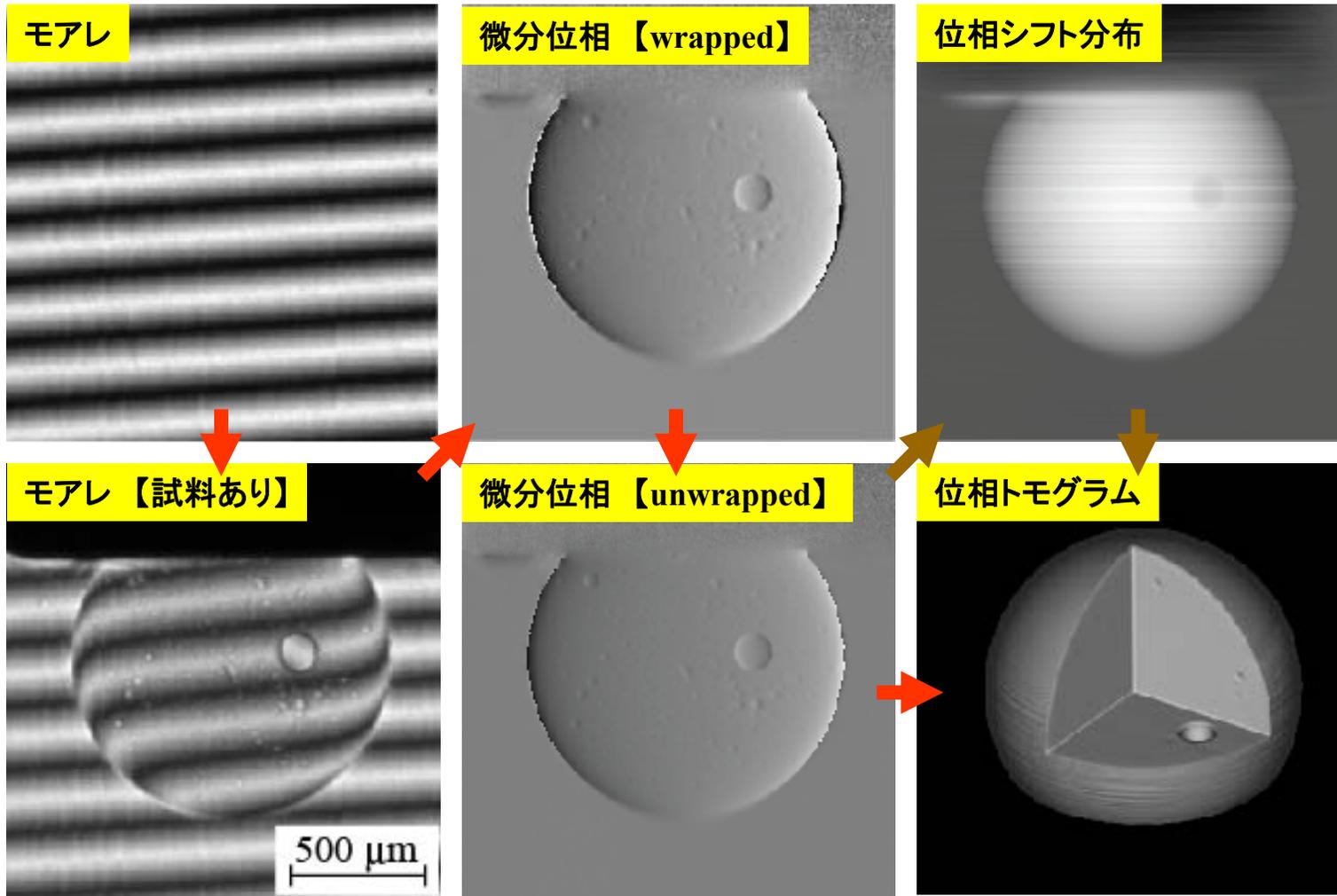


X線の屈折を検出する新しい方法

X線Talbot干渉計

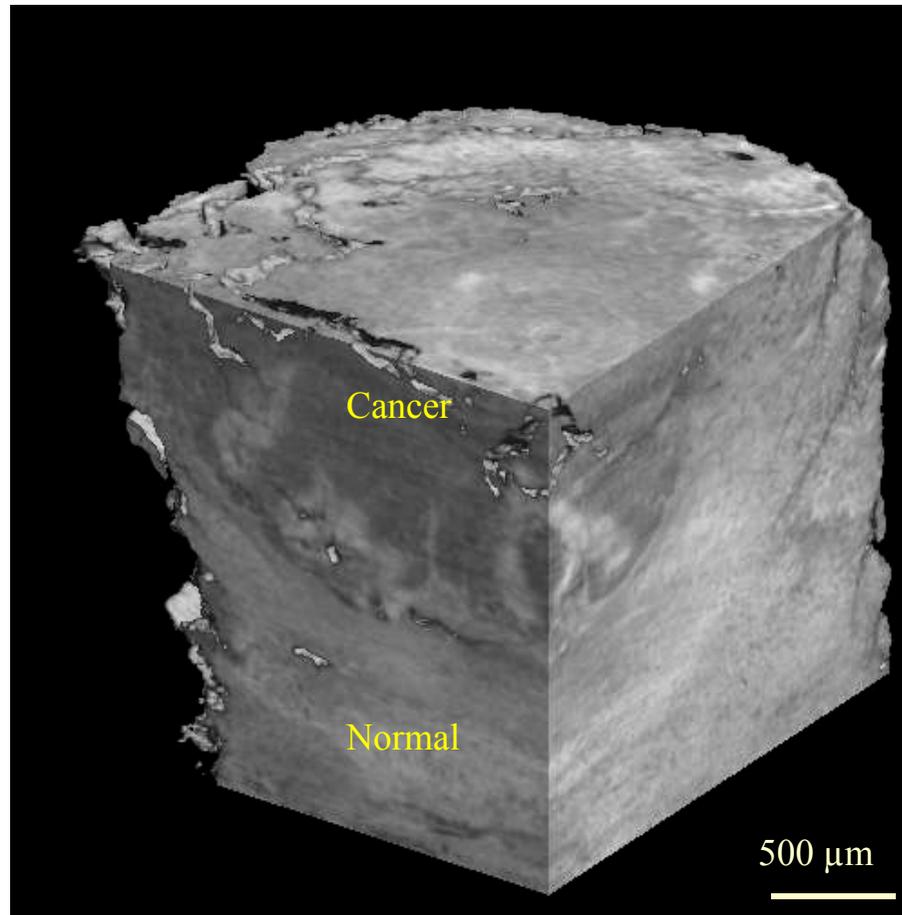
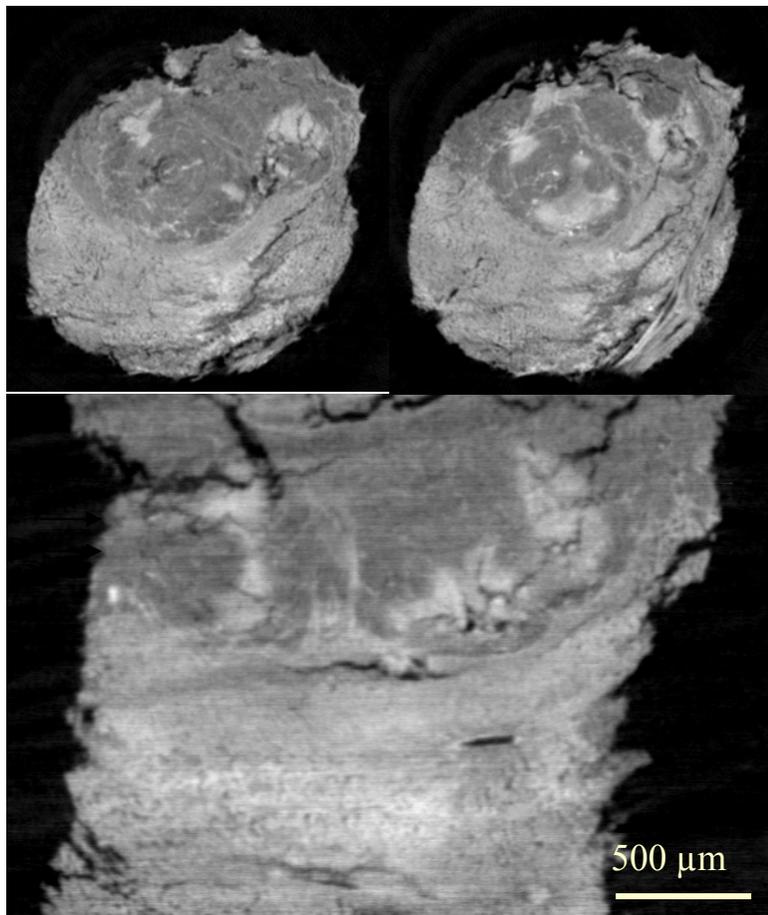


