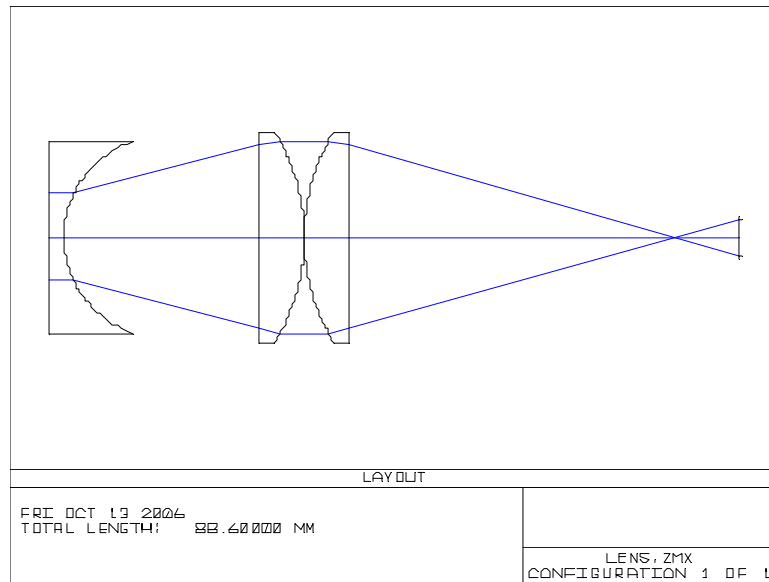


Zemax Project 1

- A. Objective: To set up the given optical system (spherically corrected 25 mm F.L. f/2.0 objective) in Zemax using a Gaussian apodization factor of 2 in order to input Gaussian laser beam with waist size equal to $(\sqrt{2})^{-1}$ times the entrance pupil radius, and wavelength of 632.8 nm, corresponding to a He-Ne laser. Lenses used are 01 LPK 003 and 01 LPX 108 of Melles Griot.

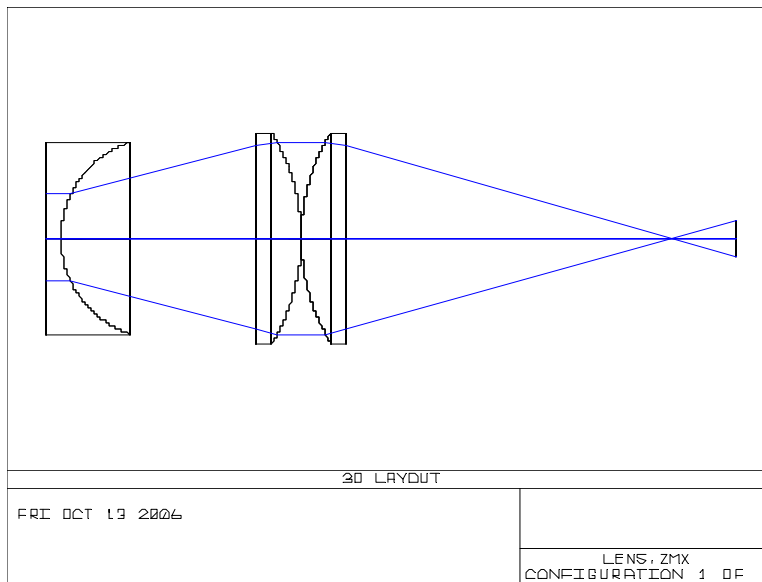
The lay out of the given optical system is shown below (fig 1).



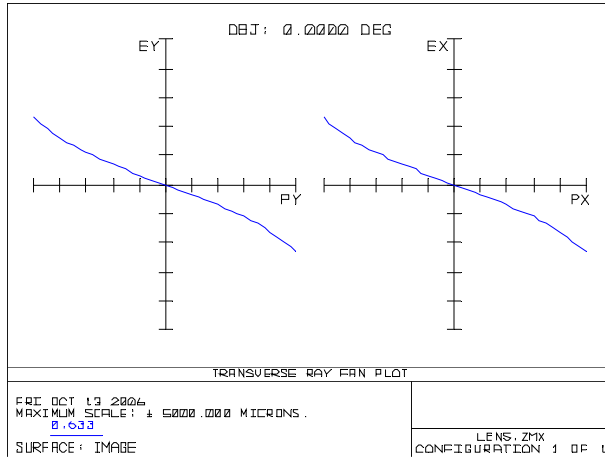
(fig 1)

The shown optical system has aberrations that have to be minimized in order to get a clearer image. It can be done by optimizing distances between lenses and image.

