Long Trace Profilometer Specification

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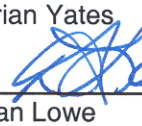
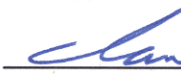
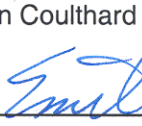
Canadian Light Source Inc.
101 Perimeter Road
University of Saskatchewan
Saskatoon, Saskatchewan Canada

	Signature	Date
Author	Brian Yates Brian Yates	August 16, 2002
Reviewer #1	 Dan Lowe	16 Aug 2002
Reviewer #2	 Ian Coulthard	2002-08-16
Approver	 Emil Hallin	2002-08-16

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REVISION HISTORY

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A	July 24, 2002	Original Draft	Brian Yates
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1.0 INTRODUCTION

1.1 PURPOSE

An optical metrology laboratory will be set up at the Canadian Light Source, Inc. (CLS) to characterize the figure and the finish of the beamline optics. This document contains the technical specification for the Long Trace Profilometer (LTP) within this facility.

1.2 SCOPE

This document specifies the requirements for the CLS Optical Metrology Laboratory Long Trace Profilometer. This work includes, but is not limited to:

- Materials
- Equipment
- Function and Performance Requirements
- Fabrication
- Assembly
- Testing & Inspections
- QA/QC documentation
- Delivery to the CLS site
- Assistance in setting up the Long Trace Profilometer at CLS

1.3 BACKGROUND

The Canadian Light Source is a national scientific research facility under construction at the University of Saskatchewan campus in Saskatoon, Saskatchewan, Canada. The CLS is a 3rd generation synchrotron light source, that will house a variety of scientific beamlines and their associated optics. This synchrotron facility will be a high intensity source of infrared, visible, ultraviolet, and x-ray radiation.

The CLS optics metrology laboratory shall be dedicated to optical surface characterizations in terms of figure, slope errors, and surface roughness. Measurements are generally carried out on the optical surface in non-contact mode, using optical instruments. The beamline mirrors will range in size from ~0.025m to 1.5m in length, and consist of a variety of substrate materials (i.e. Zerodur® glass ceramic, ultra low expansion glass ceramic- ULE®, fused silica, silicon, silicon carbide, Glidcop®) and reflection coatings (rhodium, platinum, gold, nickel, graphite, or none). These optical elements can be quite large and

heavy. A typical “long” mirror made of copper alloy may be 1.5 m x 100 mm x 100 mm in dimension, and weigh approximately 134 kg.

In general the optics will be either planar or concave/convex aspherics, including cylinders, spheres, elliptical cylinders, ellipsoids, toroids, parabaloids and hyperboloids. Many of the mirrors will contain mirror-bending mechanisms, to vary the focus somewhat. The radii of curvature currently vary from ~35mm for some of the toroidal mirrors (sagittal direction) to several kilometers for the cylindrical or toroidal mirrors (tangential direction). Since many of the mirrors will be used in the x-ray regions, state of the art slope errors will be required, often below 1 μrad rms. Surface roughness is also critical in the x-ray region, so that most mirrors will require smaller than 2 Å rms surface roughness. Some ultra-smooth mirrors will fall below an average surface roughness of even 1 Å rms.

2.0 REQUIREMENTS

The CLS optical metrology laboratory requires a complete “stand-alone” long trace profilometer to measure the absolute slope profile and absolute radius of curvature of the surface under test, from which the slope error can be determined. Surfaces up to 1.5m in length will be measured in the facility, with a lateral resolution on the order of 1 mm. An accuracy of less than 1.0 μrad rms in slope error will be required in general. Non-contact measurements are to be performed in the same orientation as mounted in the beamline – i.e. horizontal deflecting optical elements (left/right) and vertical deflecting optical elements (up/down), in order to avoid errors introduced from estimating the contributions from gravity.

2.1 FUNCTION

2.1.1 A complete “stand-alone” long trace profilometer system is to be supplied. This should include the translation stage with limit switches, laser beam source and optical interconnects, beam optics including reference, {servo,stepper}-motors and associated controllers/encoders, power supplies, computer, and software for control of the LTP and for data analysis. The only exception to this is a vibration isolation table, which the CLS will supply (See the section titled “Vibration and Acoustic Noise”). If possible, a series of reference standards for instrument calibration should be provided, as well as additional attachments and optics to allow measurement of test surfaces in horizontal deflection (left/right) and vertical deflection (down) geometries.

