



PETAWATT CLASS UPGRADE AT THE SCARLET LASER FACILITY

R. L. Daskalova
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Outline

- ◆ Brief Overview of 40 TW System
- ◆ XPW Modifications
- ◆ Improvements to Existing Amplifiers



Outline

- ◆ New Stretcher Design
- ◆ Correction of Wavefront
- ◆ Gain Modeling
- ◆ Design of Final Amplifier
- ◆ Dispersion Optimization

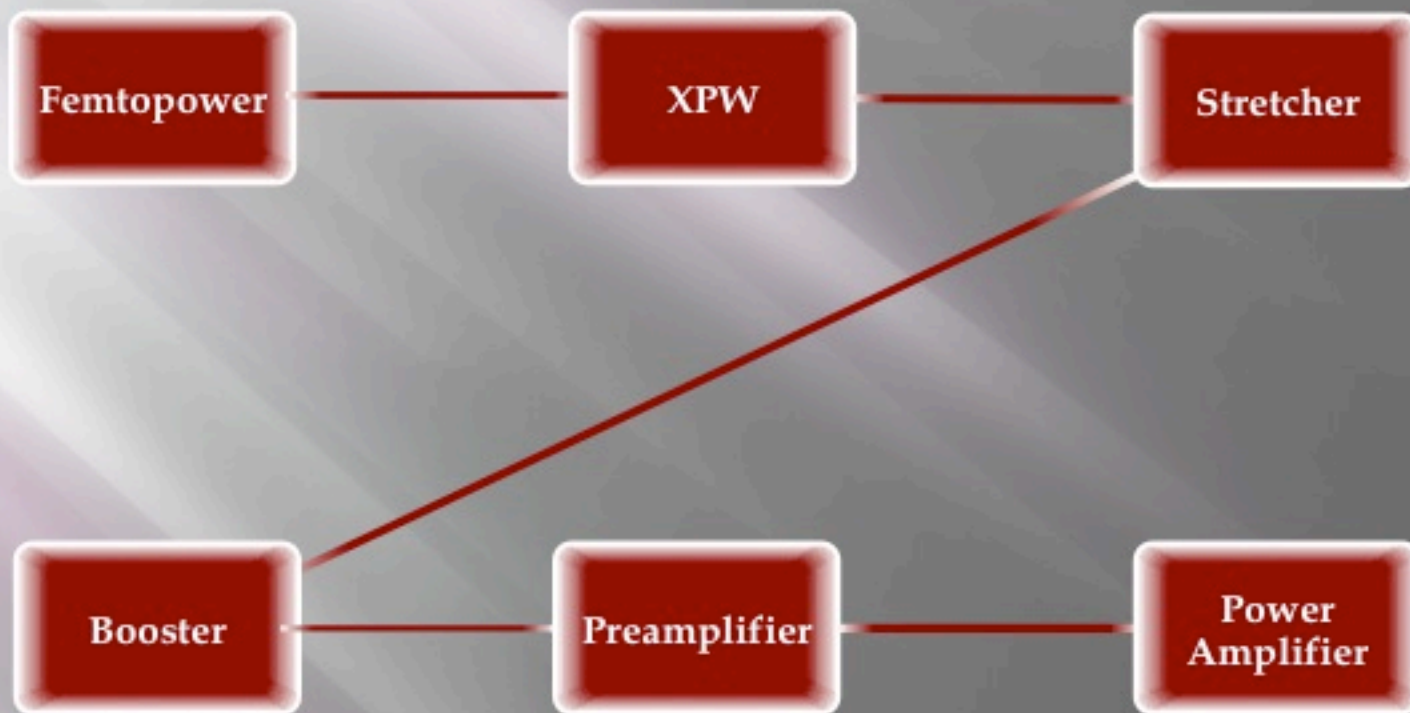


Outline

- ◆ Compressor Design
- ◆ Image Relays
- ◆ Achromat Designs
- ◆ Further Work – After 1st Light



