

# **Principles of Temporal Dispersion in Ultra-short Laser Pulse**

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# Presentation Outline

- ❑ Focusing elements for laser beam
- ❑ 1-1 imaging , using singlet lens.
- ❑ Short principles of physical optics propagation @ ZEMAX
- ❑ Conclusions

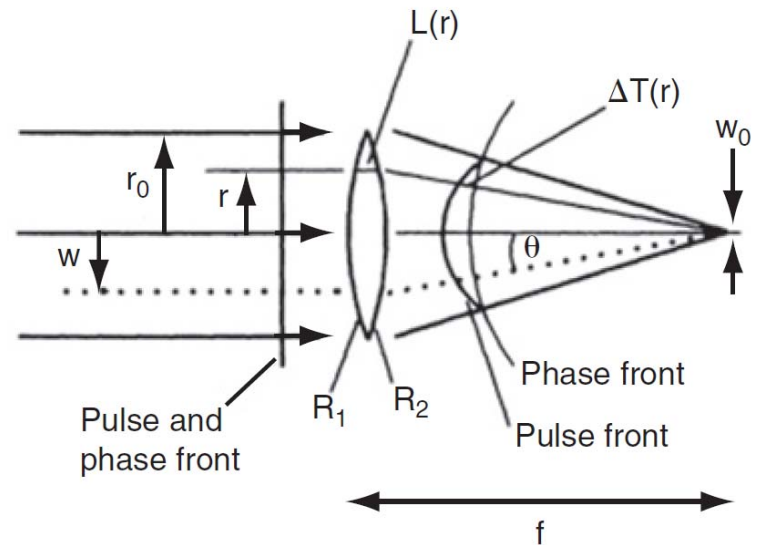
# Focusing Element

The group velocity dispersion leads to reduction of peak intensity by stretching the pulse in time.

When simple focusing singlet lenses are used, the former effect can lead to several picosecond lengthening of the time required to deposit the energy of a fs pulse on focus.

$$\nu_g = \left( \frac{dk}{d\Omega} \right)^{-1} = \frac{c}{n - \lambda_\ell \frac{dn}{d\lambda}} \neq \nu_p = c/n$$

$\lambda_\ell$  : is the wavelength in vacuum.

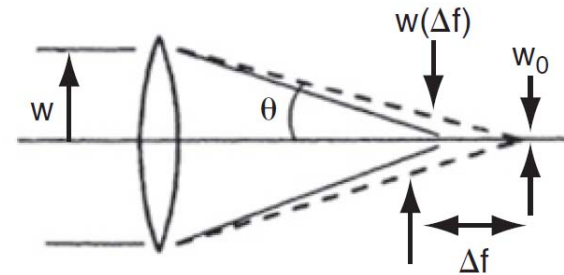
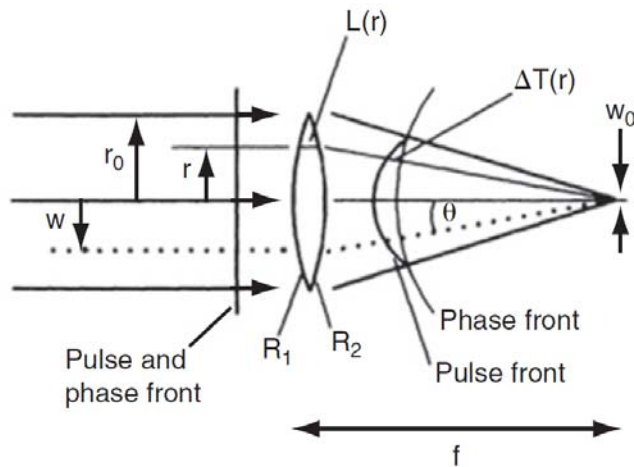


# Singlet Lens, 1:1 imaging

The difference in propagation time between the phase front and pulse front after the lens at the radius coordinate  $r$  is :

$$\Delta T(r) = \left( \frac{1}{\nu_p} - \frac{1}{\nu_g} \right) L(r)$$

$L(r)$  : is the lens thickness.



