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Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
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Prima Metrology COM2 Technical report 19-29/11/2008

Doc. No.: VLT-TRE-ESO-15730- 4674

Issue 1

Date: 09/12/2008

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CHANGE RECORD

Issue	Date	Affected Paragraphs(s)	Reason/Initiation/Remarks
1	09/12/2008	All	First issue

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1 INTRODUCTION

This document reports the results obtained during the PRIMET AIV-COM2 period held on Nov 19-29/2008, with the support of **P.Gitton, T.Phan,J.Sahlmann, C.Schmid**.

PRIMET was in the configuration left after COM1 (October 2008), which is documented in the report **VLT-TRE-ESO-15730-4653**. PRIMET was operated with the limitation of having 1 STS on G2 equipped with 1 inflatable VCM on Beam B.

The main objectives of the COM2 run were:

- Understand why no laser light was retro-reflected by STS-Beam A during COM1
- Optimize the STS-VCM curvature for PRIMET observations and compare with theoretical values
- Study the beam vignetting problem identified during COM1, which prevented to operate the pupil tracker.
- Align and operate the quacell. Record open loop pupil motion and attempt pupil tracking.
- Record PRIMET Fringes on Marcel and on AT#4-STS/Marcel.

The laser safety rules defined during the AIV period and defined in memo **TEL0820** from 14/8/08 applied during the COM2 run.

2 CONFIGURATION

PRIMET used the following configuration:

AT#4-STS (used as Telescope 1)

Station G2-DL#2

AT#4-STS VCM installed on Beam B

AT#4-STS equipped with its derotator and its TCCD

The Beam A of AT#4-STS: equipped with a “flat” fixed curvature VCM

Marcel (used as Telescope 2)

BSB_F (autotest) **ip#4-Beam B**

BSB_B (autotest) **ip#3_Beam A**

The M16 configuration is indicated in the next figure

The OPL length of ip2 through DL#2 (at OPL=0m) and AT#4-STS-G2 is approximately 73m (on way) or 146 m (returned way)

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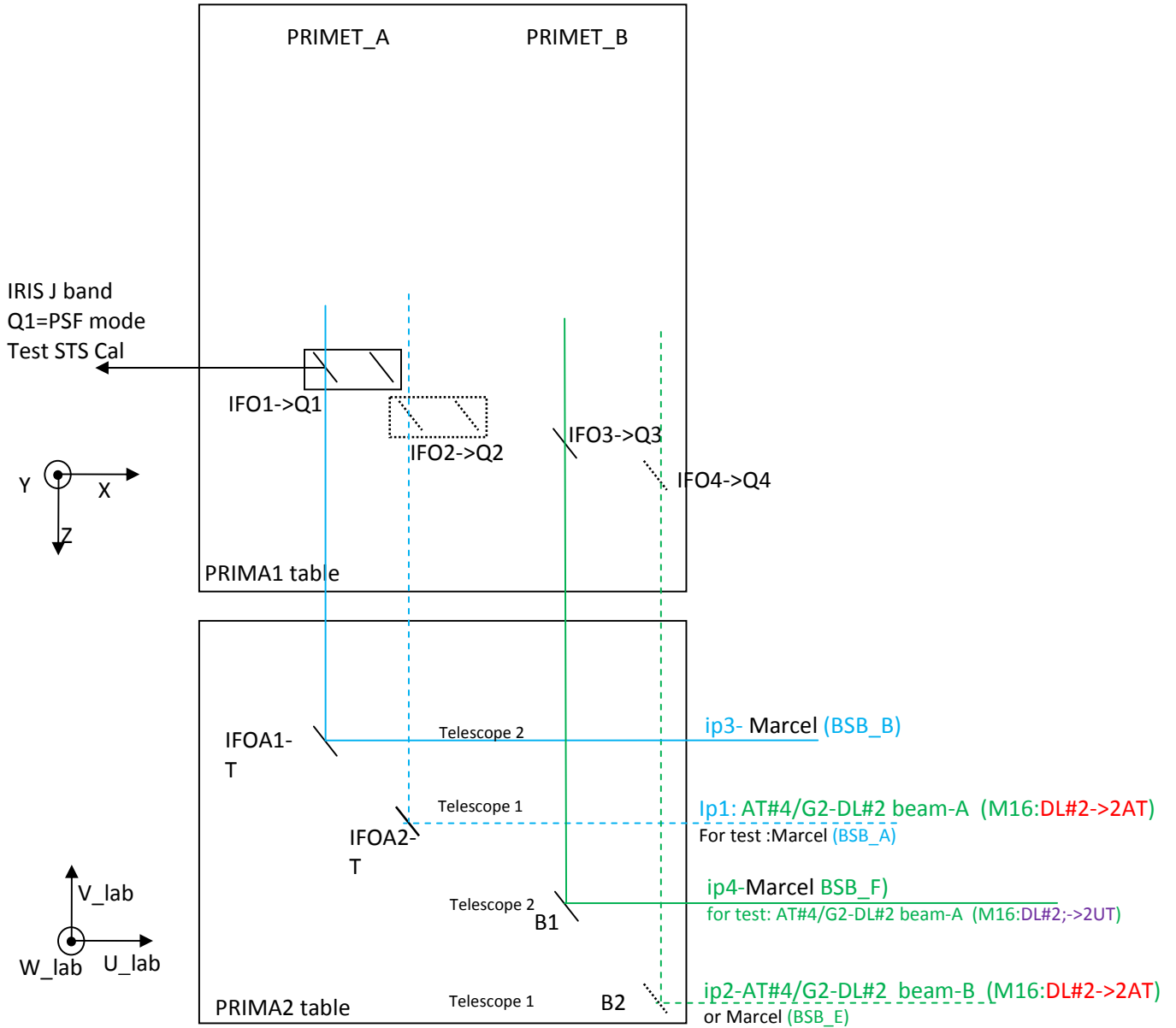


Figure 1: Beam routing for COM2

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AT#4-STSA&B-G2-DL#2 only used with PRIMET B							
FSM				VCM			
Mirror 1=Beam A		Mirror 2= Beam B		Mirror 1=Beam A		Mirror 2= Beam B	
<i>X</i> edge=30.5	<i>Y</i> edge=30.5	<i>X</i> edge=12.5	<i>Y</i> edge=12.5	<i>X</i> center=19 ¹	<i>Y</i> center=19	<i>X</i> center=26.5	<i>Y</i> center=10.5
<i>X</i> =	<i>Y</i> =	<i>X</i> =	<i>Y</i> =	<i>X</i> =-	<i>Y</i> =-	<i>X</i> =	<i>Y</i> =
<i>U</i> =	<i>W</i> =	<i>U</i> =	<i>W</i> =	<i>U</i> =-	<i>W</i> =-	<i>U</i> =	<i>W</i> =
				Fixed curvature mirror ROC=infinity (C=0 mm ⁻¹)		ROC=744 mm, C= 1.344×10 ⁻³ mm ⁻¹ ⁽²⁾ (theoretical value)	

DL	OPL	VCM Curvature/pressure
DL#2-ip2	14	ComputeVCMParametersATBC(TelescopeStation,DL,IP,DLPOS,pupil Offset,-1) ComputeVCMParametersATBC('UT2',2,2,7,4.5,-1) = 3.692112e ⁻³ mm ⁻¹ (P=1.57 bar)
DL#2-ip4	14	ComputeVCMParametersATBC('UT2',2,4,7,4.5,-1) = 3.855718e ⁻³ mm ⁻¹ (P=1.65 bar)

FSUB ACU	X	Y
TTP1	29×10 ⁻⁶ mech. rad	25×10 ⁻⁶ mech. Rad
TTP2	381×10 ⁻⁶ mech. Rad	144×10 ⁻⁶ mech. Rad

FSUB LMOT	Position
LMOT1	-134077 counts
LMOT2	0

¹ Default values. They could not be checked in the AT hall (physical problem with a pillar blocking the access for optical alignment)

² See section 3.2

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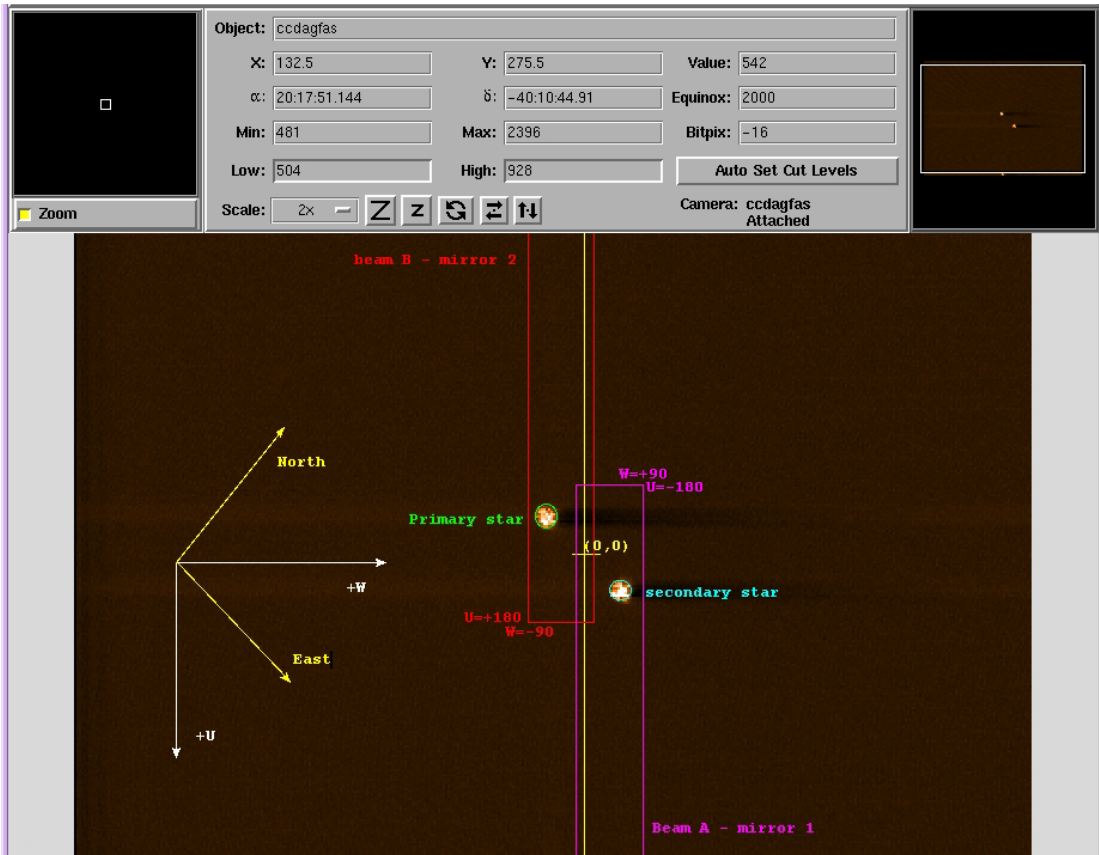


Figure 2: For example only: AT#3-STs (G2) during AIV

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3 USEFUL PUPIL RE-IMAGING DATA

3.1 Pupil positions in the laboratory

Pupil ip4: SWD-3-S V=-34935

Nominal position (without DDL): NomPos=[U=46560 ;V=-34935]

Distance(NomPos-BC_FSU)=75+2210+800+107+172+181+781=4326 mm ± LMOT pos

This includes d(TTP-BC)=781mm taking into account the geometrical path inside the K-prism but not the index of refraction:

- inside the K-prism: $\epsilon=(n-1) \times 208\text{mm} \sim 0.5 \times 208 = 104\text{mm}$
- inside the K-prism the IFO: $\sim 0.5 \times 10\text{mm} = 5\text{mm}$
- inside the FSU_BC: $\sim 0.5 \times 15 = 7.5\text{mm}$

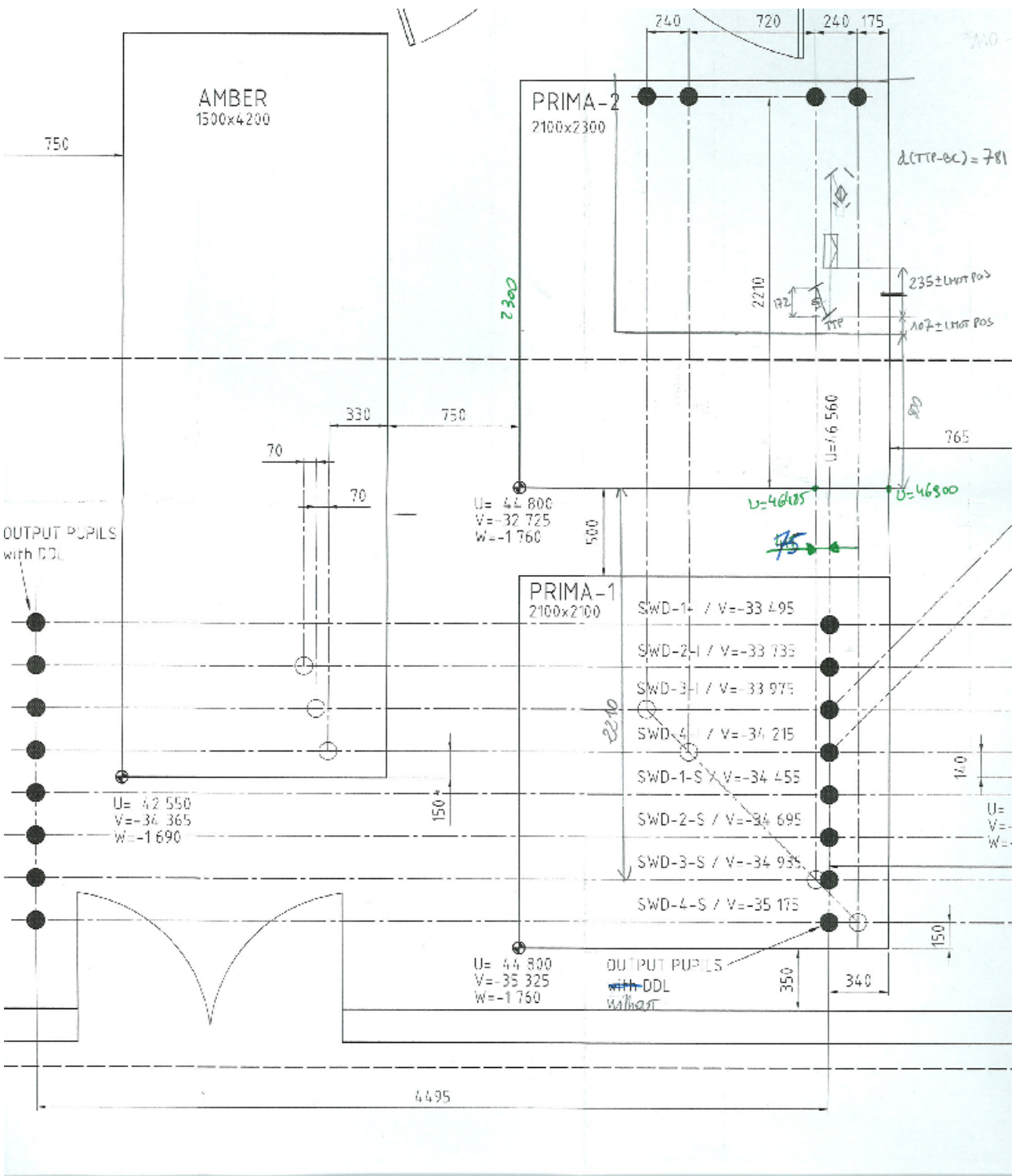
i.e a total of 116.5mm

so finally, the expected optical distance between NomPos and the BC_FSU is $\sim 4442\text{ mm} \pm \text{LMOT pos}$

This has is to be compared to the theoretical pupil longitudinal offset of **4495 mm** (i.e $\Delta=53\text{ mm}$)

Conclusion: the pupil longitudinal offset of 4.5 m to be applied to the DL-VCM is correct.