Brief Overview of 40 TW System





Cross-wave Polarization



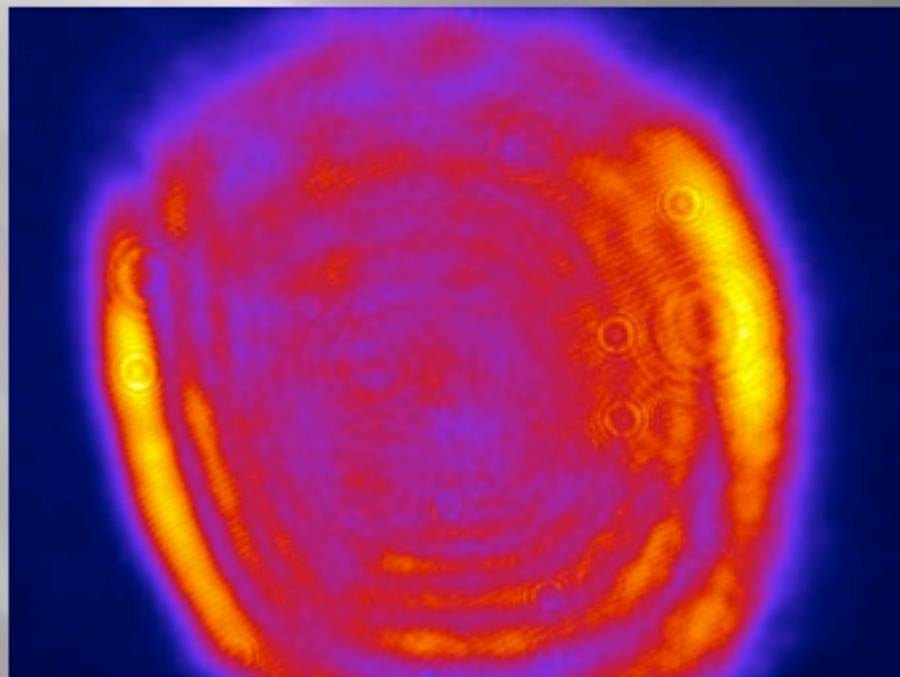


Improved Booster Amplifier



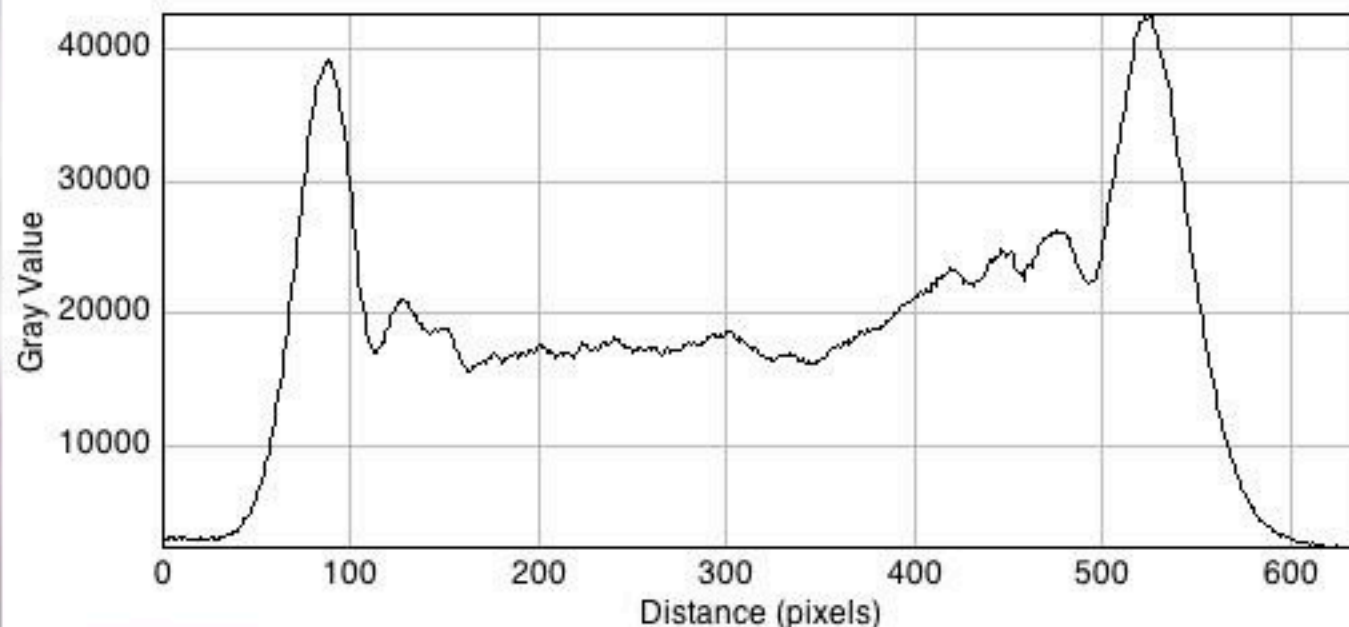


Improved Pre-amplifier



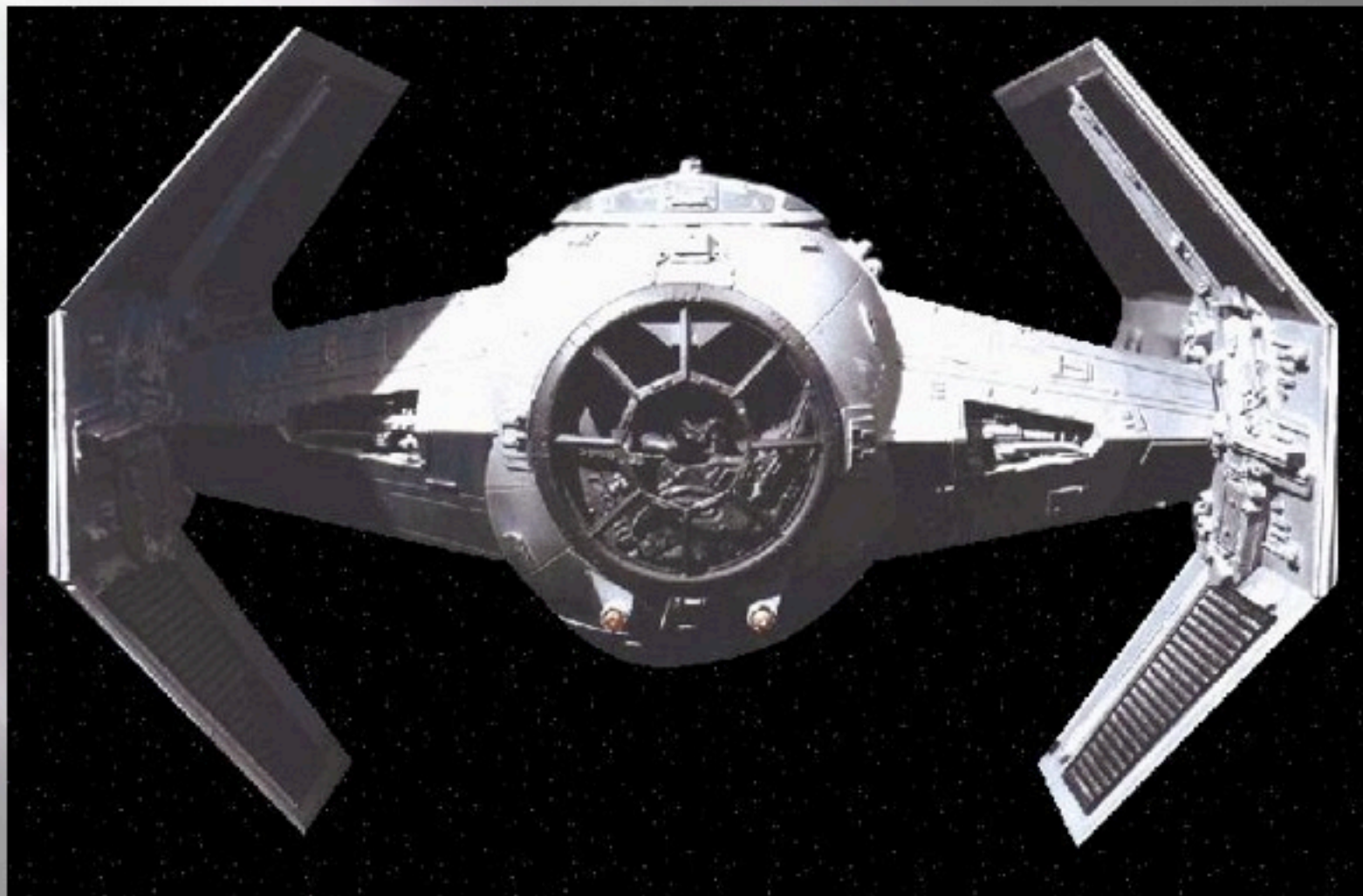


Improved Pre-amplifier



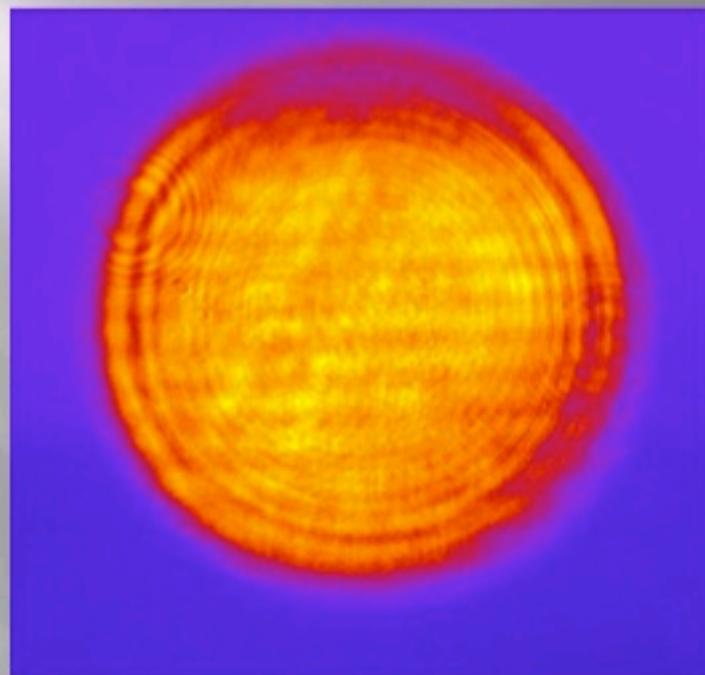


Improved Pre-amplifier





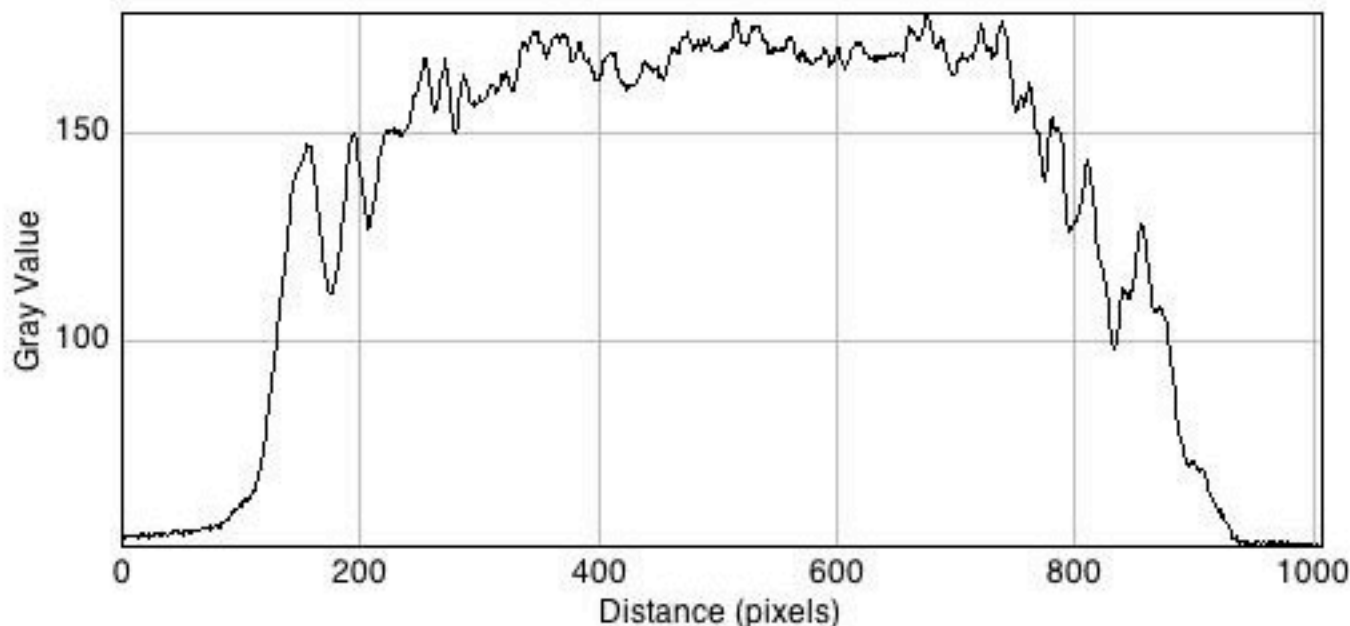
Improved Pre-amplifier



- ◆ Replaced SAGA1 with Powerlite
- ◆ Pump beams to preamp image relayed
- ◆ Added Additional Faraday Isolator to protect preamp from back propagating light



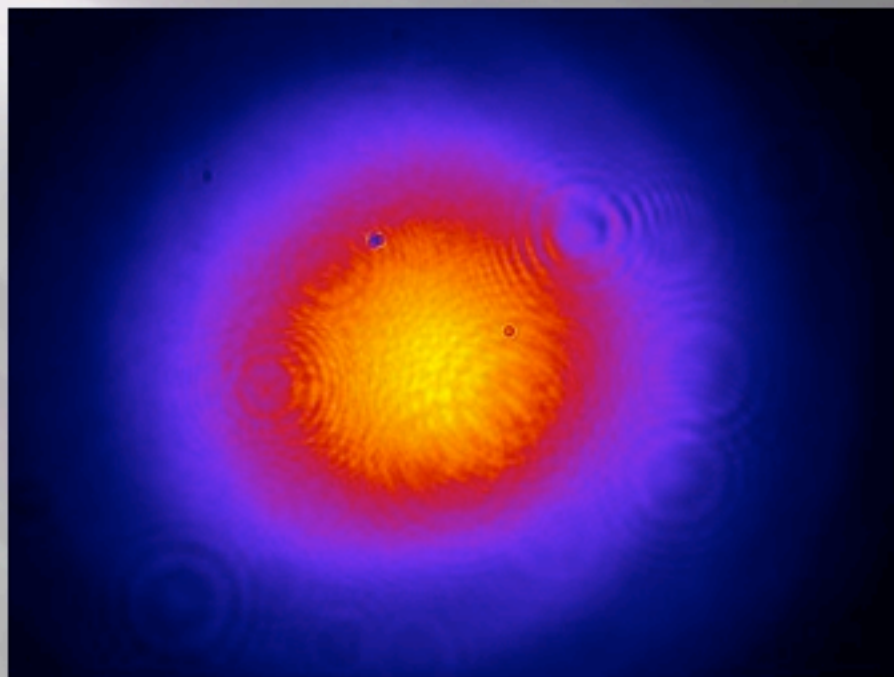
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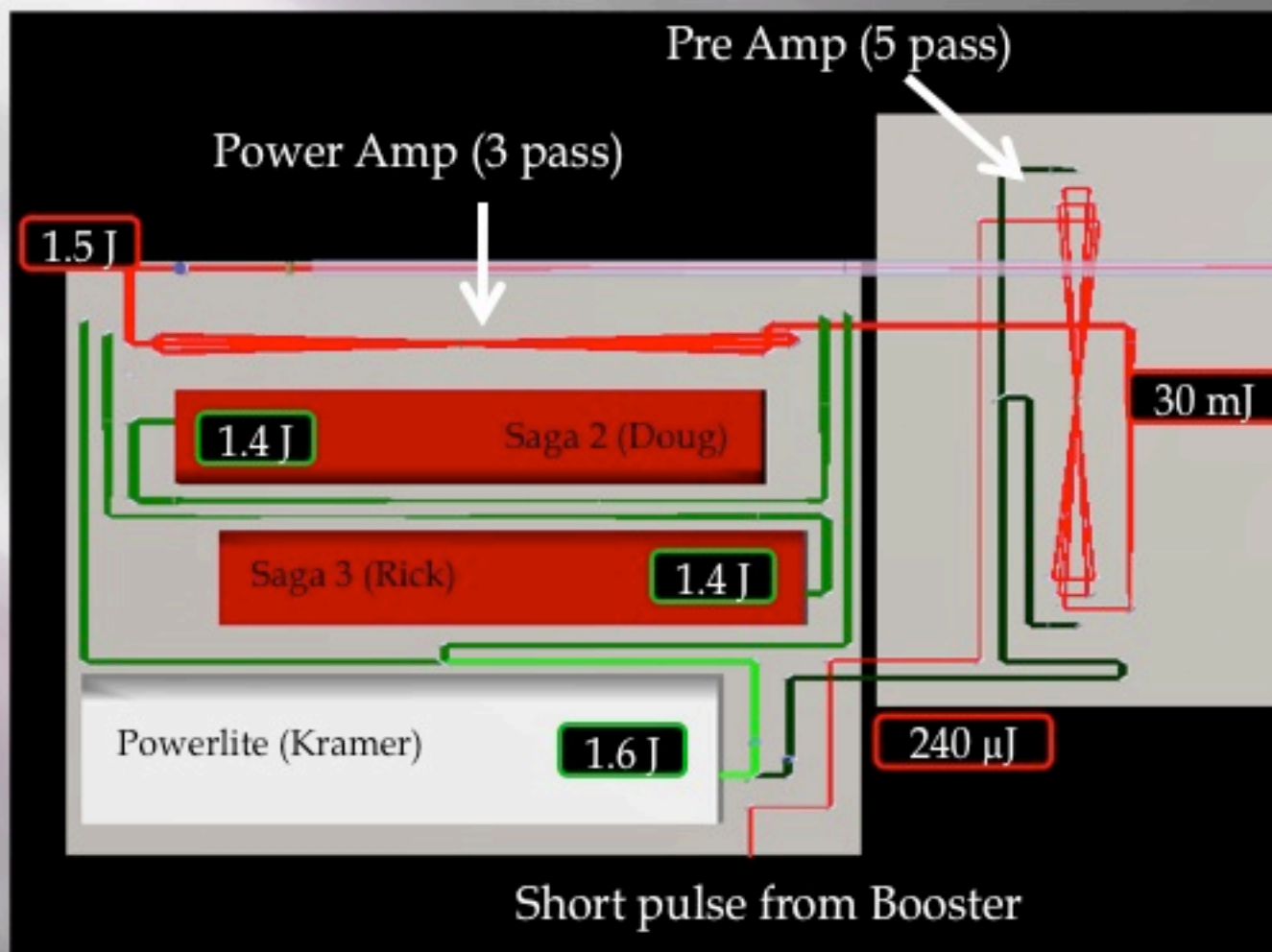
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New Amplifier Layout





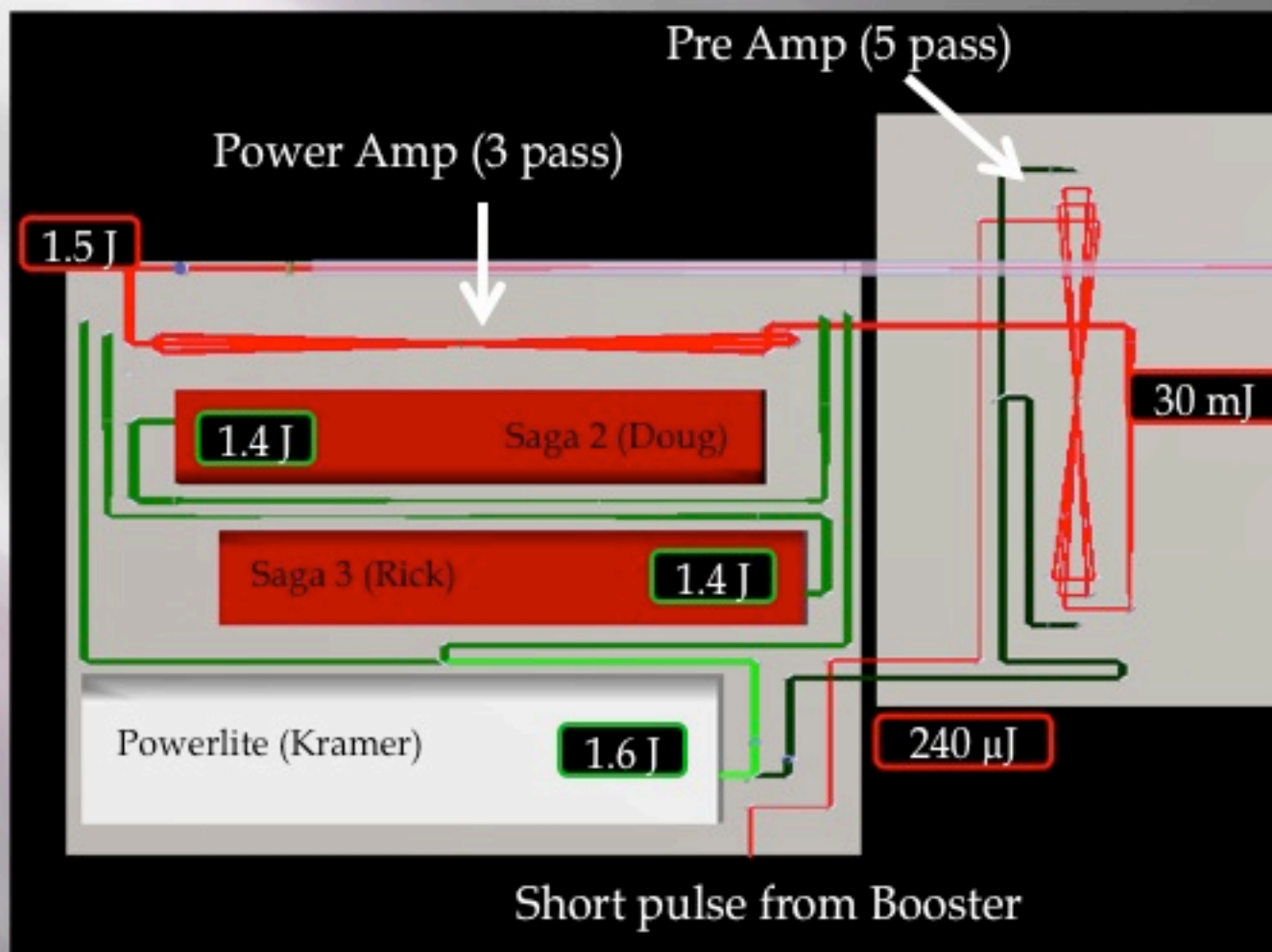
New Amplifier Layout

- ◆ Reconfigured set up due to larger components for improvement of Pre-amp
- ◆ Even pump energy from both sides of main amp
- ◆ Increased beam size on SHG in saga and then image relay





