MRO Delay Line

Prototype Trolley Test Results

INT-406-VEN-0109

The Cambridge Delay Line Team

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Change Record

Revision	Date	Author(s)	Changes
0.1	2008-01-16	MF	Outline version
0.2	2008-01-21	MF	Re-organised and more material added
0.3	2008-02-03	MF	Incorporating test results
0.4	2008-02-04	MF	Incorporated test setup descriptions
0.5	2008-02-07	MF	Incorporating test results, updating verification tables
0.6	2008-02-08	MF	Incorporation of latest test results
1.0	2008-02-08	MF	Appended graphical test results

Objective

This document presents the results of performance tests conducted on the prototype delay line trolley in the test rig established in the COAST facility at Lords Bridge and shows how they relate to the derived requirements placed on the system.

Scope

The tests results presented address the performance of the trolley and shear camera systems, the layout of the metrology system and the VME interface providing the closed loop position feedback. They do not specifically test the metrology laser or the proposed design for the launch/return optics.

While some test results are obtained by direct measurement of a particular parameter the principal tests involving the OPD performance must meet a number of pass criteria simultaneously. For these tests the test criteria are established and explained and the test results presented in a tabulated form with examples of the graphical output where appropriate.

This document also shows how the test list is related to the derived requirements and also presents a performance verification matrix to show how the derived requirements have been verified either by test, design, analysis or inspection.

Reference Documents

RD1 Top-level requirements INT-406-TSP-0002

RD2 Results of the Risk Reduction Experiments Rev. 1.0, 6th December 2005

RD3 Workstation Software Functional Description INT-406-VEN-0103

Applicable Documents

AD01 Derived Requirements INT-406-VEN-0107

AD02 List of Tests INT-406-VEN-0108

Acronyms and Abbreviations

BCA Beam Combining Area

BCF Beam Combining Facility

BRS Beam Relay System

COAST Cambridge Optical Aperture Synthesis Telescope

DL Delay Line

DLA Delay Line Area

ICD Interface Control Document

ICS Interferometer Control System (now SCS)

MROI Magdalena Ridge Observatory Interferometer

MRAO Mullard Radio Astronomy Observatory

NMT New Mexico Tech

OPD Optical Path Delay

SCS Supervisory Control System

TBC To be confirmed

TBD To be determined

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1 Introduction

The performance tests of the prototype trolley have mostly been conducted in the test rig which has been installed in the COAST facility at Lords Bridge near Cambridge. Some tests have been conducted in the test track set up in the Cavendish Laboratory.

The tests were initially carried out with the test rig at atmospheric pressure. A subset of these tests is to be carried out in vacuum soon.

The tests have been designed to verify the performance of the prototype trolley and to show that the Top Level Requirements (RD1) and the Derived Requirements (AD01) have been met in a 20m test rig. Some requirements cannot be tested without access to the full 200m delay line together with science beam feeds but where possible tests are arranged so that the results can be scaled to 200m.

The list of prototype tests is contained in a separate document (AD02).

The first section of this document briefly describes the test arrangements. The second section shows how the tests are related to the derived requirements. A detailed report of the test results are presented in section 3 which tabulates results in the various categories and presents the graphical output of a sample of test results.

1.1 The test facilities

The trolley was developed and tested in a special open track at the optics lab at the Cavendish Laboratory and then shipped to the COAST facility, where a 20m delay line test rig was erected, for final testing. This test rig is longer so that slew tests can be undertaken and it can also be evacuated to test thermal conditions on the trolley.

1.1.1 The Test Track at the Cavendish Lab

The test track is made up of a section of 16 inch pipe (used for the risk reduction experiments) which was split down its length to make a semi-circular trough of about 20 feet in length. The trough, or test track, is supported on adjustable feet on top of a series of benches. A laser metrology system with beam expander/compressor is arranged to send the expanded beam down the test track and receive the returning beam which, after compression is directed to the interferometer with a small percentage diverted to the shear sensing system. See Figure 1. A photograph of the test track is shown in Figure 2.

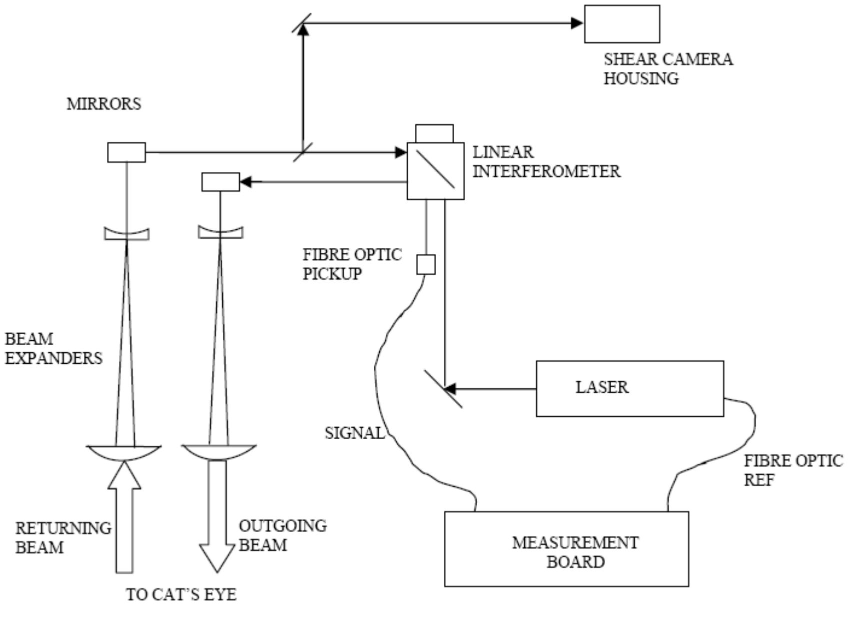


Figure 1: The test track laser metrology arrangement

Figure 2: The trolley in the test track with the laser metrology system in the foreground

1.1.2 The Test Rig at the COAST facility

The test rig erected in the COAST facility is made up from five 12 foot length of pipes with a 2 foot pipe section at each end. This gives an operating length of just over sixteen metres after buffers, limits and datum are taken into account. The height of the test rig is slightly shorter than the design developed for MROI because of height restrictions. There are other minor differences in the design of the pipe supports and the anchor method but the essential characteristics of the test rig are the same. A test rig based on the MROI design is expected to be built on the NMT Campus for acceptance testing.

The metrology system is set up on a small optical table which is supported by a framework at the correct height for the metrology entrance windows into the test rig. A space of approximately 3m exists between the metrology table and the near end of the test rig pipe to allow the trolley to be loaded into or removed from the pipe. A photograph of the test rig is shown in Figure 3. The metrology layout for the test rig, see Figure 4, uses the same components and is laid out in a similar fashion to the test track in the laboratory.