2.1.2 The long trace profilometer system must be capable of measuring via non-contact the absolute slope profile and absolute radius of curvature of the surface under test, from which the slope error can be determined. Surfaces up to 1.5 m in length will be measured in the facility, with a

lateral resolution on the order of 1 mm. Non-contact measurements are to be performed in the same orientation as mounted in the beamline – i.e. horizontal deflecting optical elements (left/right) and vertical deflecting optical elements (up/down), in order to eliminate errors from estimating gravity contributions.

2.1.3 The long trace profilometer must be capable of measuring the following test optics: planar and concave/convex aspherics, including cylinders, spheres, elliptical cylinders, ellipsoids, toroids, paraboloids and hyperboloids. The radii of curvature currently vary from ~35mm for some of the toroidal mirrors (sagittal direction) to several kilometers for the cylindrical or toroidal mirrors (tangential direction). In addition, many of the mirrors will contain mirror-bending mechanisms, to vary the focus by varying the radius of curvature slightly. Measurement of state of the art slope errors will be required, below 1 μrad rms.

2.1.4 The long trace profilometer system must be able to correct for the real-time probe beam angular errors during the traverse of the linear beam, without the need for a calibrated external reference standard. Such variations in the probe beam pointing direction are to be measured, so that they can be subtracted from the test surface slope. This is necessary to determine the absolute slope profile and measure the absolute radius of curvature of the surface under test.

2.1.5 The manufacturer shall provide the computer hardware and software required for the operation of the long trace profilometer. A minimal computer system would include a Pentium III CPU (or higher), 17" colour monitor, CD drive (preferably-RW), ethernet network card, and preferably the Microsoft Windows 2000 Professional operating system. Since the instrument will be located in a Class 10000 cleanroom, the system should be capable of printing to a network printer. The ethernet network card should be configured for DHCP. Should the control software require an alternate operating system, our preferences are secondly Microsoft Windows NT, or thirdly Microsoft Windows 98. We request that the manufacturer state what permission the control system software requires (i.e. administrator, power user, user, restricted user)- our preference is for user or restricted user, so that a user cannot accidently delete system files or alter configurations.

2.1.6 The software supplied by the manufacturer for controlling the long trace profilometer should allow the user to rapidly align the probe and reference beams to the test surface and detector. This is best accomplished with graphical feedback on the computer monitor as the user makes the necessary adjustments. Fully customizable scanning and motor control is required, as are functions to "find" the test optic and set up the scan range. Signal to Noise (S/N) enhancement of the signal by either signal averaging or Fourier filtering should be available. So called "scripting", whereby the user can memorize steps in a measurement process for a specific test optic, and save this to a library for later use, would be an

invaluable tool for test optic measurements, and should be available in the software.

2.2 PERFORMANCE

The long trace profilometer belongs to the class of "slope-measuring" interferometer rather than "height-measuring" interferometer. It measures the phase difference between two collinear probe beams as they move across the test optical surface. Slope information of the test optical surface is obtained along the scanned line direction, and by integration, its figure can be obtained.

The following is a summary of the desired performance specification requirements for the LTP:

Table 1: Long Trace Profilometer Performance Specifications

Scan Length	up to 1500 mm
Scan Velocity	Should be capable of attaining 3 mm/sec (assuming nominal 1 mm sampling step, 1 measurement taken for each sample).
Position Accuracy	0.5 μm
Slope Accuracy	< 1 μrad rms
Expected slope "noise floor"	≤ 0.1 μrad
Height Accuracy[1]	< 50 nm
Slope Measurement Range	≥ ± 5 mrad
Lateral Resolution	~ 1 mm
Radius of curvature	Current applications are ~0.035-10^4 m radius of curvature, and should be measurable on the long trace profilometer.

[1] The height accuracy is a reflection of the underlying slope accuracy of the test optic and the length over which the integration is performed. For a flat mirror of 100 mm length, and 0.4 μrad slope accuracy, one should measure a height accuracy of ~2.5 nm.
For a flat mirror of 500 mm length, and 0.7 μrad slope accuracy, one should measure a height accuracy of ~15 nm.

