Virgo change request

Quadrants photodiodes for BMS and MC end mirror

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1. Abstract

From the origin, the two quadrants photodiodes (PHD) used in the Beam Monitoring System (BMS) and one quadrants photodiode involved in the mode cleaner automatic alignment (located in transmission of the mode cleaner mirror) are "temporary" ones. Indeed one quadrants PHD has been loaned by Nice group and the two others are the ones which will be used for Pre-Mode Cleaner.

2. Motivations

Motivations are triple:
- Pre mode Cleaner is supposed to be delivered at the end of this year; the loaned quadrant photodiodes will then be required for the "PMC alignment monitor" purpose they were designed for.
- The dark noise of the quadrant photodiodes needs to be improved
- It will make some spare photodiodes available

3. Technical description on

Task 1: BMS and mode cleaner end mirror quadrant photodiodes design

1. Summary

Three quadrant photodiodes are required, BMS_QN, BMS_QF (located on the external injection bench) and MC_QT (located behind the mode cleaner end mirror).
All of them are of equivalent kind, description is given below.

2. Requirements

a. SPOT-15-YAG silicon quadrants photodiode from UDT have been selected, and are already available as light sensitive devices. There is still a doubt on their ability to support more than 1mW; if not, one may consider to select other quadrant diodes.
b. Photodiodes are used in the"+" configuration (see Annex 4 – figure 1)
c. One DC channel delivering the overall power (sum of 4 quadrants), assuming the incident power is about 6mW, and detector efficiency is 0.45A/W (silicium).
d. 2 channels giving two combinations of quarter of quadrants, relative to vertical/horizontal displacement of beam on the quadrant: Sv = Q1+Q2-Q3-Q4 (vertical) and Sh = Q1+Q3-Q2-Q4 (horizontal).
e. Those channels (Sh and Sv) will be filtered with a pre-shaping filter and connected on rio23 ADC cards. Signals transmitted through those channels will not be spoiled when connected to ADC cards. Pre-shaping filters are also part of the request.

Remark: pre-shaping filter proposal: 0dB below 1Hz, gain 20dB above 10Hz; it is compatible with signals levels (see figure 5), since rms signal before is always lower than 0,1Vrms.

f. Enclosure is a metallic box compatible with size requirements on external input bench; box height must be adjustable in order to keep detector centered on beam height (100mm axis). Adjustable system could be copied from what already used for PMC photodiode (mechanical schemes from Nice-OCA-ARTEMIS group given to EGO).

3. **Noise specifications for both BMS_QF, BMS_QN (see Annex 1 & 2) *(*)***
    a. Dark noise for channels Sh and Sv should be negligible with respect to 216pA/sqrt(Hz) (evaluated at photodiode output); spec. is set by minimum optical signal to be detected.
    b. DC offsets (evaluated at photodiode output) should be less than 32uA for both Sh and Sv signals
    c. Overall DC output (sum of 4quadrants) should be below 10V saturation, assuming 2.7mA overall current; hence R_dc_overall = 3kohms.
    d. Sh and Sv should be below saturation for a beam fully non-centered on the quadrant (with 2.7mA current, we take R_dc = 3.0 kohms) to ease the lock acquisition.
    e. Assuming R_dc = 3 kohms gives Sh/v floor of 0.65µV/sqrt(Hz) which is below ADC floor; one needs 20db amplification above 10Hz to not be spoiled by ADC noise. Pre-shaping filter, see § 3.2.e.remark.

(*) Remark

- BMS_QN_ BMS_QF, MC_QT could be designed on the basis of the most stringent specifications, that is specifications for MC_QT.
- In case UDT photo-detector accept only 1mW (instead of 6mW), one has to re-adjust pre-shaping filter amplification and also the spec. in § 3.3.a becomes 216/6=36 pA/sqrt(Hz). Is it then worth to move to centronix sensors (since QD100-4X accepts 10mA)?

4. **Noise specifications for MC_QT (see Annex 3)**
    a. Dark noise for channels Sh and Sv should be negligible with respect to 278pA/sqrt(Hz) (evaluated at photodiode output).
    b. DC offsets (evaluated at photodiode output) should be kept lower than 19uA
    c. Overall DC output (sum of 4quadrants) should be below 10V saturation, assuming 2.7mA overall current; hence R_dc_overall = 3kohms.
    d. Sh and Sv should be below saturation for a beam fully non-centered on the quadrant (with 2.7mA current, we take R_dc = 3.0 kohms) to ease the lock acquisition
    e. Assuming R_dc = 3 kohms gives Sh/v floor of 0.8uV/sqrt(Hz) which is below ADC floor; one needs 20db amplification above 10Hz to not be spoiled by ADC noise. Pre-shaping filter, see § 3.2.e.remark.

