CNRS
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INFN
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Calibration status in February 2009

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VIR-008A-09

March 5, 2009

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1 Introduction

This note gives the status of the actuation calibration in February 2009. Datasets from December 2008 to February 2009 are used to calibrate the NE and WE mirror (Up-Down coils) and marionette actuation.

Since the ITF is under commissioning, some calibration parameters are changing quite fast and are not updated after each change. Only a set of standard measurements have been performed. No systematic errors have been estimated using different types of data. Note that the absolute timing and the delay from the actuation to the dark fringe has not been calibrated in this period and have changed with the installation of the new timing system and electronics.

The calibration period is from GPS 912440000 to 919900000. The status of the mirror actuation (DSP and coil driver) is described in the calibration working area [1].

2 WE actuation calibration

2.1 WE mirror actuation in HP mode, U-D coils

Data in free swinging Michelson configurations have been taken in December 2008 and February 2009 with the suspensions in HP mode and injecting noise (lines) on the Up and Down coils. They have been analysed to measure the mirror U-D actuation in HP mode. Only the data points with coherence between the reconstructed mirror motion and the injected noise higher than 90% have been used.

The pendulum mechanical response and the delays from the optical response of the ITF have been corrected in the given actuation TF (see note [2] for details about the models). The delay induced by the dark fringe readout ($Pr\_B1p\_\{DC, ACp, ACq\}$) is included in the given TFs. It had been estimated to $\sim 75\,\mu$s after VSR1 (October 2007). It must not have changed up to end of February 2009 but was not measured again.

The results were checked for variations as function of time and of injected amplitude. The phase is compatible with a constant. For the lines below 40 Hz (6.5, 16.5 and 36.5 Hz), some time variations are observed on the modulus. Systematic errors are estimated between 0.10 and 0.20 μm/V. No indication of evolution with the amplitude is seen. From 50 to 200 Hz, the modulus is compatible with a constant. Also, for frequencies larger than 400 Hz, no variations are seen but the number of measurements is lower (less than 5 points). In the range 200 to 400 Hz (lines at 236.5 and 351.5 Hz), time variations are seen with systematic estimated to 0.3 μm/s.

The figure 1 shows the measured actuation (averaging all the data) as well as the fitted model and its residuals. The fit parameters are given in the table 1. Its χ^2 probability is 0.13% ($\chi^2/ndf = 47.5/22$).

2.2 WE mirror actuation: LN1 to HP TF ratio, U and D coils

The new coil drivers have a channel to measure the current flowing in the coil with enough dynamic to be sensitive to noise injection both in HP and in LN1 modes (also in LN2 mode). A new procedure (using an Alp macro) has been developpped to measure the actuation TF ratio LN1/HP (and LN2/HP). The suspensions being in standalone mode, noise is injected to the actuation (i.e. Sc_WE_zCorr) in HP mode and then in LN1 mode. The coil current is measured in i.e. $Ca\_WE\_RM\_CoilU$. The automatized data taking less than 10 minutes to measure all the suspensions[1]. It thus allows a regular monitoring of the TF ratio. Installation of the new coil drivers on all the mirror actuation would be of high interest to reduce the time devoted the calibration measurements during the next run (VSR2) and to reduce the calibration errors.

The noise injected has been white noise or a set of lines. Different datasets with different levels of injections were done. The measured LN1/HP TF ratio is shown in the figure 2 for all the datasets and after averaging all the data. Only the data points with coherence larger than 99.9% between the noise and the current were used. Some time variations up to 2% of the ratio are observed, especially at the frequencies of the injected lines. Their origin is still unknown and is under investigation (their correlation with the level of the current has to been checked: if there is some correlation, the variations could be due to some non-linearities of the electronics).

Also, the ratio is different for the up and down coils. This might induce systematic errors since their average is used when computing the WE actuation in LN1 mode from the actuation in HP mode.

2.3 WE mirror actuation in LN1 mode, U-D coils

The mirror actuation TF in LN1 mode is computed multiplying the actuation TF in HP mode by the TF ratio LN1/HP. The data points are used in the combination, not the fitted models. A fit is performed on the data to get the model of the actuation in LN1 mode.

The measured actuation along with the model and its residuals are shown in the figure 3. The model parameters are given in the table 1. The $\chi 2/ndf$ is 73.9/22 (probability of 10^{-7}. Note that this low probability comes from the phase points below 20 Hz (the fit probability is 13% on the modulus only and 10^{-8}% on the phase only).

2.4 WE marionette to mirror actuation

The marionette actuation TF is derived from the mirror actuation (in LN1 mode) and the marionette to mirror TF ratio.

[1] it has to be compared to the few shifts necessary to make a single measurement manually in the suspensions with the old coil drivers.

The procedure to measure the marionette to mirror TF ratio has been automatized (using Alp). When the ITF is locked, for each suspension, noise is injected to the mirror (U-D coils in LN1 mode) and then to the marionette up to $\sim$ 100 Hz. The difference of the effects of both noise injections to the dark fringe gives the marionette to mirror TF ratio. The automatized procedure lasts about 30 minutes to have a dataset for all the suspensions (NE, WE, NI, WI and BS).

A single dataset have been taken up to now. The measured ratio, where the coherence is higher than 90% in both TFs, is shown in the figure 4.