Figure 3: Test rig at the COAST facility at Lords Bridge

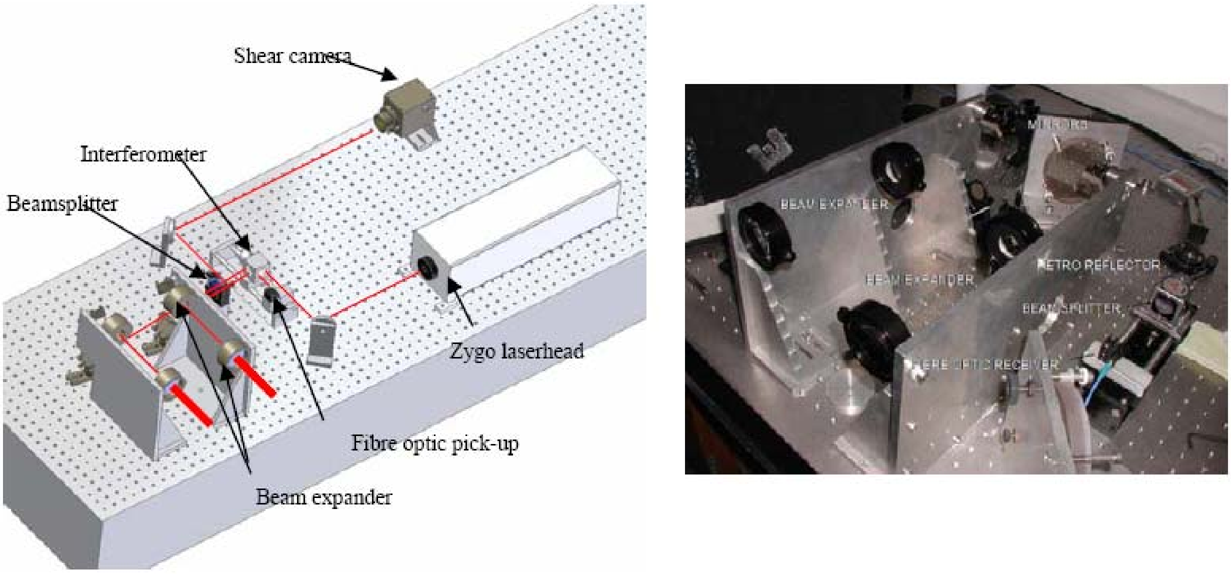


Figure 4: Metrology arrangement for the test rig at COAST

2 Relationship of Tests to Requirements

The requirements to be tested fall into two categories: the top-level requirements that impinge on the performance of the delay line and the derived requirements which are directly concerned with the performance of subsystems in the delay line. The relationship of these requirements to the tests to be conducted is described in the following tables.

2.1 Top Level Requirements

Req. No.	Requirement Description	Test Ref. (AD02)	Description
	Delay precision		
	Intra-night repeatability of <10µm rms	2.1.5.2 5.1.2.3	Acquire datum 10 times from different starting positions: at, near, far. Repeat datum throughout 8 hrs.
	Inter-night repeatability of <100µm rms	2.1.5.3	Acquire datum the following day.
	Slew speed		
	Slew 15m in less than 30s	2.1.1.2	
	Slew from any position to any other position in less than 5 min	2.1.1.2	Calculate from a single slew test
	Sidereal tracking and Jitter		
	Jitter shall be <λ/40 in 2t_o: For trolley speeds up to 15mm/s For accelerations up to 2.5µm/s	2.1.2 2.1.3	Test tracking at constant accelerations Test reversing direction while tracking
	Dynamic tracking of atmospheric fluctuations: <30ms for steps up to 10µm	2.1.4	Test response to fringe tracking offsets

2.2 Derived Requirements

The derived requirements, AD01, that are to be verified by test are listed in the following tables. Each table is based on the grouping of requirements which appear in the derived requirements and the first column in the tables relates to the subsection of that document. The second column is a very brief description of the requirement. The third column is a reference to the test which is specified in the List of Tests, AD02, and the fourth column is a very brief description of the test.

2.2.1 Cat's Eye Requirements

Req. No.	Requirement Description	Test Ref. (AD02)	Test Description
2.1.2	**Secondary Mirror**		
2.1.2.2	Tip/Tilt range [±3.9mrad]	2.1.4 test 4	Test range available
2.1.2.3	Tip/Tilt slew rate [4.7mrad/sec each axis]	2.1.4 test 5	Test slew rate
2.1.3	**Focus Stage**		
2.1.3.1	Focus resolution [20µm]	2.1.6 test 1	Test minimum repeatable focus step
2.1.3.2	Focus drift [5µm]	TBD	Test focus change with temperature

2.2.2 Voice coil drive tests

Req. No.	Requirement Description	Test Ref. (AD02)	Test Description
2.3.1	Peak drive current [9A]	2.1.7 test 1	Stopping by actuation of the pre-limit
3.1	Bandwidth [100 Hz minimum]	TBC	Lab test during tuning

2.2.3 Trolley Tests

Req. No.	Requirement Description	Test Ref. (AD02)	Description
2.2.1	Slew speed [0.7m/s]	2.1.1 test 2	16m slew test
2.2.2	Maximum acceleration [$0.14m/s^2$]	2.1.1 test1	Repositioning tests
2.4.1	Roll accuracy [±0.3º]	2.1.4 test 1	16m of tracking at 90mm/s
2.5.1	Power dissipation [<50W]	2.1.2 test 1 2.1.1 test 2	Power while tracking at min/max rate Power while slewing at 0.7m/s

2.2.4 Pipe Requirements

Req. No.	Requirement Description	Test Ref. (AD02)	Description
4.1.1	Maximum air pressure [1mbar]	2.1.8 test 1	Pump down to 0.2 to 0.5mbar
4.1.3	Minimum hold time [16hrs]	2.1.8 test 1	Check pressure a.m. and p.m.

2.2.5 Metrology system requirements

Req. No.	Requirement Description	Test Ref. (AD02)	Description
6.1.1	Minimum power [50µW per delay line]	TBD	Reduce beam intensity and confirm operation.
6.1.2	Beam pointing stability [0.45 arcsec RMS]	TBD	Measure beam tilt over a period of time using projection onto a CCD.
5.4.1	Datum switch repeatability [<10µm RMS]	2.1.5 test 1	Test of datum switch in lab
5.4.2	Datum structure stability (intra-night) [<10µm RMS]	2.1.5 test 2 2.1.5 test 3	Repeated test of datum on test rig Test datum during whole day
5.4.3	Datum structure stability (night-night) [<100µm RMS]	2.1.5 test 4	Test datum day to day.

2.2.6 Shear System Requirements

Req. No.	Requirement Description	Test Ref. (AD02)	Description
7.1.1	Closed loop residuals (track)[0.5mm RMS 2-axis]	2.1.4 test 1	2min of tracking at 15mm/s
7.1.1	Closed loop residuals (slew) [3mm RMS 2-axis]	2.1.4 test 2	16m of slewing at 0.7m/s

3 Test Results

Presentation of Test Results

Because of the volume of data which is required for testing there is too much information to present at a detailed level. Therefore the test results are grouped in sections and shown in tabulated form with a pass or fail and some indication of the nature of the failure.

Each test section states the purpose of the test and whether it addresses specific requirements or demonstrates some functionality that is necessary for the system to work as intended.

Tests which are conducted to show that the OPD performance requirement is met are subject to a set of (conservative) criteria which address different aspects of the requirements. If a test fails on a particular criterion it does not necessarily mean that the performance requirements are not satisfied and so an assessment of the failure is necessary to determine its impact on performance. The test criteria are complex so they are described and justified in Appendix A together with an example of the graphical output which is produced when the data is analysed.

Test documentation

Test results are produced from logging the status and telemetry of the delay line system by the workstation (see RD3). The logs are saved as FITS files which can be imported into Matlab using a purpose made GUI interface for extracting and plotting the results. Hence most test results are obtained by graphical output but in particular the analysis of OPD error to compare results to the test criteria is automated and plotted as described in Appendix A.

