



Optic Measurement Analysis and Visualization using ROOT as a General Framework

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*Canadian Centre canadien
Light de rayonnement
Source synchrotron*



CLS Optical Metrology Lab



Purpose: To ensure quality of Synchrotron optics prior to their installation into a beamline. Radius of Curvature, Slope Error and Surface Roughness can be measured using the three main measurement instruments.

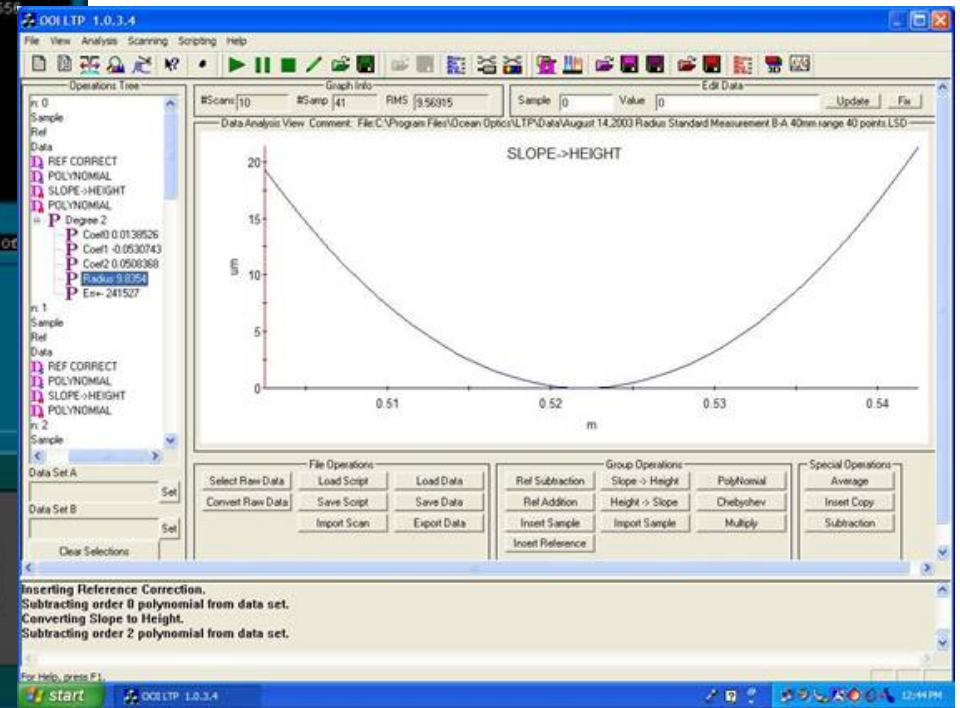
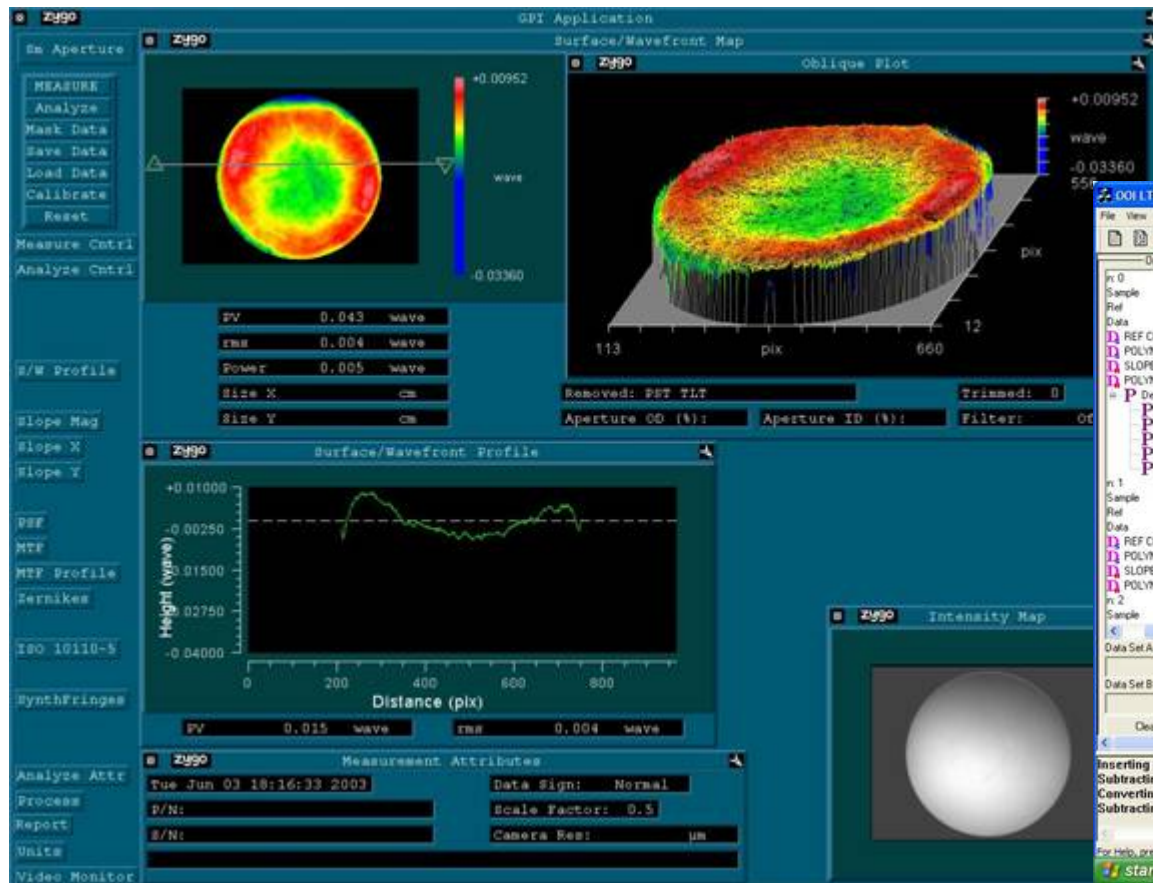
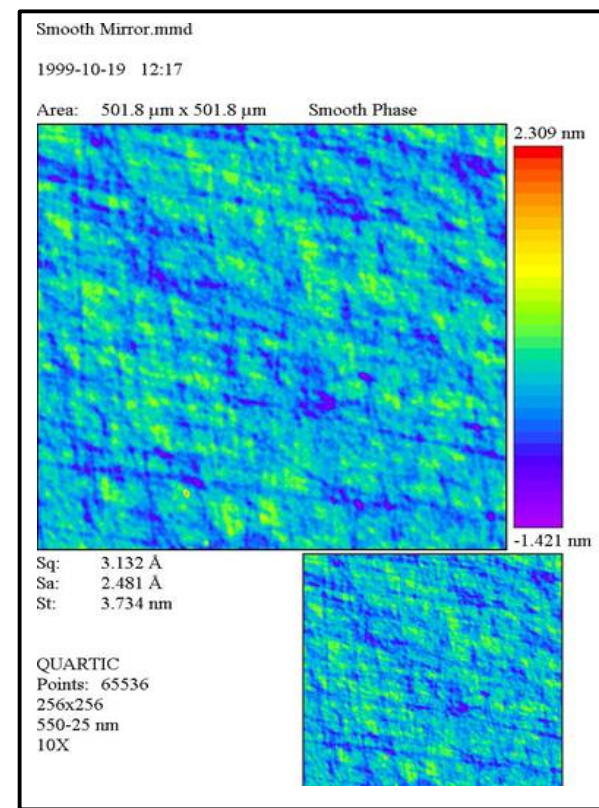
CLS Optical Metrology Lab



