

## Full Multilayer Laue Lens for Focusing Hard X-rays\*

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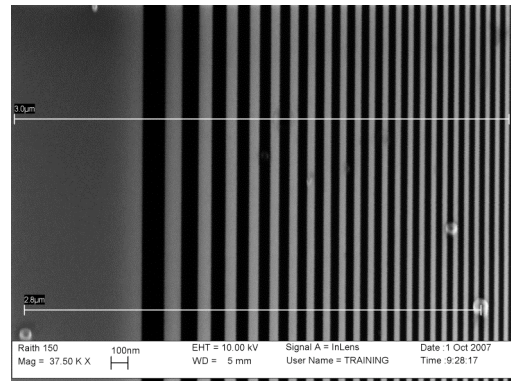
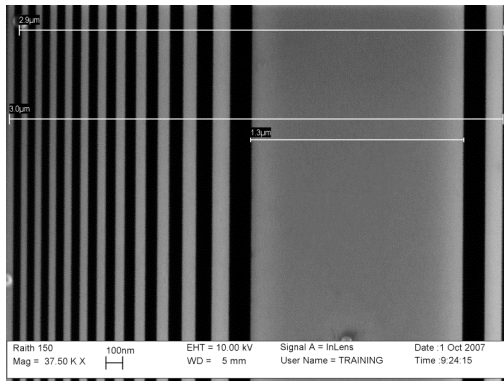
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Using partial multilayer Laue lens (MLL) linear zone-plate structures with thousands of alternating  $\text{WSi}_2$  and Si layers with thicknesses varying according to the Fresnel zone-plate formula, we have been able to focus hard x-rays to sizes as small as 16 nm [1, 2]. These partial MLLs consist of less than half of the zones in a complete linear zone-plate structure and have correspondingly smaller numerical aperture. In this study we investigate fabricating a complete linear MLL structure. The increased numerical aperture of a full MLL is expected to improve focusing. A full linear MLL can be fabricated by bonding two partial-structure-multilayer wafers using a precisely-thickness-controlled AuSn layer and heating in a vacuum oven at 280-300°C [3]. It can also be achieved by growing the whole structure using magnetron sputtering without bonding. A full structure with a total of 5166 layers of  $\text{WSi}_2$  and Si, with layer thicknesses gradually varying from 4 nm to ~400 nm and then from ~400 nm back to 4 nm, has been successfully fabricated. Two coatings were used to grow the full structure of ~40 microns, with each coating covering one half of the full structure. Each coating took over 56 h from start to finish. The sample was sliced and polished without cracking and SEM images demonstrate good contrast between  $\text{WSi}_2$  and Si layers down to 4 nm. Two center images are shown below. These results demonstrate the feasibility of a full linear MLL for focusing hard x-rays.



1. H. C. Kang, J. Maser, G. B. Stephenson, C. Liu, R. Conley, A. T. Macrander, and S. Vogt, "Nanometer focusing of hard x rays by a multilayer Laue lens," *Phys. Rev. Lett.* 96, 127401 (2006).
2. H. C. Kang et al., unpublished.
3. C. Liu, R. Conley, J. Qian, C. M. Kewish, A. T. Macrander, J. Maser, H. C. Kang, H. Yan, and G. B. Stephenson, "Bonded Multilayer Laue Lens for Focusing Hard X-rays," *Nucl. Instrum. Methods A* 582, 123 (2007).

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