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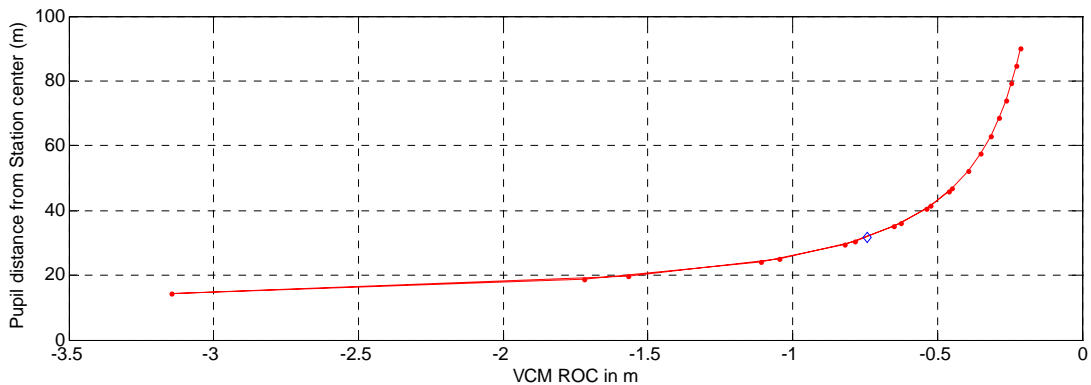
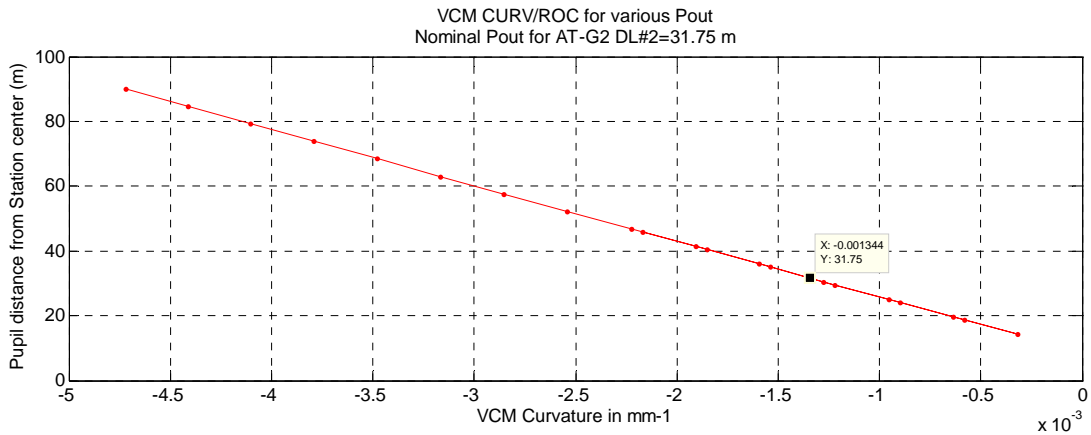
3.2 Theoretical relation between STS-VCM curvature and STS output pupil position

For AT-G2 and using DL#2, the goal is to bring the output pupil at UTExitPupuluCoordinate = 49.875m.

```
% StationCoord case 'G2'
StationPosition = struct('u',32.,'v',-24.);
% UT output pupil position along u in meters for DL2
UTExitPupuluCoordinate = 49.875;
% DL axis position along v for DL2
DLPosition = struct('v', -37.875, 'u0', 59.717);
[R_nom, Curv_nom, Pout_nom] = VCM_STS([StationPosition.u, StationPosition.v], UTExitPupuluCoordinate, DLPosition.v);
```

VCM_STS

STS VCM ROC is: -7.440535e-001 (m)
STS VCM curvature is: -1.343989e-003 (mm-1)
Pout is: 3.175000e+001 (m)



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By fitting the data:

$$P_{\text{out}}(\text{m}) = -17200 \times \text{VCM_CURV}(\text{mm}^{-1}) + 8.6664$$

$$\Delta P_{\text{out}}/\Delta C = -17200 \text{ m}/(\text{mm}^{-1})$$

3.3 Theoretical curvature of DL#2 VCM

Theoretical DL#2 VCM curvature is given by the following matlab code:

ComputeVCMParametersATBC(TelescopeStation,DL,IP,DLPOS,pupil Offset,-1)

Case 1: IP2 no offset in the VLTI lab, DL#2 at OPL=14m

- ComputeVCMParametersATBC('UT2',2,2,7,0,-1) = 2.733833e-004 mm-1

Case 2: IP2 offset of 4.5 m in the VLTI lab to match PRIMA configuration

- ComputeVCMParametersATBC('UT2',2,2,7,4.5,-1) = 3.692112e-003 mm-1
(P=1.57 bar)

Case 3: IP4 offset of 4.5 m in the VLTI lab to match PRIMA configuration

- ComputeVCMParametersATBC('UT2',2,4,7,4.5,-1) = 3.855718e-003 mm-1
(P=1.65 bar)

3.4 VCM curvature-pressure calibration for AT#4-VCM-beam B

The relation curvature/pressure, derived from the calibration data of the VCM.dbcfg files installed at Paranal, are given in the next figure. The VCM#18 is installed on AT#4-ST5 beam B.

This plot is generated by *Plot_VCMPressureCurvature.m* (which calls *VCMPressureCurvature.m*).

For AT-G2 and using DL#2, the theoretical curvature of the ST5 VCM is $C = -1.343989\text{e-}3$ (mm^{-1})

This corresponds to a Pressure of $P = 0.453$ bar for the VCM-AT#4_beam B

(For $P = 0.45$, $C = 1.337\text{e-}3$)

A linear fit around this value gives: $P = 444.93.C - 0.14827$

Thus

$$\Delta P/\Delta C = 444.93 \text{ bar}/\text{mm}^{-1}$$

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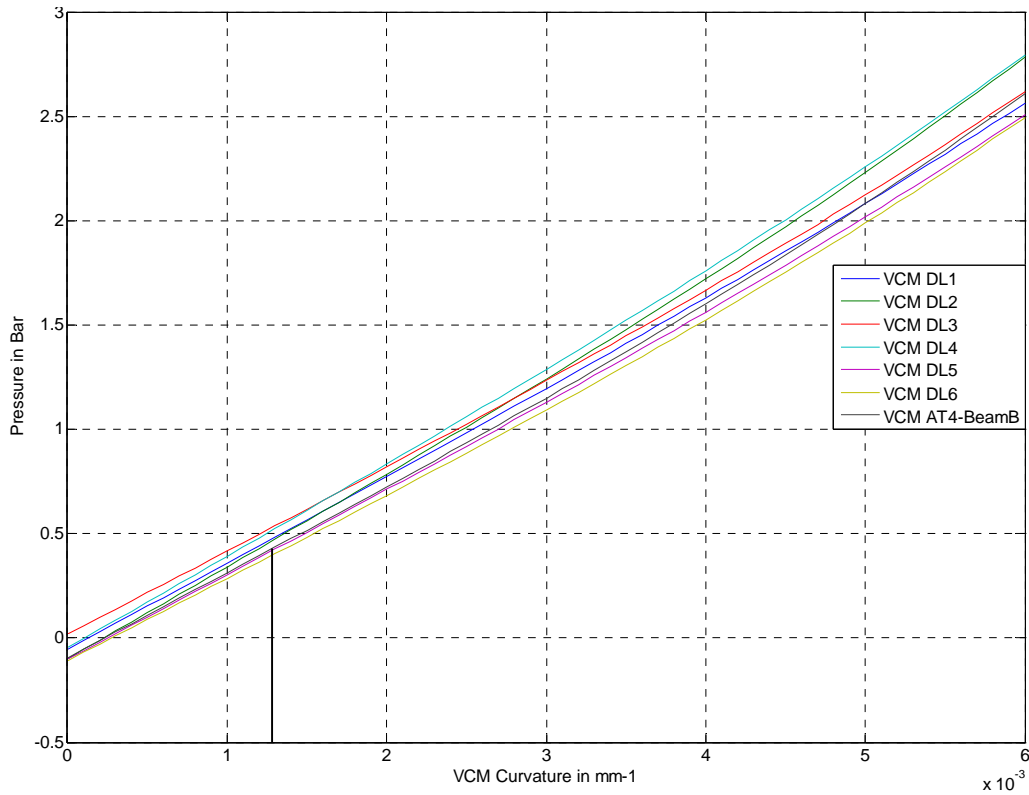


Figure 3

3.5 Impact of the VCM curvature error (STS-Beam A)

The fixed curvature the VCM on beam A is 0 instead of -1.343989×10^{-3} (mm⁻¹)

In this condition we have $\Delta C = 1.343989 \times 10^{-3}$ mm⁻¹, which leads to:

$\Delta P_{out} = [\Delta P_{out}/\Delta C] \times \Delta C = -17200 \text{ m}/(\text{mm}^{-1}) \cdot 1.343989 \times 10^{-3} (\text{mm}^{-1}) = 23 \text{ m}$ before the beam compressor, or **1.17m** after the beam compressor.

(the re-imaged pupil is $31.75 - 23 = 8.75$ m away from the center of the G2 station)

For observation on Beam A, this must be compensated by offsetting the pressure of the DL#2-VCM

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4 SATURDAY 22/11/08

4.1 Configuration

AT4 STS2 Beam B IP4 DL2 M16 4AT

AT#4-STSA&B-G2-DL#2 only used with PRIMET B							
FSM				VCM			
Mirror 1=Beam A		Mirror 2= Beam B		Mirror 1=Beam A		Mirror 2= Beam B	
<i>X</i> edge=30.5	<i>Y</i> edge=30.5	<i>X</i> edge=12.5	<i>Y</i> edge=12.5	<i>X</i> center=11	<i>Y</i> center=19	<i>X</i> center=26.5	<i>Y</i> center=10.5
<i>X</i> =	<i>Y</i> =	<i>X</i> =	<i>Y</i> =	<i>X</i> =	<i>Y</i> =	<i>X</i> =	<i>Y</i> =
<i>U</i> =	<i>W</i> =	<i>U</i> =	<i>W</i> =	<i>U</i> =	<i>W</i> =	<i>U</i> =	<i>W</i> =
				Fixed curvature mirror ROC=infinity (C=0 mm ⁻¹)		ROC=744 mm, C= 1.344×10 ⁻³ mm ⁻¹ (theoretical value)	

The VCM piezo settings are optimized to maximize the injection in the Probe fiber for the theoretical settings. Note that we have noticed that inflating/deflating the STS-VCM does not affect much the lateral pupil motion.

DL	OPL	VCM Curvature/pressure
DL#2-ip2	14	C=4. ×10 ⁻³ mm ⁻¹ (P=1.72 bar) <i>This is not the theoretical value. This value was taken by mistake from COM1</i>

ComputeVCMParametersATBC('UT2',2,4,7,4.5,-1) = 3.855718e⁻³ mm⁻¹ or P=1.65 bar)

FSUB ACU	X	Y
TTP1	29×10 ⁻⁶ mech. rad	25×10 ⁻⁶ mech. Rad
TTP2	381×10 ⁻⁶ mech. Rad	144×10 ⁻⁶ mech. Rad

FSUB LMOT	Position
LMOT1	-134077 counts
LMOT2	0

The beam profiler is used outside of the FSU path by using a beam splitter located before (-v) the shutter of IP4, to fold the returning beam to the side of the table where the beam profiler is located. The beam profiler is not put precisely at the distance equivalent to the BC. It is approximately 20 cm too far.

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What is the impact of the DL curvature error ?:

A DL-VCM curvature of $4e-3$ corresponds to the configuration of COM1 (i.e. DL#4 on IP4)

```

ComputeVCMParametersATBC('UT4',4,4,7,4.5,-1)
> Input pupil distance (*)           = 1.684200e+001 m
> Exit pupil distance required       = 1.119531e+002 m
> VCM radius required (with specific DL optical par.) = 3.999341e-003 mm-1

```

Instead of the current theoretical case:

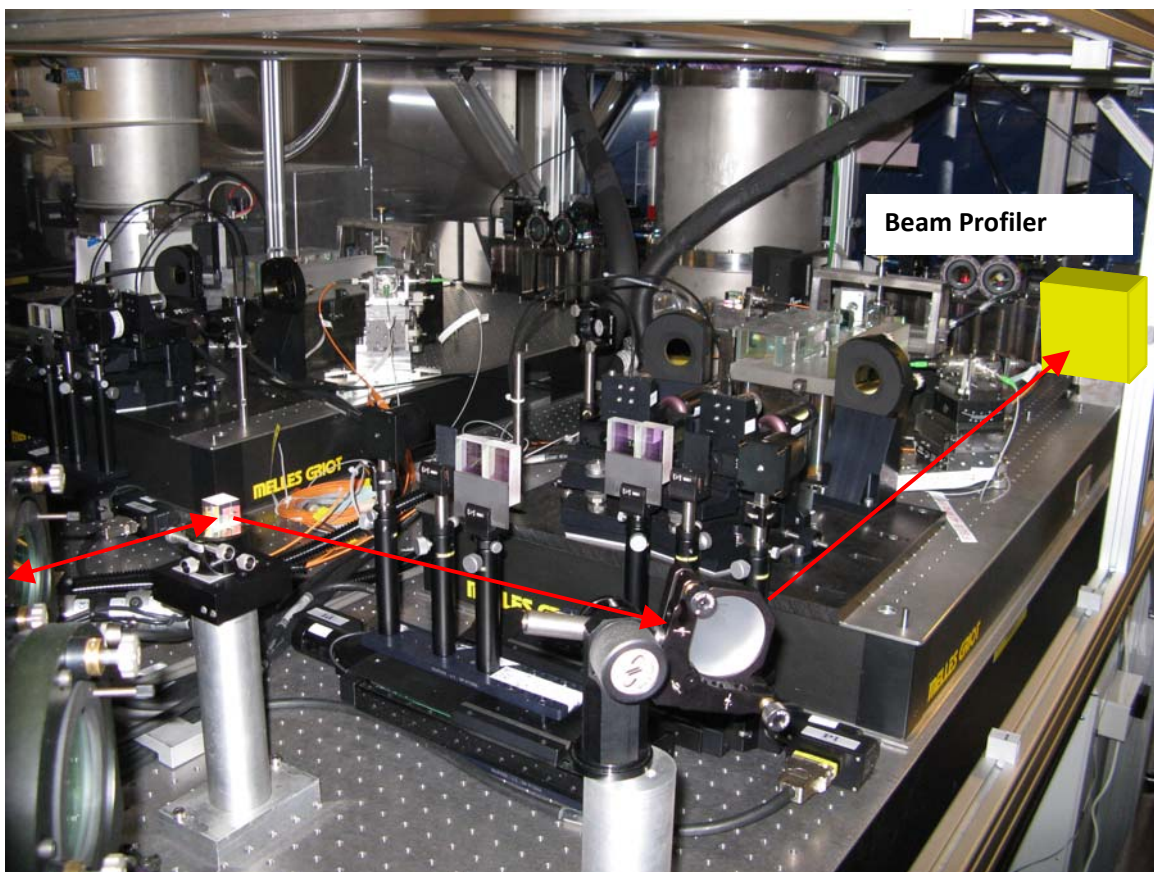
```

ComputeVCMParametersATBC('UT2',2,4,7,4.5,-1)
> Input pupil distance (*)           = 1.684200e+001 m
> Exit pupil distance required       = 1.081331e+002 m
> VCM radius required (with specific DL optical par.) = 3.855718e-003 mm-1

```

The difference between the Exit pupil distance is $1.119531e+002 - 1.081331e+002 = 3.82$ m (before the Beam Compressor). So the pressure error corresponds to a pupil offset of **19 cm** after the BC
In other words, the delay line pushed the pupil 19 cm too far.

However, the Beam profiler is ~ 20 cm too far, so the **2 effects should more or less compensate !! and we can consider that the Beam profiler is at the right location.**

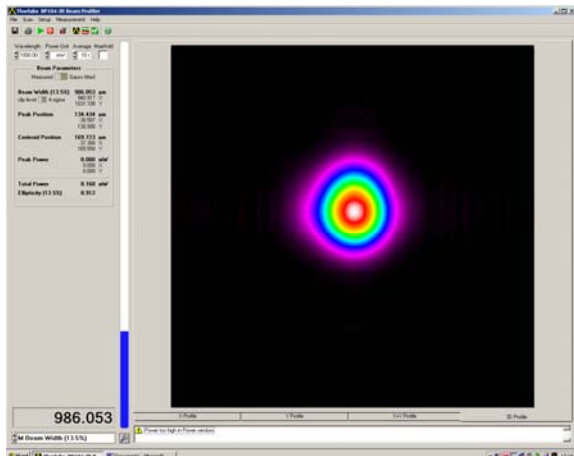


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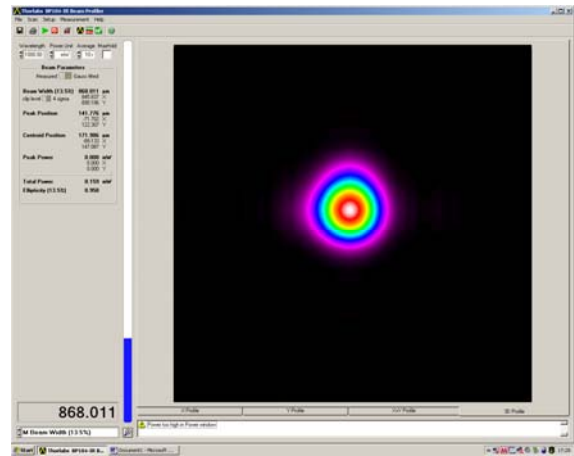
4.2 Pupil reimaging test with active STS-VCMB

The STS-VCM pressure is scanned to find the optimal image of the metrology beam.