Three Main Commercial Instruments:

- 1) Micromap 3D Surface Profiler from Micromap Corp.
- 2) Long Trace Profilometer from Ocean Optics Inc.
- 3) Fizeau Interferometer from Zygo Corp.

Problem: Three data analysis packages that are not designed for synchrotron applications or do not have an important feature. They cannot be modified or extended because they are commercial closed-source programs.



Project Goals

1. Analyse data from the three metrology instruments.
2. Display the results in a comprehensive format.
3. Print the results for easy report generation.
4. Organize both data and results for easy retrieval.
5. Easy to use graphical interface.

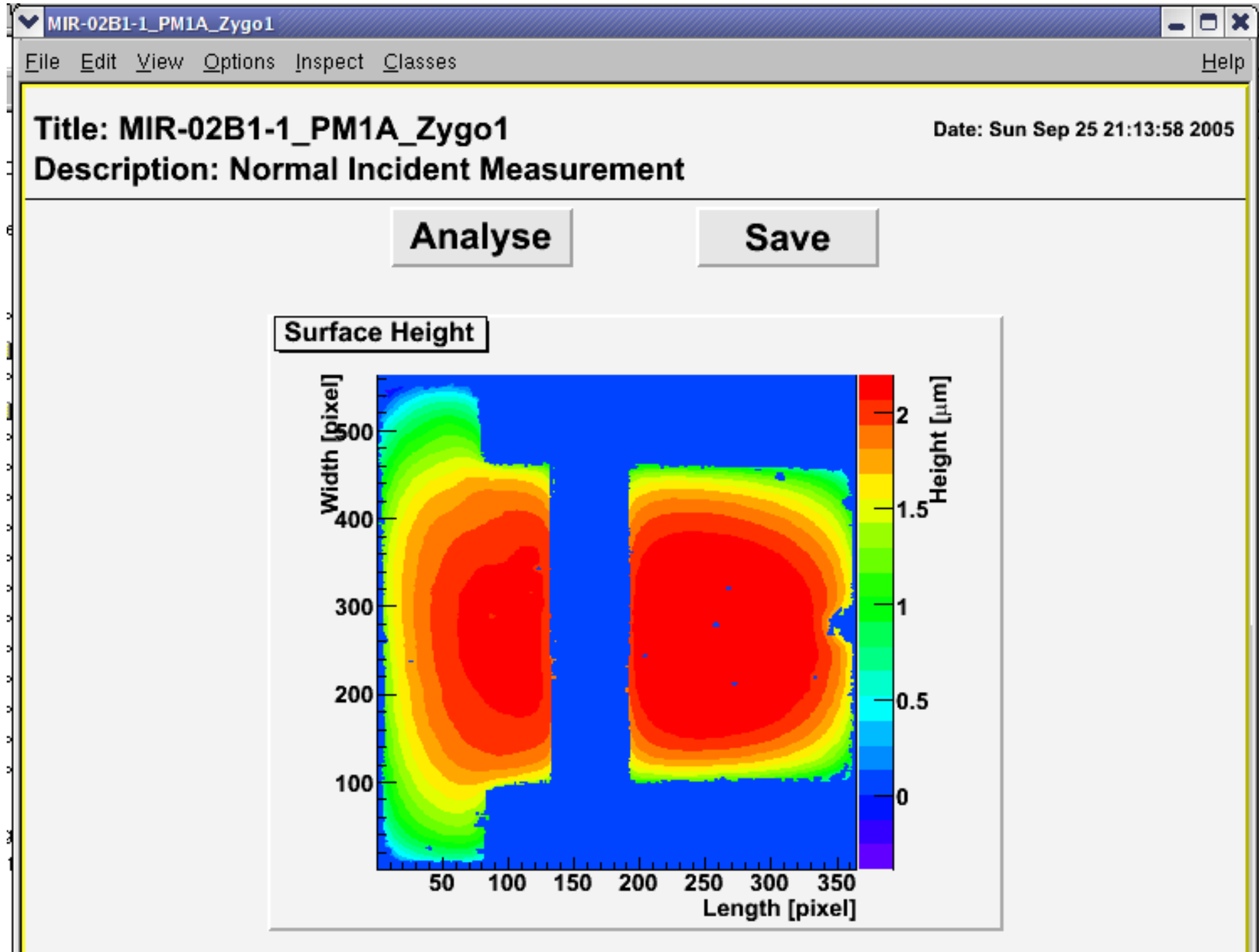
TAnalysisCanvasCLS

```
TAnalysisCanvasCLS : public TCanvas {  
    protected:  
        TRef fDataDir;  
  
    public:  
        TAnalysisCanvasCLS();  
        TAnalysisCanvasCLS(name, title,  
datadir);  
        ~TAnalysisCanvasCLS()  
        TDirectory* GetDataDir();  
        void Store();  
        virtual void Analyse();  
};
```


