CLS Optical Metrology Facility

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77

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Instrument	Measured Parameters
Long Trace Profilometer (LTP)	Figure Slope/Height Errors [line profile], Radius of Curvature
Zygo Verifire AT Fizeau Interferometer	Figure Height/Slope Errors [3D maps], Radius of Curvature
Micromap 570 Surface Profiler	Height map, Surface Roughness (Sq, Sa, St [Peak-to-valley])

Optical Metrology Facility

The CLS Optical Metrology Facility (OMF) determines the required beamline optical specifications through SHADOWVUI [1] modeling, and measures the quality of the optical components prior to beamline installation. An overview of the instrumentation available within the CLS OMF can be found in the literature [2-3] and on our website [4]. The OMF instrumentation is used to determine surface roughness, calibration of radius of curvature, figure height/slope errors and power spectral density (PSD) of optical surfaces that are used in x-ray, visible light, and infrared synchrotron beamlines. Figure, finish and mirror coating quality determines the photon flux density, focus characteristics and photon energy range delivered to the beamline experimental station. Larger than expected figure height/slope errors can result in an undesirable experimental focus, where photon flux, brightness and spot size have been compromised.

Metrology Hardware

Over the past year a major upgrade was initiated on the CLS LTP. This was driven by the need to measure two CLS beamline mirror bender mechanisms (CMCF2 and SXRMB beamlines) for slope error and to determine the radius of curvature as a function of bending force. Previously the height of these vertically deflecting mirror bender mechanisms was such that they would not fit underneath the initial CLS LTP configuration. A design that would allow for more vertical clearance between the LTP optical head and the optic to be tested was clearly necessary.

To achieve maximal height flexibility, a design was engineered to achieve the following requirements and constraints:

1. Mirror bender mechanisms up to 500 mm in height should be measurable.

2. A more robust and solid support of the LTP main beam was necessary to ensure sub-microradian stability.

3. A continuous height adjustment scheme was initially contemplated, but eventually dismissed due to concerns of meeting the criteria of overall levelness of the two sides to <1 mrad. A discrete adjustment system that meets this overall levelness criteria and allows for adjustment to within 15 mm steps over the required range was eventually selected.

4. If possible, the design should minimize alignment issues of the reference mirror to the reference light beam with a change in LTP main beam height.

5. In order to reduce the effects from air convection currents, an external enclosure is required that is decoupled from the LTP and vibration isolation table. Operations of the LTP should be directly viewable and accessible from the front. Front access doors will therefore be necessary, as well as clear plastic sheets on the exterior of this external structure.

6. Due to weight and safety considerations of the LTP main beam, the design should use mechanical advantage to adjust the beam, in such a fashion that a single person can safely perform this function.

The design used extruded aluminum beams from MK Profile [5] to build a rigid support system for the main LTP beam and for the isolated enclosure surrounding the LTP+ vibration isolation table. The surrounding enclosure is isolated from the vibration isolation table to which the LTP main beam and support is mounted, through a small clearance gap. Three support legs for the isolated enclosure are mounted to the floor, with the fourth support being the back wall.

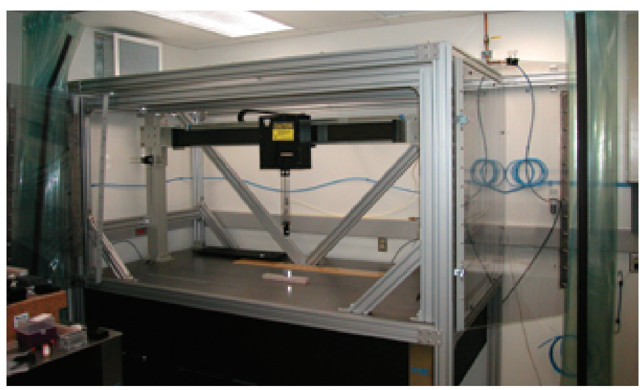

Figure 1 A front view of the upgraded CLS Long Trace Profilometer (front doors open), showing the adjustable height adjustment, rigid support of the main LTP beam, and an external decoupled enclosure to minimize air current effects.

Figure 1 shows an overview of the external isolated enclosure surrounding the vibration isolation table and rigid support system for the main LTP beam. The two hinged doors (shown open for clarity) are normally closed under operating conditions once the optical component under test has been maneuvered inside. Clear polycarbonate sheets (0.25" thickness) were used to enclose the top and side panels of the external isolated enclosure, using BUNA-N rubber grommets for additional vibration isolation.

