Drive-Laser Operations

- Drive Laser
  - Thales laser
  - Transport system
- Recent Laser Milestones
  - Safety
  - Technical
- Where do we stand today?
  - Laser Acceptance Status
- Laser Commissioning
- UV on cathode – Injector Commissioning – "Laser Operations"
- Future

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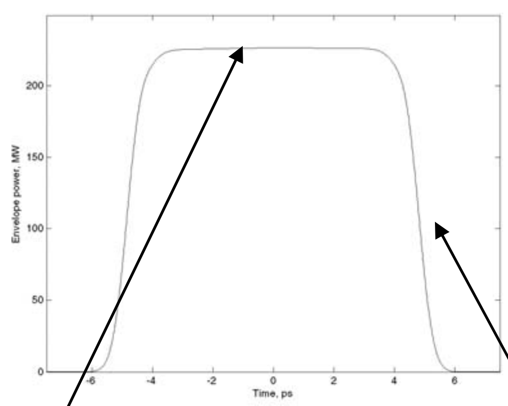
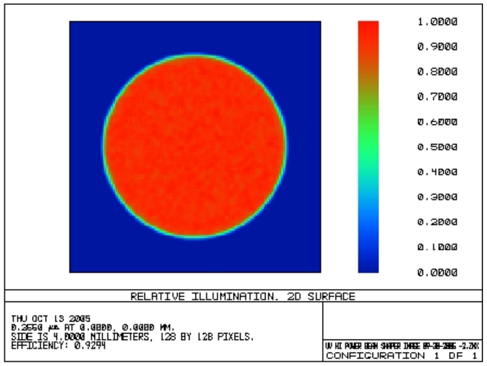
UV pulse goals

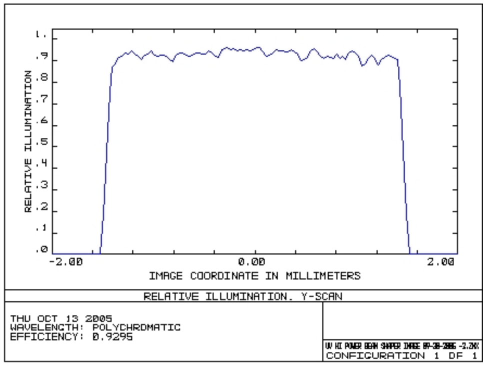
- **IR to UV conversion efficiency > 10 %, 2.5 mJ output @ 255 nm**
- **252-258 nm, < 2% energy stability**
- **120 Hz, MTBF > 5000 hours**

Spatial Profile
FWHM = 1.2 – 3.0 mm

Temporal Profile
FWHM = 10 ps
(5-20 ps)







90-10 rise and fall times < 1 ps

flat-top, < 8% peak-to peak

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Challenges

- Temporal Shape → **Most Difficult**
- Spatial Shape → **Very Difficult**
- UV conversion → **Compounds both!**
- 120 Hz
- Synchronization
- Reliability
- Characterization

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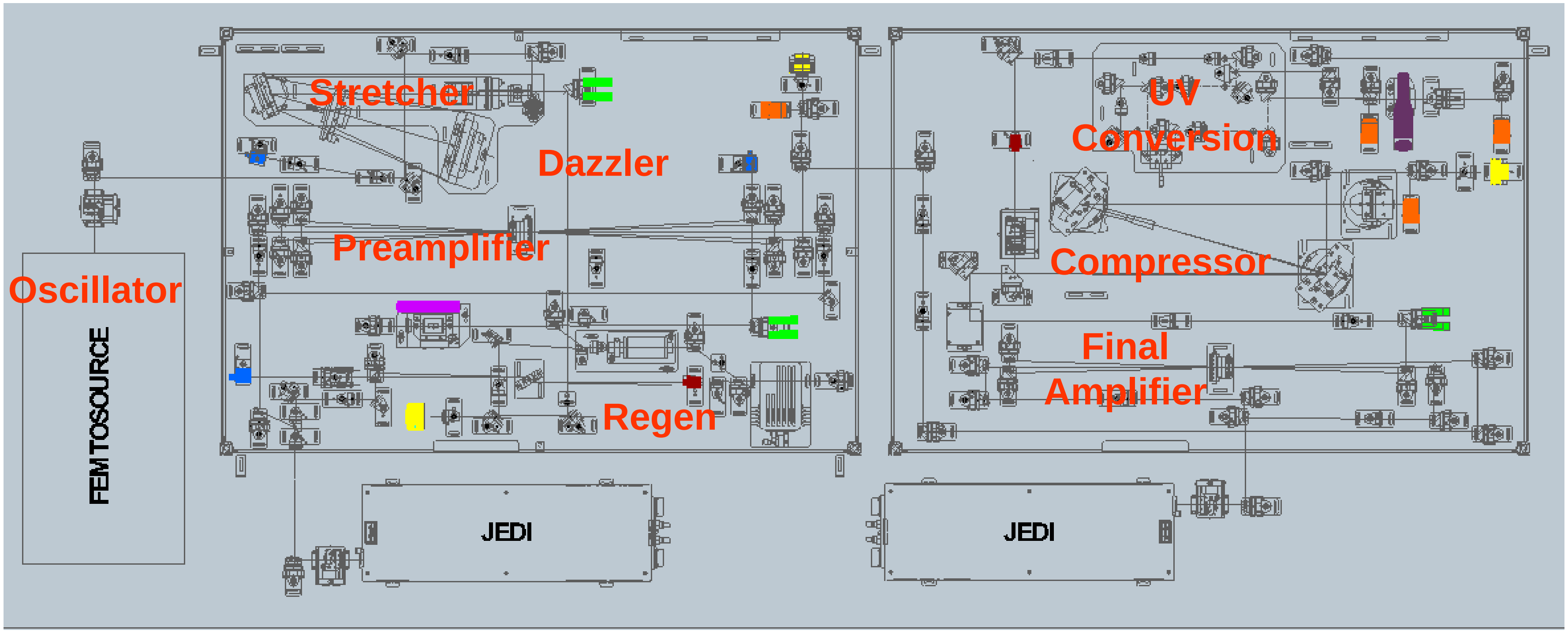
Laser Beam Specifications on the Cathode

Parameter	Nominal Spec	Tolerance
Central Wavelength	255nm	+/- 3nm
Pulse Energy	>0.4mJ Continuously adjustable	<2% RMS variation (shot-to-shot)
Spatial Fluence Profile	Uniform (adjustable)	<20% (peak-to-peak)
Spot Radius	Adjustable from 0.6mm to 1.5mm	<4% (Shot-to-shot)
Centroid Position Stability	<10% radius (RMS)	
Repetition Rate	120Hz, 60Hz, 30Hz, 10Hz, 1Hz	
Temporal Power Profile	Uniform (adjustable) Slope adjustable from -10% to +20%	<8% peak-to-peak on the plateau
Profile FWHM	10 psec (adjustable to from 5 to 20 psec)	< 2 % RMS (over multiple shots)
Profile Rise/Fall time	1.0ps (10% to 90%)	
Timing Jitter	< 0.25 psec (shot-to-shot)	with respect to the external RF source

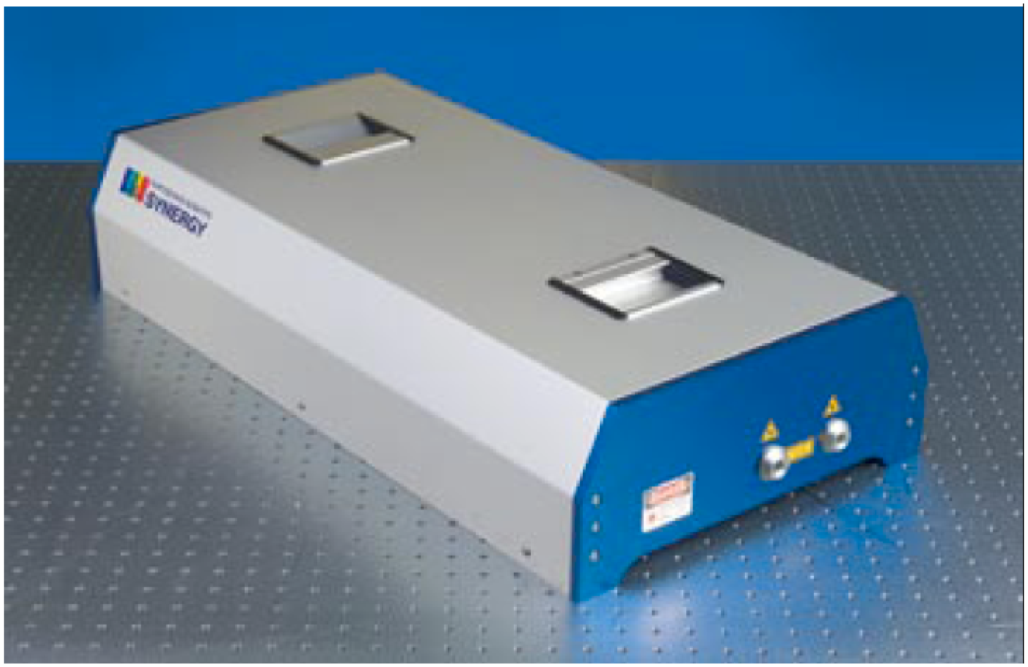
Thales Laser System Specifications

Parameter	Nominal spec	Tolerance
Wavelength	255nm nom.	+/- 3nm
Pulse energy	> 2.5 mJ	< 2 % rms variation
Spatial fluence profile	Gaussian, M^2<2	<10% peak-to-peak variation within the profile)
Pointing Stability	Less than 25 microradian	
Rep rate	120Hz, 60Hz, 30Hz, 10Hz, 1Hz	
Temporal power profile	Uniform	<8% peak-to-peak on the plateau
profile FWHM	10 psec adjustable from 5 to 20 psec	< 2 % (RMS over multiple shots)
Rise/fall time	1.0 psec (10% - 90%)	
Timing jitter	< 0.25 psec (shot-to-shot)	
MTBF	>5000 hours	With periodic maintenance

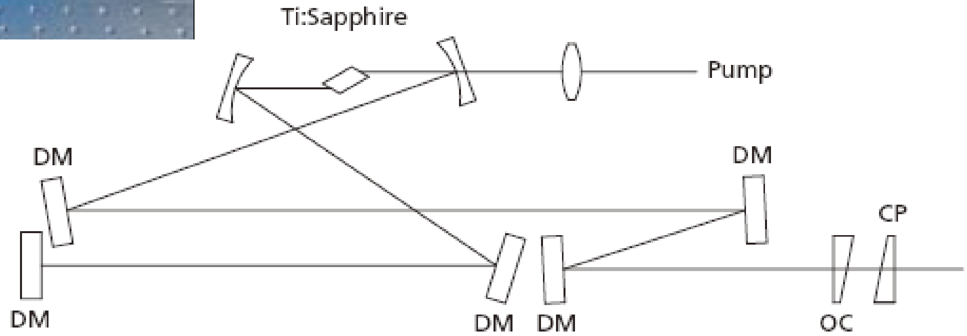
Thales Laser system



Oscillator



- Includes SP-Millenia pump
- 50nm bandwidth
- 760 nm
- 400 mW



Femtolock

4.Femtolock schematic

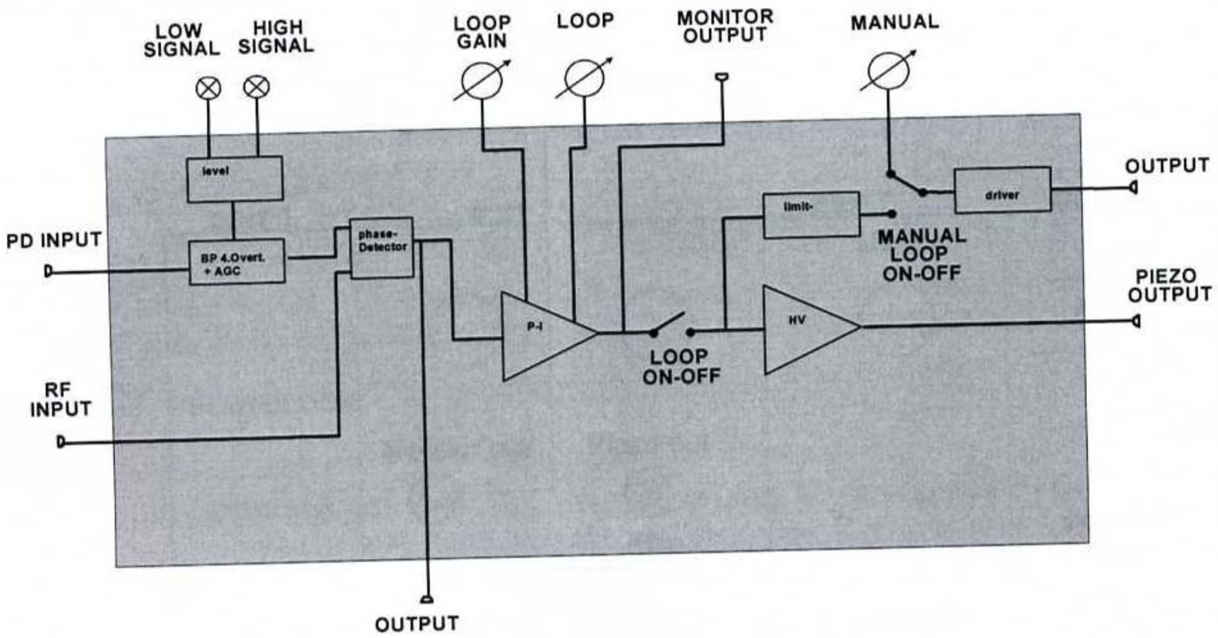


Fig.1: Schematic of the FEMTOLOCK.