Test tables

Tests are grouped for convenience of reporting as well as carrying them out but results from one test may be used in more than one table where appropriate data is obtainable from an existing test. The test tables generally consist of seven columns, described below:

1. indicates the filename of the FITS log taken during the test
2. indicates a test parameter, e.g. slew distance
3. the length of the log in seconds
4. indicates, where appropriate, a Pass (P) or Fail (F) on the test criteria
5. a comment.
6. indicates an overall Pass or Fail based on assessment
7. the filename of any graphical output (usually .pdf format). An asterisk (*) indicates that a copy of the output is included in Appendix B

3.1 Tests at Atmospheric Pressure

The test rig is not evacuated. Special end plates are fitted to allow air to escape from either end of the pipe.

3.1.1 Trolley slew tests

The purpose of these tests is

1. To demonstrate that the trolley can be continuously slewed with the power that is available to it for sufficiently long distances that it does not impact the operation of the delay line.
2. To ensure that temperature rises are within expectations
3. To demonstrate that the metrology system does not lose lock
4. To demonstrate that the received RF signal is stable
5. To demonstrate the repositioning time for the trolley.

The following tests are undertaken:

- Check velocity ramping under VME control by moving fixed distances (plus and minus): 4mm, 10mm, 20mm, 50mm, 100mm, 200mm, 500mm and 2m.
- Carry out a ~17m slew with the maximum velocity set to +0.7m/s
- Carry out a ~17m slew with the maximum velocity set to -0.7m/s
- Carry out a sequence of slews equivalent to 190m of delay line travel

3.1.1.1 Time taken for a range of slew distances

Check velocity ramping under VME control by moving fixed distances (plus and minus): 4mm, 10mm, 20mm, 50mm, 100mm, 200mm, 500mm, 2m, 10m and 16m.

Table 1 Results of ‘slew time’ tests.

File No. dllog_ 20080202	Slew Dist (mm)	Time (s)	P/F on criteria	Comment/reason for failure Time taken for slew:	Overall Pass/Fail	Pdf graphical output
153915	4	100		4s	Pass	Feb02-153915-MET
“	10			4s	Pass	
“	20			5s	Pass	
“	50			6s	Pass	
“	100			7s	Pass	
154201	200	100		5s	Pass	Feb02-154201-MET
“	500			9s	Pass	
“	1m			9s	Pass	
	2m					
20080206 104412	10m	30		16.6s	Pass	Feb06-104412.MET
20080206 105233	16m	40		27.6s	Pass	Feb06-105233.MET*

Results

The trolley repositions 16m in less than 28s.
The velocity is 0.7m/s for slews long enough to reach that value and the acceleration is $0.31ms^{-2}$ and deceleration is $0.225ms^{-2}$.

Conclusion:

The positioning time requirement, velocity and acceleration requirements are met. Therefore the top level requirements on slew speed are met.

3.1.1.2 Simulation of a long slew

Carry out a sequence of ~16m slews equivalent to at least 190m of delay line travel. This is a conservative test as it also incorporates the acceleration and deceleration of the trolley for each slew, requiring more power than a single 190m slew.

Table 2 Results from simulation of a long slew.

File No. dllog_ 20080206	Slew Dist (m)	Time (s)	P/F criteria	Overall Pass/Fail	Pdf graphical output
112236	239	400	Power is available for at least two slews	Pass	Feb06-112236-MET and others*
			Metrology lock is maintained	Fail	
			Power dissipation meets requirements	TBC	
			Temperature rise is acceptable	TBC	
			RF signal level is stable	Pass	

Results: the following results were obtained:

The supply voltage provided by the super-capacitor dropped from 39.8V to 38V and stabilised at that value. This means that the inductive supply is capable of supplying the current necessary to drive the trolley and maintain the super-capacitor in an almost fully charged state.

Metrology lock is currently lost when the trolley is travelling at a velocity of 0.7m/s in the positive direction. This is due to a particularly bad section of pipe which is well outside of specification.

The current supplied to the inductive power supply during slewing was 1.9A at 48V suggesting a total power dissipation of 91W. Losses occur in the supply of inductive power so not all of this power is dissipated on board the trolley. The power consumption of the trolley is known to be 0.9A at 30V i.e. 27W when tracking. and the current supplied to the drive motor is 1A for a slew at 0.7m/s.

The mean RF signal level varies by less than 1% throughout the length of the pipe and has only a small standing wave ripple.

Conclusions:

The inductive power supply is capable of delivering sufficient power to the trolley indefinitely. The characteristics of the inductive power transfer system will be different for a longer inductive power cable and the driving arrangements will need to change accordingly. Further specialised tests are required to establish the correct driving arrangements.

The loss of metrology lock in one direction is connected with the join at a particularly bad pipe section but the metrology system survives all the other joins. Therefore, although the test has failed we know the reason why and therefore we regard the test results as compliant.

To test the requirement for an average of 50W power dissipation over the thermal time constant of the trolley we shall need to conduct longer slew tests on the trolley.

The RF signal level varies by less than 1% over the 17m operating length of the test rig so losses will be <12% for a 200m delay line.

3.1.2 Trolley Tracking Tests

These sets of tests are to test the OPD performance while tracking at constant velocities of (plus and minus) 0.1mm/s, 0.2mm/s, 0.4mm/s, 0.6mm/s, 0.8mm/s and then 1 to 15mm/s in increments of 1mm/s. The steering and shear loops are closed. The trolley uses a stepper motor for steering and when it actuates in can sometimes cause sufficient vibration that the requirement on the 10ms coherence length OPD jitter is violated for a short period. This is called a steering event and they are all of duration shorter than 0.5 seconds. We intend to fit a micro-stepping driver to the motor after the review and test the OPD jitter on steering actuations.

3.1.2.1 Tracking positive at constant velocity

The test results are shown in Table 3. Of the twenty-three tests between 0.1mm/s and 15mm/s six fail on the peak to peak criterion (>500nm) although three of these fail by less than 100nm and a further two by only 0.7nm. One test fails on all criteria due to the rear trolley wheels crossing a bad join at ~5.6m. Four tests fail on the individual criterion of not exceeding the threshold for more than ten consecutive counts but for periods much shorter than 0.5 seconds thereby passing the overall criterion.

Table 3 Results from tracking at constant positive velocities.

File No. dllog_ 20080202	Vel mm/s	Time (s)	P/F on criteria	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output Feb02-
094750	0	30	P	Position Hold	Pass	094750-OPD
102025	0.1	30	P		Pass	102025-OPD*
102120	0.2	30	P		Pass	102120-OPD
102218	0.4	30	P		Pass	102218-OPD
102329	0.8	30	P		Pass	102329-OPD
102428	1	30	P		Pass	102428-OPD* 102428-PSD
103401	2	30	P		Pass	103401-OPD
103502	3	30	P		Pass	103502-OPD
103621	4	30	P		Pass	103621-OPD
103717	5	30	P		Pass	103717-OPD*
104504	6	30	F	pk-pk by 0.7nm	Fail	104504-OPD
104638	7	30	F	pk-pk by 88nm 10ms bin: 230ms (steering event)	Fail	104638-OPD
104744	8	30	F	pk-pk by 69nm 10ms bin: 160ms (steering event)	Fail	104744-OPD plus others
104855	8	30	F	pk-pk by 60nm	Fail	104855-OPD -PSD
105021	9	30	F	pk-pk by 0.7nm	Fail	105021-OPD
105115	10	30	P		Pass	105115-OPD*
111235	11	30	P		Pass	111235-OPD
111357	12	30	P		Pass	111357-OPD
111501	13	30	P	10ms bin: 280ms	Pass	111501-OPD
111631	14	30	P		Pass	111631-OPD
111714	15	30	P		Pass	111714-OPD
123928	15	30	F	pk-pk by 339nm 10ms bin: 180ms (steering event)	Fail	123928-OPD*
124233	15	30	F	Failed all due to join disturbance	Fail	124233-OPD

Conclusions

As can be seen all but 7 of these 23 tests are passed. In six cases the total time for which the OPD jitter criterion is exceeded is less than 0.5 seconds. Furthermore, in no case is the OPD jitter for the fringe tracker channel exceeded.