The data are combined with the model of the mirror actuation in LN1 mode. The obtained marionette TF is shown in the figure 5, along with the fitted model and residuals. The fit was performed between 1 Hz and 120 Hz. The fit parameters (a simple pole) are given in the table 2. The residuals are flat, within 5% in modulus and better than 0.1 rad in phase.

3 NE actuation calibration

3.1 NE mirror actuation in HP mode, U-D coils

Same data as for the WE calibration.

Similar systematic errors due to observed time variations of the modulus.

The figure 6 shows the measured actuation (averaging all the data) as well as the fitted model and its residuals. The fit parameters are given in the table 1. Its χ^2 probability is 0.4% ($\chi^2/ndf = 43.7/22$).

3.2 NE mirror actuation: LN1 to HP TF ratio, U and D coils

Same data as for the WE calibration.

Similar systematics are observed (and one strange dataset (GPS 916673079) has a ratio lower than the other by $\sim$ 5% on the down coil).

3.3 NE mirror actuation in LN1 mode, U-D coils

The measured actuation along with the model and its residuals are shown in the figure 7. The model parameters are given in the table 1. The $\chi 2/ndf$ is 36/22 (probability of 3%) (the fit probability is 5% on the modulus only and 0.8% on the phase only).

3.4 NE marionette to mirror actuation

Different datasets have been taken for the NE marionette. The measured ratios and the averaged ratio is shown in the figure 8. The different datasets are compatible with a constant but no information about possible time variations can be derived since they were all taken within 1 hour on January 21st 2009.

The data are combined with the model of the mirror actuation in LN1 mode. The obtained marionette TF is shown in the figure 9, along with the fitted model and residuals. The fit was performed between 1 Hz and 120 Hz. The fit parameters are given in the table 2. The residuals are quite large: within 10% in modulus and 0.2 rad in phase.

4 Conclusions

New procedures have been automatized to calibrate the mirror and marionette actuation. The automatized procedure to calibrate the LN1/HP mirror actuation ratio can only be performed with the new coil drivers (WE and NE). It lasts less than 10 minutes and will allow a regular monitoring of the actuation. Manual measurements, lasting about 5 to 10 hours, are still necessary to get the same measurements on the other suspensions, without monitoring.

The NE and WE mirror actuation TFs have been measured up to 1 kHz with systematic errors of the order of 4% from the observed time variations. Additionnal checks have not been performed and a conservative total systematic error of 10-15% can be assumed.

The NE and WE marionette actuation TFs have been measured up to 100 Hz within better than 10% (statistics and fit residuals). They have not been checked for time variations or other systematic errors. The total systematic errors can be assumed to be 15%.

The NI, WI and BS mirror actuation have been measured in HP mode only since the LN1/HP TF ratio was not (manually) measured again on the old coil drivers, modified since the post-VSR1 measurements. The same models as during VSR1 are thus used. Systematic errors of 20% can be assumed. Data have been taken to measure the BS marionette to mirror actuation ratio, but cannot be used to derive the marionette actuation precisely since the mirror actuation is not well known.

The absolute timing of the data, with the new timing system, has not been calibrated.

Since the measurements given in this note, new electronics have been installed (February 24th 2009), in particular on the dark fringe channels $Pr\_B1p\_\{DC, ACp, ACq\}$ and Pr_B1_ACp used for the calibration. Below 1 kHz, this will change the delay of actuation.

5 Tables

		WE	NE
HP	Gain (μm/V)	12.991 ± 0.011	12.8955 ± 0.0097
	Delay (μs)	479.2 ± 2.5	489.0 ± 2.9
	Φ_0 (rad)	π	π
	Pole frequency (Hz)	79.5 ± 3.2	63.4 ± 8.3
	Zero frequency (Hz)	92.5 ± 4.5	71.7 ± 11.2
	Pole frequency (Hz)	390.1 ± 57.4	257.1 ± 52.7
	Zero frequency (Hz)	454.6 ± 70.0	307.5 ± 59.5
LN1	Gain (μm/V)	13.212 ± 0.013	13.605 ± 0.010
	Delay (μs)	474.3 ± 2.6	473.2 ± 3.0
	Φ_0 (rad)	π	π
	Pole frequency (Hz)	62.4 ± 3.0	82.7 ± 3.4
	Zero frequency (Hz)	71.6 ± 4.0	95.6 ± 4.1
	Pole frequency (Hz)	335 ± 41	374 ± 24
	Zero frequency (Hz)	405 ± 52	453 ± 36

Table 1: ***WE and NE mirror actuation model, using the U-D coils*** *in HP mode and LN1 mode.*

	WE	NE
Gain (μm/V)	0.49277 ± 0.00060	0.4622 ± 0.0009
Delay (ms)	1.925 ± 0.003	0.740 ± 0.006
Φ_0 (rad)	π	π
Pole frequency (Hz)	16.896 ± 0.025	71.2 ± 1.2
Zero frequency (Hz)	-	36.22 ± 0.47
Pole frequency (Hz)	-	34.05 ± 0.34, $Q = 0.389 \pm 0.002$