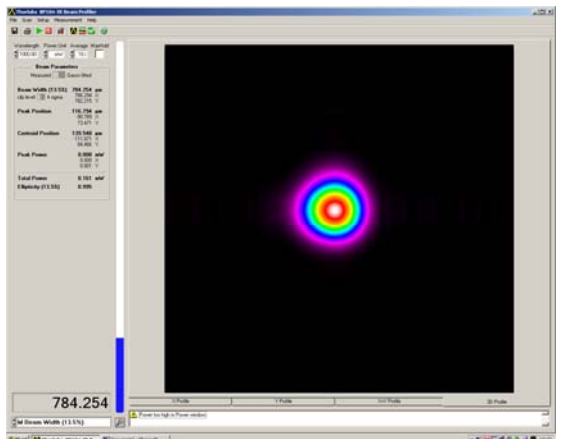
STS-VCM Pressure = 0.05 bar



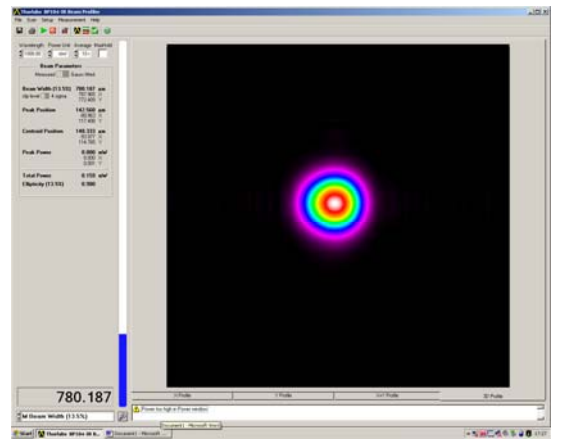
STS-VCM Pressure = 0.075 bar



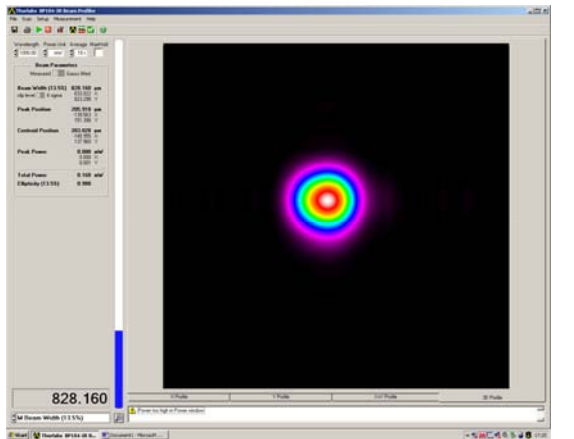
STS-VCM Pressure = 0.1 bar



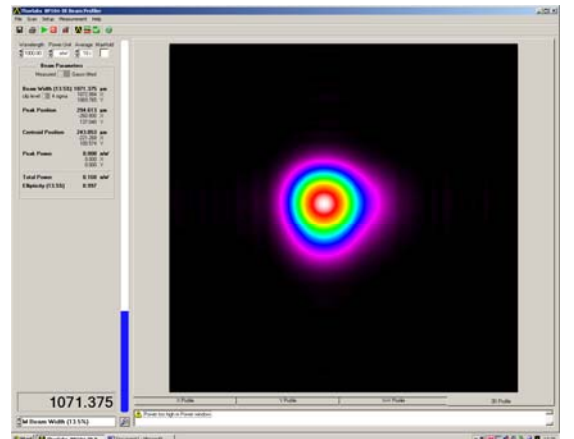
STS-VCM Pressure = 0.125 bar



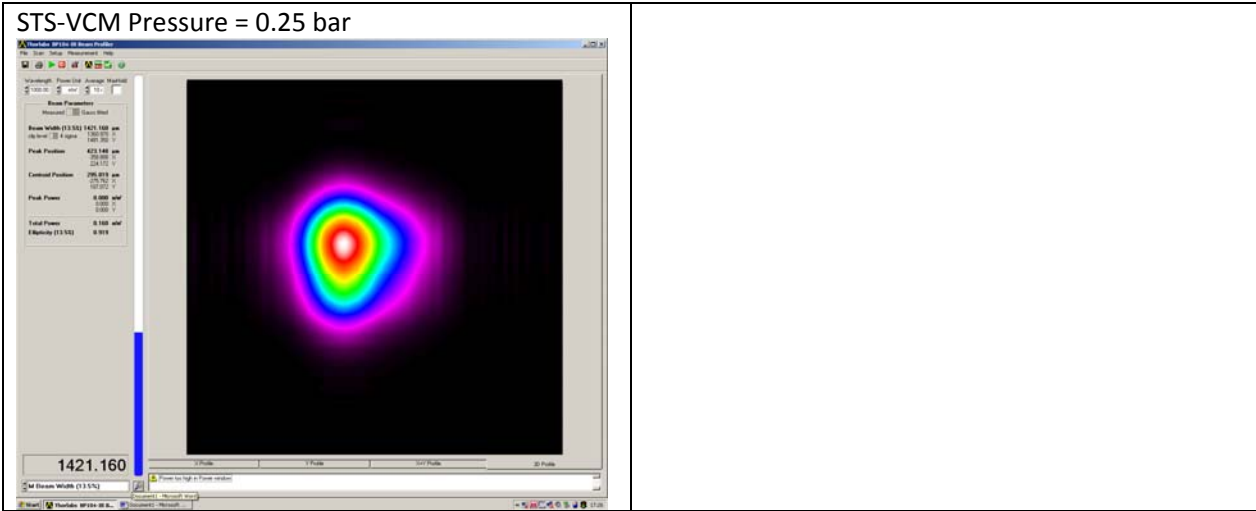
STS-VCM Pressure = 0.15 bar



STS-VCM Pressure = 0.2 bar



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Pressure (bar)	Spot diameter @ 1/e (microns)
0.05	990
0.075	870
0.1	784
0.125	780
0.15	830
0.2	1071
0.25	1421

Table 1

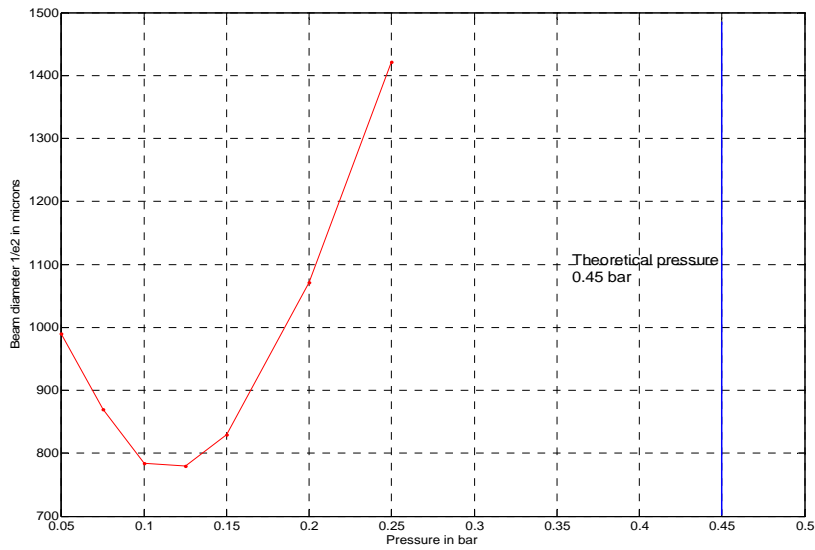


Figure 4

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The theoretical value to re-image the pupil on the BC is $C_{STS-VCM} = 1.344 \times 10^{-3} \text{ mm}^{-1}$ ($P=0.453 \text{ Bar}$)
The optimum re-imaging is found for STS-VCMB $P_{STS-VCM} = 0.125 \text{ Bar}$ ($C_{STS-VCM} = 5.4e^{-4} \text{ mm}^{-1}$), thus
 $\Delta C = 8.04e^{-4} \text{ mm}^{-1}$ ($\Delta P = 0.328$)

Based on section 3.2, $\Delta P_{out} / \Delta C = -17200 \text{ m/mm}^{-1}$.

The experimental curvature offset of $\Delta C = 8.04e^{-4} \text{ mm}^{-1}$ leads to a pupil offset in the tunnel of $\Delta P_{out \text{ Tunnel}} = 13.82 \text{ m}$
or $\Delta P_{out \text{ lab}} = 70 \text{ cm}$ in the laboratory (i.e. after the beam compressor)

4.3 Pupil reimaging test with fixed curvature STS-VCMA

The configuration is

IP1 M16 2AT STS Beam A with flat fixed VCM: Center Position: X=11;Y=19 (instead of 19;19 given by TNO)

Because Ip1 is not as accessible as Ip4 or Ip2, the Beam Splitter was installed together with a folding mirror on the FINITO table. The beam profiler position has been adjusted accordingly to match the configuration previously used on Ip4.

DL#2@14m and VCM pressure/curvature = $4e^{-3}$

Again the DL#2-VCM curvature value was taken by mistake from COM1 instead of

ComputeVCMParametersATBC('UT2',2,1,7,4.5,-1) = $3.701344e^{-003} \text{ mm}^{-1}$

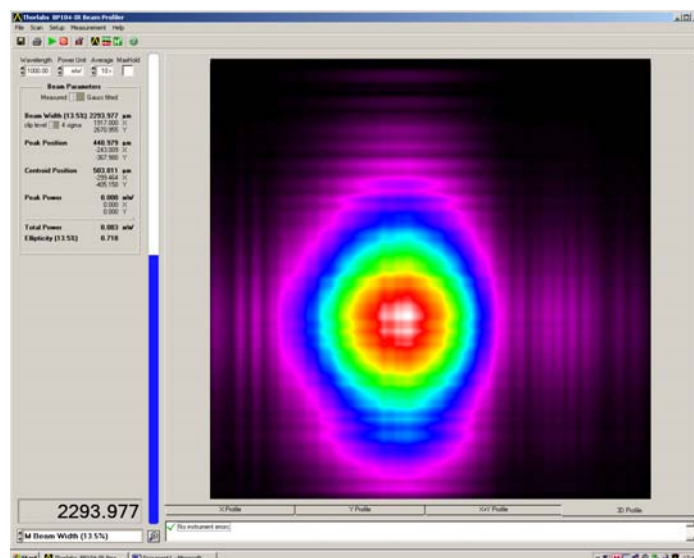
But as described in section 4.1, the beam profiler is actually located in the target pupil plane, i.e. equivalent to the FSU BC.

Note:

As expected, the theoretical pressure for Ip1/beam A it is the same as for Ip2/Beam B:

ComputeVCMParametersATBC('UT2',2,2,7,4.5,-1) = $3.692112e^{-3} \text{ mm}^{-1}$

We know, from section 3.4, that the flat VCM images the pupil 1.17 m in front of the BC (-v direction)...So the pressure is clearly wrong...



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4.4 PRIMETA/B fringes on Marcel

No particular problem.

Data look OK.

See summary results in section 10

4.5 PRIMETA/B fringes on AT#4-STSA/B and Marcel

Both beams are coming back from AT4-STSA2

Beam A pupil lateral position was initially seriously decentered. Because AT#4 is in G2 , it is easier to see the returned beam than when the telescope is in J2.

It has been noticed that with a high integration time (1s) on the telescope TCCD, it is possible to see two spots corresponding to the pump diodes of the PRIMET laser. It has to be investigated if it is necessary to provide a notch for it depending on the equivalent magnitude (to be characterized during COM3)

Configuration:

AT4 STS2 DL2@14m BC M16 2AT with theoretical pressure in both VCM:

PRIMETA

ip3: Marcel BSB_B
ip1: STS G2 beam A

PRIMETB

ip4: Marcel BSB_F
ip2: STS G2 Beam B

The VCM tilt is adjusted to optimize the flux injected in the extraction fibre

TTP FSUB

TTP1 ThetaX -29 e-6 mech. rad; ThetaY 25 e-6 mech. rad

TTP2 ThetaX 381 e-6 mech. rad ThetaY -144 e-6 mech. Rad

Filenames

[-rwxr-xr-x 1 nschuhle staff 17457265 22 Nov 21:49 lprmacPhaseMeter2008-11-22T19.12.04.txt](#)

Phase Meter Data

==> Filename: lprmacPhaseMeter2008-11-22T19.12.04.txt

Sampling frequency= 8000 Hz

Number of samples= 240000

compute PSDs...

DeltaL Mean= 3.415522e-007 m

DeltaL PV= 8.492000e-007 m

DeltaL rms= 1.570510e-007 m

DeltaL rms above f_cut= 5 Hz= 3.552444e-008 m

Status Not OK: 0

[-rwxr-xr-x 1 nschuhle staff 17453942 22 Nov 21:49 lprmacPhaseMeter2008-11-22T19.13.43.txt](#)

Phase Meter Data

==> Filename: lprmacPhaseMeter2008-11-22T19.13.43.txt

Sampling frequency= 8000 Hz

Number of samples= 240000

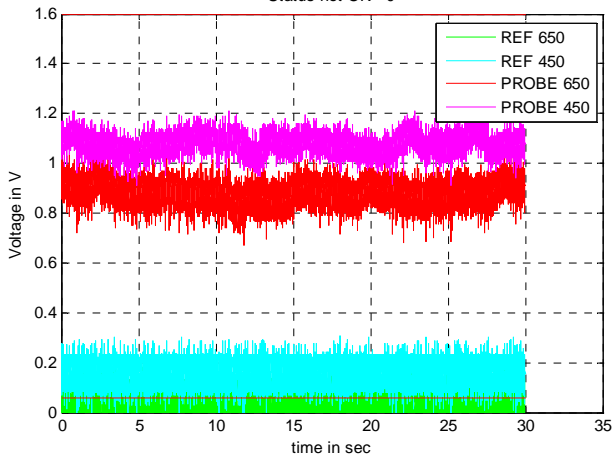
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compute PSDs...
DeltaL Mean= 2.999869e-007 m
DeltaL PV= 1.362900e-006 m
DeltaL rms= 1.122003e-007 m
DeltaL rms above f_cut= 5 Hz= 3.441690e-008 m
Status Not OK: 0

1 data point jumps by ~ 400 nm (but no glitch detected)
Significant vibrations in the 100 Hz regions

-rwxr-xr-x 1 nschuhle staff 9760401 22 Nov 21:50 lprmacPhotodiodes2008-11-22T19.12.04.txt

==> Filename: lprmacPhotodiodes2008-11-22T19.12.04.txt
Sampling frequency= 8000 Hz
Number of samples= 240000
Statistics in Volts
REF650 CH#A Mean= **0.065 V** PV= 0.238 V rms= 0.018 V
REF450 FSUB Mean= 0.158 V PV= 0.308 V rms= 0.019 V
PROBE650 CH#A Mean= 0.886 V PV= 0.406 V rms= 0.032 V
PROBE450 FSUB Mean= 1.079 V PV= 0.301 V rms= 0.027 V
Photodiode 2008-11-22T19.12.04
Fs=8000 Hz
Status not OK= 0



REF650kHz CH#A is too small

-rwxr-xr-x 1 nschuhle staff 9760401 22 Nov 21:50 lprmacPhotodiodes2008-11-22T19.13.43.txt

Same as previous file

-rwxr-xr-x 1 nschuhle staff 17632382 22 Nov 21:47 lprma2PhaseMeter2008-11-22T19.12.46.txt

Phase Meter Data

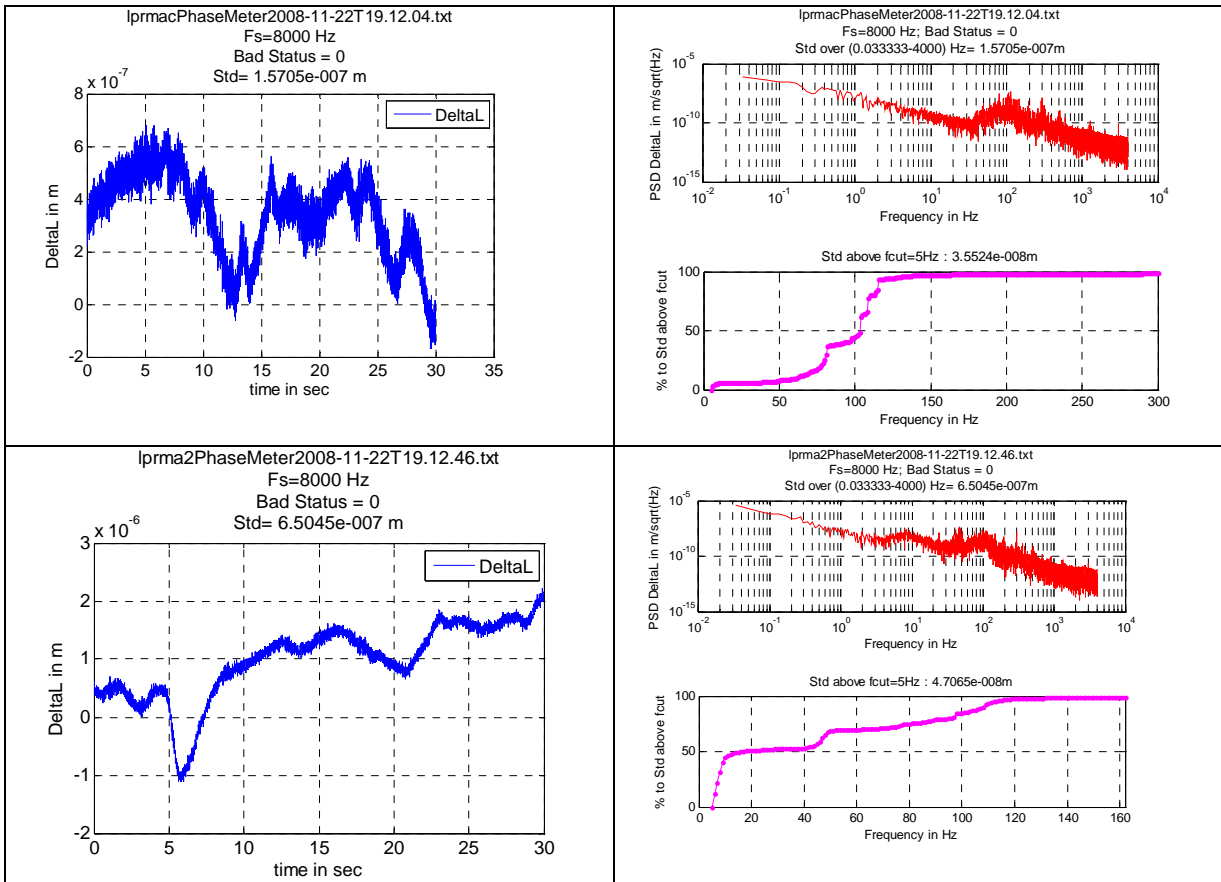
==> Filename: lprma2PhaseMeter2008-11-22T19.12.46.txt
Sampling frequency= 8000 Hz
Number of samples= 240000
compute PSDs...
DeltaL Mean= 9.736479e-007 m
DeltaL PV= 3.342400e-006 m
DeltaL rms= 6.504536e-007 m
DeltaL rms above f_cut= 5 Hz= 4.706462e-008 m
Status Not OK: 0

-rwxr-xr-x 1 nschuhle staff 17652702 22 Nov 21:47 lprma2PhaseMeter2008-11-22T19.14.22.txt

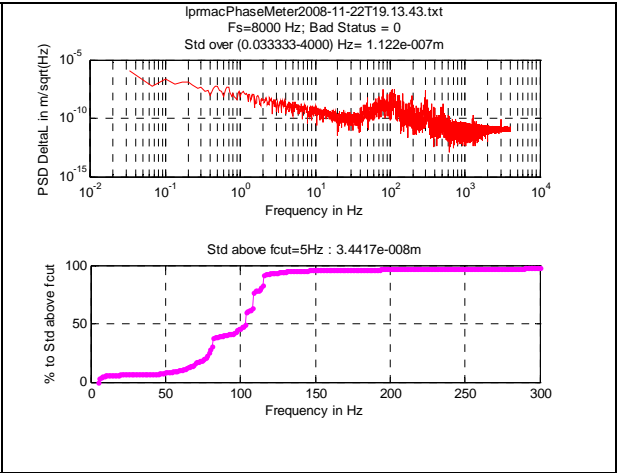
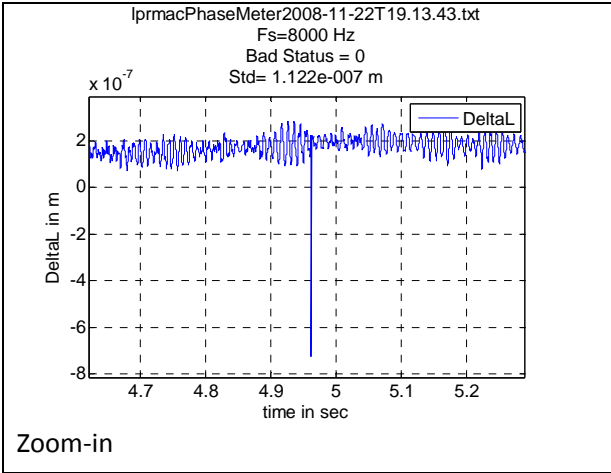
Phase Meter Data

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==> Filename: lprma2PhaseMeter2008-11-22T19.14.22.txt
 Sampling frequency= 8000 Hz
 Number of samples= 240000
 compute PSDs...
 DeltaL Mean= 9.279227e-007 m
 DeltaL PV= 9.478000e-007 m
DeltaL rms= 2.001537e-007 m
 DeltaL rms above f_cut= 5 Hz= 4.717950e-008 m
 Status Not OK: 0



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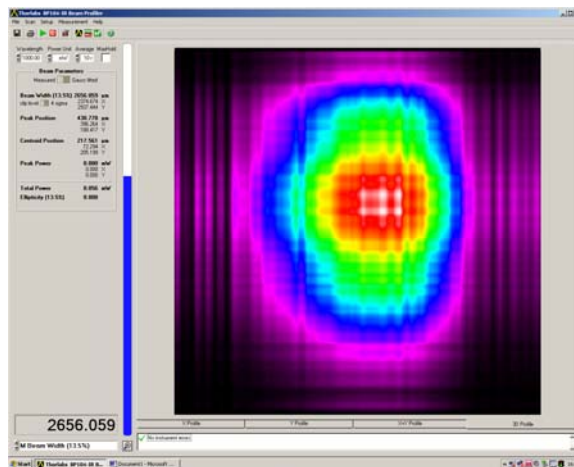
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5 SUNDAY 23/11/08

5.1 Configuration

The configuration is the following:
AT4 STS2 Beam B IP4 DL2 M16 4AT

With the FSM default setting the laser beam falls on the edge of M10. The returning beam is then enlarged by diffraction as shown below



So , the FSM is offsetted so that the laser beam does not fall on the edge of the M10.

