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# MEMORANDUM

DATE: October 26, 2012

|  |  |
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| TO: | Peter Fritschel |
| FROM: | Mike Smith |
| SUBJECT: | ALS Beams @ HAM1 |
| Refer to: | LIGO-L1200282-v5  This technical note describes the locations of the ALS and POB beams on HAM1, for the L1 and H1 interferometers.  The analysis was revised to include the effect of switching the orientation of the CPy wedge to the same side as the CPx; this causes the ALS X and ALS Y beams to be much closer together.  The X and Y arm ALS 532 nm beams were launched inside the arm cavity before the ITMHR surface, collinear with the arm cavity beam.  The POB beam and the ALS beams transmit through the HR and AR surfaces of PR2 and are focused by a 1.5 M radius of curvature mirror, then directed by steering mirrors through the center of the input Septum window VP1 between HAM 1 and HAM2 onto an ISC steering mirror on HAM 1, approximately at the center of HAM1.    PR2  1.5 M mirror  Figure : ALS Beams Steering on HAM3    Figure : Input Septum Plate Viewport Naming Convention, as Viewed from HAM1 (VP1 is used for the ALS beams)  The 1064nm POB beam and the 532 nm ALS beams principal rays were modeled using ZEMAX under two conditions: 1) the CPx and CPy wedge in opposite orientations, and 2) in the same orientation.  A target representing the steering mirror on HAM 1 was placed near the center of HAM1—the actual location of the steering mirror will be determined by ISC Group.  The ZEMAX layout of the ALS steering mirror and the ALS and POB beams at HAM1 are shown in the following figures. **CP WEDGES IN OPPOSITE ORIENTATION: CPy –X, CPx -Y**   CPy    CPx  Y  X  Figure : CPx and CPy with Opposite Orientation (note: the wedge angles are exaggerated for emphasis); CPx Thick Side in -Y Direction, CPy Thick Side in -X Direction    ALS Target  HAM1 Table  Septum Window, VP1  X  Z |

Figure : H1 HAM1 Elevation View (note: the green ALS X and blue ALS Y beams are at the same elevation above the red POB beam)



ALS Target

Septum Window, VP1

Y

X

Figure : H1 HAM1 Plan View (note: the blue ALS Y beam is in +Y direction, and the green ALS X beam is in –Y direction with respect to the red POB beam)



ALS Target

Y

X

Figure : H1 HAM1 Plan View Showing Detail of ALS Target with ALS Beams (note: the blue ALS Y is in the +Y direction, and the green ALS X beam is in the –Y direction with respect to the red POB beam)

# **CP WEDGES IN SAME ORIENTATION: CPy +X, CPx -Y**



CPy



CPx

Y

X

Figure : CPx and CPy with Same Orientation (note: the wedge angles are exaggerated for emphasis); CPx Thick Side in -Y Direction, CPy Thick Side in +X Direction



ALS Target

Septum Window, VP1

HAM 1 Table

X

Z

Figure : H1 HAM1 Elevation View (note: the green ALS X and blue ALS Y beams are at the same elevation above the red POB beam)



ALS Target

Y

X

Figure : H1 HAM1 Plan View Showing Detail of ALS Target with ALS Beams (note: the blue ALS Y beam has Flipped over to the --Y direction, and the green ALS X beam is still in the –Y direction with respect to the red POB beam)

# **CP WEDGES IN SAME ORIENTATION: CPy -X, CPx +Y**



CPy



CPx

Y

X

Figure : CPx and CPy with Same Orientation (note: the wedge angles are exaggerated for emphasis); CPx Thick Side in -Y Direction, CPy Thick Side in +X Direction



ALS Target

Septum Window, VP1

HAM 1 Table

X

Z

Figure : H1 HAM1 Elevation View (note: the green ALS X and blue ALS Y beams are at the same elevation above the red POB beam)



ALS Target

Y

X

Figure : H1 HAM1 Plan View Showing Detail of ALS Target with ALS Beams (note: the blue ALS Y beam has Flipped over to the --Y direction, and the green ALS X beam is still in the –Y direction with respect to the red POB beam)

# **NO CP WEDGES**



CPy



CPx

Y

X

Figure : CPx and CPy with No Wedge



Septum Window, VP1

ALS Target

HAM 1 Table

X

Z

Figure : H1 HAM1 Elevation View (note: the green ALS X and blue ALS Y beams are at the same elevation above the red POB beam). The vertical separation is caused primarily by the PR2 wedge, and partly by the ITM wedge.



