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PO Beam Waist Size and Location on the ISC Table

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1 OVERVIEW

The PO beam waist location on the ISC table can be varied by defocusing the ISC telescope. An optical schematic drawing of the PO beam optical train, which includes the 8X reflective telescope inside the vacuum housing and the 3.3X ISC telescope on the ISC optical table is shown in 1.The input beam waist is inside the IFO, approximately 900 m from the PO telescope. The ISC telescope is separated from the PO telescope by approximately 3 m. The input beam waist is transformed by the lens train to an output beam waist of size w_{042}, located in the vicinity of the ISC table at a distance z_{42} from the end of the ISC telescope.

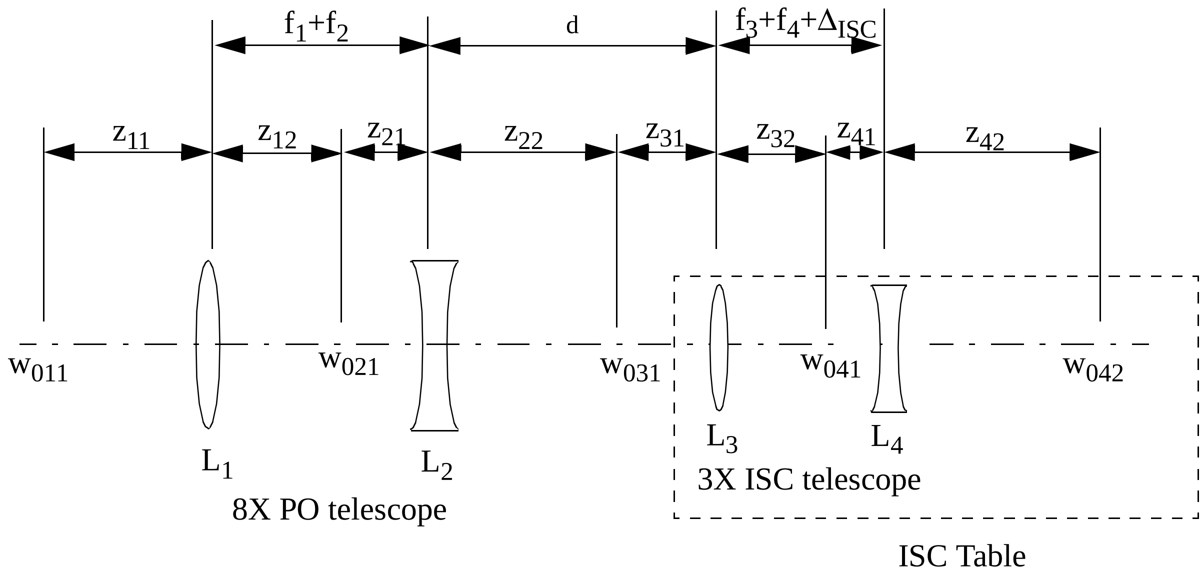

Figure 1: Optical schematic of PO beam optical train

The size and location of the output beam waist can be determined by using Gaussian beam transformation theory.

2 GAUSSIAN BEAM TRANSFORMATION THEORY

An analysis of the dependence of the output beam waist and location on the defocusing of the ISC telescope was made using the following parameters.

2.1. Telescope Parameters

PO Telescope

primary focal length, f_1	1524 mm
secondary focal length, f_2	-190.5 mm

input beam waist position, z_{11}	9×10^{5} mm
input beam waist parameter, w_{011}	36.4 mm
distance to ISC telescope, d	3000mm