AT#4-STSA&B-G2-DL#2 only used with PRIMET B							
FSM				VCM			
Mirror 1=Beam-A Not Used		Mirror 2= Beam B		Mirror 1=Beam-A Not Used		Mirror 2= Beam B	
X edge=30.5	Y edge=30.5	Xedge=12.5	Yedge=12.5	X center=19	Y center=19	Xcenter=26.5	Ycenter=10.5
X =	Y =	X= 14.596	Y= 12.50	X =	Y =	X= 28.10	Y = 3.70
U =	W =	U=	W=	U =	W =	U=	W=
				<i>Fixed curvature mirror ROC=infinity (C=0 mm⁻¹)</i>		ROC=744 mm, C= 1.344×10 ⁻³ mm ⁻¹ (theoretical value)	

DL	OPL	VCM Curvature/pressure
DL#2-ip4	14	4. ×10 ⁻³ mm ⁻¹ (P=1.72 bar) This is not the theoretical value. This value was taken by mistake from COM1

ComputeVCMParametersATBC('UT2',2,4,7,4.5,-1) = 3.855718e⁻³ mm⁻¹ or P=1.65 bar

FSUB ACU	X	Y
TTP1	29×10 ⁻⁶ mech. rad	25×10 ⁻⁶ mech. Rad
TTP2	381×10 ⁻⁶ mech. Rad	144×10 ⁻⁶ mech. Rad

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FSUB LMOT	Position
LMOT1	-134077 counts
LMOT2	0

5.2 Optimization of the STS-VCMB curvature

The beam profiler is located at a point Θ as shown in Figure 5, and such that the geometrical distance from the Beam splitter via the folding mirror to the Beam profiler, is identical to the distance between the beam splitter and the BC. So, *the beam profiler is in the theoretical pupil plane.*

According to our measurement the geometrical distance between the first mirror of ACU and the BC is 90 cm. The beam going to the beam profiler is folded by +42 cm in the u direction. Therefore to compensate for this extra-propagation the beam profiler is used 48cm only behind the first ACU mirror.

A posteriori, we realized that the pressure of the DL#4-VCM was set by mistake to $4e-3 \text{ mm}^{-1}$ instead of the theoretical value of $3.85e-3 \text{ mm}^{-1}$. Consequently, as indicated in section 4.2, the delay line pushed the pupil 19 cm too far (along v).

So the beam profiler is actually 19 cm in front of the pupil plane for an STS-VCM set to its theoretical pressure.

The remaining source of error can be approximated as follow:

Refractive index

- inside the K-prism: $\epsilon=(n-1) \times 208 \text{ mm} \sim 0.5 \times 208 = 104 \text{ mm}$
- inside the K-prism the IFO: $\sim 0.5 \times 10 \text{ mm} = 5 \text{ mm}$
- inside the FSU_BC: $\sim 0.5 \times 15 = 7.5 \text{ mm}$

i.e a total of 116.5mm. **(optical path longer than geometrical path).**

+ uncertainty on LMOT position

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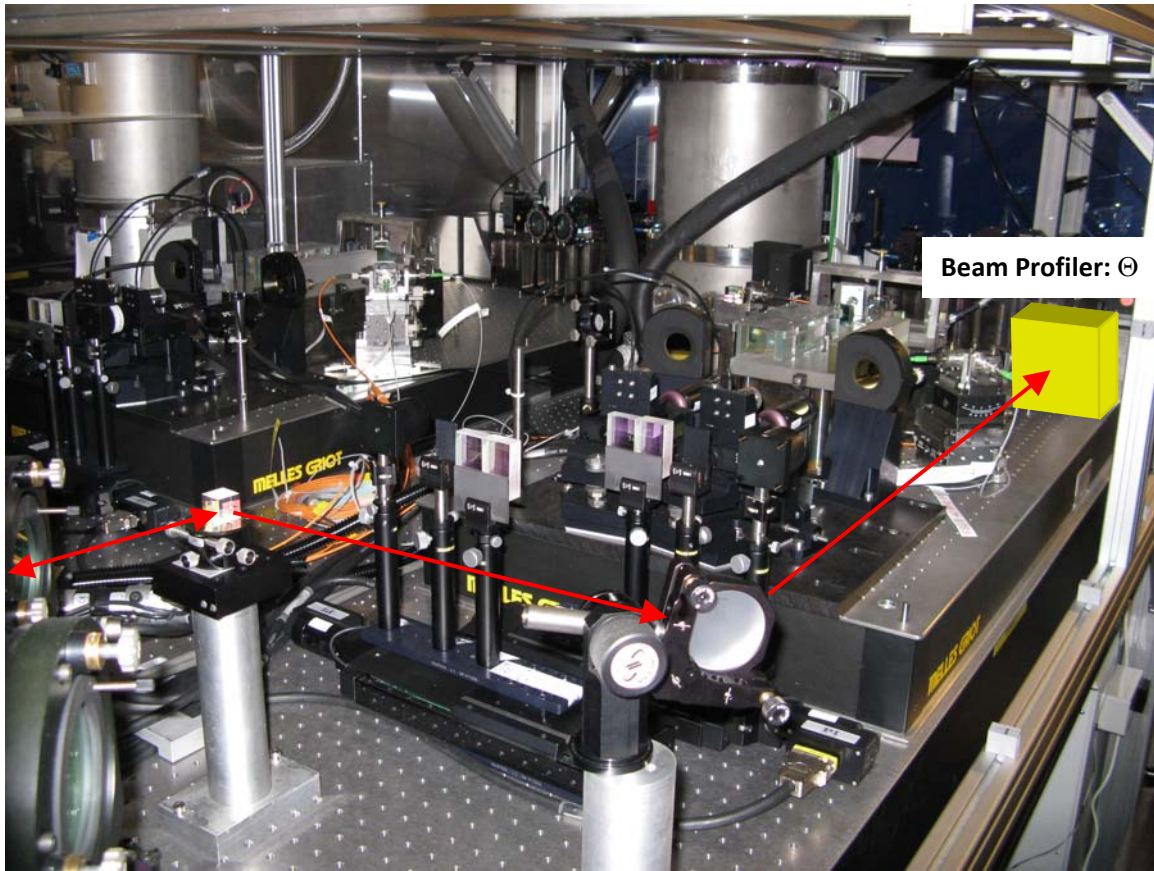
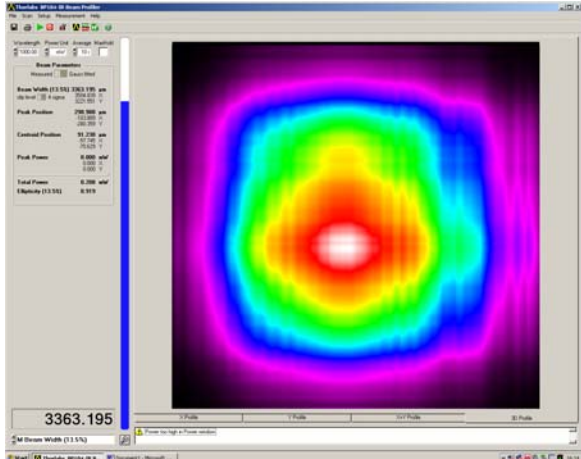


Figure 5

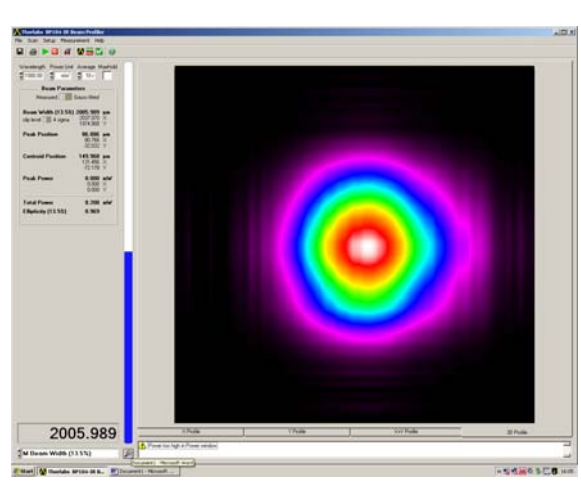
Then the pressure in the STS-VCM is scanned and screenshots of the returning spot are taken. The diameter at $(1/e^2)$ is plotted against the vcm curvature and pressure in the following figure.

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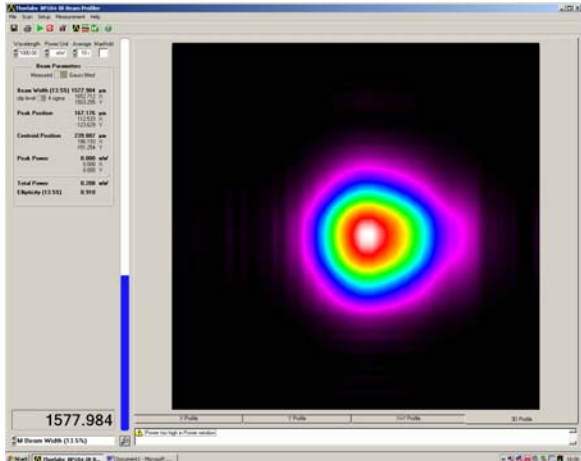
STS-VCM P = 0.45 bars / C = 0.00133 mm⁻¹ **THEORETICAL VALUE**



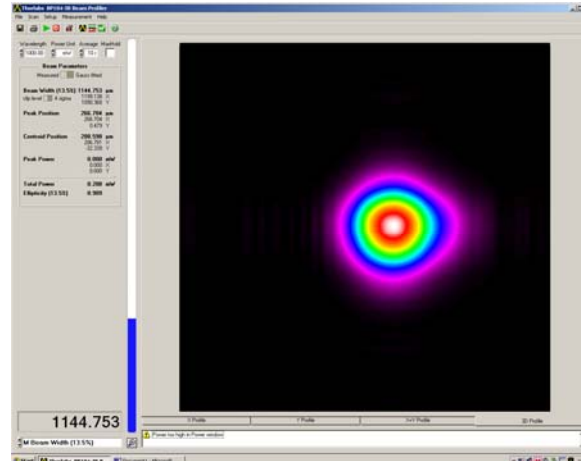
STS-VCM P = 0.3 bars / C = 0.00097 mm⁻¹



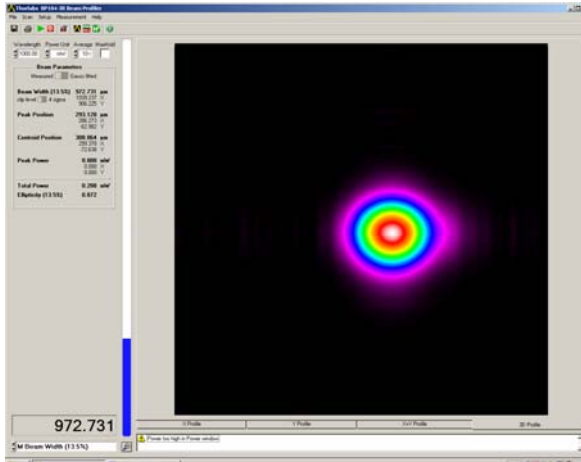
STS-VCM Pressure = 0.25 bars / Curvature = 0.00085 mm⁻¹



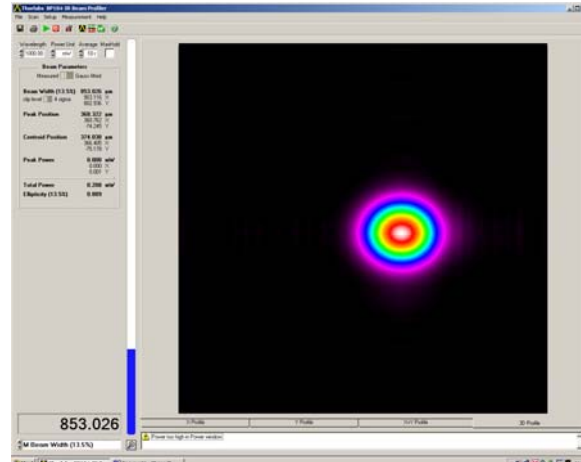
STS-VCM Pressure = 0.2 bars / Curvature = 0.000725 mm⁻¹



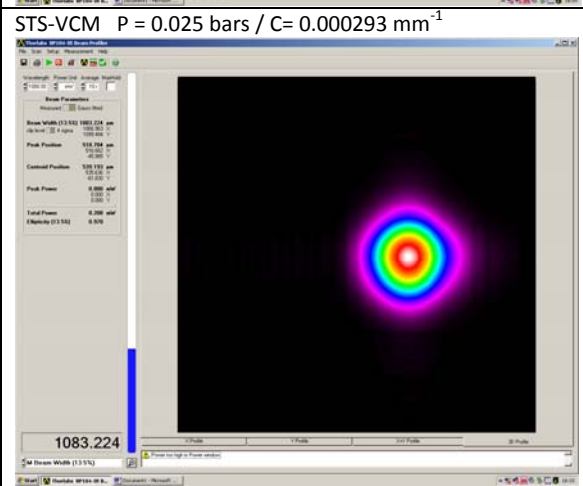
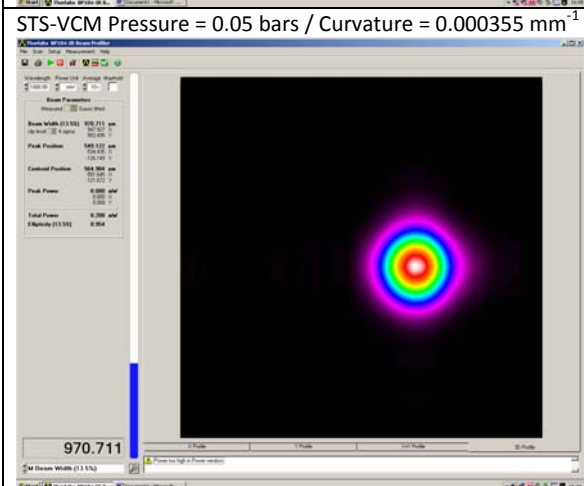
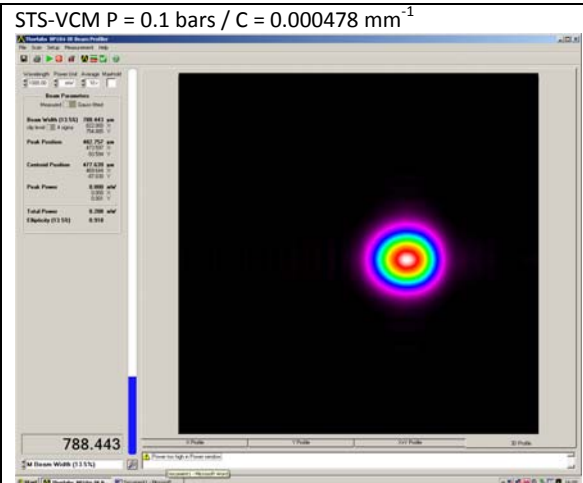
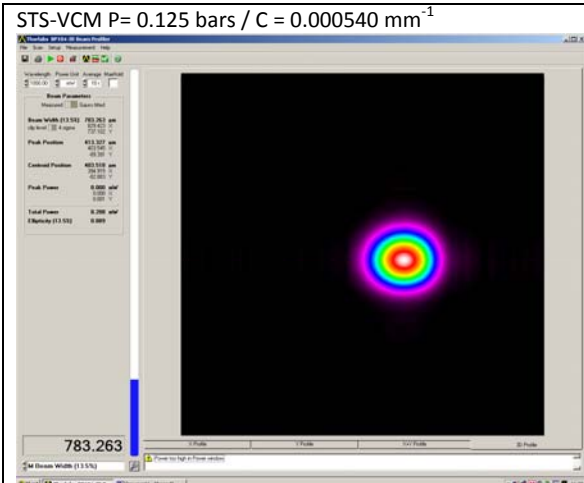
STS-VCM P = 0.175 bars / C = 0.000663 mm⁻¹