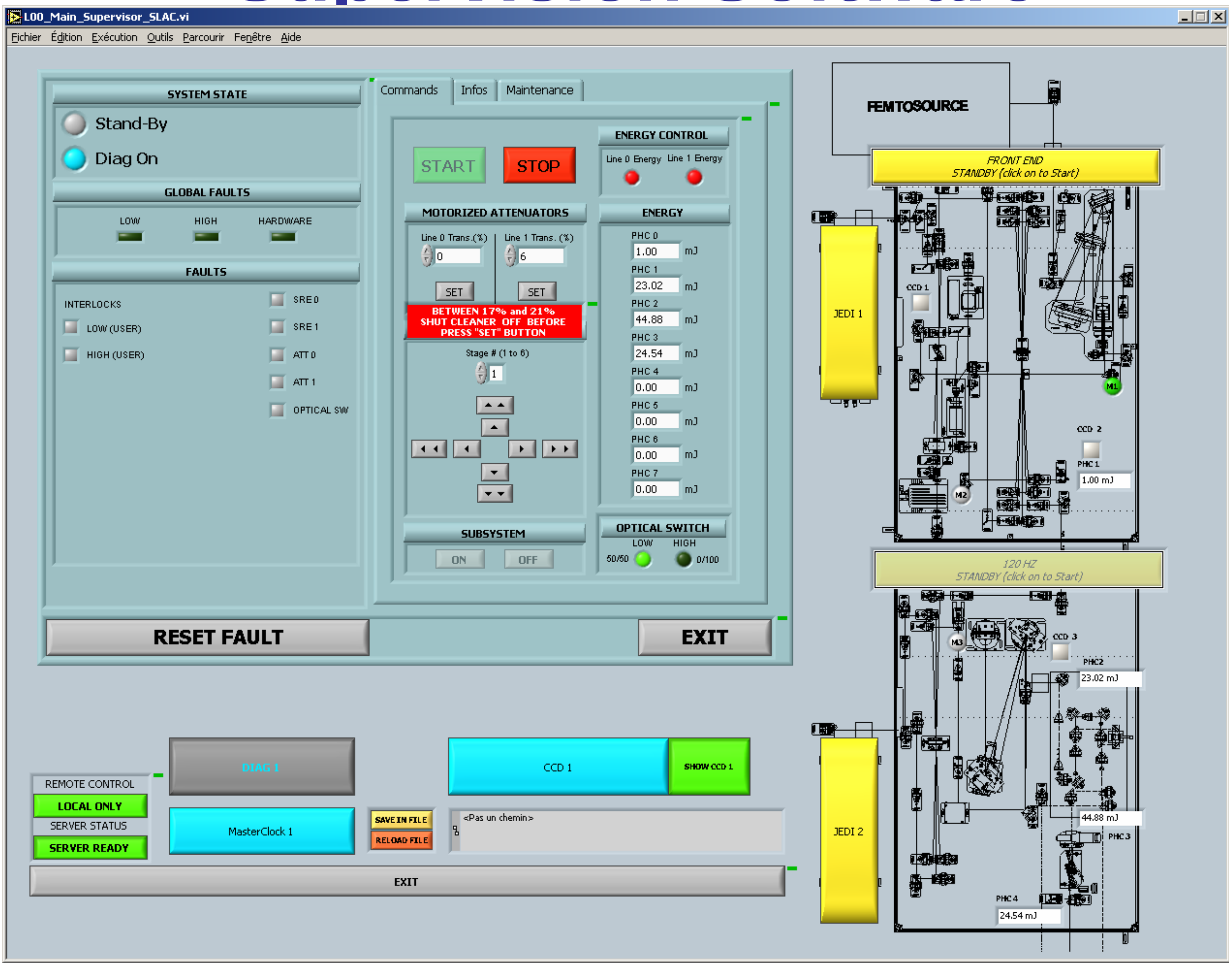
Jedi Pump Lasers

- QCW diode pumped
- MOPA design
- 2 amps
- KTP doubler

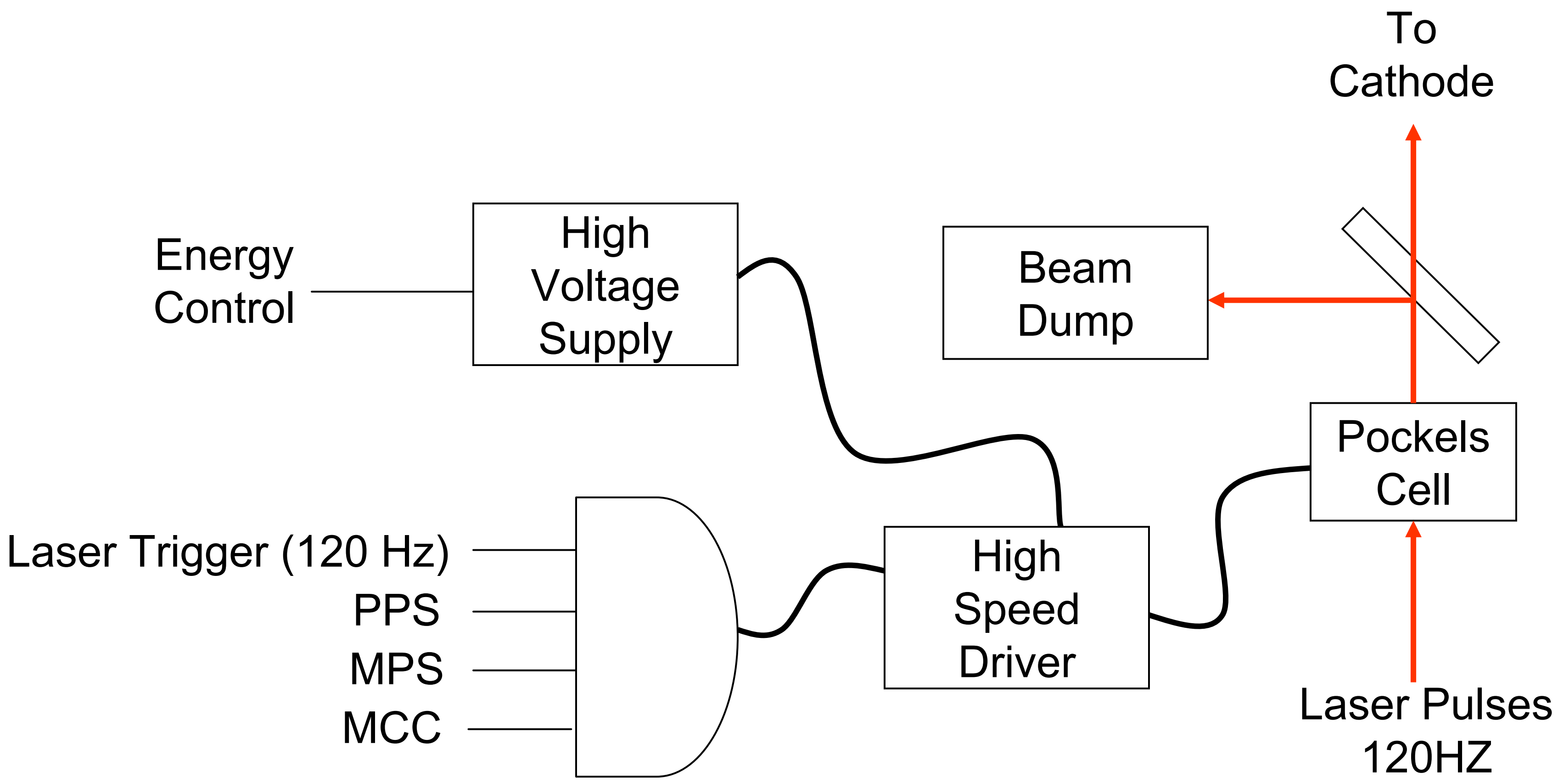
Output Specifications

Repetition rate (Hz)	100
Energy per pulse (mJ)	>120
Average power (W)	>12
Pulse width (ns)	<15
Wavelength (nm)	532
Shot-to-shot stability (1) (% rms)	< 1.5
Typical M^2	< 10
Beam pointing stability (1) (µrad)	± 50
Beam profile	Multimode, Gaussian