ISC Telescope

primary focal length, f_3	251.8 mm
secondary focal length, f_4	-74.172 mm

2.2. Gaussian Beam Transformation Equations

$$z_{12} := f_1 + f_1^2 \cdot \frac{(z_{11} - f_1)}{\left[(z_{11} - f_1)^2 + \left(\pi \cdot \frac{w_{011}^2}{\lambda}\right)^2\right]}$$

$$w_{012} := \left[\frac{1 \cdot \left(1 - \frac{z_{11}}{f_1}\right)^2}{w_{011}^2} + \frac{1 \cdot \left(\pi \cdot \frac{w_{011}}{\lambda}\right)^2}{f_1^2}\right]^{-0.5}$$

$$w_{021} := w_{012}$$

$$z_{21} := f_1 + f_2 - z_{12}$$

$$z_{22} := f_2 + f_2^2 \cdot \frac{(z_{21} - f_2)}{\left[(z_{21} - f_2)^2 + \left(\pi \cdot \frac{w_{021}^2}{\lambda}\right)^2\right]}$$

$$w_{022} := \left[\frac{1 \cdot \left(1 - \frac{z_{21}}{f_2}\right)^2}{w_{021}^2} + \frac{1 \cdot \left(\pi \cdot \frac{w_{021}}{\lambda}\right)^2}{f_2^2}\right]^{-0.5}$$

$$w_{031} := w_{022}$$

$$z_{31} := d - z_{22}$$

$$z_{32} := f_3 + f_3^{\,2} \cdot \frac{(z_{31} - f_3)}{\left[(z_{31} - f_3)^2 + \left(\pi \cdot \frac{w_{031}^{\,2}}{\lambda}\right)^2\right]}$$

$$w_{032} := \left[\frac{1 \cdot \left(1 - \frac{z_{31}}{f_3}\right)^2}{w_{031}^{\,2}} + \frac{1 \cdot \left(\pi \cdot \frac{w_{031}}{\lambda}\right)^2}{f_3^{\,2}}\right]^{-0.5}$$

$$w_{041} := w_{032}$$

$$z_{41}(\Delta_{ISC}) := f_3 + f_4 + \Delta_{ISC} - z_{32}$$

$$z_{42}(\Delta_{ISC}) := f_4 + f_4^{\,2} \cdot \frac{(z_{41}(\Delta_{ISC}) - f_4)}{\left[(z_{41}(\Delta_{ISC}) - f_4)^2 + \left(\pi \cdot \frac{w_{041}^{\,2}}{\lambda}\right)^2\right]}$$

$$w_{042}(\Delta_{ISC}) := \left[\frac{1 \cdot \left(1 - \frac{z_{41}(\Delta_{ISC})}{f_4}\right)^2}{w_{041}^{\,2}} + \frac{1 \cdot \left(\pi \cdot \frac{w_{041}}{\lambda}\right)^2}{f_4^{\,2}}\right]^{-0.5}$$

Raleigh range of ISC output, mm $$z_R(\Delta_{ISC}) := \pi \cdot \frac{w_{042}(\Delta_{ISC})^2}{\lambda}$$

2.3. Results: Output Beam Waist Size and Location

The location of the ISC telescope output beam waist, as measured from the output lens, can be varied by defocusing the ISC telescope as shown in figure 2. The Rayleigh range associated with the output beam waist is also shown in figure 2.

The output beam waist size varies as the telescope is defocused, as shown in figure 3. The actual spot size at the output of the ISC telescope is also plotted in figure 3.

