KECK NEXT GENERATION WAVEFRONT CONTROLLER

First integration test report

Document :	NGWFC_Test_Report_07_02_06__07_11_06.doc
Issue :	1
Date :	July 11th, 2006

Prepared by : MICROGATE

R.Biasi ....

D.Pescoller ....

....

Checked by : ....

Approved by : ....

Released by : ....

July 11th, 2006

CHANGE RECORDS

ISSUE	DATE	Author	Approved	QA/ QC	SECTION / PARAG. AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
1	11.07.2006	Microgate			All	First Issue

TABLE OF CONTENTS

1 ACRONYMS **6**

2 APPLICABLE DOCUMENTS **8**

3 INTRODUCTION **9**

4 DTT TESTS **10**

4.1 DTT Strain gage calibration 10
4.2 Open Loop DTT Strain Gage FFT plots and noise 12
4.3 Closed Loop DTT step response 14

5 UTT TESTS **16**

5.1 OTF-UTT Strain gage calibration 17
5.2 Open Loop OTF-UTT Strain Gage FFT plots and noise 18
5.3 Closed Loop UTT step response 20

LIST OF FIGURES

Figure 1 – Ch.0 – strain gage A calibration. 11
Figure 2 – Ch.1 – strain gage B calibration. 11
Figure 3 – Ch.2 – strain gage C calibration. 11
Figure 4 – Actuator A on Ch.0, open loop. Mean: 4.468080e-005m, Std: 4.405923e-008m 13
Figure 5 – Actuator B on Ch.1, open loop. Mean: 4.605224e-005m, Std: 9.641394e-008m 13
Figure 6 – Actuator B on Ch.1, open loop, 160’ extension cable. Mean: 4.522841e-005, Std=5.687727e-008 13
Figure 7 – Actuator C on Ch.2, open loop. Mean: 1.424418e-005, Std=5.229602e-008 14
Figure 8 – Test Actuator Ch.1, open loop. Mean: -1.538876e-006, Std=2.895761e-008 14
Figure 9 – Ch.0 step response (Actuator cable B, Sensor cable A). The 5.9kHz noise is not particularly evident on this channel. 15
Figure 10 – Ch.1 step response (Actuator cable C, Sensor cable B). The 5.9kHz noise is very evident on this channel, and it can be noticed also on the control signal due to the PID gain at this frequency. 15
Figure 11 – Ch.2 step response (Actuator cable A, Sensor cable C). In terms of noise, this channel is worse than Ch.0 but significantly better than Ch.1. 15
Figure 12 – OTF-UTT sensor cables modifications and pinout. 16
Figure 13 – Internal view of OTF-UTT command and sensor cables splitting box. The half-bridge added resistors can be clearly seen. 17
Figure 14 – Ch.0 calibration. 18
Figure 15 – Ch.1 calibration. 18
Figure 16 – FFT of Ch.0 SG signal, open loop, 160’ extension cable. 19
Figure 17 – FFT of Ch.0 SG signal, closed loop, 160’ extension cable. 20
Figure 18 – Ch.0 step response. No extension cable. 21
Figure 19 – Ch.1 step response. No extension cable. 21
Figure 20 – Ch.0 step response. 160’ extension cable on both control and SG signals. The noise increase is very evident. 21

LIST OF TABLES

Table 1 – Current connection of DTT 10
Table 2 – DTT strain gage calibration gain and offset. 12
Table 3 – UTT strain gage calibration gain and offset. 18
Table 4 – OTF-UTT SG noise measured in different conditions. 19

1 ACRONYMS

AO	Adaptive Optics
CCD	Charge Coupled Device
CIE	Command Interpreter and Executer
COTS	Commercial Off-The-Shelf
DDR	Double Data Rate
DM	Deformable Mirror
DMA	Direct Memory Access
DSP	Digital Signal Processor
DTT	Down Tip Tilt
DTTM	Down Tip Tilt Mirror
FC-IP	FibreChannel Internet Protocol
FITs	Number of Failures in 10^9 hours
FPDP	Front Panel Data Port
GPIB	General Purpose Interface Bus
HBA	Host Adapter Board
HP	Width unit for 19” chassis, corresponding to 0.2” (5.08mm)
HV	High Voltage
HVA	High Voltage Amplifier
HVC	High Voltage Control
ICMP	Internet Control Message Protocol
IIR	Infinite Impulse Response
LFpM	Linear Feet per Minute
LAN	Local Area Network
LGS	Laser Guide Star
LUT	Look Up Table
MAC	Multiply And Accumulate
mas	milliarcseconds
MGAOS	Microgate Adaptive Optics real-time System
MIMO	Multiple Input Multiple Output
MIL-STD	military standard
MMF	Multi-Mode Fiber
NDA	Non Disclosure Agreement
NFS	Network File System
NGS	Natural Guide Star
NGWFC	Next Generation Wavefront Controller
PCB	Printed Circuit Board
PIO	Programmable Input Output
PSU	Power Supply Unit