(*) Remark

In case UDT photo-detector accept only 1mW (instead of 6mW), one has to re-adjust pre-shaping filter amplification and also the spec. in § 3.4.a becomes 278/6=46 pA/sqrt(Hz). Is it then worth to move to centronix sensors (since QD100-4X accepts 10mA)?

4. Task 2: Integration of quadrants photodiodes.

5. Annexes

Annex 1 – noise specifications for BMS_QF

* Beam jitter level is supposed to reach 1e-5 urad/sqrt(Hz) at 5kHz (extrapolation with 1/f slope from 1kHz, see Annex 4 - figure 2).
One needs to be able to detect beam jitter noise up to 5kHz.

Sensitivity for BMS_QF signal is S = 2*sqrt(2/pi)/w*a*(i_dc) with a = 8.θ,
where, 8 is equivalent focal length of telescope, in meter

θ is the beam jitter in radians,
w = 800um is the beam size on the quadrant,
i_dc is the overall dc current (about 2.7mA, or 6mW),

-> S = 43. A/rad, we need to detect 430pA/sqrt(Hz) (that is 1e-5 urad/sqrt(Hz))
* A specification on the residual offset comes from the fact that we cannot rely on their stability over time. We choose the offset to induce equivalent error signal less than 1/100 of the IMC divergence (0.75urad). That is 32uA residual offset.

Annex 2 – noise specifications for BMS_QN

* Beam jitter level is supposed to reach 1e-4 um/sqrt(Hz) at 5kHz (extrapolation with 1/f slope from 1kHz, see Annex 4 - figure 3).
One needs to be able to detect beam jitter noise up to 5kHz,
Sensitivity for BMS_QN signal is S = 2*sqrt(2/pi)/w*a*i_dc with a = 1,51.δ

1,51 accounts for optical magnification of NF telescope,
δ is the beam jitter in meters,
w = 3000um is the beam size on the quadrant,
i_dc is the overall dc current (about 2.7mA, or 6mW),

-> S = 2,17 A/m, we need to detect 216pA/sqrt(Hz) (that is 1e-4 um/sqrt(Hz))

* A specification on the residual offset comes from the fact that we cannot rely on their stability over time. We choose the offset to induce equivalent error signal less than 1/100 of the IMC waist (50um). That is 108uA residual offset.

Annex 3 – noise specifications for MC_QT

MC_QT quadrant is used to control mode cleaner end mass.

a. Vertical error signal

Figure 4 shows the error signal Sc_IB_MC_tx (linear combination of Sc_MC_QT_DCv and Bs_IMC_QF_ACv signals).
Sc_IB_MC_tx reaches a floor above 1kHz at 40prad/sqrt(Hz); we fix the specification for that signal to be 4prad/sqrt(Hz).
Lets call this signal "θx", then [θx*180/7] is the displacement seen on the MC_QT photo-detector
(180m is the mode cleaner mirror radius of curvature, 1/7 is the MC_QT quadrant telescope magnification)
Assuming the MC_QT sensitivity to be S = 2*sqrt(2/pi)/1.6mm*i_dc = 2.7 A/m
(for 2.7mA overall current, or 6mW incident optical power)
The specification of 4prad/sqrt(Hz) on θx is then reached for 278pA/sqrt(Hz) at the output of the photo-detector.

* A specification on the residual offset comes from the fact that we cannot rely on offset stability over time/temperature…. We choose then the offset to induce equivalent error signal to be less than 1/100 of the IMC waist (5mm). That is 19uA residual offset.

b. Horizontal error signal

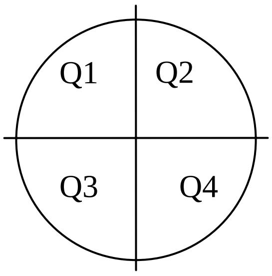
* Sc_IB_MC_ty reaches a floor above 1kHz at 40prad/sqrt(Hz); we fix the specification for that signal to be 4prad/sqrt(Hz).
Lets call this signal "θy", then [θy*180*4.5/7] is the displacement seen on the MC_QT photo-detector
(180m is the mode cleaner mirror radius of curvature, 4.5 comes from the geometry of IMC, 1/7 is the telescope magnification)
Assuming MC_QT sensitivity of 2.7A/m,
The specification of 4prad/sqrt(Hz) on θ is then reached for 1250pA/sqrt(Hz) at the output of the photo-detector.