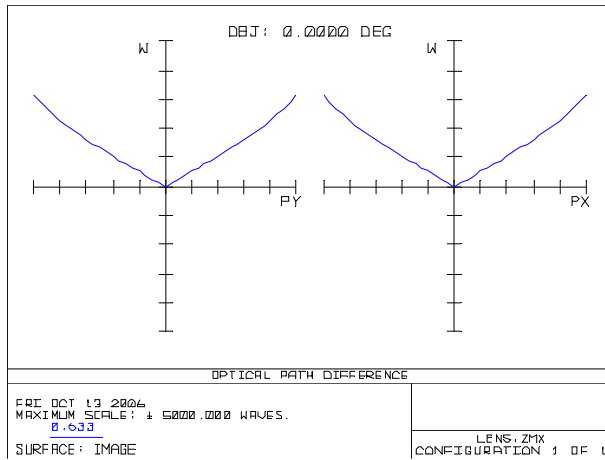
3D layout



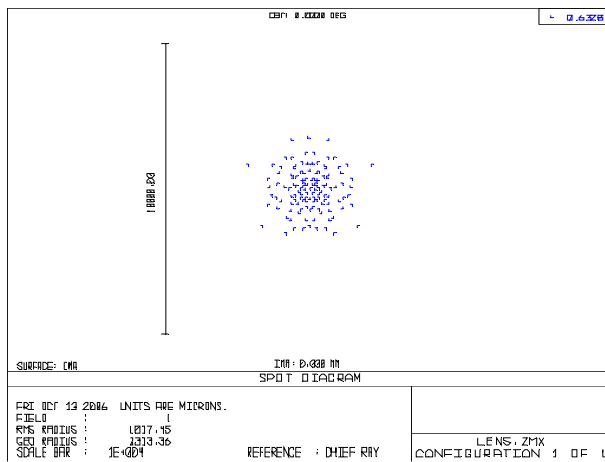
Ray fan



OPD fan



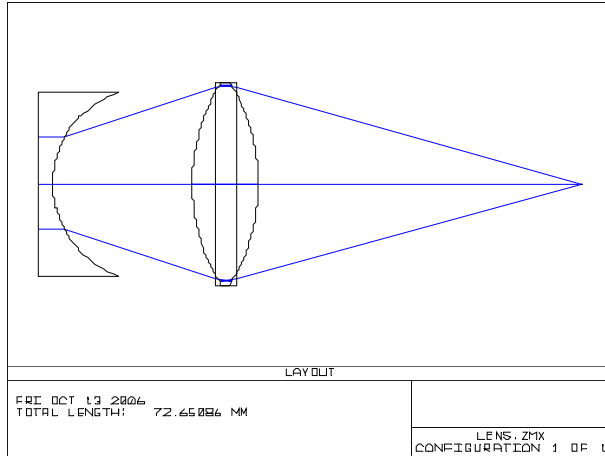
Spot diagram



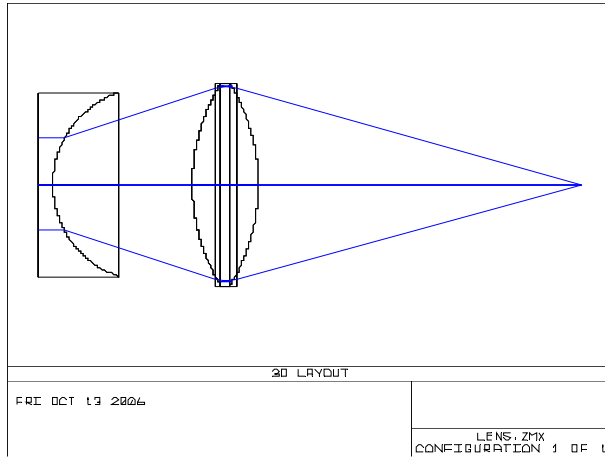
Root Mean Square (RMS) Spot size is 1017.45 microns
 Beam waist size at focus is 8.32505E-002

After optimization

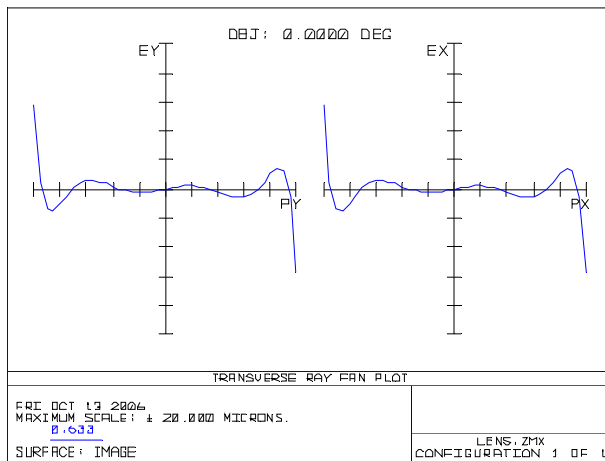
Layout



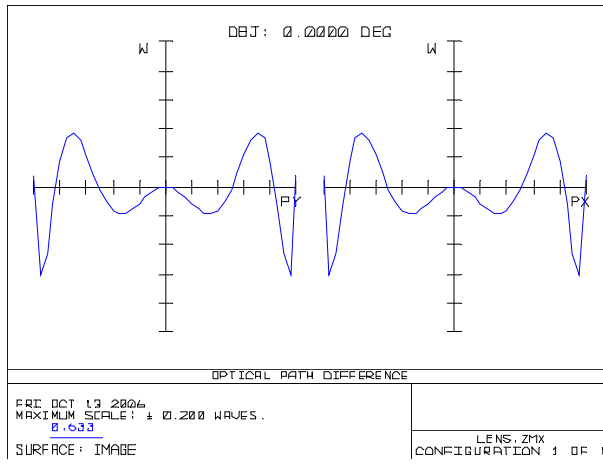
3D layout



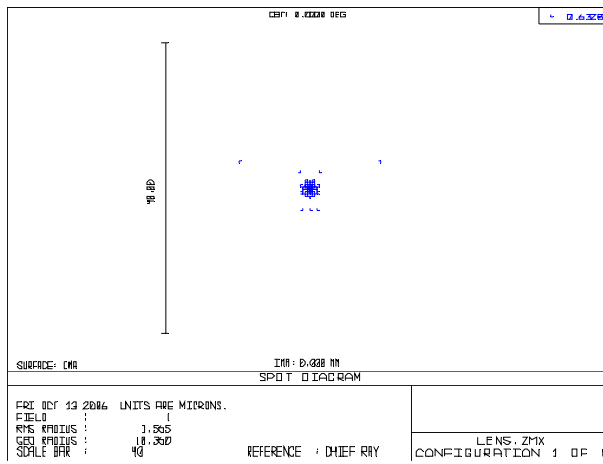
Ray fan



OPD fan



Spot diagram

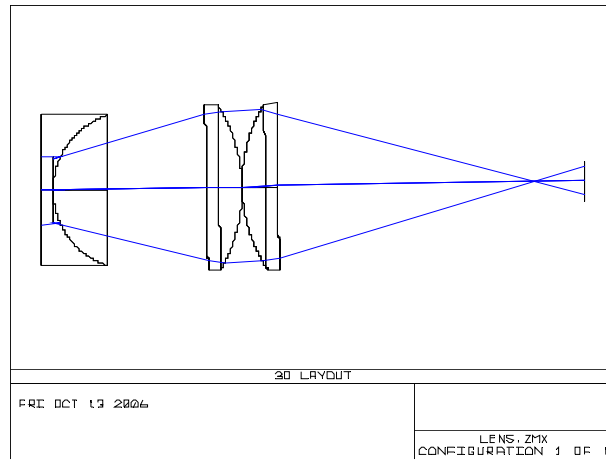


Root Mean Square (RMS) Spot size is 1.565 microns
 Beam waist size at focus is 1.00061E-001

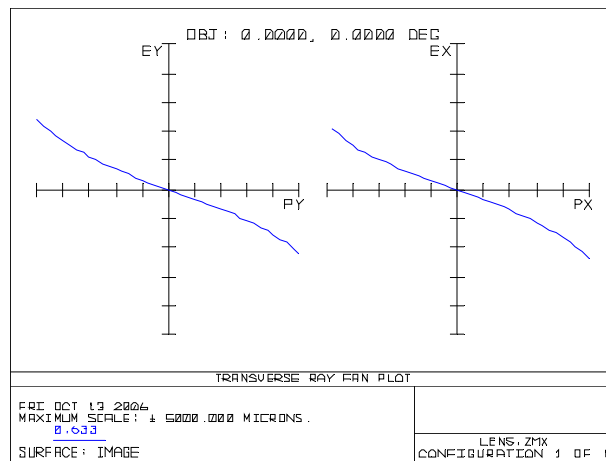
Considering the effects of tilting by 1° and de-centering by 1mm each of 3 lenses, individually, and all 3 together.