We expect to improve the peak-to-peak performance significantly through higher loop gain, optimising the viscous friction compensation and the trolley drive bandwidth.

The failure due to the join cannot be tolerated and emphasises the need to keep to specifications, and select the pipe according to the inspection information. We have identified improvements that can be made to minimise errors when tracking over joins:

(i) The motor drive can be made stiffer so that a large error does not build up

(ii) The steering servo can be improved to provide finer control of the roll or the trolley

(iii) The trolley wheels can be replaced with a set (which we have already) which has a smaller crown radius. This reduces the width of the tyre in contact with the pipe. We will be fitting these wheels to the trolley after the review.

3.1.2.2 Tracking negative at constant velocity

The test results are shown in Table 4.

Table 4 Results from tracking at constant negative velocities.

File No. dllog_ 20080202	Vel mm/s	Time (s)	P/F on criteria	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output
115824	-0.1	30	P		Pass	115824-OPD
120053	-0.2	30	P		Pass	120053-OPD
120414	-0.4	30	P		Pass	120414-OPD
120917	-0.8	30	P		Pass	120917-OPD
121032	-1	30	P		Pass	121032-OPD*
121133	-2	30	P		Pass	121133-OPD
121227	-3	30	P		Pass	121227-OPD
121429	-4	30	P		Pass	121429-OPD
121521	-5	30	P		Pass	121521-OPD
121611	-6	30	P		Pass	121611-OPD
121831	-7	30	P		Pass	121831-OPD
121910	-8	30	P		Pass	121910-OPD
121954	-9	30	F	pk-pk by 93nm	Fail	121954-OPD
122334	-9	30	P		Pass	122334-OPD
122519	-10	30	P		Pass	122519-OPD*
123110	-11	30	F	pk-pk by 125nm	Fail	123110-OPD
123155	-12	30	F	pk-pk by 138nm 10ms bin: 160ms (steering)	Fail	123155-OPD
123440	-13	30	F	Failed on pk-pk 400nm (join)	Fail	123440-OPD*
123524	-14	30	P	Failed on pk-pk by 149nm	Fail	123524-OPD
123607	-15	30	P	Failed on pk-pk by 208nm	Fail	123607-OPD

Results

Of the twenty tests between -0.1mm/s and -15mm/s six fail on the peak to peak criterion (>500nm pk-pk). Five of these exceed the peak–to-peak by less than 250nm and one (which is caused by a join event) by less than 500nm. One test fails on the 10ms OPD jitter criteria by < 200ms.

Conclusions

Although six of these 20 tests are failed, in no case is the OPD jitter for the fringe tracker channel exceeded. We expect to make improvements to peak-to-peak performance as described above.

3.1.2.3 Contiguous Tracking Tests

The purpose of these tests is to track for a typical observing time of 10 minutes and assess the quality of tracking through measurement of the OPD error and applying the test criteria.

The tests are to set continuous tracking at constant velocity for 10 minutes at the following velocities: 0.2mm/s, -1mm/s, +5mm/s, -10mm/s and +15mm/s. To keep the log files to a manageable size each log is composed of five 2 minute logs with only a few seconds gap between each log as the operator restarts the logging. The percentage pass indicates how many of the individual logs were successful and not how much of the total time was within OPD jitter specifications.

Table 5 Contiguous tracking test results

File No. dllog_ 20080204	Vel mm/s	Time (s)	P/F on criteria	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output
163518 163726 163929 164132 164336	0.2	5x120	P P P P P		100% Pass	
164833 165038 165241 165544 165646	-1	5x120	P P P F P	failure on pk-pk at join 2	80% Pass	Feb04-165444-OPD*
170152 170400 170602 170805 171006	5	5x120	F F F F P	failure on pk-pk (586nm) failure on pk-pk (590nm) and steering event (230ms) 6s failure at join 3 failure on steering event (260ms) pass	40% Pass	
171730 171943 172144 172347 172549	-10	5x120	F F F F F	failure on pk-pk (731nm) and one steering event 4.5s failure at join 2 One failure on pk-pk (1435nm) at join for <1s One failure on pk-pk (760nm) One 4s failure at join 2	20% Pass	Feb04-171730-OPD*
173439 173701 173905 174109 174311	15	5x120	F F F F F	One 1.3s failure at join 2 One failure on pk-pk (1214nm) and 2 steering events (220ms) One 1.8s failure at join 3 One 2.6s failure at join 3 One 3.3s failure at join 4	Fail	

Results

For the first two tests there is just one failure out of ten consecutive two-minute records and it occurs when the trolley front wheels cross a join in the pipe. The 10ms OPD jitter is not violated.

For the third group of tests there are two failures on peak-to-peak but both exceed the limit by <100nm.

There are two steering events each resulting in the 10ms OPD jitter criterion being exceeded but for less than 300ms. In neither of these cases is the OPD jitter for the fringe tracker channel exceeded. There is one serious failure on crossing a join which would probably result in fringe tracking being lost.

For the last two groups of tests the trolley is being moved backwards and forwards across joins and so the failures more frequent. Of the ten records there are four failures on peak-to-peak and one steering event. In non of these cases is the OPD jitter for the fringe tracker channel exceeded. There are four serious failures on crossing joins which would probably result in fringe tracking being lost.

Conclusions

We expect to improve the peak-to-peak performance as described before.

Again, the failures due to the joins cannot be tolerated and emphasises the need to keep to specifications, and select the pipe according to the inspection information. We would also apply the mitigations to the drive and steering mentioned previously.

3.1.2.4 Tracking tests across joins

The purpose of these tests is to assess the quality of the joins and the ability of the trolley to cope with the geometrical variations of the pipes. We shall be carrying out tests after the review.

3.1.3 Trolley Trajectory Tests

Three tests are grouped under this heading. The results are presented in the following subsections:

- Test trajectory acquisition and time by switching from tracking at one position to tracking at another position for a range of distances e.g 4mm, 20mm, 100mm, 200mm, 500mm, 2m 5m and 10m.
- Test tracking at constant accelerations of 0.3μms^{-2}, 0.625μms^{-2} and 1.25μms^{-2} including reversing direction while tracking with a realistic trajectory.
- Test response to fringe tracking offsets of 0.5 μm,1μm and 10μm

3.1.3.1 Slew times

The purpose of these tests is twofold:

1. To test the slew time requirement defined by the slew speed and maximum acceleration.
2. To demonstrate the trajectory acquisition and time by switching from tracking at one position to tracking at another position for a range of distances and to e.g 4mm, 20mm, 100mm, 200mm, 500mm, 2m 5m and 10m.