TAnalyseButtonCLS & TStoreButtonCLS

- Inherits from TButton.
- TAnalyseButtonCLS executes the Analyse() function.
- TStoreButtonCLS executes the Store() function.

TAnalysisCanvasCLS Example

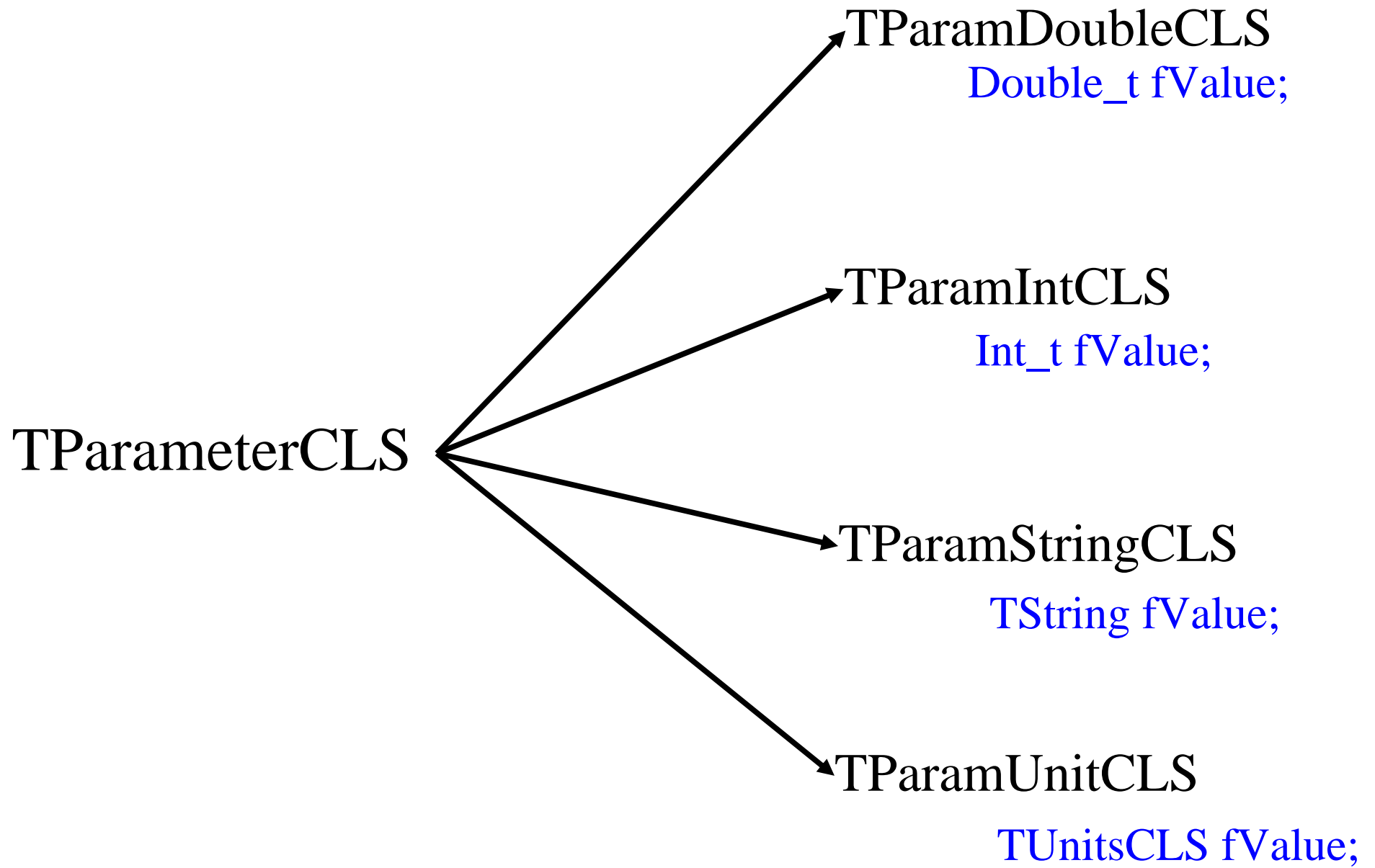


TParameterCLS

```
TParameterCLS : public TLatex {  
    protected:  
        TString fPrefix;  
        TString fSuffix;  
    public:  
        TParameterCLS();  
        TParameterCLS(name, prefix,  
suffix);  
        ~TParameterCLS()  
        DrawParam(x, y, size, align);  
};
```

TParamDoubleCLS

```
TParamDoubleCLS : public TParameter {  
    protected:  
        Double_t fValue;  
        TUnitsCLS fUnit;  
  
    public:  
        TParamDoubleCLS();  
        TParamDoubleCLS(name, value, unit, ...);  
        ~TParamDoubleCLS()  
  
        Double_t GetValue();  
        void SetValue(Double_t v); /*MENU*  
  
};
```

TUnitsCLS

- Contains an array of “known” units.
- Text and Latex names.
- Conversion factor and a 7-byte signature.
- Each byte is the exponent of 1 base SI unit.
- Custom units can be created using '*=' and '/=' operators.

TUnitsCLS

	Meter	Kilogram	Second	Ampere	Candela	Mole	Kelvin	Factor
m	1	0	0	0	0	0	0	1.0
