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Novel Passive Resonant Structures for Precision Assembly of Synchrotron X-ray Optics

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Many optics at synchrotron and free electron laser facilities need to be cooled to dissipate the heat imparted by the intense photon beams. For indirectly-cooled optics, distortion of the surface caused by excessive clamping forces during assembly, typically utilising Belleville washers with an inaccuracy of approximately 20%, can lead to significant distortion and defocussing of the X-ray beam [1,2]. To address this issue, it is necessary to monitor the effects of assembly and subsequent life cycle on the clamping forces applied to the crystal. In this paper, we present experimental verification of a non-contact approach to the monitoring of clamping forces utilising novel, additively manufactured passive resonant structures that can remain in-situ throughout an optics life cycle [3]. Two stainless steel 316L passive structures, based on a doubly curved hyperbolic paraboloid (z = xy), were incorporated as part of the first crystal assembly for the I20 monochromator at Diamond Light Source, as shown in Figure 1(a). Experimental work demonstrated the ability to monitor the clamping forces applied to the crystal throughout the assembly process by measuring the resonance of the passive structures. This monitoring process was also applied after a cryogenic thermal cycle. Laser doppler vibrometry revealed frequency shifts in the passive structures around 20-60 Hz after cryogenic cooling (see Figure 1(b)), which is indicative of a change in clamping force of up to approximately 25 %. These results were correlated with Fizeau interferometer measurements of the optical surface. The results also reveal a greater uniformity of the optical surface of the crystal for the novel approach when compared with conventional assembly, as depicted in Figure 1(c), noting the gap in the centre dur to heat exchangers. The novel approach outlined in this paper has the potential to significantly improve the accuracy to which beamline optics are assembled and, as a result, their subsequent performance on the beamline.

Figure 1 –Experimental validation of novel passive resonant structures, with (a) experimental set-up, (b) example frequency response shift before and after cooling and (c) example Fizeau interferometer measurements of the optical surface.

References

[1] E. V. Bainbridge, J. D. Griffiths, J. Clunan and P. Docker, Journal of Synchroton Radiation, vol. 29, 2022.
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I plan to submit also conference proceedings

Yes

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