Commissioning plan update
June 2006

VIR-COU-DIR-1000-225
June 9th 2006

Summary

1. Introduction

The present document is an update of the “Virgo Commissioning Plan” issue of November 2005 (VIR-COU-DIR-1000-216) [1]. The results of the last six months activity are contained in the “Commissioning progress section of the Virgo progress report of June 2006” (VIR-COU-DIR-1000-224) [2]. The major detectors upgrades [3] are described in the detector coordination section of this document.

As already stated in [1] the main goal of the commissioning plan is to describe all the steps necessary to conclude the VIRGO interferometer commissioning (that means to reach the design sensitivity with a good duty cycle). This roadmap is based on the experience cumulated in the last two and half years. Several noise sources was measured, modelled and simulated. Actions are planned to reduce their amplitudes and/or their coupling with the interferometer output. The attempt to make an ultimate planning for the VIRGO commissioning faces with the problem to predict the influence of noise sources whose modelling is difficult (diffused light, environmental disturbances, clipping, etc.). This is particularly true for the low frequency region (i.e. below 50 Hz), where many technical noises show up and no data or experience is available in the international community.

- Section 2 contains an update of the task “completion of the recycled interferometer commissioning”. We will refer often to [1] for the details of the task to be completed and to [2] for the recent achievements.

- Section 3 contains an update of the tasks “noise hunting”, divided – for practical reasons – in the sections: “high frequency”, “intermediate frequency” and “low frequency”.

- Section 4 Contains commissioning plan global view for 2006 and 2007. The plan from now to the first science run (planned at the end of 2006) is obviously more detailed. A tentative plan for 2007 is also given.

With respect to [1], in this document we include some more deep estimations of the main limiting noise source at low frequency (longitudinal ad angular control noises).

2. Completion of the recycled interferometer commissioning update

This part includes the implementation of the remaining control systems (mainly alignment and hierarchical control on the beam splitter) and the improvements of the control systems which showed problems before the shutdown (offsets in the angular and longitudinal error signals, diagonalization of longitudinal sensing and driving matrices, etc…).

To perform this tasks locking periods at least of tens of minutes are needed. The first priority is then to improve the interferometer robustness, through the understanding and the removal of the interferometer signals oscillations described in [2].

2.1. Interferometer stability problems

As already explained in [2] one of the cause of these oscillations can be some thermal lensing effects, and its coupling with alignment fluctuations.

In order to understand the oscillations we plan to decrease the laser power by a factor 3 (~2.3 W interferometer input power). This requires to re-tune all the locking loops both analog and digital.

When the power will be reduced there will be at least four possibilities:

- The oscillations disappear, as well as the decrease of the sidebands and carrier power. If the locking periods will be of the order of few tens of minutes, the commissioning of the recycled interferometer can continue (mainly the commissioning of the automatic alignment). In parallel solutions for the sidebands and carrier power decrease should be found. In particular, if it's demonstrated that the power decrease is produced by thermal lensing, a thermal compensation system should be studied and planned.
- The oscillations disappear but the sidebands and carrier decrease don't. The oscillations should then be investigated at this reduced power level (to simplify the interferometer behaviour). At the same time solution for the sidebands and carrier power decrease should be found.
- The oscillations don't disappear, as well as the power decrease. In this case a further power reduction should be done (C7 level, <1 W interferometer input power), or a different mechanism for these power decrease, which does not involve the laser power, should be investigated.
- The oscillations don't disappear, but the power decrease is strongly reduced. Then the commissioning of the automatic alignment must be completed in parallel with oscillations investigations.

The time needed for power reduction itself is about 1 week. The time needed to solve the problem of the oscillations greatly depends on the results of the tests done in June.

Simulations of the thermal lensing and its comparison with the experimental data taken during the last weeks is started.

2.2. Remaining controls and other commissioning activities

The automatic alignment is the main remaining control system to be implemented. As described in [2] 5 over 10 loops have been already closed with full bandwidth and a first implementation of the new alignment scheme for the injection system have been done. The main parts remaining to be completed are: 1) implementation of the automatic alignment on 10 degrees of freedom (C7 configuration) 2) beam control and BS low frequency control.

A tentative time duration for this task is 8 weeks. This is the main time consuming task. In parallel (using the 2 shift/day commissioning structure) activities are planned about the following items:

- General improvements of longitudinal controls
- BS hierarchical control
- Improvements of automatic procedures
- Interferometer characterization

If possible, the noise of the interferometer will be investigated during this phase and reduced.

3. Noise hunting update

3.1. Noise reductions at high frequency

3.1.1. Interferometer internal power

The current interferometer input power is ~ 7 W. If we consider the beginning of the locking periods (excluding the power decrease) the recycling factor for the carrier ~ 40 , which is the nominal one with the new power recycling mirror within an error of 10-20%. These values give a 280W power on the beam splitter (value measured without a complete automatic alignment), being the nominal power 500W.

The mode-cleaner input power is 17 W, being the best matching with the laser with the mode-cleaner of the order of 90%. More than 50% of the power is then lost inside the mode-cleaner.

The main improvement in order to reach the nominal power on the beam splitter is then increase of the mode-cleaner transmission and the only solution found up to now is the change of the mode-cleaner mirror, planned for the 2007 shutdown (see [3] for the mode-cleaner curved mirror replacement plans).

3.1.2. Oscillator phase noise

The Marconi generator has been changed with the LNFS-100 one. Recently a second LNFS-100 generator has been bought, allowing direct measurement of the LNFS-100 stability and also the entire local oscillator transmission chain. The measurements are on going and some results should be available in the following weeks.

3.1.3. Laser power noise at the modulation frequency

Plans for the installation of the pre mode-cleaner are ready. See [3] for details. The mode-cleaner will be installed according to the evolution of the noise hunting, when the sensitivity will start to be limited by the laser power noise at the modulation frequency.

3.2. Noise reductions at intermediated frequency

3.2.1. Actuators noise

No major update on the actuator noise with respect to the previous plan.

The main activity to be performed is the modification of the coils driver with emphasis-deemphasis filter and/or with a further reduction of the coil drivers dynamical range. A change in the hierarchical control strategy can be needed. The installation and commissioning time expected is ~ 1 month.