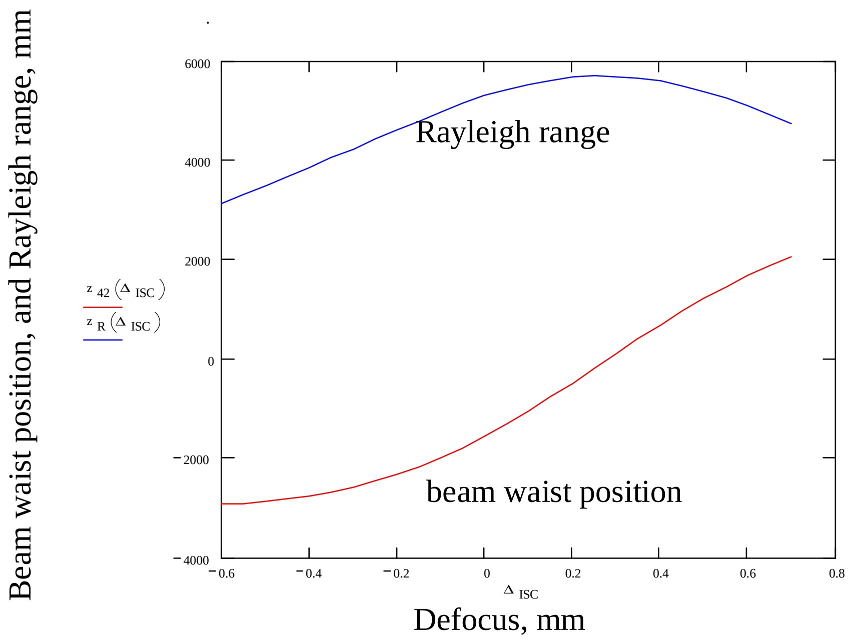

Figure 2: Beam waist position and Raleigh range versus ISC defocus, d=3000mm

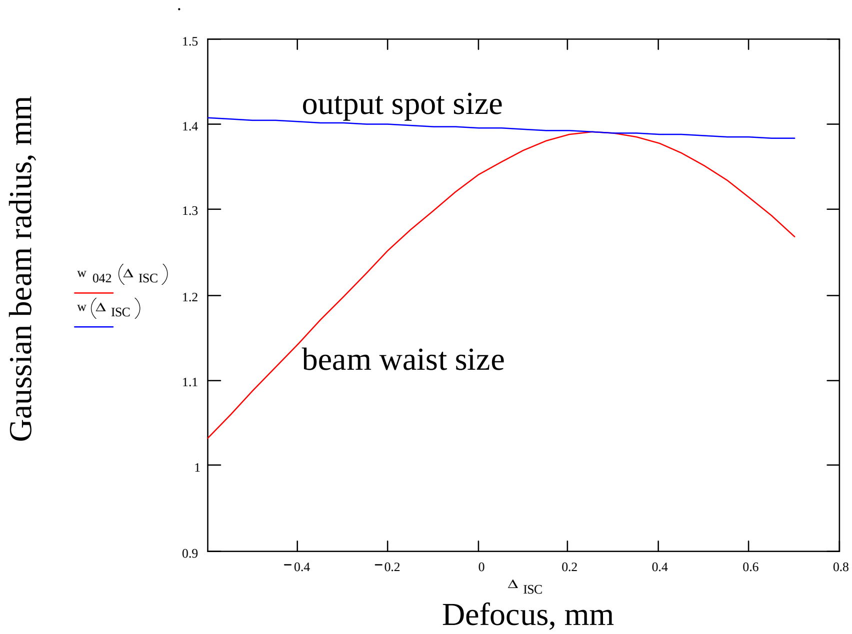

Figure 3: Beam waist size versus ISC defocus, d=3000mm

2.3.1. Locating the Far Field of the ISC Telescope

It is desirable to minimize the effect of the position of the ISC telescope on the Guoy phase at the WFS detector, by placing the first Guoy lens of the WFS system in the far field of the ISC telescope output. This can be accomplished by defocusing the ISC telescope approximately -0.6 mm, which will place the apparent output beam waist at the location -3000 mm (refer to figure 2). And since the Rayleigh range is +3000 mm, the output beam will be in the far field as it emerges from the ISC telescope.

3 ISC TELESCOPE DESIGN DETAILS

3.1. Optical Design Specification

The optical design specification for the ISC telescope is shown in the optical schematic of figure 4. It will incorporate stock lenses, with AR coatings for 1064 nm wavelength, as specified