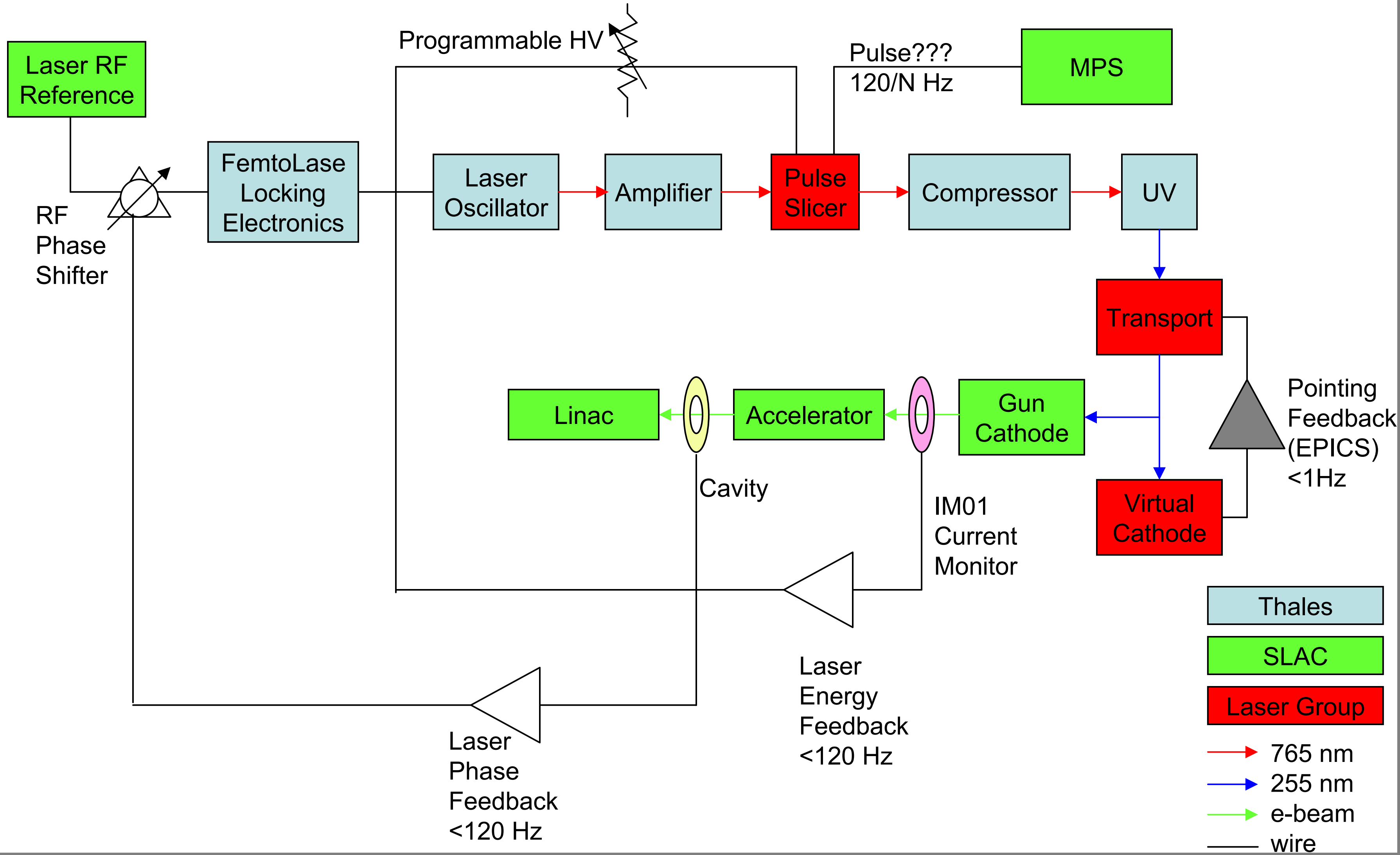
Supervision Software



Drive Laser Pulse Control



Laser Feedback



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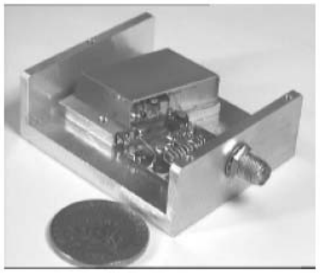
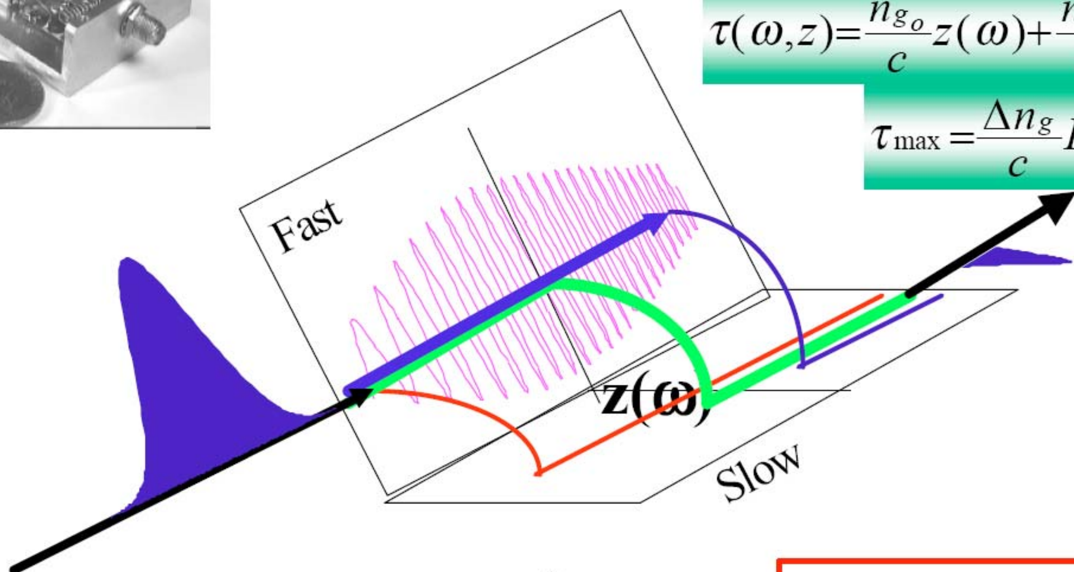
Pulse Shaping - Dazzler



PHYSICAL CONCEPT

$$\tau(\omega,z)=\frac{n_{g_o}}{c}z(\omega)+\frac{n_{g_e}}{c}\left(L-z(\omega)\right)$$

$$\tau_{\max}=\frac{\Delta n_g}{c}L$$

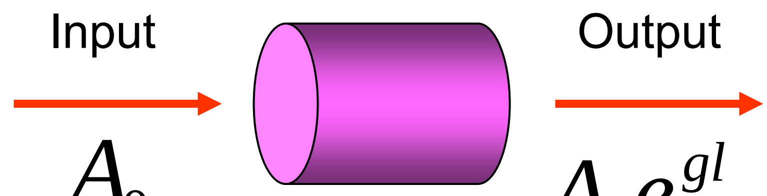


$$E_{out}(t)\propto S(t/\alpha)\otimes E_{in}(t) \quad \text{où} \quad \alpha=\frac{f_{ac}}{f_{opt}}\approx 10^{-7} \Rightarrow \boxed{E_{out}(\omega)\propto S(\alpha\omega)E_{in}(\omega)}$$

P. Tournois, Opt. Comm. **140**, 245 (1997)
F. Verluise, V. Laude, Z. Cheng, Ch. Spielmann et P. Tournois, Opt. Lett. **25**, 575 (2000)

FASTLITE

Solid State Saturation Fluence



$$A_0 \qquad A_0 e^{gl}$$

$$g = \sigma n$$

$$g = \frac{g_0}{\left(1 + {I}/{I_s}\right)}$$

Material Dependent $\longrightarrow$ $J_{sat} = \dfrac{h\nu}{\sigma}$

$$I_s = \frac{h\nu}{\sigma \tau_f}$$

In general, lasers are designed to operate at Jsat because:

•Optimize gain and energy extraction

•Better energy stability

Intensity at Saturation (2 ps)

Material	Jsat (J/cm^2)	Imax (W/cm^2)
Nd:Silicate	6	3×10^{12}
Yb:Silicate	32	1.6×10^{13}
Ti:Sapphire	1	5×10^{11}

- ALL >> 5×10^9 W/cm^2

Conclusion:
We must reduce pulse
INTENSITY
during amplification

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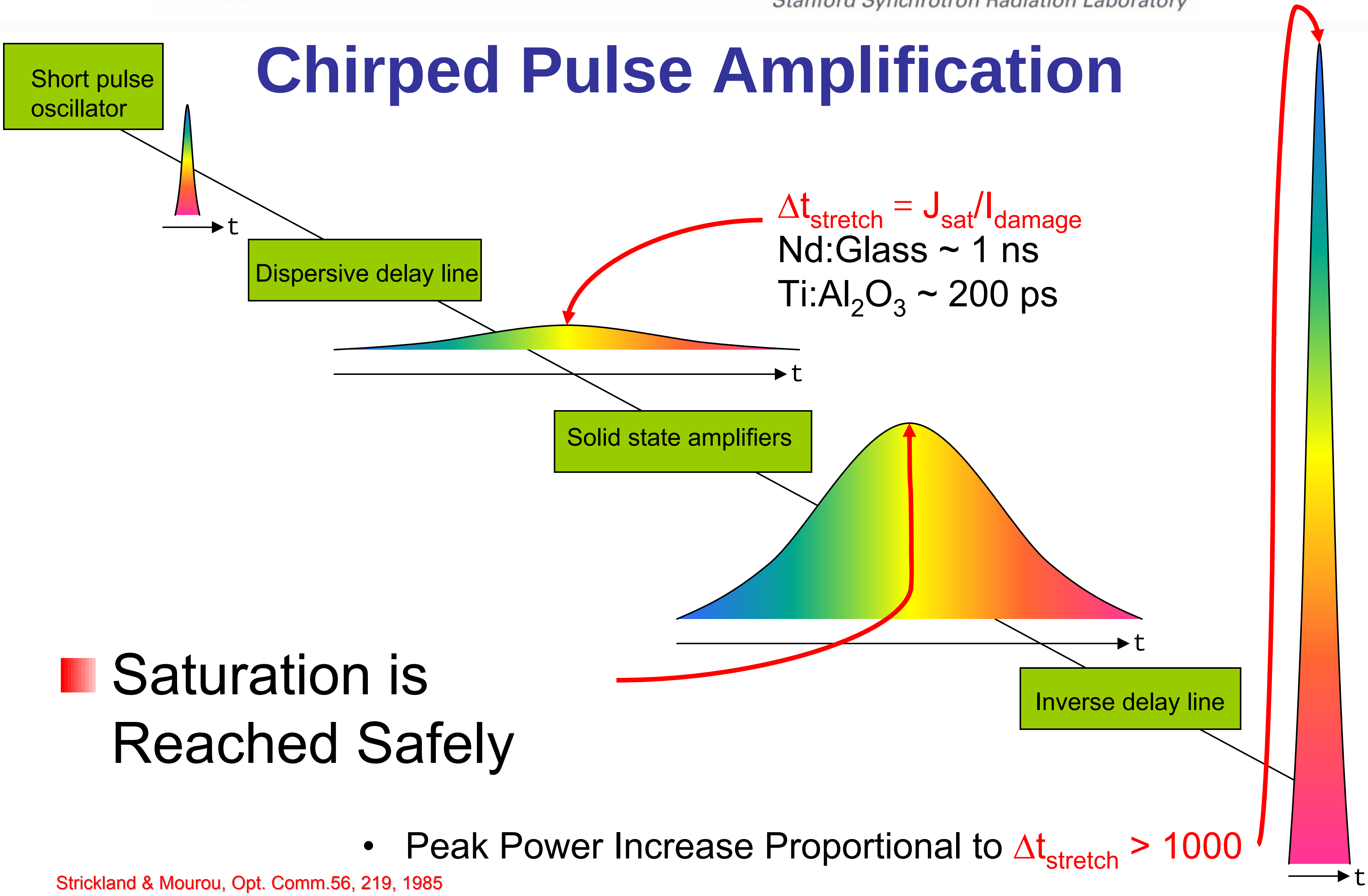
Chirped Pulse Amplification



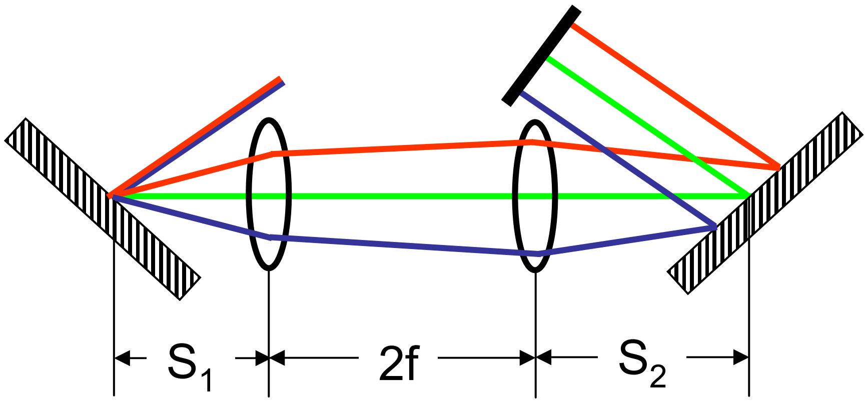
- Saturation is Reached Safely

- Peak Power Increase Proportional to $\Delta t_{stretch} > 1000$

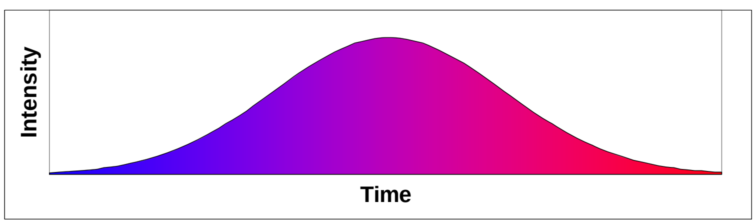
Strickland & Mourou, Opt. Comm.56, 219, 1985