* A specification on the residual offset comes from the fact that we cannot rely on offset stability over time/temperature…. We choose then the offset to induce equivalent error signal to be less than 1/100 of the IMC divergence (0.75urad). That is 184uA residual offset (i.e. 0.75urad*4.5*142m/7*2.7A/m).

Remark: From UDT data sheet, N.E.P = 3e-14W/sqrt(Hz) is compatible with 1pA/sqrt(Hz) level.

Annex 4 - figures

Figure 1



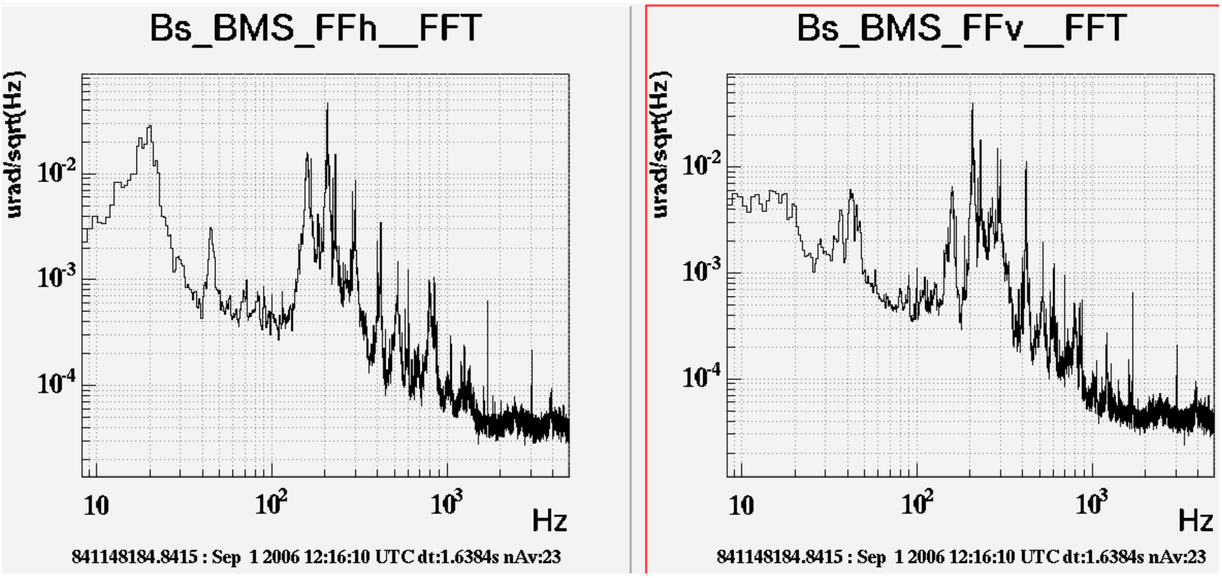


Figure 2

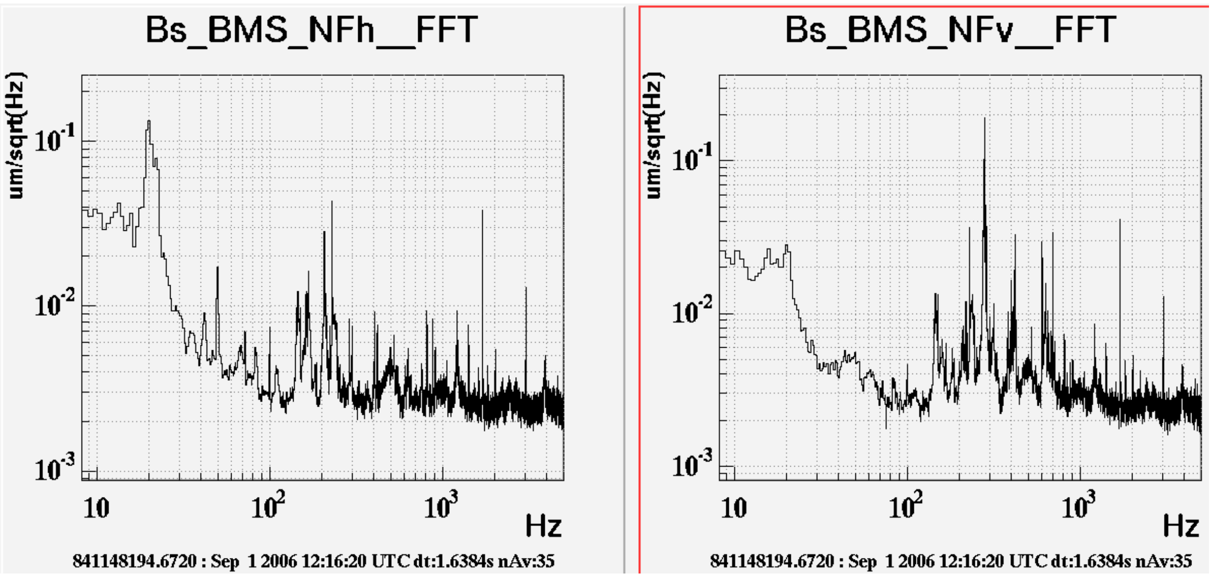


Figure 3

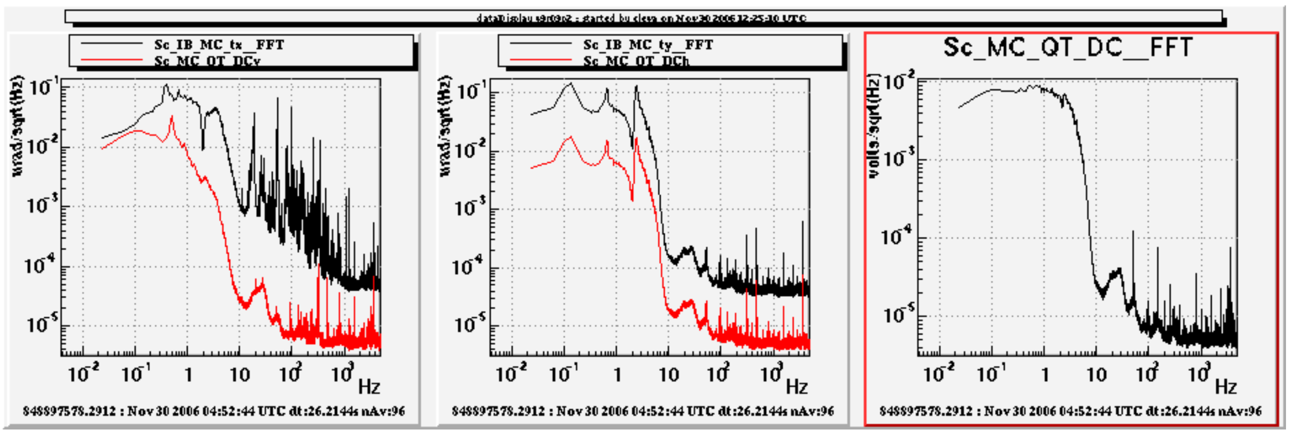


Figure 4

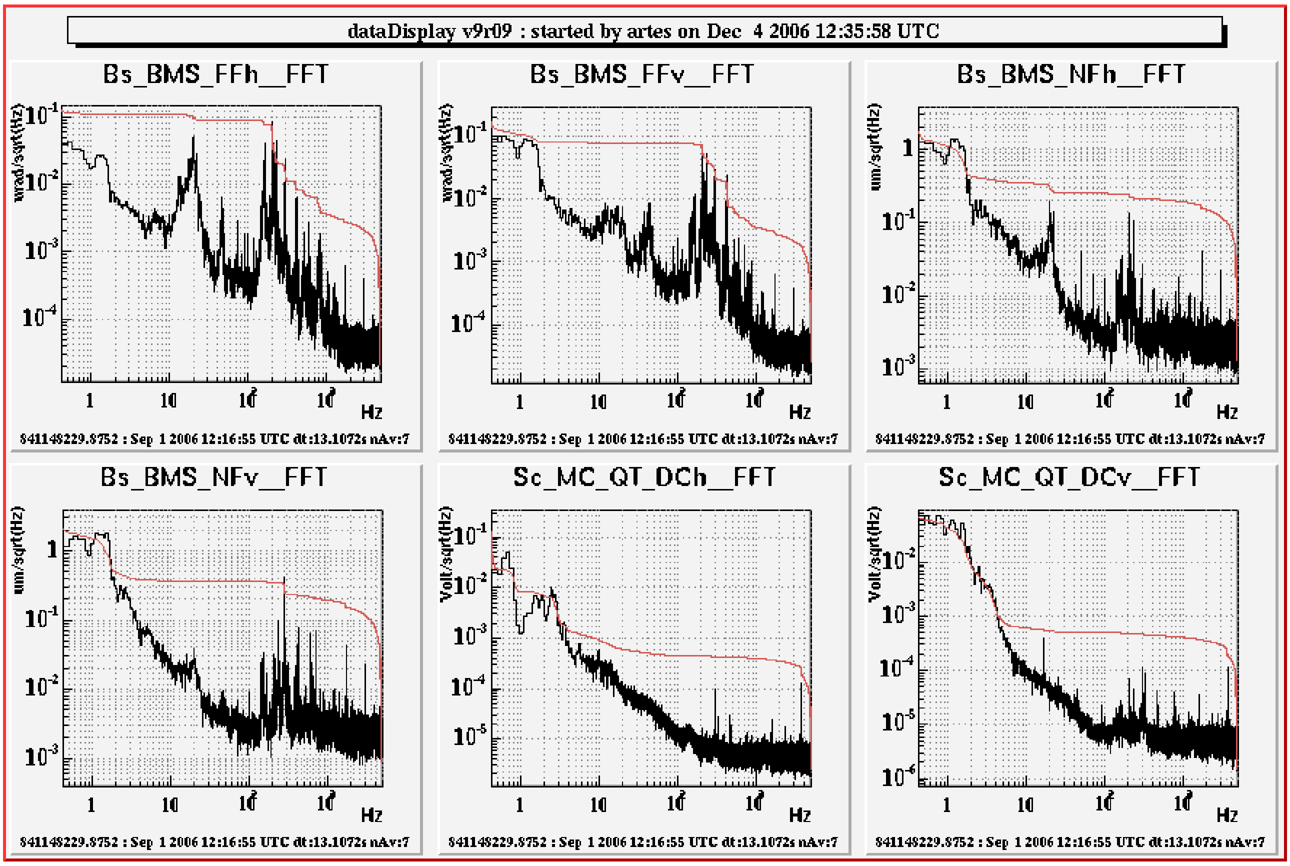


Figure 5

BMS_FFh & v expressed in urad/sqrt(Hz) with 9urad/V calibration
BMS_NFh & v expressed in um/sqrt(Hz) with 540um/V calibration