Table 6 Slew time results

File No. dllog_ 20080202	Slew Dist (mm)	Time (s)	P/F on criteria	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output
170157	4		P	Tracking at 0.1mm/s	Pass	170157-OPD
171033	10		P	Tracking at 0.1mm/s	Pass	171033-OPD
171858	4		P	3s Tracking at 1mm/s	Pass	171858-OPD*
“	20		P	4s “ “	Pass	
“	100		P	5.5s “ “	Pass	
	200		P	5 s 100mm step was commanded	Pass	
“	500		P	7s Tracking at 1mm/s	Pass	

Conclusions

The time taken from tracking at one position to tracking at another position meets the requirements.

3.1.3.2 Accelerations and reversal

The purpose of these tests is to demonstrate that the tracking OPD requirements are met over a range of constant accelerations and also through reversal of the trolley under realistic trajectory conditions. The tests are:

1. Test tracking at constant accelerations of 0.3μms^{-2}, 0.625μms^{-2} and 1.25μms^{-2}
2. Test reversing direction while tracking with a realistic trajectory

Most files also have an associated -MET pdf figure showing the trajectory followed.

Table 7 Acceleration and tracking reversal results

File No. dllog_ 20080202	Acc'n μms^{-2}	Time (s)	P/F on criteria	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output
165717	0.3	30	P		Pass	165717-OPD
165139	0.625	30	F	10ms bin:110ms (disturbance)	Pass	165139-OPD
165359	0.625	30	P		Pass	165359-OPD
163824	0.5	200	P		Pass	163824-OPD
164336	-1.25	50	P	Reversal +ve to -ve	Pass	164336-OPD
164734	+1.25	30	P	Reversal –ve to +ve	Pass	164734-OPD*
164031	-1.25	200	P	Reversal +ve to -ve	Pass	164031-OPD
163159	10	30	F	Reversal 10ms bin: 220ms (steering event)	Pass	163159-OPD*

Results

The last file contained a steering actuation which caused the 10ms OPD jitter criterion to be exceeded but for only 220ms. The OPD jitter for the fringe tracker channel was not exceeded.

Conclusions

The requirements to meet the OPD criteria while tracking with acceleration and through reversal have been met.

3.1.3.3 Fringe tracker offsets (step response)

The purpose is to test the OPD response to fringe tracking offsets of up to 10μm. The test system is not capable of yet of pre-filtering the offset command and so offsets are applied as a single step in one sample period (200μs).

The offsets applied are ±0.5μm, ±1μm and ±10μm

Table 8 Fringe tracker offset step response results

File No. dllog_ 20080202	Offset μm	Time (s)	Req't	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output
114652	0.5	30	<30ms	<30ms	Pass	114652-MET*
"	1	30	"	<30ms (120ms, 10ms OPD jitter)	Pass	"
113600	10	30	"	50ms (140ms, 10ms OPD jitter)	Fail	113600-MET
115231	-0.5	30	"	<30ms	Pass	115231-MET
115624	-1	30	"	<30ms	Pass	115624-MET
115716	-10	30	"	40ms (130ms, 10ms OPD jitter)	Fail	115716-MET

Results

Two tests fail to meet the step response requirement. These are the 10µm step tests. One of the 1µm step tests results in 120ms of 10ms OPD jitter but the OPD jitter for the fringe tracker channel is not exceeded.

Conclusions

The requirements are met for the 0.5µm and 1µm step but not for the 10µm step. One would expect a 10µm step to be applied incrementally and we shall devise a method of doing this after the review, probably by adding additional functionality to the code in the VME system to ensure that any step requests of this magnitude are handled properly.

3.1.4 Trolley Roll and Shear Loop Tests

3.1.4.1 Shear loop tests

The purpose of these tests is to demonstrate that:

1. the requirements on shear residuals are met
2. the shear deviations can be measured

To demonstrate (1) the trolley is tracked at 15mm/s and also 0.7m/s and the shear residuals are logged.

To demonstrate (2) the trolley is slewed at 90mm/s with the shear loop open and the shear deviations are logged.

Table 9 Shear loop test results

File No. dllog_	Vel (mm/s)	Time (s)	Req't	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output
20080204 173701	+15	120	0.5mm rms	Shear residuals (tracking) 0.14mm rms 2-axis	Pass	Feb04-173701-SHE*
20080206 110014 105845	+700 -700	40 40	3mm rms	Shear residuals (slew) 1.7mm rms 2-axis 1.9mm rms 2-axis	Pass	Feb06-105845
20080205 112716	-90	200	-	Shear loop off	-	Feb05-112716-SHE*

Conclusions

The requirements for shear residuals have been met.

The survey of the pipe (shown in the plot in Appendix B) reveals the deviations in the pipe as measured by the shear system, i.e. twice the actual deviation. The pipe sections are evident and the right hand side of the plot corresponds to pipe nearest the metrology system. The rate of change of the deviations is much higher than specified for the pipes and keeping the pipe within the maximum shear amplitude means that the rate of change of deviation across the joins is necessarily increased in some cases.

3.1.4.2 Roll loop tests

The purpose of these tests is to demonstrate that:

1. the requirement on roll control of the trolley is met
2. the trolley is stable with steering centred and the steering loop open
3. the trolley is stable with steering at maximum steering angle

To demonstrate (1) the trolley is slewed at 90mm/s and the roll angle is logged

To demonstrate (2) the trolley is slewed for the full length of the test rig at a constant velocity of 90mm/s while logging with steering loop off but centred and the roll logged (this checks trolley's balance about the roll axis).

To demonstrate (3) Slew the trolley for the full length of the test rig at a constant velocity of 90mm/s while logging and with steering loop off but set at maximum deviation (this checks the limiting roll angle under a simulated failure condition).

Table 10 Roll loop test results

File No. dllog_	Vel (mm/s)	Time (s)	Req't	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output
20080205 112716	-90	200	±0.3º (5.2mrad)	-5.2 mrad to +12mrad (bad pipe)	Fail	Feb05-112716-TROL*
20080206 145315	90	200	-	Steering off and centred - produces trend in roll	-	Feb06-145315-TROL*
20080206 151443	+100	200	Trolley stable	Steering off and at max angle produces 0.39rad of roll	Pass	Feb06-1541443-TROL*

Conclusions

The steering accuracy requirement has not been met. The maximum deviations are associated with the bad pipe and join positions and this goes some way to explaining why the tracking over the joins has been a problem. There is scope for increasing the responsiveness of the steering servo but the shape of some of the pipes may limit what can be achieved.

The trolley steering, when centred, produces a trend in the roll which means that the steering is either not actually centred or the trolley is imbalanced transversely. This test is used for differentiating between steering and imbalance by determining if a trolley follows the same track in the opposite direction.

The final test measures the limiting roll of the trolley if the steering mechanism were to fail at maximum deviation. Although the length of pipe we have is not quite long enough it is fairly clear the maximum roll of the trolley under this condition is approximately 0.4 radians or 23º, which is perfectly safe.

3.1.5 Secondary Tip/tilt Tests

The purpose of these tests is to demonstrate that:

1. the tip/tilt range provides for ±5mm of shear
2. the tip/tilt slew rate meets the 4.7mrad/s minimum requirement

To demonstrate both (1) and (2) the tip/tilt actuator is switched between its positive and negative extremes in each axis and the resulting deflections of the metrology beam are measured by the shear system and logged.