RMS	Root-Mean-Square
RTC	Real Time Controller
SAN	Storage Area Network
SAS	Serial Attached SCSI
SCSI	Small Computer System Interface
SFP	Small Form factor Pluggable
SG	Strain Gage
SI	The International System of Units
SH	Shack-Hartmann
SRAM	Static Random Access Memory
SDRAM	Synchronous Dynamic Random Access Memory
STRAP	System for Tip-tilt Removal with Avalanche Photo-diodes
TBC	To Be Confirmed
TBD	To Be Defined
TRS	Telemetry Recorder/Server
U	Height unit for 19” chassis, corresponding to 1.75” (44.45mm)
UTT	Uplink Tip Tilt
UTTM	Uplink Tip Tilt Mirror
VME	VersaModule Eurocard
WBS	Work Breakdown Structure
WCP	Wavefront Controller Command Processor
WIF	Wavefront Controller Interface
WFP	Wavefront processor
WFS	Wavefront Sensor

2 APPLICABLE DOCUMENTS

[AD1] CARA/W.M. Keck
NGWFC RTC Requirements – Keck Adaptive optics note #311. Version 1.0, March 11th, 2005

[AD2] CARA/W.M. Keck
NGWFC RTC Tip-Tilt Requirements – Keck Adaptive optics note #329. Version 1.0, May 25th, 2005

[AD3] CARA/W.M. Keck
NGWFC RTC Acceptance Test Plan - Keck Adaptive optics note #374

[AD4] CARA/W.M. Keck
NGWFC Detailed Design Report - Keck Adaptive optics note #371
December 2nd, 2005

3 INTRODUCTION

This document contains a brief report of the test activities performed during the first NGWFC integration between July 2nd and July 11th, 2006. The activities have been performed on NGWFC Unit #1, installed on Keck 1, and on the NGWFC Unit #2 at HQ in Waimea.

This document does not contain a detailed description of the performed activity, it rather aims to describe the test results and put to evidence problems and open issues.

4 DTT tests

These tests have been performed on DTT installed on Keck1. DTT was connected to NGWFC Unit #1.

Remark:

- We discovered a cable swapping problem. This has been simply solved by changing the connection of the actuator control cables and keeping the original order on SG sensors. The actuators have been swapped as follows:

HVC board channel	Actuator	SG Sensor
0	B	A
1	C	B
2	A	C

Table 1 – Current connection of DTT

4.1 *DTT Strain gage calibration*

The strain gage calibration is obtained by pistoning the mirror up and down (i.e. moving all three actuators simultaneously) and acquiring the SG ADC values at different position. The motion range is from 5µm to 85µm and is repeated 4 times and just the last three 'turns' are used in the computation, to get rid as much as possible of the actuator hysterisis. For the same reason, the upper and lower extremes of the acquired values have been eliminated, as indicated by the dashed vertical lines on the plots (only the values between 15µm and 75µm have been used).
Thereafter, the linear best fit of the acquired values is computed, obtaining the gain and offset values. These parameters are then stored in the proper *init* file, in particular these calibrations are valid for NGWFC Unit #1. Considering that the gain and offset deviation of the HVC board inputs are by far better than the intrinsic accuracy of this calibration, which is anyway slightly affected by histerisis, the calibration values can be used on Unit #2 as well (alternatively the procedure can be easily repeated).
The *offset* is used to make sure that a given command drives the mirror approximately to the same position, regardless if the CLMP is open or closed. The *approximation* is clearly due to the actuator intrinsic hysterisis and non-linearity. Zero Volt driving will correspond to (approx) zero position.

The script used for this calibration can be found in
..\Keck_July06\DTT_Calibration\calibrateDTTSG.m

All relevant data are stored in
..\Keck_July06\DTT_Calibration\SGCalibration_07_09_06__01_21.mat

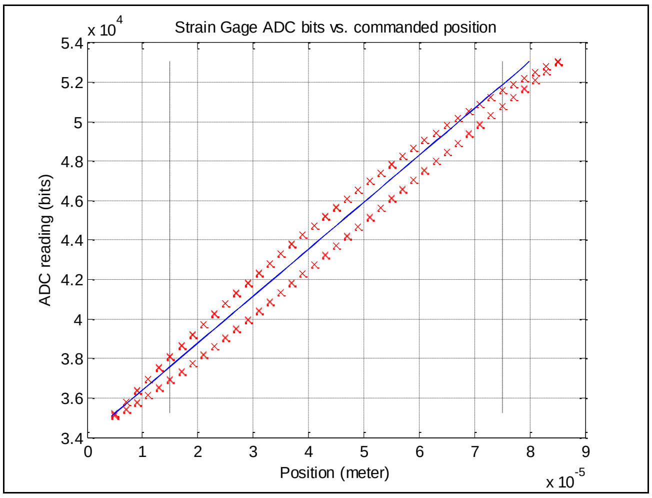

Figure 1 – Ch.0 – strain gage A calibration.

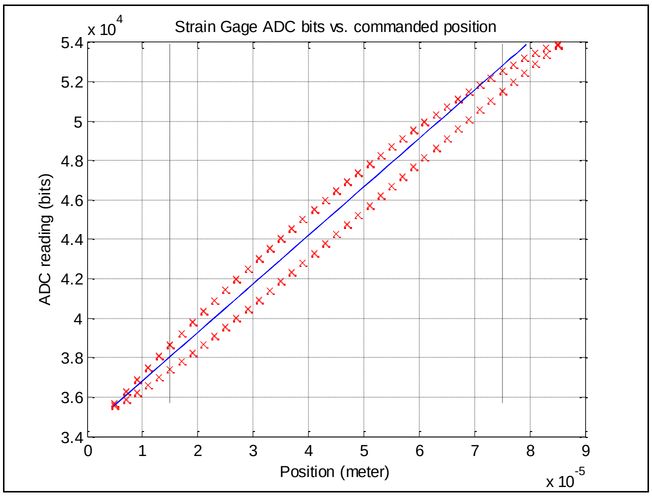

Figure 2 – Ch.1 – strain gage B calibration.