3.2.2. Environmental noise reduction

Laser laboratory:

The acoustic contamination of the ITF signal has been shown through few tests during the Summer 2005 tests (M8,C6,C7); coherence has been seen between microphones in the laser lab and the dark fringe signal. Test of reverberation have been made in the laser lab showing a certain permanence of the acoustic waves in the laboratory, probably due to walls and floating floor vibration. Furthermore, noise sources are present both in the laser lab and in the neighbor experimental hall.

While the first noise source has been mitigated displacing the electronic racks in the laser lab during the January shutdown, a more effective solution has been investigated. An acoustic isolation enclosure has been designed for the two optical benches in the laser lab, while a lead-carpet will isolate the floating floor below the benches.

The enclosures have been ordered to an external company and are realized in a sandwich of different materials, optimized for the frequency range we have to dump, compatible with the cleanliness and safety requirements in the lab.

The installation time of the acoustic isolation enclosure and the following re-commissioning is ~ 1 week.

Detection laboratory:
It was observed during C6 run that some noise structures present around 2 kHz disappeared when the vacuum pumps of the detection tower were switched OFF. It is likely that mechanical resonances (of the tower of the bench components) are excited by the pump vibrations. The hypothesis of seismic noise has been retained since:

- The noise measured on the dark fringe is coherent with the accelerometer located on the detection bench while it is not with the acoustic channel
- The vibrations can easily propagate through the legs of the optical bench which sits on the tower base

It has therefore been decided to isolate the optical bench from the ground by inserting insulation plates into its legs.

This operation and the consequent re-commissioning should last ~ 1 week.

Further investigations will be performed with acoustic tests in the detection lab in order to check if acoustic isolation is also needed.

End Benches:
It was observed during C6 a noise bump in the 100-300Hz frequency range, due to scattered light in the terminal benches, vibrating under acoustic excitation at that frequencies. This bump has been cured dumping few parasitic beams in the NE end bench, but a similar process is expected to show up again as soon as the sensitivity improves. An acoustic shielding of the terminal benches is foreseen as soon as the performances of the acoustic isolation in the laser laboratory are understood.

Clipping on the Brewster window
As reported in [2] a clipping on the Brewster window has been found and removed in April 2006. This clipping was probably present since before the shutdown and could be responsible

of environmental noise coupling. To be checked as soon as a a reliable sensitivity measurement will be performed.

3.3. Noise reductions at low frequency

This part contains new simulation studies. For sack of clarity it's re-inserted completely in the document.

3.3.1. Longitudinal degrees of freedom noise reduction

In order to keep the interferometer on its working point, four degrees of freedom have to be controlled . The differential length (DARM) is controlled with the signal extracted at the anti-symmetric port (the *gravitational wave* signal). The other lengths (CARM, PRCL and MICH) are referred as *auxiliary* degrees of freedom. Due to optical couplings of the interferometer, fluctuations of the auxiliary lengths produce signals at the anti-symmetric port. In particular, the control of the PRCL and MICH degrees of freedom, respectively done acting on the PR and BS mirrors[1], was reintroducing noise at the anti-symmetric port in the low frequency region:

- the BS control was the limiting noise source below 100 Hz;
- during C6 the control noise of the PR mirror was also limiting the sensitivity around few hundred Hz.

A simulation study (with SIESTA) was performed in order to understand the coupling mechanism. It was observed that all the photodiodes readout noise (in this case shot noise) was introduced via the beam splitter control. This is illustrated in figure 1.

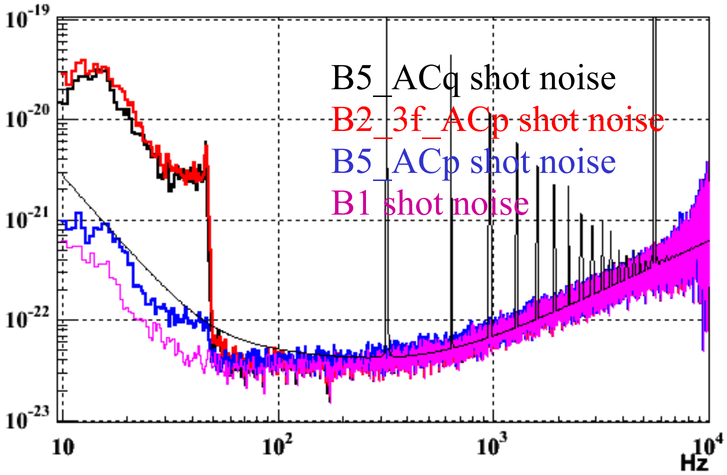

Fig 1: *Noise introduced by the control loops (SIESTA simulation): the shot noise is alternatively turned ON on the photodiodes used to provide the error signal (dark fringe shot noise is always ON) The thin black line is the Virgo design.*

The couplings of the photodiodes readout noise to the dark fringe can be explained in the following ways:

- The position noise of the BS mirror is equivalent to a position noise of the end mirrors (with a reduction factor $2F/\pi = 32$ corresponding to the number of round trips in the cavities).

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[1] A diagonal driving matrix was applied in C6 and C7 (cfr last paragraph).

- The laser frequency is controlled with the in-phase B5 signal. The readout noise of this photodiode is converted into frequency noise. Since the BS mirror is controlled with the in-quadrature signal of the same photodiode, this signal is sensitive to frequency noise proportionally to the mistuning of the demodulation phase. Frequency noise is therefore introduced via the BS control.
- The power recycling length noise gives a signal equivalent to frequency noise (both are common mode noise) except that its phase is two degrees apart (this is a simulation result). Therefore this length noise is also seen by the in-quadrature B5 signal even if the demodulation phase is well tuned.

These noises can be reduced in several ways: a better signal-over-noise ratio, more aggressive control filters, a subtraction of this noise with an improved control scheme. These possibilities, in part tested during C6 and C7, will be discussed in the following.
It is important to remark that since all the control noises seem to propagate through the BS control loop, the improvement of this control loop will also reduce the impact of other control noises (for example with an optimized filter for the BS mirror or/and with the BS noise subtraction technique, see below.)