Case 1: Lens 1 – tilted by 1° and de-centered by 1 mm (Lens 1 is the left most lens)

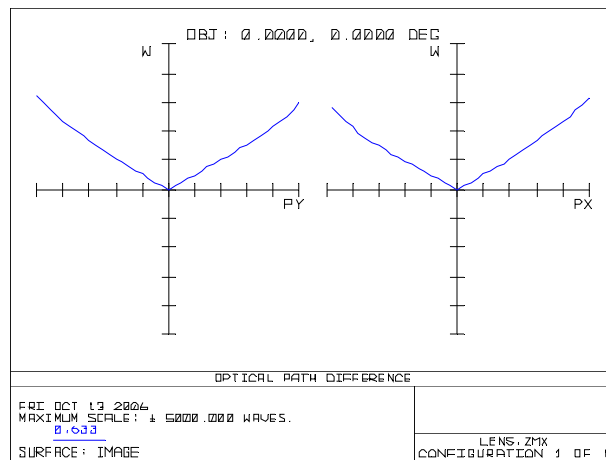
3D layout



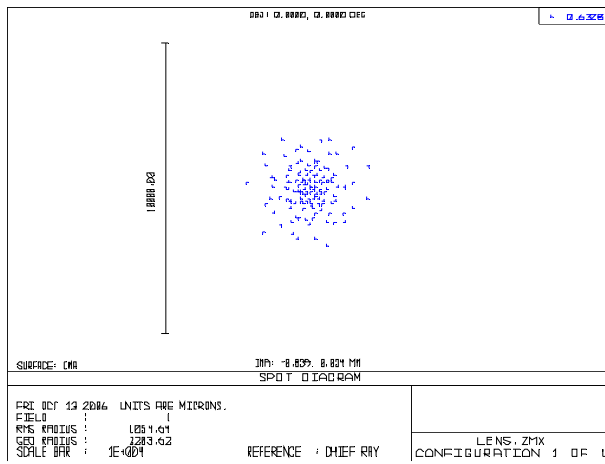
Ray fan



OPD fan



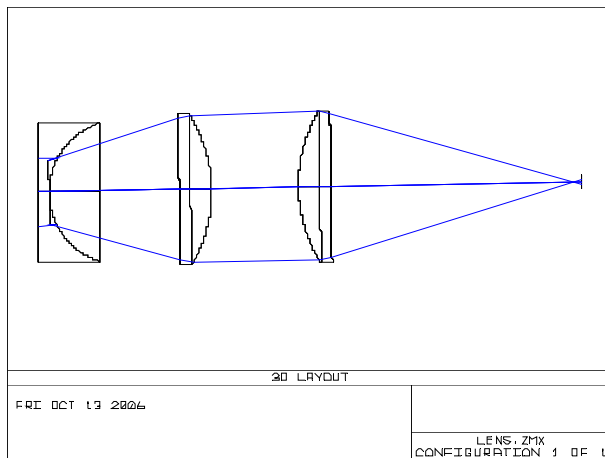
Spot diagram



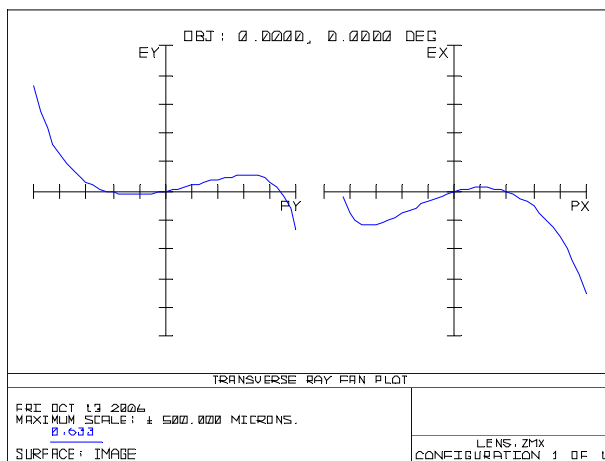
Root Mean Square (RMS) Spot size is 1054.64 microns
 Beam waist size at focus is 8.32505E-002