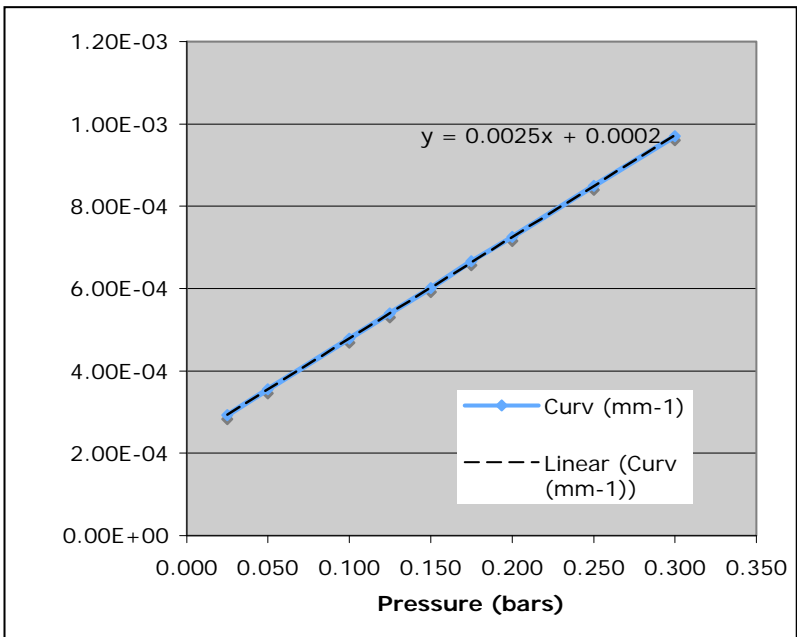
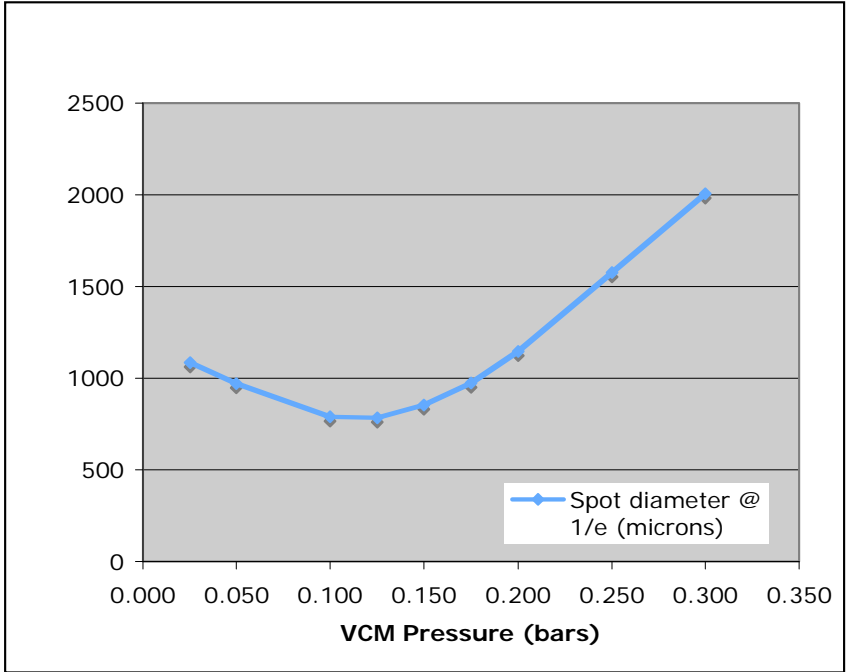
STS-VCM P = 0.15 bars / C = 0.000601 mm⁻¹



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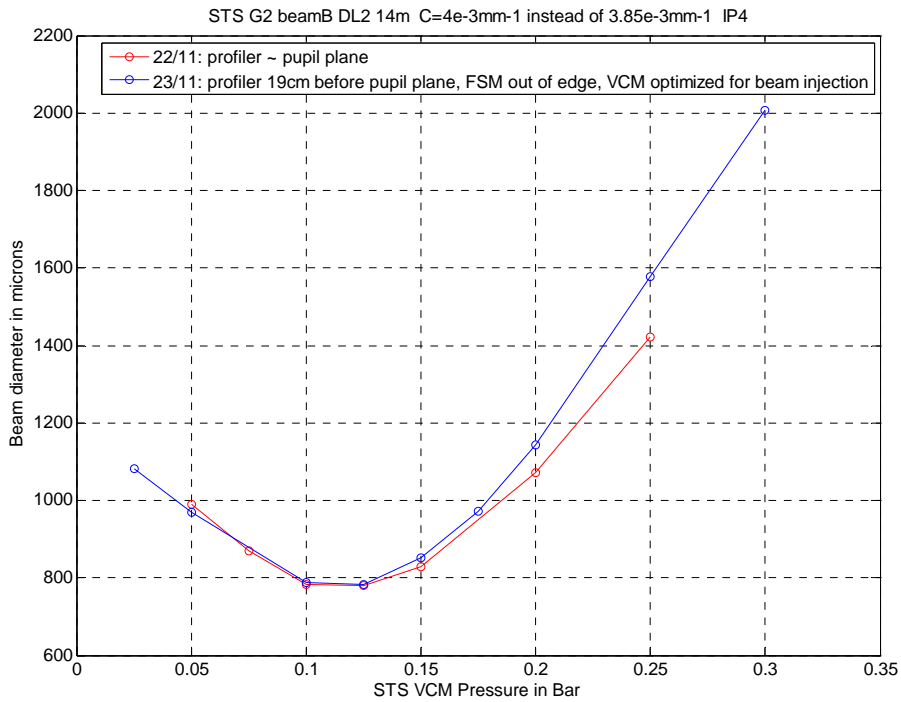
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Pressure (bar)	Spot diameter @ 1/e (microns)	Curv (mm-1)	R (m)
0.025	1083	2.93E-04	3.41
0.050	970	3.55E-04	2.82
0.100	788	4.78E-04	2.09
0.125	783	5.40E-04	1.85
0.150	853	6.01E-04	1.66
0.175	972	6.66E-04	1.50
0.200	1144	7.25E-04	1.38
0.250	1577	8.50E-04	1.18
0.300	2006	9.70E-04	1.03

The beam profiler has moved by ~ 20cm compared to Table 1 (22/11) but the same “optimum” values are obtained to minimize the spot size: P=0.125 and Spot=783 microns . This can be explained by the fact that the beam diameter varies slowly with respect to the beam profiler position around the optimum position (see Figure 6) and the somewhat low resolution of the measurements.

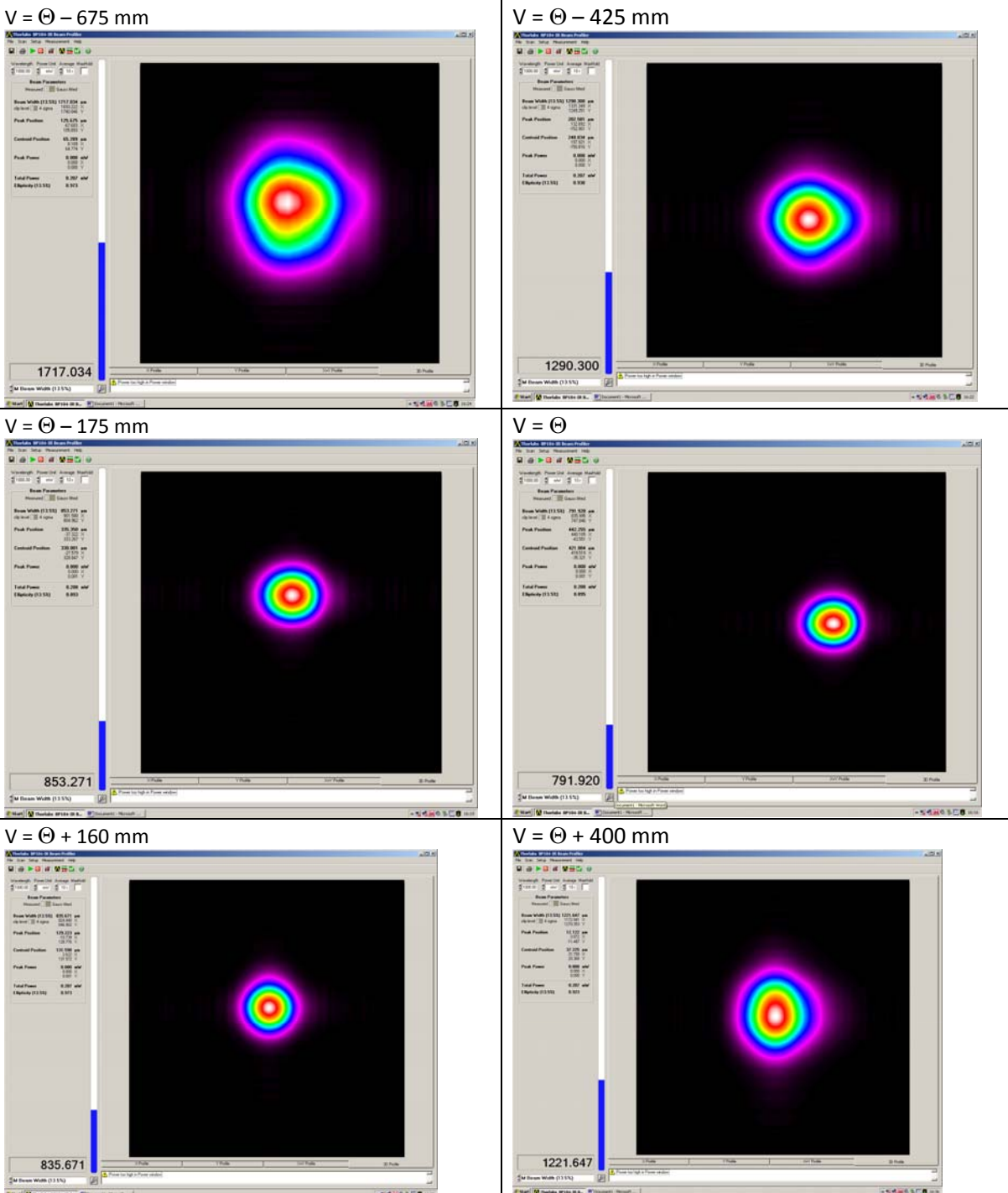


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5.3 Longitudinal scan of beam profiler

The STS-VCM is set at the optimal pressure = 0.125 bars / Curvature= 5.4e-4 mm-1

The beam profiler is translated along the V direction, from the position Θ used in the previous section



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Beam profiler Offset with respect to Θ (mm)	Spot diameter @ 1/e (microns)	Deviation from the nominal beam size
-675	1717	117 %
-425	1290	63 %
-175	853	7.8 %
0	791	0 %
160	836	5.7 %
400	1222	54.5%

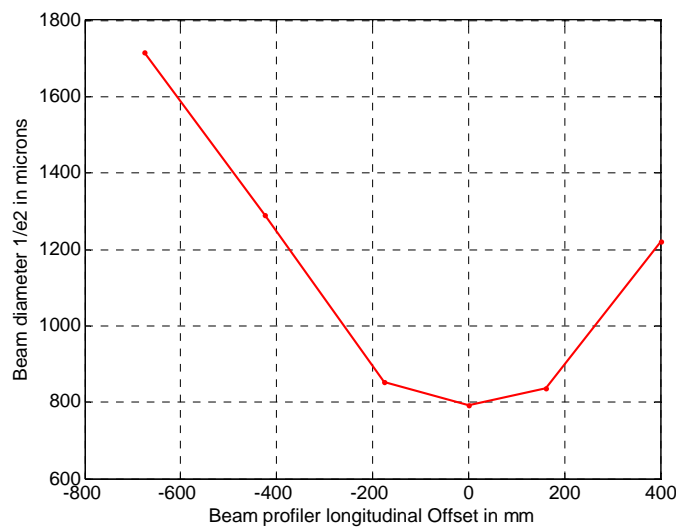


Figure 6

Starting from $V = \Theta + 400$ mm, we alternatively adjust the pressure of the STS-VCM (case 1 of Table 2) and of the DL-VCM (case 2 of Table 2) to re-optimize the beam shape and therefore compensate for the offset of $\delta V=400$ mm.

The offset of 400 mm can be compared to the theoretical pupil longitudinal shift, $\Delta P_{\text{out lab}}$, introduced by a given curvature variation, ΔC

$\Delta P_{\text{out lab}}$ is estimated from $\Delta C_{\text{STS-VCM}}$ based on section 3.2, where $\Delta P_{\text{out}} / \Delta C = -17200 \text{ m/mm}^{-1}$.

$\Delta P_{\text{out lab}}$ is estimated from $\Delta C_{\text{DL\#4-VCM}}$ based on the matlab routine:

```
ComputeVCMParametersATBC('UT2',2,4,7,4.69,-1)
```

```
> Exit pupil distance required = 1.118854e+002 m
```

```
> VCM radius required (with specific DL optical par.) = 4.0000e-003 mm-1
```

```
ComputeVCMParametersATBC('UT2',2,4,7,4.9071,-1)
```

```
> Exit pupil distance required = 1.161730e+002 m
```

```
> VCM radius required (with specific DL optical par.) = 4.165e-003 mm-1
```

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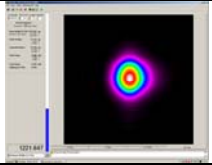
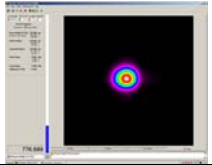
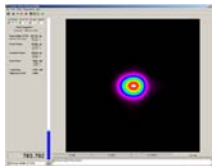
$\Delta V = +400\text{mm}$	STS-VCM	DL#2 VCM
	$P_{\text{STS-VCM}}=0.125 \text{ Bar}$ $C_{\text{STS-VCM}}=5.4e^{-4} \text{ mm}^{-1}$	$P_{\text{DL\#4-VCM}} = 1.72 \text{ bar}$ $C_{\text{DL\#4-VCM}} = 4. \times 10^{-3} \text{ mm}^{-1}$
Case 1 	$P_{\text{STS-VCM}} = 0.21 \text{ bars}$ $C_{\text{STS-VCM}} = 7.49 e-4 \text{ mm}^{-1}$ $\Delta C_{\text{STS-VCM}} = 2.09e-4 \text{ mm}^{-1}$ $\rightarrow \Delta P_{\text{out lab}} = 182 \text{ mm}$	$P_{\text{DL\#4-VCM}} = 1.72 \text{ bar}$ $C_{\text{DL\#4-VCM}} = 4. \times 10^{-3} \text{ mm}^{-1}$ $\Delta C_{\text{DL\#4-VCM}} = 0$
Case 2 	$P_{\text{STS-VCM}}=0.125 \text{ Bar}$ $C_{\text{STS-VCM}}=5.4e^{-4} \text{ mm}^{-1}$ $\Delta C_{\text{STS-VCM}}=0$	$P_{\text{DL\#4-VCM}} = 1.802 \text{ bar}$ $C_{\text{DL\#4-VCM}} = 4.165 \times 10^{-3} \text{ mm}^{-1}$ $\Delta C_{\text{DL\#4-VCM}} = 0.165 \times 10^{-3} \text{ mm}^{-1}$ $\rightarrow \Delta P_{\text{out lab}} = 217 \text{ mm}$

Table 2: VCM pressure/curvature offsets required to compensate for a longitudinal shift of $\Delta V=+400\text{mm}$

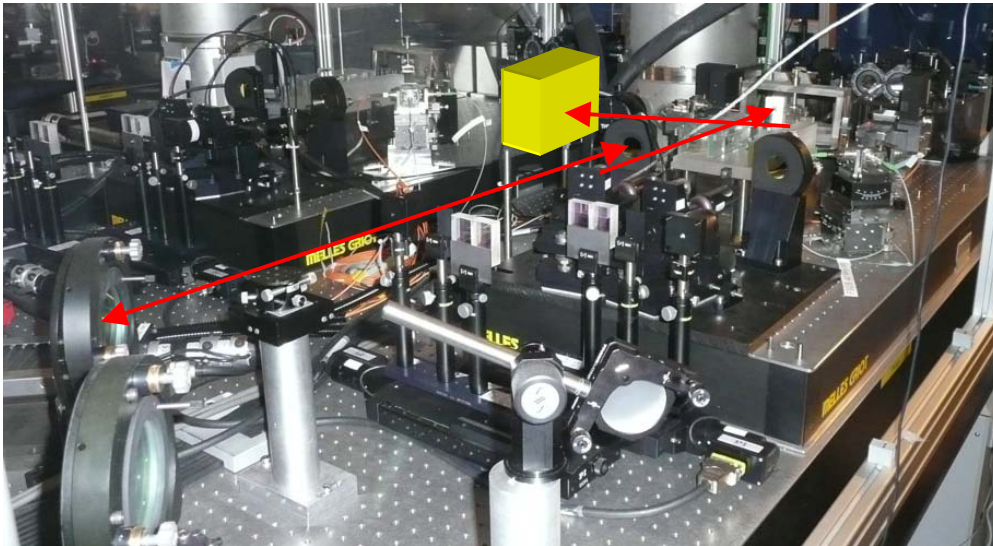
The results show that the $\Delta P_{\text{out lab}}$ does not match ΔV (factor 2).

The origin of this discrepancy is not yet identified. However we are limited by the fact that the optimization of the beam shape is practically difficult in the region $\Theta \pm 200\text{mm}$ (see Figure 6)

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5.4 Beam shape after the beam combiner

Configuration:



The beam splitter which was used to fold the beam toward the beam profiler without going through the beam combiner is removed. The beam now goes through the beam combiner and is detected by the beam profiler located between the beam combiner and the folding mirror. The beam profiler is located at 23 cm from the beam combiner.

