Demonstrating optical aberrations in the laboratory

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[2] School of Physics, University of KwaZulu-Natal

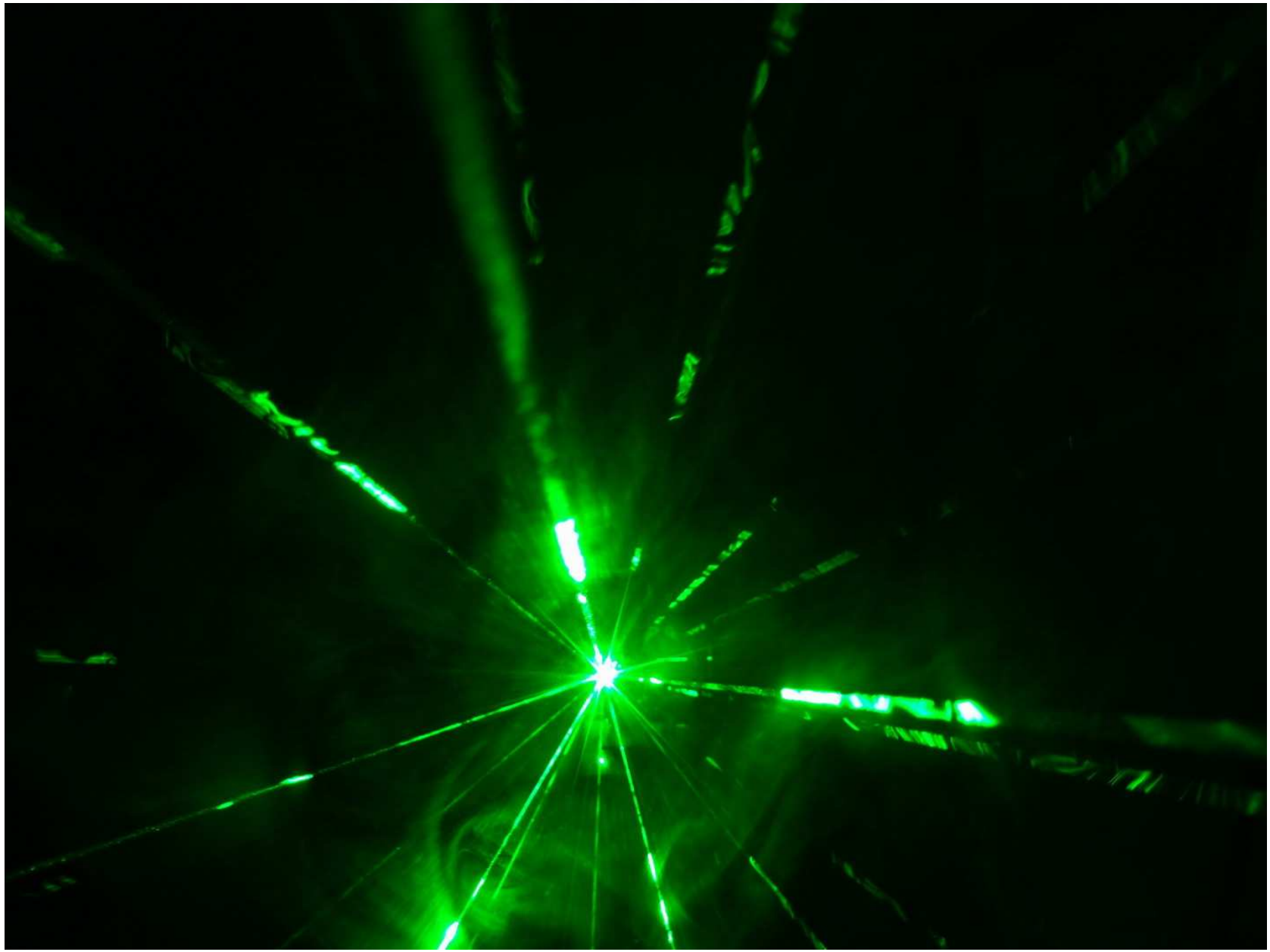
our future through science

OPTICAL ABERRATIONS

AN OPTICAL ABERRATION IS A DISTORTION OF AN IMAGE AS COMPARED TO THE OBJECT DUE TO DEFECTS IN AN OPTICAL SYSTEM

TILT IS THE DEVIATION OF A LASER BEAM OFF THE OPTICAL AXIS

OPTICAL ABERRATIONS



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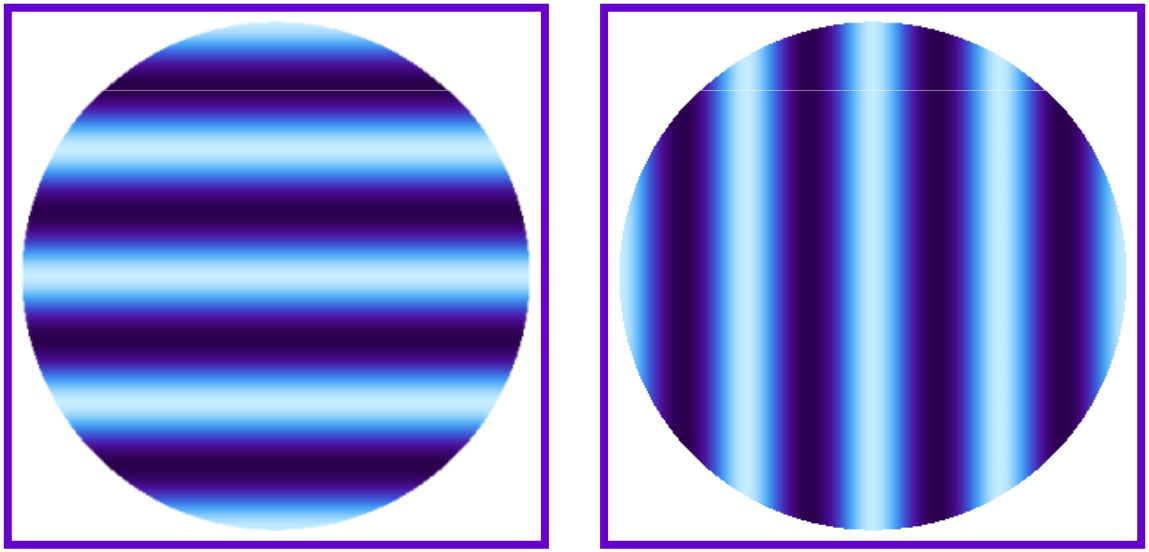
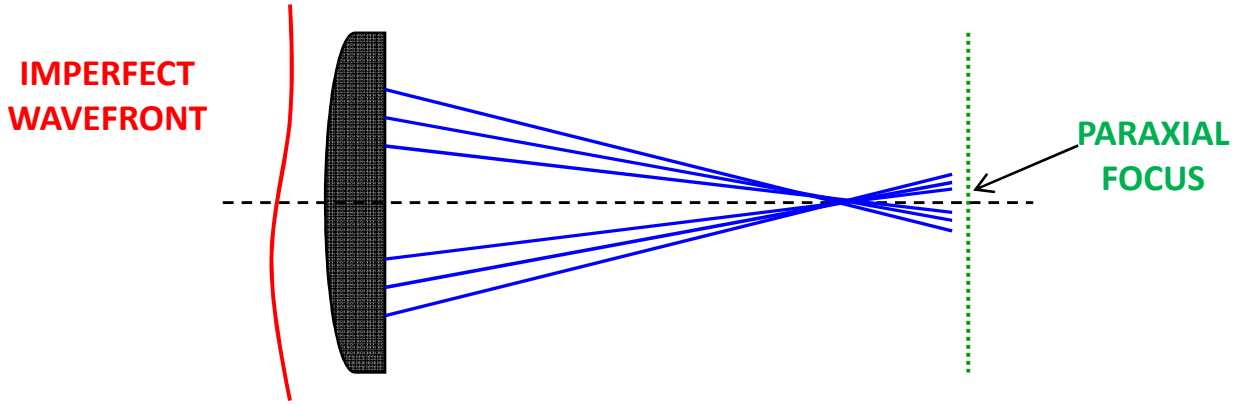