Table 11 Secondary tip/tilt test results

File No. dllog_ 20080205	test	Req	Result	Comment/	Overall Pass/Fail	Pdf graphical output
142141	Tip/tilt range	±5mm	X = +9.4mm – 8mm Y = +7.1mm – 7.7mm		Pass	Feb05-142141SHE*
"	Tip/tilt slew rate	4.7 mrad/s	X=29.3mrad/s Y=34.0mrad/s	63% rise time	Pass	"

Conclusion: the tip/tilt actuator meets both requirements

3.1.6 Secondary Focus tests

The purpose of these tests is to demonstrate that focus actuator meets the 20μm minimum resolution requirement.

To demonstrate this, the focus actuator is moved in increments of 5μm and 10μm and the encoded value is logged. This will establish the effective resolution of the mechanism

Table 12 Secondary focus test results

File No. dllog_ 20080206	Test	Req't	Result	Comment/reason for failure	Overall Pass/Fail	Pdf graphical output
161421 161011	±5um ±10μm	20μm	±5um ±10μm		Pass	Feb06-161421-FOC* Feb06-161011-FOC

Conclusion: the focus actuator meets the resolution requirement.

3.1.7 Datum Tests

The purpose of these tests is to demonstrate the requirements on datum stability are met.

The test procedure is to acquire datum at least 10 times from different starting positions and note the metrology value at the instant before the datum causes a reset to zero position. The variability of the reset position may be due to:

1. Repeatability of the switch function
2. Stability of metrology table with respect to test rig
3. Position of cat's eye with respect to trolley shell

There are no results for the datum tests at COAST yet. Tests on the test track in the lab were satisfactory, producing between 7μm and 10μm rms. Datum tests on the test rig are not yet producing consistent results. The datum switch fitted to the delay line pipe at COAST is a slightly different model but it is also staring through a window and is further away from the trolley than was the case in lab tests. We shall be investigating the reason for the poorer performance at COAST after the review.

3.1.8 Wedge tests

After aligning metrology system without wedges, log a slew at 200mm/s then mount the wedges and repeat. Check that the tip/tilt deviations are as expected.

This test has not yet been conducted.

3.2 Tests under Vacuum

No tests have been conducted under vacuum so far although the integrity of the vacuum has been tested.

3.2.1 Vacuum test of the test rig at COAST

The requirement for holding vacuum in the delay line is that the maximum pressure is 1mbar and the minimum hold time is 16 hours.

The test rig at COAST was sealed by fitting end plates to the pipe (one with metrology and science window ports fitted with blanking plates). The pipe was evacuated to 0.1mbar and the pressure checked from day to day. The greatest detectable rate of change occurred over ten days when the pressure had risen from 0.2 mbar to 0.4mbar. This represents a leak rate of 0.02mbar per day.

There was no trolley moving in the pipe during this period and no out-gassing components other than the seals at the joins.

4 Requirements and Performance Verification

4.1 Discussion

Design Requirements verification and performance verification are handled in one set of compliance tables. For each table the columns are:

1. A reference to the section of the Derived Requirements (AD01)
2. A brief description of the requirement
3. Four columns of verification:
    a. Design
    b. Analysis
    c. Inspection
    d. Test
4. Comments

A particular requirement can be verified by design, analysis, inspection or test or a combination of any of these depending on the nature of the requirement. The definition of verification for the column headed ‘inspection’ is that an item may have a particular specification or test sheet associated with it which provides the necessary verification of compliance.

The column headed ‘Test’ indicates what items are to be verified by test and the comment column is used to describe or reference the test.

The columns contain the level of compliance (if any) that are associated with a requirement. There are five levels of compliance:

C Compliant

TBC To Be Confirmed - expected to comply, but requires confirmation

PC Partially Compliant

NC Non-Compliant

X Not yet tested or verifiable.

4.2 Trolley Requirements

4.2.1 Cat's eye requirements

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
2.1.1	**Primary Mirror**					
2.1.1.1	Clear aperture [300mm minimum]	C		C		
2.1.1.2	Focal length (~ f4) within secondary positioning range	C		C		1295mm±6.5mm
2.1.1.3	Surface error [25.3nm]	C		C		
2.1.1.4	Support error 10nm	C				Requires 6:1 aspect ratio for simple support
2.1.1.5	Thickness [50mm±1mm]	C		C		
2.1.1.6	Material Zerodur	C		C		
2.1.1.7	Centration [axial <1mm, normal <2arcmin]	C		C		3mm wide chamfer normal to optical axis
2.1.2	**Secondary Mirror**					
2.1.2.1	Diameter [>8mm]	C		C		
2.1.2.2	Tip/Tilt range [±3.9mrad]	C		C	C	±5mrad unit installed
2.1.2.3	Tip/Tilt slew rate [4.7mrad/sec each axis]	C			C	
2.1.3	**Focus Stage**					
2.1.3.1	Focus resolution [20µm]	C			X	Repeatability test to establish this
2.1.3.2	Focus drift [5µm]	C			C	
2.1.4	**Tube**					
2.1.4.1	Tube CTE [$<0.77\times10^{-6}$/K]	C			X	Need a controlled environment for this

4.2.2 Trolley drive system

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
2.2.1	Slew speed [0.7m/s]	C			C	
2.2.2	Maximum acceleration [$0.14m/s^2$]	C			C	

4.2.3 Voice coil drive requirements

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
2.3.1	Peak drive current [9A]	C			X	10A peak capability

4.2.4 Roll control

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
2.4.1	Roll accuracy [±0.3º]	C			C	

4.2.5 Thermal

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
2.5.1	Power dissipation [<50W]	C	C		TBC	Use Power supply current to estimate tracking power

4.3 OPD Control Loop Requirements

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
4.3.1	Bandwidth [>100 Hz]	C			C	Laboratory measurement
4.3.2	Latency [<40μs]	C				A direct measurement has not been made. Compliance is demonstrated through measurement of OPD jitter.

4.4 Pipe Requirements

4.4.1 Vacuum

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
4.1.1	Maximum air pressure [1mbar]	C			C	
4.1.2	Minimum air pressure [0.05mbar]			X		To be stated in operations manual
4.1.3	Minimum hold time [16hrs]	C			C	Design aims for leak rate to be <0.5mbar per day.

4.4.2 Windows

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
4.2.1	Science exit window clear aperture [Min.135mm]	C		X		
4.2.2	Science exit window thickness [Min. 15mm]	C		X		
4.2.3	Metrology window clear aperture [Min. 43mm]	C		X		
4.2.4	Metrology window thickness	C		X		

4.4.3 Pipe sections

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
4.3.1	Material [Aluminium]	C		X		6061-T6 preferred
4.3.2	Length [Max 17 feet (5182 mm), Min 12 feet (3658 mm)]	C		X	X	Nominal length 16.4 feet 5000mm
4.3.3	External diameter [16 in. (406 mm) ± 0.085 in. (2.16mm)]	C		X	X	ASD specification = ±0.085 in
4.3.4	Wall thickness [0.5 in. (12.5 mm) ± 0.045 in (1.16mm)]	C		X	X	ASD specification = ±0.045 in
4.3.5	Eccentricity [≤0.06in. (1.27mm)]	C		X	X	ASD specification is ≤0.06in
4.3.6	Straightness [≤0.258in. (6mm) per section and 0.0148in per foot for any measured length greater than 1 foot]	C		X	X	Goal is to meet this in 5m length
4.3.7	Circularity [≤0.2in (5.1mm)]	C		X	X	ASD specification is ≤0.2in
4.3.8	Surface quality [≤0.012in (0.3mm)]	C		X	X	Conforms to ASD spec.