After optimization

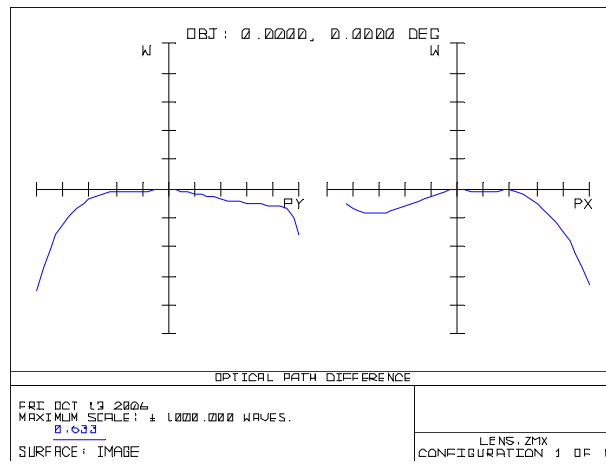
3D layout



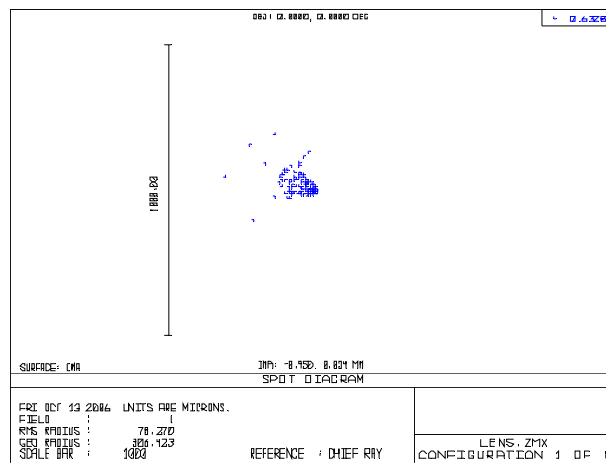
Ray fan



OPD fan



Spot diagram

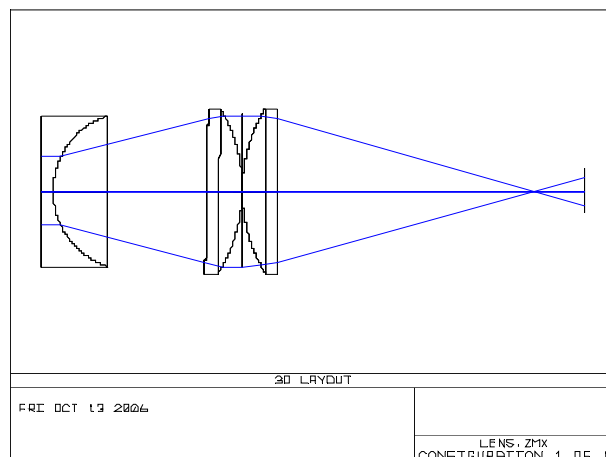


Root Mean Square (RMS) Spot size is 78.270 microns

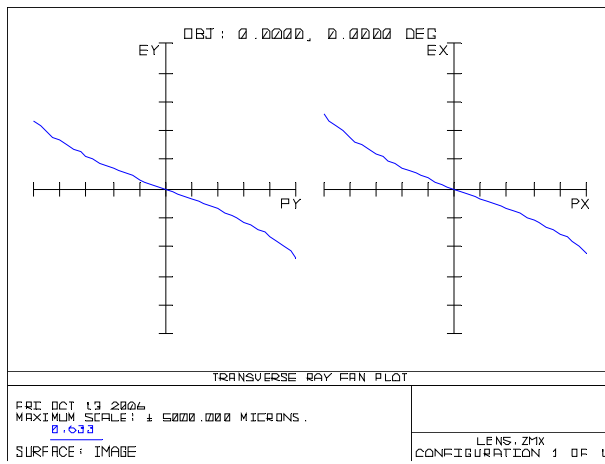
Beam waist size at focus is 8.52004E-002

Case 2: Lens 2 – tilted by 1° and de-centered by 1 mm (Lens 2 is the middle lens)

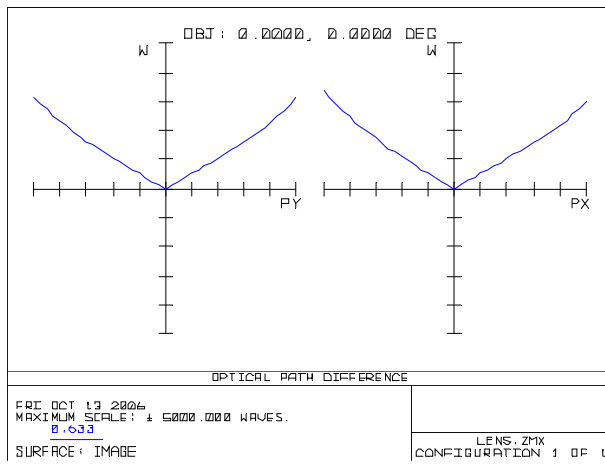
3D layout



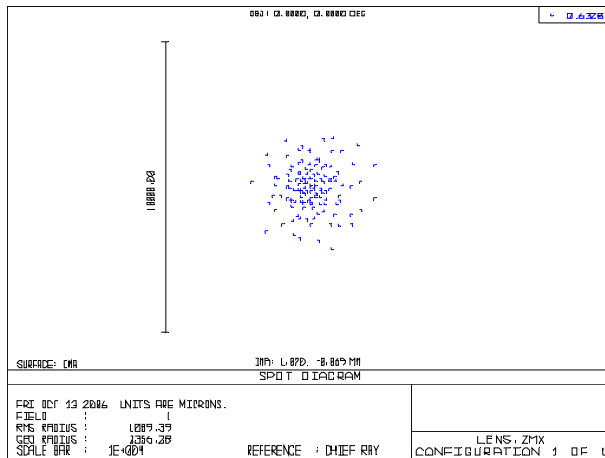
Ray fan



OPD fan



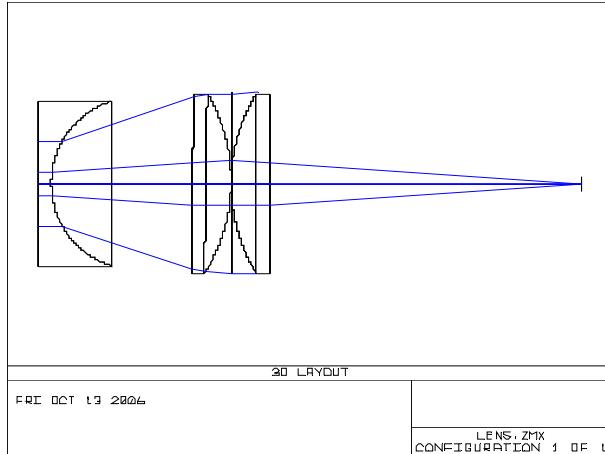
Spot diagram



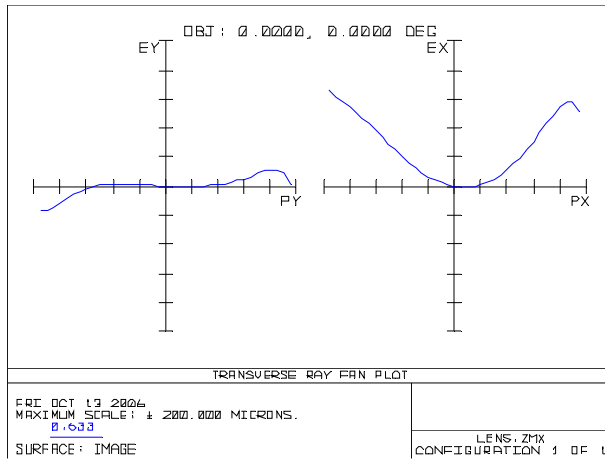
Root Mean Square (RMS) Spot size is 1089.39 microns
 Beam waist size at focus is 8.32505E-002