mm	1	0	0	0	0	0	0	0.001
mile	1	0	0	0	0	0	0	1608
N	1	1	-2	0	0	0	0	1.0
J	2	1	-2	0	0	0	0	1.0
erg	2	1	-2	0	0	0	0	1.0E-7

TOpticMetrologyCLS

The image shows a ROOT Object Browser window with a file tree on the left and a table of contents on the right. A dialog box titled "OpticMetrology" is overlaid on the right side, displaying a welcome message and a "Browse" button.

ROOT Object Browser
File View Options Help

OpticMeasurement

All Folders

- root
- PROOF Sessions
- /mnt/dmz/common/Code/cpp/roo
- ROOT Files
 - OpticMeasurements.root
 - FIR-01 B1-1
 - EM2
 - LTP 1
 - LTPData
 - LTP 2
 - LTPData
 - LTP 3
 - LTP 4
 - LTP 5
 - LTP 6
 - LTP 7
 - LTP 8
 - LTP 9
 - LTP 10
 - LTP 11
 - LTP 12
 - LTP 13
 - LTP 14
 - PM4
 - Zygo1
 - MIR-02B1-1
 - CM6
 - CM7
 - PM1 A
 - PM1 B
 - CM 10ID 1

Contents of "/ROOT Files/OpticMeasurements.root"

Name	Title
FIR-01 B1-1	Far Infrared Beamline 01 B1-1
MIR-02B1-1	Mid Infrared Beamline 02B1-1
OpticMetrology;1	CLS Optical Metrology
SM-10ID-1	Spectromicroscopy 10ID-1

OpticMetrology
File Edit View Options Inspect Classes Help

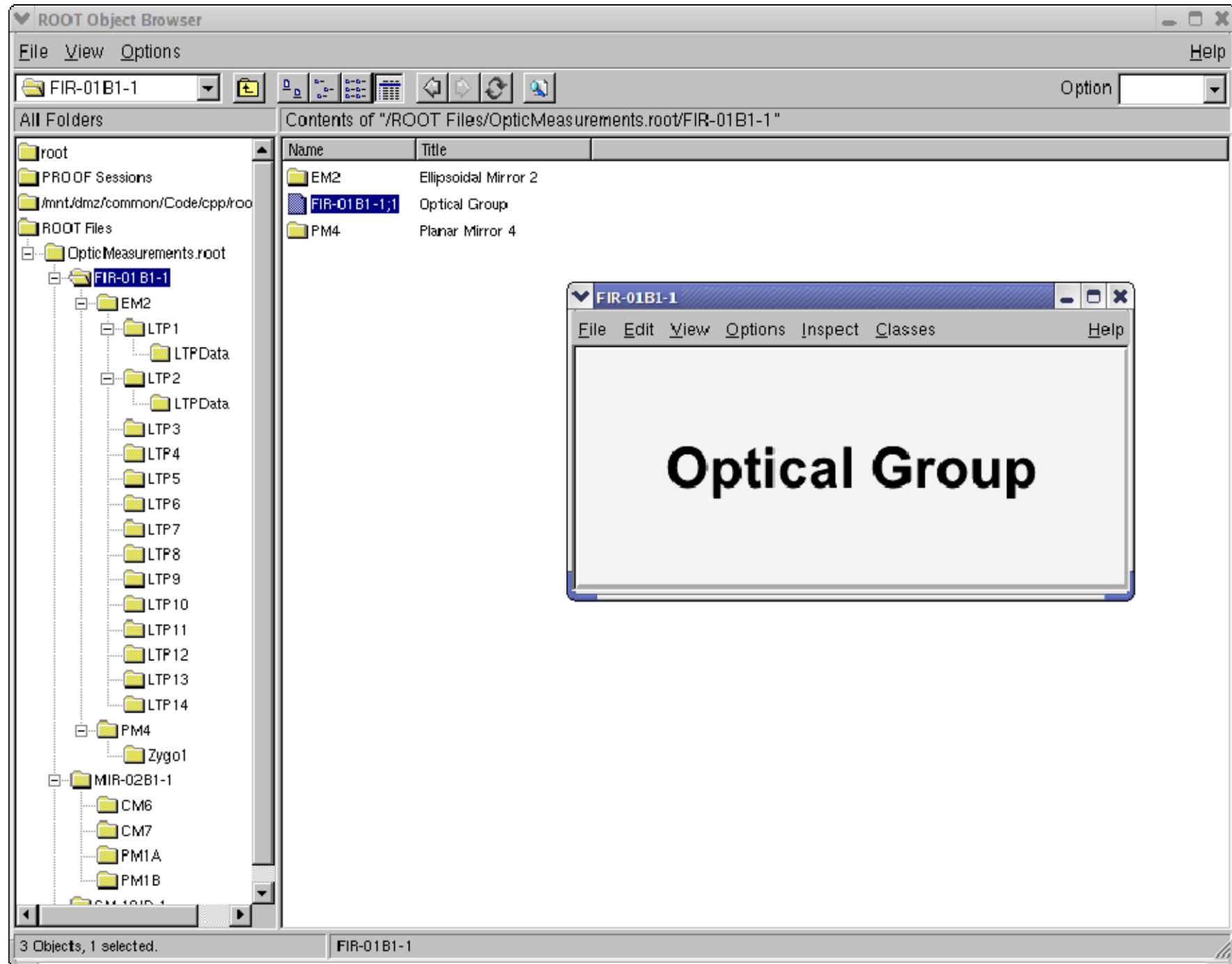
Welcome to the
Canadian Light Source, Inc.
Optical Metrology Lab