MC_QT_DCh & v expressed in V/sqrt(Hz).
Rms value (red curve) are always much lower than 0.1Vrms

6. Deliverable 1

- 3+1 quadrant photodiodes, assuming one common design for the three photodiodes (one will be a spare)
- Associated pre-shaping filters
- Associated mechanical mounts and feet.

7. Involved Virgo sub-systems

#	Subsystem Name	Description of the involvement
1	Injection alignment	Quadrant photodiode integration

8. Involved EGO infrastructures

#	Infrastructure	Description of the involvement
1	Electronic	Electronic realization, test
2	Mechanical workshop	Mount realization

9. Planning

Implementation Plan												
	February 2007				**March 2007**				**April 2007**			
Tasks and Deliverables	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Tasks												
Task #1												
Task #2												
Deliverables												
Deliverable #1												

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10. Budget

#	Item	Contractor / supplier	Cost (€) (taxes incl.)	Charged to EGO/Virgo lab.
4	Electronic + mechanics		<2000 € ?	EGO

Total cost (€):
Request to EGO (€)

11. Document/Procedure history

Date	Event	Comment
dd/mm/yyyy	Start of the procedure	
dd/mm/yyyy	Presentation to the detector meeting	
dd/mm/yyyy	New release of the document	
dd/mm/yyyy	Submission to the VSC	

12. Automatic information fields

Description	**Value**
Last saved by:	cleva
Last saved time:	21/12/2006 10.23
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Filename	CRE_PHD_BMS&MC_2.doc