After optimization

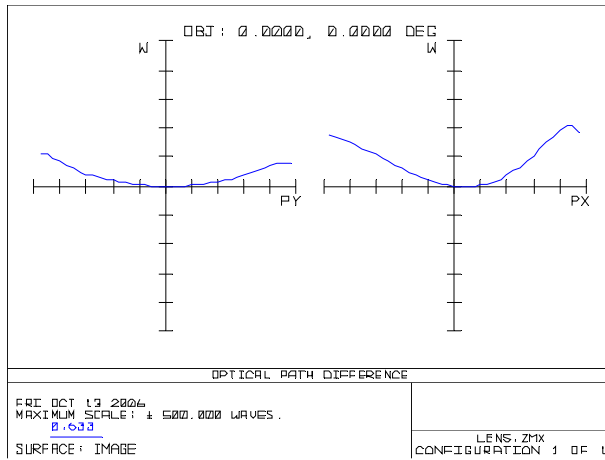
3D layout



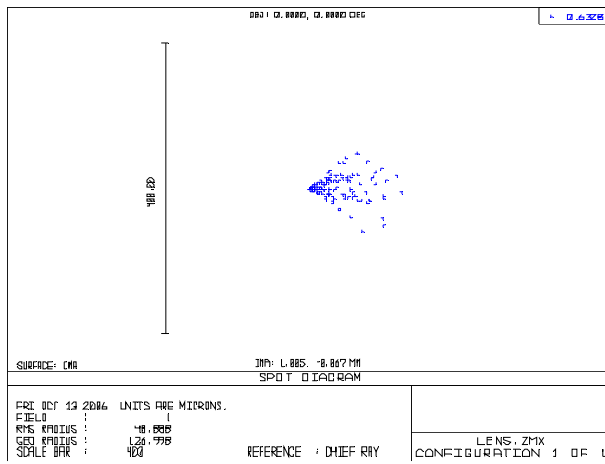
Ray fan



OPD fan



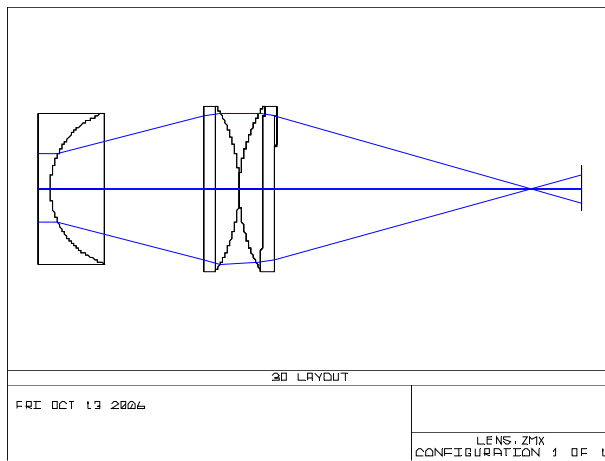
Spot diagram



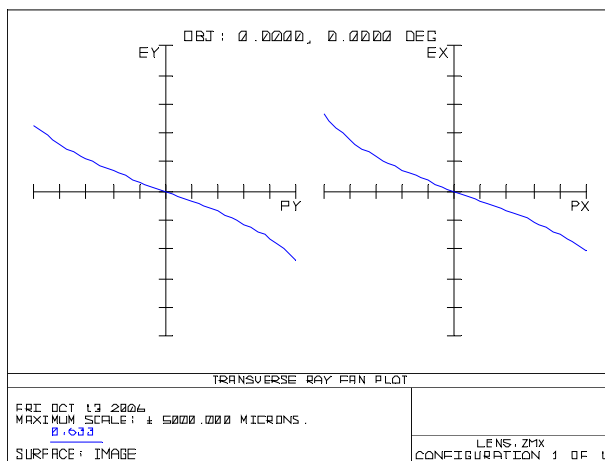
Root Mean Square (RMS) Spot size is 48.888 microns
Beam waist size at focus is 1.01925E-001

Case 3: Lens 3 – tilted by 1° and de-centered by 1 mm (Lens 3 is the lens next to image)