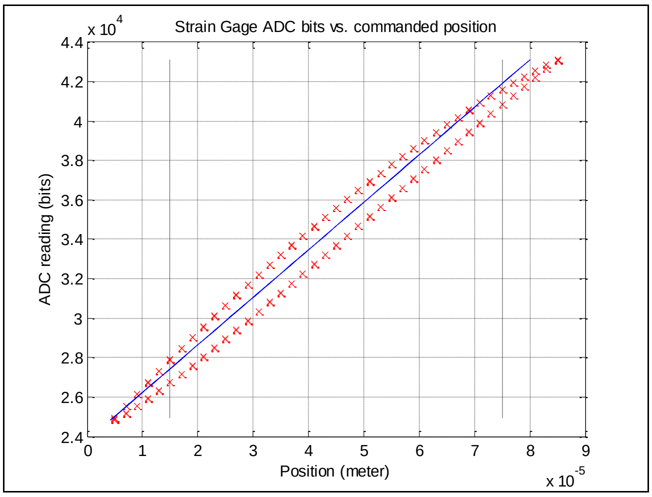

Figure 3 – Ch.2 – strain gage C calibration.

Channel	Gain (m/bit). Stored in variable _wfp_DTT_dist_A_coeff	Offset (m). Stored in variable _wfp_DTT_dist_B_coeff
0	4.203210e-009	-1.430182e-004
1	4.066458e-009	-1.397630e-004
2	4.146143e-009	-9.874815e-005

Table 2 – DTT strain gage calibration gain and offset.

4.2 Open Loop DTT Strain Gage FFT plots and noise

Acquiring the DTT strain gage signals, we have noticed that the DTT sensors are affected by some unexpected noise. It has been verified that the noise is on the sensors and that it is not generated by the HVC board or by the Agilent high voltage supply unit. In fact:

- The noise is present regardless of the actuator position, open/closed loop or even if the actuators command signals are disconnected.
- In closed loop operation, the noise is visible on the actuator control signal only at high gain. This is normal because the PID controller has still some gain at frequency of the main noise source.
- Connecting the test actuator to HVC, the noise disappears.

After a preliminary analysis, we can evince the following considerations :

- Analyzing the FFT of the SG signal, the main noise contributions come from a narrowband source around 5.9kHz. It has been observed that the frequency is slightly drifting over time, but always around 5.8~5.9kHz. The second and third harmonics are also visible.
  A second noise source can be noticed around 7kHz. This is wider band and appears as close, equally spaced peaks. Therefore if could be the effect of some PWM drive, e.g. power supply.
- The noise is significantly on Sensor B, sensor A is the most quiet, C slightly worse than A (see data below).
- Using the long extension cables on actuator B, the noise std value is significantly improved, but the noise ‘color’ is still there. Additionally, we noticed some more peaks at low frequency, below 1kHz.
- It is quite unlikely for the noise contribution to be generated mechanically. Considering the frequency and the amplitude, it would imply a significant amount of energy to be transferred to the mirror. The electrical pick-up is much more realistic.
- Aliasing is also quite unlikely because of 2nd order anti-aliasing filters @ 26kHz (Nyquist is at 30kHz).

The following plots show the FFT of the acquired signal with CLMP open. Sampling frequency is 60kHz. 30000 samples acquired. The mean value is given just for reference.

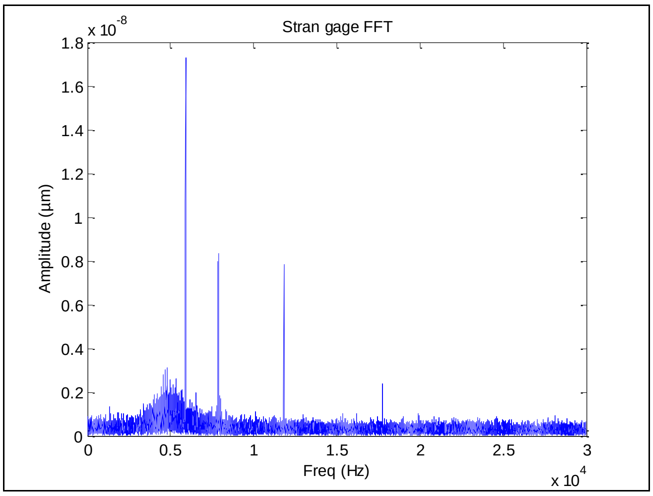

Figure 4 – Actuator A on Ch.0, open loop. Mean: 4.468080e-005m, Std: 4.405923e-008m

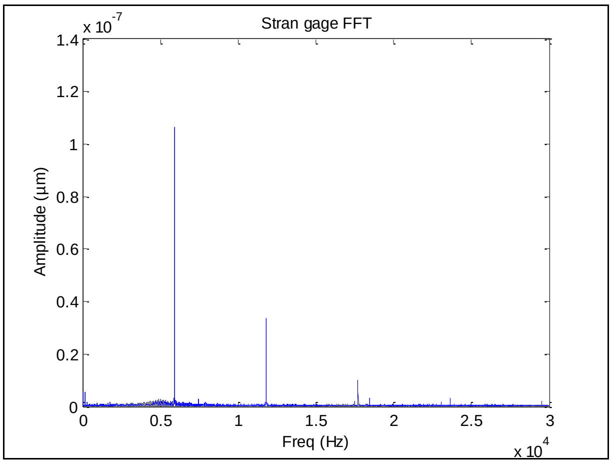

Figure 5 – Actuator B on Ch.1, open loop. Mean: 4.605224e-005m, Std: 9.641394e-008m