As in section 5.1

AT#4-STSA&B-G2-DL#2							
FSM				VCM			
Mirror 1=Beam A Not Used		Mirror 2= Beam B IP4-DL#4		Mirror 1=Beam A Not used		Mirror 2= Beam B IP4-DL#4	
Xedge=30.5	Yedge=30.5	Xedge=12.5	Yedge=12.5	Xcenter=19	Ycenter=19	Xcenter=26.5	Ycenter=10.5
X=	Y=	X = 14.596	Y = 12.50	X=	Y=	X = 28.10	Y = 3.70
U=	W=	U=	W=	U=	W=	U=	W=
				Fixed curvature mirror ROC=infinity (C=0 mm ⁻¹)		P=0.125 bars C= 0.54e ⁻³ mm ⁻¹ (theory C= 1.344x10 ⁻³ mm ⁻¹)	

As in section 5.3

DL	OPL	VCM Curvature/pressure
DL#2-ip4	14	C=4.165e ⁻³ mm ⁻¹ (P=1.802 bars)

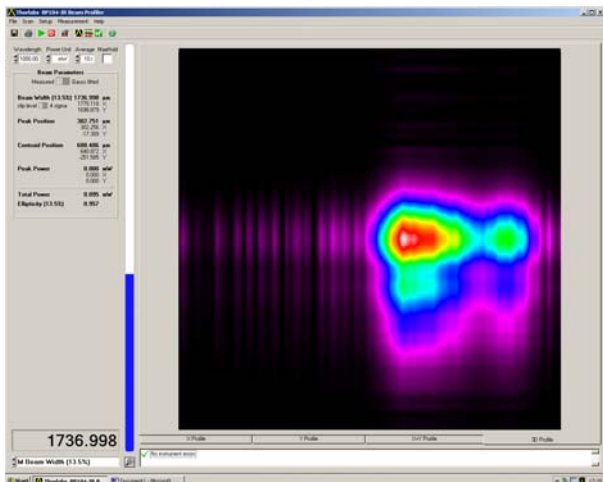
ComputeVCMParametersATBC('UT2',2,4,7,4.5,-1) = 3.855718e⁻³ mm⁻¹ (P=1.65 bar)

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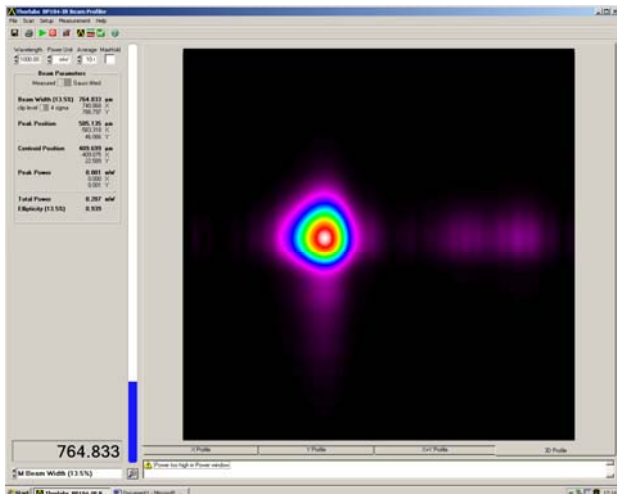
FSUB ACU	X	Y
TTP1	29×10^{-6} mech. rad	25×10^{-6} mech. Rad
TTP2	381×10^{-6} mech. Rad	144×10^{-6} mech. Rad

FSUB LMOT	Position
LMOT1	-134077 counts
LMOT2	0

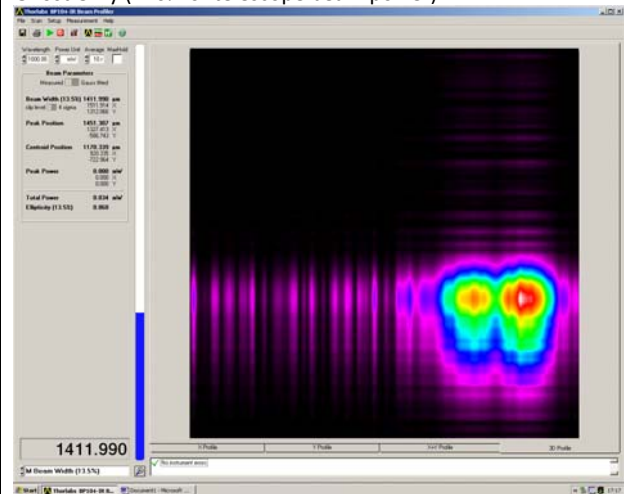
VCM position previously optimized on the extraction fiber (=28.10;3.7): Beam vignetting occurs. Diffraction due to the BC polarizing patch. The extraction block has been aligned on MARCEL. Due to the size of the beam returning from MARCEL it is possible that the alignment is not optimum. It seems that the extraction fibre (and therefore the quadcells) were aligned close to the edge of the BC PRIMET polarizing patch.



VCM Alignment offset U=+1 (=29.10;3.7)



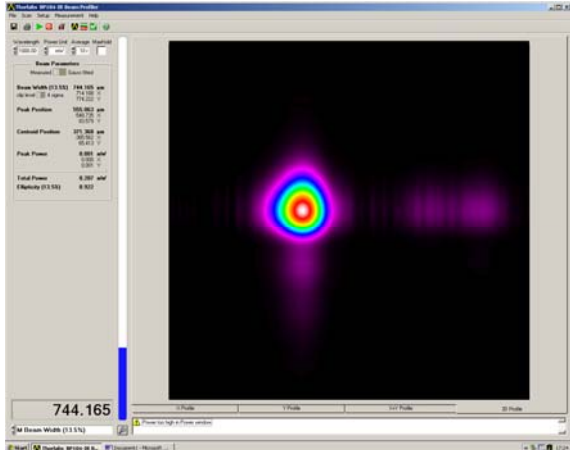
VCM Alignment offset U=+1 (=29.10;3.7). Telescope beam blocked Ghost Only (=16% of telescope beam power)



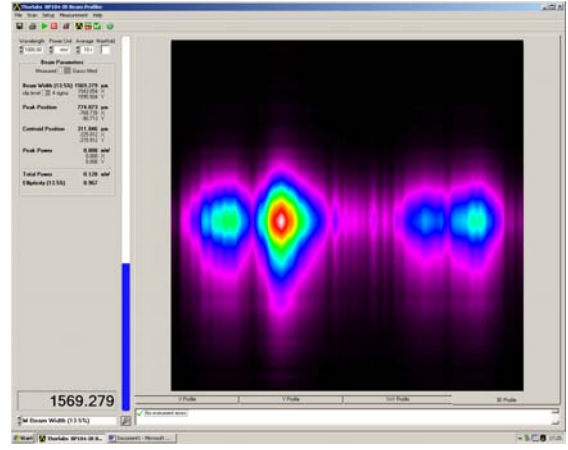
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We now scan the STS-VCM to find the size of the patch.

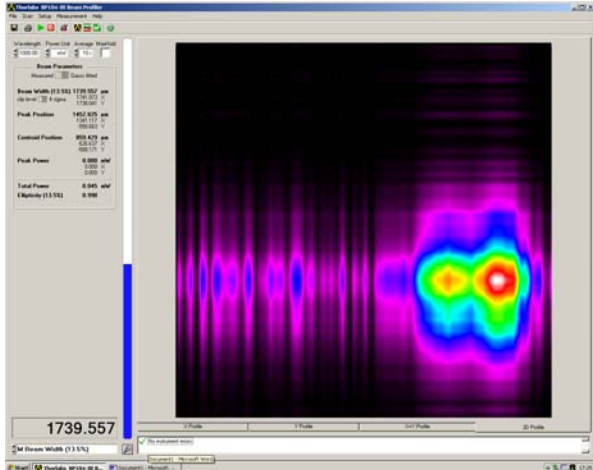
$x = 29.1$ $y = 3.70$: Shape is good



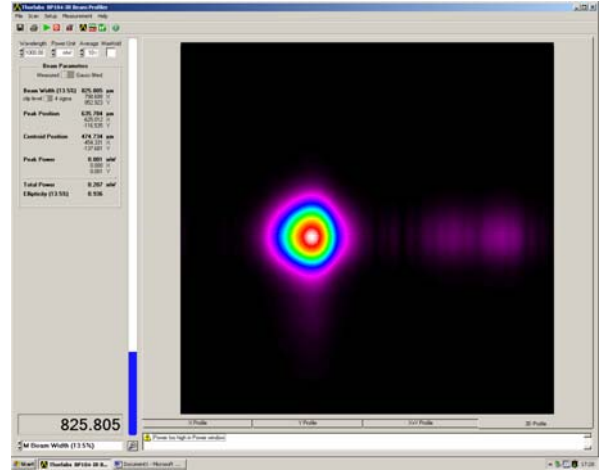
$x = 29.5$ $y = 3.7$ image vignets (lower flux) -> the ghost appears brighter because of the automatic gain adjustment



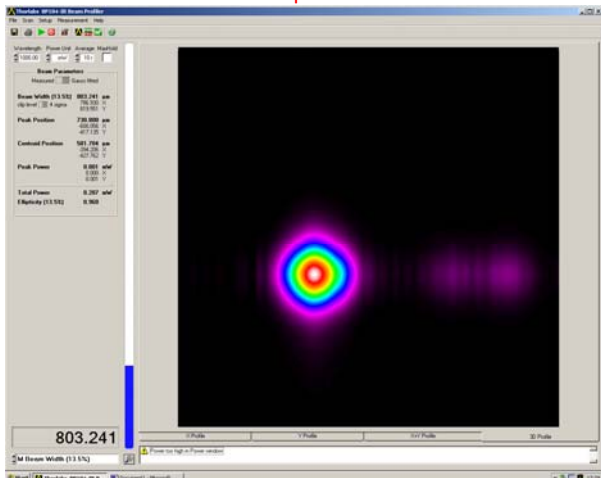
$x = 29.9$ $y = 3.7$ ghost only !



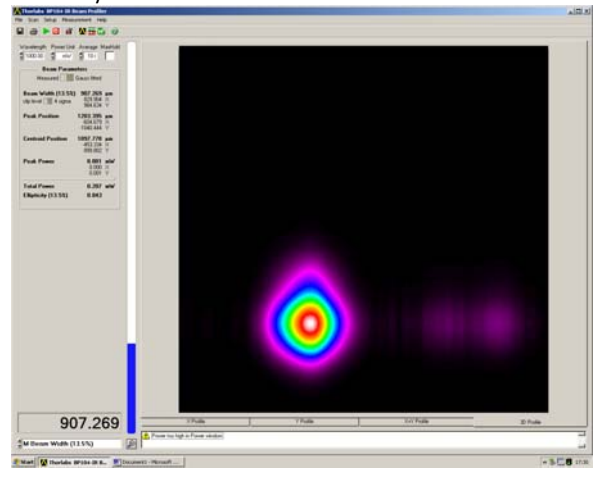
$x = 29.1$ $y = 4.0$



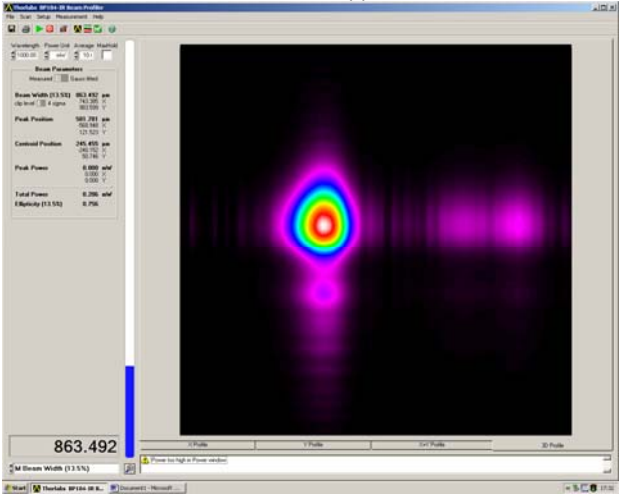
$X = 29.1$ $Y = 4.3$ Best beam shape and diameter



$X = 29.1$ $y = 4.9$



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<p>X = 29.1 Y = 2.7 Only the ghost is visible!</p>	<p>X 29.1 Y = 3.5 limit before beam disappear</p> 
---	--

X=29.1 seems to provide the best horizontal position (i.e. the returned beam does not vignette on the BC) (X=29.5 is already too large, however the lower X limit was not searched)

Displacement along VCM Y axis (W offset)

	VCM Y (VCM X=29.1)	Beam centroid X in μm	Beam Centroid Y in μm	Ellipticity
before scan	3.7	-409.1	22.59	0.939
lower limit	3.5	-240.15	50.75	0.756
	3.7	-365.56	65.41	0.922
	4	-454.33	-137.68	0.936
Best shape	4.3	-394.2	-427.76	0.96
	4.9	-453.33	-999.8	0.843

Estimation of the Sensitivity: beam Radial displacement /VCM alignment offset in $\mu\text{m}/\mu\text{m}_{\text{piezo}}$

VCM - W offset in $\mu\text{m}_{\text{piezo}}$	Radial displacement (μm)	Sensitivity $\mu\text{m}/\mu\text{m}_{\text{piezo}}$
0.2	126.26	631.32
0.3	221.64	738.81
0.3	296.25	987.49
0.6	575.09	958.48

These results needs to be compared to:

- The theoretical value: 1370 $\mu\text{m}/\mu\text{m}_{\text{piezo}}$;
- The value found during the May2008 test AT#4 on G2 (no FSU BC): 1200 $\mu\text{m}/\mu\text{m}_{\text{piezo}}$

The values highlighted in green are probably more representative because they were taken around the best shape.

Note: the repeatability of the position can be estimated from the 2 measurements taken at Y=3.7

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The result gives 60 microns. In addition internal turbulence affects the measurements ($\sim < 100$ microns). So the measured sensitivity is fairly close to the theoretical value.

The discrepancy between the theoretical sensitivity and the sensitivity measured during COMM1 (200 $\mu\text{m}/\mu\text{m}_{\text{piezo}}$ on AT#4-J2, see COMM1 report p.23) cannot be explained by a vignetting on the BC because the measurements were done before the BC...

Estimation of the vignetting-free area inside the patch

From $X = 29.1$ $Y = 4.3$

The size is

Along Y

At least $\pm 0.6 \mu\text{m}_{\text{piezo}}$ around VCM $Y=4.3$, corresponding to **575 μm** (with a sensitivity of $958.48 \mu\text{m}/\mu\text{m}_{\text{piezo}}$)

Or **72 %** of the 800 μm diameter spot

Along X

Limited to: $+X < 0.4 \mu\text{m}_{\text{piezo}}$ (VCM $X=29.1$ to 29.5)

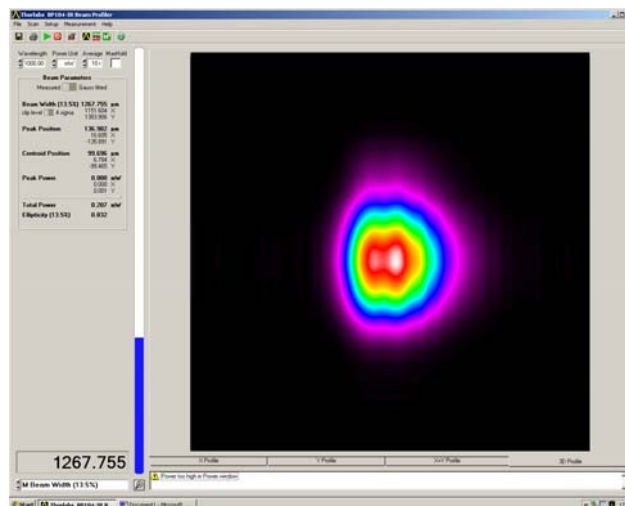
This corresponds to **<383 μm** or **48 %** of the 800 μm diameter spot

No data in the other direction:, i.e.-X

5.5 Beam shape after the folding mirror

The beam profiler is located after the folding mirror (BC-BP = 520 mm)

$x = 29.1$ $y = 4.9$



When stopping the telescope returned beam, the ghost does not appear. The mask put on the mirror efficiently vignets the ghost.

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6 MONDAY 24/11 TO TUESDAY 25/11

Support to PRIMA commissioning.
No metrology commissioning activity.

7 WEDNESDAY 26/11

Re-alignment of the lateral position of the injection block as well as of the VCM_B to optimize the returned spot on the Beam profiler located at the output of the BC. Unfortunately, the alignment does not converge most probably because the ACU of FSU_B was not at the nominal tilt positions.

8 THURSDAY 27/11

8.1 Optimization of the returned spot after the BC

After optimization , the final configuration is:

M16 4AT

AT#4-STSA&B-G2-DL#2 only used with PRIMET B							
FSM				VCM			
Mirror 1=Beam A NOT USED		Mirror 2= Beam B		Mirror 1=Beam A NOT USED		Mirror 2= Beam B IP4-DL#2	
X_{edge}=30.5	Y_{edge}=30.5	X _{edge} =12.5	Y _{edge} =12.5	X_{center}=19	Y_{center}=19	X _{center} =26.5	Y _{center} =10.5
X_c=	Y_c=	X= 16.7	Y= 12.50	X_c=	Y_c=	X= 28.3	Y = 3.8
U_c=	W_c=	U=	W=	U_c=	W_c=	U=	W=
				Fixed curvature mirror ROC=infinity (C=0 mm ⁻²)		C= 5.1×10 ⁻⁴ mm ⁻¹ (0.1125 Bar) (≠ Theory)	

The FSM is offsetted so that the laser beam does not fall on the edge of the M10.

DL	OPL	VCM Curvature/pressure
DL#2-ip4	14	4. ×10 ⁻³ mm ⁻¹ (1.72 bar)

ComputeVCMParametersATBC('UT2',2,4,7,4.5,-1) = 3.855718e⁻³ mm⁻¹

FSUB ACU	X	Y
TTP1	29×10 ⁻⁶ mech. rad	25×10 ⁻⁶ mech. Rad
TTP2	381×10 ⁻⁶ mech. Rad	144×10 ⁻⁶ mech. Rad

FSUB LMOT	Position
LMOT1	-134077 counts
LMOT2	0

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8.2 Estimation of the size of the BC central patch and of the corresponding VCM_B tilt amplitude

We have measured the size of the polarizing patch and centered the returned beam with respect to the patch at the extraction, by using the VCM. The beam measured after the BC looks fine, diameter ~ 800 μm and shape ok even though it is “breathing” a bit on the right side (see movie).

Distance to the beam combiner: 22 cm

Based on Table 3:

Estimation of the alignment sensitivity of the VCM: S:

(The values presented below suffer from lateral displacement introduced by internal turbulence ~ >100μm peak as shown in Table 4)

VCM Position μm_piezo	Peak X on Beam profiler μm	Peak Y on Beam profiler μm	Sensitivity in μm/μm_piezo
X=28.9, y=3.8	-931	315	
x=28.3, y=3.8: ΔX=0.6	-325 ΔX_pk=606	252 ΔY_pk=63 (10% crosstalk)	S=606/0.6~1000μm/μm_piezo
X=28.3, y=4.15: ΔY=0.35	-141 ΔX_pk=184 (58% crosstalk...)	-64 ΔY_pk=316	S=316/0.35~900μm/μm_piezo

Estimation of the size of the patch

From X = 28.3 Y = 4.15

And using a sensitivity of S~1000μm/ μm_piezo

Along Y

dY<+/- 0.95 μm_piezo

corresponding to **950 μm**

Along X

+dX=(28.9-28.3)=0.6 μm_piezo . This corresponds to **600μm**

-dX=(27.9-28.3)=-0.4 μm_piezo. This corresponds to **400 μm**

The above results can be compared to those derived in section 5.5:

- The sensitivity is similar
- The “size” of the patch is now better thanks to the re-alignment.