Increase of the SNR of the signals involved in the auxiliary degrees of freedom
In order to increase the SNR of the signals involved in the control scheme of the interferometer, several solutions can be applied:

- Increase of the signal to noise ratio of the photodiodes:

  The light impinging on the photodiodes is presently at its maximum but the signal to noise ratio can nevertheless be improved with the increase of the modulation depth. As an example, the l_{PRCL} noise was well reduced after the increase of the modulation depth (C7 run): the reflected (B2) signal demodulated at 3 times the modulation frequency is used for this control, therefore an increase of the modulation depth by a factor 2 lead to a reduction of the noise by a factor 8.

- Use more sensitive signals in the control scheme.

  The *variable finesse* technique has been designed to use the reflected 3f-demodulated signal to control the recycling cavity length during the full lock acquisition sequence to control l_{PRCL}. Despite its properties of stability and small sensitivity to other degrees of freedom, which makes it interesting for lock acquisition, the 3f signal has a bad SNR. Once the dark fringe will be reached, the switch to a more sensitive signal, as the reflected f-demodulated one, will be therefore needed. This should allow a reduction of the control noise by a factor 100.

  An alternative solution is to move the control from the reflected 3f-demodulated signal to the demodulated signal extracted from the second face of BS: this requires previously to stabilize the laser frequency by involving the reflected f-demodulated signal.

Optimization of the control filters

The control filters have to be optimized in order to reduce the noise reintroduced in the detection band. The solution adopted so far has been to reduce as much as possible the bandwidth of these filters, (around 10 Hz for the Michelson loop and 30 Hz for the recycling cavity length loop) and to design aggressive roll-off around 50 and 100 Hz respectively.
The following plot shows the Bode diagram of a simple derivative filter (blue) used for lock acquisition, with respect to the 7th order elliptic filter designed to work in *science mode* (red): the reduction of the gain @ 100 Hz is about 20 dB. A further reduction of the gain, and a consequent reduction of the unity gain frequency, can not be applied without compromising the stability of the loop. It has been experimentally tested, for instance, that a unity gain frequency lower than 6 Hz can not be adopted for the MICH loop.

Some work has been already started in order to find a better compromise between the stability of the loop, by increasing the phase margin at the unity gain frequency, and a low frequency cut-off.

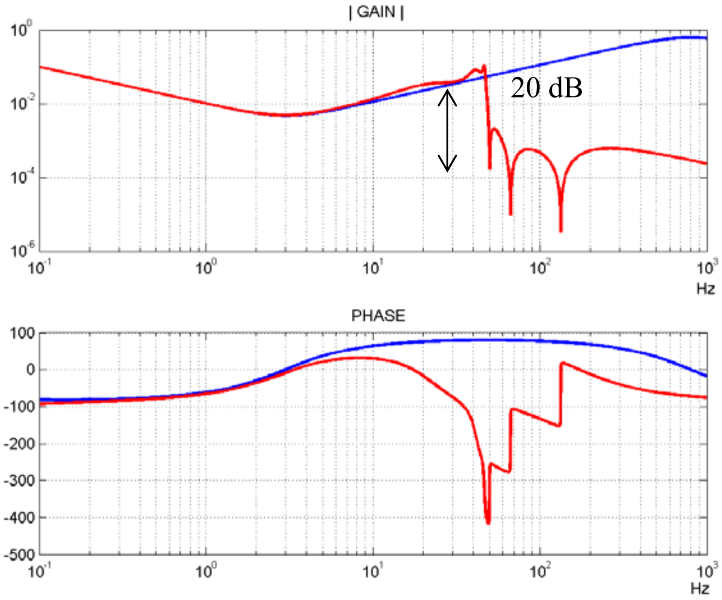


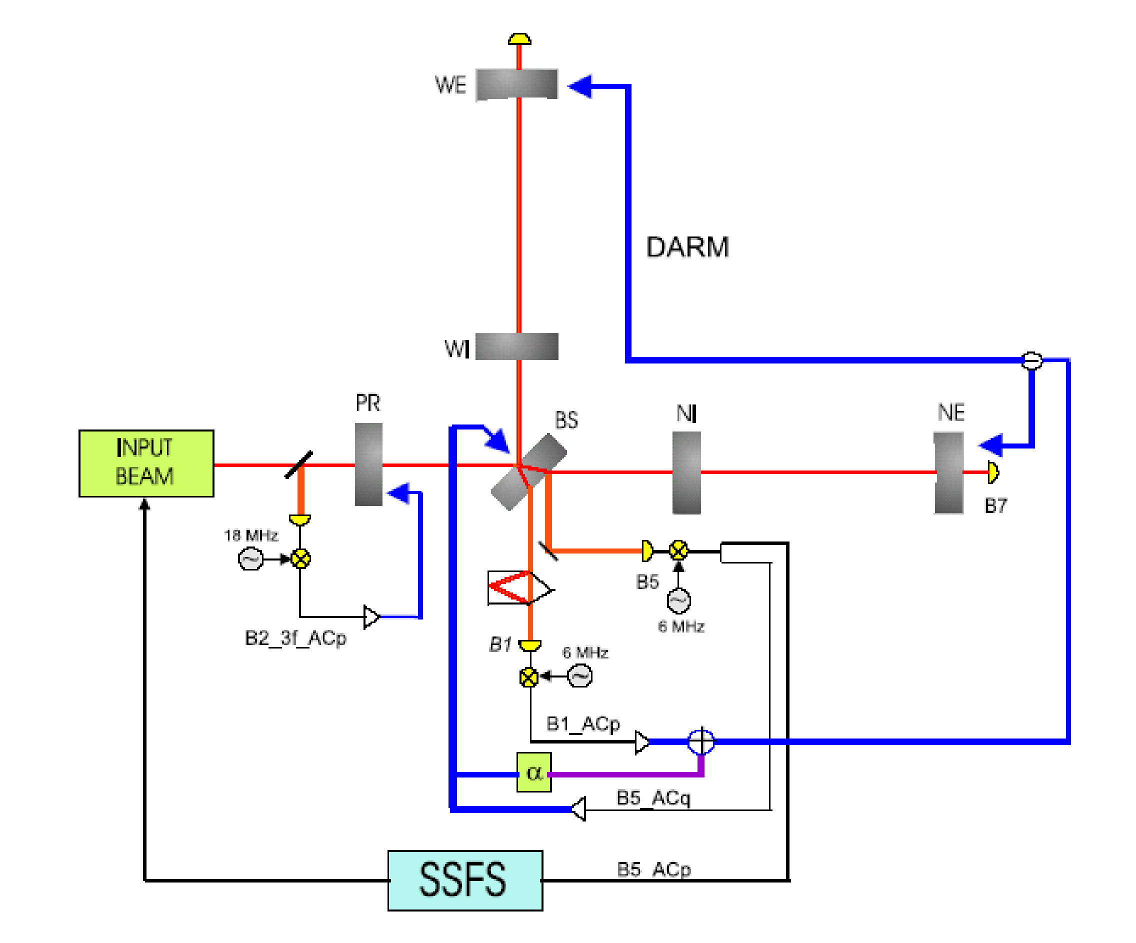
Fig. 2 – Optimization of the control filters (see explanation in the text)