Data Analyser and Viewer

Browse

4 Objects, 1 selected.

TOpticGroupCLS



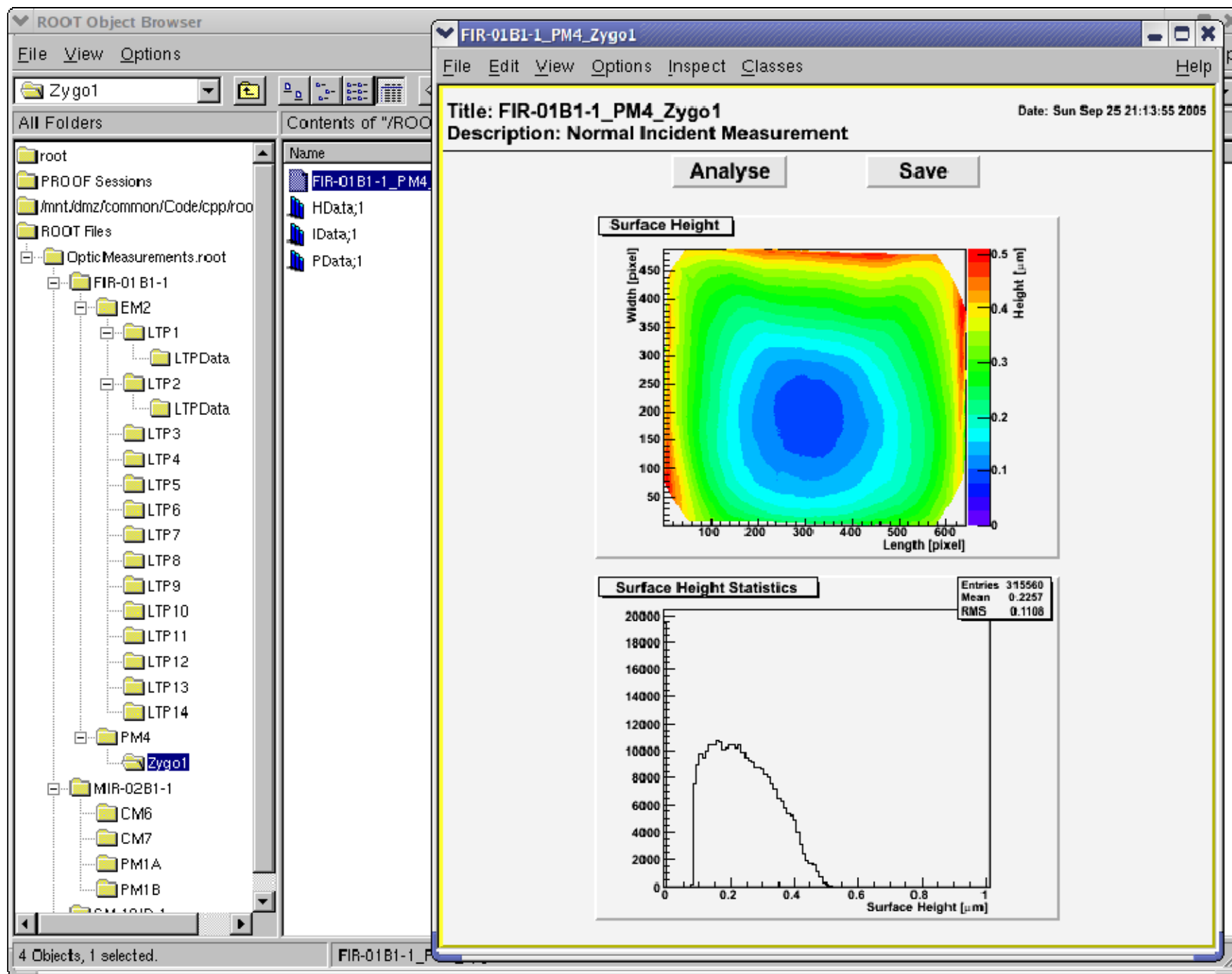
TOpticElementCLS

The screenshot shows the ROOT Object Browser interface. The left pane displays a tree view of folders, with 'EM2' selected under 'FIR-01B1-1'. The right pane shows the contents of the selected folder as a table:

Name	Title
FIR-01B1-1_EM2;1	Optical Element
LTP1	LTP Measurement
LTP10	LTP Measurement
LTP11	LTP Measurement
LTP12	LTP Measurement
LTP13	LTP Measurement
LTP14	LTP Measurement
LTP2	LTP Measurement
LTP3	LTP Measurement
LTP4	LTP Measurement
LTP5	LTP Measurement
LTP6	LTP Measurement
LTP7	LTP Measurement
LTP8	LTP Measurement
LTP9	LTP Measurement

A pop-up window titled 'FIR-01B1-1_EM2' is open, displaying the text 'Optical Element' in a large font. The status bar at the bottom indicates '15 Objects, 1 selected.' and the current folder is 'FIR-01B1-1_EM2'.

TOpticZygoDataCLS



TOpticLTPDataCLS

The screenshot displays the TOpticLTPDataCLS software interface. On the left is the 'ROOT Object Browser' showing a hierarchical tree of folders. The main window is titled 'FIR-01B1-1_EM2_LTP1' and contains several data analysis plots and parameters.

ROOT Object Browser:

- File View Options
- LTP1
- All Folders
- root
- PROOF Sessions
- /mnt/dmz/common/Code/cpp/roo
- ROOT Files
- OpticMeasurements.root
 - FIR-01 B1-1
 - EM2
 - LTP1 (selected)
 - LTP2
 - LTP3
 - LTP4
 - LTP5
 - LTP6
 - LTP7
 - LTP8
 - LTP9
 - LTP10
 - LTP11
 - LTP12
 - LTP13
 - LTP14
 - PM4
 - Zygo1
 - MIR-02B1-1
 - CM6
 - CM7
 - PM1A
 - PM1B

Main Window: FIR-01B1-1_EM2_LTP1

File Edit View Options Inspect Classes Help

Title: FIR-01B1-1_EM2_LTP1 Date: Sun Sep 25 21:13:52 2005

Description: Sagittal Centerline - 20mm - 3Scans

Analyse Scan: 0 (Scan 0 is Average, Total 3 Scans)
Correction Sign: 0 (Addition>0, Subtraction<0, Auto=0)
Fit in: Slope (Options: Slope or Height) **Analyse**
Remove Figure: Tilt (Options: None, Piston, Tilt or Curvature) **Save**
Source Distance: 0 m (Required for Ellipse Only)
Image Distance: 0 m (Required for Ellipse Only)
Incident Angle: 0° (Required for Ellipse Only)
Position Unit: m Slope Unit: rad Height Unit: mm

Corrected Slope Data:

Fit to: A
A: 0.0091393 rad ± 0.21822 rad

Slope RMS: 0.0041822 rad
Slope Mean: 4.1303e-19 rad
Height RMS: 0.011292 mm
Height Mean: -0.021864 mm

Residual Slope Data:

Residual Slope Histogram:

Residual Height Data:

Residual Height Histogram:

3 Objects, 1 selected. FIR-01B1-1_EM2_LTP1

TOpticLTPDataCLS

FIR-01B1-1_EM2_LTP1

File Edit View Options Inspect Classes Help

Title: FIR-01B1-1_EM2_LTP1 Date: Sun Sep 25 21:13:52 2005

Description: Sagittal Centerline - 20mm - 3Scans

Analyse Scan: 0 (Scan 0 is Average, Total 3 Scans)
Correction Sign: 0 (Addition>0, Subtraction<0, Auto=0)
Fit in: Slope (Options: Slope or Height)
Remove Figure: Tilt (Options: None, Piston, Tilt or Curvature)
Source Distance: 0 m (Required for Ellipse Only)
Image Distance: 0 m (Required for Ellipse Only)
Incident Angle: 0 ° (Required for Ellipse Only)

Position Unit: m Slope Unit: rad Height Unit: mm

Analyse
Save

Corrected Slope Data

The plot shows a series of data points (asterisks) that follow a linear upward trend. The x-axis is labeled 'Position [m]' and ranges from 0.88 to 0.9. The y-axis is labeled 'Slope [rad]' and ranges from 0.002 to 0.016. A horizontal green line is drawn across the plot at approximately y = 0.009, representing a fit to the data.