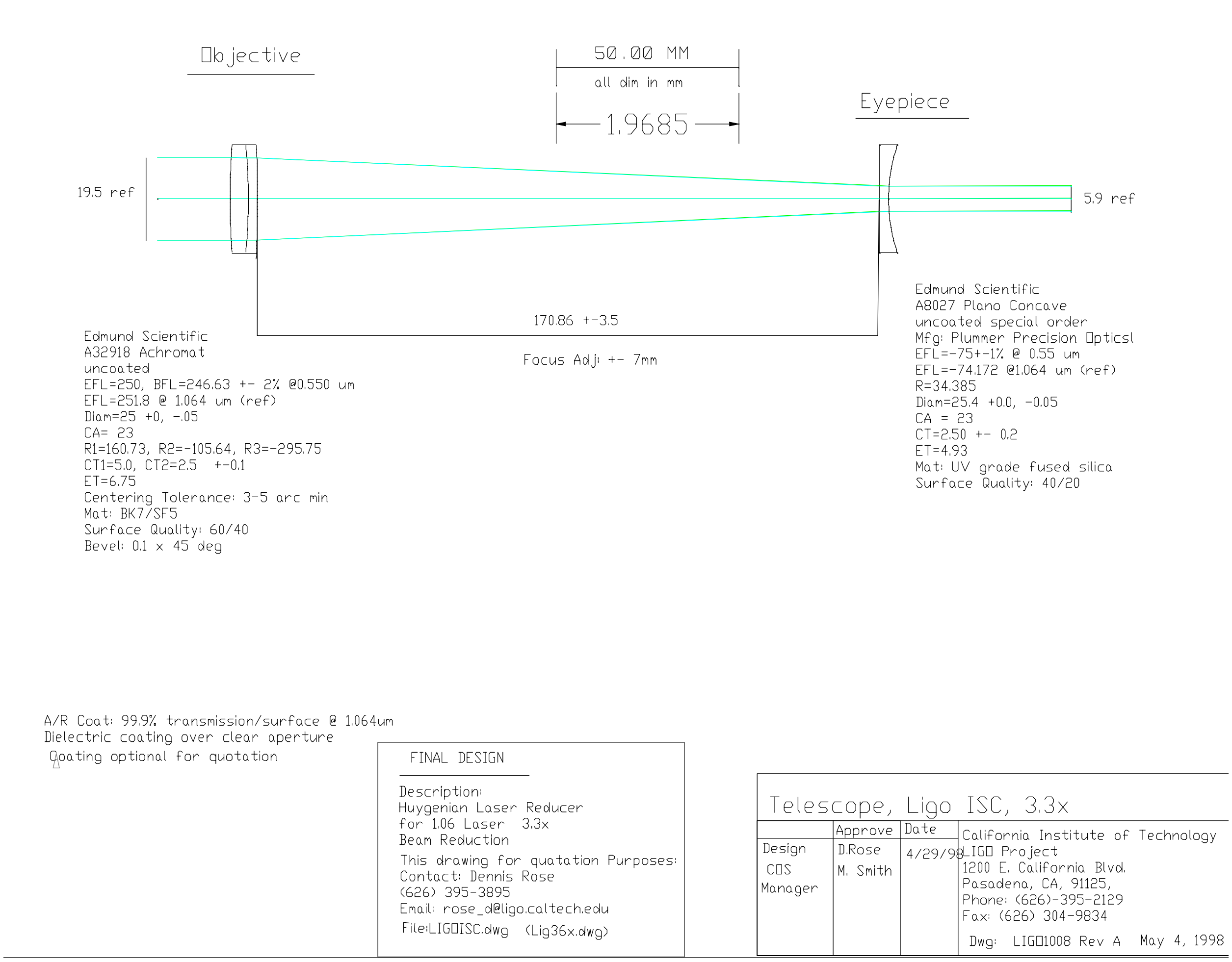

Figure 4: ISC Telescope, optical schematic

3.2. Mechanical Characteristics

objective lens:

part number	Edmund Scientific, p/n D32918
nominal focal length	250 mm
diameter	25.00 +0.00 - 0.05 mm
clear aperture	23 mm
center thickness	7.5 mm
edge thickness	6.75 mm
material	BK7/SF5

eyepiece lens:

part number	Edmund Scientific, p/n D8027
nominal focal length	-75 mm
diameter	25.40 +0.00 - 0.05 mm
clear aperture	23 mm
center thickness	2.5 mm
edge thickness	4.93 mm
material	UV grade fused silica

3.3. Clear Aperture and Field of View Requirements

The COS ISC telescope was designed with an optical axis displacement tolerance of +/- 1.8 mm, and a field-of-view tolerance of +/- 4x10^-4 rad.

