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Supporting information for article:

Method of calculating the aberrations of soft X-ray and vacuum ultraviolet optical systems

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S1. Modification aberration coefficients due to the second-order accuracy of aperture ray and extrinsic aberration coefficients

$$\tilde{d}_{200} = -\Lambda_{m(2)} \cos \beta_2 \left(\frac{3dw_{300(1)}}{\cos \beta_1 \cos \alpha_2} - \frac{\phi_2}{A_l} \right), \quad (\text{A.1})$$

$$\tilde{d}_{020} = -\Lambda_{m(2)} \cos \beta_2 \left(\frac{dw_{120(1)}}{\cos \beta_1 \cos \alpha_2} - \phi_3 \right), \quad (\text{A.2})$$

$$\tilde{d}_{300} = \frac{6r'_0 \phi_2}{A_l^2 \cos \beta_2} \left(w_{300(2)} - A_l^3 w_{300(1)} \right) - \frac{18r'_0 dw_{300(1)} w_{300(2)}}{A_l \cos \beta_1 \cos \alpha_2 \cos \beta_2} + 2\Lambda_{m(2)} \sin \beta_2 \left(\frac{3dw_{300(1)}}{A_l \cos \beta_1 \cos \alpha_2} - \frac{\phi_2}{A_l^2} \right) \left(c_{2,0(2)} - \frac{\cos \beta_2}{r'_{m2}} \right), \quad (\text{A.3})$$

$$\begin{aligned} \tilde{d}_{120} = & \frac{2r'_0}{\cos \beta_2} \left[\frac{\phi_5}{B_l r'_{s1}} \left(A_l B_l^2 w_{120(1)} - w_{120(2)} \right) - A_l \phi_2 w_{120(1)} \right] + \frac{6r'_0 \phi_3 w_{300(2)}}{A_l \cos \beta_2} - \frac{4r'_0 dw_{120(1)} w_{120(2)}}{B_l \cos \beta_2} - \frac{6r'_0 dw_{120(1)} w_{300(2)}}{A_l \cos \beta_1 \cos \alpha_2 \cos \beta_2} \\ & + 2d\Lambda_{m(2)} \sin \beta_2 \left[\frac{2c_{0,2(2)}}{B_l} - \frac{1}{A_l \cos \beta_1 \cos \alpha_2} \left(\frac{\cos \beta_2}{r'_{m2}} - c_{2,0(2)} \right) \right] w_{120(1)} + 2\Lambda_{m(2)} \sin \beta_2 \left(\frac{\phi_5 c_{0,2(2)}}{B_l r'_{s1}} - \frac{\phi_3 c_{2,0(2)}}{A_l} \right) \\ & + \frac{\Lambda_{m(2)} \phi_3 \sin 2\beta_2}{A_l r'_{m2}}, \end{aligned} \quad (\text{A.4})$$

$$\tilde{d}_{011} = -\Lambda_{m(2)} \cos \beta_2 \left(\frac{dw_{111(1)}}{\cos \beta_1 \cos \alpha_2} - 2\phi_1 \right), \quad (\text{A.5})$$

$$\tilde{d}_{002} = -\frac{d\Lambda_{m(2)} \cos \beta_2 w_{102(1)}}{B_l^2 \cos \beta_1 \cos \alpha_2}, \quad (\text{A.6})$$