New Amplifier Layout





Design Goals for Upgrade

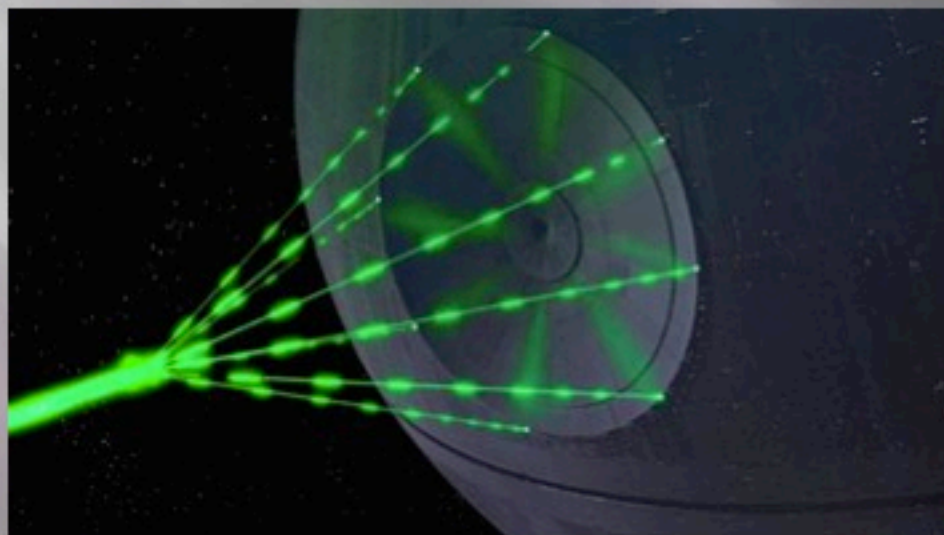
- ◆ 400 TW Peak Power
- ◆ Peak Focal Intensity 10^{22} W/cm²
- ◆ > 10 J Pulse Energy
- ◆ < 60 fs Pulse Width





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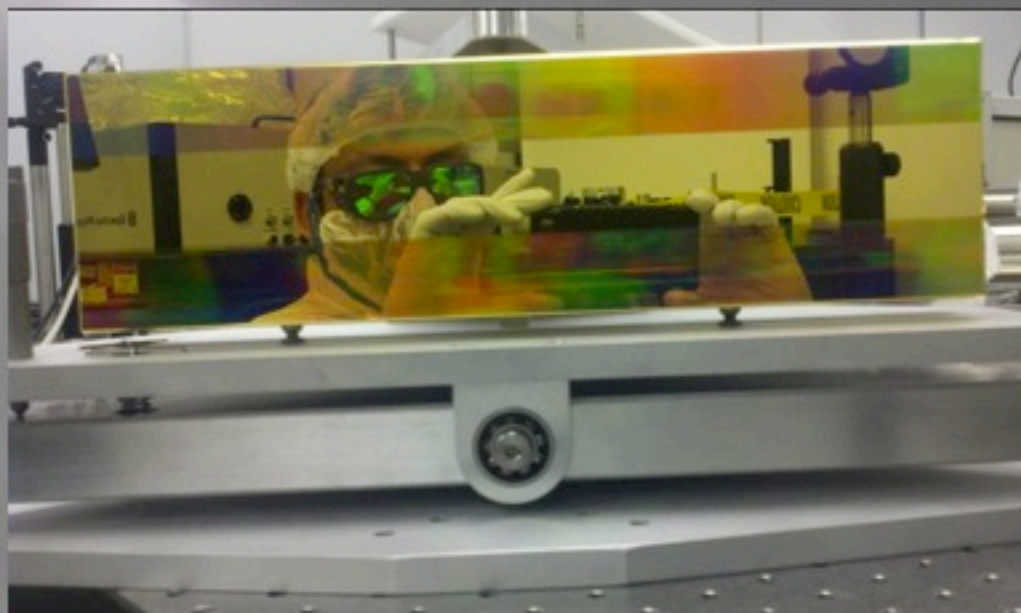
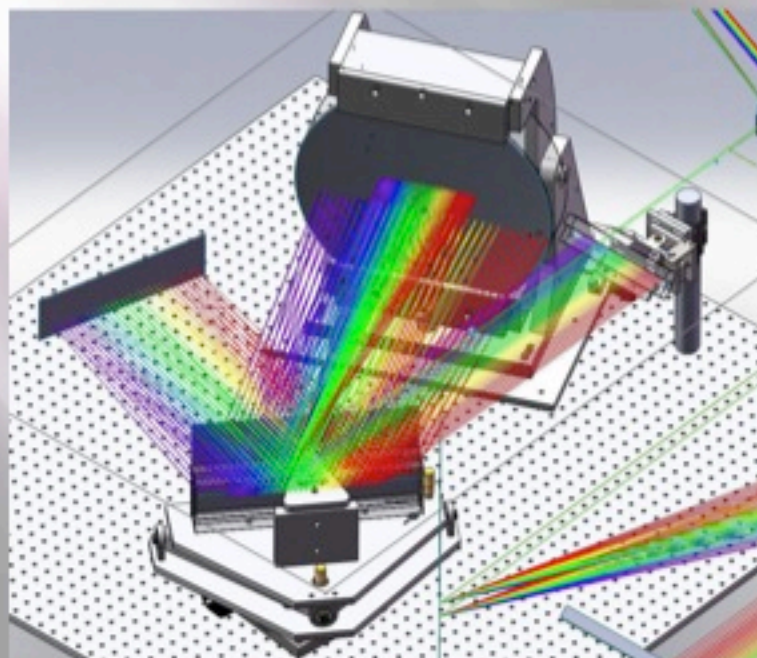
Upgraded Laser Architecture





Stretcher Design

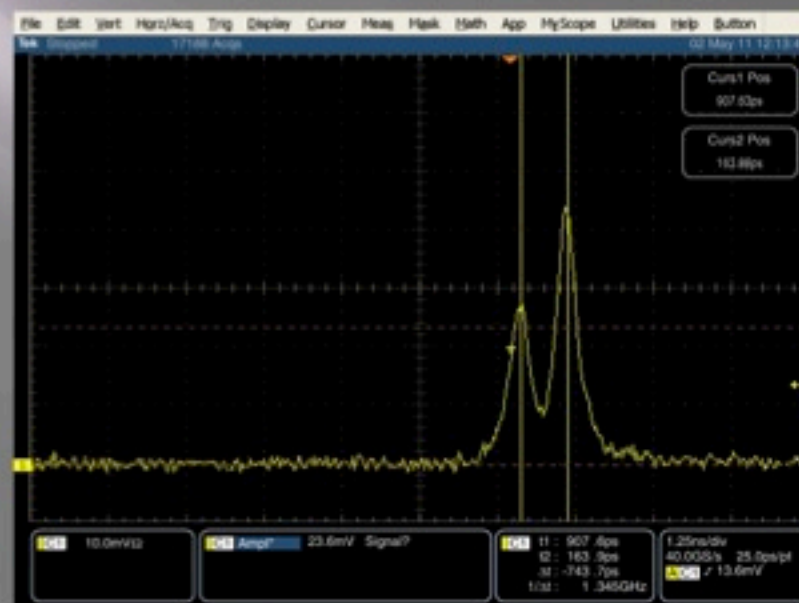
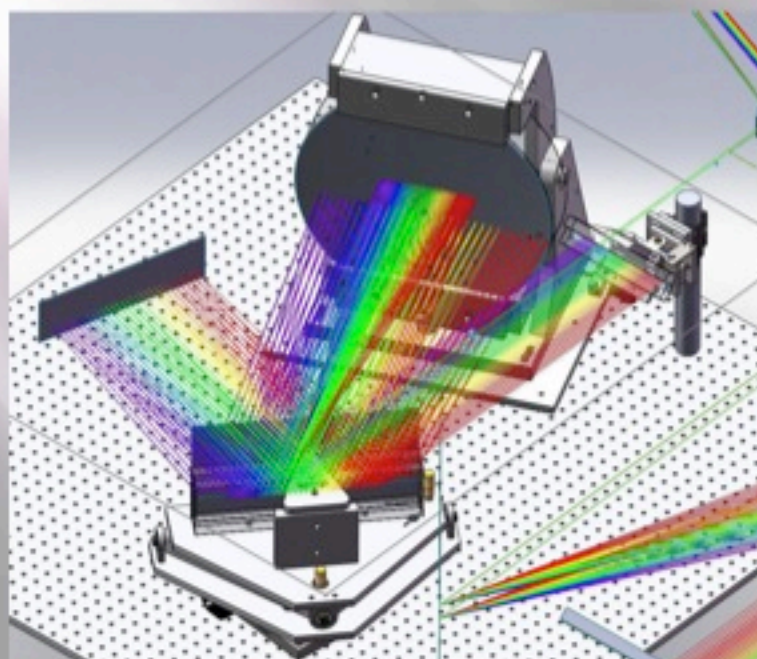
- ◆ Pulse stretched to $\sim 850\text{ps}$
- ◆ Large Bandwidth: $730\text{nm} \rightarrow 860\text{nm}$
- ◆ Compact Striped Grating design