The total position shift and angular error in the COS pick off beam at the ISC table due to initial COC alignment errors, pump-down shifts, and long term stack drifts are estimated to be +/- 13 mm and 4x10^-3 rad; which exceed the design requirements of the ISC telescope.

Therefore it will be necessary to direct the beam into the ISC telescope commensurate with the clear aperture and field-of-view design constraints. (See COS PDR sec. 7.3.3, and Table 13).

3.4. Mounting Configuration

The ISC telescope lenses will be mounted in a simple focus tube configuration, as shown in figure 5. The focus tube must have a range of adjustment of -0.6 mm in order to place the output of the telescope in the far field, as described previously. See “Locating the Far Field of the ISC Telescope” on page 6. The telescope tube can be mounted to the ISC table with a standard tube mount fastened to an optical post, as shown.

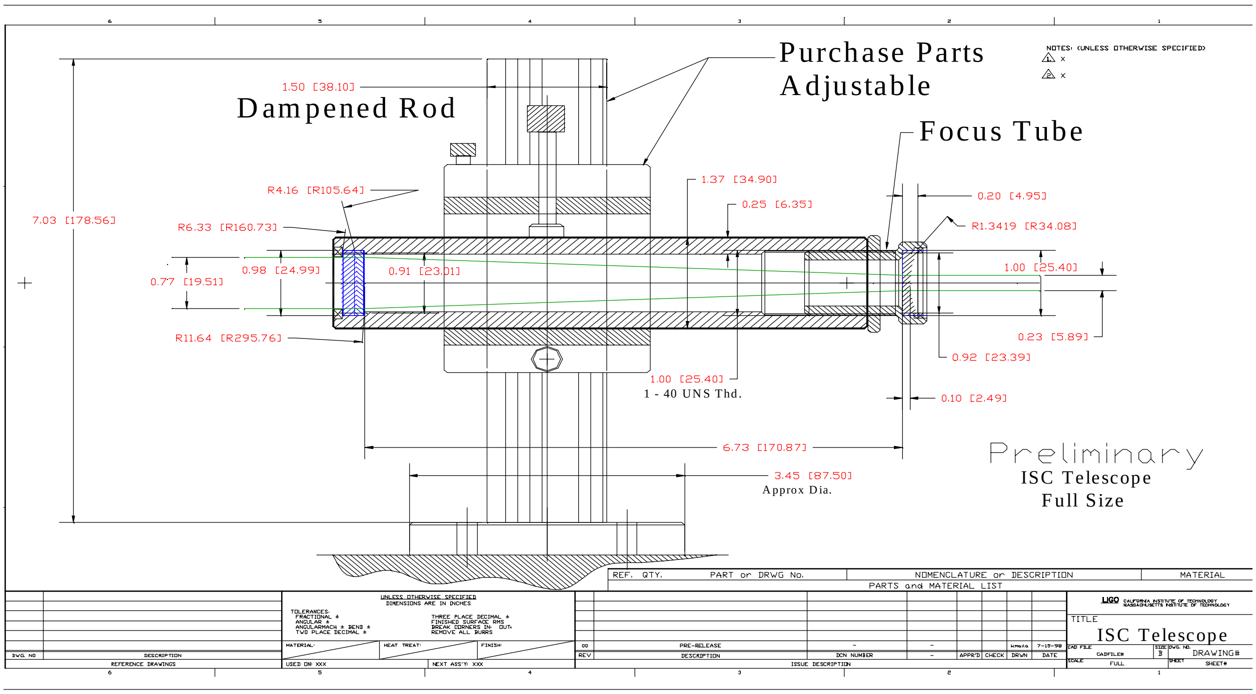

Figure 5: Mounting configuration, outline drawing for ISC telescope