4.5 Pipe Support Requirements

4.5.1 Support geometry

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
5.1.1	Support leg minimum length [1m]	C				
5.1.2	Support leg angular range [±5º]	C				
5.1.3	Height adjustment range [±20mm TBC]	C	C			Greater adjustment is provided by two sizes of support base.

4.6 Metrology System Requirements

4.6.1 Laser

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
6.1.1	Minimum power [50µW per delay line]	X	X	X	X	Zygo laser requires 5µW returned
6.1.2	Beam pointing stability [0.45 arcsec RMS]	X		X	X	
6.1.3	Coherence length [>200m]	X		X		
6.1.4	Stability				X	

4.6.2 Mirrors and beam-splitters

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
6.2.1	Beam splitting system angular stability [0.45 arcsec RMS wf]	C				
6.2.2	Interferometer angular stability [0.45 arcsec RMS wf]	C		X		
6.2.3	Launch mirror adjustment resolution [1.8 arcsec wf]	C		X		
6.2.4	Launch mirror tilt stability [0.9 arcsec wf per pair]	C		X		
6.2.5	Receiver mirror adjustment resolution [2.7 arcsec wf]	C		X		
6.2.6	Receiver mirror tilt stability [1.96 arcsec RMS wf per pair]	C		X		

4.6.3 Beam expanders and compressors

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
6.3.1	Focus resolution [34µm]	C	C		X	
6.3.2	Focus stability [34µm]	C	C		X	
6.3.3	Beam expander tilt stability [0.13 arcsec RMS wf]	C			X	
6.3.4	Beam compressor tilt stability [1.96 arcsec RMS wf]	C			X	

4.6.4 Datum requirements

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
6.4.1	Datum switch repeatability [<10µm RMS]	C			X	Controlled test of switch in lab
6.4.2	Datum structure stability (intra-night) [<10µm RMS]	C			X	Test rig
6.4.3	Datum structure stability (night-night) [<100µm RMS]	C			X	Test rig

4.7 Shear System

4.7.1 Shear system performance

Req. No.	Requirement Description	Verification method(s)				Comment
		Design	Analysis	Inspection	Test	
7.1.1	Closed loop residuals (track) [0.5mm RMS 2-axis]	C			C	
7.1.2	Closed loop residuals (slew) [3mm RMS 2-axis]	C			C	
7.1.3	Frame size [min 180 x 180 pixels]	C		C		
7.1.4	CCD frame rate [minimum 20 Hz]	C		C		

Appendix A

Trolley OPD Test Criteria

1 Introduction

This appendix describes the test criteria which have been used to assess the performance of the delay line trolley in the acceptance tests undertaken at Cambridge and which will be used on the NMT campus. The data to be analysed are the OPD errors reported by the metrology system, which are sampled at a rate of 5 kHz. Since the metrology system provides trolley distance the OPD error is equal to twice the metrology value.

1.1 Definitions

Because of the potentially unfamiliar way in which the raw 5 kHz OPD error data are handled to determine whether the performance criteria have been met, it is important that there are clear definitions of the datasets referred to in this document. There are four key definitions the reader should be aware of:

“Observation”:

This is the length of time the delay line has spent tracking and taking data. In a typical astronomical scenario, an “observation” is expected to last between 60 and 180 seconds.

“Signal”:

This is the term used to describe the contiguous stream of 5 kHz samples of the OPD error for the whole or some defined part of an observation.

“Segment”:

This is a small time-slice of the signal of a specific length. For the purposes of the delay line performance evaluation, there are three important segment lengths of 10ms, 35ms and 50ms. These correspond to the typical coherent integration time expected for interferometric measurements undertaken at 600nm, 1650nm and 2200nm respectively under good seeing conditions (0.75 arcseconds).

“Sequence”:

This refers to the set of values of the RMS of the 5 kHz OPD error for a contiguous set of segments of the signal.

For example, an “observation” of 100s can be considered as consisting of 10^4 consecutive 10ms “segments”. If the RMS value of the OPD error is computed for each consecutive segment, then the time sequence of these values is what we refer to as a “sequence”.

1.2 Timescales

There are five timescales over which the OPD error must meet specific test criteria. These timescales are as follows:

(i) the whole signal length;

(ii) segment lengths of 10 milliseconds (associated with interferometric measurements at 600 nm);

(iii) segment lengths of 35 milliseconds (associated with interferometric measurements at 1650 nm);

(iv) segment lengths of 50 milliseconds (associated with interferometric measurements at 2200 nm);

(v) multiple consecutive segment lengths within the signal.

The test criteria for each of these timescales are defined in detail below.

2 Test Criteria

2.1 The signal

There are two criteria that need to be met:

(a) The mean value of the error must be less than 10 µm. This ensures that any mean offset between the commanded OPD and the actual OPD introduced by the delay line will be small compared to the expected instantaneous atmospheric OPD of approximately 60 µm peak-to-peak (i.e. 10 µm RMS). A figure of 10µm is also consistent with the expected intra-night baseline length stability of order 10 µm.

Failing to meet this criterion will impact the amount of time needed to find fringes before the fringe-tracking subsystem can “lock-up”.

(b) The peak-to-peak deviation of the error must be less than 500 nm (i.e. roughly 83 nm RMS). This ensures that any contribution to the error in position of the “white light” fringe about a mean offset will be insignificant compared to the ~ 1 µm contribution resulting from residual atmospheric piston fluctuations above the 1 Hz fringe-tracker closed loop bandwidth.

Failing to meet this criterion will lead to a small reduction in fringe visibility. For example, a *fixed* error in the white light fringe position of ×4 the desired criterion will give a 0.7% reduction in fringe contrast for R = 30 in the J band.

2.2 The segments

The specified threshold value for the RMS of the error in a segment depends upon the segment length. The threshold values for each segment length are:

(i) 15nm for a 10ms segment length;
(ii) 41nm for a 35ms segment length;
(iii) 55nm for a 50ms segment length.

In each of these cases, the specified threshold arises directly from the top-level requirements that the OPD jitter be less than λ/40 at the wavelength of observation, giving no more than a 2.5% loss in fringe contrast over the specified segment length.

There are three criteria applied for each segment length:

(a) The RMS of the sequence must be less than the threshold. This ensures that the top-level visibility loss budget is satisfied.

(b) The number of segments for which the RMS error exceeds twice the threshold must be less than 1% of the total number of segments in the sequence. This ensures that even if the instantaneous threshold is exceeded, the resulting visibility loss in an observation will be less than 0.05% (as long as the standard deviation of the sequence under consideration is less than the threshold).

(c) The threshold must not be exceeded for 10 or more consecutive segments within the sequence. This ensures that the "dropouts" of the fringe-tracker will not occur due to long time periods of OPD jitter.

3 Test analysis

The test analysis we have reported encompasses all the test criteria and also provides other useful information. It is performed on the OPD error which is twice the value of metrology error returned with the telemetry data from the VME system and embedded in the FITS log files. The analysis scripts carry out the following computations on the OPD error signal:

(1) The mean value and the peak-to-peak value of the signal are computed and compared to the requirements. The tests are:

(i) $S_{mean} < 10$ µm
(ii) $S_{pk\text{-}pk} < 0.5$ µm

(2) The OPD error signal is divided into consecutive *x* ms segments (where *x* = 10 ms, 35 ms and 50 ms).

