

## Lens Mount Design

### Introduction

This report designs a mechanical mount structure for a doublet lens system with tolerancing limits. The doublet lens is a two lens system, one positive and one negative, which are both using N-SK15 glass and are separated by a 1.0mm air gap. In figure 1 below, the lens prescription data for the doublet lens system is displayed. This design has a residual wavefront error of  $.002\lambda$  and is used to focus a collimated 632.8nm (HeNe) beam onto a position sensing detector (PSD).

Surf:	Type	Comment	Radius	Thickness	Glass	Semi-Diameter	Conic
OBJ	Standard		Infinity	Infinity		0.000000	0.000000
STO	Standard		Infinity	0.000000		10.000000 U	0.000000
2*	Standard		88.600000	5.000000	N-SK15	12.500000 U	0.000000
3*	Standard		-277.000000	1.000000		12.500000 U	0.000000
4*	Standard		-97.000000	4.000000	N-SK15	12.000000 U	0.000000
5*	Standard		-174.000000	98.829288 V		12.500000 U	0.000000
TMA	Standard		Infinity	-		2.732817E-004	0.000000

Figure 1: Zemax Lens Prescription Data

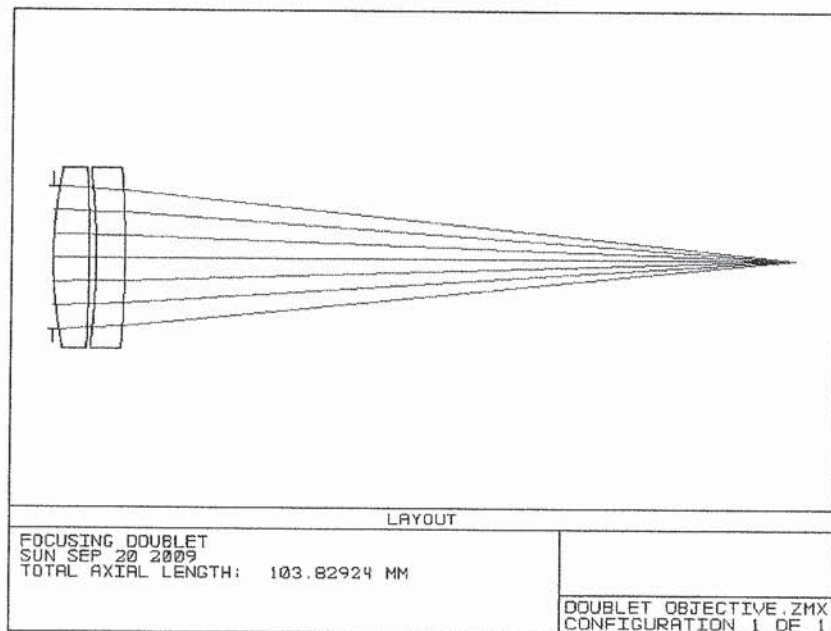


Figure 2: 2D Layout of Doublet Lens System.

## Lens Mount Requirements

Labeled below are the specific requirements the mechanical system must have for the doublet lens system. All degrees of freedom for mounting the lenses including tilt, de-center, and axial positions are considered in the tolerancing limit for the lens mount requirements.

### Optical Requirements

- A 20mm entrance pupil diameter
- Nominal EFL = 100 mm
- Operating wavelength at 632.8 nm
- Diffraction limited operation with a Strehl Ratio > 80%
- A maximum limit of  $\pm 5 \mu\text{m}$  can be made by moving the PSD.

### Performance Requirements

- $0.04 \lambda_{\text{rms}}$  Tolerances of the Lenses
- $0.04 \lambda_{\text{rms}}$  Assembly Tolerances
- $0.04 \lambda_{\text{rms}}$  Operational Changes
- $0.07 \lambda$  Total RMS Wavefront Error

## Design

The doublet lens system is a simple lens configuration, especially since there are no environmental specifications or known uses. To accommodate the spacing between the lenses, a spacer element is placed in-between the doublet elements. The lens and spacer system are held in the barrel with a threaded retainer. Since there is no specification on the type of environment the barrel is working in, an aluminum alloy 6061 barrel should be good enough since it is light-weight and cheap. The retainer ring will also be aluminum since it should be easy to manufacture the part. The lens spacer will be nylon since it is an elastic material and is against the lenses which can conform to the lenses. Shown below in figure 3 is the design concept for the lens barrel system.