Conventional CPA Stretcher/Compressor

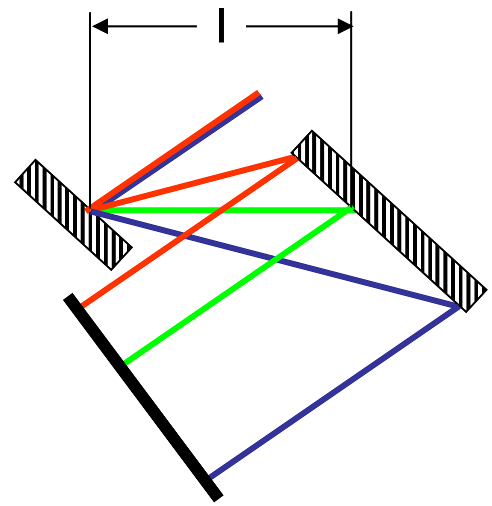
Positive dispersion stretcher

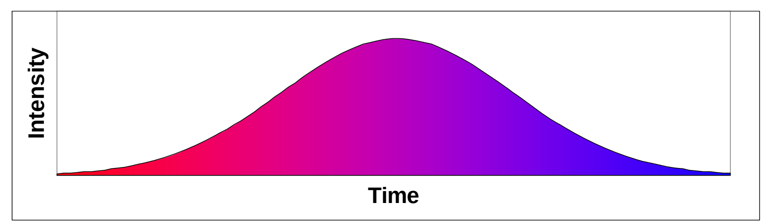


$l_{eff}=(f-S_1)+(f-S_2)$

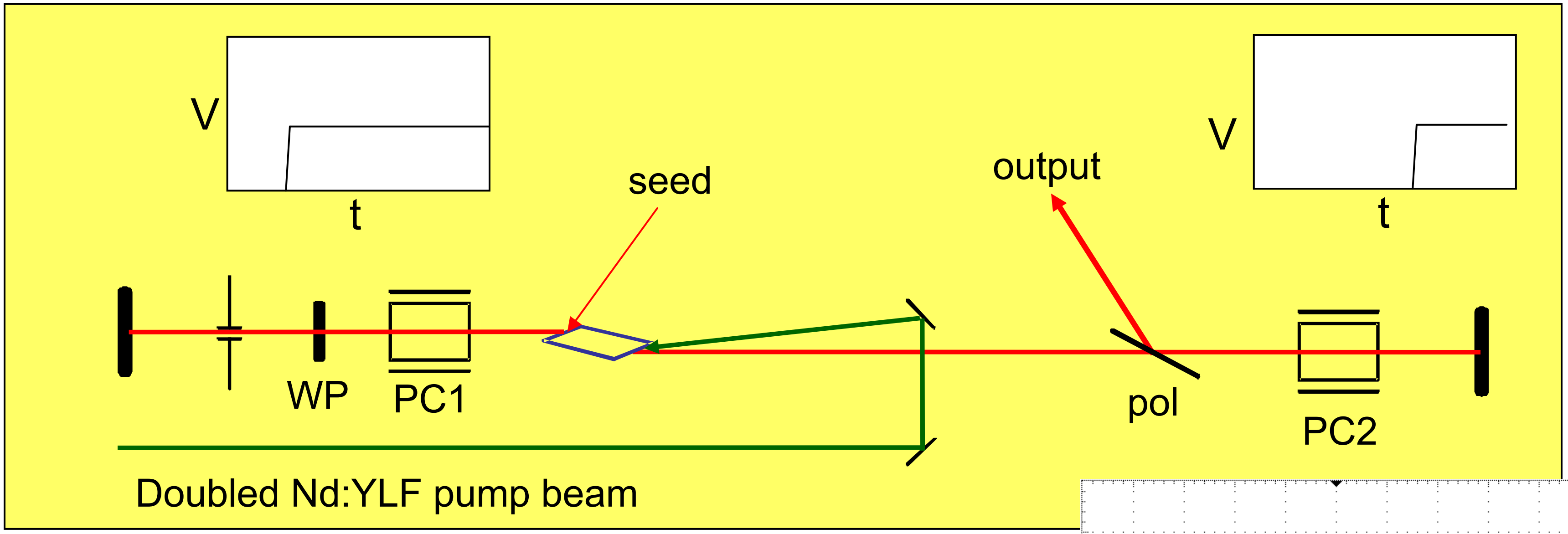


Negative dispersion compressor

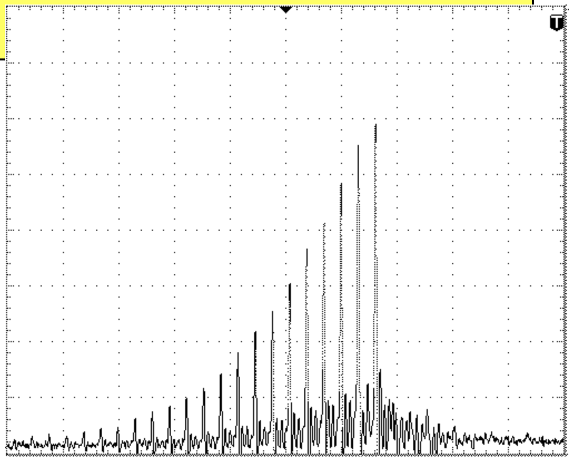




Generic Regenerative Amplifier

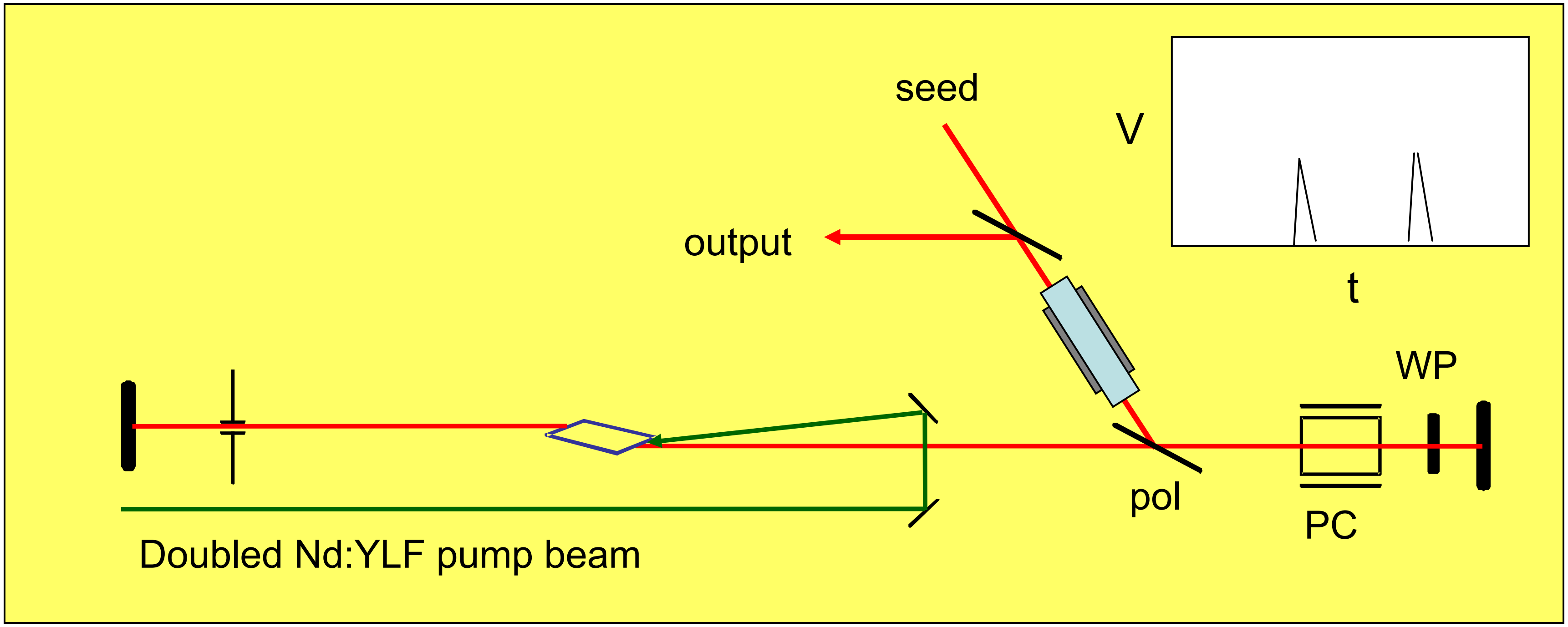


- Low energy seed pulse injected into regen cavity
- First Pockels cell traps pulse in cavity
- Pulse gains energy on each pass through rod
- Second Pockels cell ejects pulse off of polarizer when stored energy is depleted



Pulse build-up in regen cavity

Generic Regenerative Amplifier



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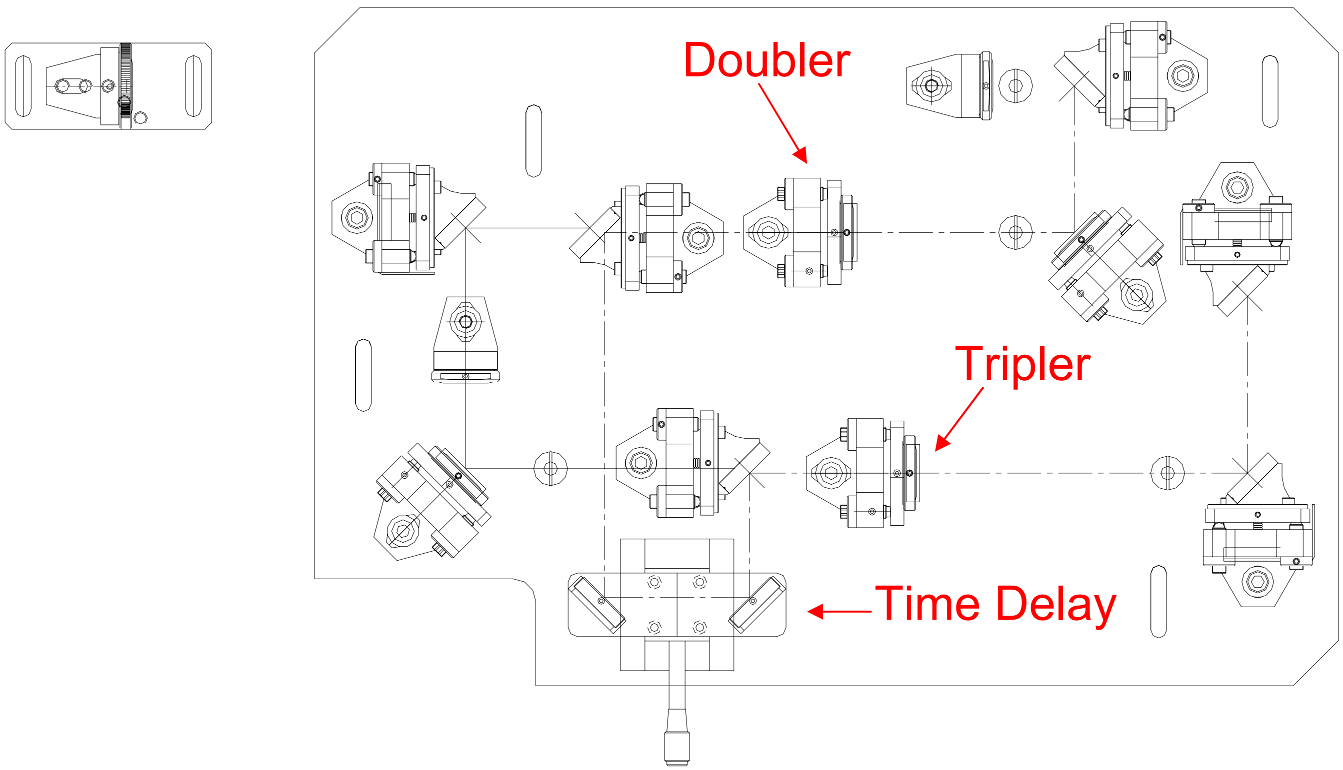
THG Module