ALS Target

Y

X

Figure : H1 HAM1 Plan View Showing Detail of ALS Target with ALS Beams (note: the blue ALS Y beam is collinear with the red POB beam; and the green ALS X is deviated in the –Y direction with respect to the red POB beam due to the BS wedge.)

# **ALS Beam Coordinates**

The global coordinates of the ALS and POB beams, and the beam separations in the Y and Z coordinate directions are given in the following table. Note that the positions of the ALS beams on HAM1 are critically dependent upon the alignment of the main IFO X and Y arm beams at the BS and PR3 mirrors. The main beams were accurately aligned for the updated results in LIGO-L1200282-v3.

* **Opposite CP Wedge Angle Orientation: CPy -X, CPx -Y**

The ALS X and ALS Y beams are 13.3 mm above the POB beam. The separations of each ALS beam from the POB beam is > 3.8 mm. The separation between ALS X and ALS Y is 8.5 mm.

Table : Beam Global Coordinates at HAM1, Opposite CP Wedge Orientation: CPy -X, CPx -Y

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Beam** | **Global Coordinates at HAM1** | | | **Separation from POB** | | | **Separation between ALS** | | |
|  | **X, mm** | **Y, mm** | **Z, mm** | **ΔX, mm** | **ΔY, mm** | **ΔZ, mm** | **ΔX, mm** | **ΔY, mm** | **ΔZ, mm** |
| ALS X | -22864.0 | 503.3 | 288.7 | 0.0 | -3.8 | 13.3 | 0.0 | -8.5 | 0.0 |
| ALS Y | -22864.0 | 511.8 | 288.7 | 0.0 | 4.6 | 13.3 |  |  |  |
| POB | -22864.0 | 507.1 | 275.5 |  |  |  |  |  |  |

The ray vector angles at HAM1 are given in the following table. The yaw angle is measured counterclockwise from the positive X axis direction. The pitch angle is measured from the global horizontal plane in the positive vertical direction.

Table : Ray Vector Angles at HAM1, Opposite CP Wedge Orientation: CPy -X, CPx -Y

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **GLOBAL** | | | **GLOBAL** | | |
| **BEAM** | **INCIDENT RAY VECTOR COSINES** | | | **INCIDENT RAY VECTOR ANGLES, deg** | | |
|  | **X** | **Y** | **Z** | **X** | **Y** | **Z** |
| ALS X | -0.999784 | 0.007329 | 0.019463 | 179.580 | NA | 1.115 |
| ALS Y | -0.999780 | 0.007785 | 0.019462 | 179.554 | NA | 1.115 |
| POB | -0.999795 | 0.007670 | 0.018736 | 179.560 | NA | 1.074 |

* **Same CP Wedge Angle Orientation: CPy +X, CPx -Y**

The ALS X and ALS Y beams are 13.3 mm above the POB beam. The separations of each ALS beam from the POB beam is > 3.9 mm. The separation between ALS X and ALS Y is 1.3 mm.

Table : Beam Global Coordinates at HAM1, Same CP Wedge Orientation: CPy +X, CPx -Y

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Beam** | **Global Coordinates at HAM1** | | | **Separation from POB** | | | **Separation between ALS** | | |
|  | **X, mm** | **Y, mm** | **Z, mm** | **ΔX, mm** | **ΔY, mm** | **ΔZ, mm** | **ΔX, mm** | **ΔY, mm** | **ΔZ, mm** |
| ALS X | -22864.0 | 520.4 | 288.7 | 0.0 | -3.9 | 13.3 | 0.0 | 1.3 | 0.0 |
| ALS Y | -22864.0 | 519.1 | 288.7 | 0.0 | -5.2 | 13.3 |  |  |  |
| POB | -22864.0 | 524.3 | 275.4 |  |  |  |  |  |  |

The ray vector angles at HAM1 are given in the following table. The yaw angle is measured counterclockwise from the positive X axis direction. The pitch angle is measured from the global horizontal plane in the positive vertical direction.

