Optical Path Design for Legacy Wavefront Sensors on ISC End Tables

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1 Motivation

After the One Arm Test at LIGO Hanford, the wavefront sensing system was deemed to be of little value and was removed. During HIFO-X, it was found that the high transmissivity of the ETMX coating interfered with cavity locking. To address this issue, it was necessary to reinstall the wavefront sensors to support auto-alignment. This document summarizes the design and layout of the wavefront sensor system as installed on the ISC End Tables.

2 Design

The wavefront sensing system consists of a near field and a far field wavefront sensor. For optimal operation, the spot size on the sensors needs to be between 2.5-4 mm in diameter, and the Guoy phase separation between the near and far field sensors needs to be $90^o \pm 10^o$.

As the beam path was added after the table was in operation, the design is physically constrained to the open space on the ISC end station tables. A large enough space is accessible by taking a pickoff from the LSC RFPD path, but the limited space available presents difficulties in choosing a precise distance for placement of wavefront sensors. The solution for the original wavefront sensing path was designed by Bram Slagmolen. This four-lens solution expands the beam spot size while keeping Guoy phase relatively insensitive to the position of the wavefront sensors. The layout for the wavefront sensor paths is based on this solution. In the component separation tables, I define the acceptable range as the distance at which Guoy phase changes from its ideal value by no more than $\pm 2.5^o$ while the beam size remains within the 2-4.5mm range.

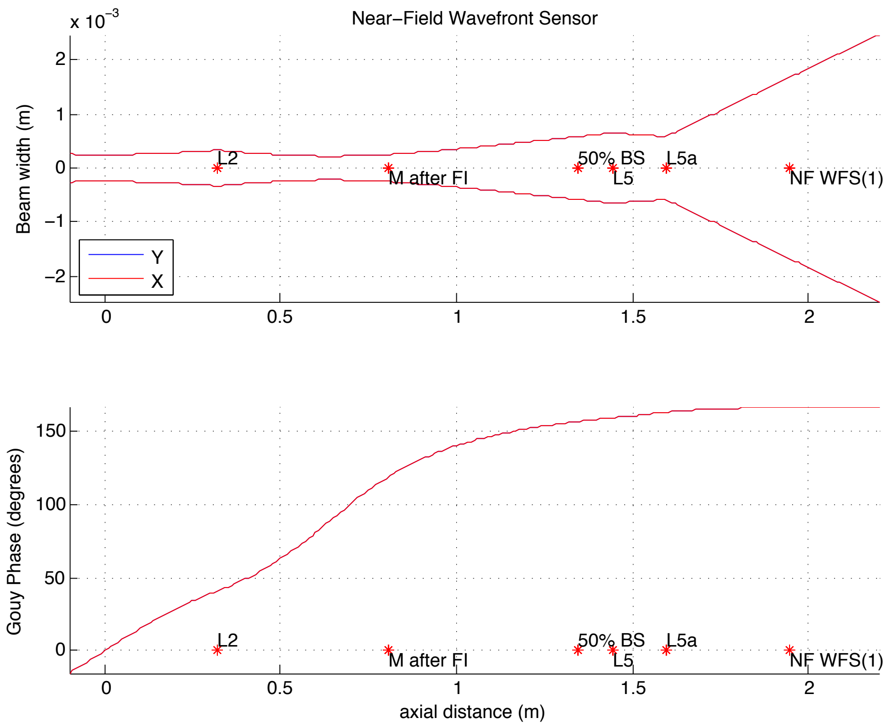

Fig. 1: Near Field Solution from alamode

Both solutions use two lenses to expand the beam size while keeping the Guoy phase relatively stable. For the near field solution, the first lens (L5 in the alamode plot) has radius of curvature R = 250mm. The second lens (L5a in the alamode plot) has radius of curvature R = -75mm.

Component	distance (m)
BS to first lens (R = 250mm)	0.1
First lens to second lens (R = -75 mm)	0.151
Second lens to WFS (ideal)	0.351
Second lens to WFS (range)	0.13 - 0.41

Note that the Guoy phase characteristics remain good even when the placement of the near field wavefront sensor is nearly touching the second lens. The primary consideration in the layout of the near field wavefront sensor path is attaining an appropriate spot size at the wavefront sensor.