# Singlet Lens, 1:1 imaging (case study)

## Excimer Laser (KrF):

$T_{\text{pulse}}$  (FWHM) = 50 fs

$w_0 = 0.6 \mu\text{m}$

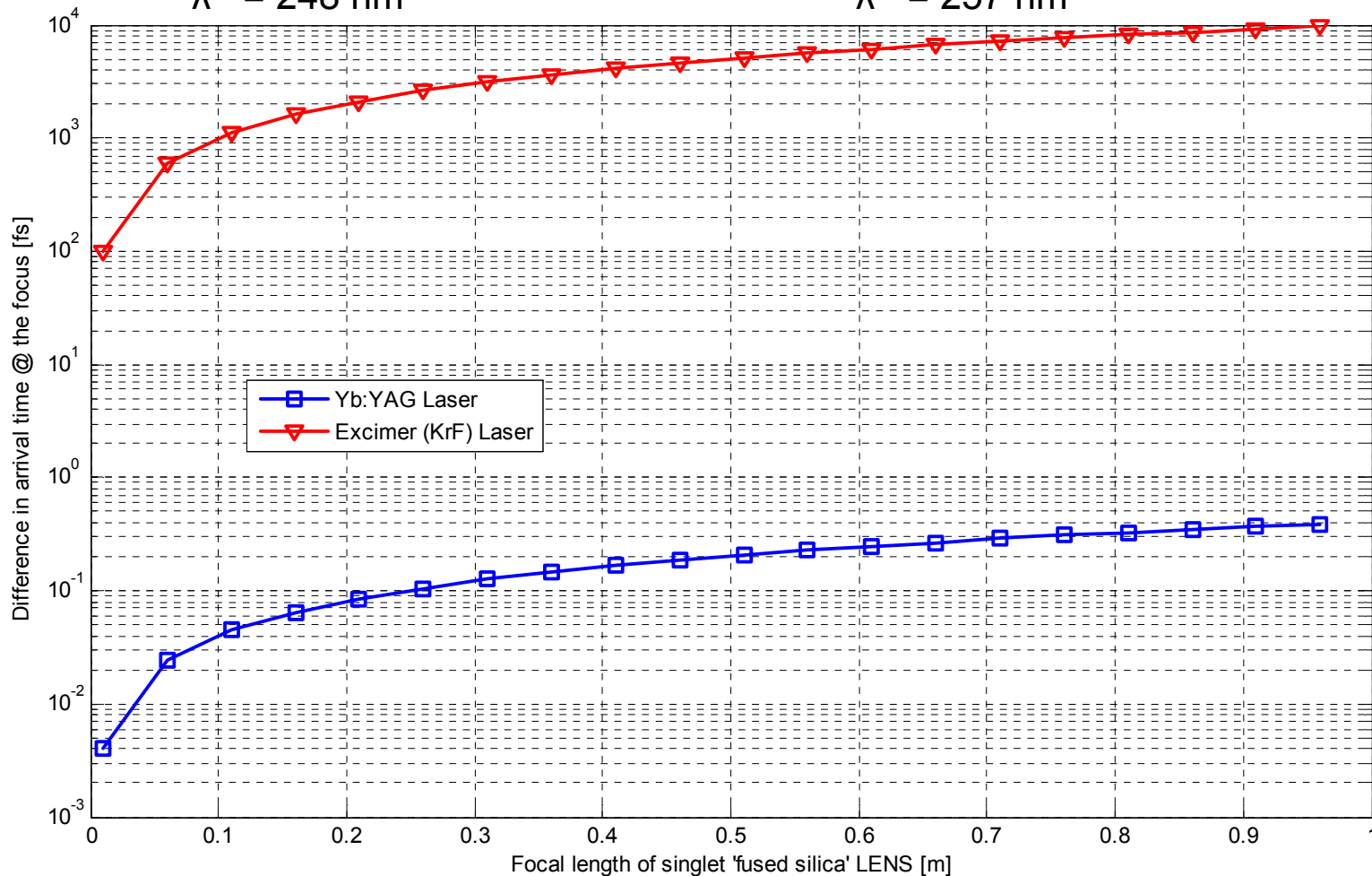
$\lambda = 248 \text{ nm}$

## Yb:YAG Laser:

$T_{\text{pulse}}$  (FWHM) = 20 ps

$w_0 = 100 \mu\text{m}$

$\lambda = 257 \text{ nm}$



# Singlet Lens, 1:1 imaging

## Excimer Laser (KrF):

$T_{\text{pulse}}$  (FWHM) = 50 fs

$w_0 = 0.6 \mu\text{m}$

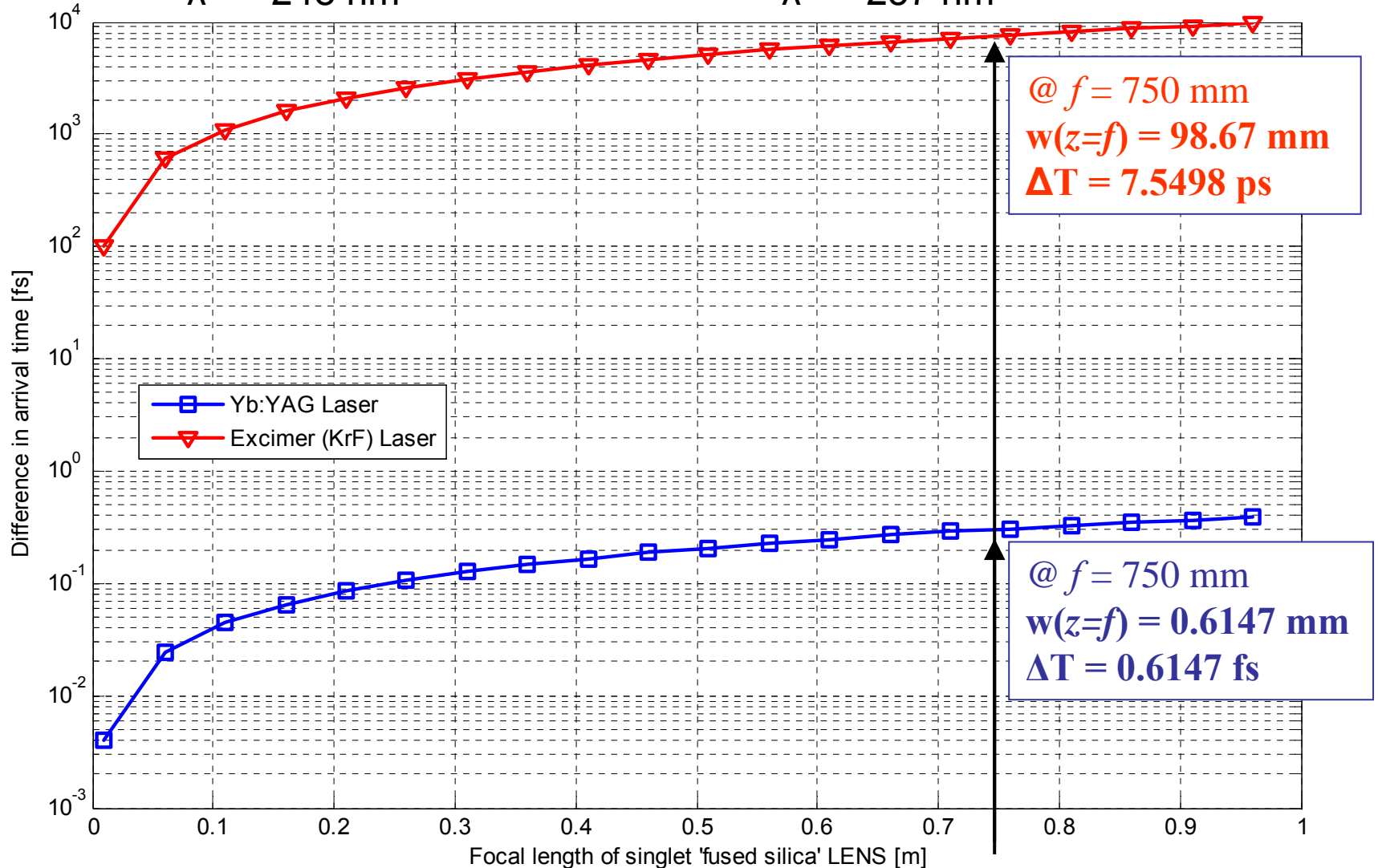
$\lambda = 248 \text{ nm}$

## Ytterbium-doped YAG Laser:

$T_{\text{pulse}}$  (FWHM) = 20 ps

$w_0 = 100 \mu\text{m}$

$\lambda = 257 \text{ nm}$



# Physical Optics Propagation @ ZEMAX

$f = 100 \text{ mm}$

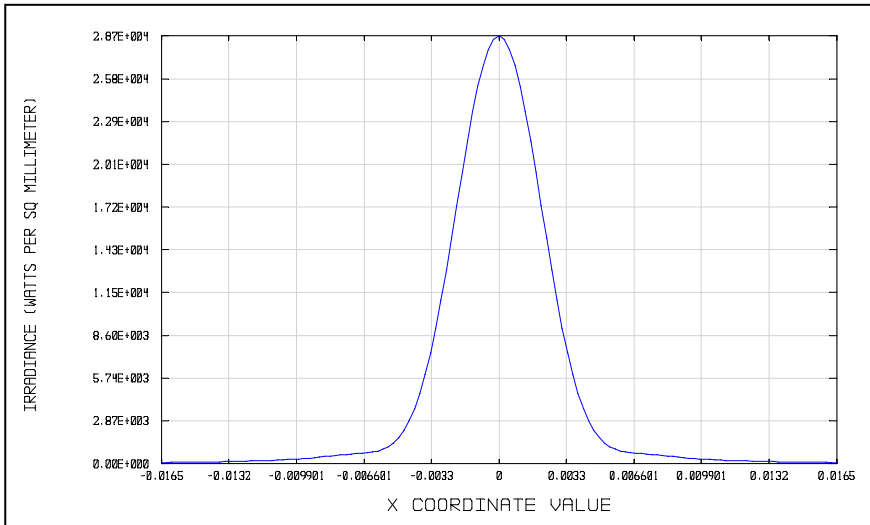
Fused silica lens