Table 2: ***WE and NE marionette actuation models.***

6 Figures

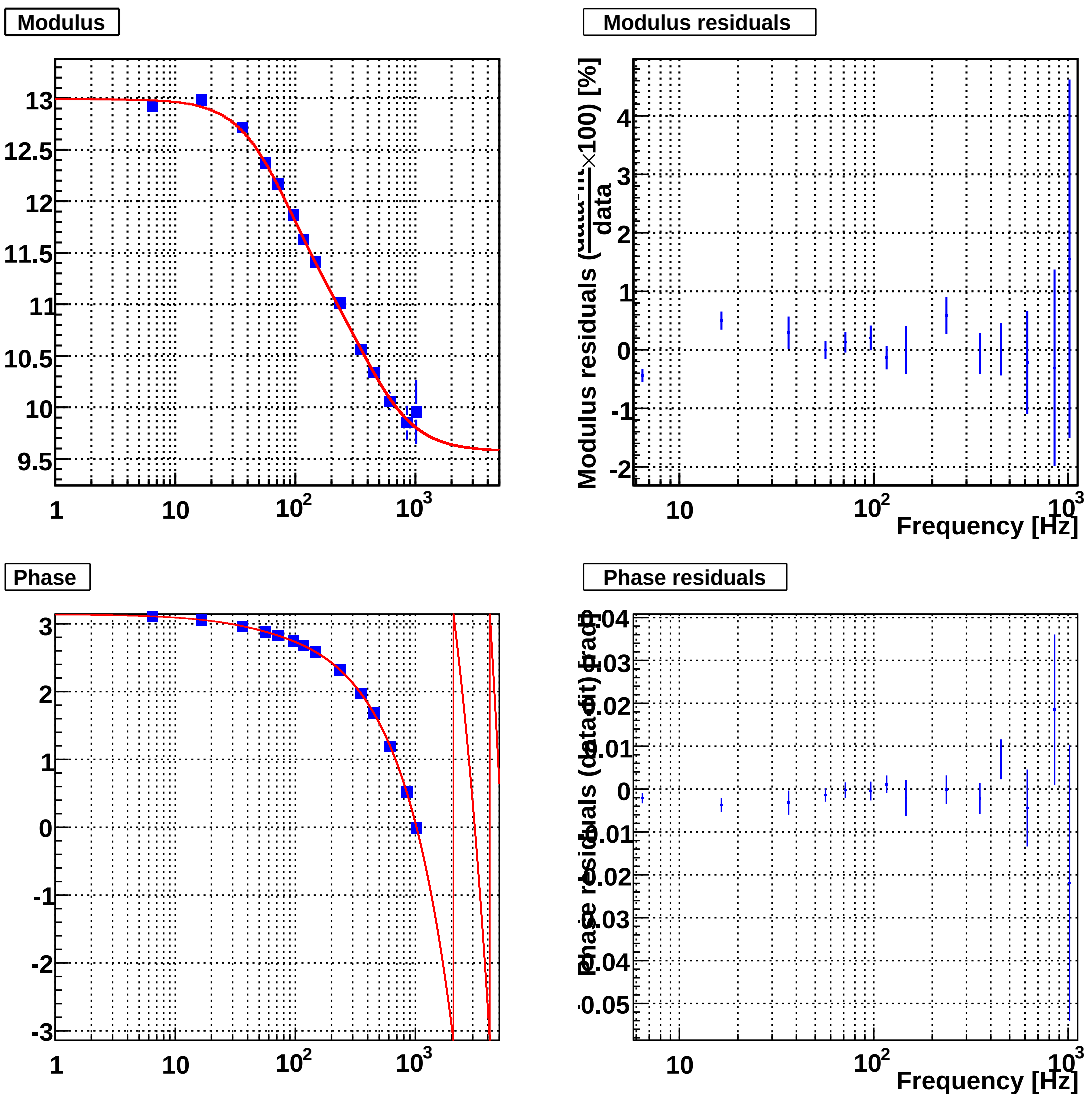
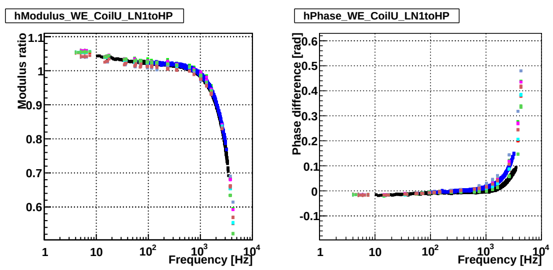
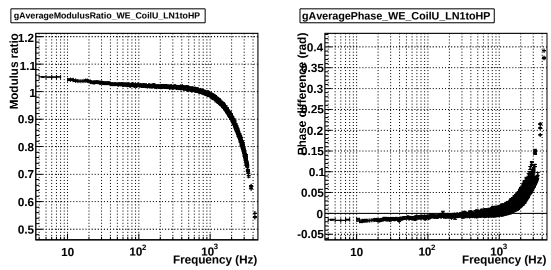


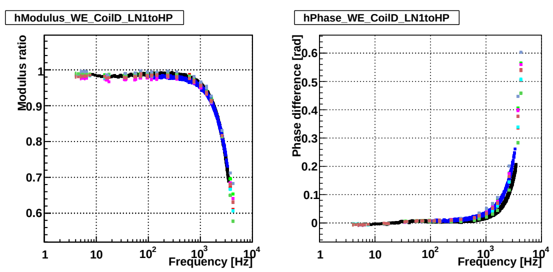
Figure 1: ***Measured actuation of the WE mirror using the U-D coils in HP mode****, fitted model and residuals.*