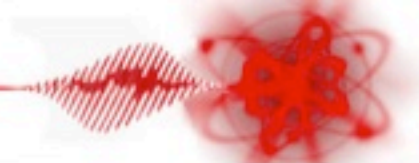




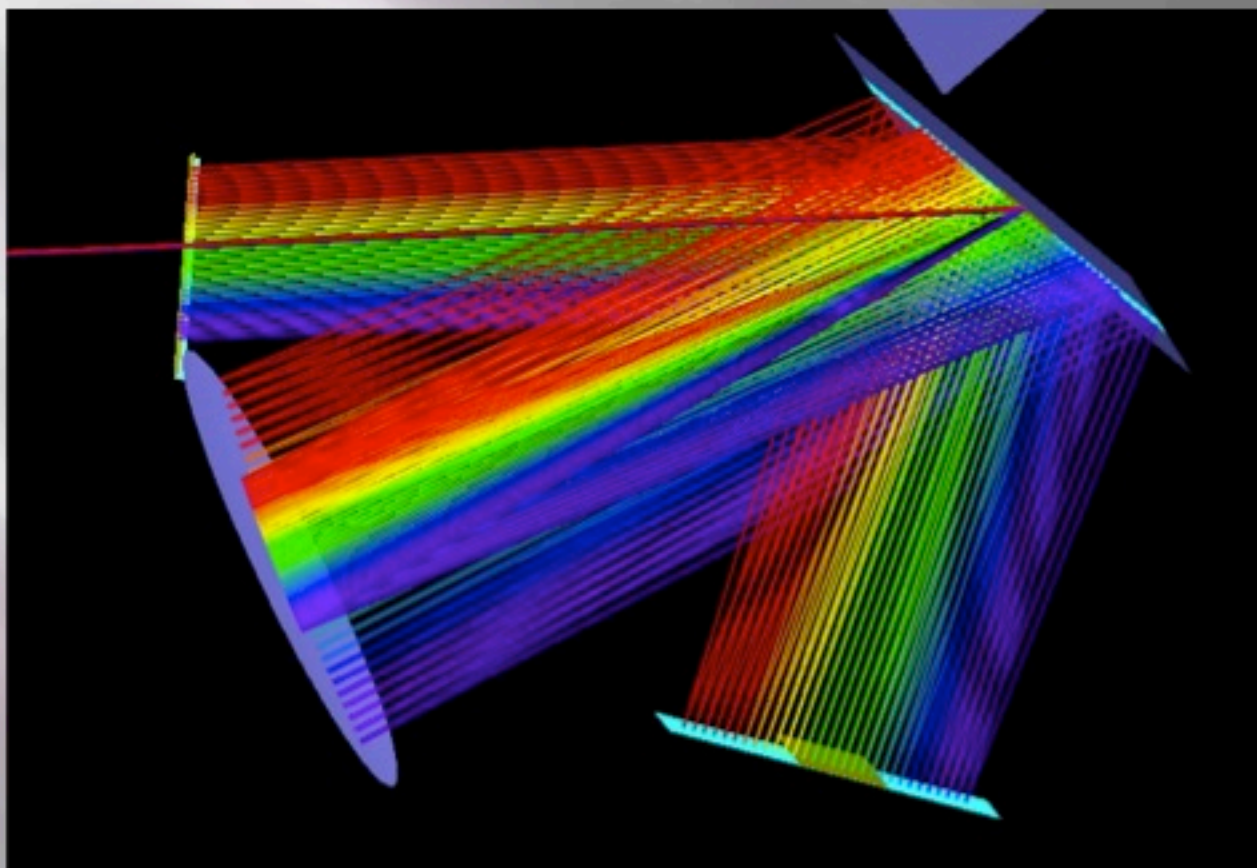
Stretcher Design

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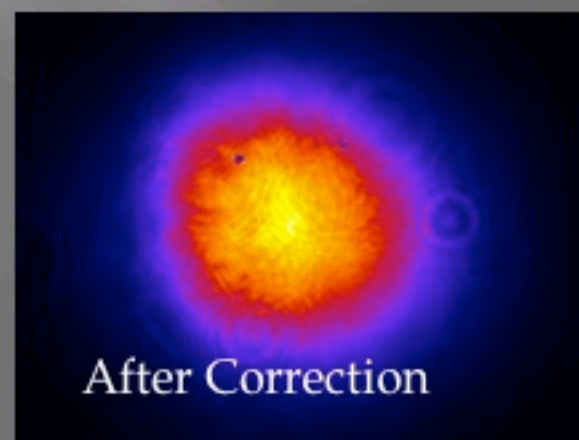
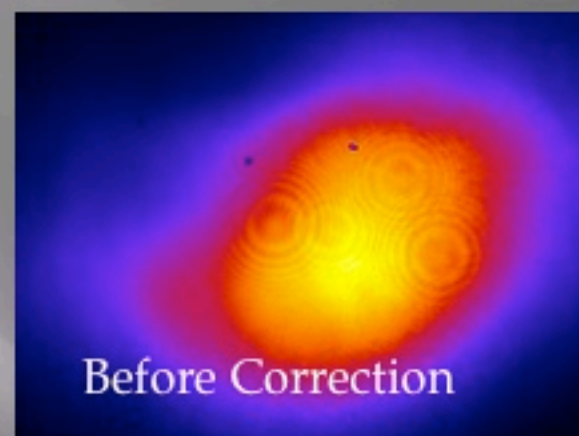
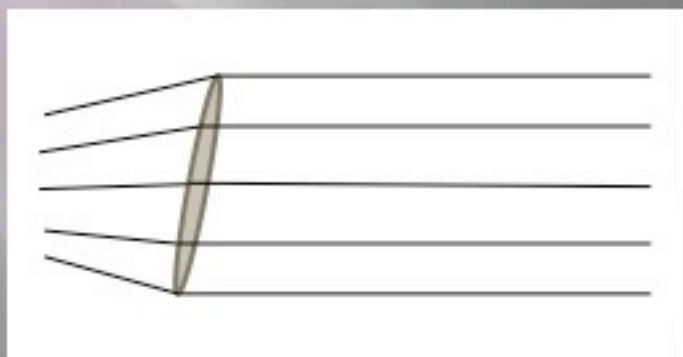
Stretcher Design





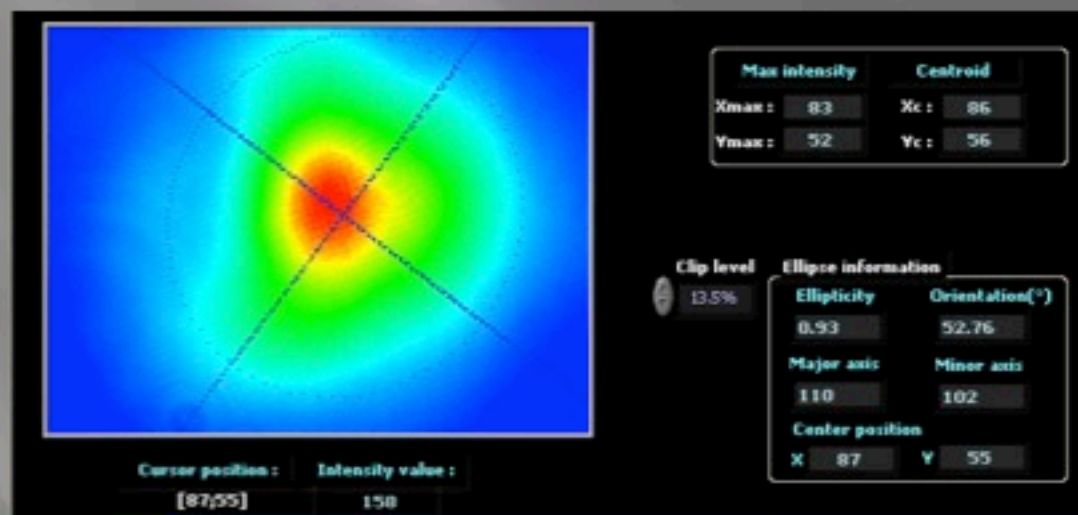
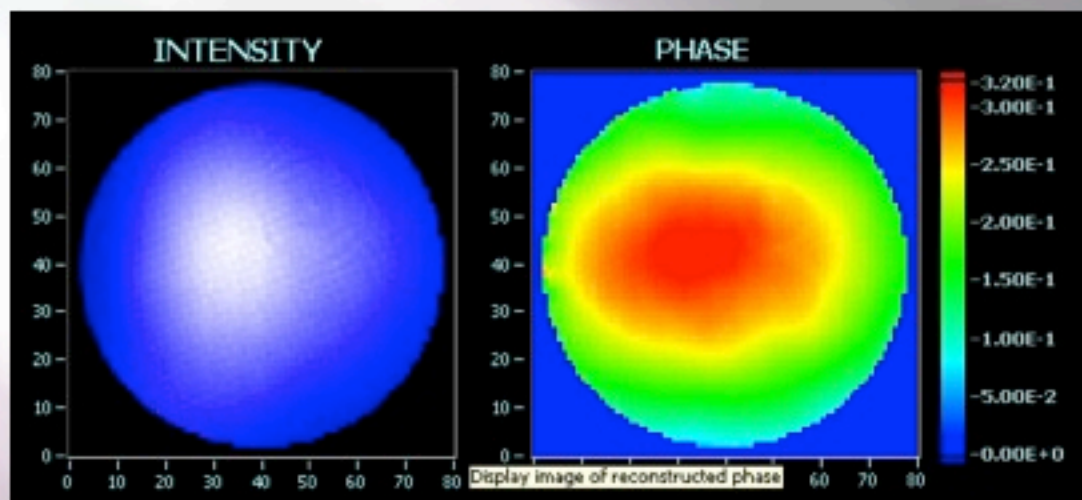
Correction of Wavefront Errors Into Stretcher

- ◆ The beam from the XPW to the stretcher input exhibits weak divergence in addition to slight astigmatism
- ◆ To correct, a weak lens was placed in the beam and tilted to correct the astigmatism.



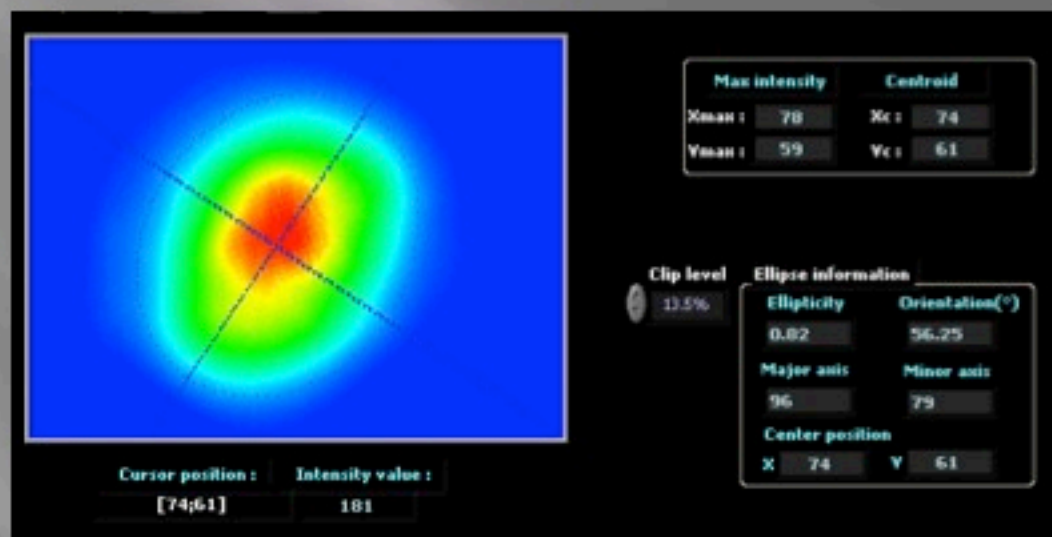
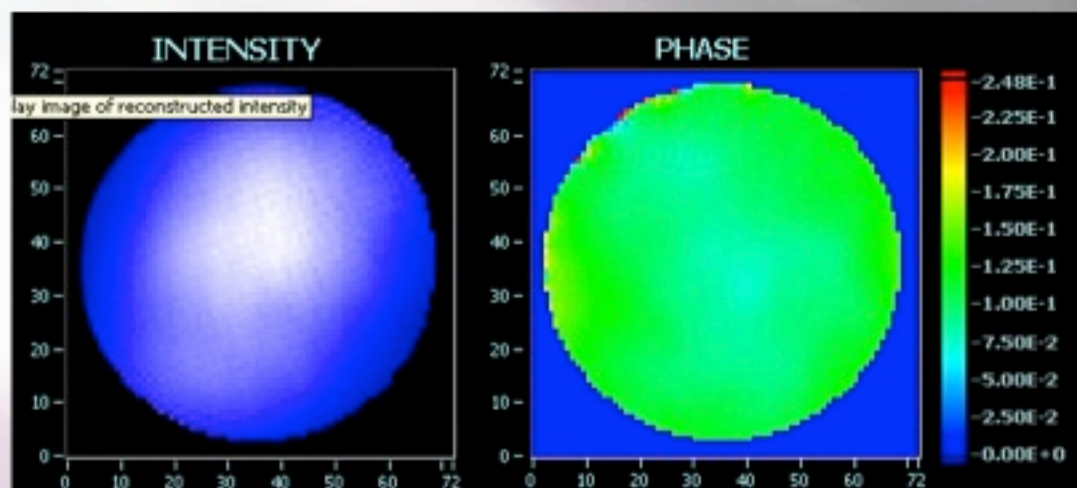


Phase Error Before Correction





Phase Error After Correction





Gain Modeling

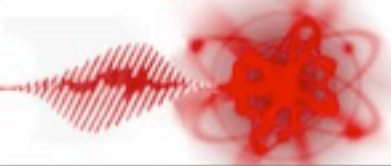
Frantz-Nodvick Gain Equation

$$G = \frac{E_s}{E_{in}} \ln \left\{ 1 + \left[\exp \left(\frac{E_{in}}{E_s} \right) - 1 \right] G_0 \right\}$$

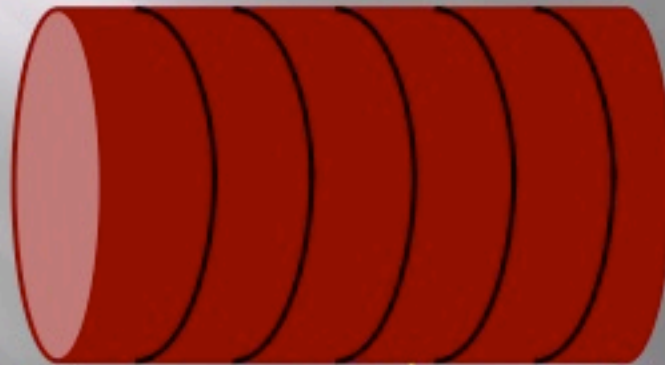
Assumptions:

- ◆ Constant absorption cross section
- ◆ Square pulse in time
- ◆ Uniform stored pump energy density in crystal





Gain Modeling



- ◆ Crystal is divided into thin slices
- ◆ Spectrum split into wavelength bins
- ◆ Wavelengths pass through crystal individually.