$$\begin{aligned} \tilde{d}_{111} = & \frac{2r'_0 \phi_4}{B_l \cos \beta_2} \left(A_l B_l^2 w_{120(1)} - w_{120(2)} \right) + \frac{12r'_0 \phi_1 w_{300(2)}}{A_l \cos \beta_2} + \frac{r'_0}{\cos \beta_2} \left[\frac{B_l \phi_5}{r'_{s1}} \left(A_l w_{111(1)} - w_{111(2)} \right) - 2A_l \phi_2 w_{111(1)} \right] \\ & - \frac{2r'_0 d}{B_l \cos \beta_2} \left(B_l^2 w_{120(1)} w_{111(2)} + w_{111(1)} w_{120(2)} \right) - \frac{6r'_0 dw_{111(1)} w_{300(2)}}{A_l \cos \beta_1 \cos \alpha_2 \cos \beta_2} + 4B_l d\Lambda_{m(2)} l_2 c_{0,2(2)} \sin \beta_2 w_{120(1)} \\ & + \frac{2d\Lambda_{m(2)} \sin \beta_2}{A_l} \left[\frac{A_l c_{0,2(2)}}{B_l} + \frac{1}{\cos \beta_1 \cos \alpha_2} \left(c_{2,0(2)} - \frac{\cos \beta_2}{r'_{m2}} \right) \right] w_{111(1)} - \frac{4\Lambda_{m(2)} \phi_1 \sin \beta_2}{A_l} \left(c_{2,0(2)} - \frac{\cos \beta_2}{r'_{m2}} \right) \\ & + 2\Lambda_{m(2)} c_{0,2(2)} \sin \beta_2 \left(\frac{B_l l_2 \phi_5}{r'_{s1}} + \frac{\phi_4}{B_l} \right), \end{aligned} \quad (\text{A.7})$$

$$\begin{aligned} \tilde{d}_{102} = & \frac{r'_0 B_l \phi_4}{\cos \beta_2} \left(A_l w_{111(1)} - w_{111(2)} \right) + 2B_l d\Lambda_{m(2)} l_2 c_{0,2(2)} \sin \beta_2 w_{111(1)} - \frac{2r'_0 A_l \phi_2 w_{102(1)}}{\cos \beta_2} - \frac{r'_0 B_l d}{\cos \beta_2} w_{111(1)} w_{111(2)} \\ & - \frac{6r'_0 dw_{102(1)} w_{300(2)}}{A_l \cos \beta_1 \cos \alpha_2 \cos \beta_2} + \frac{2d\Lambda_{m(2)} \sin \beta_2}{A_l \cos \beta_1 \cos \alpha_2} \left(c_{2,0(2)} - \frac{\cos \beta_2}{r'_{m2}} \right) w_{102(1)} + 2B_l \Lambda_{m(2)} \phi_4 l_2 c_{0,2(2)} \sin \beta_2, \end{aligned} \quad (\text{A.8})$$

$$\tilde{h}_{110} = \Lambda_{s(2)} \left(2dw_{120(1)} + \frac{\phi_5}{r'_{s1}} \right), \quad (\text{A.9})$$

$$\tilde{h}_{101} = \Lambda_{s(2)} \left(dw_{111(1)} + \phi_4 \right), \quad (\text{A.10})$$

$$\begin{aligned}\tilde{h}_{210} = & -\frac{2r'_0}{A_1} \left[\frac{\phi_5}{r'_{s1}} \left(A_1 B_1^2 w_{120(1)} - w_{120(2)} \right) + \frac{\phi_2 w_{120(2)}}{B_1} \right] + 6r'_0 A_1 B_1 \phi_3 w_{300(1)} + \frac{6r'_0 d}{B_1 \cos \beta_1 \cos \alpha_2} w_{300(1)} w_{120(2)} \\ & + \frac{4r'_0 d w_{120(1)} w_{120(2)}}{A_1} + \frac{d \Lambda_{s(2)} \sin \beta_2}{r'_{s2}} \left(\frac{2w_{120(1)}}{A_1} + \frac{3w_{300(1)}}{B_1 \cos \beta_1 \cos \alpha_2} \right) + \frac{\Lambda_{s(2)} \sin \beta_2}{A_1 B_1 r'_{s2}} \left(\frac{B_1 \phi_5}{r'_{s1}} - \phi_2 \right),\end{aligned}\quad (\text{A.11})$$