OPTICAL ABERRATIONS…

DEFOCUS

OCCURS WHEN AN IMPERFECT WAVEFRONT IS **FOCUSED** TO A POINT THAT IS EITHER BEFORE OR AFTER THE PARAXIAL FOCUS



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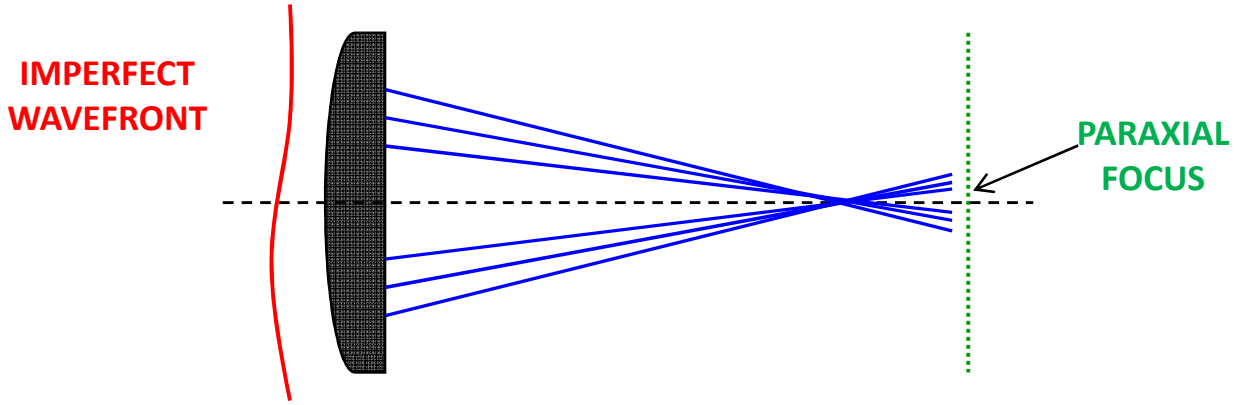
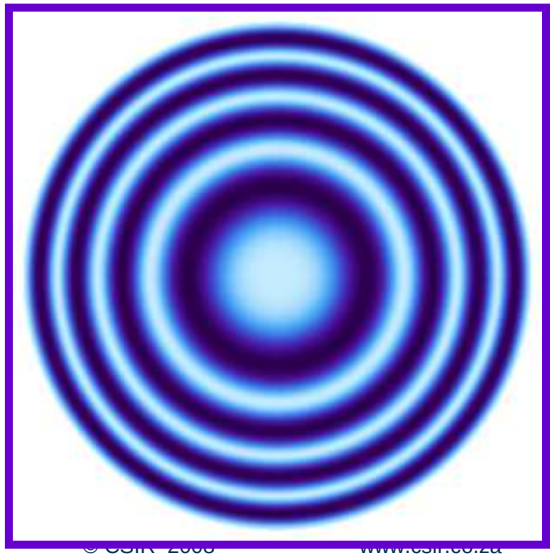
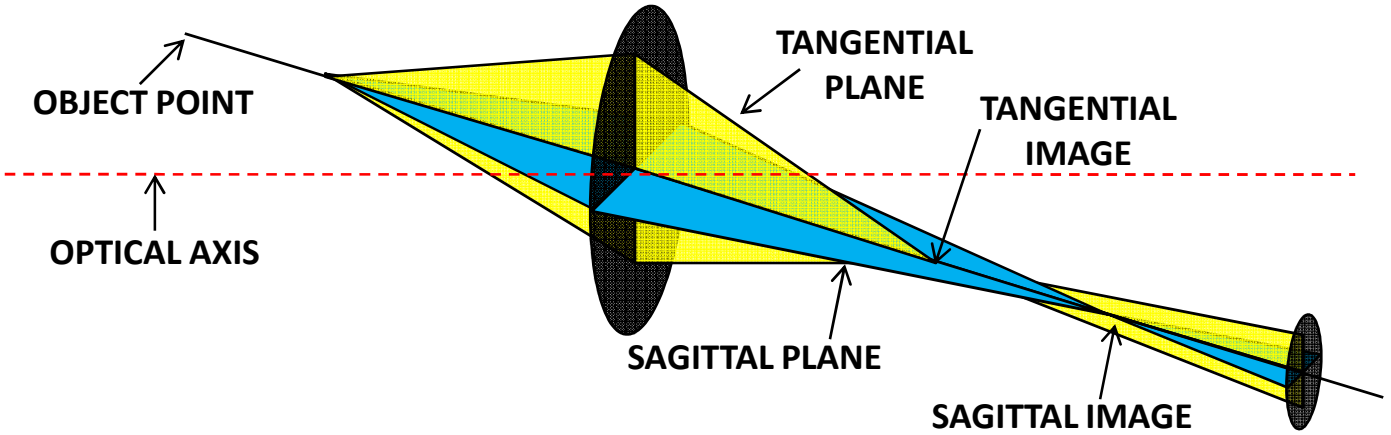




OPTICAL ABERRATIONS…

ASTIGMATISM

ARISES WHEN THE TANGENTIAL AND SAGITTAL FOCI DO NOT COINCIDE AND THE SYSTEM APPEARS TO HAVE **2** POINTS OF FOCUS



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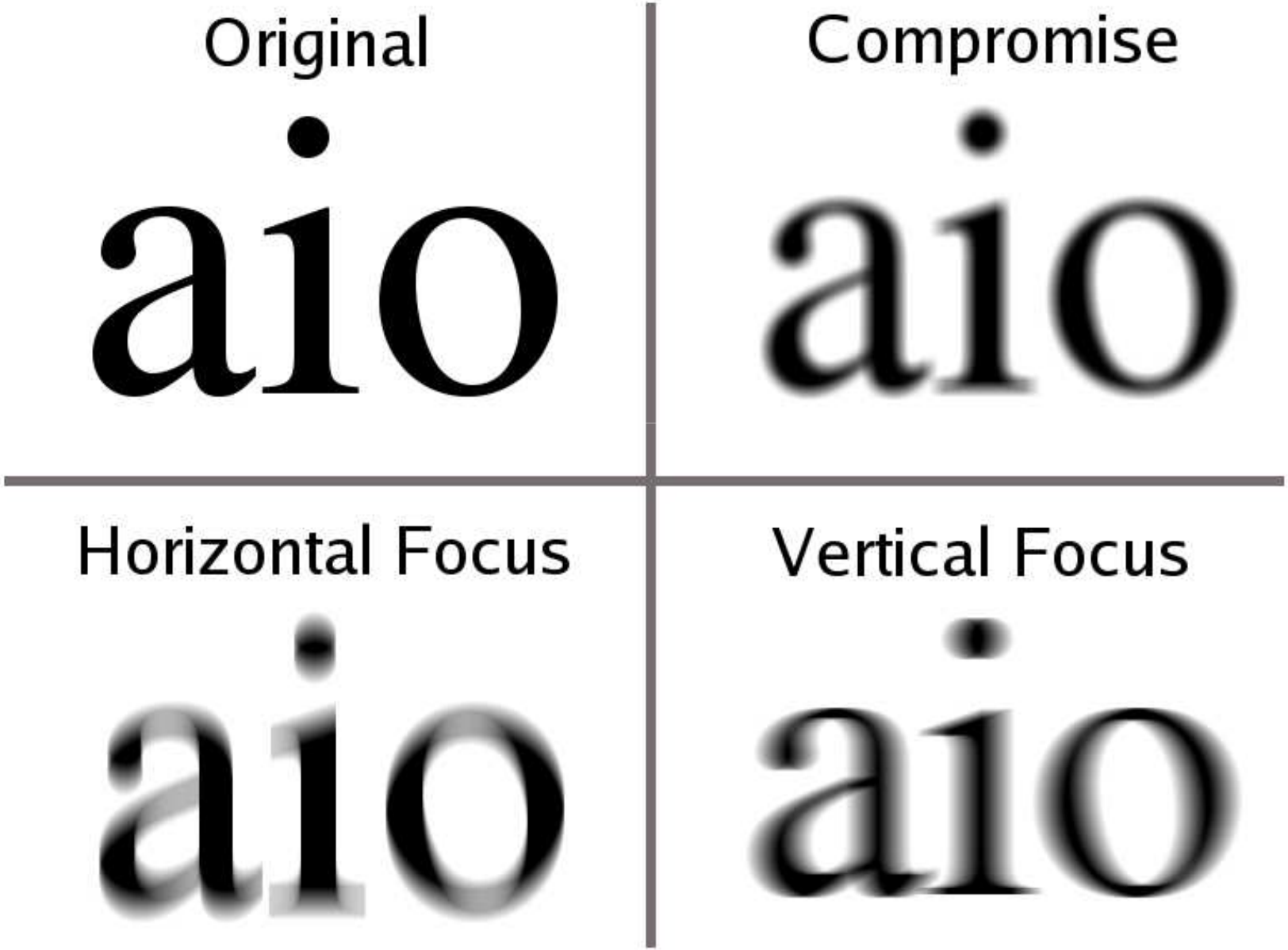