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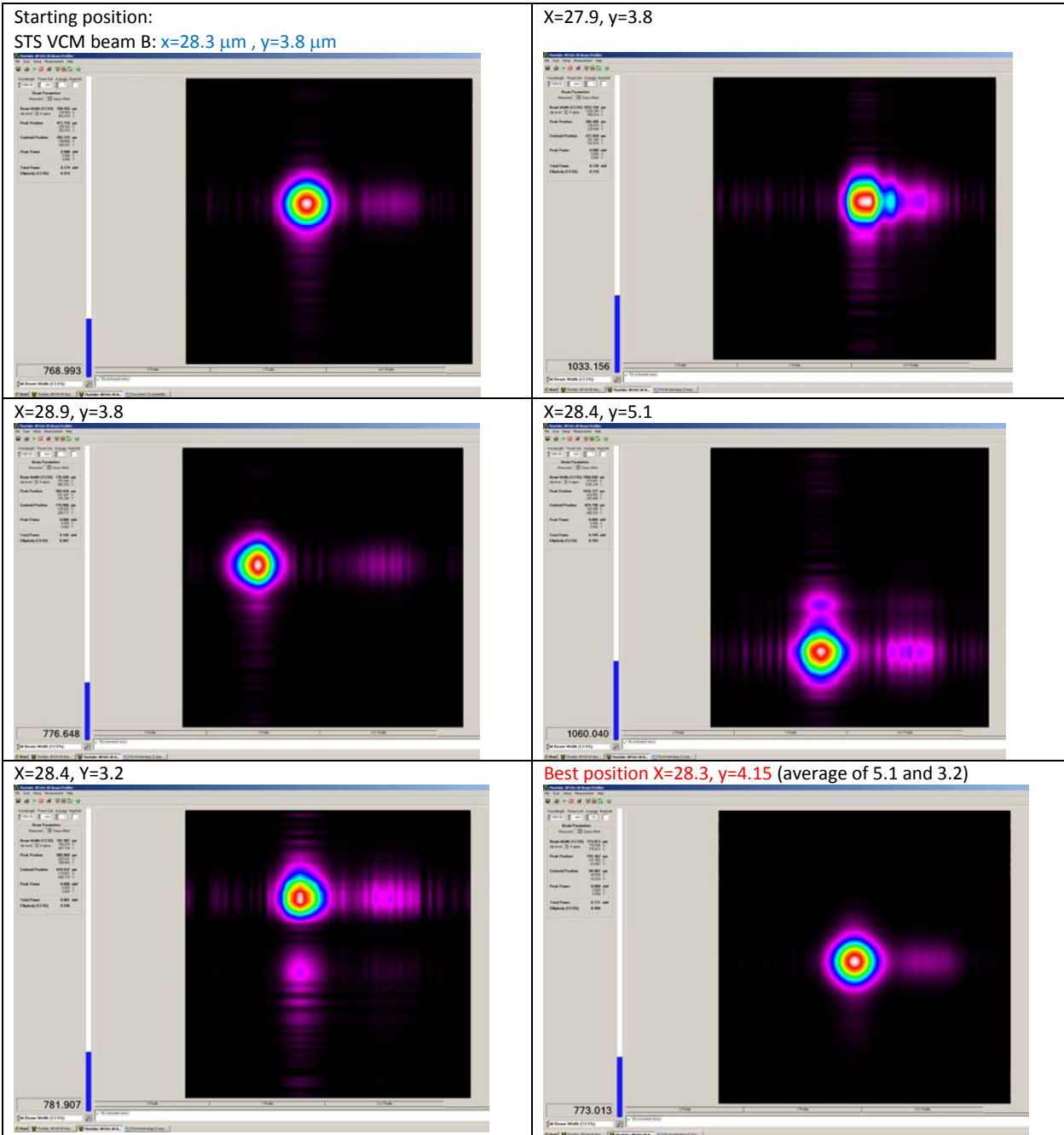
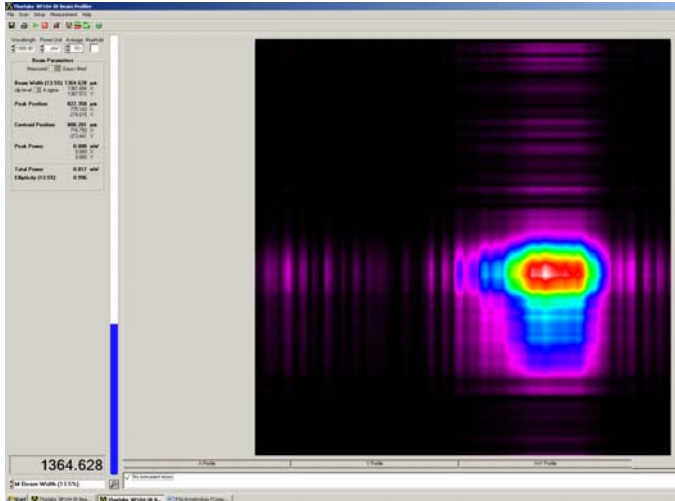


Table 3

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Ghost



8.3 Measurement of the returned Beam diameter

The beam diameter after the folding mirror is 1600 μm .

In order to check if this is introduced by diffraction on the Folding mirror , we used two diaphragms reduced to the minimum aperture to define two references for the axis of the extraction. We translate the mirror and keep the beam aligned on the reference. We are still injecting flux in the fibre. The beam looks a bit better but the diameter is the same.

The beam profiler is in fact located at almost 54cm from the BC. The diameter corresponds roughly with what I measured with Philippe when scanning the BP longitudinal position for a given VCM setting.

We took a screenshot of the spot at the level of the quadcell by introducing a BS between the two bs of the extraction block and holding the BP. **The beam diameter is about 2.3 mm diameter at $1/e^2$.**

8.4 Alignment of the quadcell

After alignment of the quadcell, the AOM transmission and laser power have to be decreased to avoid saturating the quadcells (as identified during COMM1).

$P_{\text{Laser}} = 150 \text{ mW}$

$T_{\text{AOM}} = 1\%$.

PGA gain of the quadcell= 5.6

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8.5 Pupil tracking test on AT#4-G2-B: open loop data

Initially PMPD is not working: lprmpd does not boot properly. The bootScript line is missing in the bootChange. It is corrected by Thanh. The lcu works.

Open loop data are recorded:

A first batch of file is taken with the diaphragm limiting the beam to its actual size:

28T02.30.49 to 28T02.52.18

The second batch is with no diaphragms.

28T03.06.50 to 28T03.30.57

Close loop pupil tracking does not work: no corrections are sent!

To be checked.

Ip: Input Channel Fs:sampling frequency (Hz) Fc:Correction frequency (hz)

Tobs: Observing time (sec) Rad.Pk: Peak Radial beam displacement (fraction of beam radius)

Rad rms: Standard deviation of the beam displacement (fraction of the beam radius)

Filename	IP	Fs	Fc	Tobs	Beam radius	Rad.Pk(rad)	Rad rms (rad)
MetQuadCentroids2008-11-28T02.30.49.604020.txt	IP4	1000	N/A	120.0	1.15 mm	0.118	0.022
MetQuadCentroids2008-11-28T02.33.58.074018.txt	IP4	1000	N/A	120.0	1.15 mm	0.115	0.020
MetQuadCentroids2008-11-28T02.36.59.954018.txt	IP4	1000	N/A	120.0	1.15 mm	0.107	0.020
MetQuadCentroids2008-11-28T02.40.04.944018.txt	IP4	1000	N/A	120.0	1.15 mm	0.127	0.025
MetQuadCentroids2008-11-28T02.46.01.563020.txt	IP4	1000	N/A	120.0	1.15 mm	0.098	0.017
MetQuadCentroids2008-11-28T02.49.13.173019.txt	IP4	1000	N/A	120.0	1.15 mm	0.131	0.023
MetQuadCentroids2008-11-28T02.52.18.363018.txt	IP4	1000	N/A	300.0	1.15 mm	0.101	0.017
MetQuadCentroids2008-11-28T03.06.50.812019.txt	IP4	1000	N/A	300.0	1.15 mm	0.157	0.022
MetQuadCentroids2008-11-28T03.13.26.302017.txt	IP4	1000	N/A	300.0	1.15 mm	0.148	0.024
MetQuadCentroids2008-11-28T03.24.00.241019.txt	IP4	1000	N/A	300.0	1.15 mm	0.134	0.023
MetQuadCentroids2008-11-28T03.30.57.211018.txt	IP4	1000	N/A	300.0	1.15 mm	0.129	0.019

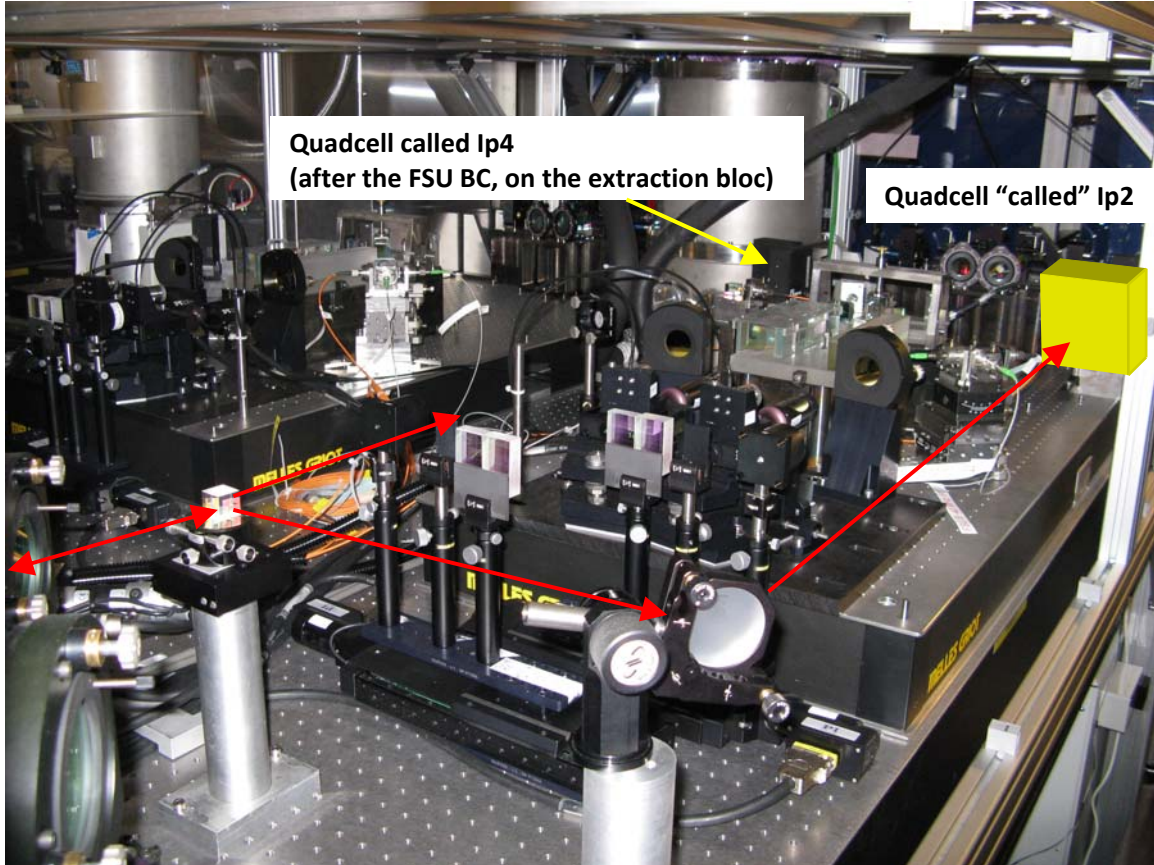
Table 4: open loop pupil motion

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9 FRIDAY 28/11 TO SATURDAY 29/11

9.1 Pupil tracking test on AT#4-G2-B: open loop data

The motion of the returned beam from AT#4-GE-B-IP4 is measured simultaneously on 2 quadcells according to the following configuration. The beam diameter is 2100 microns (quad Ip4) and 800 microns (quad ip2).



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FileName	Loop	Enclosure	IP	Fs(Hz)	Tobs(s)	Beam diam. um	Radial Peak(rad) w.r.t 1st point	Radial rms (rad)	Radial Pk um	Ratio Pk Ip4/Ip2	Radial rms um	Ratio Rms Ip4/Ip2	CorrX Ip2 & Ip4	CorrY Ip2 & IP4
MetQuadCentroids2008-11-29T00.17.39.966019.txt	open	AT4 closed Other ATs Open	IP4	1000	300	2100	0.137	0.023	143.85	1.49	24.15	1.47	0.86	0.81
MetQuadCentroids2008-11-29T00.17.39.966019.txt	open	AT4 closed Other ATs Open	IP2	1000	300	800	0.242	0.041	96.8	N/A	16.4	N/A		
MetQuadCentroids2008-11-29T00.25.03.176018.txt	open	AT4 closed Other ATs Open	IP4	1000	121.8	2100	0.098	0.021	102.9	1.27	22.05	1.58	0.90	0.89
MetQuadCentroids2008-11-29T00.25.03.176018.txt	open	AT4 closed Other ATs Open	IP2	1000	121.8	800	0.203	0.035	81.2	N/A	14	N/A		
MetQuadCentroids2008-11-29T00.27.59.315019.txt	open	AT4 closed Other ATs Open	IP4	1000	120	2100	0.111	0.022	116.55	1.39	23.1	1.41	0.93	0.87
MetQuadCentroids2008-11-29T00.27.59.315019.txt	open	AT4 closed Other ATs Open	IP2	1000	120	800	0.209	0.041	83.6	N/A	16.4	N/A		
MetQuadCentroids2008-11-29T00.30.49.315017.txt	open	All 4 ATs open	IP4	1000	120	2100	0.085	0.015	89.25	1.38	15.75	1.41	0.84	0.77
MetQuadCentroids2008-11-29T00.30.49.315017.txt	open	All 4 ATs open	IP2	1000	120	800	0.162	0.028	64.8	N/A	11.2	N/A		
MetQuadCentroids2008-11-29T01.03.09.343022.txt	open	All 4 ATs open	IP4	1000	120	2100	0.102	0.019	107.1	1.19	19.95	1.13	0.73	0.70
MetQuadCentroids2008-11-29T01.03.09.343022.txt	open	All 4 ATs open	IP2	1000	120	800	0.225	0.044	90	N/A	17.6	N/A		
MetQuadCentroids2008-11-29T01.09.49.182018.txt	open	All 4 ATs open	IP4	1000	120	2100	0.128	0.02	134.4	1.56	21	1.64	0.73	0.61
MetQuadCentroids2008-11-29T01.09.49.182018.txt	open	All 4 ATs open	IP2	1000	120	800	0.215	0.032	86	N/A	12.8	N/A		
MetQuadCentroids2008-11-29T01.45.40.629018.txt	open	All 4 ATs open	IP4	1000	120	2100	0.127	0.025	133.35	1.54	26.25	1.73	0.73	0.73
MetQuadCentroids2008-11-29T01.45.40.629018.txt	open	All 4 ATs open	IP2	1000	120	800	0.217	0.038	86.8	N/A	15.2	N/A		
MetQuadCentroids2008-11-29T01.49.03.969018.txt	open	All 4 ATs open	IP4	1000	120	2100	0.144	0.025	151.2	1.66	26.25	1.77	0.67	0.63
MetQuadCentroids2008-11-29T01.49.03.969018.txt	open	All 4 ATs open	IP2	1000	120	800	0.228	0.037	91.2	N/A	14.8	N/A		
MetQuadCentroids2008-11-29T01.52.05.609019.txt	open	All 4 ATs open	IP4	1000	120	2100	0.107	0.021	112.35	1.59	22.05	1.62	0.72	0.58
MetQuadCentroids2008-11-29T01.52.05.609019.txt	open	All 4 ATs open	IP2	1000	120	800	0.177	0.034	70.8	N/A	13.6	N/A		
MetQuadCentroids2008-11-29T01.56.54.278020.txt	open	All 4 ATs open	IP4	1000	120	2100	0.113	0.023	118.65	1.41	24.15	1.63	0.68	0.77
MetQuadCentroids2008-11-29T01.56.54.278020.txt	open	All 4 ATs open	IP2	1000	120	800	0.21	0.037	84	N/A	14.8	N/A		
MetQuadCentroids2008-11-29T02.04.32.428018.txt	open	All 4 ATs open	IP4	1000	120	2100	0.148	0.028	155.4	1.33	29.4	1.50	0.69	0.76
MetQuadCentroids2008-11-29T02.04.32.428018.txt	open	All 4 ATs open	IP2	1000	120	800	0.292	0.049	116.8	N/A	19.6	N/A		

The Data are well correlated between the 2 quadcells measuring simultaneously on Ip4 (CorrX and CorrY). The Peak radial displacement varies between 100 and 150 microns (Ip4, 2100 microns beam) over a time scale of 2-5 minutes.

However, the amplitude of the open loop beam motion recorded by the 2 quadcell cannot be directly compared because of the different beam diameter.

Indeed, for a given physical beam displacement, the measured displacement will be more rapidly underestimated by the quadcell having a smaller beam diameter. This effect is even stronger if the beam was initially decentered on the quadcell.

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For example, using a 0.8 mm diameter beam, if the beam is initially de-centered by 100 um (25%) , any further shift by 100 um will result in underestimating the displacement by about 70 microns (see Figure 7 and Figure 8) For a 2.1 mm diameter beam , a de-centering of 100 um and a shift of 100 um gives only a ~ 10 microns error.