画像変換の流れ



観察例① ウサギ肝臓 (VX2)

A. Momose *et al.*, *Jpn. J. Appl. Phys.* 45 (2006) 5254



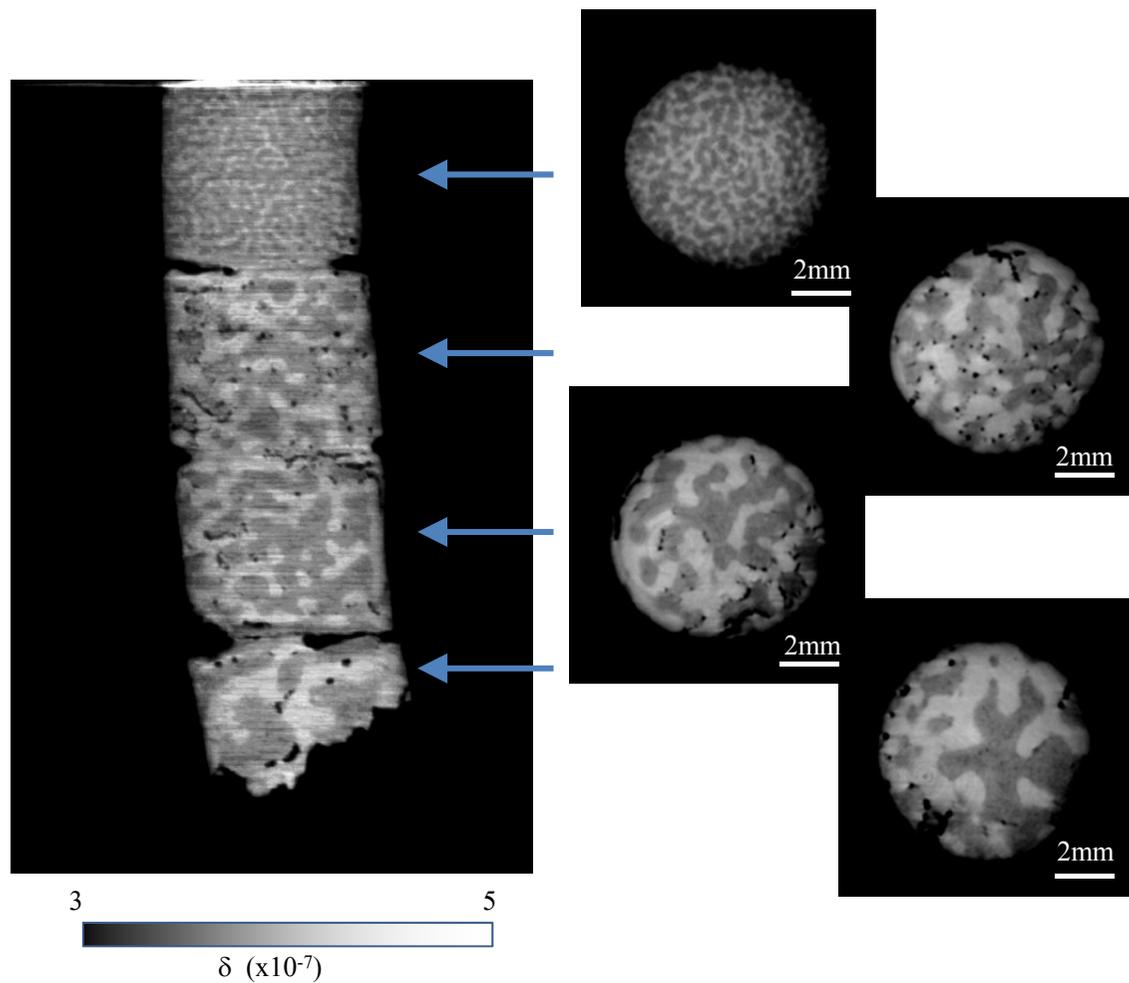
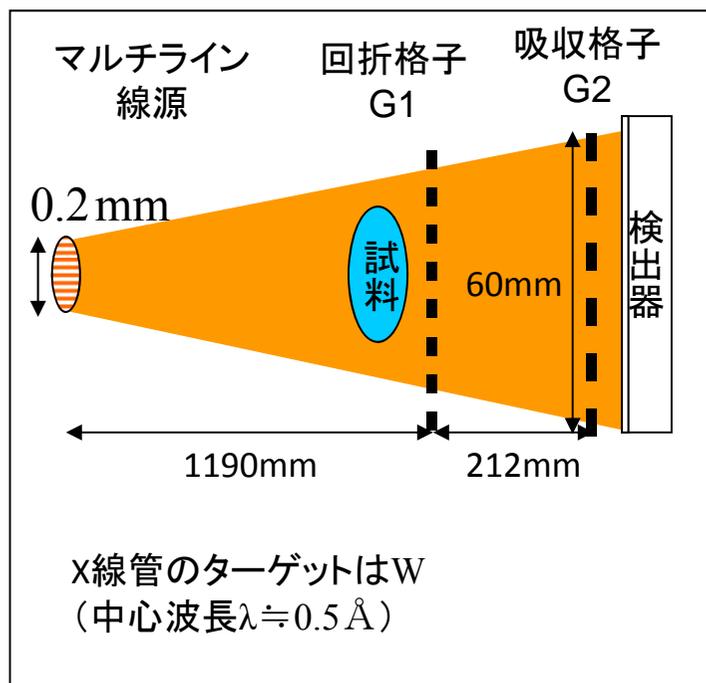
0