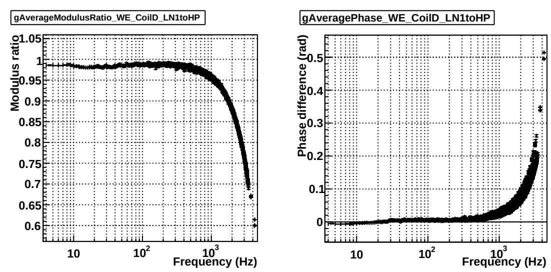
(a) Coil Up, all datasets



(b) Coil Up, averaged



(c) Coil Down, all datasets



(d) Coil Down, averaged

Figure 2: ***Measured actuation TF ratio (LN1/HP) for the up and down coils of the WE mirror****. All the datasets are shown (a color corresponds to a dataset) as well as the averaged result.*

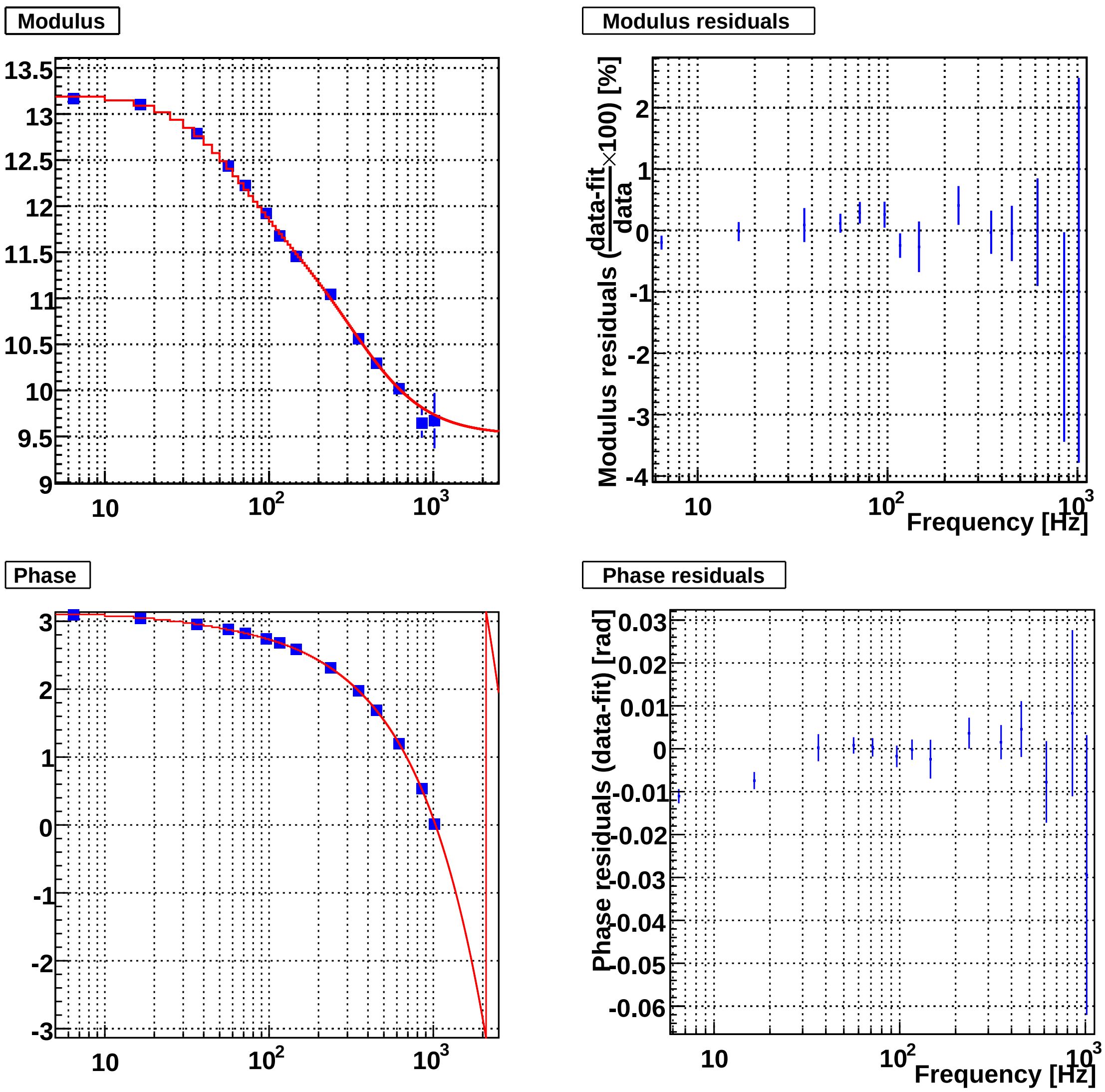


Figure 3: ***Measured actuation of the WE mirror using the U-D coils in LN1 mode****, fitted model and residuals.*