Pinhole  
 $\text{Ø} = 6 \mu\text{m}$

Beam type: Gaussian waist

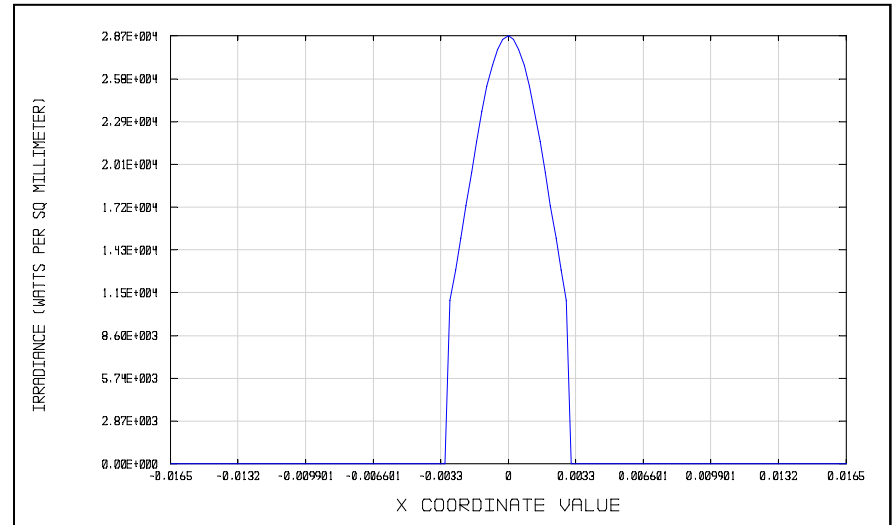
$w_0 = 100 \mu\text{m}$

$\lambda = 257 \text{ nm}$



IRRADIANCE X-CROSS SECTION SURFACE 4 BEFORE PINHOLE

DEMONSTRATES PINHOLE APERTURE CLEANUP OF BEAM  
 MON FEB 8 2010  
 WAVELENGTH 0.25750  $\mu\text{m}$  IN INDEX 1.00000 AT 0.0000 DEG  
 CENTER\_Y = 0.0000E+000  
 PEAK IRRADIANCE = 2.8681E+004 WATTS/MILLIMETERS<sup>2</sup>, TOTAL POWER = 1.0000E+000 WATTS  
 PILOT: SIZE = 2.0518E-003, WAIST = 2.0518E-003, POS = -2.9104E-007, RAYLEIGH = 5.1363E-002



IRRADIANCE X-CROSS SECTION SURFACE 5 AFTER PINHOLE

DEMONSTRATES PINHOLE APERTURE CLEANUP OF BEAM  
 MON FEB 8 2010  
 WAVELENGTH 0.25750  $\mu\text{m}$  IN INDEX 1.00000 AT 0.0000 DEG  
 CENTER\_Y = 0.0000E+000  
 PEAK IRRADIANCE = 2.8681E+004 WATTS/MILLIMETERS<sup>2</sup>, TOTAL POWER = 4.9550E-001 WATTS  
 PILOT: SIZE = 2.7119E-003, WAIST = 2.5606E-003, POS = 2.7899E-002, RAYLEIGH = 7.9994E-002

# Conclusions

$$\nu_g = \left( \frac{dk}{d\Omega} \right)^{-1} = \frac{c}{n - \lambda \frac{dn}{d\lambda}} \neq \nu_p = c/n$$

1. The difference in arrival time of laser pulse in Air is **~ 47fs** per meter  
for **L = 30 m**,  **$\Delta T \sim 1.4$  ps.**
2. The time dispersion in the first lens will accumulate with the next lenses, the relationship will be nonlinear.
3. According to Fermat's principle, the dispersion will increase in case of magnification ( $M_s \neq 1$ ).



**Thank you**