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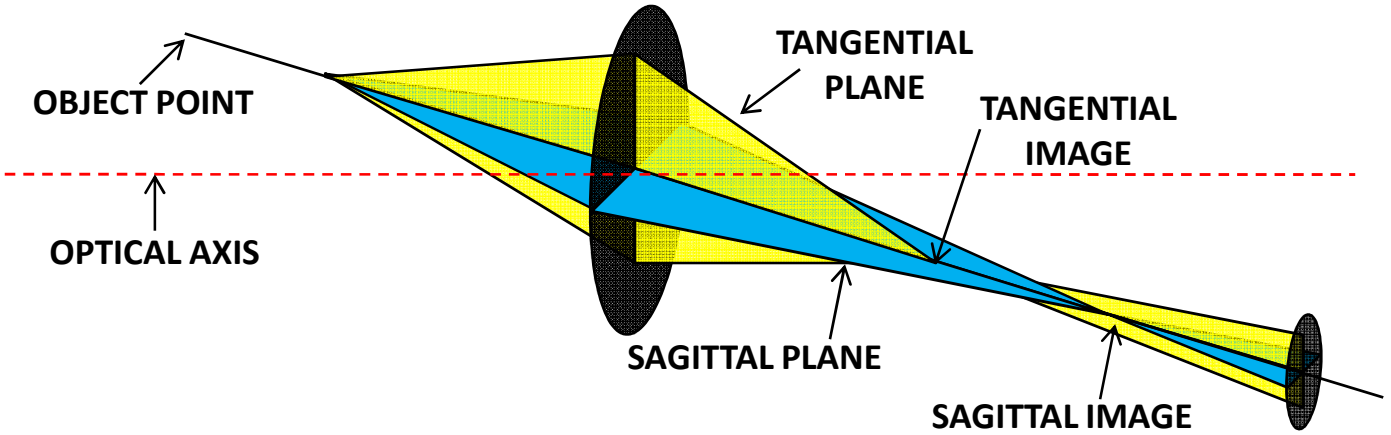

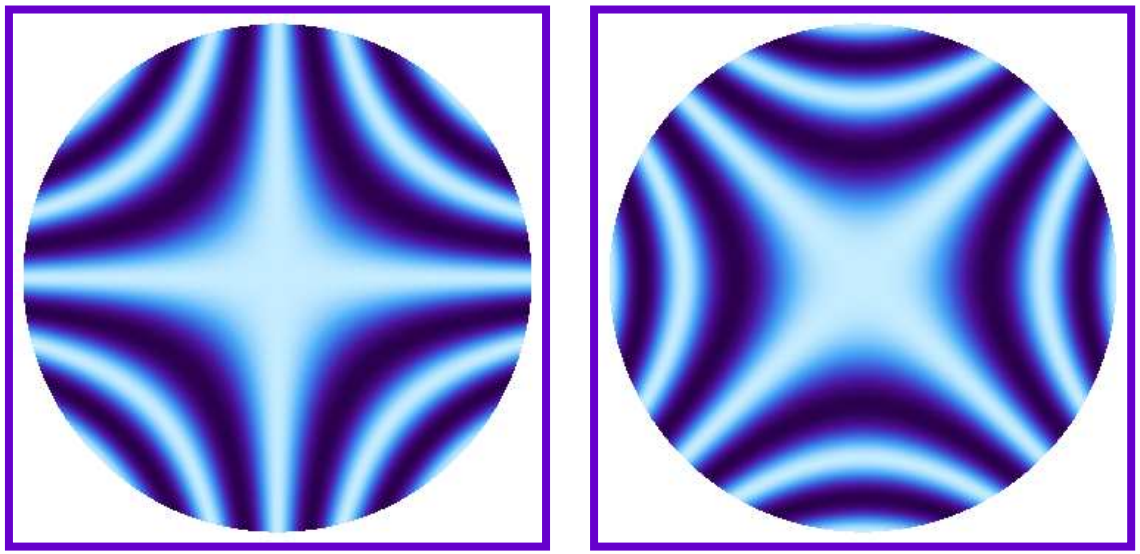

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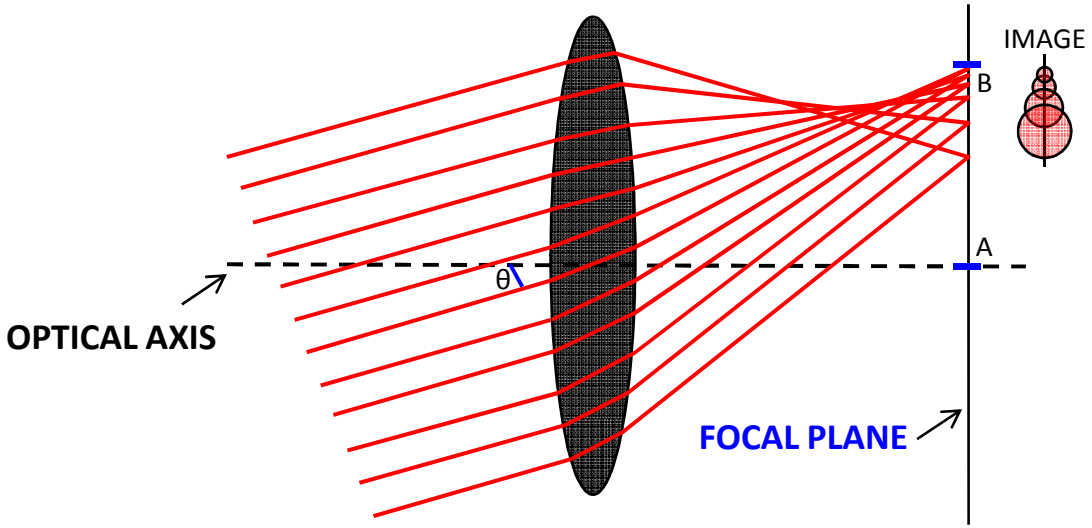
COMA

COMA IS PRODUCED WHEN A WAVEFRONT FROM AN OFF-AXIS OBJECT POINT ARE IMAGED BY DIFFERENT ZONES OF THE LENS



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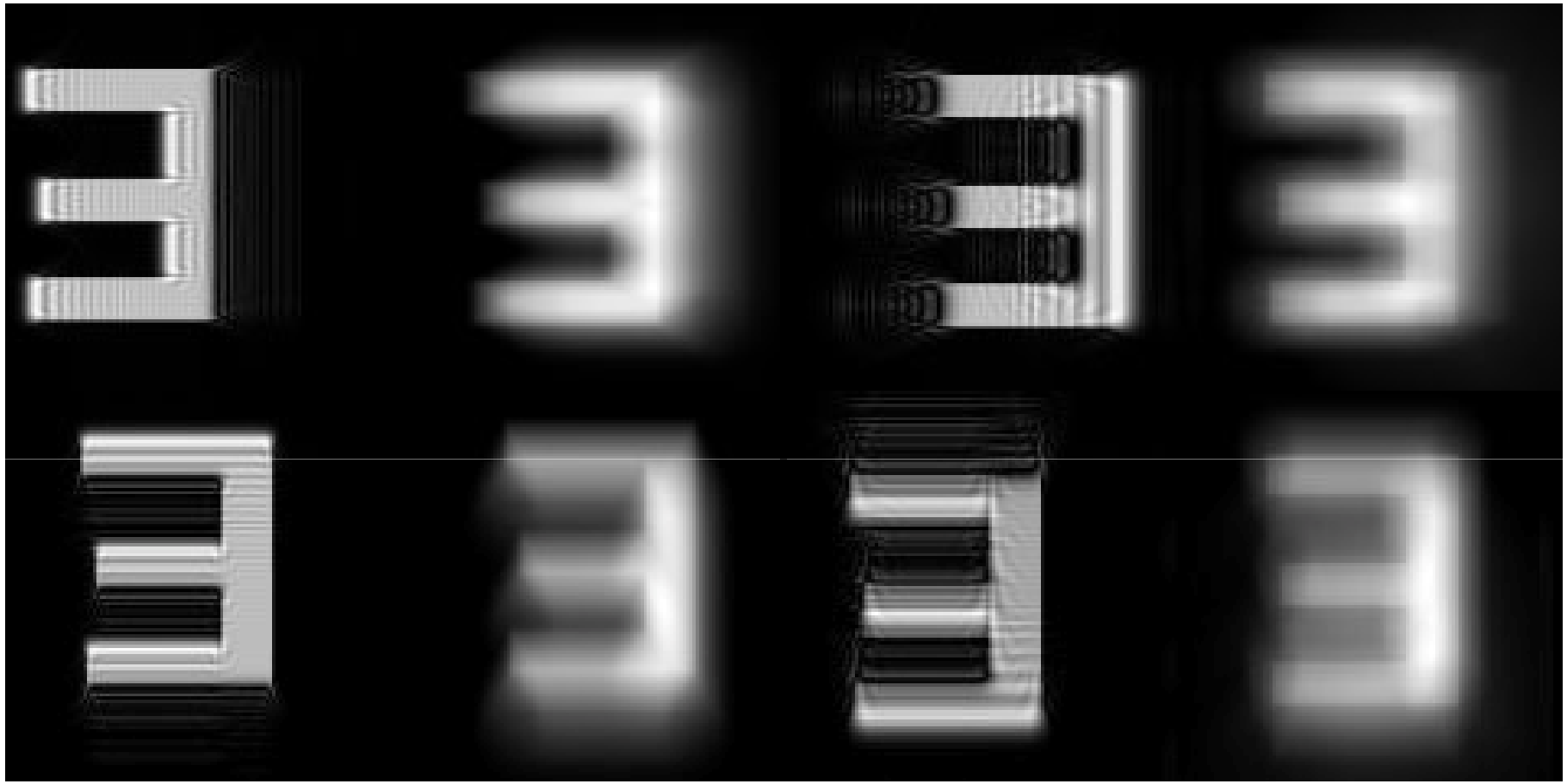