A more detailed view of the rigid support structure for the main LTP beam can be seen in Figure 2. A worm gear hand winch can be used manually to lift loads up to 2000 pounds using a 3/16" stainless steel braided cable. The hand winch employs a 41:1 gear ratio so that a single person can lift the LTP beam up or down to the desired discrete position on the aluminum towers. The worm gear is of a "no back drive" design. Two cables are employed on the worm gear – one to raise the right portion of the LTP beam (through a short cable and anchor shackle/eyebolt), the other to simultaneously raise the left portion of the LTP beam (through a longer cable, turnbuckle, and similar anchor shackle/ eyebolt). The turnbuckle allows the tension of the two cables to be adjusted until they are the same. Typically the entire worm gear mechanism and cables are removed once the appropriate height for the LTP main beam has been achieved and locked down.

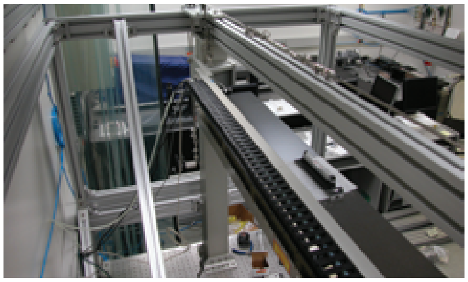

Figure 2 A back view of the upgraded CLS Long Trace Profilometer showing the rigid support structure for the main LTP beam. Note that this picture was taken before the external decoupled enclosure was assembled. The worm gear hand winch (middle-middle portion) and wire/pulley system (middle-top portion) that can be used to raise or lower the main LTP beam to the desired height above a test optic.

Figure 3 A front view of the left tower support structure showing the wire/pulley system and anchor shackle/eyebolt that can be used to raise or lower the main LTP beam. Also visible are the precision drilled holes in the tower (15 mm spacing over a range of 510 mm) to which the height can be adjusted, and the lever/expanding pin that is used to align and level both sides to better than 1 mrad, before lock-down.

Figure 3 shows a blowup of the left aluminum tower that supports the left portion of the LTP main beam. The aluminum towers are precision machined from solid aluminum (6061-T6) 4"x4" bar. Thirty five precisely drilled holes in each aluminum tower allow for the height of the LTP main beam to be adjusted over a total range of 510 mm, to within the nearest 15 mm. The expanding pin shown in Figure 3 (left bottom) is used to align both sides of the LTP main beam to the same height, to better than 1 mrad levelness. Once level the two bolts beside the expanding pin are tightened to lock the LTP main beam down, and the expanding pin removed. The reference mirror is rigidly mounted on a plate that is attached to this same plate to which the expanding pin clamps down on – as a result the reference mirror is mounted fixed relative to the LTP main beam, thereby minimizing adjustment of the reference mirror with a change in the LTP main beam height.

The next step in the LTP upgrade is to replace the current aluminum LTP main beam from New Way (~79 microradian RMS straightness), with a superior ceramic beam from Coorstek (< 5 microradians RMS straightness).

Over the past year or so we have initiated an international collaboration with the Advanced Light Source Metrology Laboratory, primarily through contacts with Dr. Wayne McKinney and Dr. Valeriy Yaschuk. Certain common goals have been identified, namely how best to achieve nano-radian figure slope errors with the LTP and metrology software standardization and improvement. Our group has contributed to improvements in their "Virtual Metrology Lab" software, by rewriting some of the existing IDL code to include the latest IDL iTools data visualization and analysis platform. A standard protocol has been developed in this software package to compute the power spectral density (PSD) of surface roughness data collected by the Micromap 3D surface profiler. Modulation transfer function corrections for differences between the X and Y readouts of the CCD detector used in this common surface profiler is critical in determining proper sagittal and tangential PSD's [6]. Future improvements will extend this package to include PSD analysis (in both height and slope spaces) of LTP and Fizeau Interferometer slope and height data, data cropping and dropout/ spike manipulation, data filtering and standardized figure removal (i.e. piston, tilt, power (curvature), twist).

References

1. M. Sanchez del Rio, R.J. Dejus, SPIE Proc. 5536, 171-174 (2004).

2. Brian W. Yates and Dylan G. Maxwell, "Canadian Light Source: Optical Metrology Facility", Can. J. Chem. 85, 685-659 (2007).

3. Brian Yates, Dylan Maxwell, Siyue Chen, and Bruce Truax, "The Canadian Light Source Optical Metrology Facility", Nucl. Instr. And Meth. A 582, 146-148 (2007).

4. CLS Optical Metrology Facility Web Site Link: http://ex.lightsource.ca/oml/

5. MK is the copyright for Maschinebau Kitz. MK2040.52 Aluminum beam was used. See http://www.mkprofiles.co.uk/

6. Valeriy V. Yaschuk, Andrew D. Franck, Steve C. Irick, Malcolm R. Howells, Alastair A. MacDowell and Wayne R. McKinney, "Two dimensional power spectral density measurements of X-ray optics with the Micromap interferometric microscope", SPIE Proc. 5858, 85-96 (2005).

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