屈折率差

9.0×10^{-8}

SPring-8, BL20XU@12.4 keV

観察例 PS/PMMAブレンド



Third Contrast

Dark-field image
 Visibility image
 Scattering image

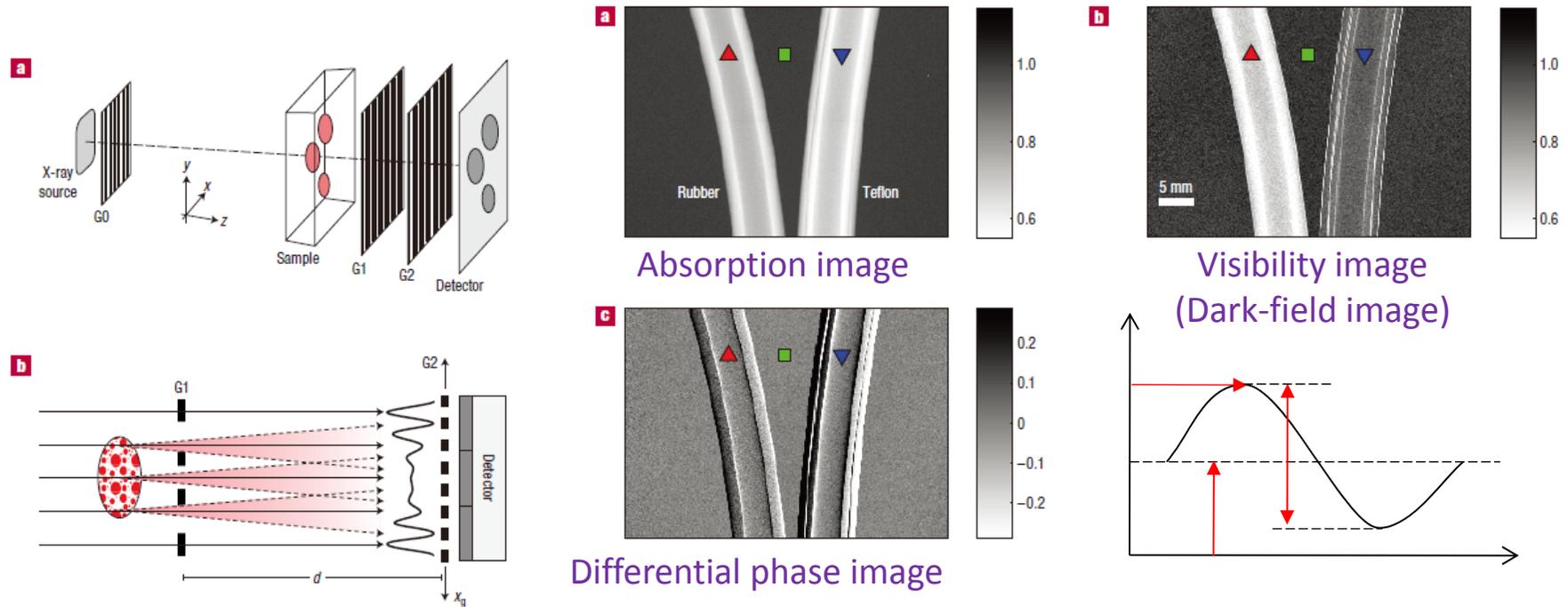
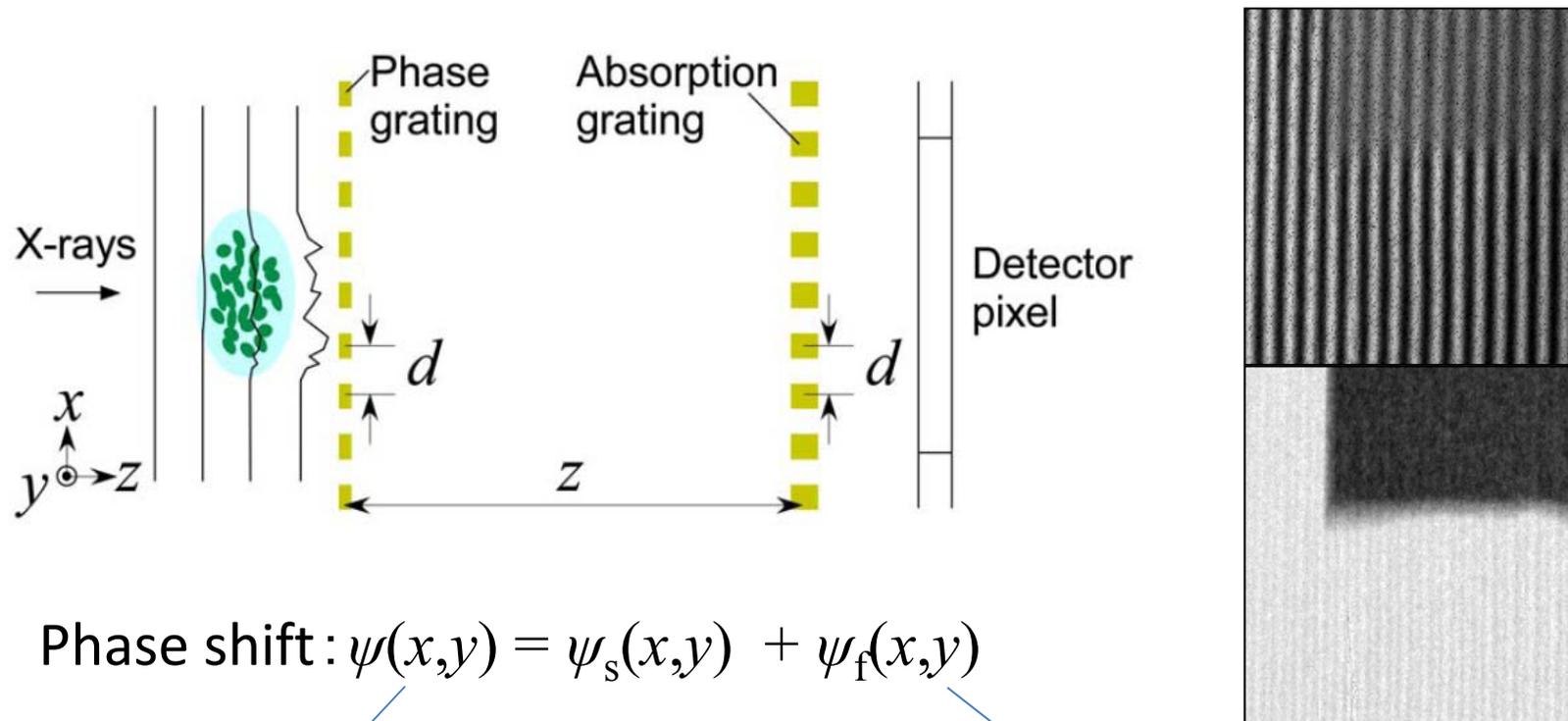