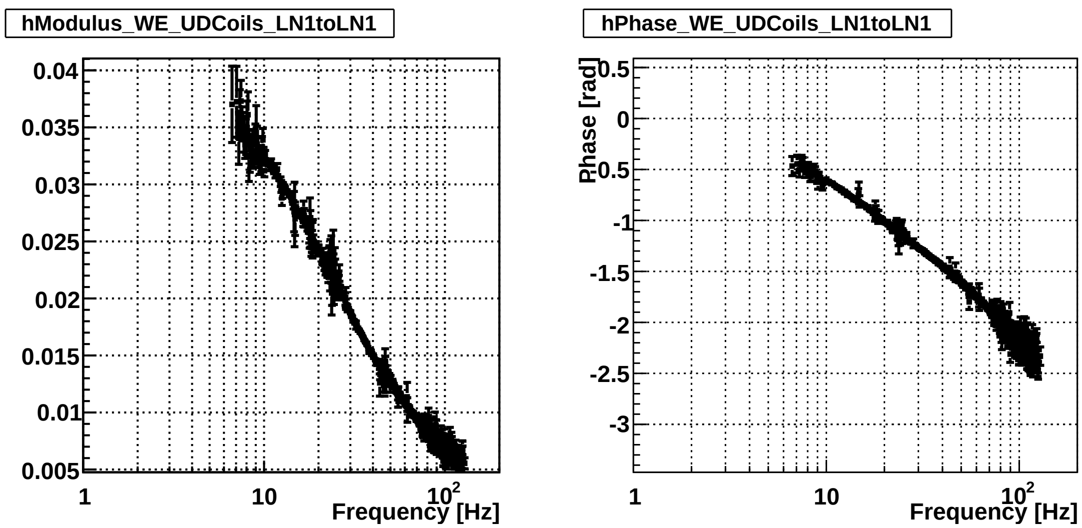


Figure 4: ***Measured marionette to mirror actuation TF ratio of the WE suspension.***

