Influence of the Groove Curvature on the Spectral Resolution in a Varied-line-spacing Plane Grating Monochromator (VLS-PGM)

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Abstract

Diffraction-limited synchrotron radiation (DLSR) light source with smaller source size and emittance makes ultra-high spectral resolution beamline possible. Here, we report an undulator-based beamline optical design with ultra-high spectral resolution using a varied-line-spacing plane grating monochromator (VLS-PGM), which is a well-proven design for achieving ultra-high resolution in the soft X-ray band. A VLS plane grating with a central groove density of 2400 l/mm is utilized to cover the photon energy region of 250 ~ 2000eV. VLS gratings are generally fabricated using the holographic method, but the resulting grating grooves are two-dimensionally curved curves, which can affect the resolution of the monochromator. To analyse this effect, we first use a spherical wavefront and an aspherical wavefront to generate the fringes and optimized the recording parameters. We also present a method for calculating the groove curvature of holographic plane VLS grating grooves. Furthermore, the influence of grating groove curvature on beamline resolution is theoretically analysed based on the aberration theory of concave grating.

Varied-line-spacing Plane Grating Monochromator Optical Design

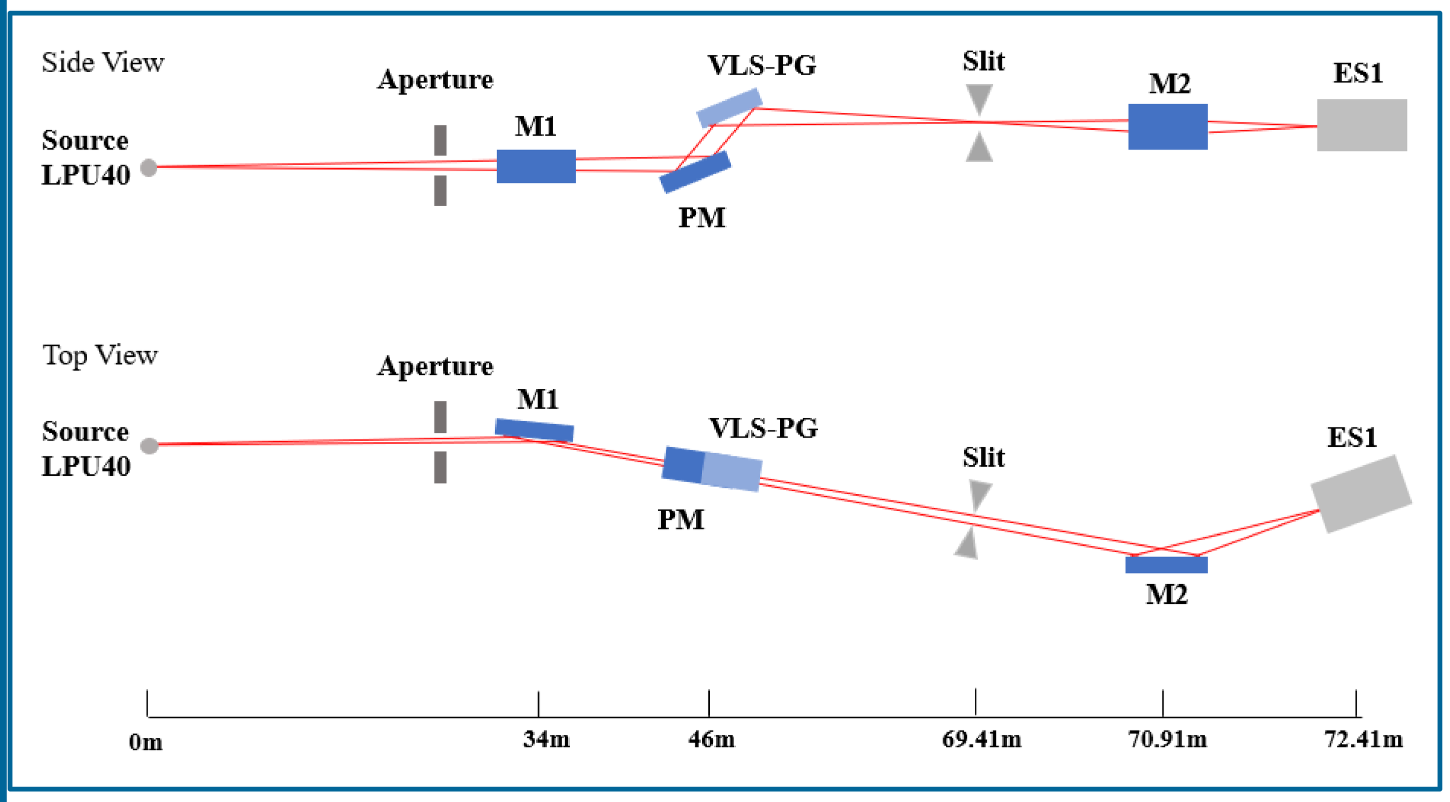

Fig.1 Undulator-based beamline optical design with ultra-high spectral resolving power.

- **Energy range: 250-2000eV**
- **Resolving power: 10^5@1000eV**
- **Varied-line-spacing plane grating monochromator (VLS-PGM)**

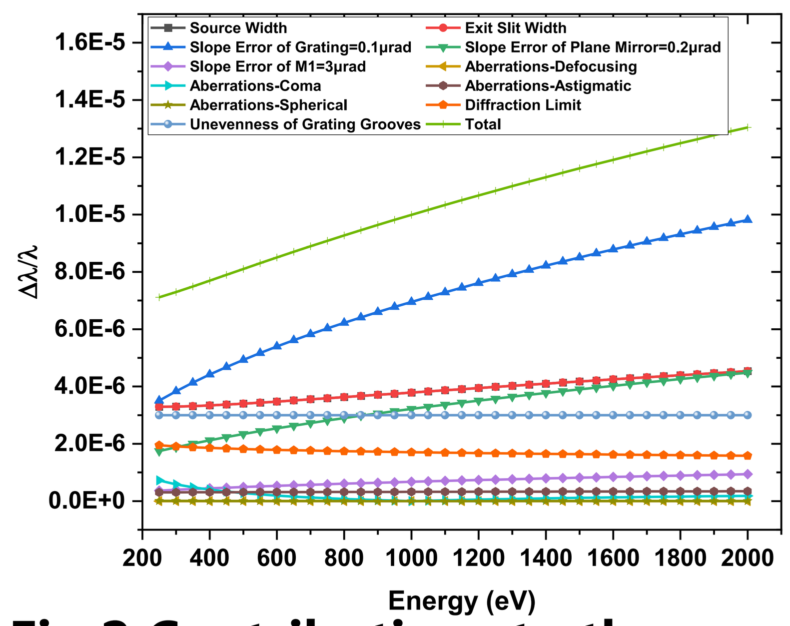

Fig.2 Contributions to the spectral broadening from different factors.

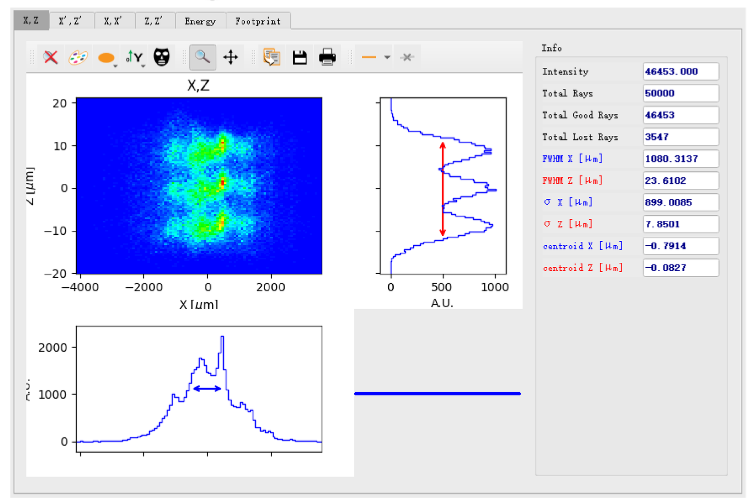

Fig.3 Ray-tracing result @ SHADOW Res.P= 10^5@1000eV.