Subtraction of the control noise

One possible solution to overcome the problem of the strong requirements on the controller filters consists in applying the *subtraction noise technique*. The main idea is to subtract the BS noise reintroduced into the gravitational wave signal (B1_ACp) by adding the BS correction signal in differential mode to the end mirrors (see figure 3). In order to efficiently apply the subtraction technique, a fine measurement of the transfer functions $l_{MICH} \rightarrow B1\_ACp$ and $l_{DARM} \rightarrow B1\_ACp$ is needed. In particular, as it has been observed in Ligo, in order to have an attenuation of the BS control noise of about 20 dB, the transfer functions have to be known with 90% of accuracy. For this reason, an interferometer stably locked under automatic alignment is needed to perform precise measurements.

A simple scheme of the subtraction technique for the BS control noise has been already implemented in the running locking algorithm, where the coupling is modeled with a constant term α. This is illustrated on figure 4.

This technique was used during C7 run, resulting in a reduction of the BS control noise by an order of magnitude, equivalent to a tuning of the coefficient α with a 7% accuracy. Simulation shows that an accuracy of 1% will be needed in order to reach the design sensitivity (see figure below).



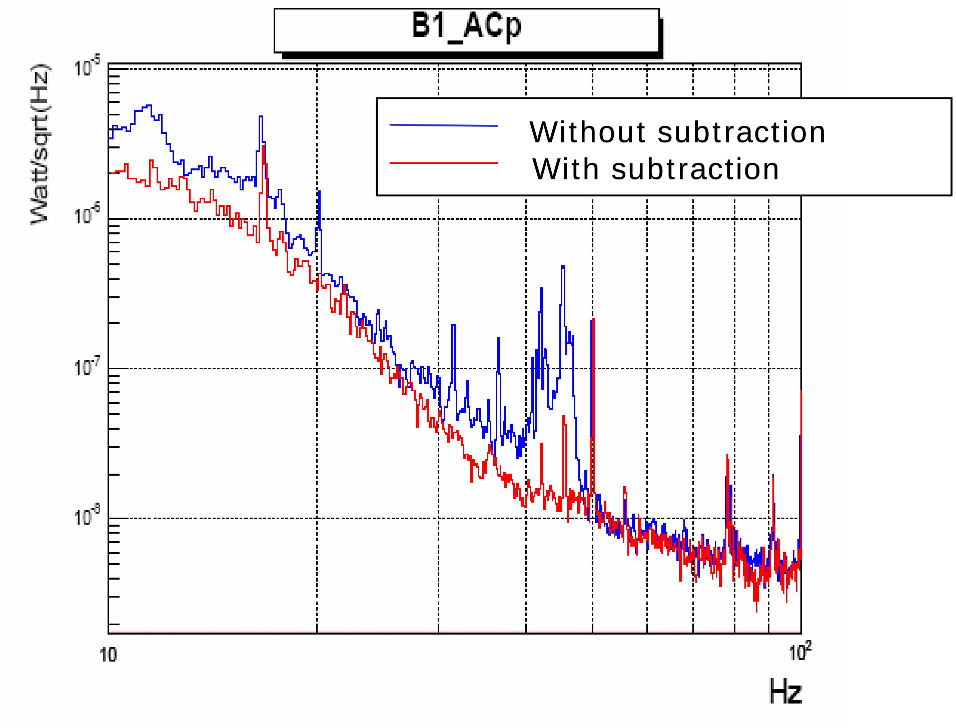


Fig. 4: *Dark fringe spectrum with and without the subtraction technique. The beam splitter control noise is concentrated around 40-50Hz.*

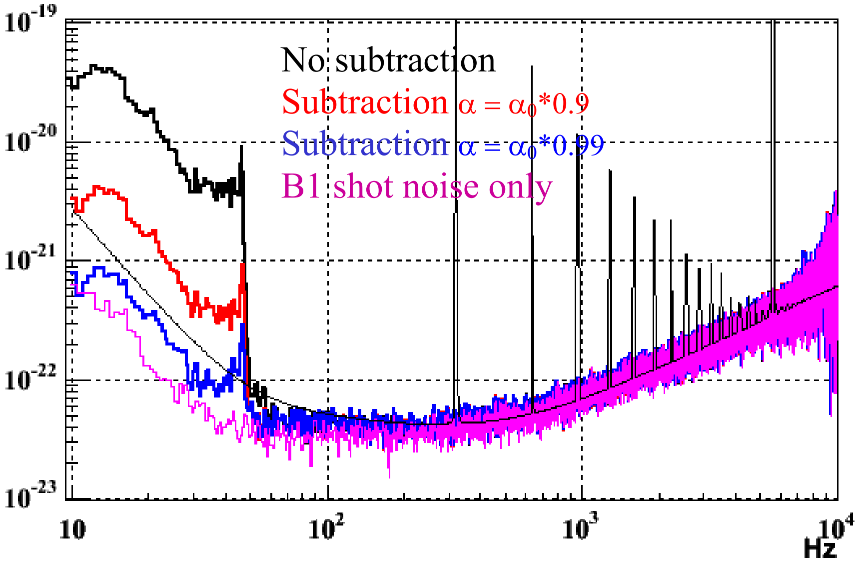


Fig 5: *Noise introduced by the control loops (SIESTA simulation) with and without the subtraction technique: all the photodiodes shot noise is included and the α coefficient is tuned at 10% or 1% away from its optimal value (α_0) .*

Reduction of couplings between different degrees of freedom

The optimization of the demodulation phases of the involved signals plays a crucial role also in order to reduce the coupling between the different degrees of freedom. A trial of fine tuning has been done before C6, but better results are expected with the interferometer stably controlled under automatic alignment.