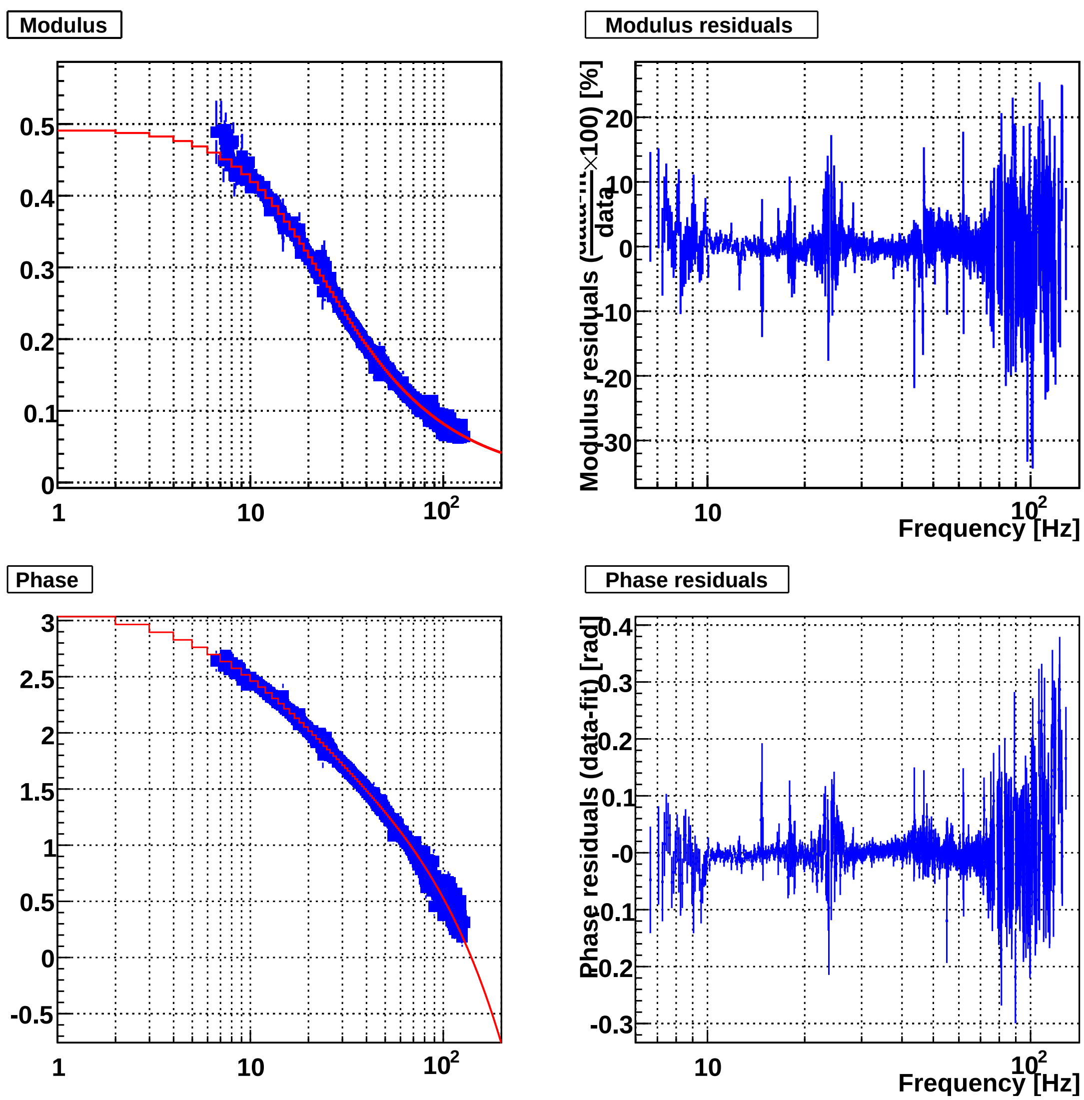


Figure 5: ***Measured WE marionette actuation TF****, fit and residuals.*

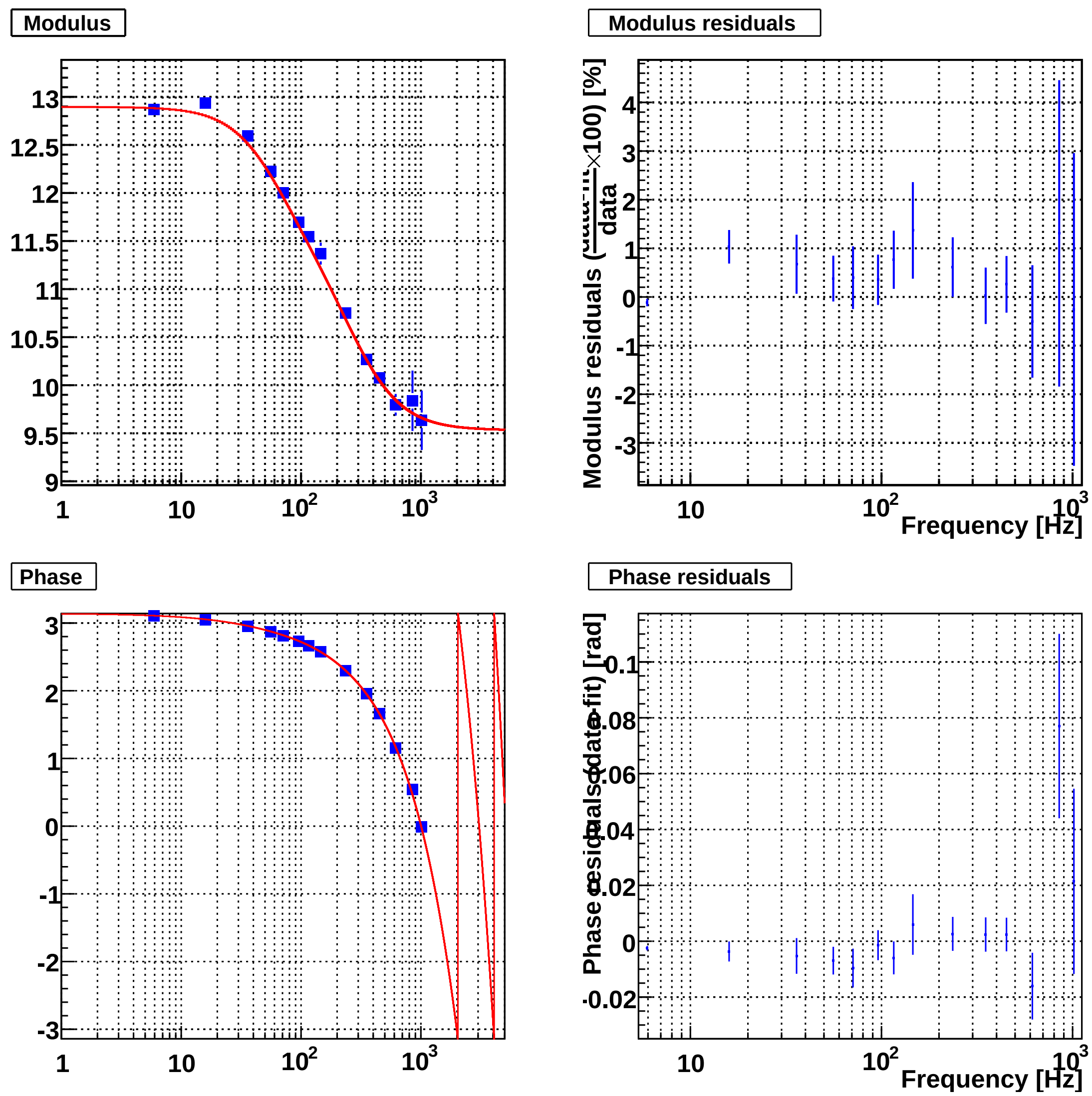


Figure 6: ***Measured actuation of the NE mirror using the U-D coils in HP mode****, fitted model and residuals.*