Figure 2 X-ray imaging of a test sample consisting of a PTFE (Teflon) plastic tube and a natural rubber tube. **a**, Conventional X-ray transmission image (normalized to the empty beam). **b**, Dark-field image of the same sample (normalized visibility, see text). **c**, Differential phase-contrast image. All images are shown on a linear grey scale. **d**, Intensity oscillations for three detector pixels extracted from a series of eight images taken at different values of x_g . Clearly visible is the loss of fringe visibility in the detector pixel behind the natural rubber tube due to the strong small-angle scattering produced by microscopic density fluctuations (pore structure). The total exposure time for the whole data set was 40 s.

第3のコントラスト visibility像



$$\text{Phase shift: } \psi(x,y) = \psi_s(x,y) + \psi_f(x,y)$$

$\psi_s(x,y)$: Component varying slowly comparing to the system spatial resolution

$\psi_f(x,y)$: wave front fluctuation with the scale smaller than the system spatial resolution = 極小角散乱

Differential phase contrast

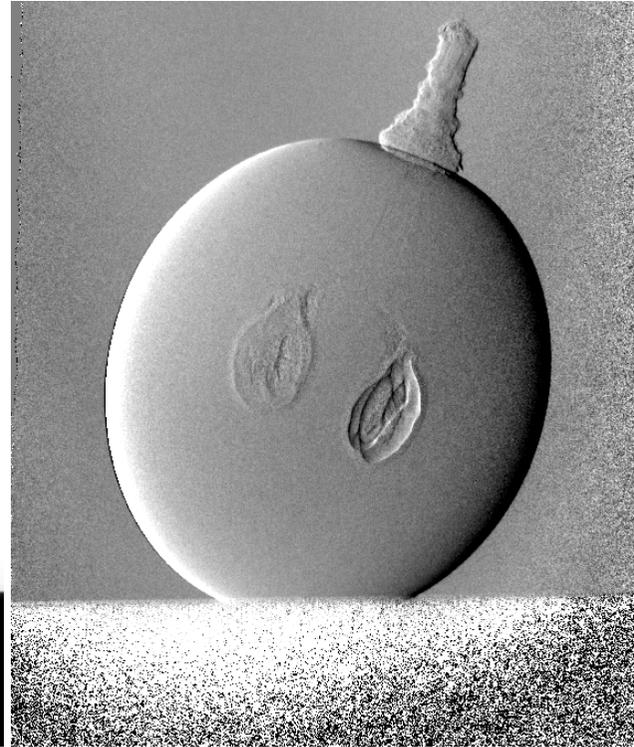
Visibility reduction

Visibility像の効果

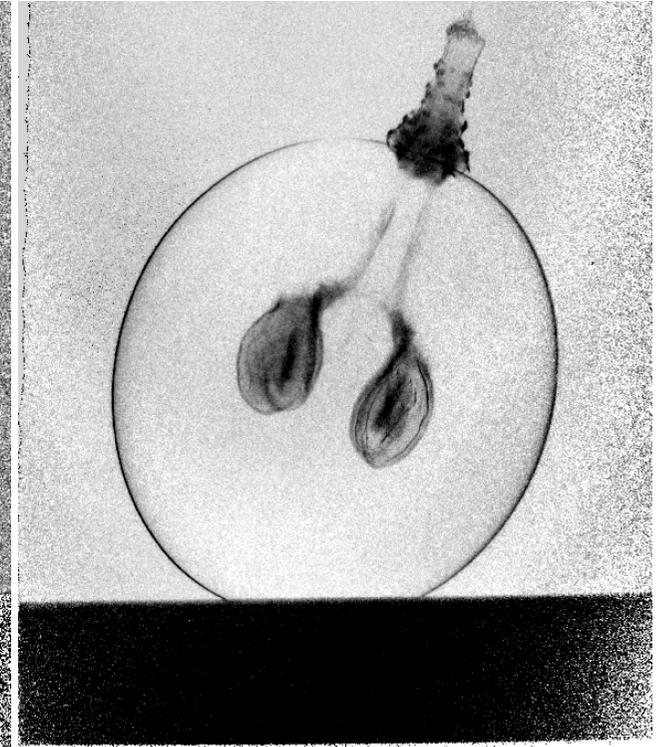
ぶどう



吸収像



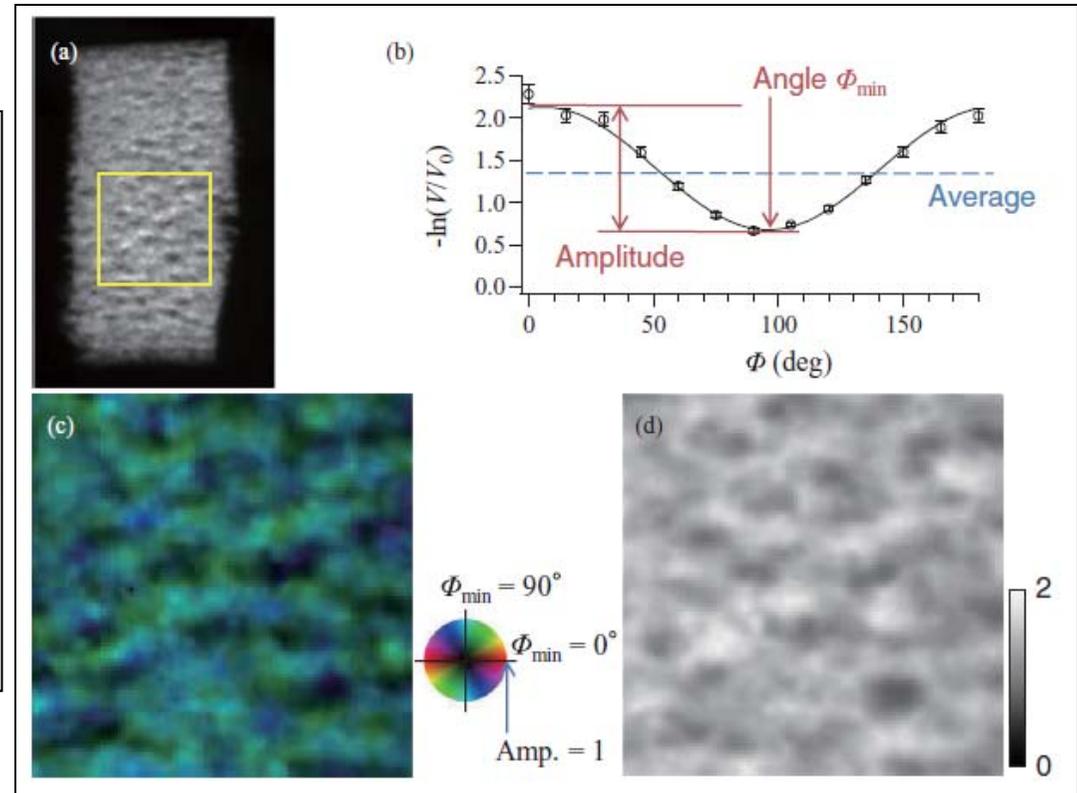
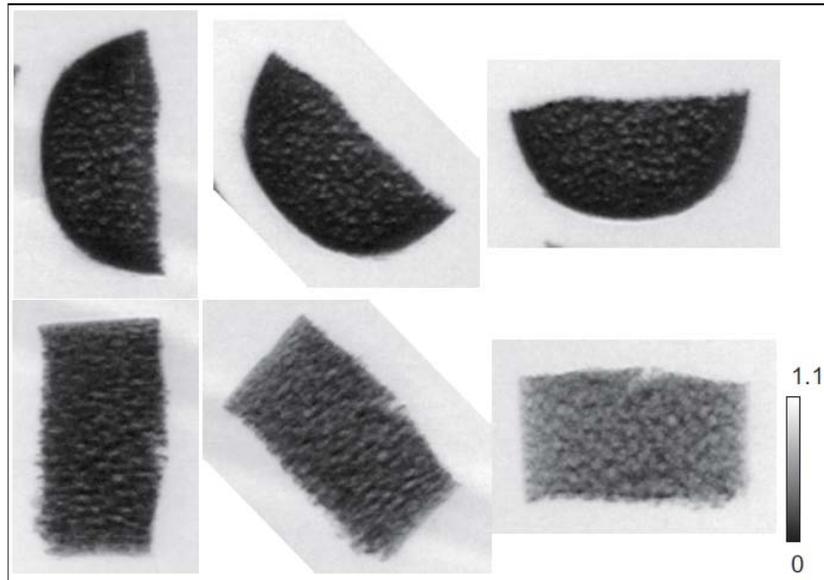
微分位相像