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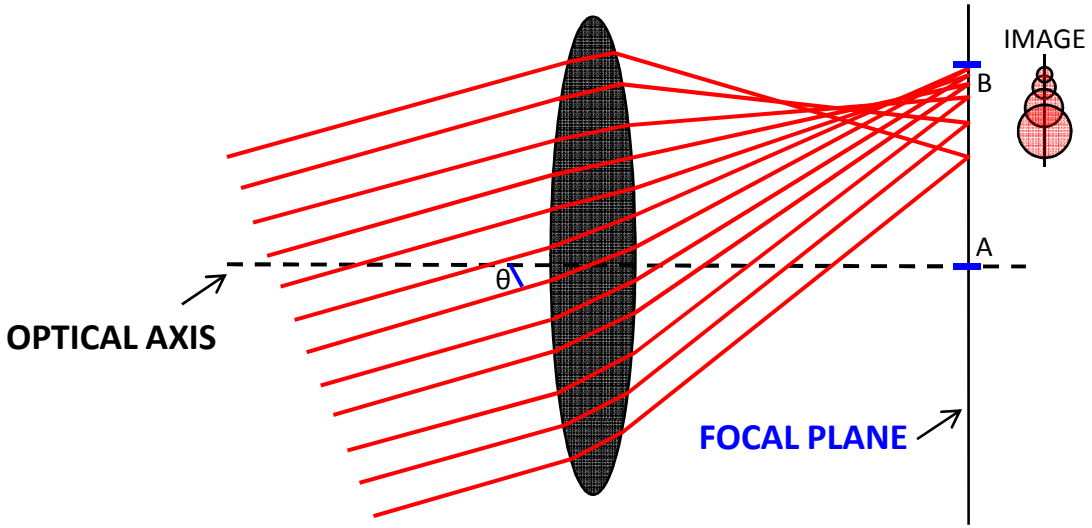
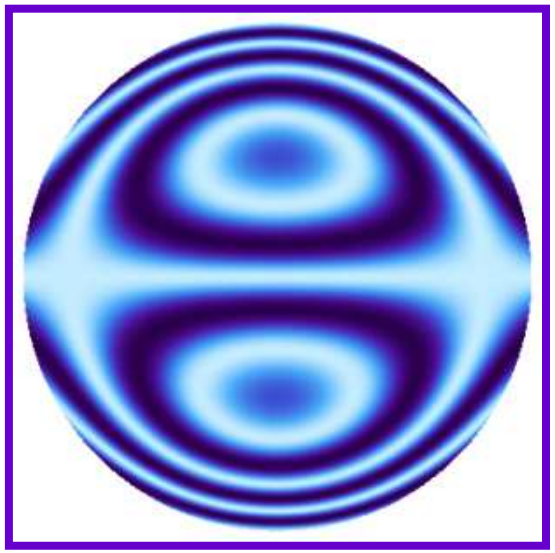
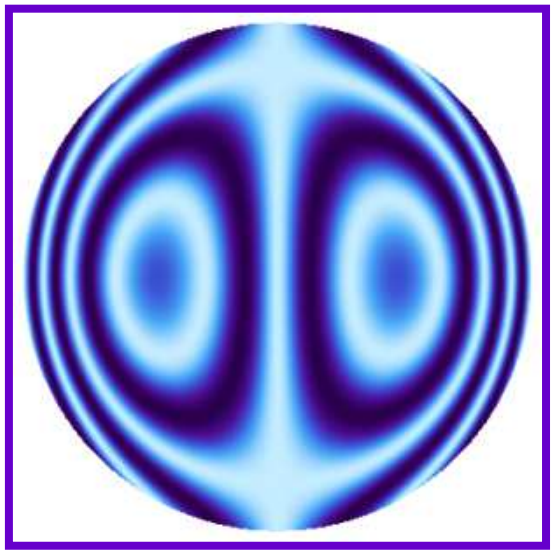