- Two type I BBO SHG and THG crystals



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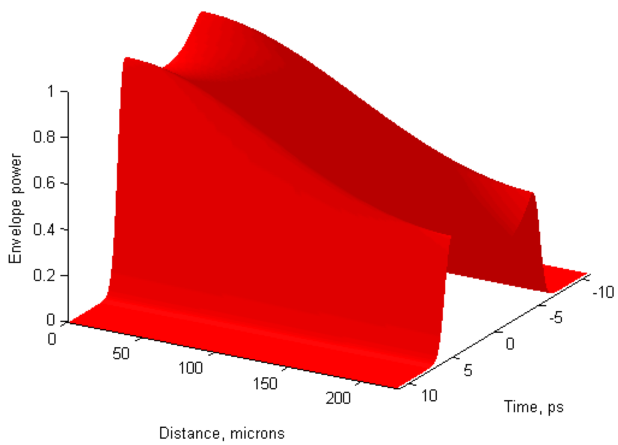
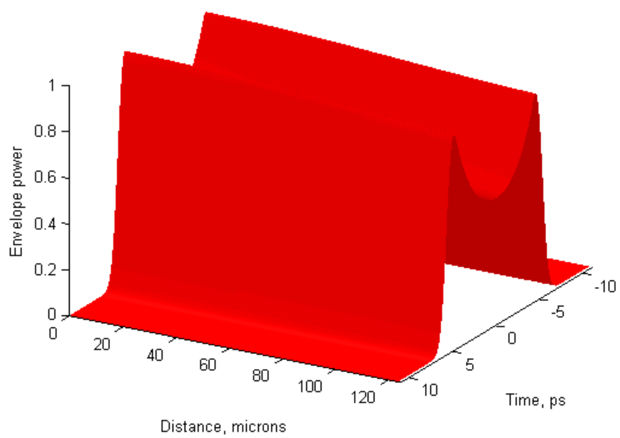
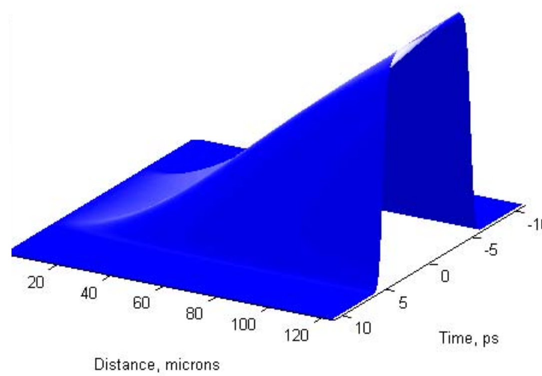
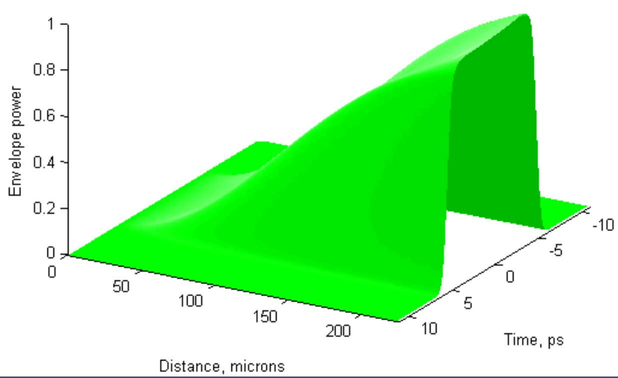
Coupled NL Splitstep FFT Pulse Propagation

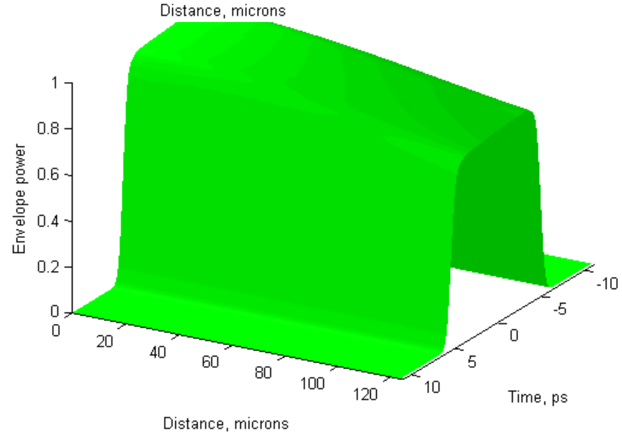
Temporal discretization > 4096
Spatial discretization per stage > 1000











Brent Stuart, John Heebner, Chris Ebbers, Igor Jovanovic, Susan Haynes, Ben Pyke
(LLNL)

Transport -Layout

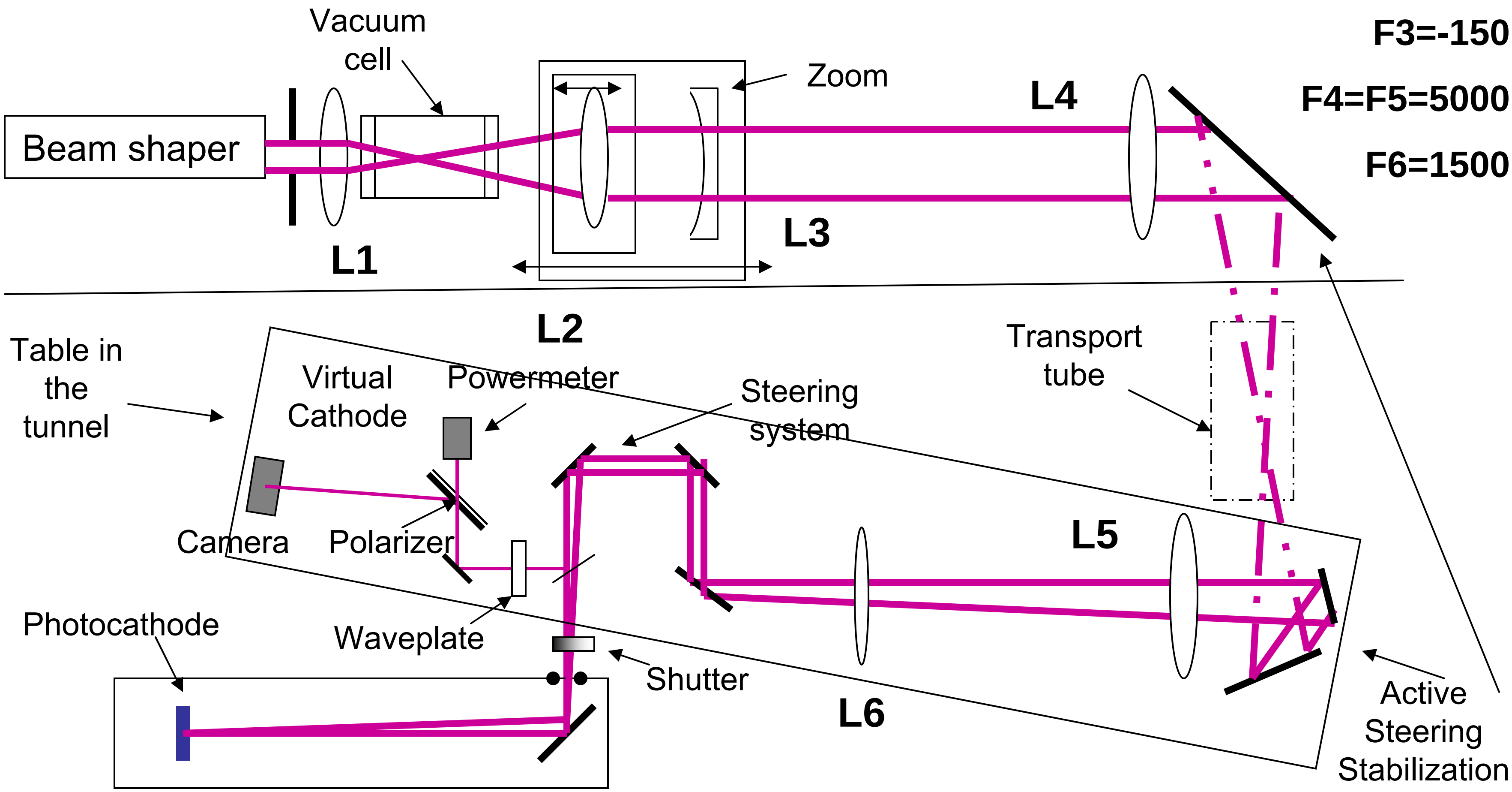
F1=200

F2=120

F3=-150

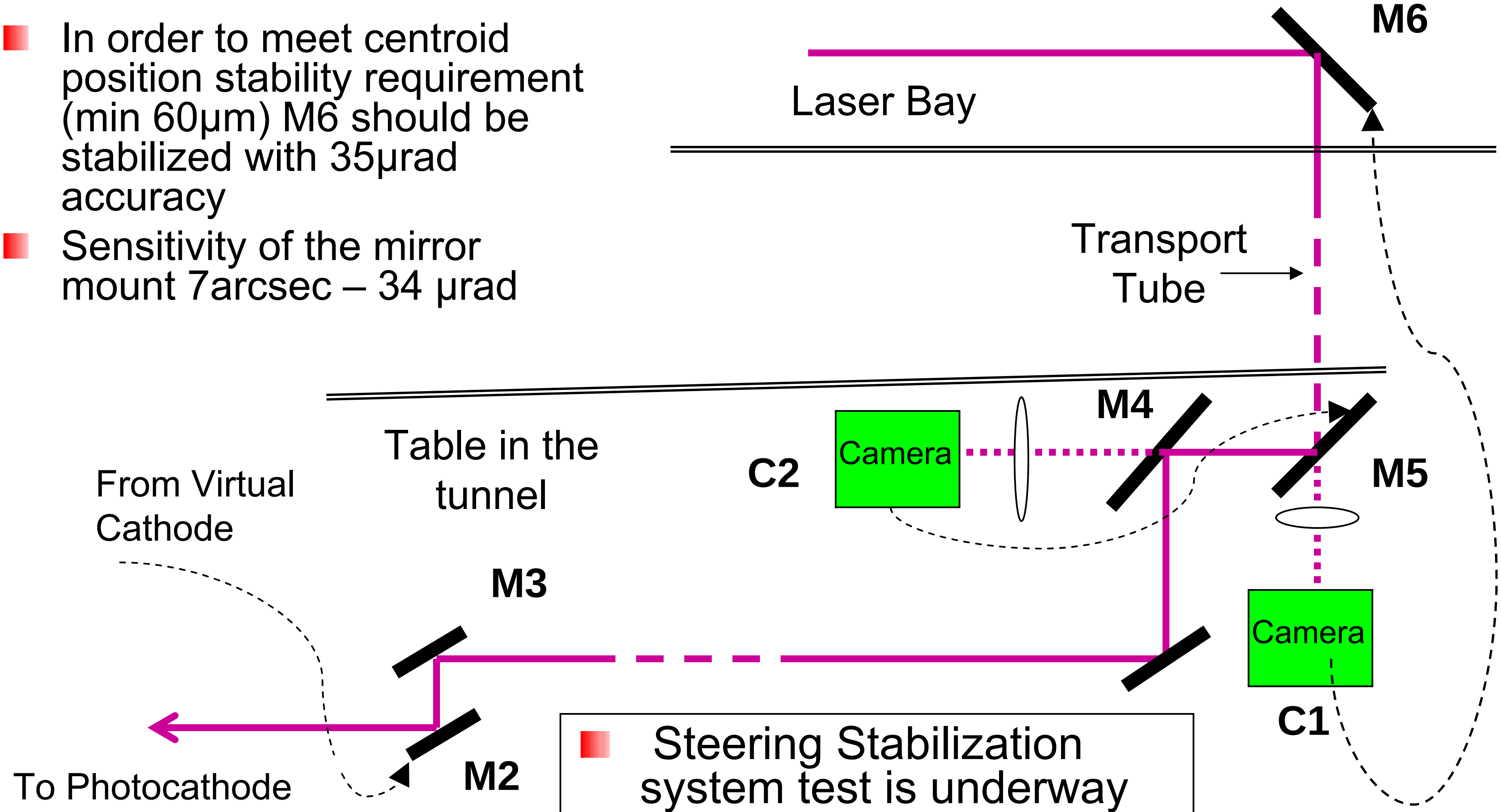
F4=F5=5000

F6=1500



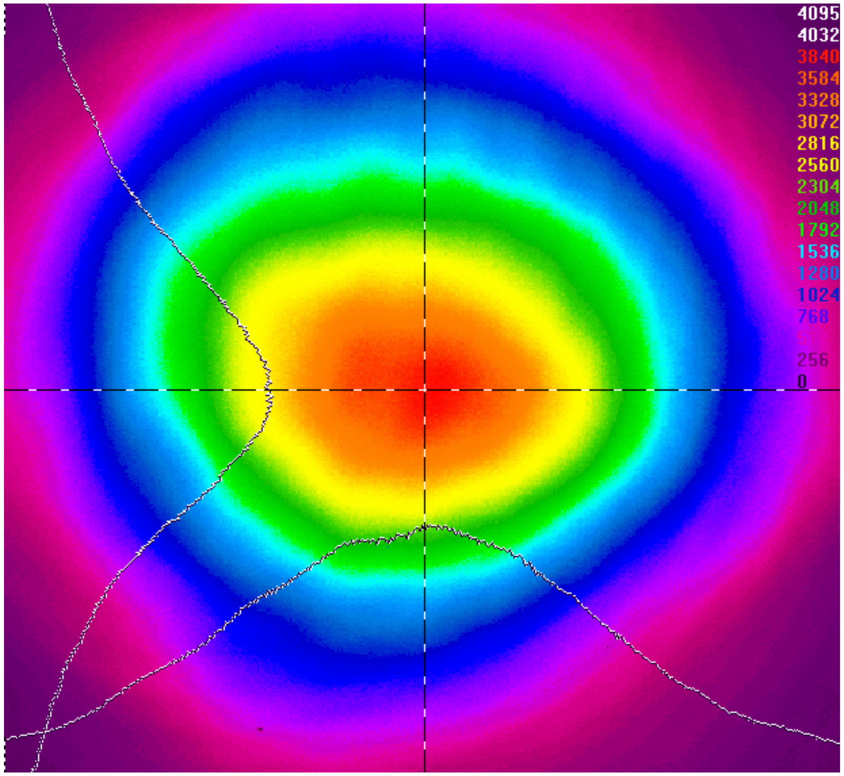
Active Steering Stabilization

- In order to meet centroid position stability requirement (min 60μm) M6 should be stabilized with 35μrad accuracy
- Sensitivity of the mirror mount 7arcsec – 34 μrad