Holographic Recording

The holographic recording method is used to fabricate the 2400l/mm VLS grating.

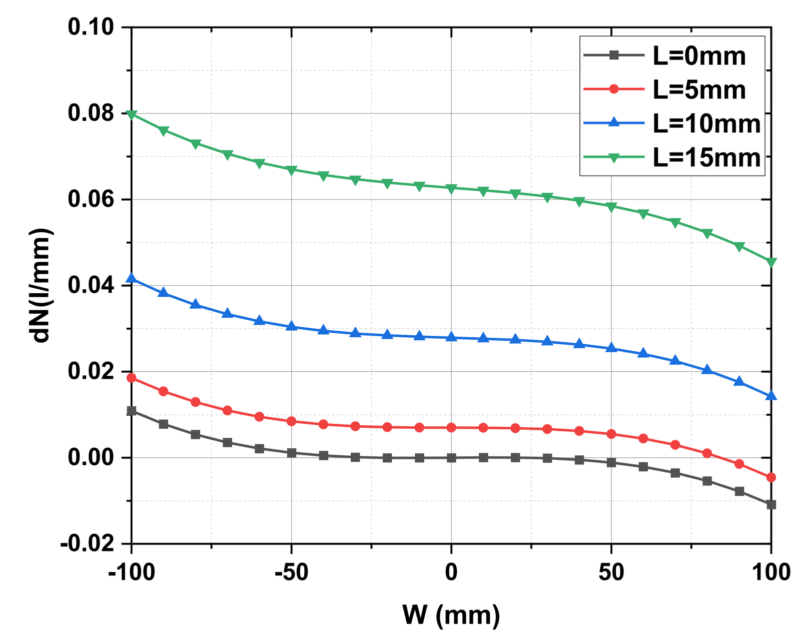

Fig.4 The dN error diagram between the optimized holographic grating and the target VLS grating along the W(grating Length) axis under different L (grating Width) widths.