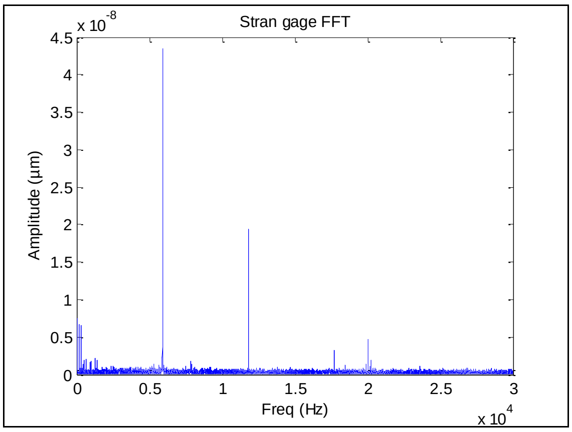

Figure 6 – Actuator B on Ch.1, open loop, 160’ extension cable. Mean: 4.522841e-005, Std=5.687727e-008

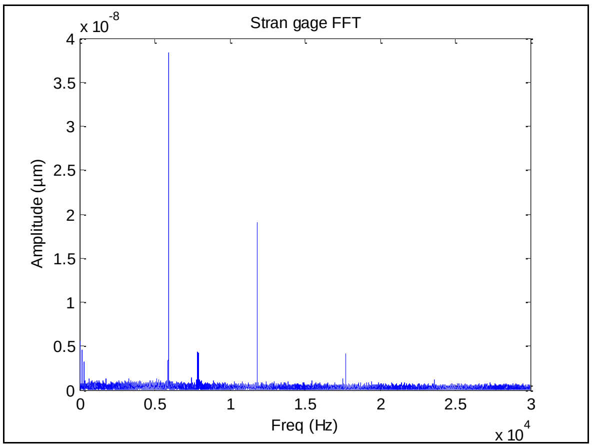

Figure 7 – Actuator C on Ch.2, open loop. Mean: 1.424418e-005, Std=5.229602e-008

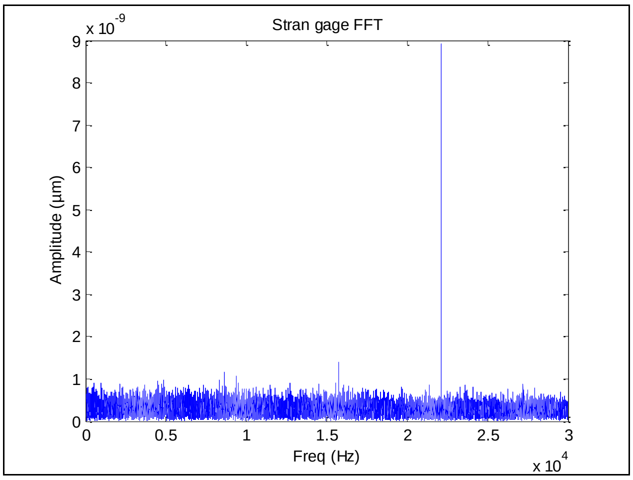

Figure 8 – Test Actuator Ch.1, open loop. Mean: -1.538876e-006, Std=2.895761e-008

4.3 Closed Loop DTT step response

The following plots show the DTT closed loop (CLMP) step response. The step has been performed one actuator at a time, but with all three actuators in closed loop. Step amplitude is 3µm. PID controller coefficients and gain are the nominal ones from *init* file. Preshaper is set to 270µs settling time (the PID controller is significantly slower than the preshaper here).
Red: SG sensor. Green: control signal. The control signal is given in *meter* considering the nominal actuator gain (9e-7 m/V).
Note that the driving signal is significantly different with respect to the actual motion due to hysterisis.

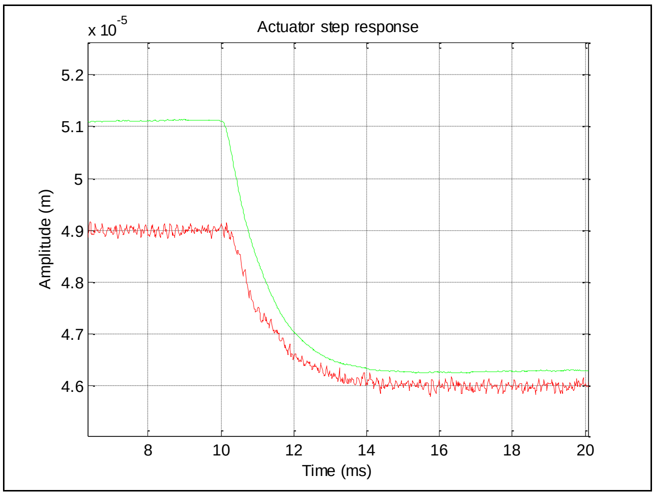

Figure 9 – Ch.0 step response (Actuator cable B, Sensor cable A). The 5.9kHz noise is not particularly evident on this channel.