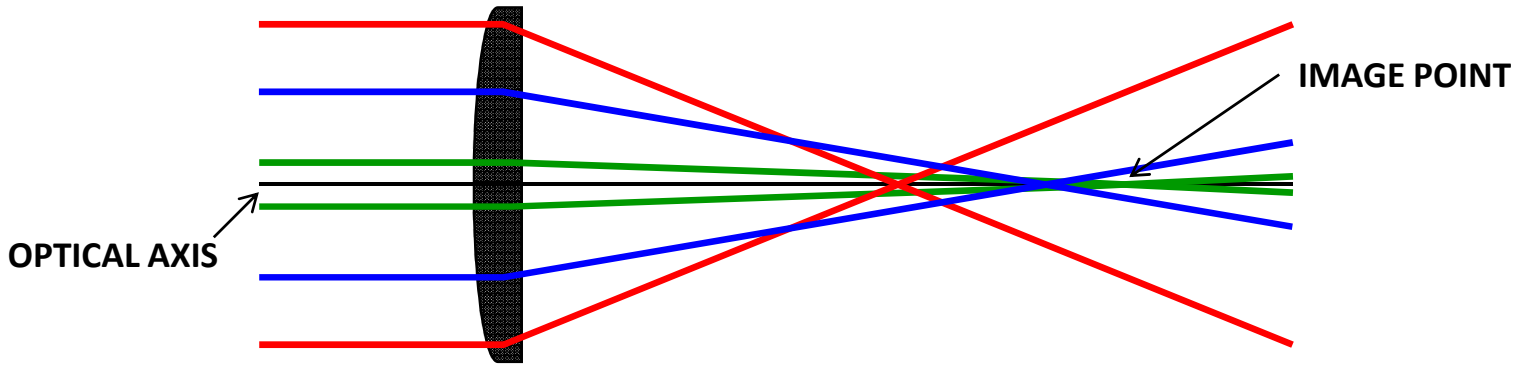




OPTICAL ABERRATIONS…

SPHERICAL ABERRATION

SPHERICAL ABERRATION IS A DEVIATION OF THE LASER WAVEFRONT FROM AN IDEAL SPHERICAL SHAPE



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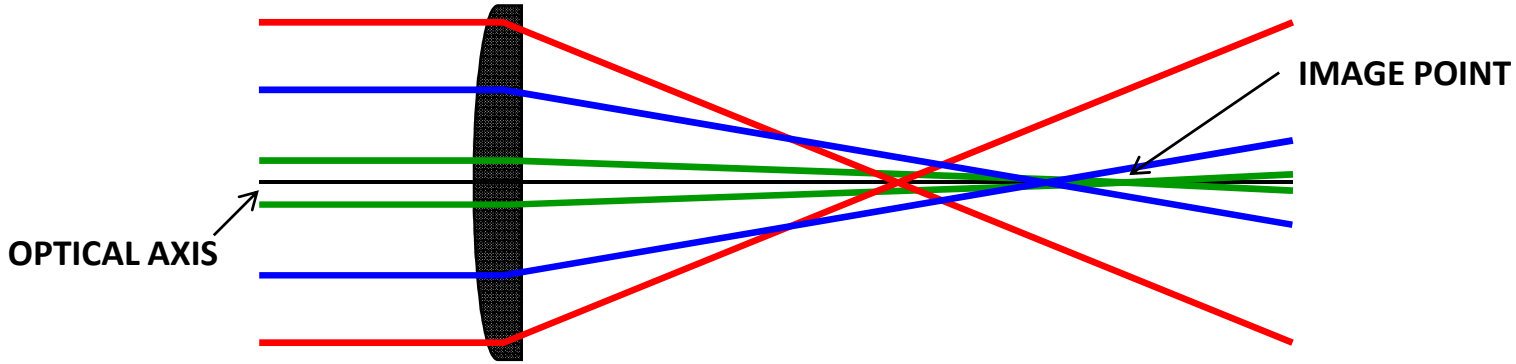
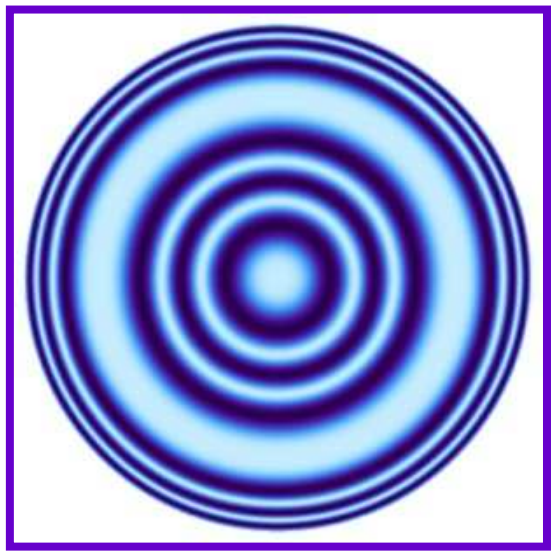




ZERNIKE POLYNOMIALS

ZERNIKE POLYNOMIALS ARE AN **ORTHOGONAL** SET

EACH POLYNOMIAL HAS AN ASSOCIATED **WEIGHTING** COEFFICIENT

$$Z_n^m(r,\theta) = R_n^m(r)e^{im\theta}$$

$$Z_n^m(r,\theta) = \underbrace{R_n^m(r)\cos(m\theta)}_{\text{EVEN}} + \underbrace{iR_n^m(r)\sin(m\theta)}_{\text{ODD}}$$

ABERRATION PHASE

$$\Phi(r,\theta) = \sum_{n=0}^{\infty}\sum_{m=0}^{n}[A_n^m R_n^m(r)\cos(m\theta) + B_n^m R_n^m(r)\sin(m\theta)]$$