$$\tilde{h}_{030} = \frac{2r'_0 \phi_3}{B_1} \left(A_1 B_1^2 w_{120(1)} - w_{120(2)} \right) + \frac{2r'_0 d}{B_1 \cos \beta_1 \cos \alpha_2} w_{120(1)} w_{120(2)} + \frac{\Lambda_{s(2)} \sin \beta_2}{B_1 r'_{s2}} \left(\frac{dw_{120(1)}}{\cos \beta_1 \cos \alpha_2} - \phi_3 \right), \quad (\text{A.12})$$

$$\begin{aligned}\tilde{h}_{201} = & \frac{2r'_0 \phi_4 w_{120(2)}}{A_1} + 6r'_0 A_1 B_1 \phi_1 w_{300(1)} - r'_0 B_1 \left(\frac{B_1 \phi_5 w_{111(1)}}{r'_{s1}} + \frac{\phi_2 w_{111(2)}}{A_1} \right) + \frac{3r'_0 B_1 d w_{300(1)} w_{111(2)}}{\cos \beta_1 \cos \alpha_2} + \frac{2r'_0 d w_{111(1)} w_{120(2)}}{A_1} \\ & + \frac{3B_1 d \Lambda_{s(2)} \Lambda'_{l(2)} \sin \beta_2}{\cos \beta_1 \cos \alpha_2} w_{300(1)} + \frac{d \Lambda_{s(2)} \sin \beta_2}{A_1 r'_{s2}} w_{111(1)} + \frac{\Lambda_{s(2)} \sin \beta_2}{A_1} \left(\frac{\phi_4}{r'_{s2}} - B_1 \Lambda'_{l(2)} \phi_2 \right),\end{aligned}\quad (\text{A.13})$$

$$\begin{aligned}\tilde{h}_{021} = & \frac{2r'_0 \phi_1}{B_1} \left(A_1 B_1^2 w_{120(1)} - 2w_{120(2)} \right) + r'_0 B_1 \phi_3 \left(2A_1 w_{111(1)} - w_{111(2)} \right) + \frac{r'_0 d}{B_1} \left(B_1^2 w_{120(1)} w_{111(2)} + 2w_{111(1)} w_{120(2)} \right) \\ & + \frac{d \Lambda_{s(2)} \sin \beta_2}{B_1 \cos \beta_1 \cos \alpha_2} \left(B_1^2 \Lambda'_{l(2)} w_{120(1)} + \frac{w_{111(1)}}{r'_{s2}} \right) - \frac{\Lambda_{s(2)} \sin \beta_2}{B_1} \left(\frac{2\phi_1}{r'_{s2}} + B_1^2 \Lambda'_{l(2)} \phi_3 \right),\end{aligned}\quad (\text{A.14})$$

$$\begin{aligned}\tilde{h}_{012} = & 2r'_0 B_1 \phi_1 \left(A_1 w_{111(1)} - w_{111(2)} \right) + 2r'_0 A_1 B_1 \phi_3 w_{102(1)} + \frac{r'_0 d}{B_1 \cos \beta_1 \cos \alpha_2} \left(B_1^2 w_{111(1)} w_{111(2)} + 2w_{102(1)} w_{120(2)} \right) \\ & + \frac{d \Lambda_{s(2)} \sin \beta_2}{B_1 \cos \beta_1 \cos \alpha_2} \left(B_1^2 \Lambda'_{l(2)} w_{111(1)} + \frac{w_{102(1)}}{r'_{s2}} \right) - 2B_1 \Lambda_{s(2)} \Lambda'_{l(2)} \phi_1 \sin \beta_2,\end{aligned}\quad (\text{A.15})$$

$$\tilde{h}_{003} = 2r'_0 A_1 B_1 \phi_1 w_{102(1)} - 2B_1 r'_0 \phi_6 w_{111(2)} - \frac{r'_0 d w_{102(1)} w_{111(2)}}{B_1^2 \cos \beta_1 \cos \alpha_2} - \frac{d \Lambda_{s(2)} \Lambda'_{l(2)} \sin \beta_2 w_{102(1)}}{B_1^2 \cos \beta_1 \cos \alpha_2}, \quad (\text{A.16})$$