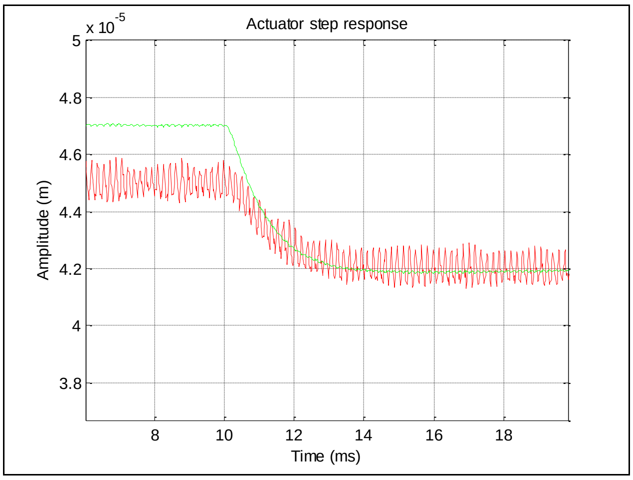

Figure 10 – Ch.1 step response (Actuator cable C, Sensor cable B). The 5.9kHz noise is very evident on this channel, and it can be noticed also on the control signal due to the PID gain at this frequency.

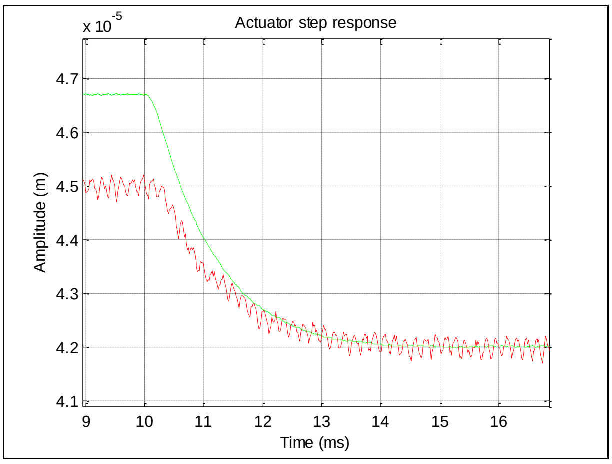

Figure 11 – Ch.2 step response (Actuator cable A, Sensor cable C). In terms of noise, this channel is worse than Ch.0 but significantly better than Ch.1.

5 UTT tests

Even we are calling these tests *UTT tests*, the activity has been actually performed on the mirror installed on OTF. The tip-tilt stage is identical to the one foreseen for UTT, but the mirror mass is different. The OTF-UTT was connected to NGWFC Unit #2.

The OTF-UTT cables were modified at MG premises to be compatible with the HVC board connectors. At same time, we also completed the SG bridges because it was noticed that the SG is configured as half-bridge on this actuator. The modification has been implemented in the small connection box that splits the actuator and sensor cables in three and two cables respectively.