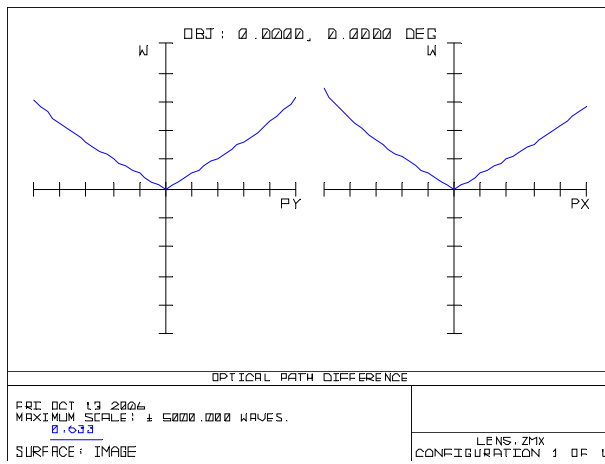
3D layout



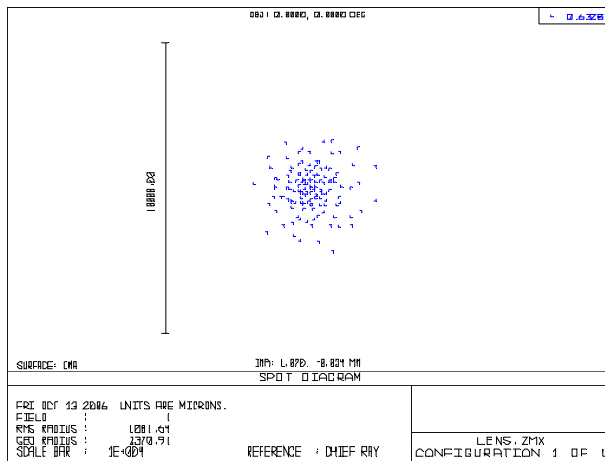
Ray fan



OPD fan



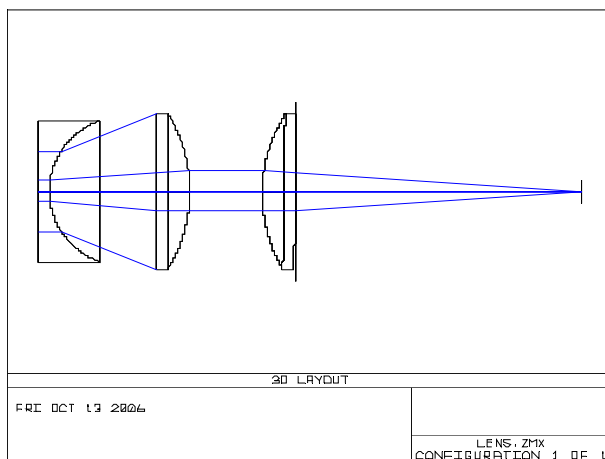
Spot diagram



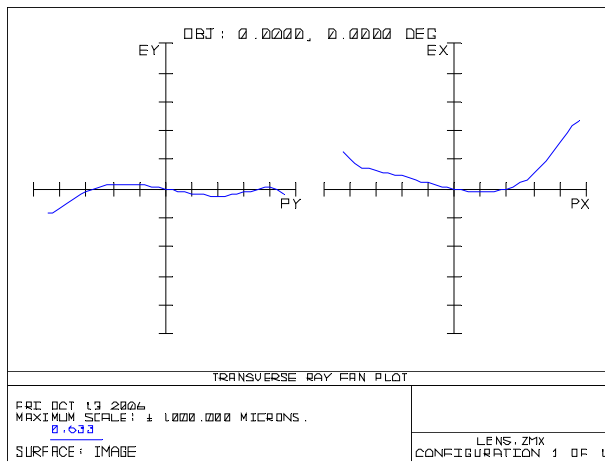
Root Mean Square (RMS) Spot size is 1081.64 microns
 Beam waist size at focus is 8.32505E-002

After optimization

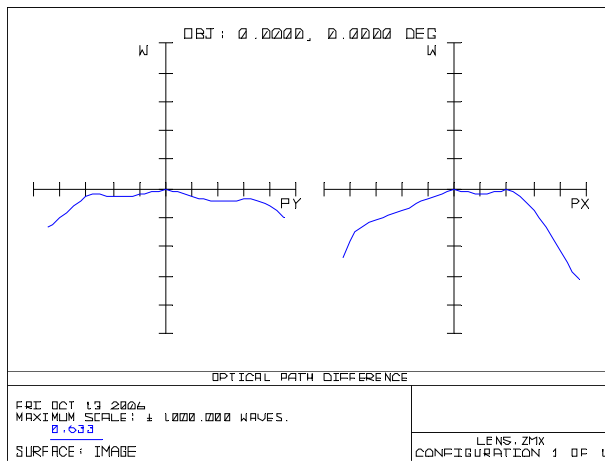
3D layout



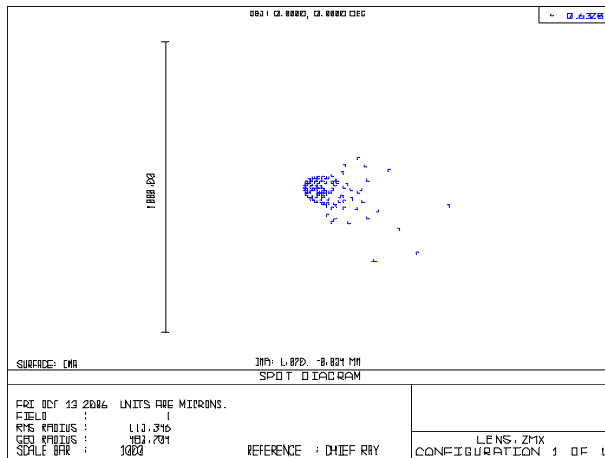
Ray fan



OPD fan



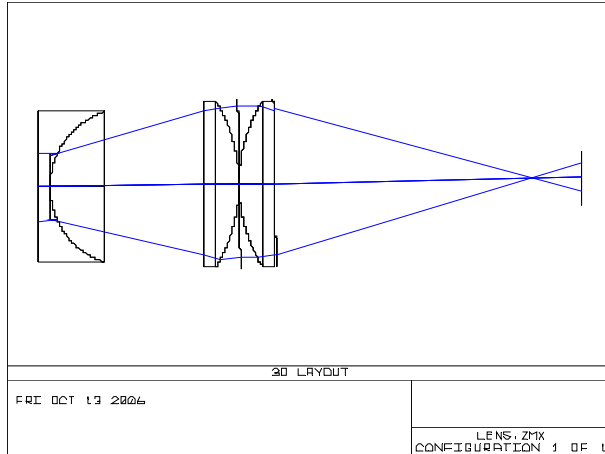
Spot diagram



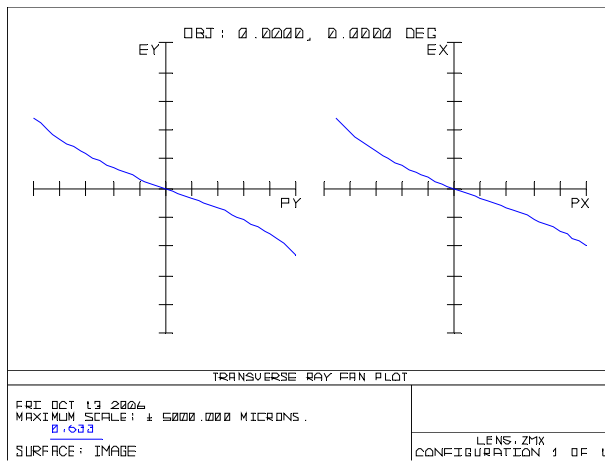
Root Mean Square (RMS) Spot size is 113.346 microns
 Beam waist size at focus is 1.09739E-001

Case 4: Lenses 1, 2 & 3 – tilted by 1° and de-centered by 1 mm (Lens numbering from left)