(3) For each *x* ms segment, the RMS of the OPD error is computed. This produces sequences of RMS's, hereafter referred to as sigmas, which we denote by the notation: *x*10-sigmas, *x*35-sigmas, and *x*50-sigmas.

(4) For each sequence, the histogram of values is plotted and the mean, median, and modal values are computed for information. The test for each sequence is:

(i) Are any members of *x*10-Sigmas > 15nm?
(ii) Are any members of *x*35-Sigmas > 41nm?
(iii) Are any members of *x*50-Sigmas > 55nm?

(5) For each sequence, the number times the sigma value is greater than the "threshold" is computed and represented as a percentage of the total number in the sequence. This is provided for information.

(6) For each sequence, the square root of the mean squared value is computed for assessing the validity of the subsequent test described below. The test outlined below will be valid as long as the following criteria are met:

(i) RMS(*x*10-Sigmas) < 15nm
(ii) RMS(*x*35-Sigmas) < 41nm
(iii) RMS(*x*50-Sigmas) < 55nm

(7) For each sequence, the number of times, N, that any sigma value is greater than twice the "threshold" is computed and represented as a percentage of the total number, L, in the sequence. The test for each sequence is:

(i) 100*N(*x*10-Sigmas) /L(*x*10-Sigmas) < 1%
(ii) 100*N(*x*35-Sigmas) /L(*x*35-Sigmas) < 1%
(iii) 100*N(*x50*-Sigmas) /L(*x*50-Sigmas) < 1%

(8) The number of times, N, there are M or more consecutive values in any sequence that exceed the threshold is computed together with the total time the threshold is exceeded for these events. The value of M has currently been chosen as 10 and is based on the expected performance of the fringe-tracker. The tests are:

(i) For *x*10-Sigmas: N = 0
(ii) For *x*35-Sigmas: N = 0
(iii) For *x*50-Sigmas: N = 0

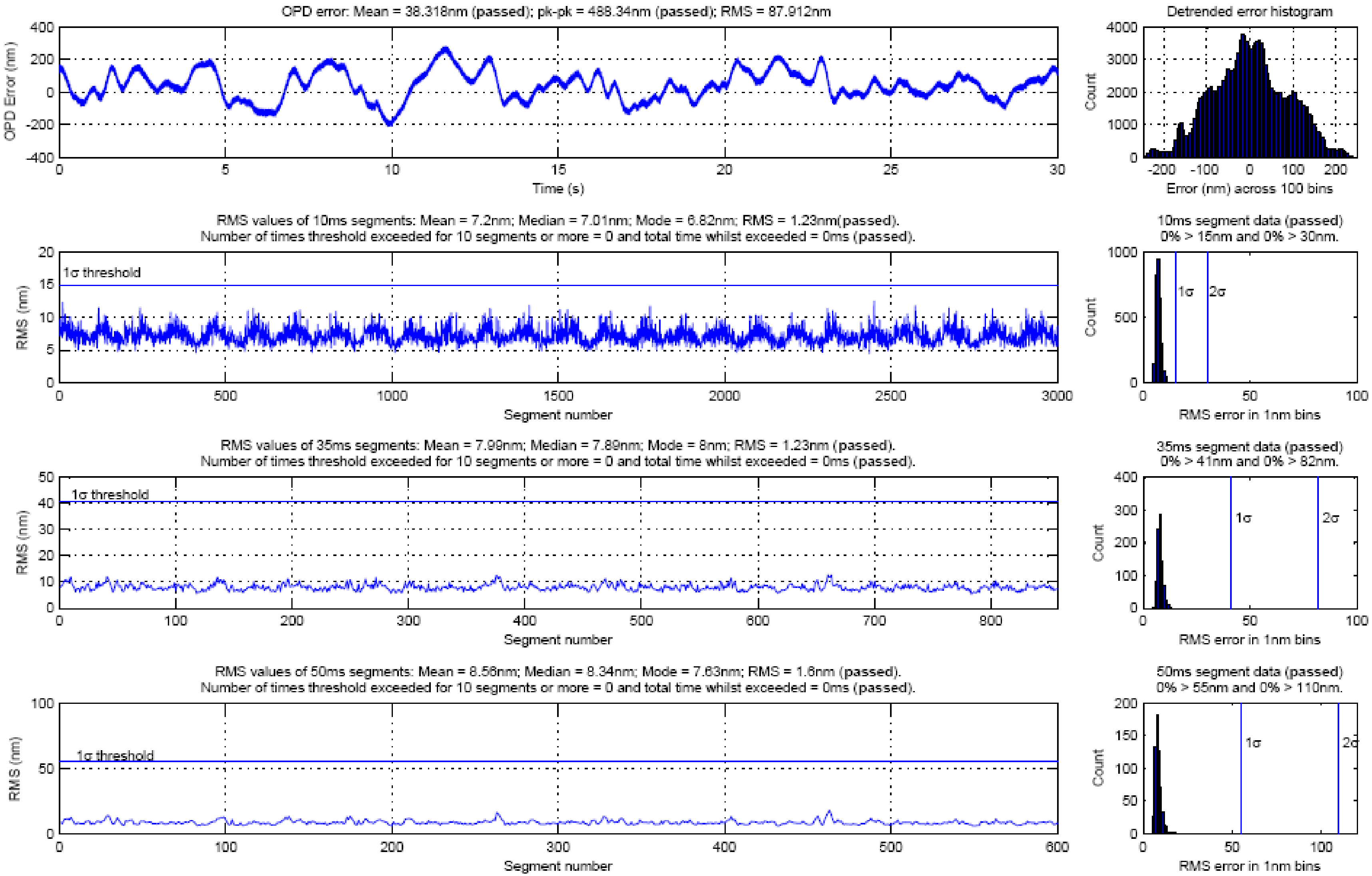
4 Test Results

These are presented in annotated plots on one sheet per test run. For long tests the FITS log files may be split into sequential files to be analysed separately in which case the results for each test run are tabulated on a title sheet. The individual plots are described below and an example of the output for one test is shown on the following page.

Each plot sheet contains:

1. A super-title giving the log filename and the conditions of the test run.
2. A plot of the OPD error with a title including the mean and peak-to-peak values and whether these have passed the test criteria.
3. A histogram of the de-trended error spread over one hundred bins.
4. A plot of the sequence of 10ms segment RMS values incorporating:
    a. a horizontal line indicating the threshold (or 1σ value) and with a title including: the mean, median and mode values;
    b. the mean-subtracted RMS of the sequence and the result of applying the test criteria;
    c. the number of times the threshold has been exceeded for 10 or more consecutive values, the total time whilst exceeded, and the result of applying the test criterion.
5. A histogram of the 10ms RMS values in 1nm bins incorporating vertical lines indicating the threshold (1σ value) and twice the threshold (2σ value) and with a title including the percentage of values exceeding the 1σ threshold and 2σ threshold, and the result of applying the test criterion.
6. A plot of the sequence of 35ms segment RMS values (as described in (4)).
7. A histogram of the 35ms RMS values (as described in (5)).
8. A plot of the sequence of 50ms segment RMS values (as described in (4)).
9. A histogram of the 50ms RMS values (as described in (5)).

dllog-20080202-103717.fits - OPD error. Test description: Tracking at +5mm/s. (**Test Run passed**)



Appendix B

Graphical output of Selected Tests