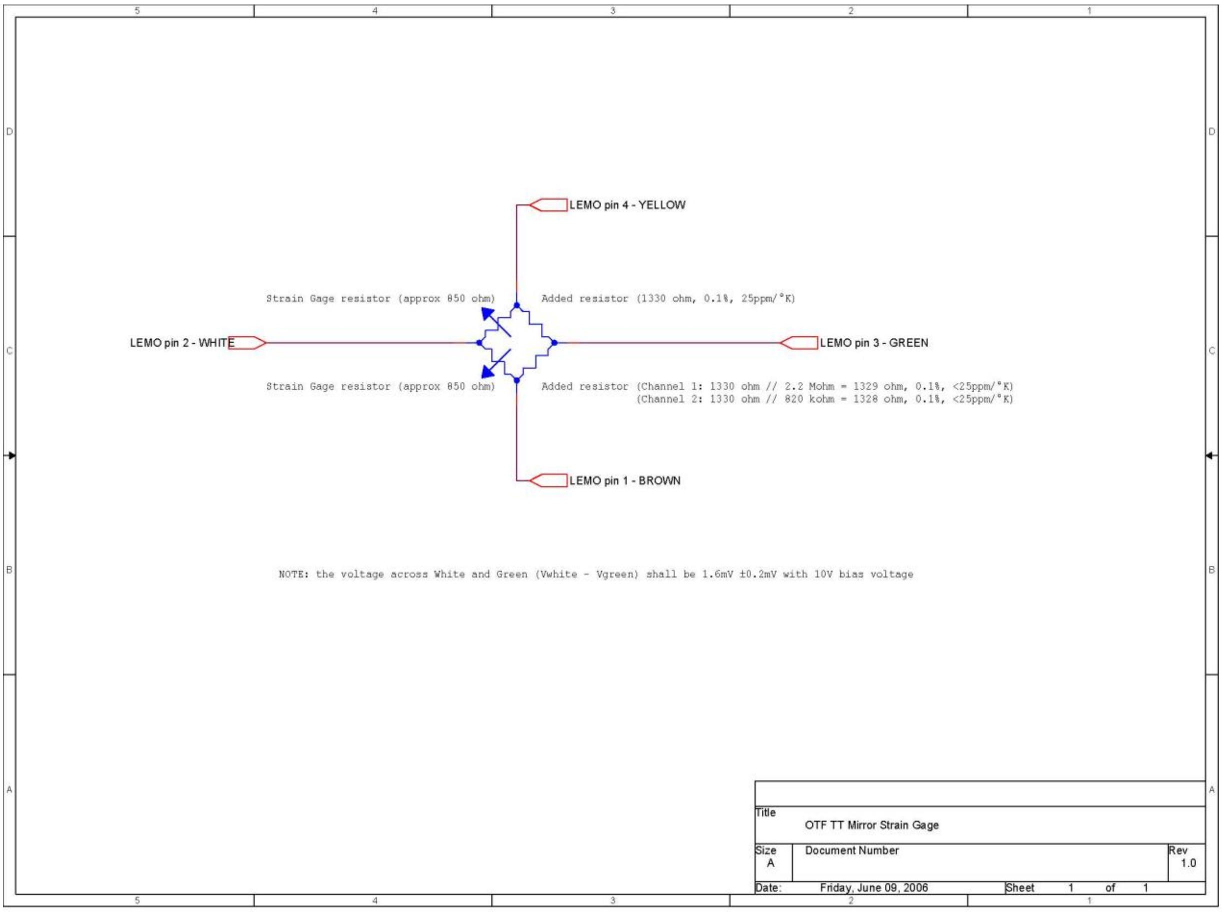

Figure 12 – OTF-UTT sensor cables modifications and pinout.

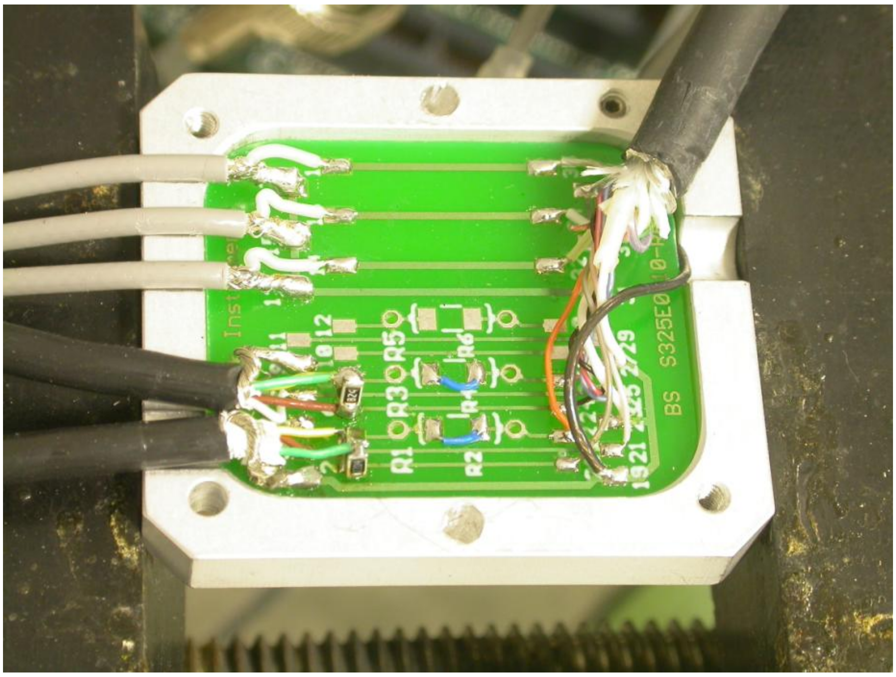

Figure 13 – Internal view of OTF-UTT command and sensor cables splitting box. The half-bridge added resistors can be clearly seen.

5.1 OTF-UTT Strain gage calibration

The strain gage calibration is obtained by tilting the mirror simultaneously in X and Y and acquiring the SG ADC values at different position. While doing this, the third electrode was biased at 100Vdc constant. The motion range is from 0.2mrad to 1.8mrad and is repeated 4 times and just the last three 'turns' are used in the computation, to get rid as much as possible of the actuator hysterisis. For the same reason, the upper and lower extremes of the acquired values have been eliminated, as indicated by the dashed vertical lines on the plots (only the values between 0.3mrad and 1.7mrad have been used).
Thereafter, the linear best fit of the acquired values is computed, obtaining the gain and offset values. These parameters are then stored in the proper *init* file, in particular these calibrations are valid for NGWFC Unit #2. Considering that the gain and offset deviation of the HVC board inputs are by far better than the intrinsic accuracy of this calibration, which is anyway slightly affected by histerisis, the calibration values can be used on Unit #1 as well (alternatively the procedure can be easily repeated).
The *offset* is used to make sure that a given command drives the mirror approximately to the same position, regardless if the CLMP is open or closed. The *approximation* is clearly due to the actuator intrinsic hysterisis and non-linearity. Zero Volt driving will correspond to (approx) zero tilt, <u>always with the third electrode biased at 100Vdc</u>.

The script used for this calibration can be found in
..\Keck_July06\UTT_Calibration\calibrateUTTSG.m

All relevant data are stored in

..\Keck_July06\UTT_Calibration\SGCalibration_07_11_06__04_14.mat

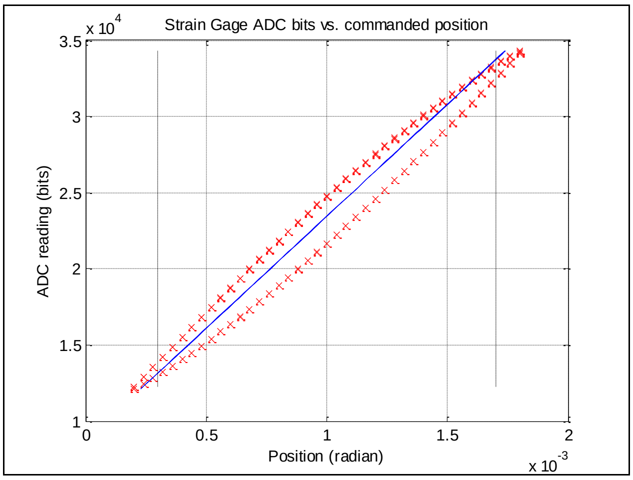

Figure 14 – Ch.0 calibration.