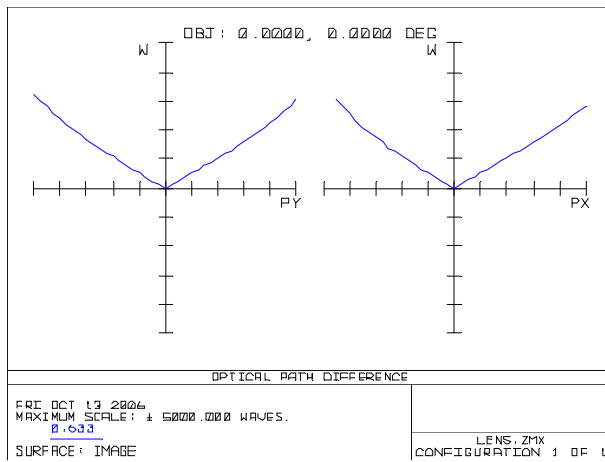
3D layout



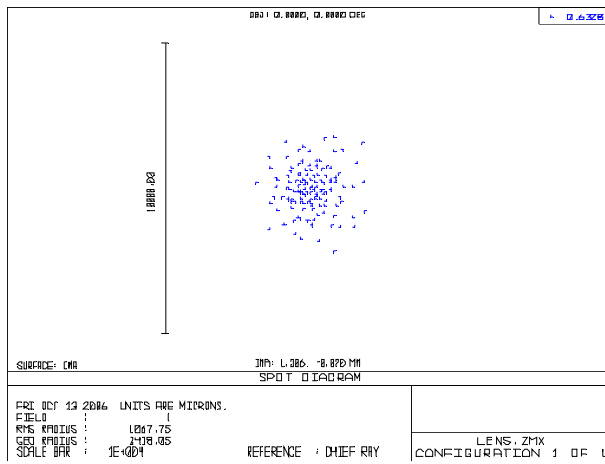
Ray fan



OPD fan



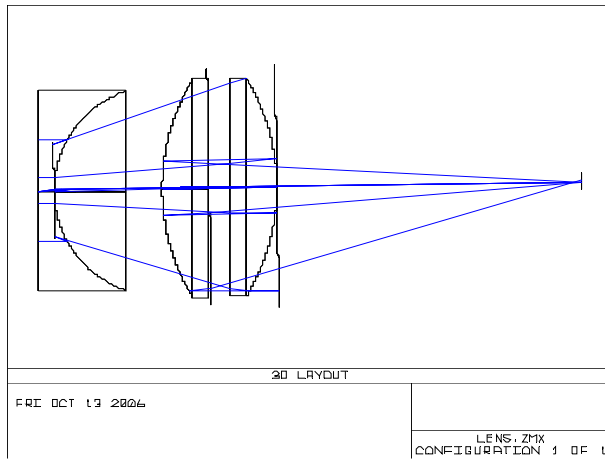
Spot diagram



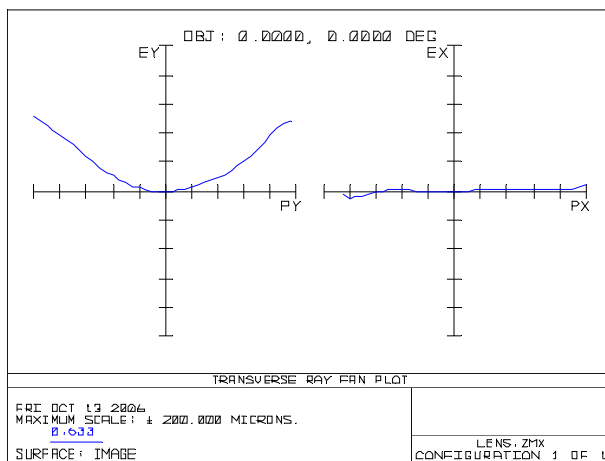
Root Mean Square (RMS) Spot size is 1067.75 microns
 Beam waist size at focus is 8.32505E-002

After optimization

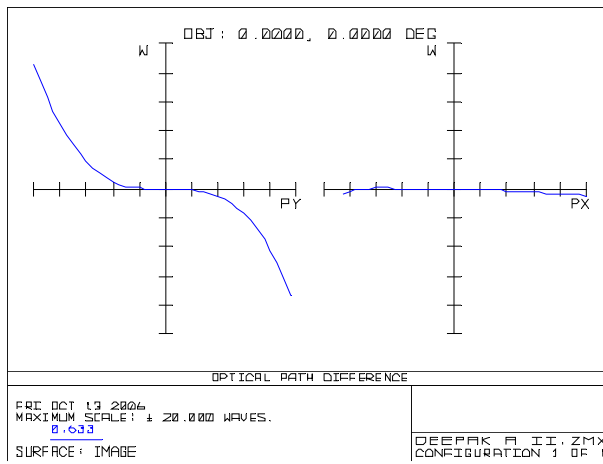
3D layout



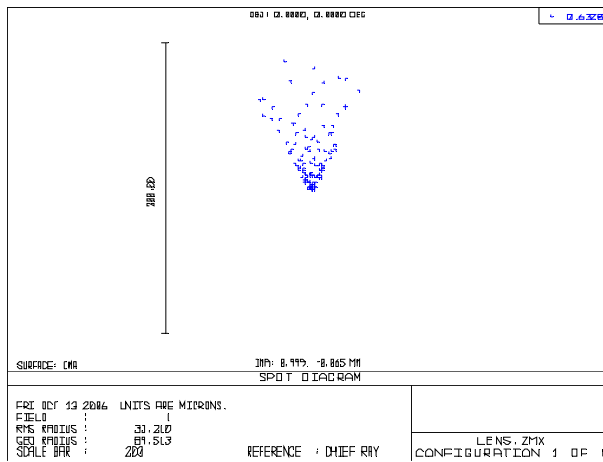
Ray fan



OPD fan



Spot diagram



Root Mean Square (RMS) Spot size is 33.210 microns
 Beam waist size at focus is 9.86753E-002

B. Objective: To perform

(B1) Tolerancing Analysis

(B2) Monte Carlo analysis of the system.

B1: Tolerancing Analysis

Summary of Tolerancing Analysis

Tolerancing analysis yields possible optical designs for an optical system by taking into consideration the effect of de-centering, tilting, etc., which allows the optical designers to make optical systems efficiently by forecasting the effect of misalignment, etc. on the final image.

The present project involves a spherically corrected 25 mm focal length f/2.0 objective. Tolerancing analysis was performed on this system in sensitivity mode at test wavelength of 632.8 nm, which corresponds to He-Ne laser. The criteria set for this analysis was RMS spot size.