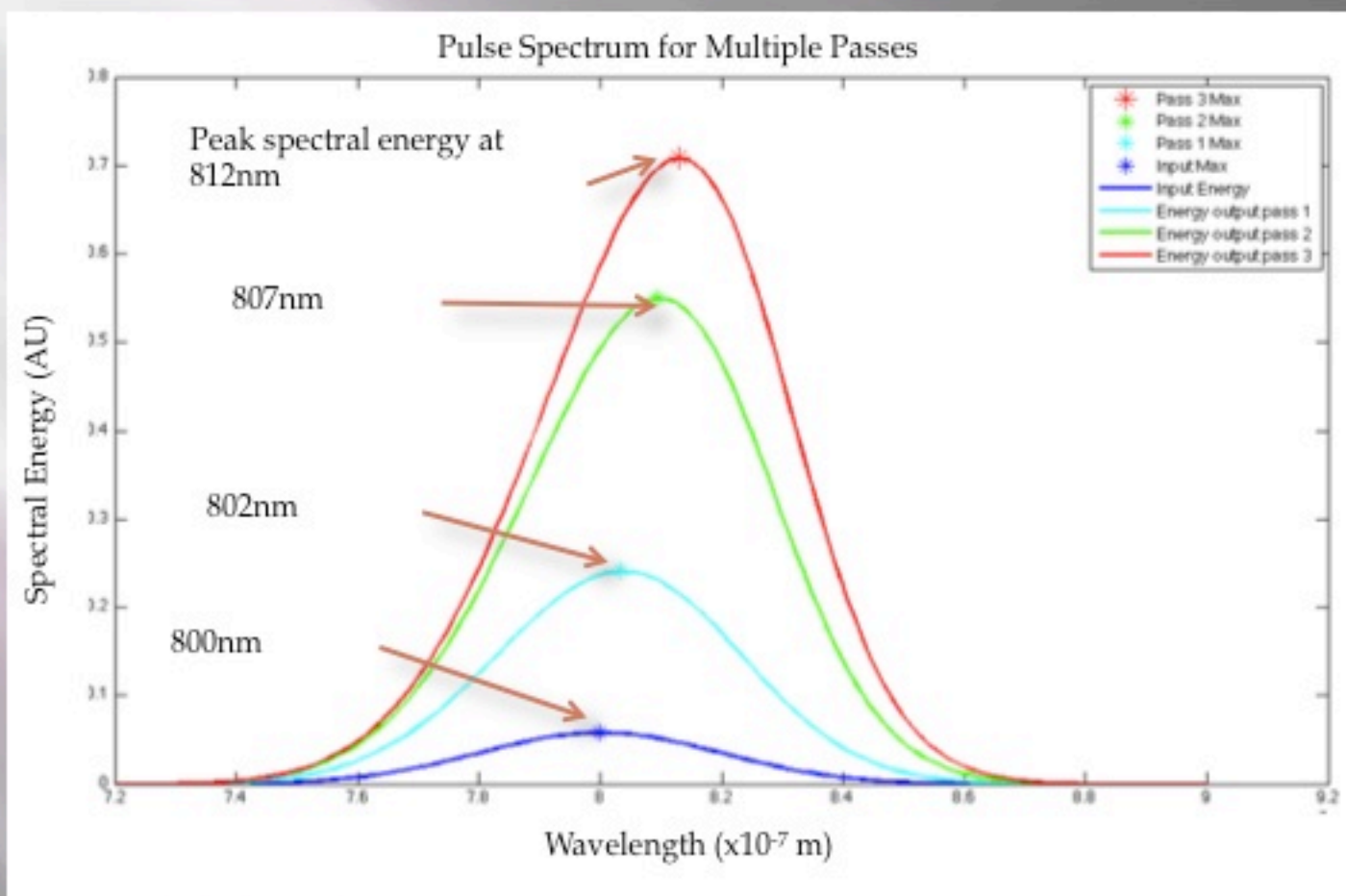
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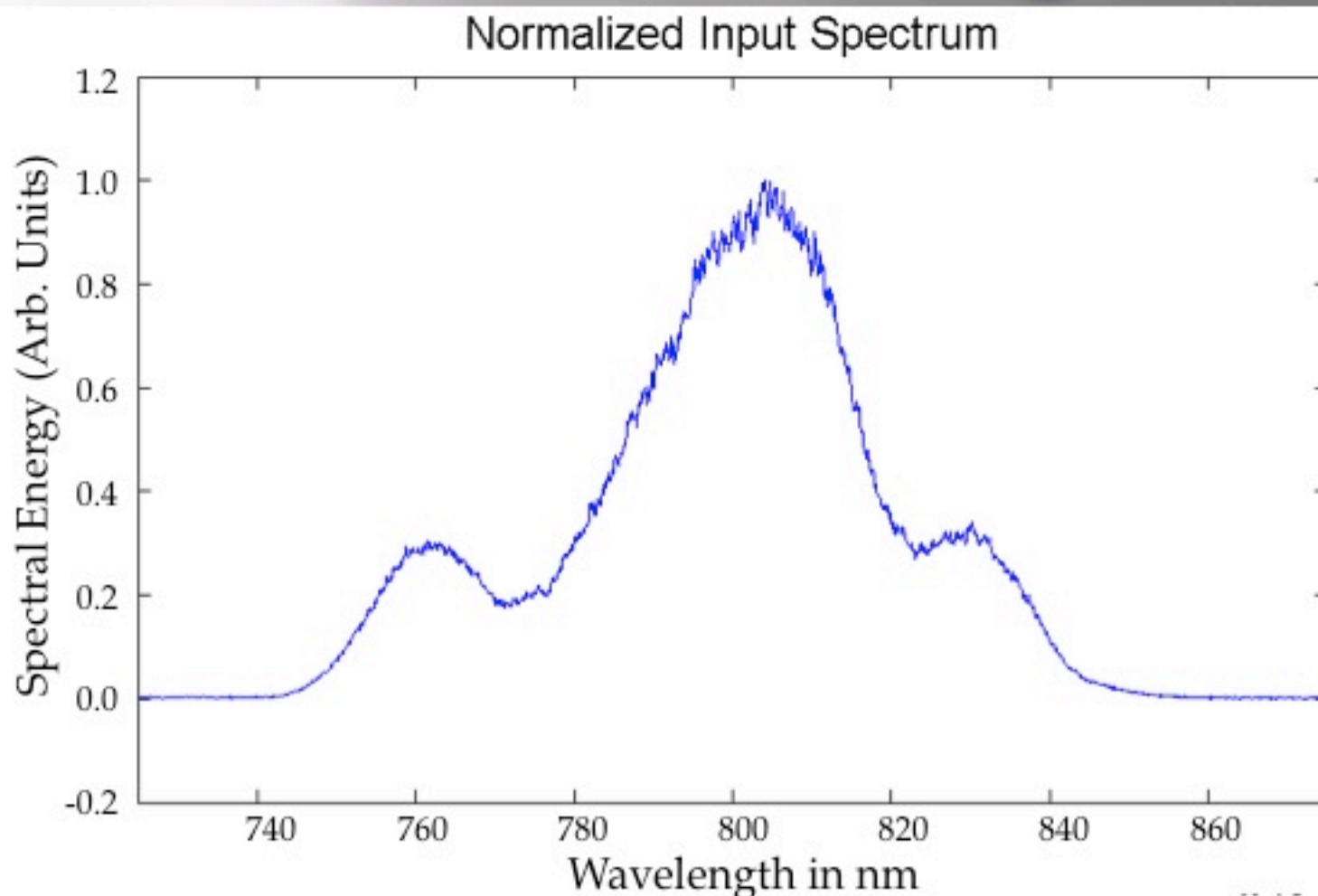