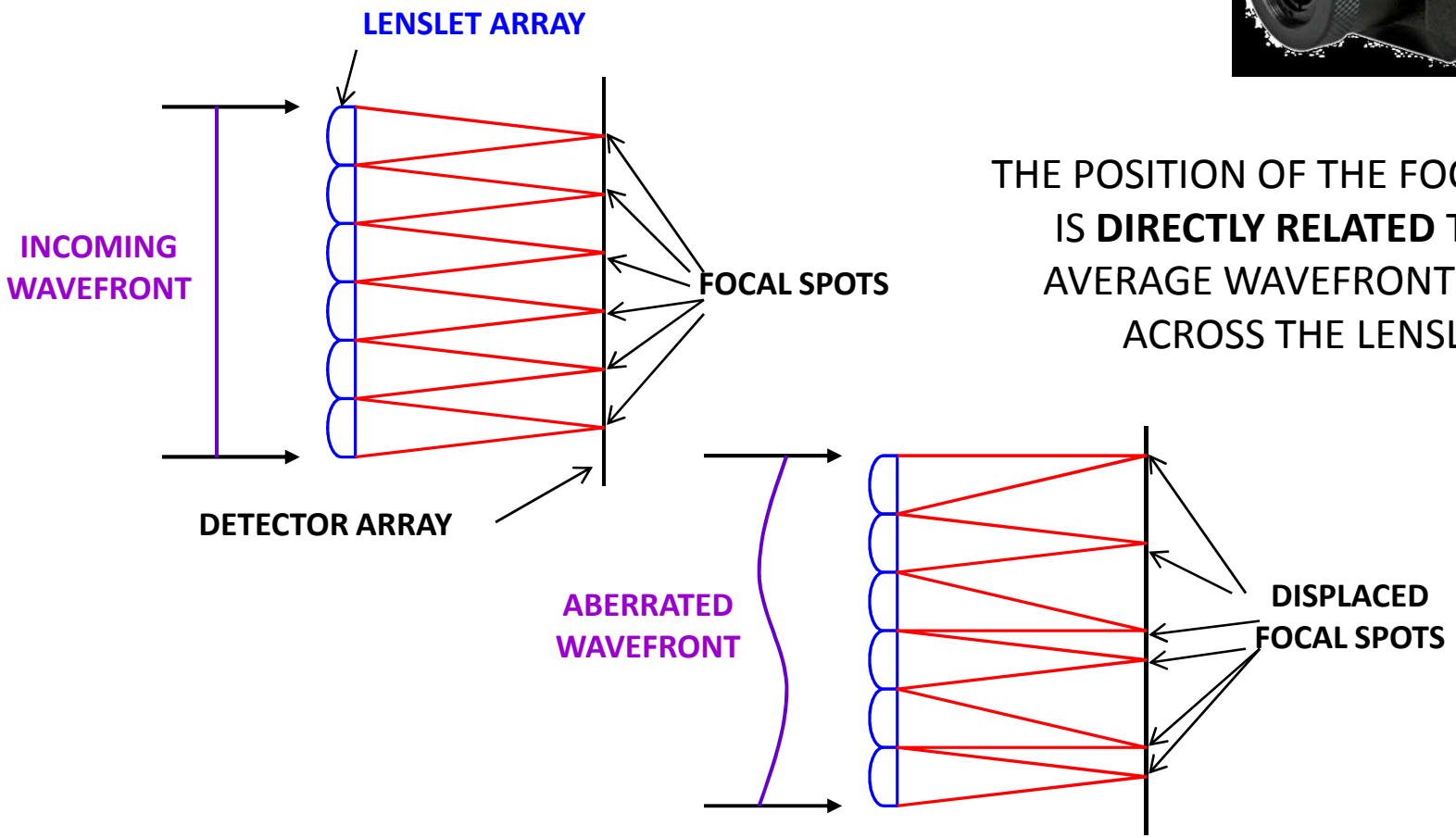
ODD WEIGHTING COEFFICIENT

EVEN WEIGHTING COEFFICIENT

ZERNIKE POLYNOMIALS ARE FITTED TO 3-DIMENSIONAL DATA TO **DESCRIBE** THE ABERRATIONS OF WAVEFRONT MEASUREMENTS

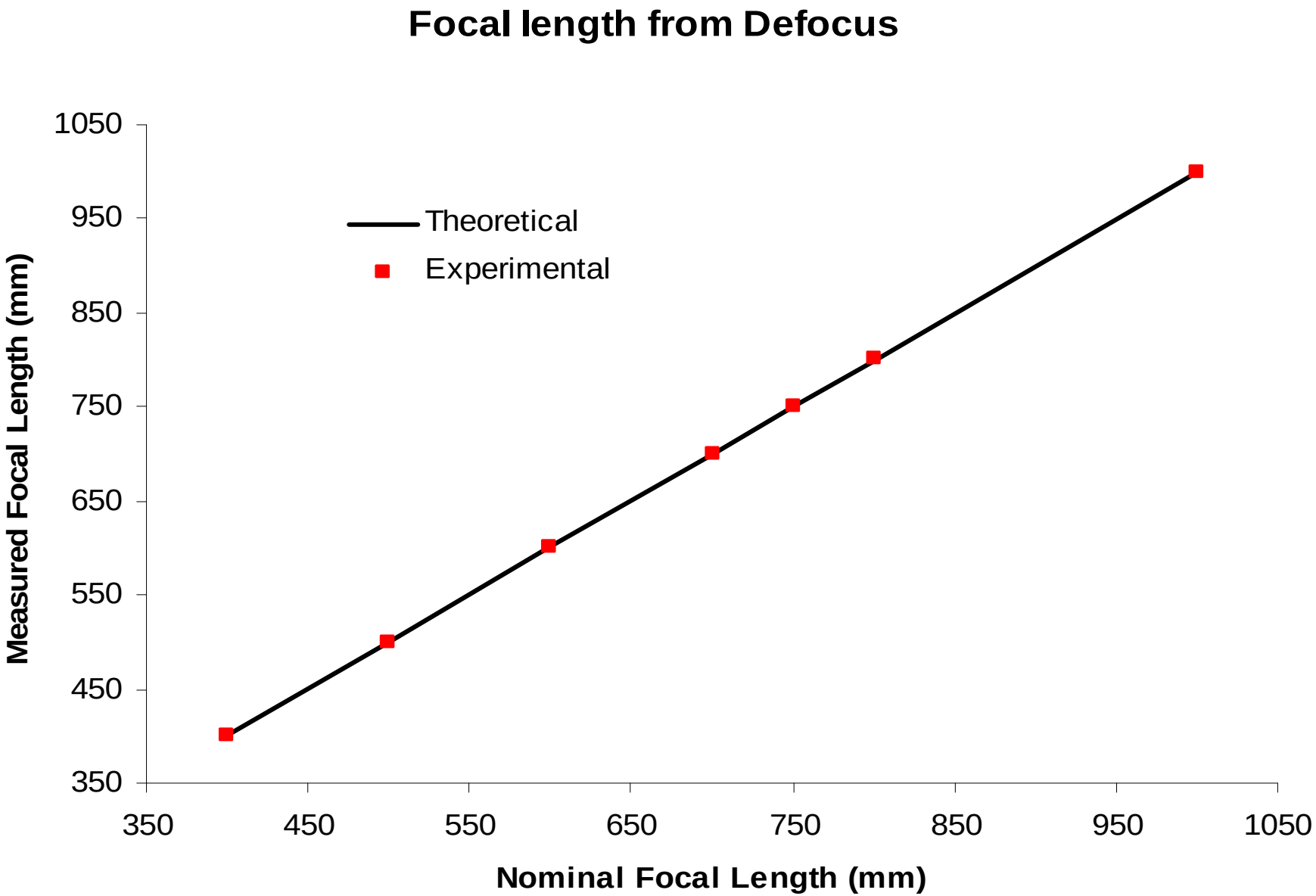
SHACK-HARTMANN WAVEFRONT SENSOR

IMPORTANT ELEMENTS OF DESIGN INCLUDE A LENSLET ARRAY AND A POSITION-SENSING DETECTOR



THE POSITION OF THE FOCAL SPOTS IS **DIRECTLY RELATED** TO THE AVERAGE WAVEFRONT SLOPE ACROSS THE LENSLET

DEMONSTRATING OPTICAL ABERRATIONS



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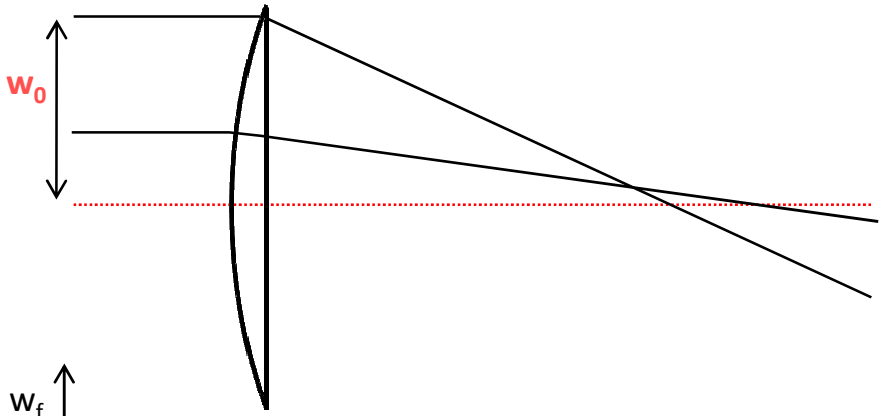
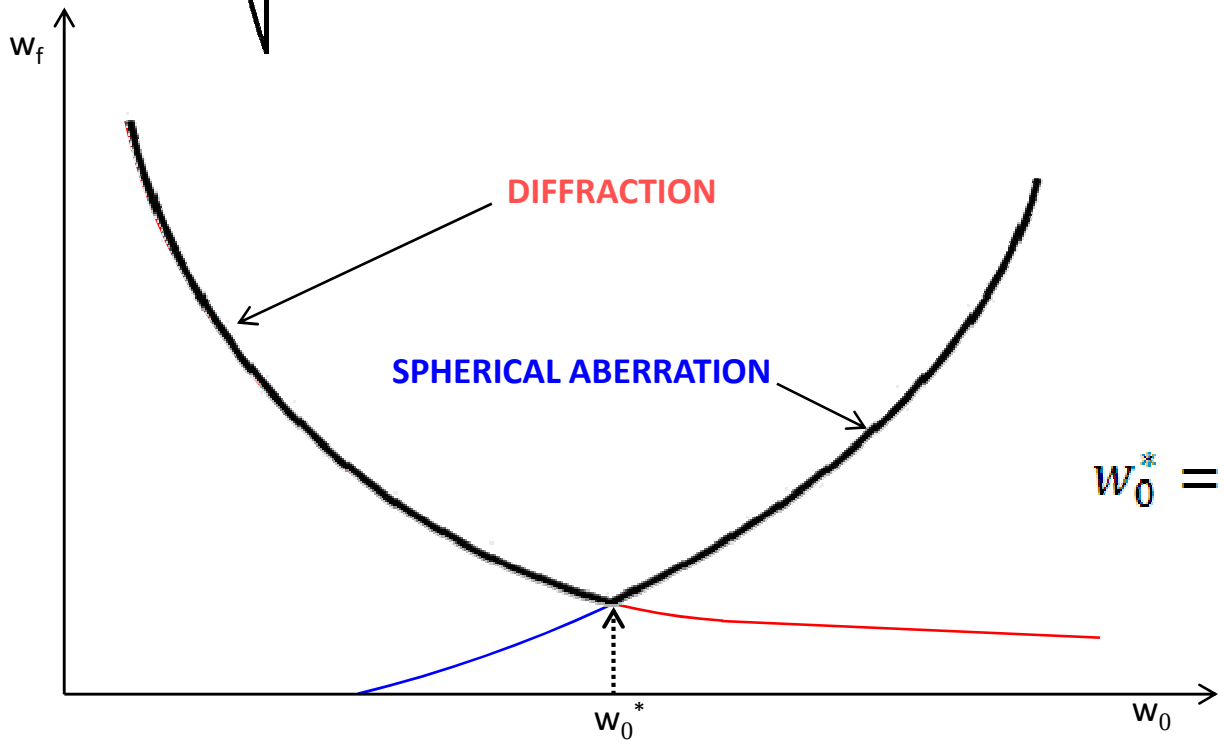


DUE TO DIFFRACTION

$$w_f = \frac{4kw_0^3}{f^2}$$

DUE TO SPHERICAL ABERRATION

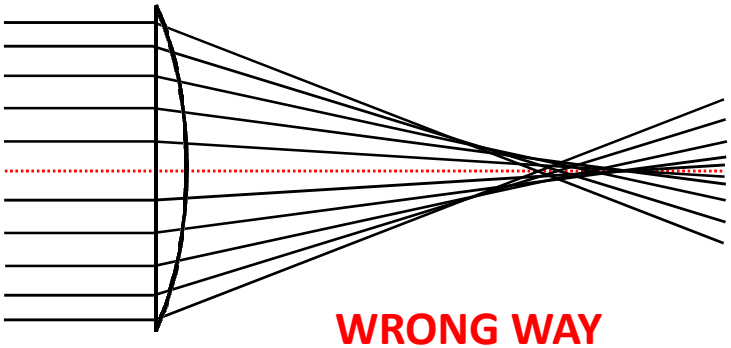
$$w_f = \frac{M^2\lambda f}{\pi w_0}$$



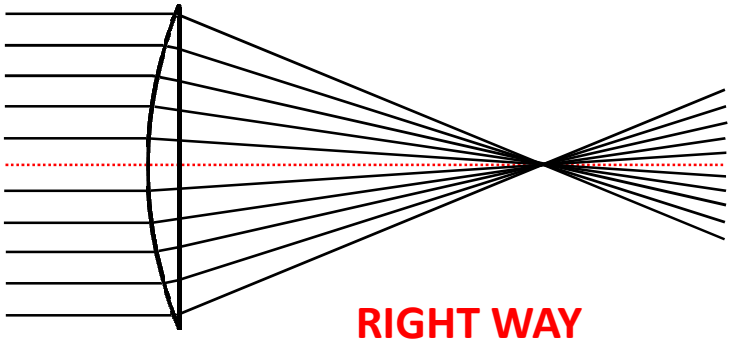
$$w_0^* = \left(\frac{M^2\lambda f^3}{4\pi k}\right)^{1/4}$$