Not only in the read-out of the signals, but even in *driving* the mirrors a better diagonalization of the system can be performed. In particular, VIRGO is now applying a simplified diagonal driving matrix, which controls MICH and PRCL by acting on BS and PR independently. Since a BS displacement produces not only a variation of MICH, but also of PRCL, because of the geometry of the interferometer, a not diagonal driving matrix should be applied. If in the first part of the commissioning a hierarchical system of the feedback loops took care to keep them stably controlled, it will not be efficient anymore when the requirements on the reintroduced noise are more strict.

3.3.2. Angular degrees of freedom noise reduction

The reduction of alignment noise requires understanding of the noise sources; a useful tool for this is the noise projection, where noise is injected in one part of the interferometer, and the transfer function is measured with the dark fringe signal. This gives an estimate on how much the actually measured noise in that part contributes to the gravitational wave signal. Some initial noise projections, done before the shutdown, indicate that during C7, the low frequency noise limit came from the alignment control loops. Therefore, particular care must be taken to reduce the transformation of mirror alignment fluctuations to longitudinal noise (beam/mirror centering), and to reduce alignment forces within the Virgo sensitivity band (develop alignment correctors with steep cut-off). Noise projection work will continue with increased intensity once a stable linear alignment configuration has again been reached.

Cut-off filter optimisation
The potential for the reduction of low frequency noise by steep cut-off correction filters is shown in figure 1.

During C7, the control noise introduced by the alignment system on the Θ_y degree of freedom of the North input mirror was seen at 50 and 100 Hz in the dark fringe signal; this extra noise was eliminated by optimising, in a short break during C7, the corrector for a steeper roll-off, without compromising its low-frequency characteristics. The resulting correction signal suppression is shown in figure2. A subsequent noise budget calculation showed that even with this improved filter some alignment noise might still dominate the Virgo sensitivity at very low frequency; therefore, a further optimisation was performed (the result is also shown in figure1. This second optimisation was possible after deciding a change in the control system layout, making the choice of alignment correctors independent from the local control correctors, and thus allowing a more flexible choice of correctors. The new corrector was not yet applied in practice.

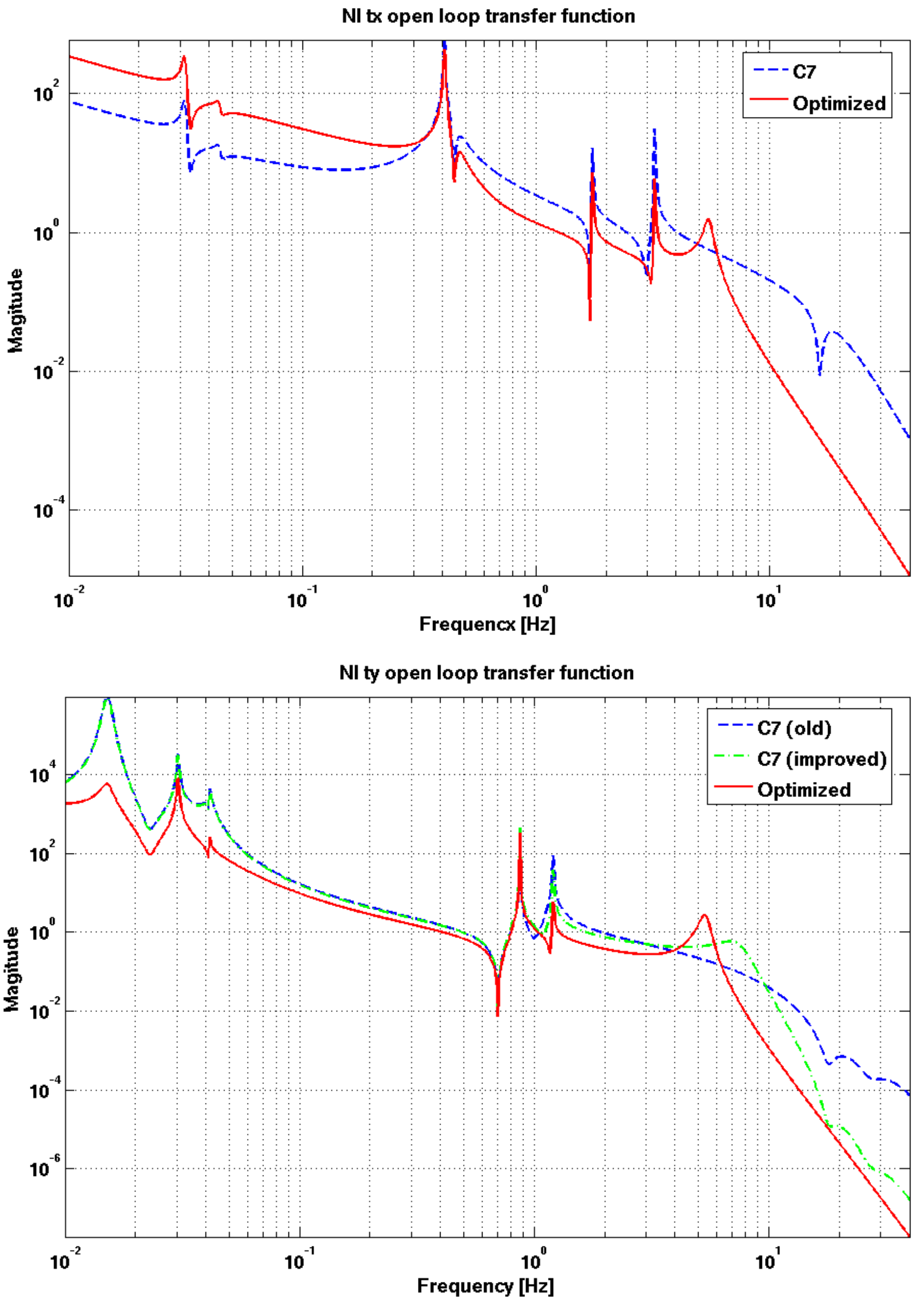


Figure 1: A comparison of the open loop transfer function of the vertical (Θ_x, left) and horizontal (Θ_y, right) angular degree of freedom of the North input mirror at the beginning of C7 (blue), after the first improvement during C7 (green), and a more aggressive optimisation (red); the optimisation target is the strongest possible gain reduction above 10 Hz.