Gain Modeling





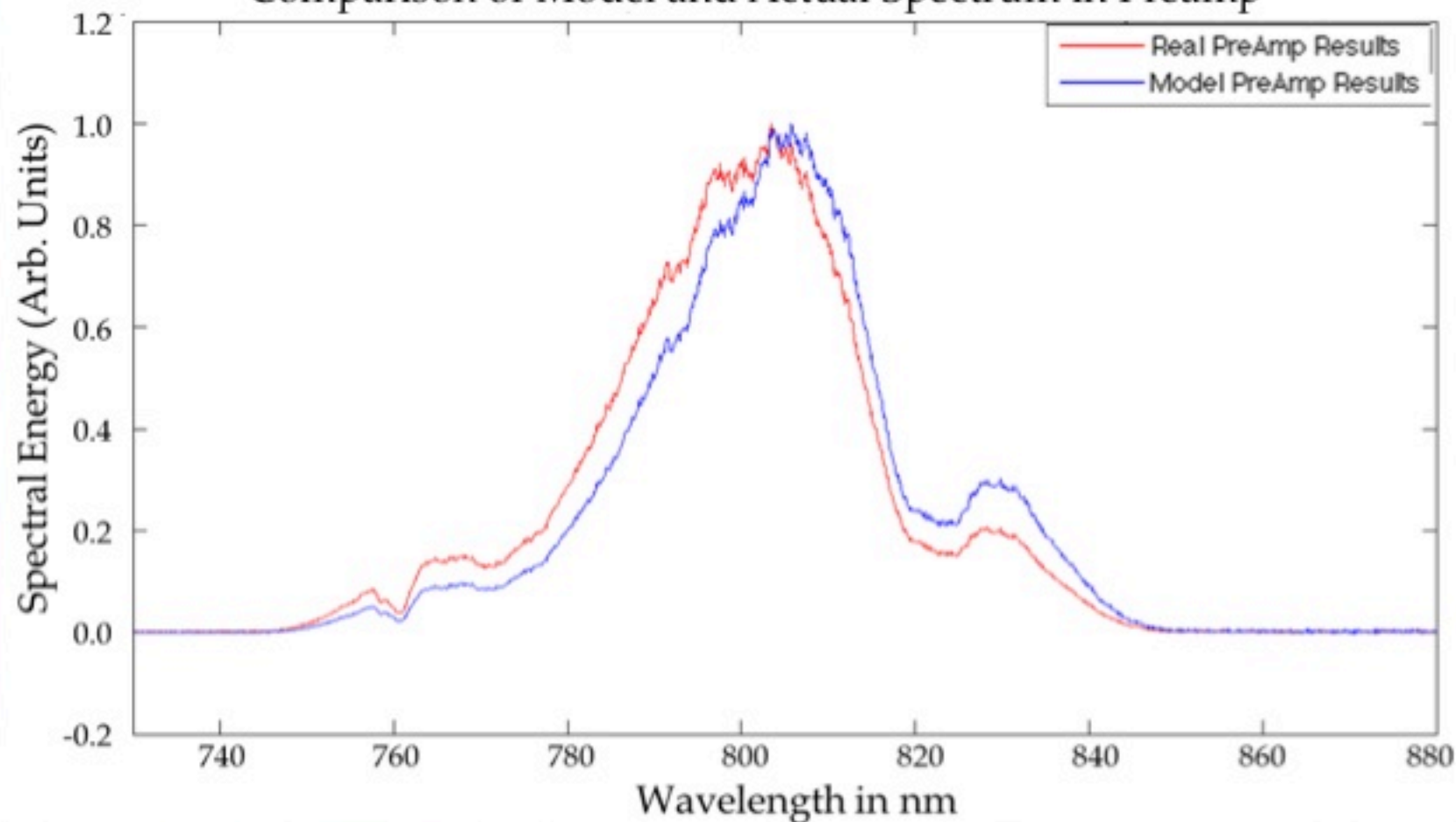
Gain Modeling





Gain Modeling

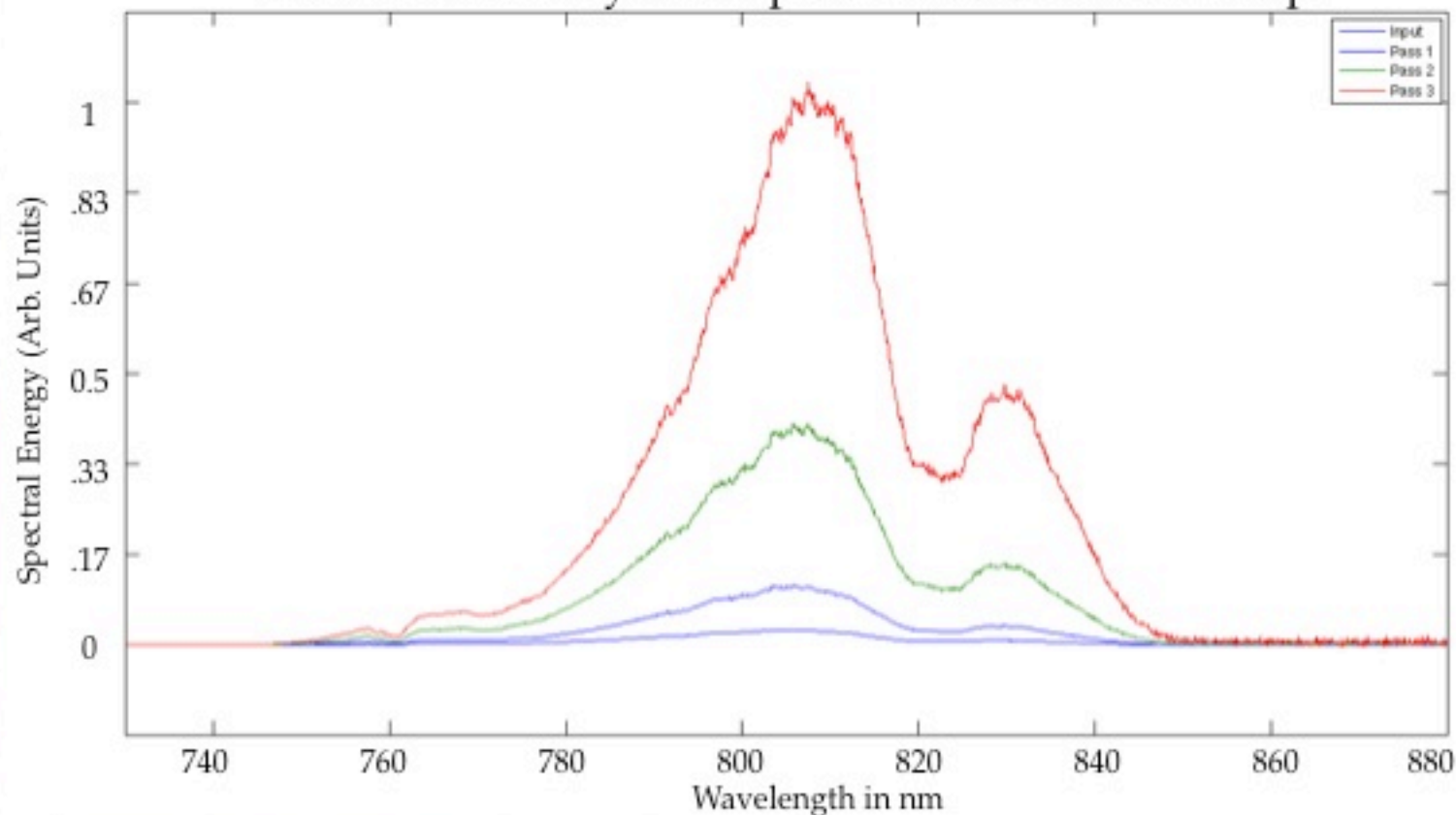
Comparison of Model and Actual Spectrum in Preamp





Gain Modeling

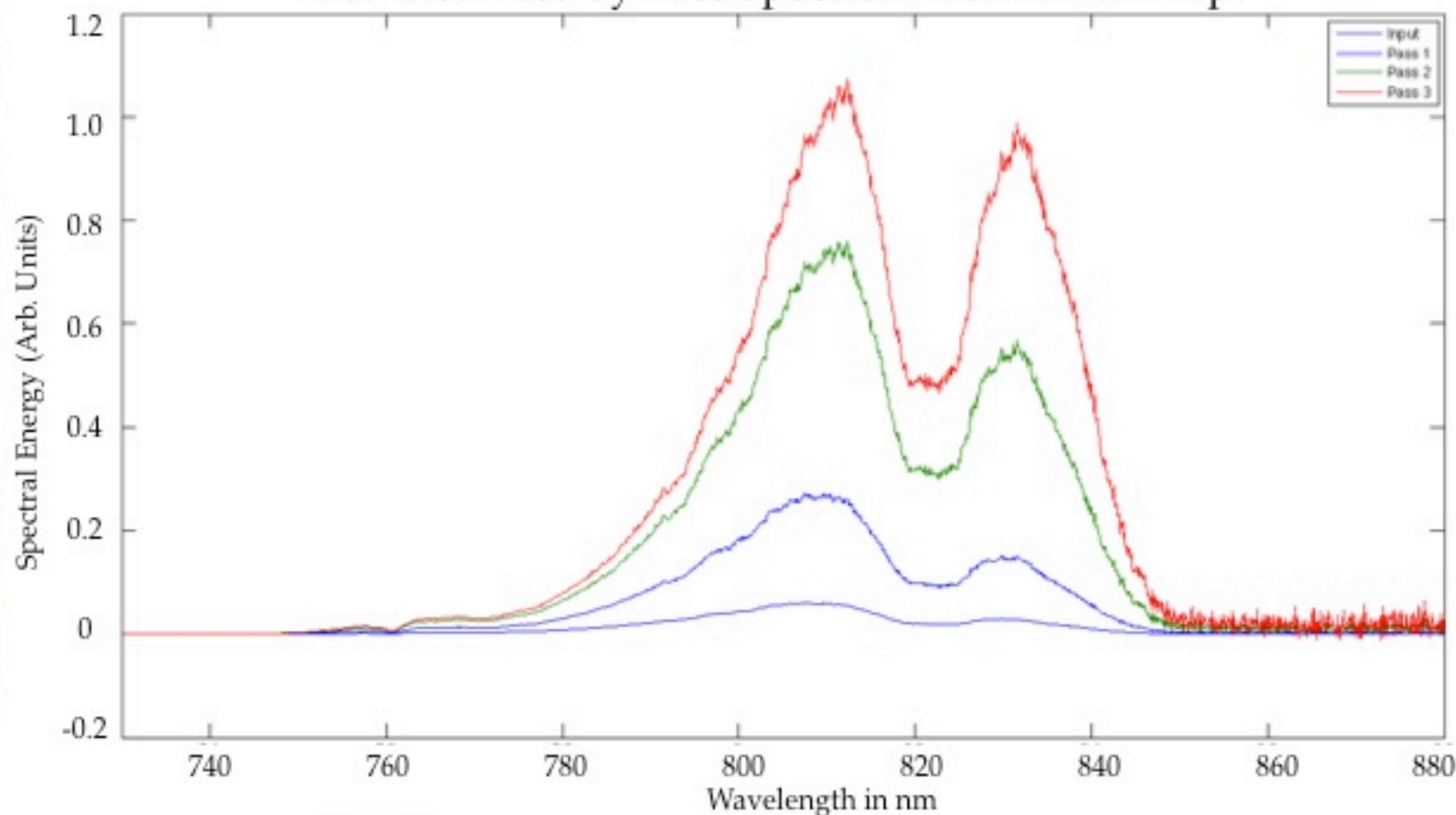
Predicted Pass-by Pass Spectrum from 40 TW Amp





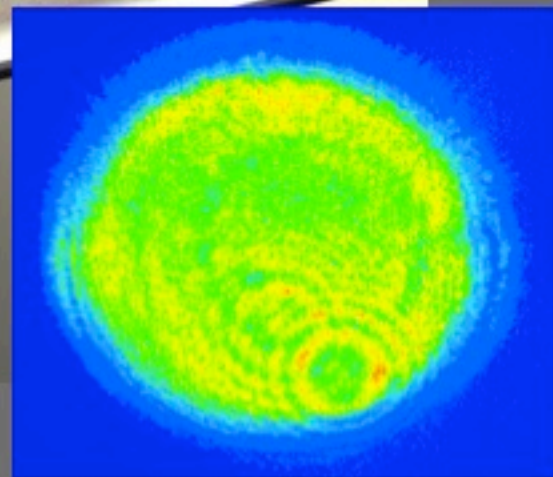
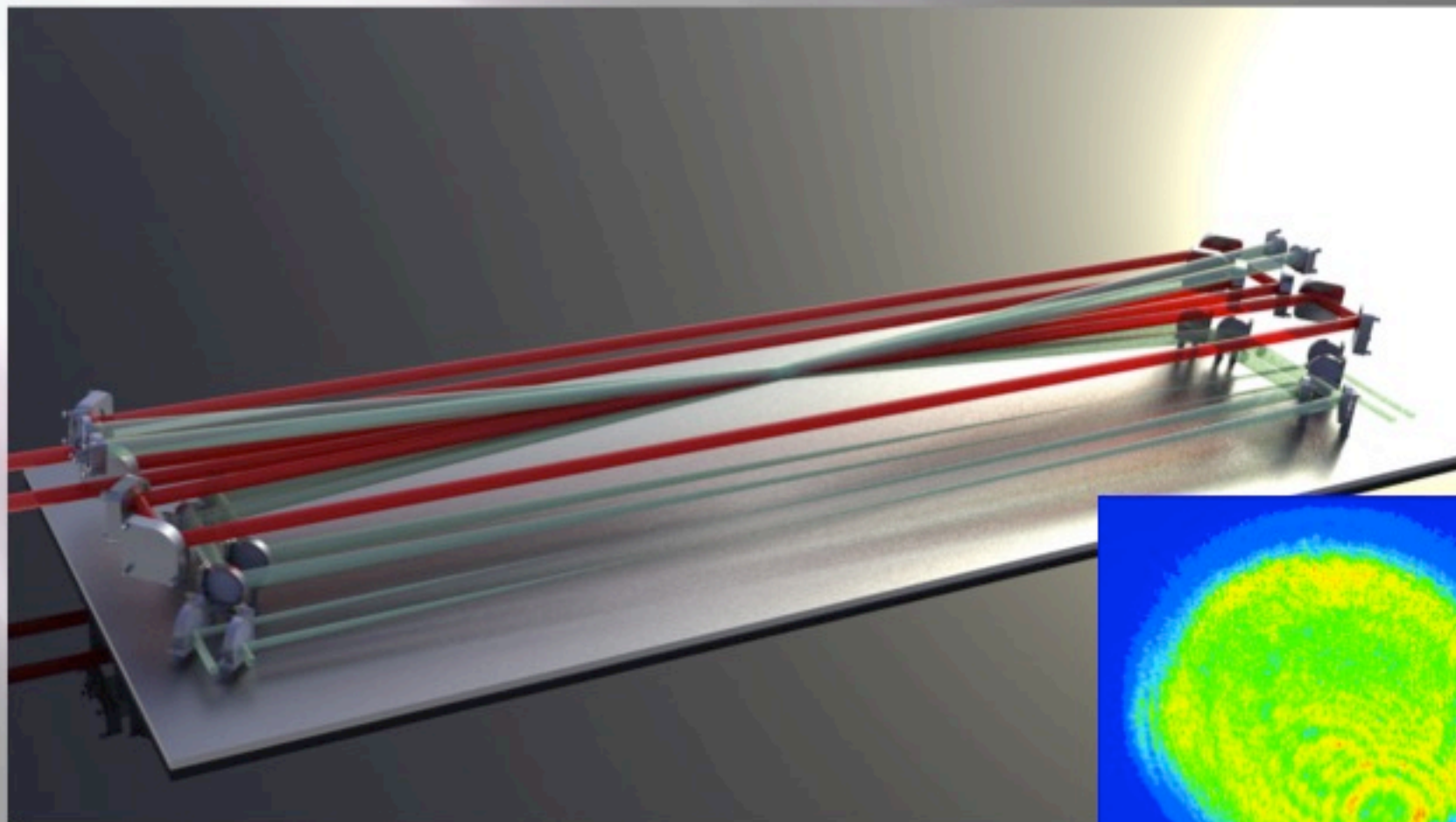
Gain Modeling

Predicted Pass-by Pass Spectrum from Final Amp





Design of Final Amp





Dispersion Modeling

- ◆ Calculate spectrally weighted RMS phase (per Walker et al.)
- ◆ Subtract linear and constant phase terms

$$\phi_{err}^2 = \frac{\int I [\phi - \phi_r - \phi_p - \bar{\phi}]^2 d\omega}{\int I d\omega}$$