Position [m]	Slope [rad]
0.881	0.0022
0.882	0.0030
0.883	0.0038
0.884	0.0045
0.885	0.0052
0.886	0.0060
0.887	0.0068
0.888	0.0075
0.889	0.0082
0.890	0.0090
0.891	0.0098
0.892	0.0105
0.893	0.0112
0.894	0.0120
0.895	0.0128
0.896	0.0135
0.897	0.0142
0.898	0.0150
0.899	0.0158

Fit to: A
A: 0.0091393 rad ± 0.21822 rad

Slope RMS: 0.0041822 rad
Slope Mean: 4.1303e-19 rad
Height RMS: 0.011292 mm
Height Mean: -0.021864 mm

TOpticLTPDataCLS

Object Browser

▼ FIR-01B1-1_EM2_LTP1

File Edit View Options Inspect Classes Help

Title: FIR-01B1-1_EM2_LTP1 Date: Sun Sep 25 22:11:59 2005

Description: Sagittal Centerline - 20mm - 3Scans

Analyse Scan: 0 (Scan 0 is Average, Total 3 Scans)
Correction Sign: 0 (Addition>0, Subtraction<0, Auto=0)
Fit in: Slope (Options: Slope or Height)
Remove Figure: Tilt (Options: None, Piston, Tilt or Curvature)

Source Distance: 0 m (Required for Ellipse Class)
Image Distance: 0 m (Required for Ellipse Or
Incident Angle: 0 ° (Required for Ellipse Only)

Position Unit: m Slope Unit: μ rad

Analyse

Save

Corrected Slope Data

Parameter	Value
TPParamStringCLS::remove	
SetValue	
SetSuffix	
SetPrefix	
SetText	
SetX	
SetY	
SetName	
SetTitle	
Delete	
DrawClass	
DrawClone	
Dump	
Inspect	
SetDrawOption	
SetTextAttributes	

$\pm 0.21822 \mu$ rad

ad
2 μ rad
mm
4 mm

TOpticLTPDataCLS

FIR-01B1-1_EM2_LTP1

File Edit View Options Inspect Classes Help

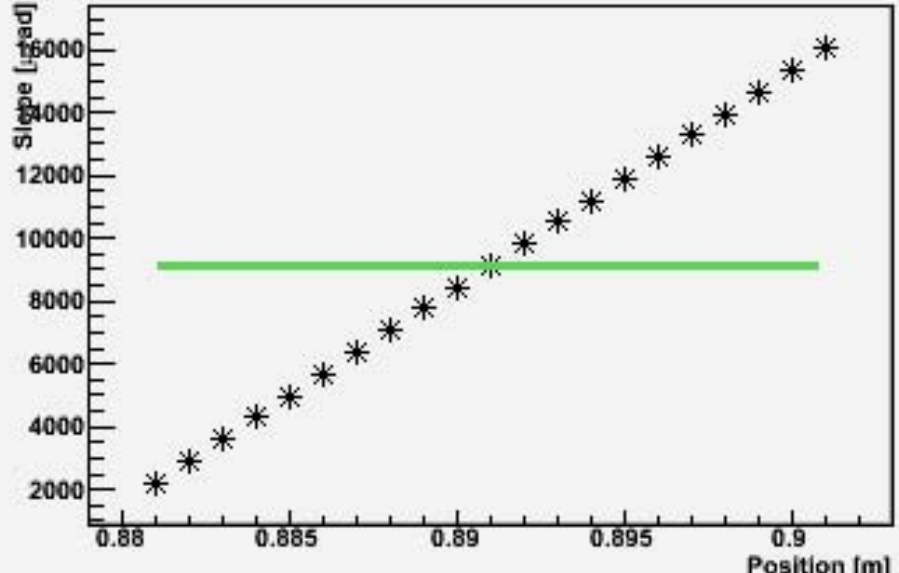
Title: FIR-01B1-1_EM2_LTP1 Date: Sun Sep 25 22:11:59 2005

Description: Sagittal Centerline - 20mm - 3Scans

Analyse Scan: 0 (Scan 0 is Average, Total 3 Scans)
Correction Sign: 0 (Addition>0, Subtraction<0, Auto=0)
Fit in: Slope (Options: Slope or Height)
Remove Figure: Tilt (Options: None, Piston, Tilt or Curvature)
Source Distance: 0 m (Required for Ellipse Only)
Image Distance: 0 m (Required for Ellipse Only)
Incident Angle: 0 ° (Required for Ellipse Only)

Position Unit: m Slope Unit: μrad Height Unit: mm

Corrected Slope Data



Position [m]	Slope [μrad]
0.882	2000
0.883	3000
0.884	4000
0.885	5000
0.886	6000
0.887	7000
0.888	8000
0.889	9000
0.890	10000
0.891	11000
0.892	12000
0.893	13000
0.894	14000
0.895	15000
0.896	16000
0.897	17000
0.898	18000
0.899	19000
0.900	20000

Fit to: A

▼ TParamStringCLS::SetValue
(const Char_t*) value
Curvature
OK Cancel

Slope RMS: 4182.2 μrad
Slope Mean: 1.5158e-12 μrad
Height RMS: 0.011292 mm
Height Mean: -0.021864 mm

TOpticLTPDataCLS

FIR-01B1-1_EM2_LTP1 - □ ×

File Edit View Options Inspect Classes Help

Title: FIR-01B1-1_EM2_LTP1 Date: Sun Sep 25 22:37:46 2005

Description: Sagittal Centerline - 20mm - 3Scans

Analyse Scan: 0 (Scan 0 is Average, Total 3 Scans)
Correction Sign: 0 (Addition>0, Subtraction<0, Auto=0)
Fit in: Slope (Options: Slope or Height)
Remove Figure: Curvature (Options: None, Piston, Tilt or Curvature)
Source Distance: 0 m (Required for Ellipse Only)
Image Distance: 0 m (Required for Ellipse Only)
Incident Angle: 0 ° (Required for Ellipse Only)