So the 0.8mm beam (ip2) always underestimates the beam motion, especially along the X direction. In typical cases the beam was decentered by $x \sim 30\%$ and $Y \sim 10\%$ (whereas on ip4 the decenter was limited to $dx = 10\%$ $dy \sim 0$)

In order to limit the open loop measurement error to few % of the beam diameter, the initial off-centering and open loop motion should stay within ~ 30% of the beam diameter. So the best is to re-center the beam before open loop data are taken.

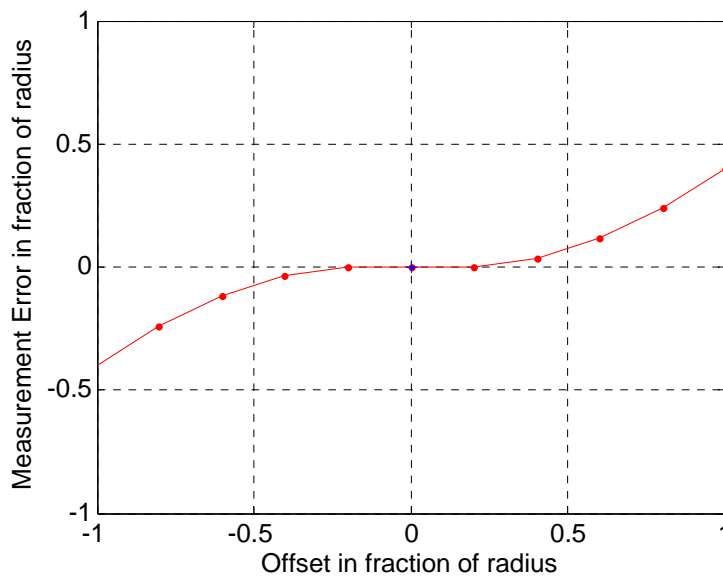


Figure 7: Measurement error as a function of the beam displacement along X

Using Matlab data fitting:

$$y = p1 \cdot x^7 + p2 \cdot x^6 + p3 \cdot x^5 + p4 \cdot x^4 + p5 \cdot x^3 + p6 \cdot x^2 + p7 \cdot x + p8$$

with $p1 = 0.01376$ $p2 = -5.326e-019$ $p3 = -0.13239$ $p4 = -2.5232e-017$ $p5 = 0.47055$ $p6 = 3.8546e-017$

$p7 = 0.038761$ $p8 = -1.3405e-017$

Norm of residuals = 0.032517

Offset in fraction of the beam radius	Measurement error in fraction of the beam radius
0	0.0017
0.2	0.035
0.4	0.115
0.6	0.24
0.8	0.4

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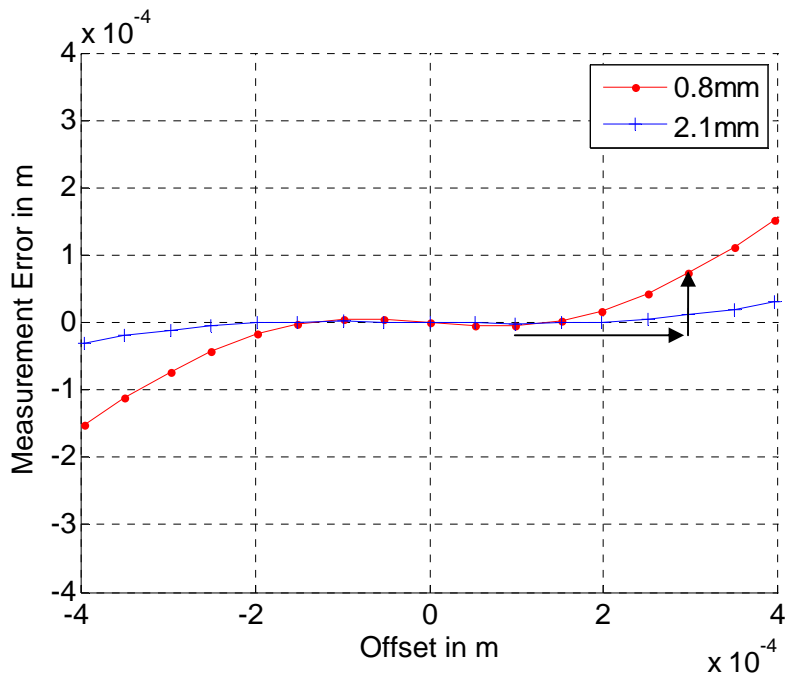


Figure 8

9.2 PRIMET A/B fringes on Marcel

See summary results in section 10

9.3 PRIMET A/B fringes on AT4-STSB and Marcel

Three files are recorded under the following conditions:

A=ip(3,1)= Marcel (b,a) B= Ip(4,2) =STS-G2_B-Marcel(e).

One file was recorded during the motion of the DL at a speed of 30mm/sec (lprma2PhaseMeter2008-11-29T01.37.26.txt) but it glitched on the 450kHz probe...

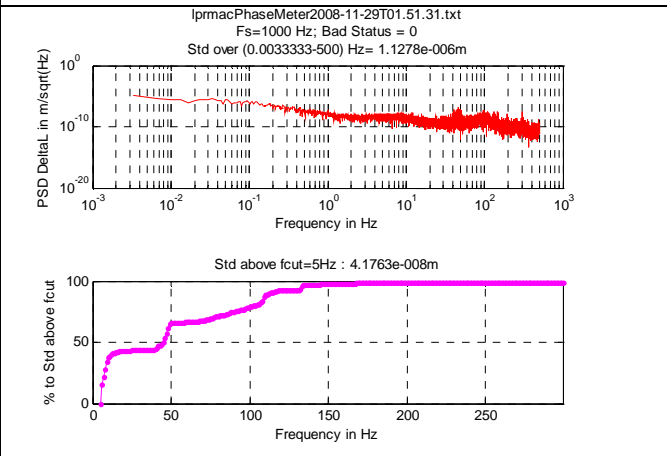
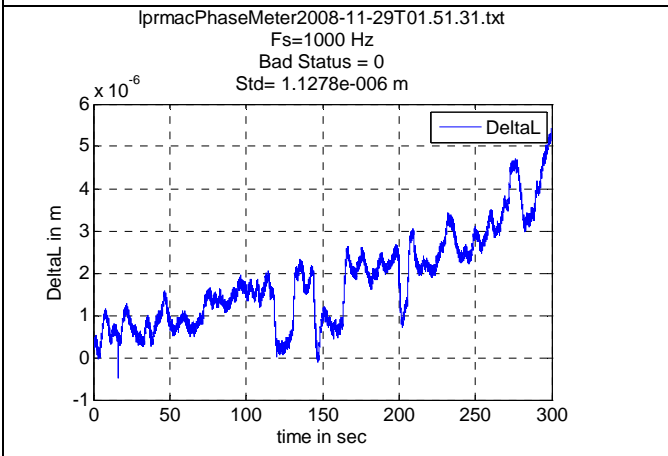
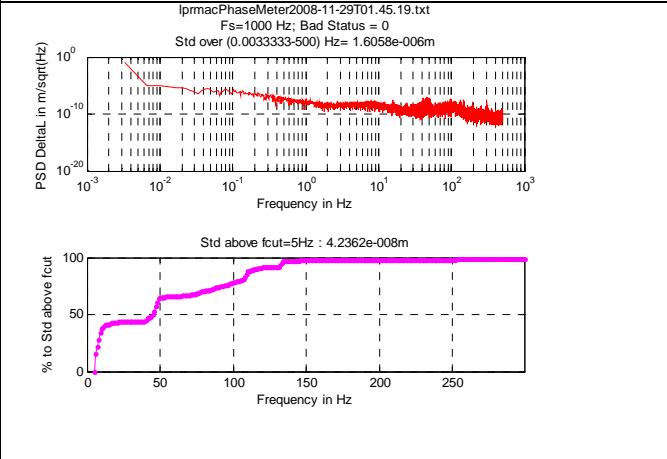
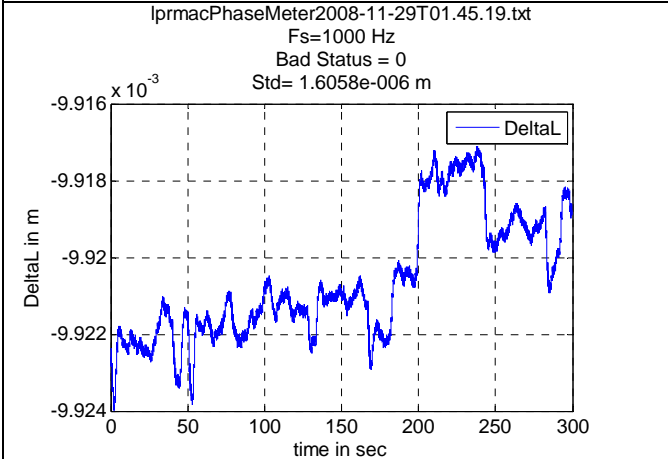
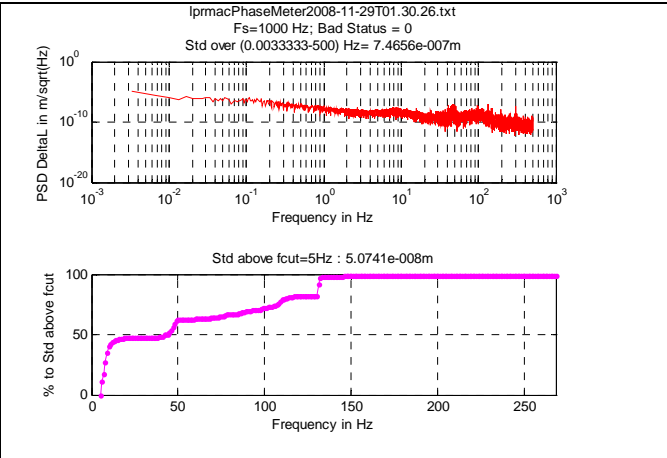
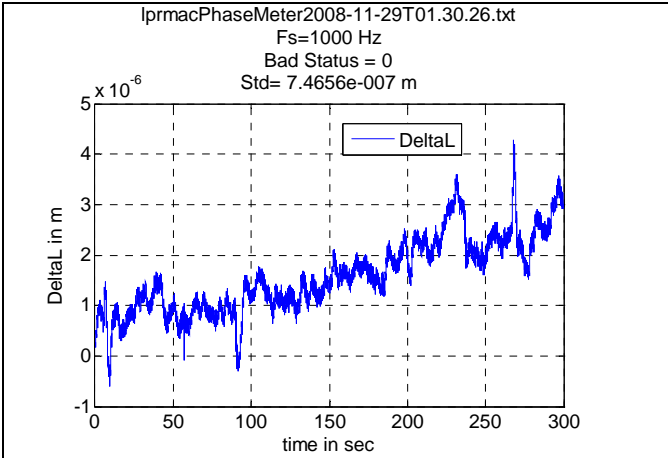
lprma2PhaseMeter2008-11-29T01.45.17.txt

lprma2PhaseMeter2008-11-29T01.51.32.txt

were recorded in parallel with the quadcell centroids measurements:

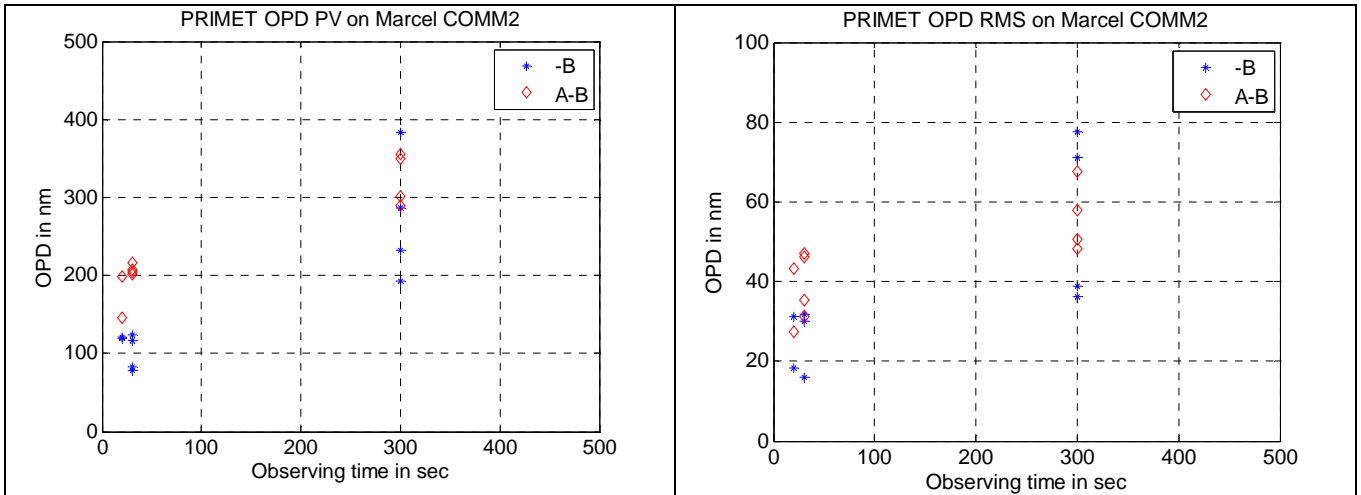
MetQuadCentroids2008-11-29T01.45.40.629018.txt

MetQuadCentroids2008-11-29T01.52.05.609019.txt



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10 PRIMET A/B FRINGES ON MARCEL: SUMMARY RESULTS



The results are similar to those recorded during COM1

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11 CONCLUSION

The conclusion on the main objectives set for PRIMET COM2 are:

Why no laser light was retro-reflected by STS-Beam A during COM1 ?

This was most probably due to a wrong definition of the nominal VCM tip/tilt position called “center position”. This position was defined by TNO at [X=19;Y=19]. However it cannot be fully checked during optical alignment in the AT Hall, because a concrete pillar is blocking the beam.

During COM2, the AT4-ST5 was located in the maintenance station G2. It was easier to determine visually the necessary offsets to be applied on the VCM tilt and to redefine the “center position”. Consequently PRIMET fringes were recorded using beam A of AT#4-ST5.

When the AT-ST5 will be located on any other station (i.e with no physical access), it is recommended to use the automatic “Beam Search” feature available in the PRIMET software.

Optimize the STS-VCM curvature for PRIMET observations and compare with theoretical values

We observed a discrepancy between the experimental curvature of the STS-VCM and the theoretical one. However this is limited to a longitudinal pupil shift of about 70 cm in the laboratory (± 10 -20cm). It is anticipated that this additional offset required for PRIMET will not affect the performance of the FSU. Indeed up to now the FSU was operated with a pupil offset of 4.5 m.

For PRIMET, the strategy will be to minimize the diameter of the returned beam at the level of the FSU BC to avoid vignetting and slightly increase the measuring displacement range on the quadcells.

Study the beam vignetting problem identified during COM1, which prevented to operate the pupil tracker.

During COM1, pupil tracking could not be operated with the quadcell located on PRIMET extraction unit. Part of the beam was slightly vignettted along the X direction (or VCM_U). During COM2, we identified that the extraction bloc was actually aligned along a line of sight pointing close to the edge of BC polarizing patch. Therefore, the vignetting was generated by the BC polarizing patch itself. After realignment, the beam was observed at the level of the extraction bloc with a beam profiler.

The measured VCM displacement sensitivity is $\sim 1000 \mu\text{m} / \mu\text{m_piezo_vcm}$, close to the theoretical value of $1200 \mu\text{m} / \mu\text{m_piezo_vcm}$, considering that the measurements are suffering from internal turbulence. Some strategies could be tried to better estimate the sensitivity:

- Sending offsets during close loop operation
- Sending offsets automatically along a regular grid and averaging the data using the “user guiding offsets”

Several points need to be tackled for COM3:

- I. Define a more precise procedure to co-align the extraction fiber and the quadcells on the FSU_BC patch
- II. Implement an automatic procedure to determine the interaction matrix between STS-VCMtip/tilt and the quadcell axes. This can be handled using “User guiding offsets” of pmpsd . If the interaction matrix is not closed to the nominal one (i.e. the Identity) or to a pure rotation matrix with an angular offset less than few degrees , this is an indication that the returned laser beam is vignettted.
- III. Elaborate a strategy to estimate the beam quality after a beam search using only the quadcell signals. (i.e. without the beam profiler which is not available during operation)

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Align and operate the quacell. Record open loop pupil motion and attempt pupil tracking.

Open loop pupil motions were recorded on AT#4-G2 beam B

The Peak radial displacements varied typically between 100 and 150 microns over a time scale of 2 to 5 minutes.

Pupil tracking was attempted during the last hours of COM2. It initially failed because of a wrong configuration of the IP address of the *lat4VCM* LCU where the corrections are sent to. After solving this problem the loop could still not be closed. Most probably, the beam position had drifted too much which degraded the beam quality on the quadcell and made the loop unstable.

This indicates that the “*beam detected*” condition which is currently implemented is not a sufficient condition to close the loop. The beam is considered as detected if the voltage SUM of the 4 quadrants is larger than 500mV. A possible improvement could be to modulate the beam position around the “*beam detected*” position by a small amount and to verify that the SUM remains sufficiently constant before to attempt closing the loop.

Record PRIMET Fringes on Marcel and on AT#4-ST5/Marcel.

PRIMET data were routinely recorded on Marcel. The amplitudes of the optical path variations are similar to those measured during COM1 (40 to 80 nm rms over 300 sec). At these OPD level, the path variations does not seem to be correlated between the 2 FSU’s.

PRIMET was operated on Marcel/ST#4-G2 along a path of ~ 150m. However measurements were still performed with fixed delay lines.

List of OPEN actions and perspectives for COM3

- Check OPD values measured on Marcel with /without Marcel fiber:
- Cross-Check OPL sign for a given LMOT and DL motion:
- Check if longitudinal pupil offsets of more than 1 m are acceptable during FSU operation.
- Address the non compatibility of the full laser power with quadcell operation (saturation with G=1)
- Co-Alignment of 2x quadcells, the extraction fiber and the FSU BC:
- Address pupil tracking weakness: verify if “Beam search” is still working as in May2008; Implement the automatic calibration of the interaction matrix, improve the “Beam detected” conditions.
- Test the PRIMET new State Machine and PRIMET OSF script:
- Check new Phase meter overflow conditions:
- Test DDL transmission, beam displacement and more generally their impact on the PRIMET operation