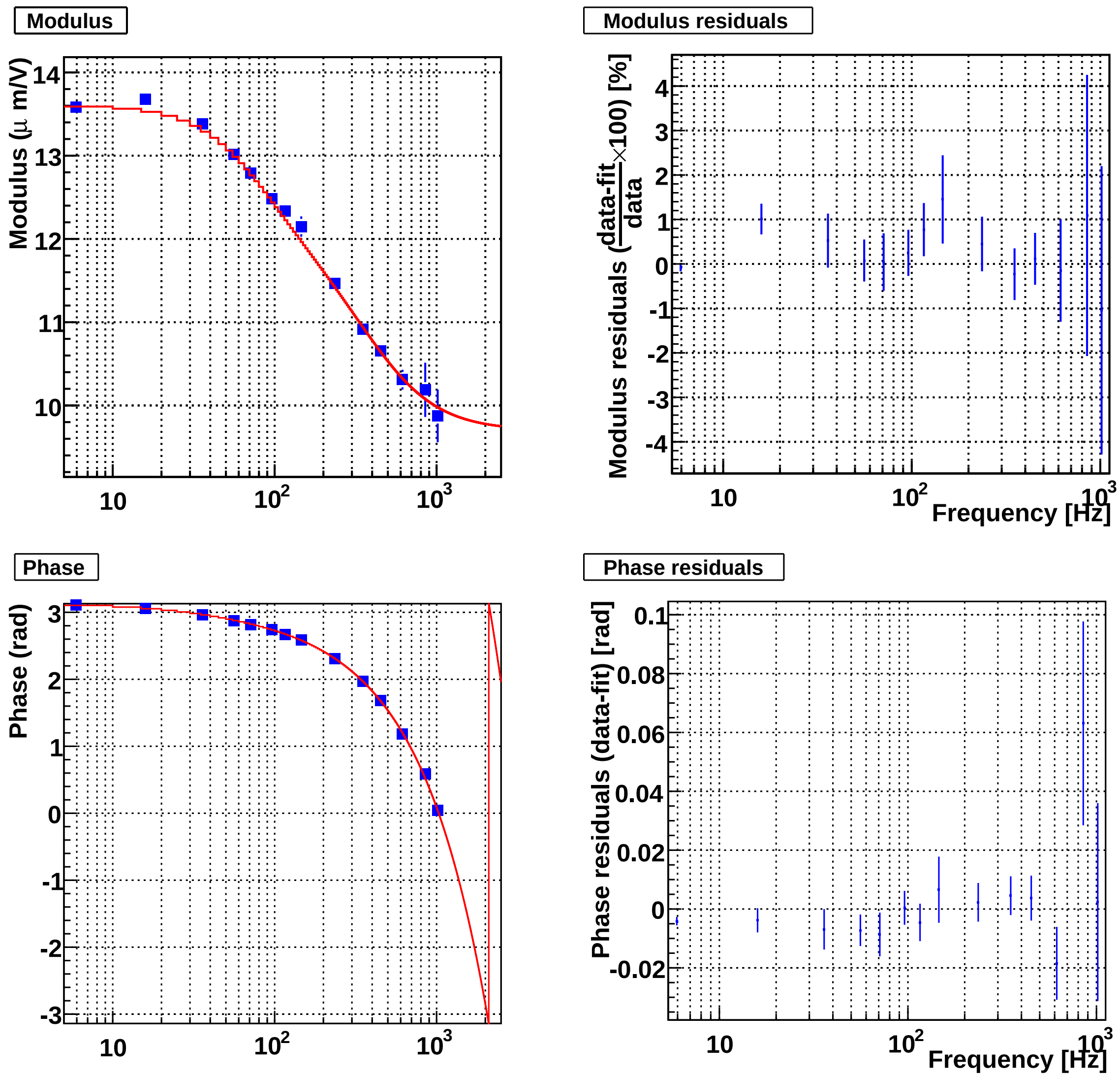
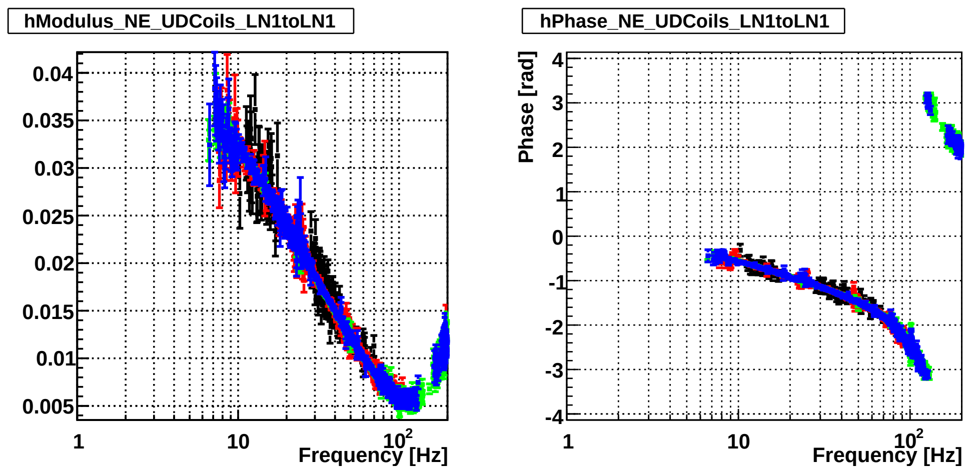
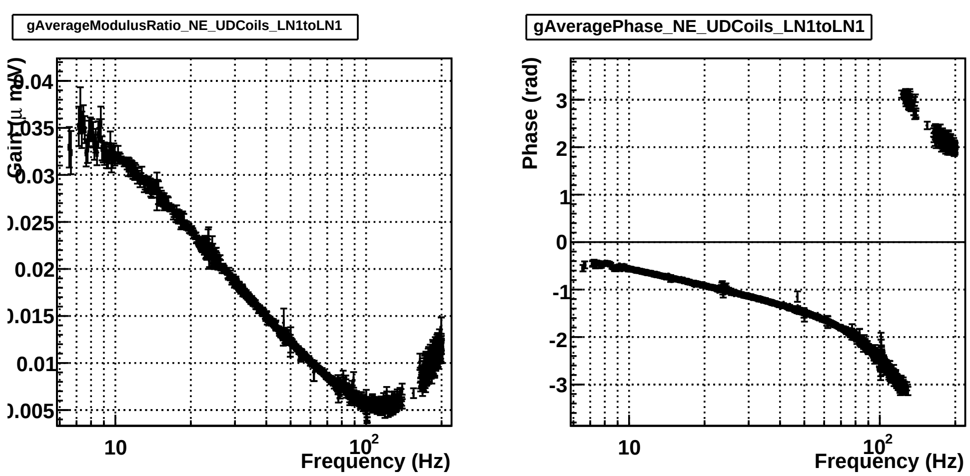