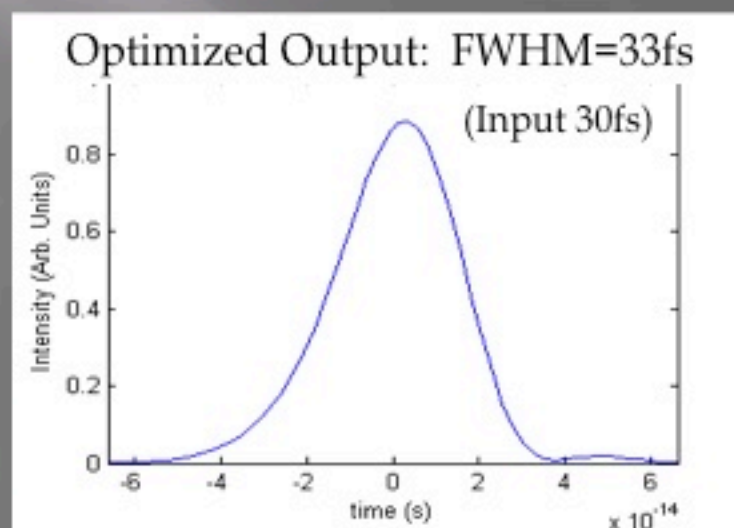
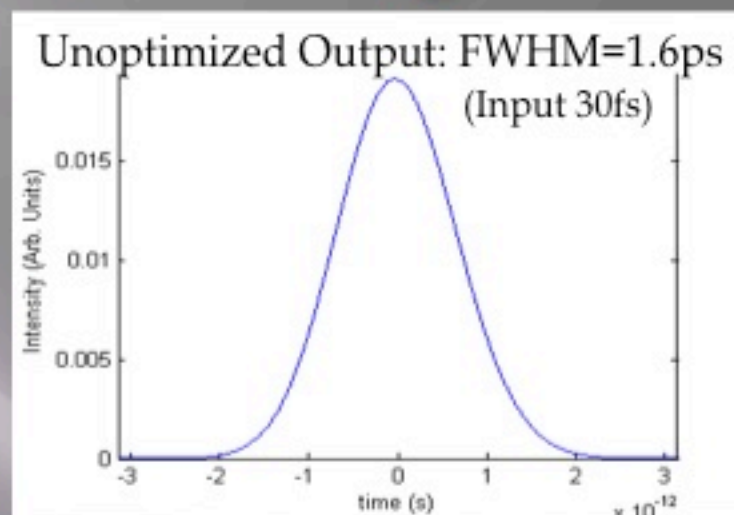
$$\bar{\phi} = \left[\frac{\int I [\phi - \phi_r - \phi_p] d\omega}{\int I d\omega} \right]$$

$$\phi_p = \omega \left[\frac{\int I \frac{d(\phi - \phi_r)}{d\omega} d\omega}{\int I d\omega} \right]$$



Dispersion Modeling

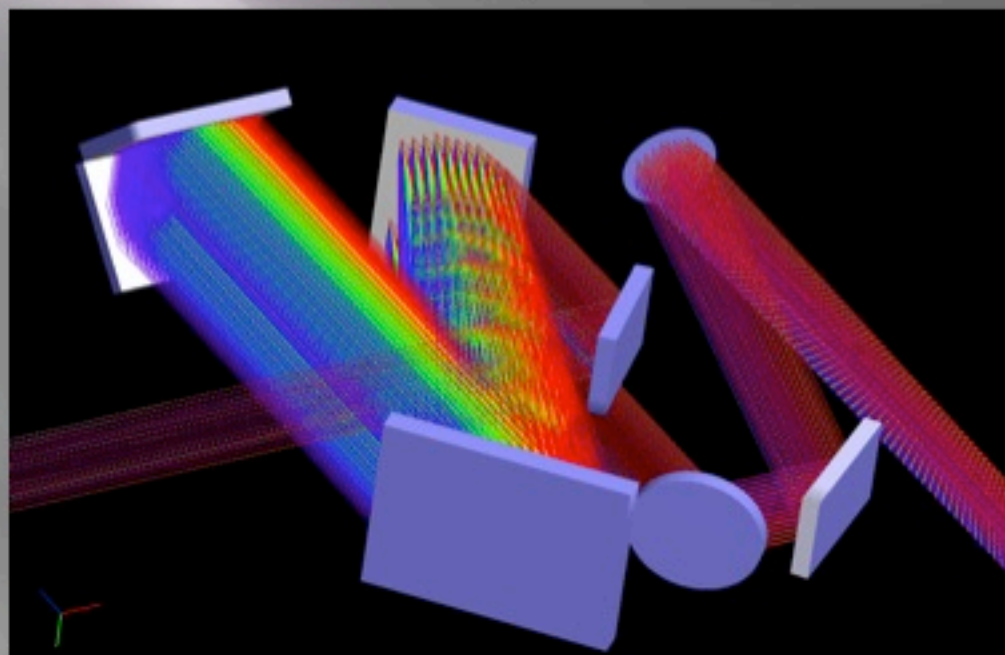
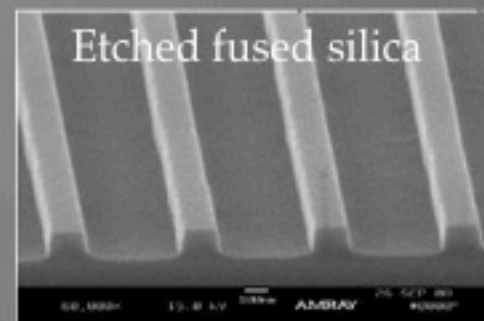
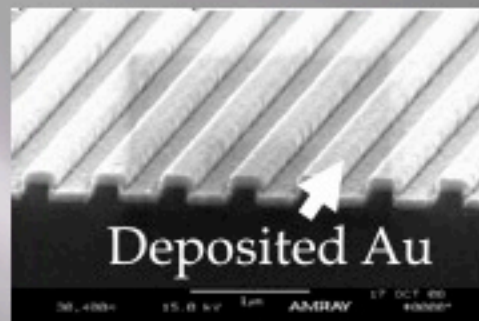
- ◆ Genetic algorithm calculates RMS phase error for many compressor configurations
- ◆ Compressor optimized for a given stretcher and amplifier design





Compressor

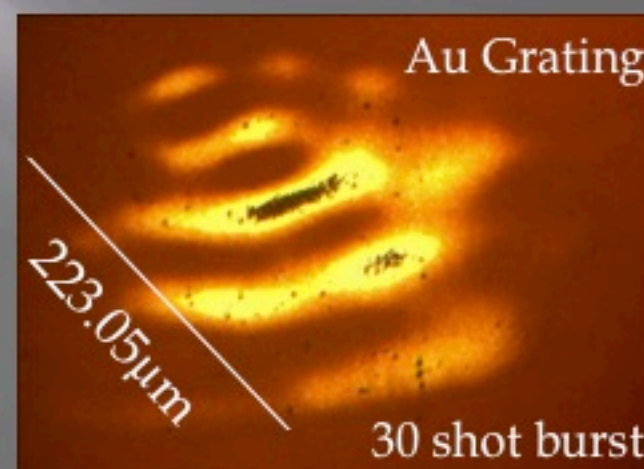
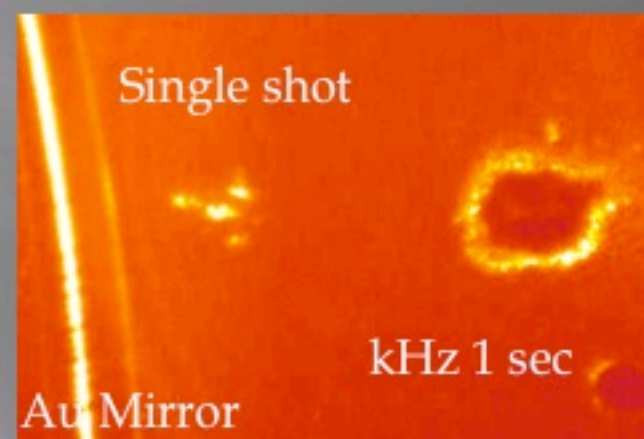
- ◆ 49° grating angle
- ◆ 36 x 42 cm and 56 x 42 cm
- ◆ ~75% efficiency
- ◆ No photoresist material



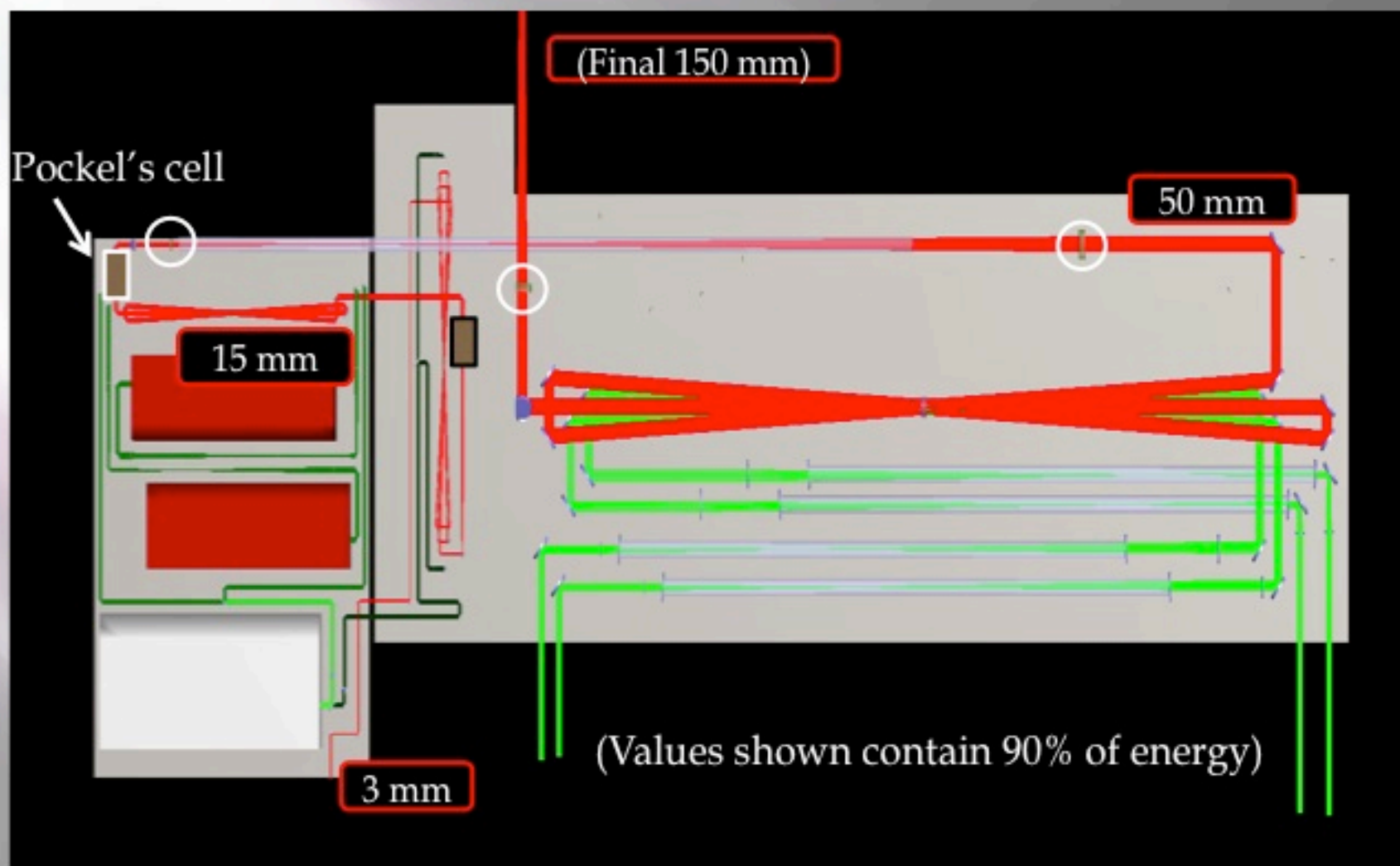


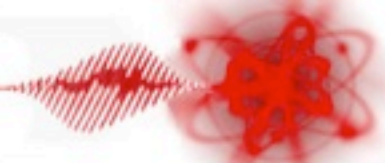
Damage Testing

- ◆ Single shot and kHz tests
- ◆ At air and in vacuum
- ◆ Gold mirror instead of etched grating