Position Unit: m Slope Unit: μrad Height Unit: mm

Analyse

Save

Corrected Slope Data

Position [m]	Slope [μrad]
0.881	2200
0.882	3000
0.883	3800
0.884	4500
0.885	5200
0.886	6000
0.887	6800
0.888	7500
0.889	8200
0.890	9000
0.891	9800
0.892	10500
0.893	11200
0.894	11800
0.895	12500
0.896	13200
0.897	13800
0.898	14500
0.899	15200
0.900	16000

Fit to: A
A: 9139.3 μrad $\pm 0.21822 \mu\text{rad}$

Slope RMS: 4182.2 μrad
Slope Mean: 1.5158e-12 μrad
Height RMS: 0.011292 mm
Height Mean: -0.021864 mm

TOpticLTPDataCLS

FIR-01B1-1_EM2_LTP1

File Edit View Options Inspect Classes Help

Title: FIR-01B1-1_EM2_LTP1 Date: Sun Sep 25 22:37:46 2005

Description: Sagittal Centerline - 20mm - 3Scans

Analyse Scan: 0 (Scan 0 is Average, Total 3 Scans)
Correction Sign: 0 (Addition>0, Subtraction<0, Auto=0)
Fit in: Slope (Options: Slope or Height)
Remove Figure: Curvature (Options: None, Piston, Tilt or Curvature)
Source Distance: 0 m (Required for Ellipse Only)
Image Distance: 0 m (Required for Ellipse Only)
Incident Angle: 0 ° (Required for Ellipse Only)
Position Unit: m Slope Unit: μrad Height Unit: mm

Analyse
Save

Corrected Slope Data

The plot shows a series of data points (asterisks) that follow a linear upward trend. A solid green horizontal line is drawn across the plot, representing a fit to the data. The y-axis is labeled 'Slope [μrad]' and ranges from 0 to 16000. The x-axis is labeled 'Position [m]' and ranges from 0.88 to 0.895.

Fit to: A
A: 9139.3 μrad $\pm 0.21822 \mu\text{rad}$

TDataLTPScanCLS::fit

- SetSlopeUnit
- SetHeightUnit
- SetPositionUnit
- GetSampleData
- GetReferenceData
- GetCorrectedAdd
- GetCorrectedSub
- GetCorrectedAuto
- SetShowUnits

2.2 μrad
158e-12 μrad
11292 mm
021864 mm

TOpticLTPDataCLS

The screenshot displays the TOpticLTPDataCLS software interface. On the left is the 'ROOT Object Browser' showing a hierarchical file structure. The main window on the right is titled 'FIR-01B1-1_EM2_LTP1' and contains analysis data for a 'Sagittal Centerline - 20mm - 3Scans'.

ROOT Object Browser:

- File View Options
- LTP1
- All Folders
- Contents of "/ROOT File
- root
- PROOF Sessions
- /mnt/dmz/common/Code/cpp/root
- ROOT Files
- OpticMeasurements.root
 - FIR-01B1-1
 - EM2
 - LTP1 (selected)
 - LTP2
 - LTP3
 - LTP4
 - LTP5
 - LTP6
 - LTP7
 - LTP8
 - LTP9
 - LTP10
 - LTP11
 - LTP12
 - LTP13
 - LTP14
 - PM4
 - Zygo
 - MIR-02B1-1
 - CM6
 - CM7
 - PM1A
 - PM1B

Main Analysis Window (FIR-01B1-1_EM2_LTP1):

Title: FIR-01B1-1_EM2_LTP1
Date: Sun Sep 25 22:16:10 2005
Description: Sagittal Centerline - 20mm - 3Scans

Analyse Scan: 0 (Scan 0 is Average, Total 3 Scans)
Correction Sign: 0 (Addition>0, Subtraction<0, Auto=0)
Fit in: Slope (Options: Slope or Height)
Remove Figure: Curvature (Options: None, Piston, Tilt or Curvature)
Source Distance: 0 m (Required for Ellipse Only)
Image Distance: 0 m (Required for Ellipse Only)
Incident Angle: 0 ° (Required for Ellipse Only)
Position Unit: m Slope Unit: μrad Height Unit: mm

Corrected Slope Data:

Fit to: $A + Bx$
A: $-6.0679 \times 10^5 \mu\text{rad}$ $\pm 32.108 \mu\text{rad}$
B: $6.9061 \times 10^5 (\mu\text{rad})/\text{m}$ $\pm 36.035 (\mu\text{rad})/\text{m}$
Radius: 1.448 m $\pm 0.724 \text{ m}$

Slope RMS: 6.8028 μrad
Slope Mean: 3.861e-11 μrad
Height RMS: 1.871e-05 mm
Height Mean: 4.447e-06 mm

Residual Slope Data:

Residual Slope Histogram:

Residual Height Data:

Residual Height Histogram:

6 Objects. FIR-01B1-1_EM2_LTP1

Summary

TAnalysisCanvasCLS

- “Smart” Canvas
- Knows where to Find the Data
- Knows how to Analyse and Display the Data

TParameterCLS

- Used for Input or Output
- Displayed on Canvas or Browser

TUnitsCLS

- Units Conversion
- Build Custom Units



Thanks



Brian Yates
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