The effect of the grating profile on the illumination uniformity of the X-ray condenser

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In full-field X-ray microscopy (FXM), a condenser as a beam shaper is essential for illuminating the testing area of the target material uniformly. Condensers with glass fibers have been developed for high efficiency illumination, but the manufacture is rather complicated and the uniformity of intensity still remains problematic. The alternative condenser is Fresnel zone plates in Au. But the uniformity of illumination intensity is not satisfactory. Recently, new brands of condensers consisting of integrated gratings are developed as shown in figure 1, which greatly improves the illumination uniformity. However, in practice, the structural defects in fabricated condensers can deteriorate the illumination uniformity. In this paper, we focus on the effect of grating profile on the illumination quality. As shown in figure 2, three different grating profiles are frequently seen in the fabrication process when the electron beam lithography is not carried out under optimized condition. Each of the profile has different verticality, which may cause the variation of electromagnetic field in near field such that the spatial distributions of light intensity in far field are effected.

The light intensity (E^2) in the near field of gratings is calculated by Finite Difference Time Domain (FDTD) simulation software, as shown in figure 2. Clear deviation in the E^2 is observed. Among them, the grating with vertical sidewall gives rise to the symmetric distribution, which shall result in uniform illumination on the target material in far field. The other two profiles, however, exhibit asymmetric distribution of the transmitted light intensity, leading to uneven illumination on the sample. By optimizing the EBL processes, the condensers with strictly vertical sidewall of integrated gratings were fabricated (Figure 3). Its illumination uniformity was characterized by the X-ray at 9 keV in Shanghai Light Source (SLS). Extremely uniform illumination has been achieved as Figure 4 shows.

In summary, the effect of the grating profile in condensers on the illumination distribution was theoretically investigated by numeral calculation using FDTD software. It was then experimentally verified that structural defects can deteriorate the uniformity of illumination on target material, using the fabricated condenser with integrated gratings. This work is important for achieving high quality X-ray imaging with large viewing field, high uniformity and nanoscale resolution.

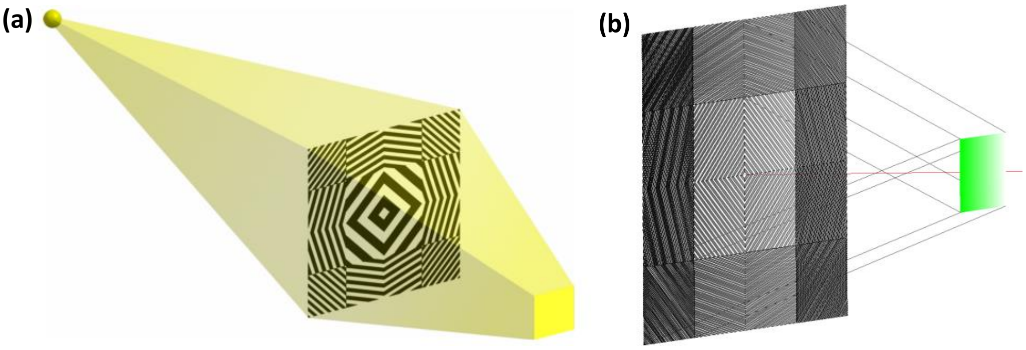

Fig 1.Schematic diagram of beam-shaping condenser lens focal plane

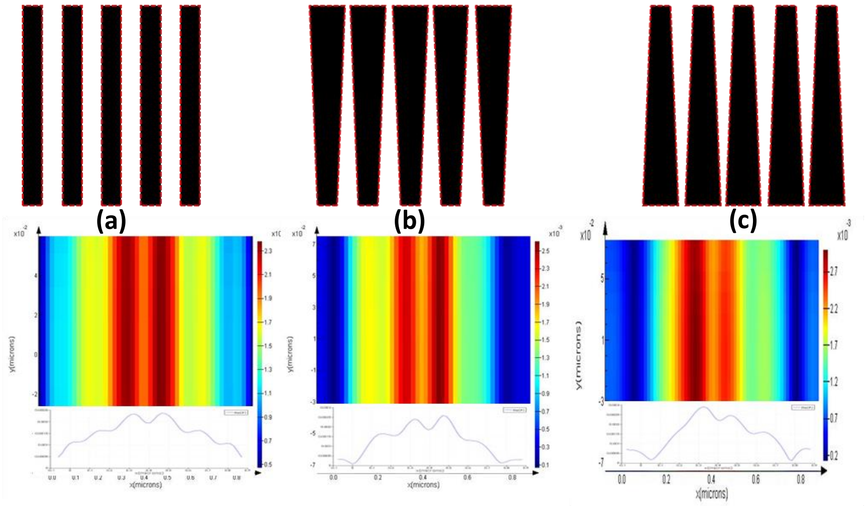

Fig 2. Simulation results of illumination distribution of different grating profiles

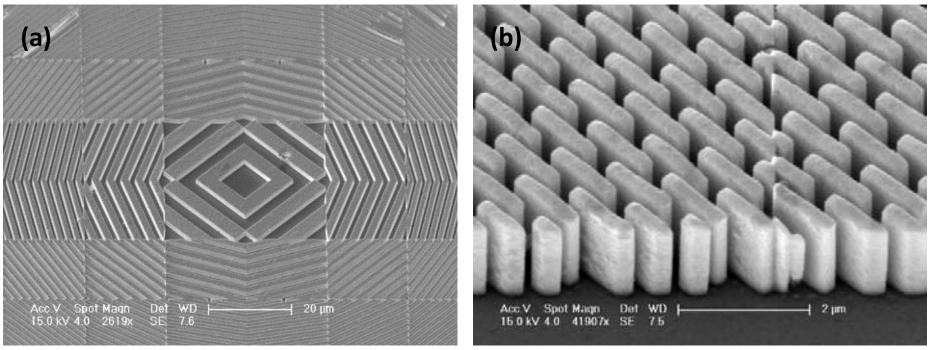

Fig 3.The SEM images of the beam-shape electroplated on Si_3N_4

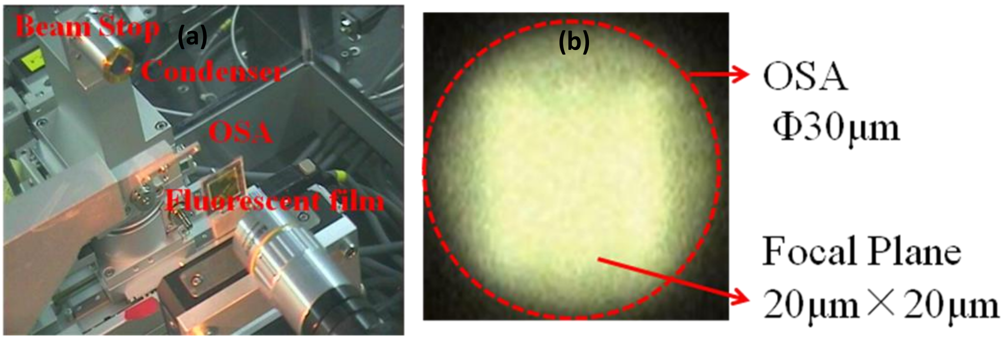

Fig 4. (a) The setup of the measurement and (b) the focal plane of the condenser.