Ten years of X-ray phase imaging development with grating analyzer

Atsushi Momose[1,2,3]

[1] Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan.
[2] JST, ERATO, Momose Quantum Beam Phase Imaging Project, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan.
[3] JASRI/SPring-8, 1-1-1 Kouto, Sayo-cho, Hyogo 679-5198, Japan.
Email: momose@tagen.tohoku.ac.jp

In the 1990s, a variety of techniques for generating X-ray phase contrast were extensively studied to observe weakly absorbing objects [1]. In an early stage, X-ray phase-contrast images were recorded simply by X-ray films or X-ray image detectors. Even if X-ray phase contrast is successfully generated, however, not only absorption contrast but also other contrasts originating from the phase-contrast method used and imperfection of optical elements are normally contained. Therefore, the contrasts in resultant images were occasionally too complicated to understand the inner structure of samples. 'X-ray phase imaging' has been developed to solve this inconvenience; that is, X-ray phase imaging involves a phase retrieval technique that extracts images quantitatively corresponding to amplitude and phase of X-rays passing through a sample from digitally recorded phase-contrast images. All X-ray phase-contrast methods were combined with some phase retrieval technique in that decade. Thanks to the quantitative feature of X-ray phase imaging, the combination with X-ray computed tomography was realized (X-ray phase tomography) for three-dimensional high-sensitive image reconstruction.

The performance of X-ray phase imaging motivates us to realize its practical applications to medicine and industry. However, the technology only at synchrotron radiation facilities never meet these demands. While many types of X-ray phase imaging methods essentially require the use of synchrotron radiation because of its high brightness and high coherence, X-ray grating interferometry (XGI), such as X-ray Talbot or Talbot-Lau interferometry, which detects X-ray refraction and scattering by using a analyzer grating, brought a breakthrough towards practical applications in the 2000s [2, 3]. A XGI-based apparatus for diagnosing articular rheumatism by depicting cartilage has been successfully developed and used for patients at hospitals now for clinical study [4].

XGI has also brought great flexibility to synchrotron-based X-ray phase imaging. Since it is compatible with a spherical wave, the combination with an X-ray imaging microscope is possible. This enables us to realize X-ray phase imaging/tomography with a mesoscopic spatial resolution [5,6]. Furthermore, since XGI is compatible with polychromatic X-rays, X-ray phase imaging with white synchrotron radiation is possible. This implies that high-speed phase imaging and four-dimensional phase tomography is attainable [7,8]. Recently I have established a team at SPring-8 to explore these technologies further under JST-ERATO Momose quantum-beam phase imaging project.

In the presentation, I will review the last decade of XGI development and discuss the future of this field.

References

[1] A. Momose, *Jpn. J. Appl. Phys.* **44** (2005) 6355-6367.

[2] A. Momose, S. Kawamoto, I. Koyama, Y. Hamaishi, K. Takai, Y. Suzuki, *Jpn. J. Appl. Phys.* **42** (2003) L866-L868.

[3] F. Pfeiffer, T. Weitkamp, O. Bunk and C. David, *Nat. Phys.*, 2006, **2**, 258-261.

[4] A. Momose, W. Yashiro, K. Kido, J. Kiyohara, C. Makifuchi, T. Ito, S. Nagatsuka, C. Honda, D. Noda, T. Hattori, T. Endo, M. Nagashima, J. Tanaka, *Phil. Trans. R. Soc. A* **372** (2014) 20130023.

[5] Y. Takeda, W. Yashiro, T. Hattori, A. Takeuchi, Y. Suzuki, A. Momose, *Appl. Phys. Express* **1** (2008) 117002.

[6] W. Yashiro, Y. Takeda, A. Takeuchi, Y. Suzuki, A. Momose, *Phys. Rev. Lett.* **103** (2009) 180801.

[7] A. Momose, W. Yashiro, H. Maikusa, Y. Takeda, *Opt. Express* **17** (2009) 12540–12545.

[8] A. Momose, W. Yashiro, S. Harasse, H. Kuwabara, *Opt. Express* **19** (2011) 8423-8432.