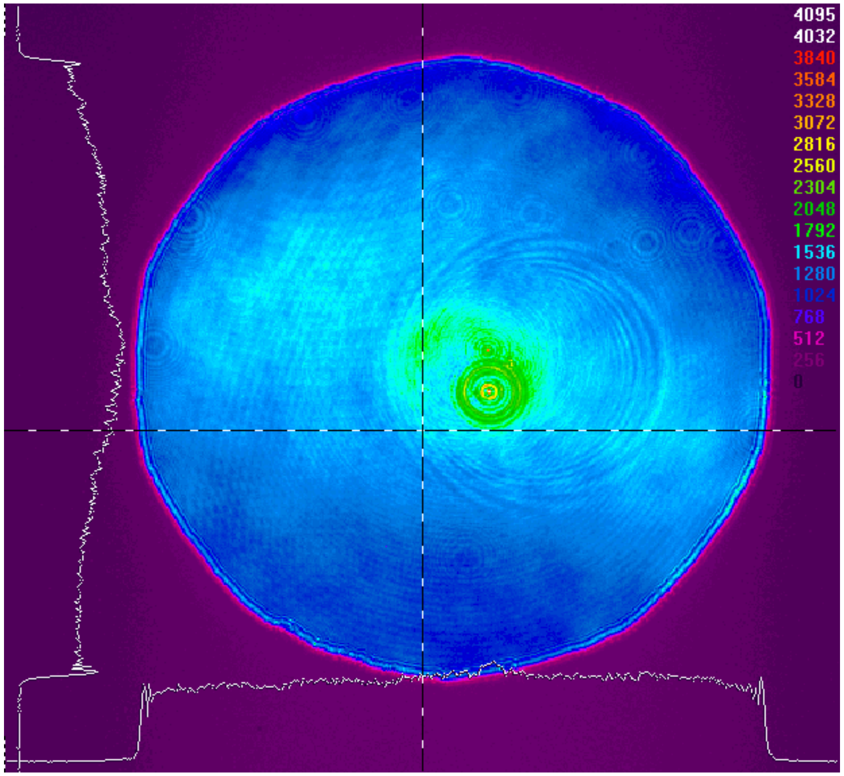


- Steering Stabilization system test is underway

Testing of the Newport Shaper



- Input beam



- Image of the aperture after the shaper

Courtesy of John Castro

Recent Milestones

- Safety
  - LSS certified 11/3/06
  - Final SOP approved 11/6/06
  - ESC Walkthrough 11/8/06

Standard Operating Procedure
and Approval to Operate
The
LCLS Injector Laser Laboratory
(LCLS ILL)

Author:	***Sasha Gilevich*, LCLS ILL System Laser Safety Officer**
Date and Version:	**10/11/2006, Version 4**
Department:	**LCLS**
Location:	**Sector 20**
Expiration Date:	**until special notice**

APPROVAL OF STANDARD OPERATING PROCEDURE(S) DESCRIBED HEREIN:

John Galayda, Director, LCLS — Date

Sasha Gilevich, LCLS Injector Drive Laser Safety Officer — Date

Bill White, Laser Group Leader — Date

Ted Fieguth, SLAC Laser Safety Officer — Date

APPROVAL TO OPERATE SYSTEM(S) DESCRIBED HEREIN UNTIL EXPIRATION:

John Galayda, Director, LCLS — Date

Sasha Gilevich, LCLS Injector Drive Laser Safety Officer — Date

Ted Fieguth, SLAC Laser Safety Officer — Date

NLTL SOP and Operation Approval, 10/13/06, Version 4.0, pg. 1/23

Recent Milestones

- July 21 – Laser Arrives at Sector 20

Recent Milestones

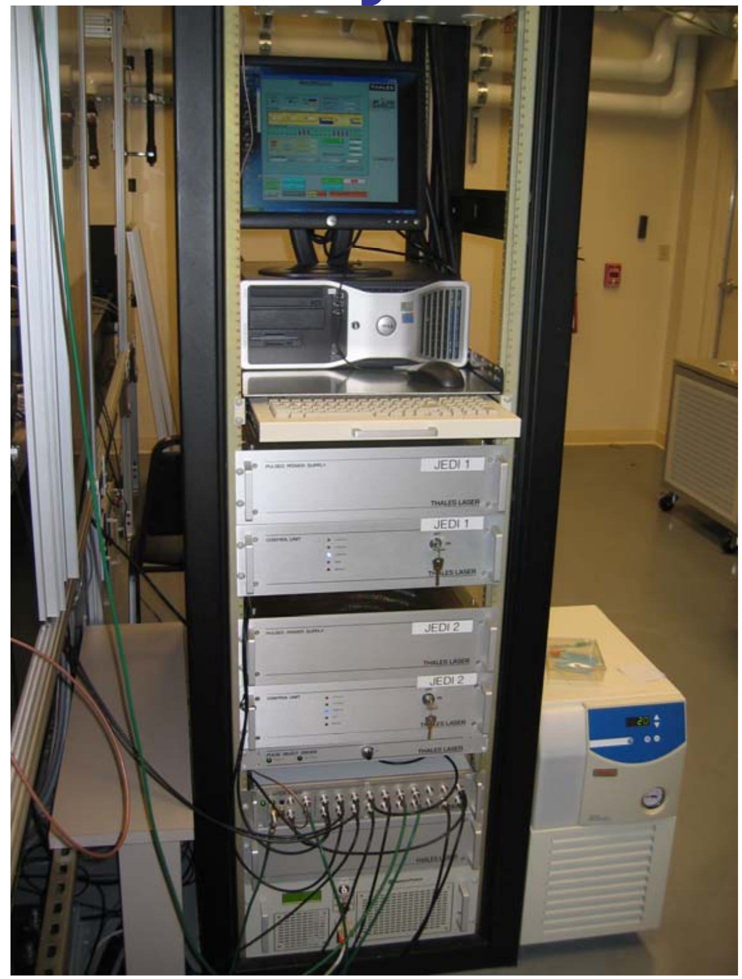
- July 14 – Laser Tables Installed

Recent Milestones

- July 24 – Complete system on table

Where are we now? - Today

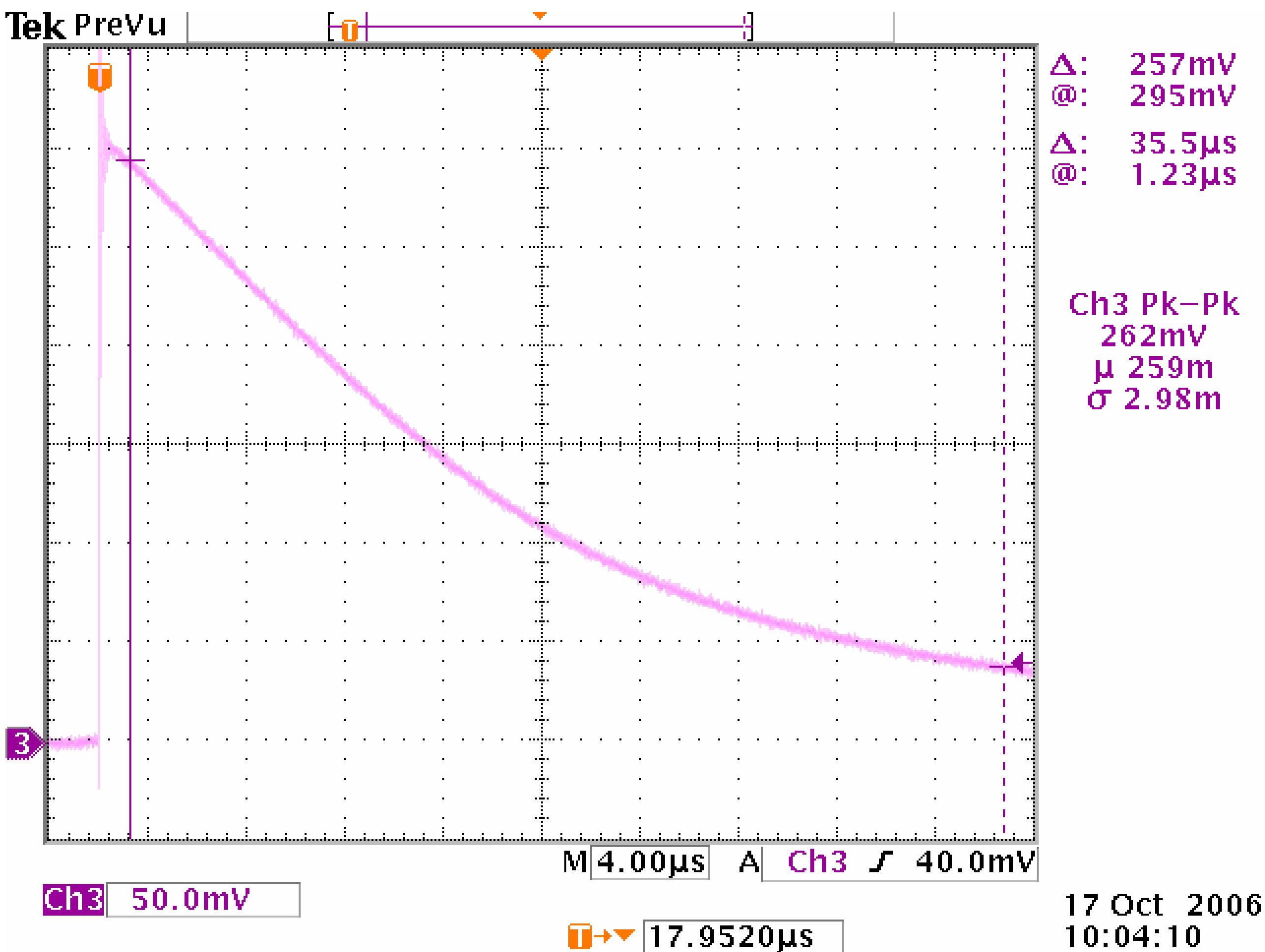
Laser Infrastructure complete



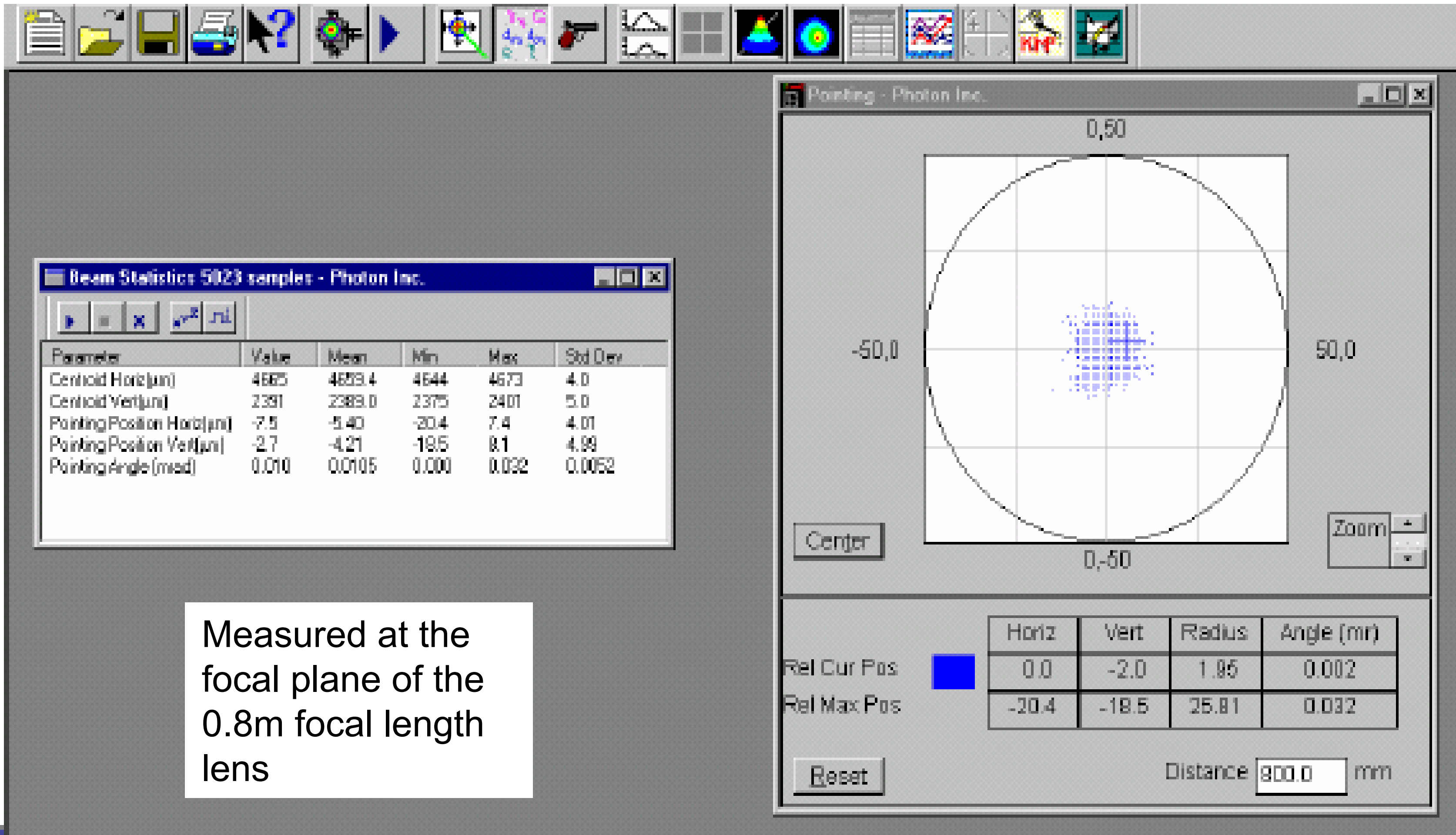
Thales Laser System Performance

- Pulse Energy
  - After compressor – 35mJ
  - UV output-2.8mJ
- Energy jitter in UV – 1.1% (rms)
- Spatial shape in IR – Gaussian, M^2=1.5
- Pointing Stability – 5 μrad
- Timing Jitter – 0.21psec

Energy Jitter Measurements



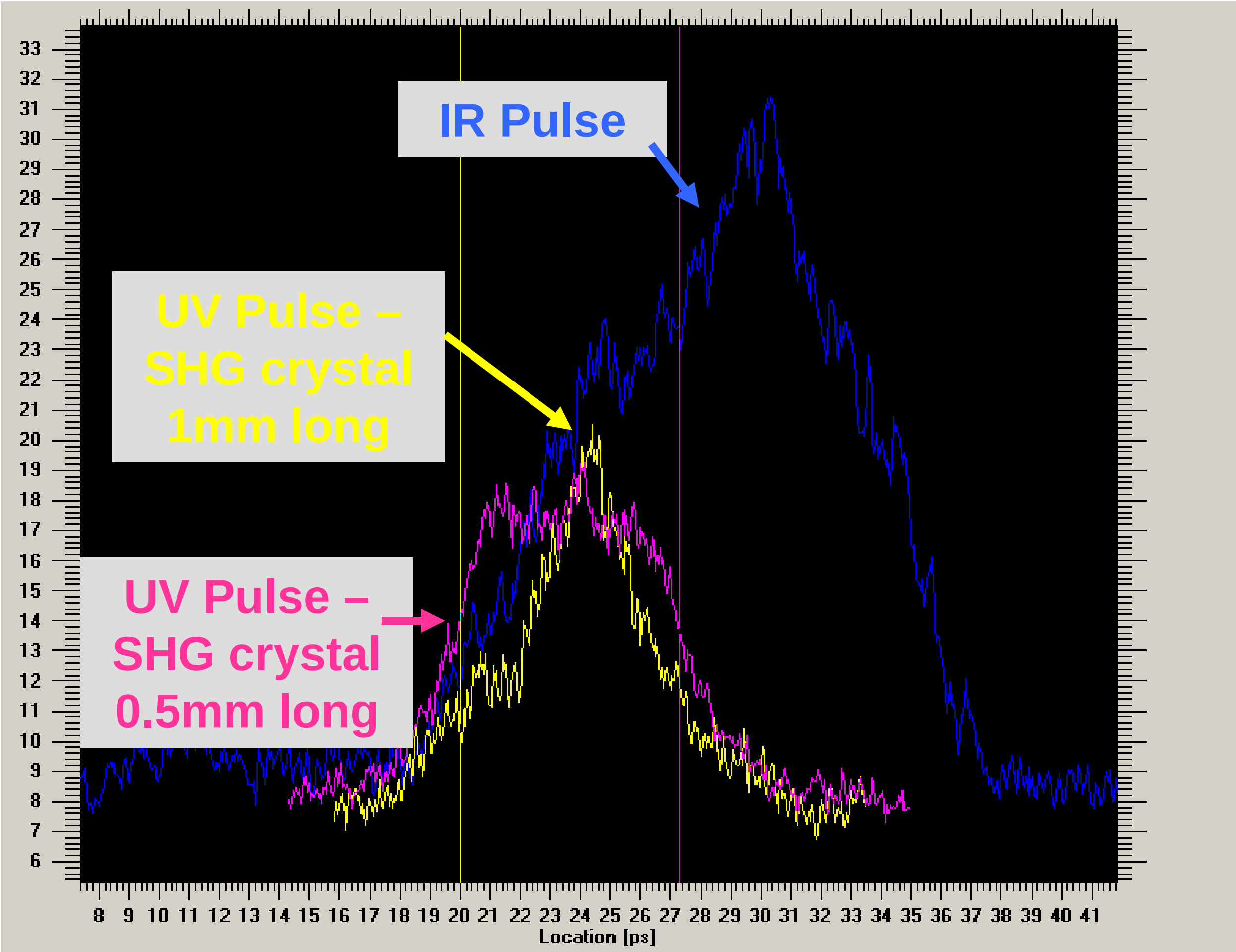
Pointing Stability Measurements



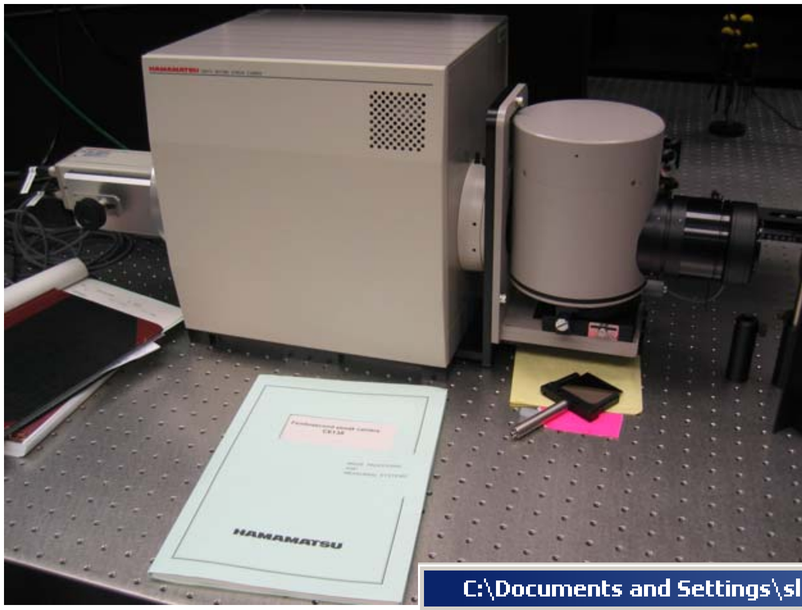
Measured at the focal plane of the 0.8m focal length lens

Temporal Shaping and UV Conversion

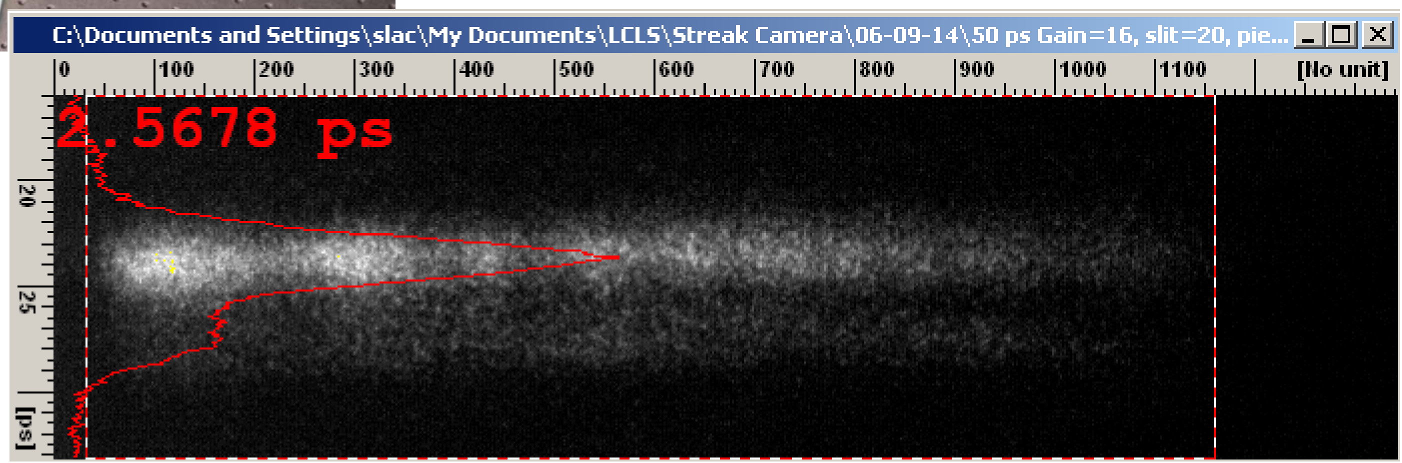
- UV Conversion process affects the temporal shape – Optimum crystal length is essential