The analysis suggests the possible changes in alignment of the lenses (tolerances corresponding to de-center X and de-center Y, TIRX, TIRY, TSDX, TSDY, Irregularities of surfaces in fringes, Index tolerance and Abbe tolerance). It also includes the possible combinations of misalignments that will result in worst result. The tolerancing analysis shows that the optical components of the system are sensitive to tilt and de-center types of misalignment. It shows the estimated performance changes based on Root-Sum-Square method as:

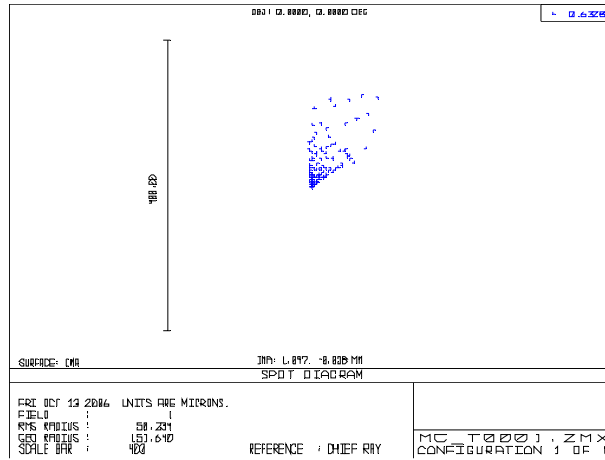
Nominal RMS spot radius	: 0.039544
Estimated change	: 0.022977
Estimated RMS spot radius	: 0.062522

The analysis also outlines the changes that can be made to back focus as:

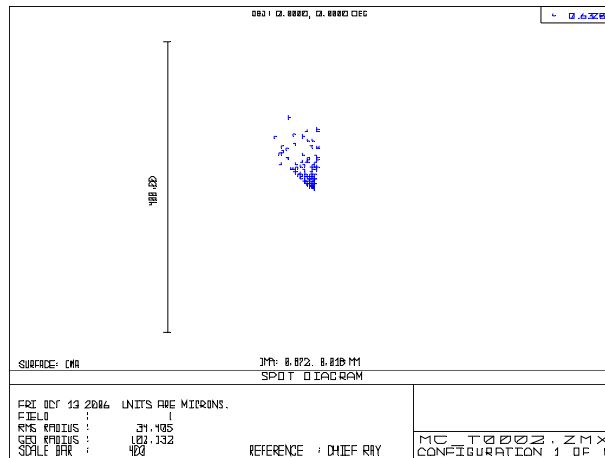
Minimum	: -0.398327
Maximum	: 0.409846
Mean	: 0.000144
Standard Deviation	: 0.103466

Spot diagrams (dithered ray pattern) from Monte Carlo Analysis

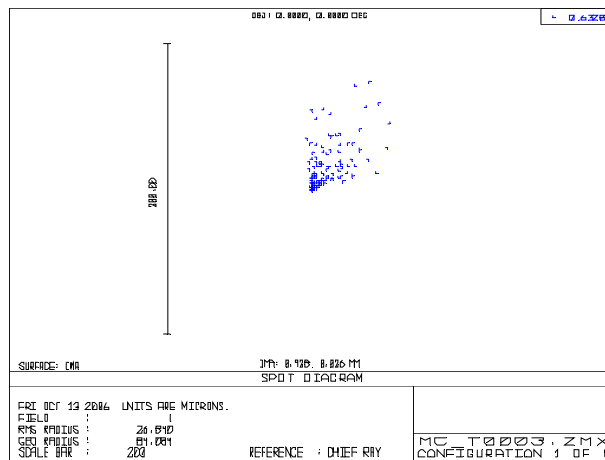
1) Spot diagram 1 (RMS spot size: 50.234 microns)



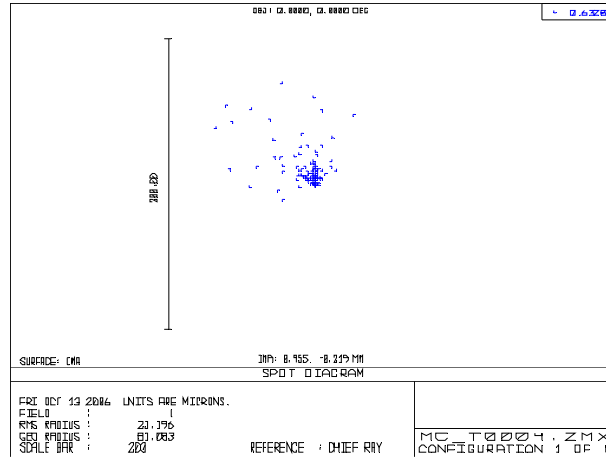
2) Spot diagram 2 (RMS spot size: 34.405 microns)



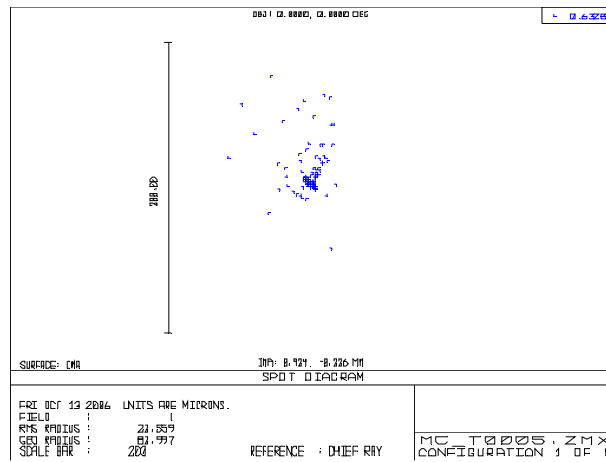
3) Spot diagram 3 (RMS spot size: 26.840 microns)



4) Spot diagram 4 (RMS spot size: 23.196 microns)



5) Spot diagram 5 (RMS spot size: 22.559 microns)



The type of the aberration is found to be mostly spherical aberration and it appears to be the most troublesome for this optical system. Hence, I do **not** recommend this optical system for tightly focusing a laser beam. The focused spot appears like a scattered V-shape in most of the cases.

Summary of Tolerancing Analysis

Tolerancing analysis yields possible optical designs for an optical system by taking into consideration the effect of de-centering, tilting, etc., which allows the optical designers to make optical systems efficiently by forecasting the effect of misalignment, etc. on the final image.

The present project involves a spherically corrected 25 mm focal length f/2.0 objective. Tolerancing analysis was performed on this system in sensitivity mode at test wavelength of 632.8 nm, which corresponds to He-Ne laser. The criteria set for this analysis was RMS spot size.

The analysis suggests the possible changes in alignment of the lenses (tolerances corresponding to de-center X and de-center Y, TIRX, TIRY, TSDX, TSDY, Irregularities of surfaces in fringes, Index tolerance and Abbe tolerance). It also includes the possible combinations of misalignments that will result in worst result. The tolerancing analysis shows that the optical components of the system are sensitive to tilt and de-center types of misalignment. It shows the estimated performance changes based on Root-Sum-Square method as:

Nominal RMS spot radius	: 0.039544
Estimated change	: 0.022977
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The analysis also outlines the changes that can be made to back focus as:

Minimum	: -0.398327
Maximum	: 0.409846
Mean	: 0.000144
Standard Deviation	: 0.103466