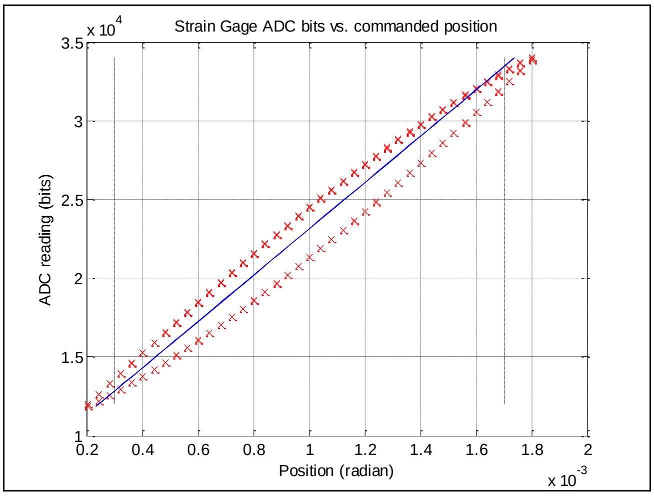

Figure 15 – Ch.1 calibration.

Channel	Gain (radian/bit). Stored in variable _wfp_UTT_dist_A_coeff	Offset (radian). Stored in variable _wfp_UTT_dist_B_coeff
0	6.801107e-008	5.946829e-004
1	6.811963e-008	-5.766940e-004

Table 3 – UTT strain gage calibration gain and offset.

5.2 Open Loop OTF-UTT Strain Gage FFT plots and noise

The noise on OTF-UTT strain gage signals has been measured both connecting directly the mirror to the HVC board and using the 160' extension cables.

The longer cables caused a significant increase of noise, by about 8 times. The noise is picked up by the sensor cable only, as expected we were not observing any difference using the extension cable on the actuator command side.
It should be noticed that the sensor extension cable was rolled and placed close to the VME crate, in particular to the fans. We suggest to repeat the test in a better condition.
The noise appears to be quite broad-band with a peak around 9kHz.
The results are presented in Table 4.

Test condition	Noise standard deviation over 30000 samples	
	Channel 0	Channel 1
Open loop, no cable extension	7.53e-7 rad	7.33e-7 rad
Open loop, cable extension on actuator control and SG of Channel 0 only (see Figure 16)	5.73e-6 rad	6.96e-7 rad
Closed loop (1ms settling), no cable extension	6.89e-7 rad	6.92e-7 rad
Closed loop (1ms settling), cable extension on actuator control and SG of Channel 0 only (see Figure 17)	5.88e-6 rad	7.12e-7 rad

Table 4 – OTF-UTT SG noise measured in different conditions.

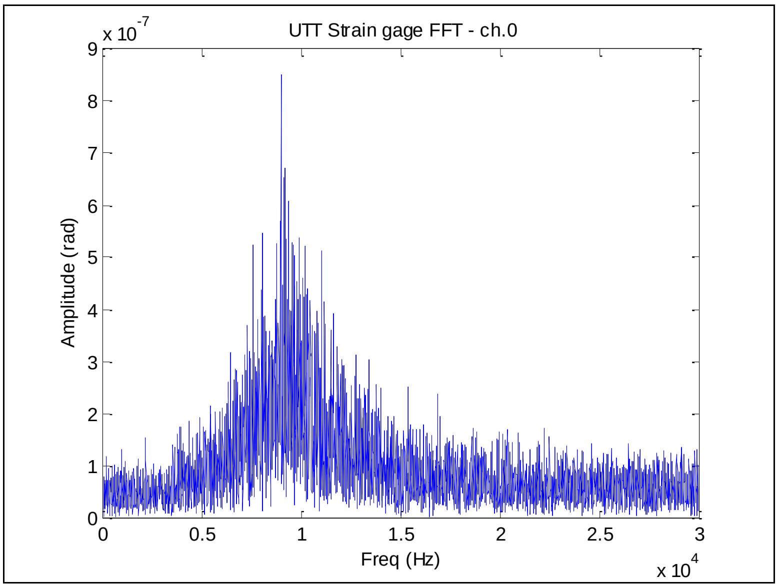

Figure 16 – FFT of Ch.0 SG signal, open loop, 160' extension cable.