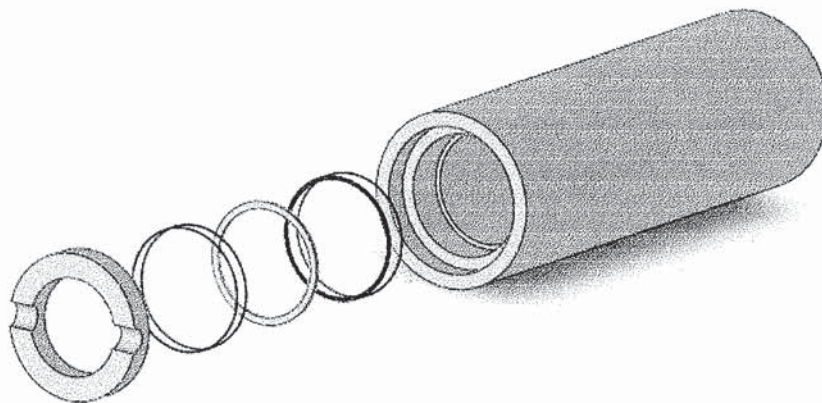
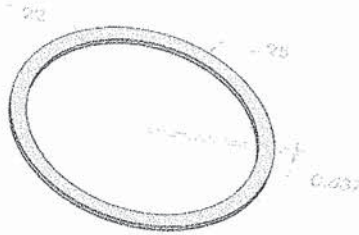


Figure 3: Solidworks Barrel Design.

## Element Designs

Below are the element designs for the mechanical mount structure which were made in Solidworks. Their sizes and dimensions are based on the tolerancing limits determined from the tolerancing analysis performed using Zemax, which can be seen in appendix A. The lens specifications are not specified here since the details are shown in figure 1, the lens prescription data.

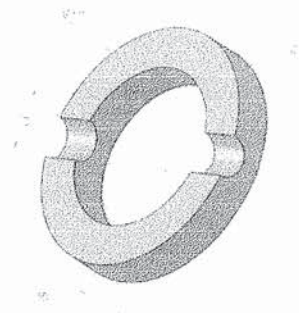
### Spacer



**Figure 3:** Solidworks Spacer Ring.

For the spacer design, the thickness was made thin to accommodate the necessary lens separation and the ring diameter was made small so it does not interfere with the sag of the lens elements. It was not too important to have the ring's design arc to fit the lenses since the lens separation has a large tolerance and the material is nylon which will allow it to conform to the lenses. See appendix B for Solidworks schematic drawings.

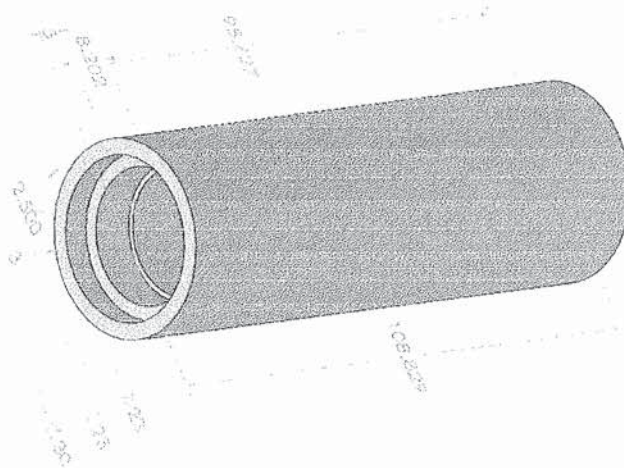
### Retainer



**Figure 4:** Solidworks Retainer.

The retainer design serves as the system stop and had its dimensions selected to accommodate the barrel size as well as the stop requirements for the doublet system. It is made out of aluminum and is threaded on the outside (not shown in picture). This allows for quick and easy installation. The retainer also has notches for added leverage when inserting it into the barrel. See appendix B for Solidworks schematic drawings.

## Barrel



**Figure 5:** Solidworks Barrel.

The barrel serves as the protective housing and the mounting holder for the doublet assembly. Three distinct drill holes are created from a block of aluminum with their sizes shown above in figure 5. The first hole cut out is threaded to match the retainer. There are no bevels in the design since it simply needs to hold the other elements. See appendix B for Solidworks schematic drawings.

## **Performance Analysis**

The following shows the performance of the system when external forces are applied. I have an arbitrary temperature change of five degrees just to show performance change.

### Thermal

#### Lens Defocus

$$\Delta f = \beta f \Delta T = \left( \alpha - \frac{1}{n-1} \frac{d_n}{d_T} \right) * f * \Delta T = 2.07 \mu m$$

where,

$$\alpha = 6.1 \frac{\text{ppm}}{\text{K}}$$

$$n = 1.62$$

$$\frac{d_n}{d_T} = 2.5 \frac{\text{ppm}}{\text{K}}$$

$$f = 100 \text{mm and } \Delta T = 5^\circ \text{K}$$

#### Barrel Length Change

$$\Delta L = f \alpha \Delta T = 11.5 \mu m$$

where,

$$\alpha = 23 \frac{\text{ppm}}{\text{K}}$$

therefore,

$$\Delta z = \Delta L - \Delta f = 9.43 \mu m$$

therefore,

$$W_{rms} = .0361 \frac{\Delta z}{F^2} = \frac{\Delta z}{\left(\frac{f}{EP}\right)^2} = .0136 \mu m = \frac{0136 \mu m}{632 nm} = .02 \lambda$$

Radius Change

$$\Delta R = \Delta \alpha * \Delta T * R = \frac{17 ppm}{K} * 5^\circ K * 12.5 mm = 8.5 \mu m$$

Shock

$$\sigma_a = \sqrt{\frac{FE}{LR}}$$

Using the equation above would give the limiting shock that this system can receive. Since no specifications on the shock have been made, the rule of thumb for this system would be to not go over 7MPa for long periods or 30MPa for short periods of shock for the glass.