Influence of Grating Groove Curvature on Beamline Resolution

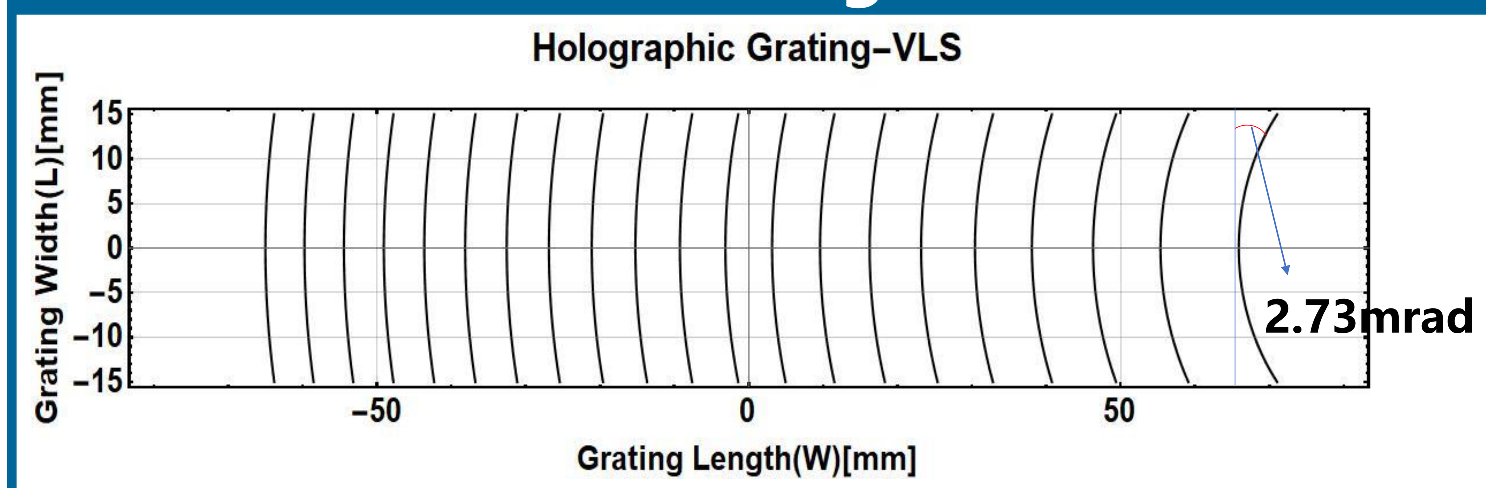

Fig.5 Since the VLS grating grooves fabricated by the holographic method are two-dimensional curved curves, the maximum groove curvature at the grating edge (90mm) is calculated to be 2.73mrad.

$$F = \langle AP \rangle + \langle PB \rangle + N(w,l) m\lambda$$

$$\frac{\partial F}{\partial w} = 0, \quad \frac{\partial F}{\partial l} = 0$$

$$\Delta\lambda = \sqrt{\Delta\lambda_M{}^2 + \Delta\lambda_G{}^2 + \Delta\lambda_A{}^2 + \Delta\lambda_N{}^2 + \Delta\lambda_D{}^2 + \Delta\lambda_{S1}{}^2 + \Delta\lambda_{S2}{}^2}$$

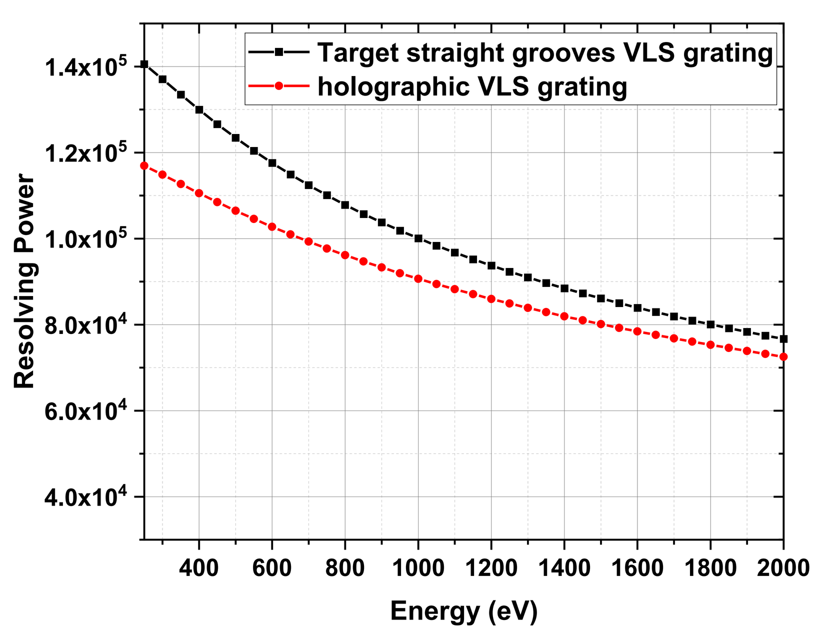

Fig.6 Variation of the beamline resolving power with photon energy.

According to the concave grating aberration theory, the influence of grating groove curvature on aberration is added when calculating the beamline resolving power.

Conclusion

In this work, we introduce an ultra-high resolution beamline optical design and the optimized design of the VLS grating holographic recording system.

We calculated the curvature of the grating grooves and the influence of holographic grating groove curvature on the beamline resolving power through concave grating aberration theory.

We theoretically analyzed the factors that contribute to the spectral broadening of the grating monochromator from the perspective of grating fabrication process.

References

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