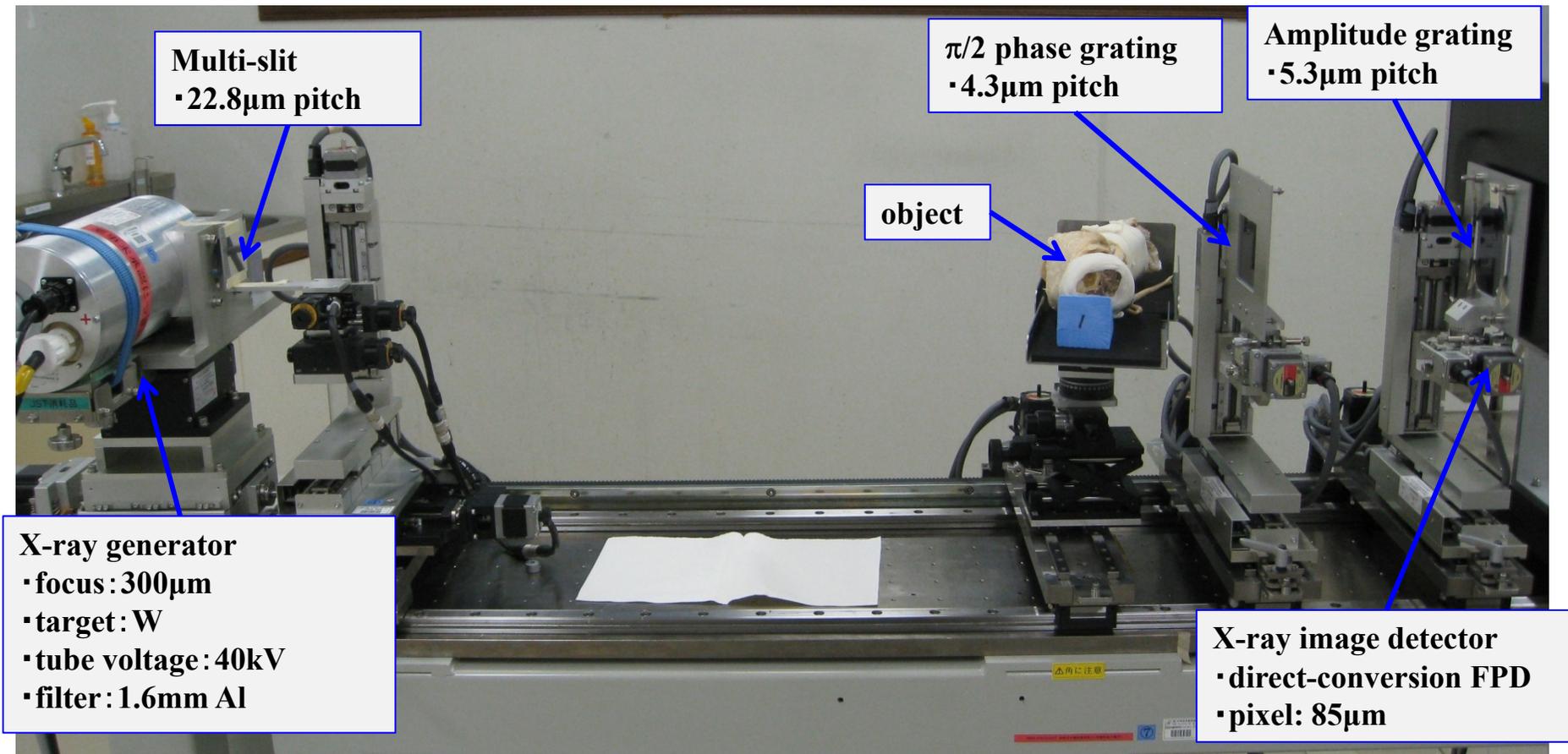
Visibility像

Visibility像の方位異存性

CRスポンジ
17 keV @ PF



X-ray Talbot-Lau Interferometer for Pre-clinical Test

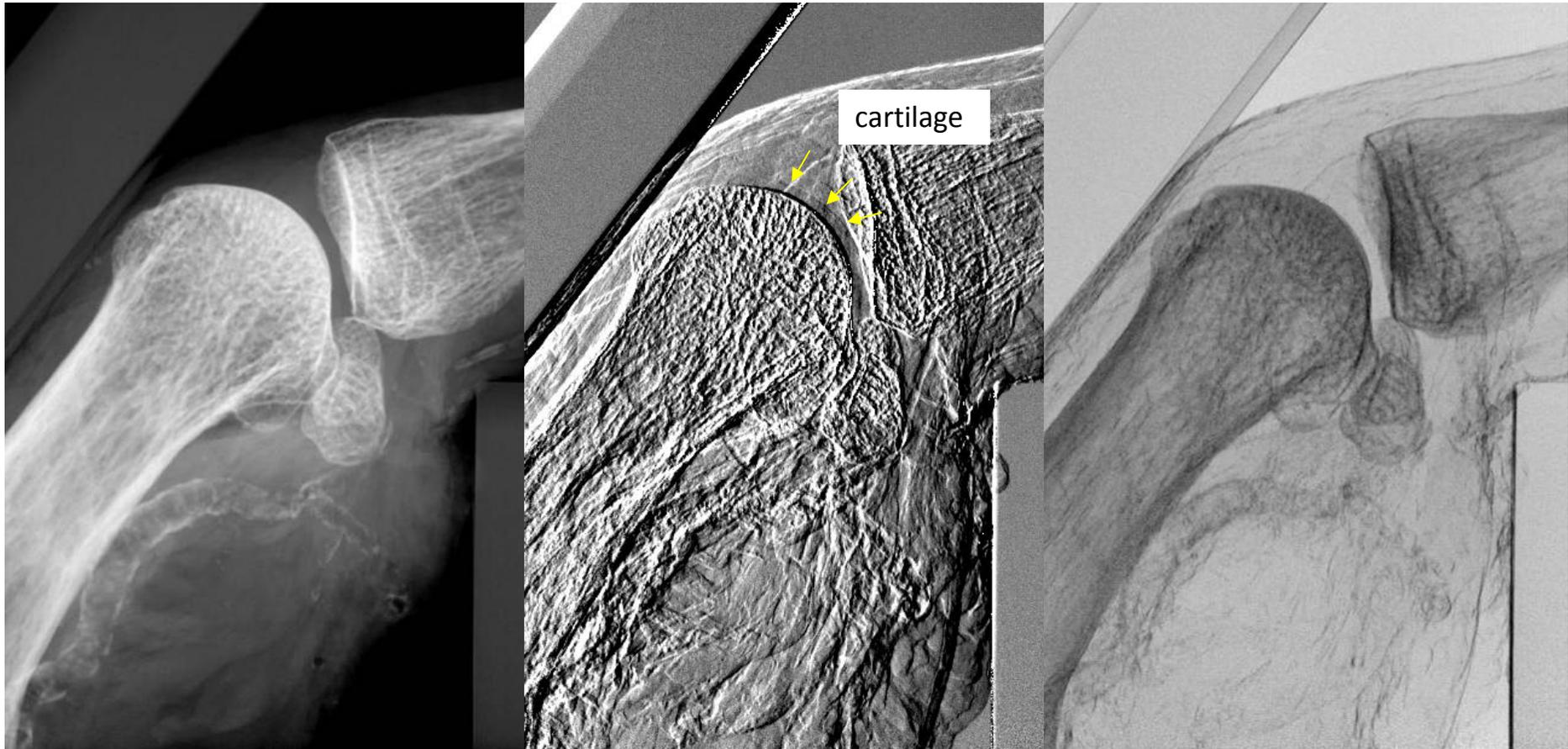


metacarpophalangeal joint of human thumb

Absorption

differential phase

visibility

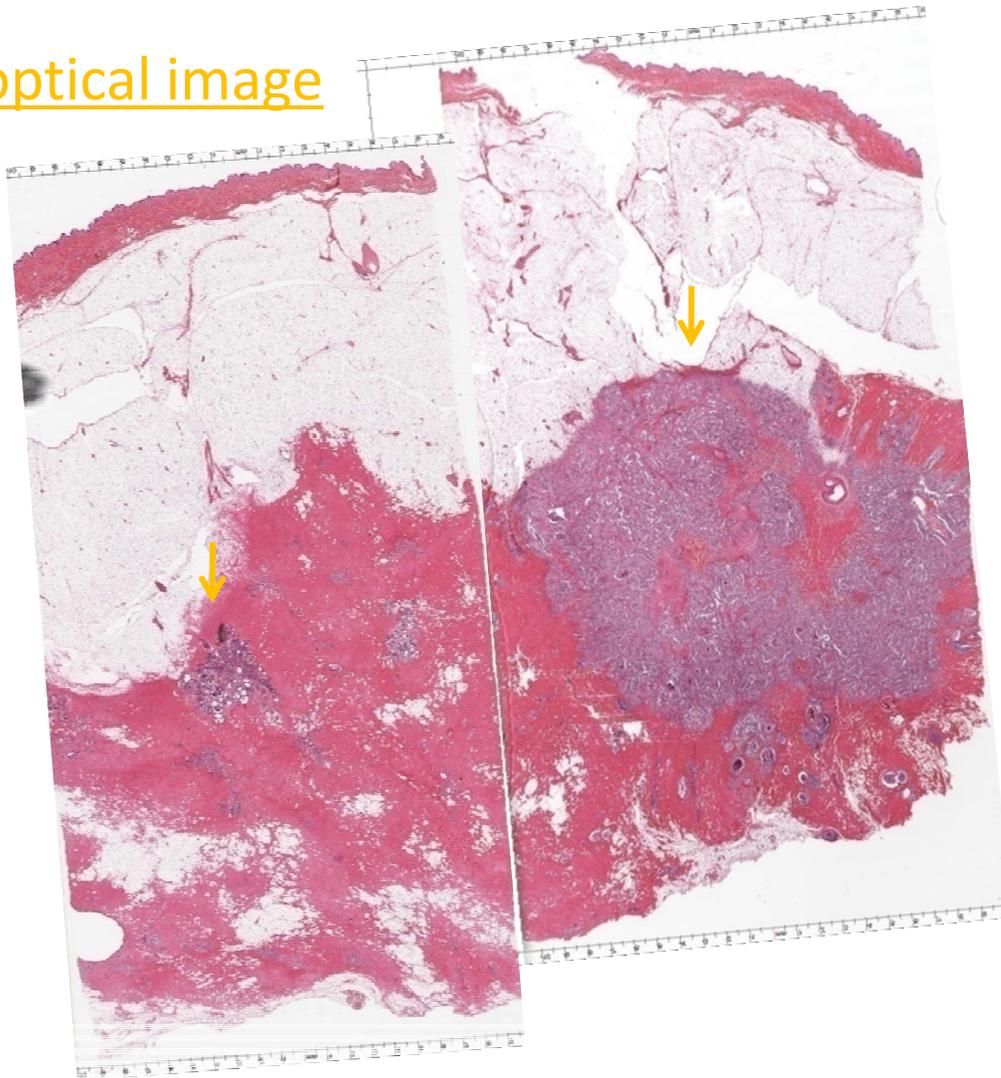


Prof. J. Tanaka, MD, Prof. M. Nagashima, MD
@Saitama Medical School, Japan