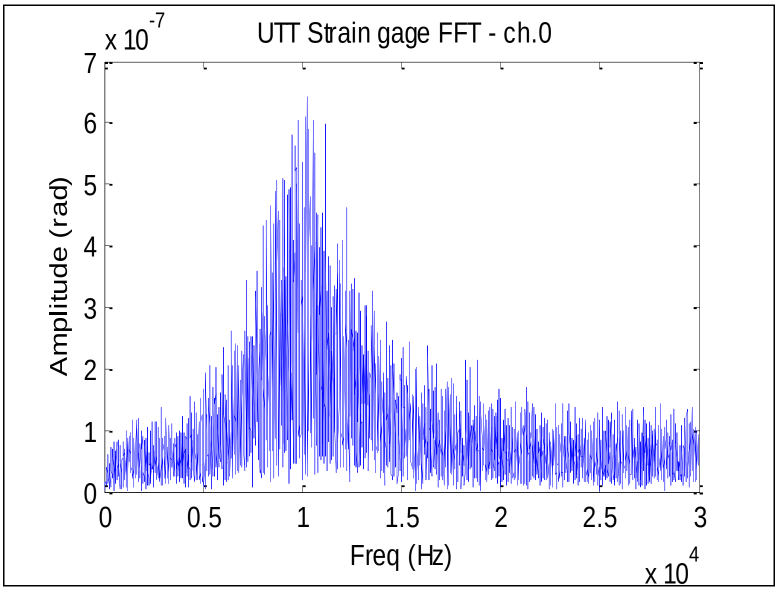

Figure 17 – FFT of Ch.0 SG signal, closed loop, 160' extension cable.

5.3 Closed Loop UTT step response

The following plots show the UTT closed loop (CLMP) step response. The step has been performed one actuator at a time, but with all three actuators in closed loop. Step amplitude is 20µradian. PID controller coefficients and gain are the nominal ones from *init* file. Preshaper is set to 270µs settling time (the PID controller is significantly slower than the preshaper here).
Red: SG sensor. Green: control signal. The control signal is given in *meter* considering the nominal actuator gain (2e-5 rad/V).
Note that the driving signal is significantly different with respect to the actual motion due to hysterisis. In the step response with extension cable (see Figure 20) the effect of noise is very evident, but it was possible anyway to close the loop with the nominal gain, therefore the dynamic performance is not affected by the increased noise. We expect however that the noise will impact the closed loop performance as soon as the dynamic performance will optimized.

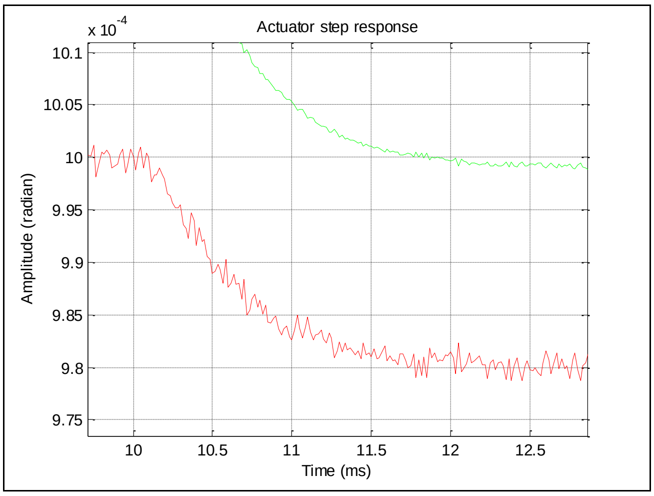

Figure 18 – Ch.0 step response. No extension cable.

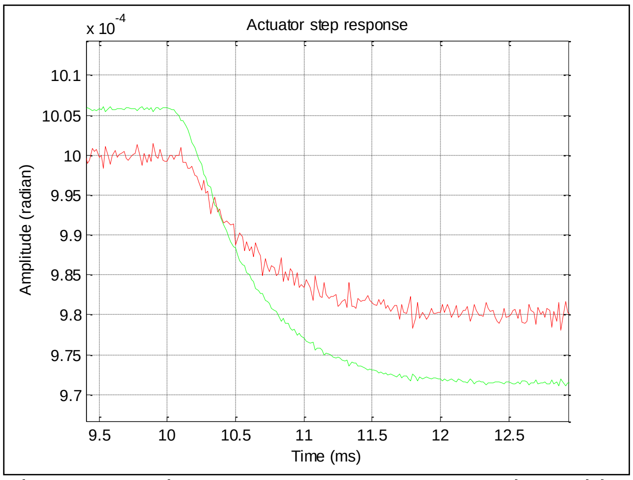

Figure 19 – Ch.1 step response. No extension cable.

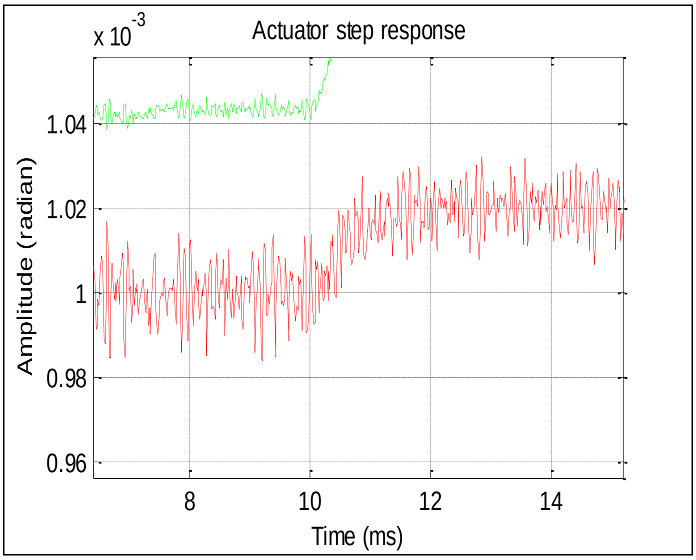

Figure 20 – Ch.0 step response. 160' extension cable on both control and SG signals. The noise increase is very evident.