2.3 SAFETY AND ENVIRONMENTAL

2.3.1 Hardware limit switches should be placed at each end of the bench, in order to prevent a run-away condition, and damage to the optical test element. This must be done in hardware- i.e. once either limit switch has been engaged, power should be removed from the {servo,stepper}-motor

or controller, so as to prevent any further movement until the system has been "reset". Software programmable limit switches should be included in the control software, however the hardware limit switches shall always have precedence over these software limit switches.

2.3.2 The temperature in the Optical Metrology Laboratory Facility will be 23^{o}C ± 1^{o}C. The normal relative humidity is expected to vary between 20% and 55%.

2.4 APPLICABLE CODES, STANDARDS AND PROCEDURES

The manufacturer shall comply with the codes, standards, and procedures for the CLS[1], or identify in the quotation how they deviate.

2.5 QUALITY ASSURANCE

The manufacturer shall maintain and apply a quality assurance program compliant with ISO-9001 for the design, manufacture and testing of the equipment.

2.6 INSPECTION, TESTING AND COMMISSIONING

2.6.1 The manufacturer shall propose an acceptance test to verify the performance specification requirements listed in Table 1. The acceptance test and the test equipment used shall be reviewed and accepted by CLS.

2.6.2 The acceptance test will take place at the manufacturer's plant before shipment, and then repeated after the long trace profilometer has been installed at CLS. The manufacturer is responsible for setting up, commissioning and acceptance testing the long trace profilometer at the CLS with the assistance of CLS personnel.

2.7 RELIABILITY AND MAINTAINABILITY

The manufacturer shall provide hard copies of an operating and maintenance manual for the long trace profilometer, including electrical drawings/wiring diagrams and AutoCAD drawings, as outlined in the CLS documentation specification[2]. Hard copies[2] of a spare parts list should be provided, with the manufacturer part numbers and current prices. The manufacturer shall also provide hard copies[2] of a detailed parts list, with original manufacturer's part number, name, address, and telephone number. An electronic version of these manuals, diagrams, drawings, and spare/detailed parts lists are to be provided on CD-ROM (in addition to the hard copies). All manuals, documentation and lists are to be written in English. In addition, software source code for the control program (if available) should be included on the CD-ROM. The original third party component manuals (i.e. computer, {servo,stepping}-motors and controllers/encoders, power supplies, HeNe laser source, CCD array detector, etc.) should also be supplied.

2.8 VIBRATION AND ACOUSTIC NOISE

2.8.1 The vibrations in the main floor of the CLS hall have amplitudes in the sub-micrometer range, and should not affect the measurements. CLS will supply a vibration isolation table for the long trace profilometer. The manufacturer shall state any special requirements that might be required for the vibration isolation table, to mount the long trace profilometer.

2.8.2 The long trace profilometer should be designed and fabricated to be relatively insensitive to vibrations and other environmental influences such as temperature and relative humidity. An "equal-path interferometer" design would be highly desirable, since this will minimize such effects, as would an extremely rigid (yet light) construction for the linear beam/support/optical head.

2.9 SERVICES

2.9.1 The manufacturer shall state the detailed requirements for all services (for example- water [purity, pressure range, flow rate, recommended temperature range], pressurized air [purity and recommended filter equipment, pressure range], electrical services, etc.), needed for the operation of the long trace profilometer. Pressurized air, if required, shall not exceed 80 psi.

2.9.2 The electrical services available are 120 V AC and 208 V AC, 60 Hz. The manufacturer shall state the electrical services needed, including the power and current requirements for each voltage needed. CLS would prefer 120 V AC, 60 Hz service if possible.

2.10 OTHER REQUIREMENTS AND CONSTRAINTS

2.10.1 All documentation to the CLS shall be in English and conform to the CLS documentation specification [2].

2.10.2 The shipping containers shall be properly labeled in English to ensure proper care during shipment.

2.10.3 Crates shall be designed such that they can be moved using standard handling devices (forklift or pallet jack).

2.10.4 Tolerances and specifications, where not defined or difficult to achieve, are subject to negotiations.

3.0 REFERENCES

1 E. Matias, "Control System Technical Specification", 7.4.39.1 Rev. 2, April 24, 2002.

2 D.S. Lowe, "CLS Documentation Specification", 0.4.1.1 Rev. 2, December 14, 2000.