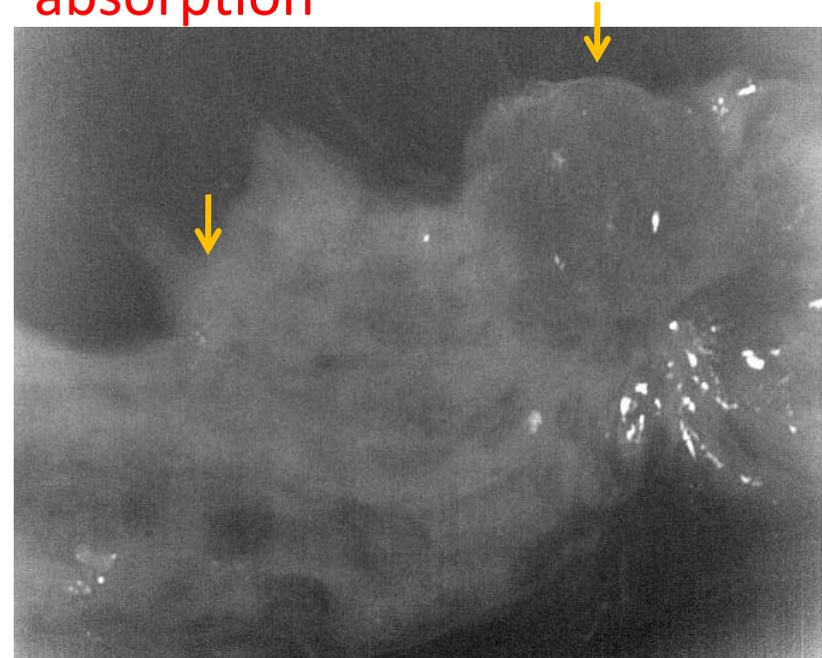
Human breast tissue

Dr. T. Endo
@ Nagoya Medical Center, Japan

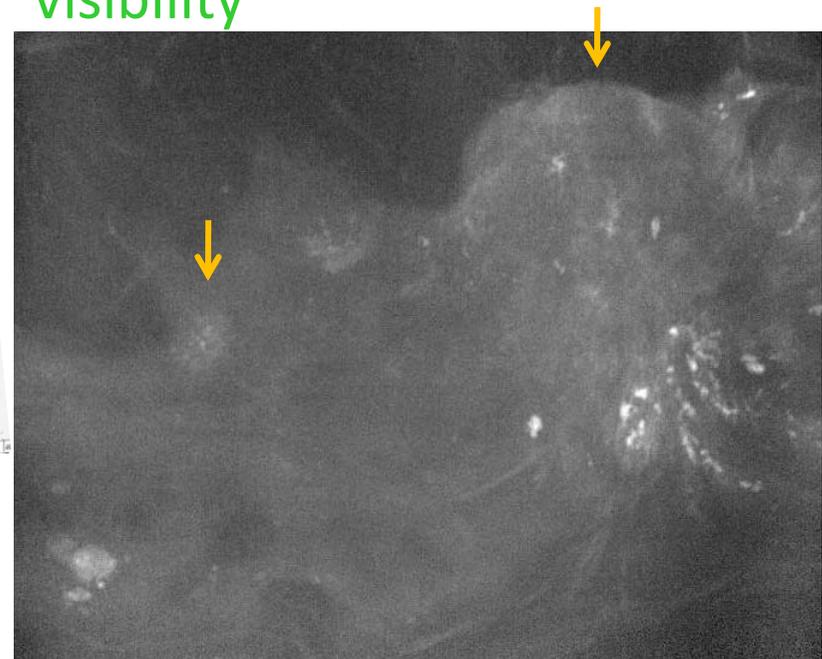
optical image



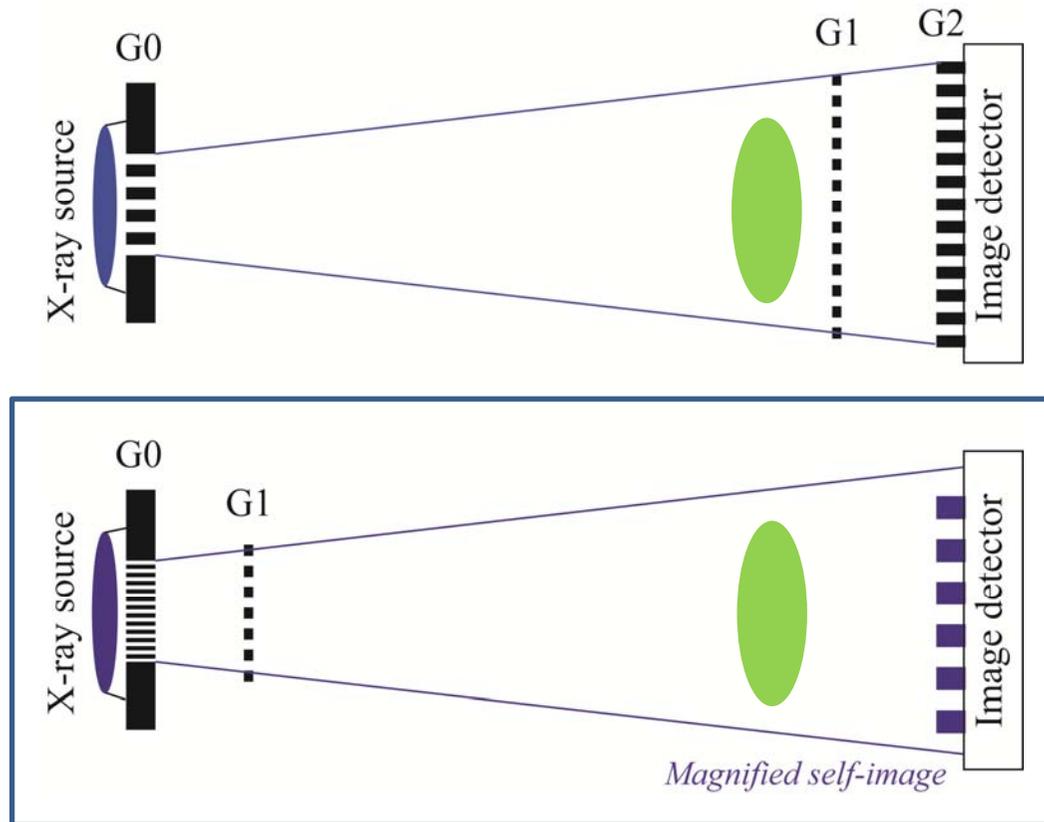
absorption



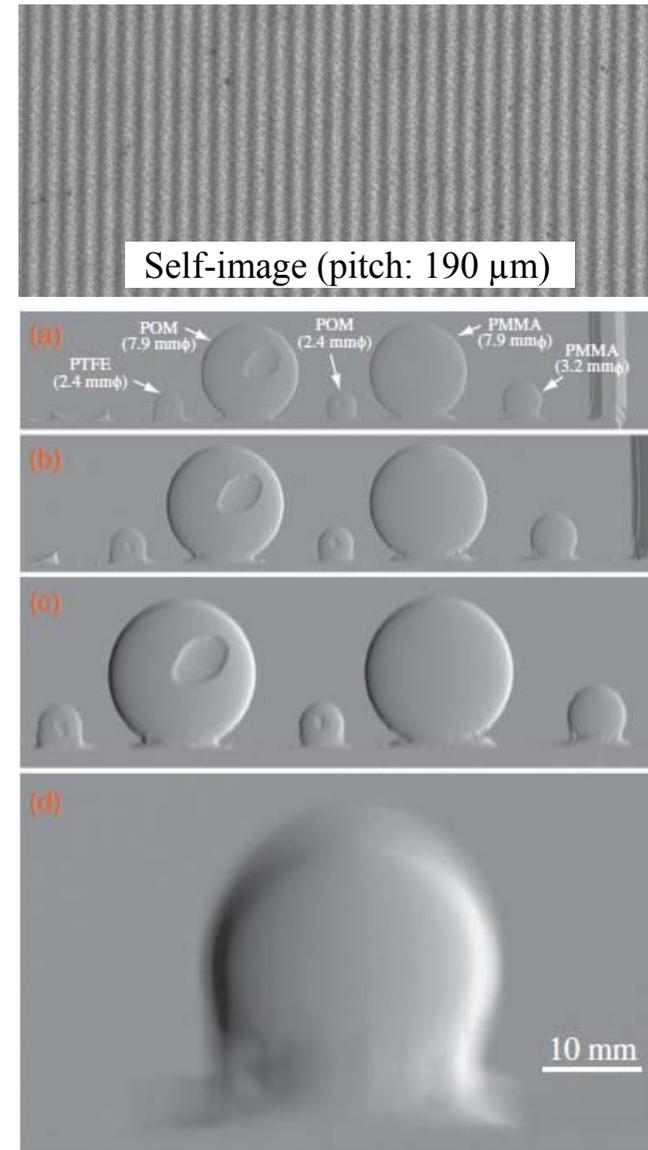
visibility



X-ray Lau interferometry



◆製作が最も難しい振幅格子(G2)を省略



cERLへの期待

- 放射光並み(?)画質のX線位相イメージングの普及(位相トモグラフィ、位相敏感X線顕微鏡、など)
- THz光イメージングとの融合ステーション(構造と機能の融合計測)