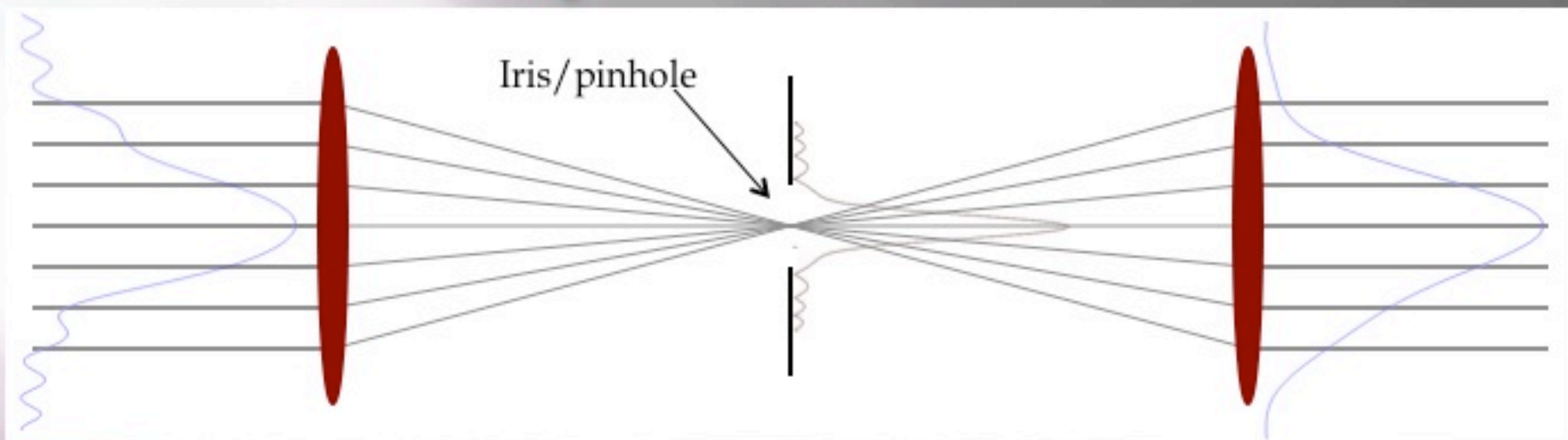


		Air Fluence (J/cm ²)	Vacuum Fluence (J/cm ²)	Air Intensity (W/cm ²)	Vacuum Intensity (W/cm ²)
Au Mirror	Single shot	1.5	1.7	6.0E+13	6.7E+13
	Multi shot	1.0	1.5	3.9E+13	5.8E+13
Au Grating (Photor.)	Single shot	0.30		1.2E+13	
	Multi shot	0.27	0.3	1.1E+13	1.2E+13

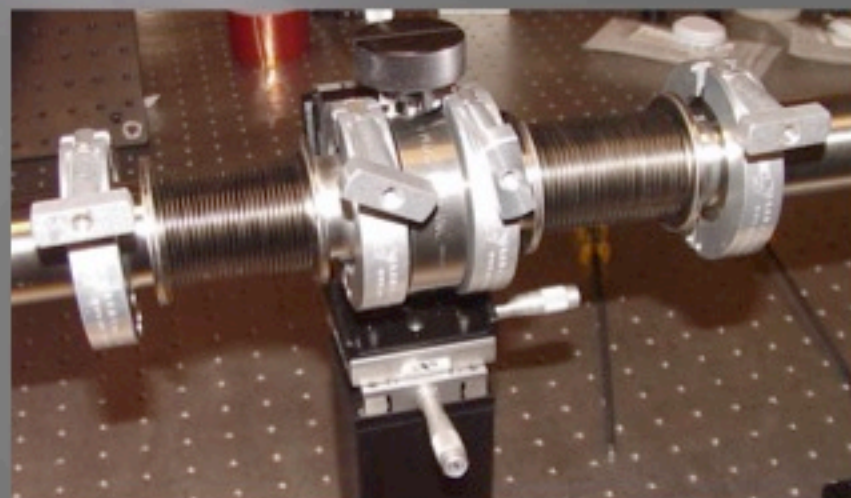




Spatial Filter



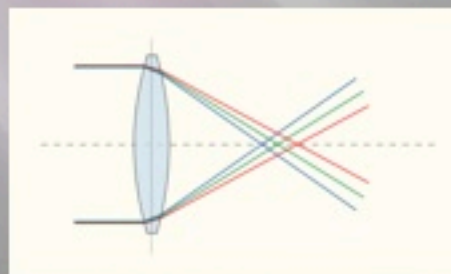
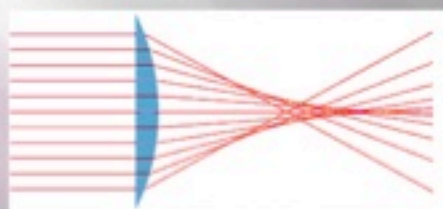
- ◆ By filtering at focus, beam profile is smoothed
- ◆ Also protects from back-reflections
- ◆ Interchangeable 1 and 1.5 mm pinholes



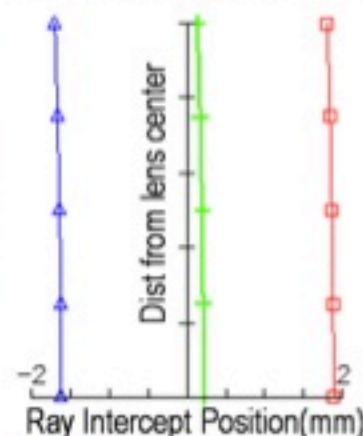
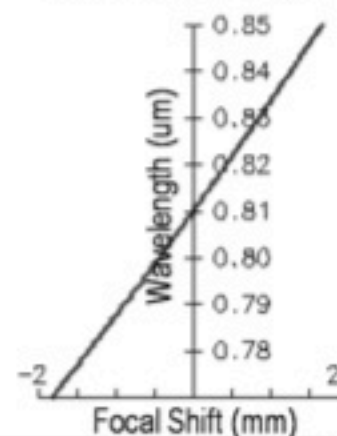


Achromat Optimization

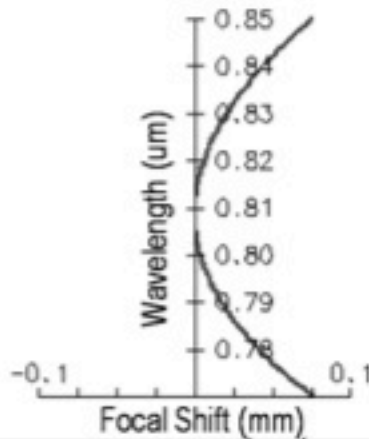
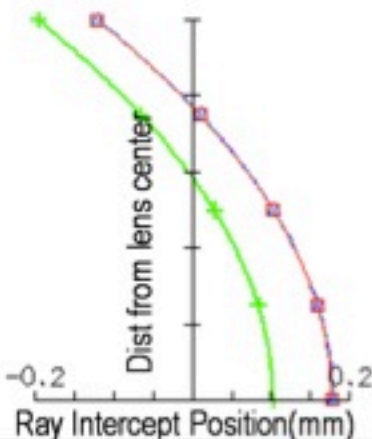
$\lambda_1 = 770$
nm
 $\lambda_2 = 810$
nm
 $\lambda_3 = 850$
nm



Singlet Lens

LONGITUDINAL
SPHERICAL ABER. (mm)CHROMATIC
FOCAL SHIFT (mm)

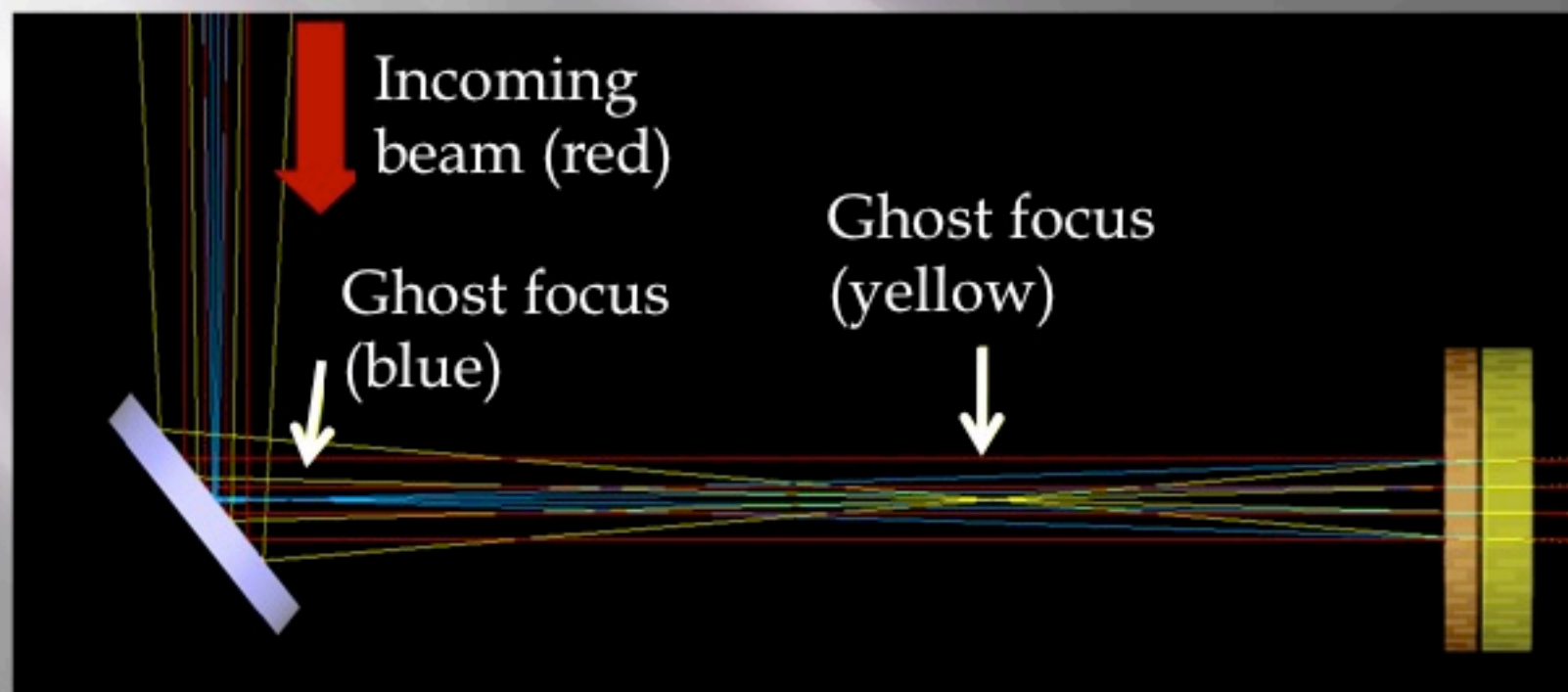
Achromat Lens





Ghost Focus Analysis

- ◆ Under .25% AR coating on each surface
- ◆ Focusing second-order reflections could damage
- ◆ After adjustments all optics have $<.07 \text{ J/cm}^2$ from back-reflections





Fold Chamber & OAP

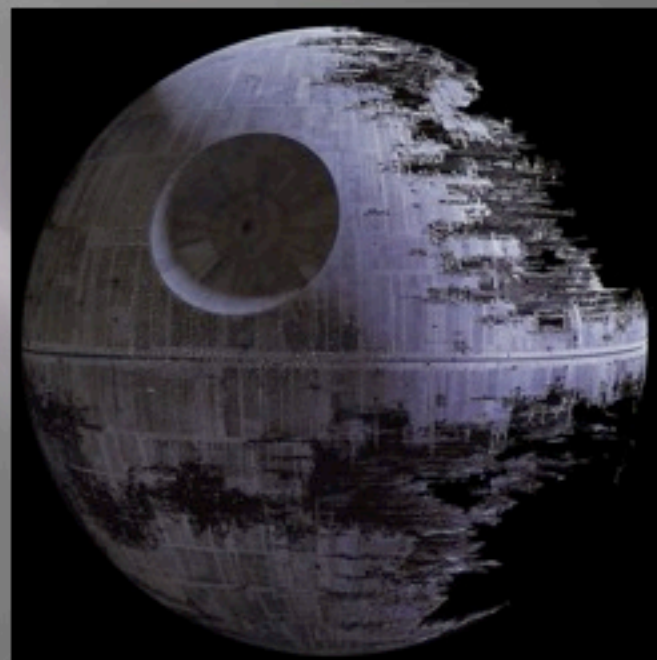
- ◆ 3x magnification
- ◆ ~11m image relay to last hit on grating
- ◆ Allows for smaller diameter deformable mirror





Further Work

- ◆ Deformable mirror
- ◆ Retro reflectors to collect unused PW amp pump light
- ◆ Utilize unused IR from PW amp pumps
- ◆ Pulse width down to 40 fs



ACKNOWLEDGEMENTS

- ◆ Rick Freeman
- ◆ Linn Van Woerkom
- ◆ Douglass Schumacher
- ◆ Enam Chowdhury
- ◆ John Marketon
- ◆ Taryn Kaufman
- ◆ Aakash Patel