Figure 7: ***Measured actuation of the NE mirror using the U-D coils in LN1 mode****, fitted model and residuals.*



(a) All measured ratios.



(b) Averaged ratio.

Figure 8: ***Measured marionette to mirror actuation TF ratio of the NE suspension*** *for the different datasets (one color is a dataset) and averaged.*

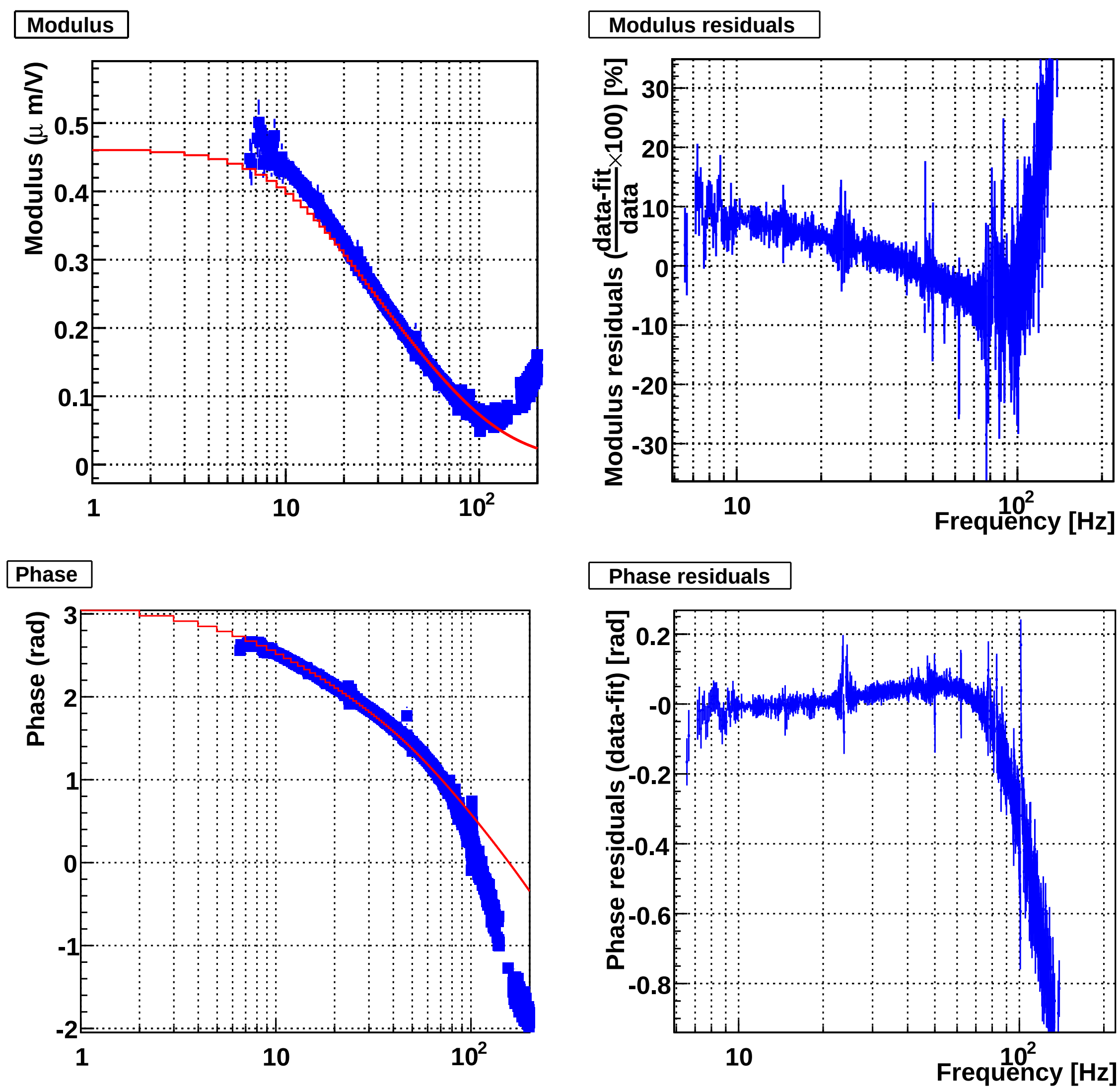


Figure 9: ***Measured NE marionette actuation TF****, fit and residuals.*

References

[1] https://workarea.ego-gw.it/ego2/virgo/data-analysis/calibration-reconstruction/auth-only/actuators/dsp-coil- driver-status-on-february-2009

[2] L. Rolland, F. Marion, B. Mours *Mirror and marionette actuation calibration for VSR1* (2008) VIR-015A-08.