- 医療画像診断応用を推進するためには、cERLの更なるコンパクト化への青写真が必要。

謝辞: JST, 先端計測
服部正(兵庫県立大)、ナノクリエート(株)
コニカミノルタエムジー(株)
田中淳司(埼玉医科大学)
遠藤登喜子(名古屋医療センター)
矢代航他百生研学生スタッフ(東北大)
兵藤一行(PF), 鈴木芳生(SP8)

謝辞

SENTAN–Project (Oct. 2004 – Nov. 2007)



- Univ. Tokyo (A. Momose, W. Yashiro, Y. Takeda, K. Wan)
- Univ. Hyogo (T. Hattori, D. Noda)

SENTAN–Project (Dec. 2007 – Mar. 2012)



- Univ. Tokyo (A. Momose, W. Yashiro, S. Harasse)
- Konica Minolta Medical & Graphic, Inc (C. Honda, S. Nagatsuka, et al.)
- Univ. Hyogo (T. Hattori, D. Noda)
- Saitama Medical Univ. (J. Tanaka, M. Nagashima)
- Nagoya Medical Center (T. Endo)

SENTAN–Project (Oct. 2011 – Mar. 2014)



- Konica Minolta Medical & Graphic, Inc (S. Nagatsuka et al.)
- Saitama Medical Univ. (J. Tanaka, M. Nagashima)
- Univ. Tokyo -> Tohoku Univ. (A. Momose, W. Yashiro)