DEMONSTRATING OPTICAL ABERRATIONS

LENS QUALITY



WRONG WAY



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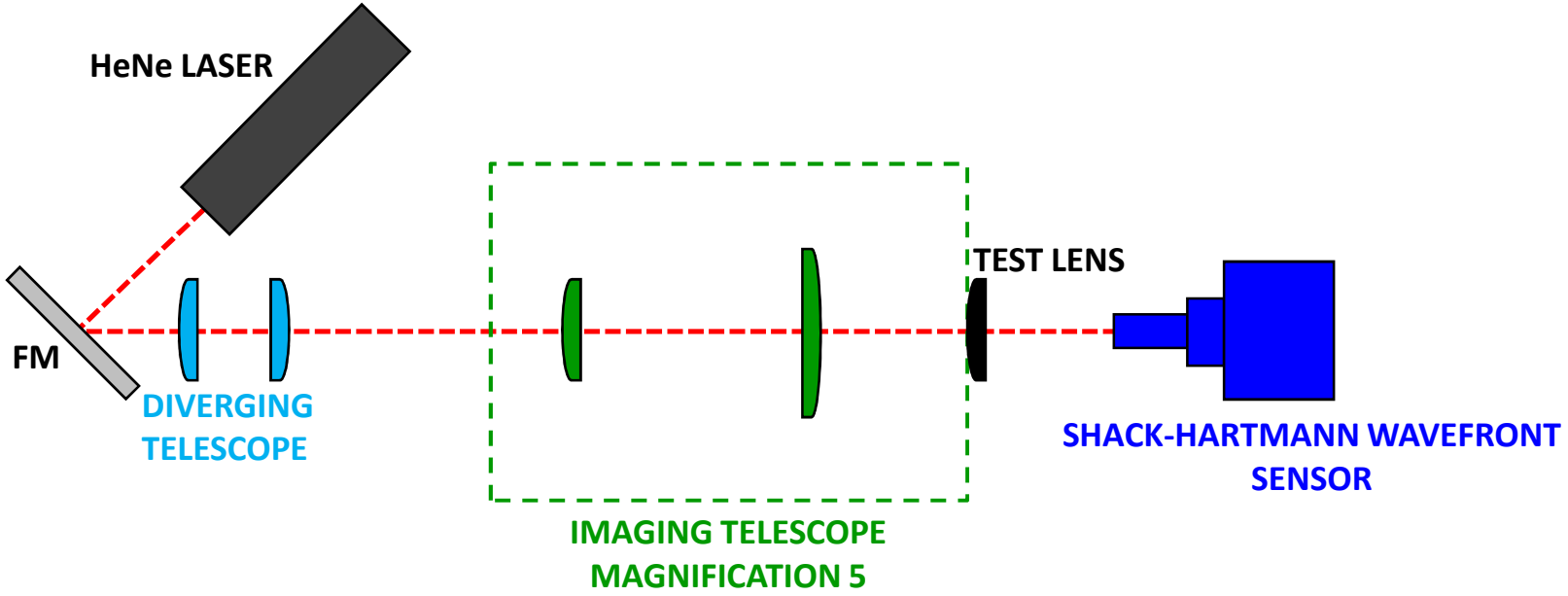

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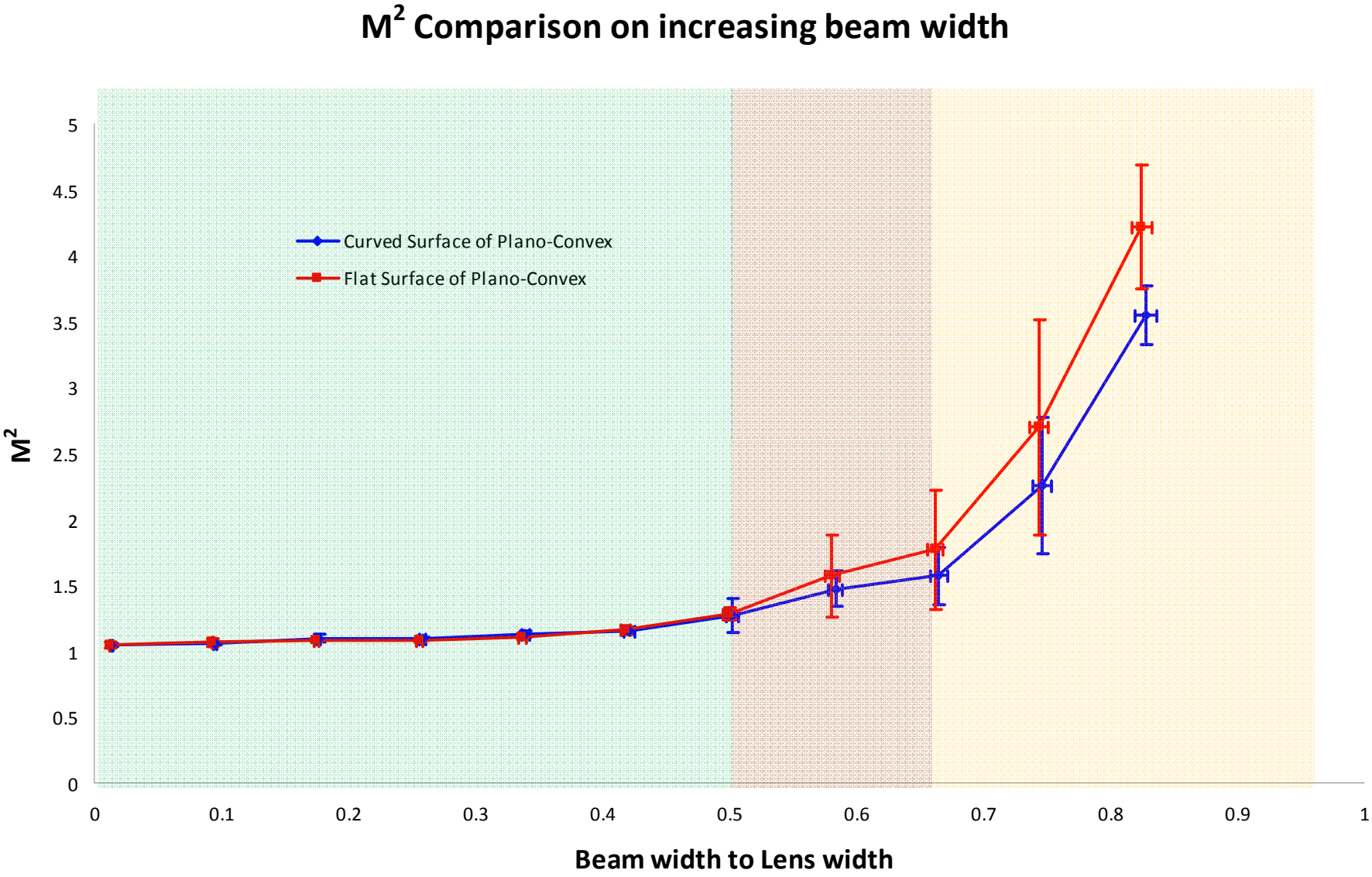