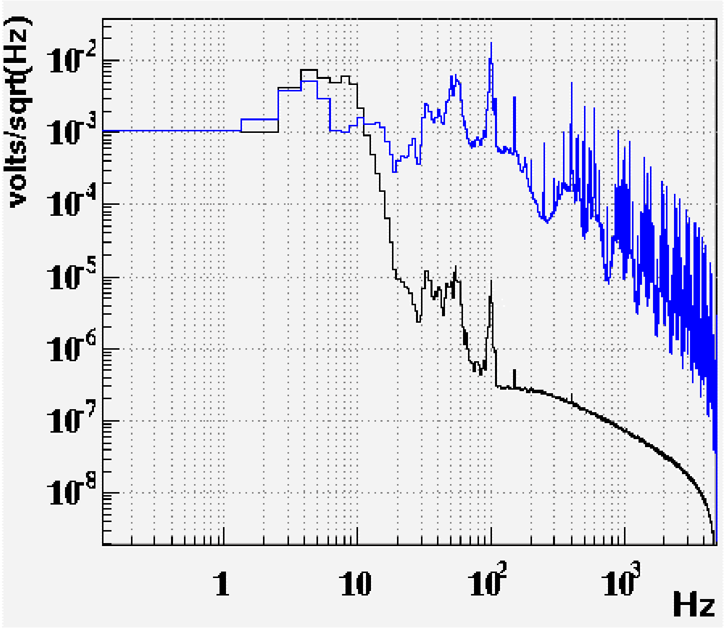


Figure 2: A comparison of the total control noise going to the NI Θ_y coil actuators at the beginning of C7 (blue), and after the first corrector improvement performed during C7 (black). The improvement is two orders of magnitude at 30 Hz, and four at 100 Hz.

Control system improvements

In the present configuration of linear alignment, one of the mirrors (West input) remains under local control. During C7 the influence of this rather noisy control system on the dark fringe signal was clearly seen, and some improvement was obtained also here by modifying the corrector filters. In the final configuration, the local control systems are supposed to be substituted by either the linear alignment system, or by beam pointing systems, using DC signals from the terminal benches for keeping the beam centered on the end mirrors. These beam pointing systems are less noisy than the local control, but probably still too noisy for a full bandwidth control (3 Hz). Reduction of the loop bandwidth in combination with steep roll-off filters (see above), allows to avoid noise re-injection into the measurement bandwidth.

Beam-mirror centering

The already mentioned beam/mirror centering will reduce the sensitivity of the dark fringe to the residual angular motion of the mirrors by reducing the angular-to-longitudinal coupling at the impact point of the beam on the mirror. Two possibilities are considered for determining an off-centering of the beam with respect to a mirror. The first one consists in shaking the mirror angularly by injecting a sinus voltage on its coils, and searching the perturbation in the dark fringe. By lateral or vertical shifting of the mirror, the perturbation can be minimized. The second technique consists in using the thermally (or externally) excited internal vibrations of the mirror; again, their effect on the dark fringe signal is minimized by shifting the mirror. This technique should allow an absolute centering of the beam, independently of an eventual misbalancing of the actuator coils, which can then afterwards be corrected using the first technique. In Ligo (see thesis R. Adhikari) the line injection technique was used; they improved the equivalent beam miscentering (including also the coil imbalances) 10 to 0.2 mm by adjusting the coil forces to 0.5%, without an absolute beam centering using the thermal mirror vibrations.

During the pre-alignment of the new injection bench and the interferometer beam, the beam/mirror centering was successfully applied to the vertical degree of freedom of the interferometer mirrors in the central building. Although the goal was here the correct pre-positioning of the optics and the avoidance of beam clipping, the techniques developed will also be used for the mirror centering for optimising alignment noise. Two centering techniques were used. The coarse method consisted in using camera images of the beam scattered on the mirror surface, and visually verifying the centering with respect to the geometrical edges of the mirror. In the fine method, the mirror's natural oscillation around its wire suspension loop was excited by a sinus voltage on the appropriate coil combinations; the longitudinal coupling was observed in the correction forces of longitudinal locking, which were minimized by shifting the mirror. Excitation of the suspension resonance has the advantage that, to first order, an eventual imbalance in the coil forces has no influence on the measurement. As a result of this activity, the miscentering of the beam on the central mirrors was reduced from about 1cm to around 1-2 mm.

Electronics and shot noise budget

In order to have an order-of-magnitude estimation of the ultimate limit of alignment noise onto the interferometer sensitivity, a theoretical noise budget was calculated. The noise sources taken into account were the electronics noise of the quadrant diode hardware (preamplifier noise, ADC noise), and the shot noise. This noise was propagated in a Matlab model simulating the alignment loop for Θ_x/Θ_y of each mirror. The alignment loop was modelled by the transfer function of the mechanical system, the alignment system corrector, and a very much simplified model for the optical system (propagation of mirror motion to error signal), which didn't account for couplings and some uncertainties in the loop gains. For the noise propagation from the quadrant diodes to the error signals for each mirror, the actual reconstruction matrix from C7 was used. The result of the noise budget calculation for C7 is shown in the left of figure 3. For the mirror miscentering we supposed 10mm everywhere, a certainly pessimistic assumption, which is justified only on some degrees of freedom. A quantitative comparison of simulated and actually measured error and correction signals was used for verifying the validity of the employed method.