Table : Ray Vector Angles at HAM1, Same CP Wedge Orientation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **GLOBAL** | | | **GLOBAL** | | |
| **BEAM** | **INCIDENT RAY VECTOR COSINES** | | | **INCIDENT RAY VECTOR ANGLES, deg** | | |
|  | **X** | **Y** | **Z** | **X** | **Y** | **Z** |
| ALS X | -0.999777 | 0.008258 | 0.019461 | 179.527 | NA | 1.115 |
| ALS Y | -0.999777 | 0.008187 | 0.019461 | 179.531 | NA | 1.115 |
| POB | -0.999788 | 0.008603 | 0.018735 | 179.507 | NA | 1.073 |

* **Same CP Wedge Angle Orientation: CPy -X, CPx +Y**

The ALS X and ALS Y beams are 13.3 mm above the POB beam. The separations of each ALS beam from the POB beam is > 4.8 mm. The separation between ALS X and ALS Y is 18.5 mm.

Table : Beam Global Coordinates at HAM1, Same CP Wedge Orientation: CPy -X, CPx +Y

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Beam** | **Global Coordinates at HAM1** | | | **Separation from POB** | | | **Separation between ALS** | | |
|  | **X, mm** | **Y, mm** | **Z, mm** | **ΔX, mm** | **ΔY, mm** | **ΔZ, mm** | **ΔX, mm** | **ΔY, mm** | **ΔZ, mm** |
| ALS X | -22864.0 | 499.9 | 288.7 | 0.0 | -13.6 | 13.3 | 0.0 | -18.5 | 0.0 |
| ALS Y | -22864.0 | 518.4 | 288.6 | 0.0 | 4.8 | 13.3 |  |  |  |
| POB | -22864.0 | 513.6 | 275.4 |  |  |  |  |  |  |

The ray vector angles at HAM1 are given in the following table. The yaw angle is measured counterclockwise from the positive X axis direction. The pitch angle is measured from the global horizontal plane in the positive vertical direction.

Table : Ray Vector Angles at HAM1, Same CP Wedge Orientation: CPy -X, CPx +Y

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **GLOBAL** | | | **GLOBAL** | | |
| **BEAM** | **INCIDENT RAY VECTOR COSINES** | | | **INCIDENT RAY VECTOR ANGLES, deg** | | |
|  | **X** | **Y** | **Z** | **X** | **Y** | **Z** |
| ALS X | -0.999783 | 0.007385 | 0.019458 | 179.577 | NA | 1.115 |
| ALS Y | -0.999776 | 0.008380 | 0.019456 | 179.520 | NA | 1.115 |
| POB | -0.999790 | 0.008254 | 0.018730 | 179.527 | NA | 1.073 |

* **No CP Wedge Angle Orientation**

The ALS X and ALS Y beams are 13.3 mm above the POB beam. The separations of ALS X beam from the POB beam is 8.8 mm. The separations of ALS Y beam from the POB beam is 0.3 mm. The separation between ALS and ALS Y is 8.4 mm.

Table : Beam Global Coordinates at HAM1, No CP Wedge

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Beam** | **Global Coordinates at HAM1** | | | **Separation from POB** | | | **Separation between ALS** | | |
|  | **X, mm** | **Y, mm** | **Z, mm** | **ΔX, mm** | **ΔY, mm** | **ΔZ, mm** | **ΔX, mm** | **ΔY, mm** | **ΔZ, mm** |
| ALS X | -22864.0 | 509.8 | 288.7 | 0.0 | -8.8 | 13.3 | 0.0 | -8.4 | 0.0 |
| ALS Y | -22864.0 | 518.2 | 288.7 | 0.0 | -0.3 | 13.3 |  |  |  |
| POB | -22864.0 | 518.5 | 275.4 |  |  |  |  |  |  |

The ray vector angles at HAM1 are given in the following table. The yaw angle is measured counterclockwise from the positive X axis direction. The pitch angle is measured from the global horizontal plane in the positive vertical direction.

Table : Ray Vector Angles at HAM1, No CP Wedge

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **GLOBAL** | | | **GLOBAL** | | |
| **BEAM** | **INCIDENT RAY VECTOR COSINES** | | | **INCIDENT RAY VECTOR ANGLES, deg** | | |
|  | **X** | **Y** | **Z** | **X** | **Y** | **Z** |
| ALS X | -0.999780 | 0.007799 | 0.019459 | 179.553 | NA | 1.115 |
| ALS Y | -0.999777 | 0.008254 | 0.019459 | 179.527 | NA | 1.115 |
| POB | -0.999789 | 0.008406 | 0.018732 | 179.518 | NA | 1.073 |