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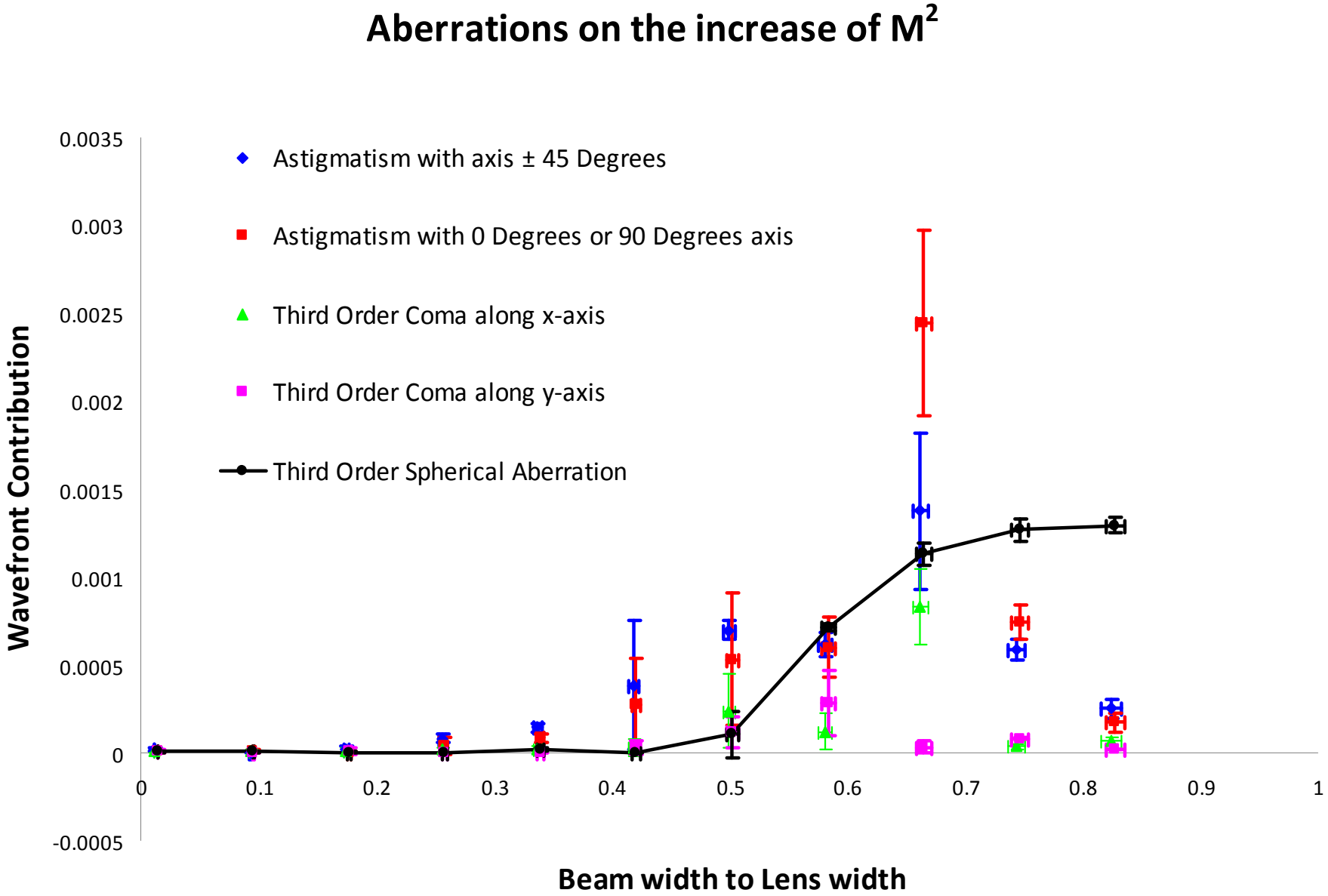
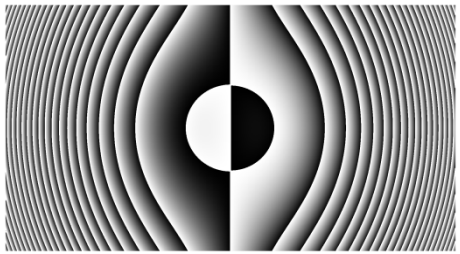


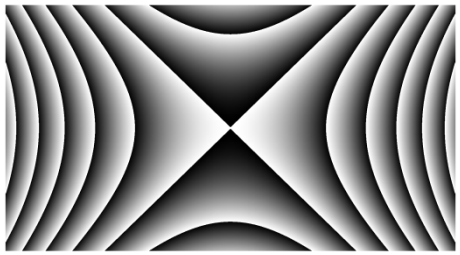
DEMONSTRATING OPTICAL ABERRATIONS…

SPATIAL LIGHT MODULATOR

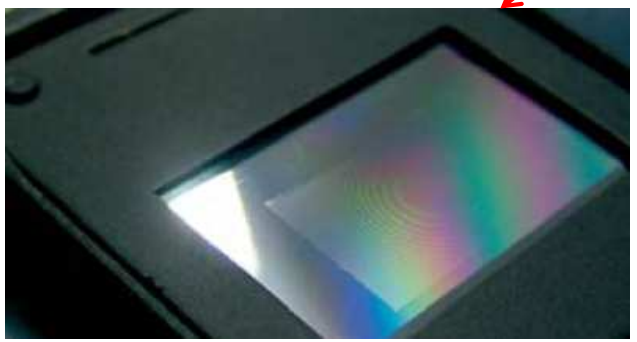
COMA



ASTIGMATISM

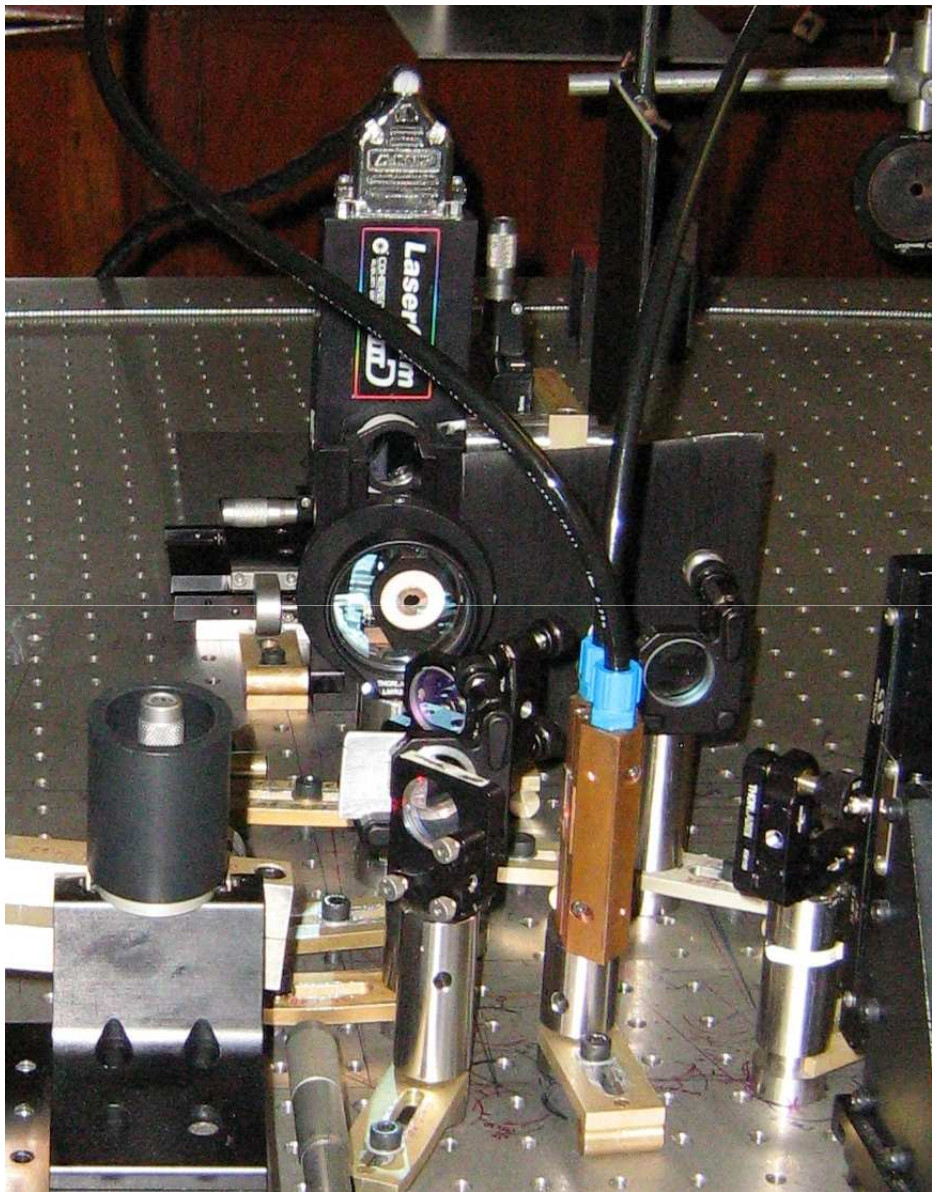


DEFOCUS



DEMONSTRATING OPTICAL ABERRATIONS…

FUTURE WORK



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