## Preliminary Assembly Plan

Assembly

1. Put protective gloves on.
2. Perform lens cleaning such as drag method using acetone, isopropyl, and distilled water.
3. Clean metallic structures using acetone and distilled water.
4. Insert Lens 2 into the barrel using suction cup.
5. Insert spacer carefully on top of Lens 2.
6. Insert Lens 1 on top of barrel using suction cup.
7. Screw in retainer till snug and do not cross thread.
8. Tighten retainer with tool and do not over tighten.
9. Test system using star test and microscope.

## Design Analysis

The design of this lens mount is very simple for three distinct reasons. One, there has not been any specification for a robust system. Two, no information is given about the environment that the system is operating in. Three, the doublet lens system is a simple lens system that does not have high performance and operation requirements. Because of this, the lens mount structure was designed for meeting its performance, the ease of manufacturing, and low cost. The tolerance limits of the design meet all the specifications and are within manufacturability. Also, the lens mount system does not have bevels or any odd curves in the design. This allows for quick and easy creation of the parts. Also, the materials used in the design are not expensive and have high availability. This allows the parts to be manufactured very cheaply and gives the overall lens mount design a low cost appeal.

## Appendix A (Original Zemax Tolerance Data)

Oper #	Type	Surf	Adjus	-	Residual	Min	Max
1 (CDMG)	CDMG	1	0	-	33.828238	-5.000000E-003	5.000000E-003
2 (THAV)	THAV	-	-	-	0.442800	-	-
3 (TINI)	TINI	3	5	-	1.000000	-0.225000	0.225000
4 (TECK)	TECK	2	5	-	0.000000	-0.100000	0.100000
5 (TECV)	TECV	2	5	-	0.000000	-0.100000	0.100000
6 (TETK)	TETK	1	5	-	0.000000	-0.100000	0.100000
7 (TEV)	TEV	2	5	-	0.000000	-0.100000	0.100000
8 (TEK)	TEK	4	5	-	0.000000	-0.100000	0.100000
9 (TEV)	TEV	4	5	-	0.000000	-0.100000	0.100000
10 (TEK)	TEK	4	5	-	0.000000	-0.100000	0.100000
11 (TEV)	TEV	4	5	-	0.000000	-0.100000	0.100000

Figure A-1: Tolerance Values in 'Tolerance Data Manager'.

Sensitivity Analysis:

Type	Value	Minimum	Change	Value	Maximum	Change
TINI 3 5	-0.22500000	0.00124035	-0.01341776	0.22500000	0.02811279	0.02467295
TECK 2 5	-0.10000000	0.02358205	0.01935299	0.10000000	0.02358205	0.01935299
TECV 2 5	-0.10000000	0.02358205	0.01935299	0.10000000	0.02358205	0.01935299
TETK 2 5	-0.10000000	0.02202838	0.01742627	0.10000000	0.02202838	0.01742627
TEV 2 5	-0.10000000	0.02202838	0.01742627	0.10000000	0.02202838	0.01742627
TEK 4 5	-0.10000000	0.03107824	0.02800505	0.10000000	0.03107824	0.02800505
TEV 4 5	-0.10000000	0.03107824	0.02800505	0.10000000	0.03107824	0.02800505
TEK 4 5	-0.10000000	0.03239315	0.02945745	0.10000000	0.03239315	0.02945745
TEV 4 5	-0.10000000	0.03239315	0.02945745	0.10000000	0.03239315	0.02945745

Figure A-2: Sensitivity Analysis for Zemax.

90% <	0.04384326
80% <	0.03358715
50% <	0.03117892
20% <	0.01956331
10% <	0.01411151

Figure A-3: Final Value of Tolerances.

	Tolerance	Sensitivity		Change in WFE	
		-Tolerance	+Tolerance	-Tolerance	+Tolerance
<b>Residual Design</b>				-0.002	0.002
<b>Lens 1</b>					
Decenter	0.1	0.02358205	0.02358205	0.01935299	0.01935299
Tilt	0.15	0.02202838	0.02202838	0.01742627	0.01742627
<b>Lens 2</b>					
Decenter	0.15	0.03107824	0.03107824	0.02800505	0.02800505
Tilt	0.15	0.03239315	0.03239315	0.02945745	0.02945745
<b>Lens 1 - Lens 2</b>					
Spacing	0.225	0.00124035	0.02811279	-0.01341776	0.02467295
<b>RSS (waves)</b>	0.03958715				

## Appendix B (Solidworks Drawings)