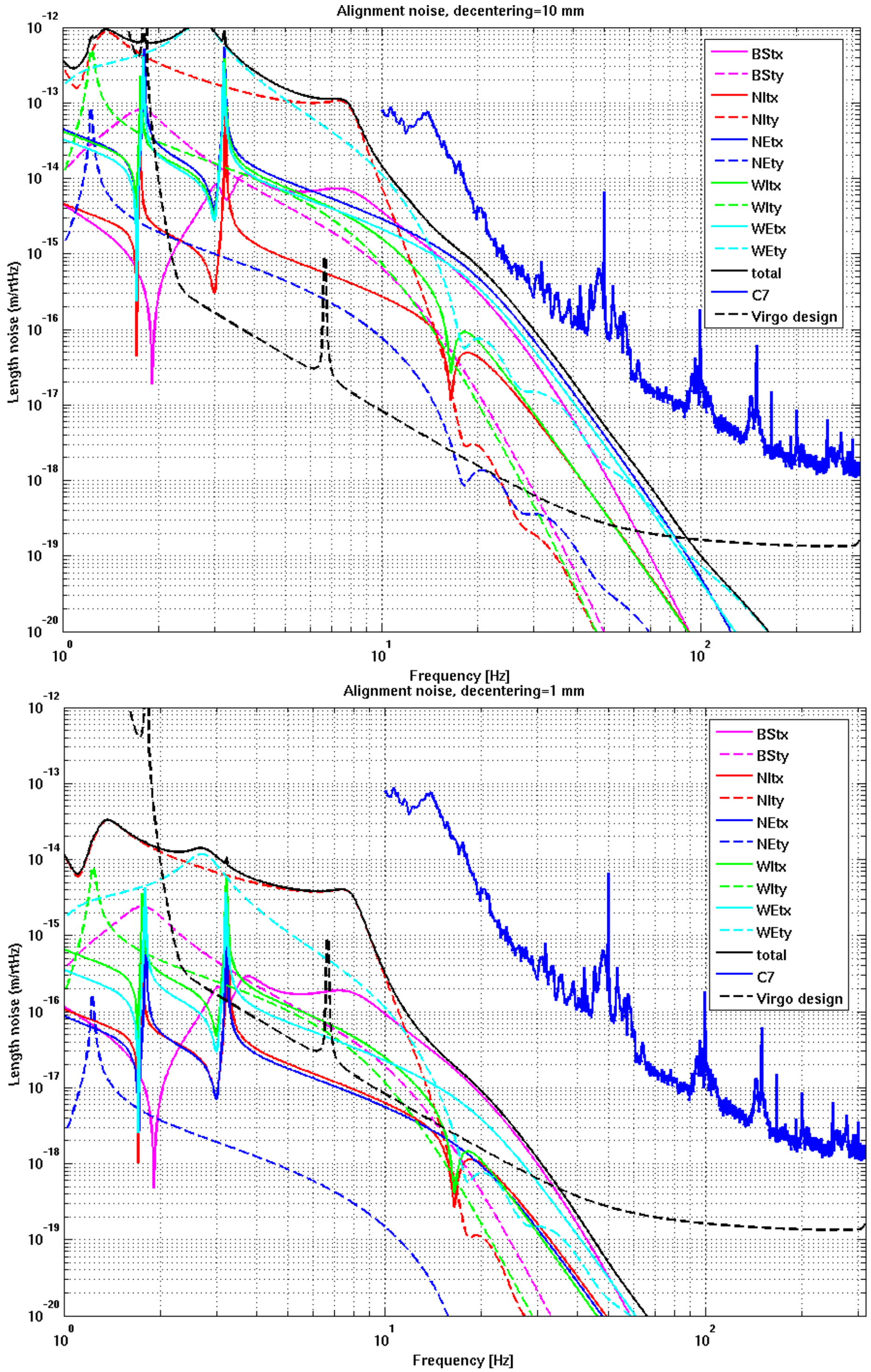


Figure 3: Estimated theoretical noise budget for C7 (upper), and with optimised quadrant diode powers and reduced miscentering (lower). The Virgo design sensitivity is given for comparison.

The next step in the simulation was to suppose an improved beam miscentering of only 1 mm, and an optimisation of the powers incident on the quadrant diodes in order to improve the signal-to-noise ratio. We supposed that 50% of the maximum allowed power was incident on the quadrant diodes (1.5 mW), except the dark fringe diode, where we supposed a factor 10 less. The result is shown in the of figure 3 low. As one sees, there is still some improvement needed at low frequency, which triggered our work on improvement of correctors with steep roll-off. Figure 4 shows the noise estimate obtained when using the preliminary results of our corrector optimisation. One order of magnitude is gained at 10 Hz, and two at 20 Hz; alignment noise is now below the Virgo requirements above 13 Hz. No corrector optimisation was done on the beam splitter.

It is important to note that these calculations can only give an order-of-magnitude estimate. It is, at present, difficult to estimate the precise propagation of a mirror misalignment through the optical system up to the quadrant diodes; related to this is the fact that we have only an estimate of the unity gain bandwidth of the alignment loops during C7, since no detailed characterization measurements had been done due to lack of time. The optimised noise budgets use the same loop gains as during C7, where especially the Θ_x gains were very low. The noise budget computation is still ongoing; we will have to take into account future changes of the alignment strategy, like having the beam splitter instead of the West input mirror under local control.