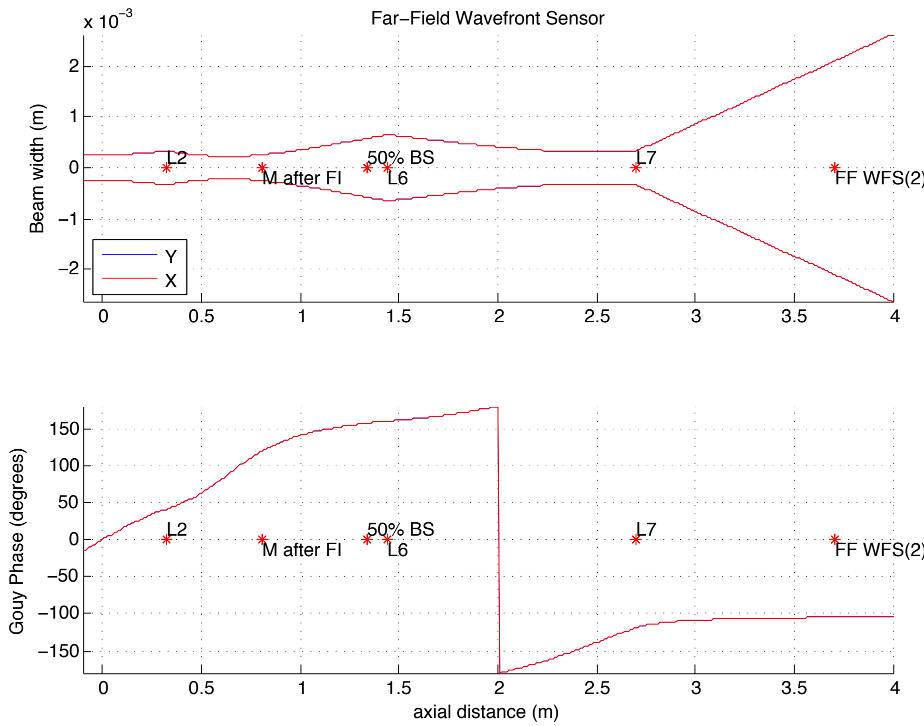

Fig. 2: Far Field Solution from alamode

For the far field solution, the first lens (L6 in the alamode plot) has radius of curvature R = 250mm. The second lens (L7 in the alamode plot) has radius of curvature R = -100mm.

Components	distance (m)
BS to first lens (R = 250mm)	0.1
First lens to second lens (R = -100 mm)	1.355
Second lens to WFS (ideal)	1.004
Second lens to WFS (range)	0.422 - 1.092

The Guoy phase characteristics are a stricter constraint on the placement of the far field wavefront sensor. The distance between the second lens and the far field wavefront sensor needs to be at least 0.42 m. Fortunately, there is a fairly large range of acceptable distances, so it is not strictly necessary to have 2.5 m of beam path after the beamsplitter.

3 Layouts

The wavefront sensing path layouts differ between ISCTEX and ISCTEY due to the differing physical constraints of the two tables.

The near field paths are more optically similar, but their layouts clearly differ between the two tables. On ISCTEX, there is space to place the near field wavefront sensor next to the ALS periscope. On ISCTEY, the open space between the periscopes is not accessible due to the location of the IR transmission periscope, requiring the use of a shorter path with a single folding mirror for the near field path.

Distance	d_X (m)	d_Y (m)
BS to L1	0.14	0.14
L1 to L2	0.14	0.14
L2 to WFSA	0.34	0.25

The far field path appears similar between the two tables. The optical components are identical, with some difference in their placement on the table. On ISCTEX, the first folding mirror was placed directly above the Hartmann sensor already in place. On ISCTEY, the layout is more conservative to accommodate the future install of the Hartmann Wavefront Sensor path. This constraint on path length resulted in a shorter overall beam path on ISCTEY, although it is still within the tolerances given in section 2.

Distance	d_X (m)	d_Y (m)
BS to L1	0.15	0.14
L1 to L2	1.46	1.28
L2 to WFSB	0.9525	0.457