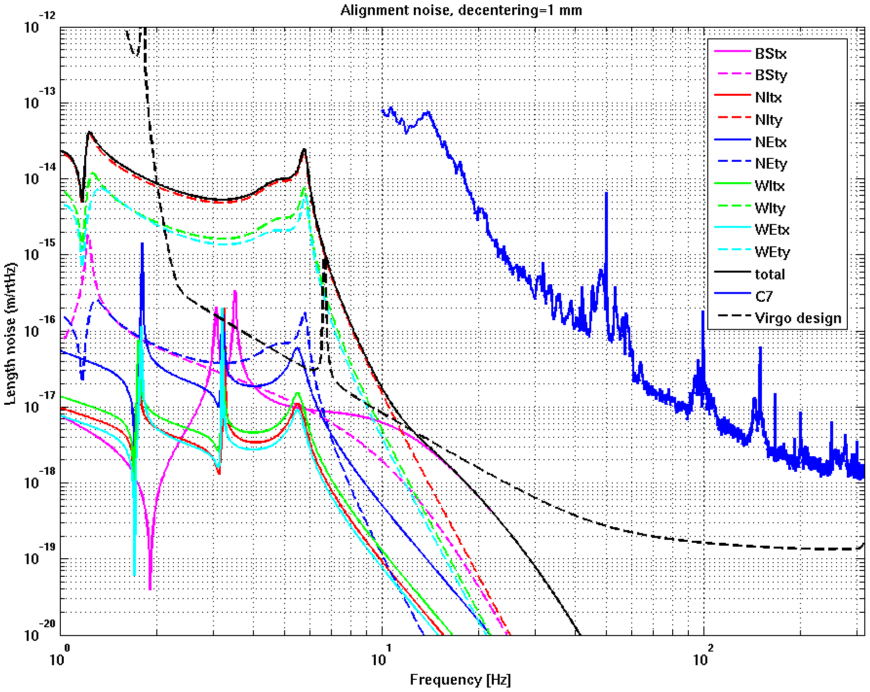


Figure 4: Estimated theoretical noise budget for the case with optimised optical parameters from figure3, but but additionally using the optimised filters from figure 1.

4. Commissioning plan global view

4.1. Plan June-December 2006

The commissioning plan for 2006 is resumed in the table 1. In this plan we assume that the problem of interferometer signal oscillations is solved (either by reducing the power or by other means) within the end of June 2006. If the problem is not solved, all the planning should be shifted.

In the following we give a brief description of the sequence. The title of each item is the main operation performed. This not excludes parallel operations on other items.

4.1.1. Laser power decrease (June 2006)

The possible results involved with this test are described in section 2.1. If the thermal drifts are demonstrated, it's reasonable to remains at the same power level until a thermal compensation system is ready. At the same time some robustness improvements of the injection system can be done.

4.1.2. Completion of the recycled interferometer commissioning (8 weeks)

During this phase a first implementation of the 12 d.o.f. automatic alignment is done and the beam low frequency control. The locking robustness should increase during this phase, and the interferometer noise can also be studied. High frequency noises (frequency noise, oscillator phase noise, shot and electronic noise) can be addressed during this phase (and it should continue along all the following steps.

4.1.3. Noise hunting: already planned operations (6 weeks)

Reduction of actuators noise, including modifications of coil drivers and change of reallocation strategy on the marionette.
Acoustic enclosure of laser laboratory, seismic isolation feet in the detection laboratory.

4.1.4. Noise hunting: angular and longitudinal control noises first reduction (6 weeks)

First optimization of the alignment filter (as described 2.3.2) and a fine coil balancing, in order to have a first reduction of the angular control noise. In parallel some reduction of the longitudinal noise can be performed (switch to B2 for power recycling control, alpha technique,…).

4.1.5. Noise hunting: scattered light first reduction (4 weeks)

A first reduction of the scattered light from in-air benches (end benches, detector benches in the laser and detection laboratory) can be addressed using the experience and the data taken in the previous months. Following our experience (and the one of other GW experiments) this includes long investigations of the potential scattering sources (mirrors, photodiodes,…) followed by several changes in the optical set-up.

4.1.6. Thermal compensation implementation (?)

If needed, a shutdown thermal compensation implementation should be added to this plan.

4.2. Data takings in 2006 and first science run

During 2006 we expect to have significant improvements of the sensitivity. A tentative goal in terms of linear spectral density improvement can be to gain 1 order of magnitude between 10 Hz and 10 kHz. This will translate in an NS-NS “horizon” 10 times higher than the one obtained for C7 (~ 15 Mpc).

Data takings during the week-ends can be progressively started as soon as the robustness is good enough and sensitivity of the interferometer better than the one obtained in C7 (few hours of lock with NS-NS inspiral range of 1.5 Mpc). These data takings will have a duration starting from 8 hours (1 shift) to 3 and half days (long week-end).

At the end of 2006 a science run will start. Its duration, goal and exact conditions should still to be defined.

4.3. Plans for 2007

4.3.1. 2007 Shutdown and re-commissioning (3 months)

The plans for the 2007 shutdown greatly depend on the achievements of the previous noise hunting phase. The goal of this shutdown is to concentrate all the major detector upgrades. See [3] for details.

Some of the possible upgrades are:

- Eddy current removal. See [3]
- Thermal compensation implementation (if needed and not done before)
- Mode-cleaner curved mirror replacement
- Acoustic mitigation 2nd generation (if needed)
- Optical table re-shuffling and diffused light mitigation 2nd generation (if needed)

The duration of this shutdown and of the re-commissioning depends on each of the upgrades. In the following we will plan 1 month shutdown + 2 months re-commissioning.

4.3.2. Noise hunting

This second period of noise hunting will be mainly dedicated to the low frequency noises. More sophisticated filtering techniques, and more sophisticated subtraction techniques will be applied (i.e. the alpha technique frequency dependent) to the control noises.
Experience in other GW experiments shows that a second/third generation of diffused light mitigation could be necessary.

It should also noted that approaching the design sensitivity, the noise hunting becomes more and more complicated, due to the presence of several noises at the same level. The estimation of the duration for this phase is difficult, and could be equal to the first noise hunting phase.
There will be also science data taking during this noise hunting phase (long week-ends).
After this phase we can expect to approach the Virgo sensitivity also at low frequency.

Plans for June-December 2006

<table>
<tr><th>Main task</th><th>Duration (weeks)</th><th>In parallel/ Remarks</th></tr>
<tr><td>Power decrease oscillations investigation</td><td>3</td><td>Optimization of injection system controls</td></tr>
<tr><td>Completion of recycled interferometer commissioning (mainly alignment)</td><td>8</td><td>High frequency noises hunting and reduction
Longitudinal controls robustness increase</td></tr>
<tr><td colspan="3">Stable conditions should be reached at this point. This will allow us to start to take science data (according the achieved sensitivity) during the next steps.</td></tr>
<tr><td>Noise hunting: already planned operations (actuators noise reduction, acoustic enclosure, feet detection lab)</td><td>6</td><td></td></tr>
<tr><td>Noise hunting: control noises “first” reduction (angular and longitudinal</td><td>6</td><td>High and intermediate frequency noise hunting</td></tr>
<tr><td>Noise hunting: scattered light reduction</td><td>4</td><td>High and intermediated frequency noise hunting</td></tr>
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