Where are we now? - Today

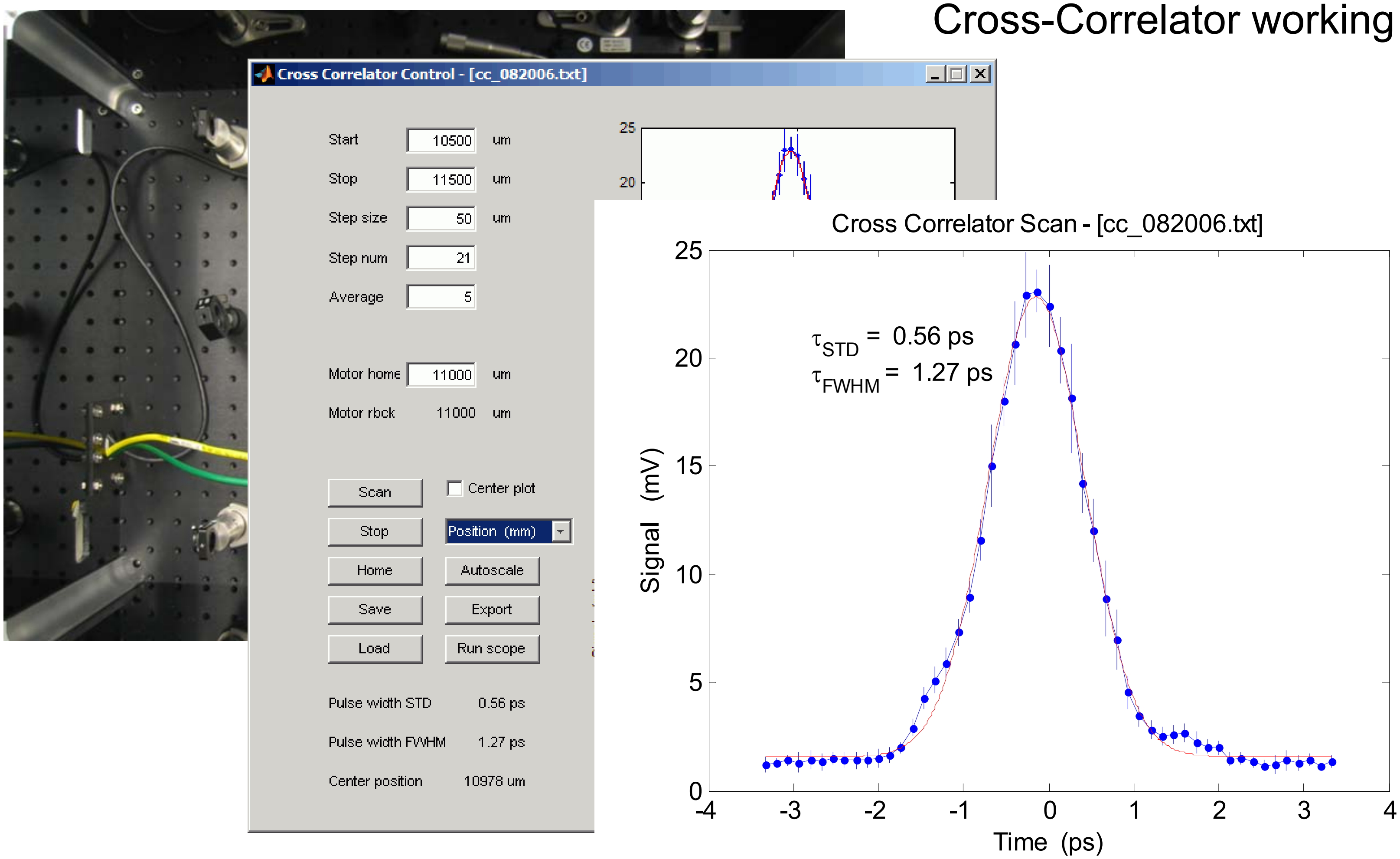


Streak Camera installed and working



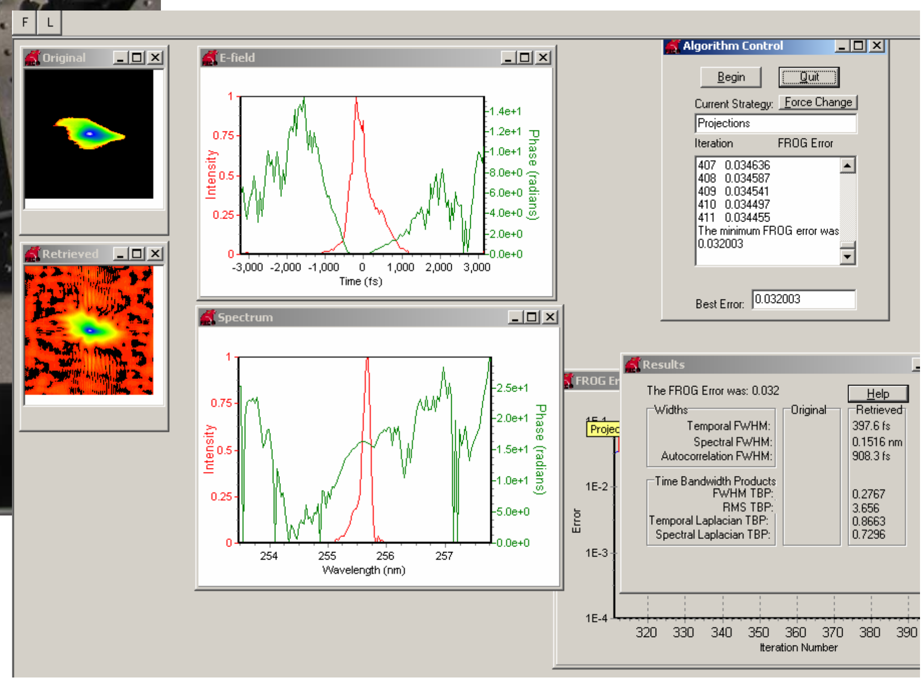
Where are we now? - Today

Cross-Correlator working



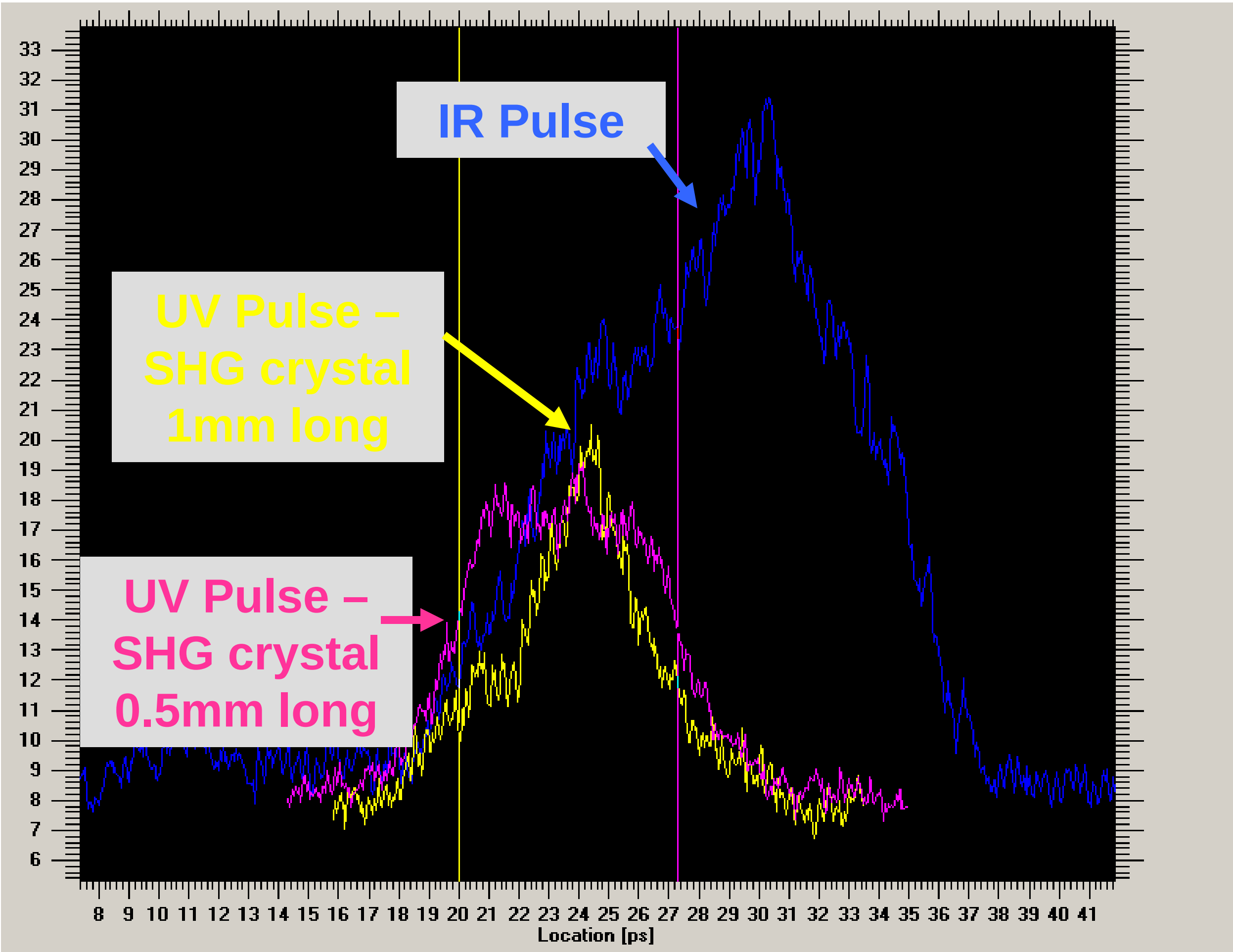
Where are we now? - Today

TG-FROG working



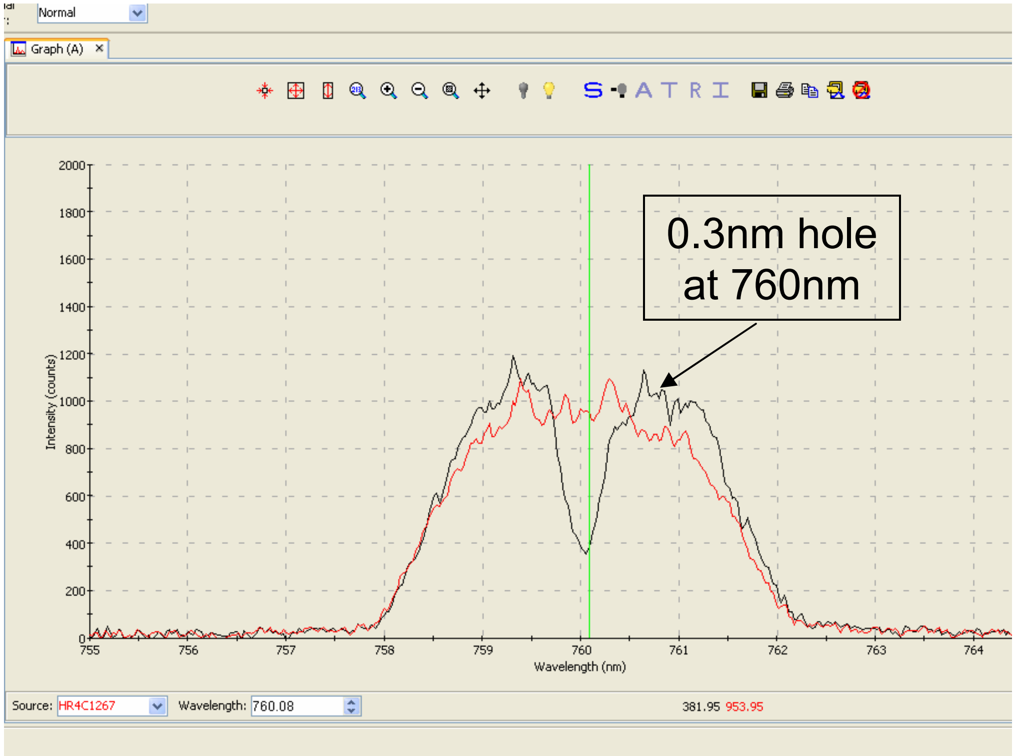
Temporal Shaping and UV Conversion

- UV Conversion process affects the temporal shape – Optimum crystal length is essential

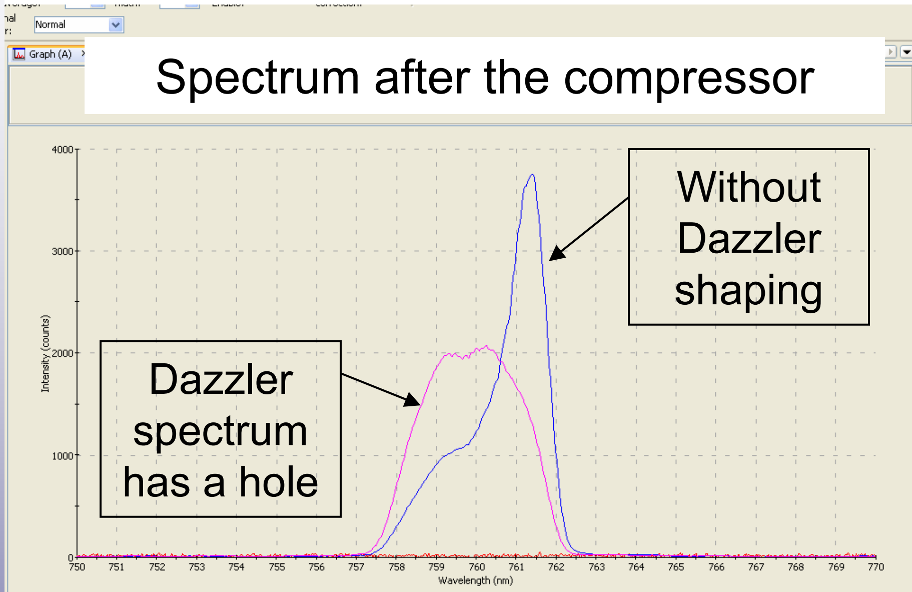


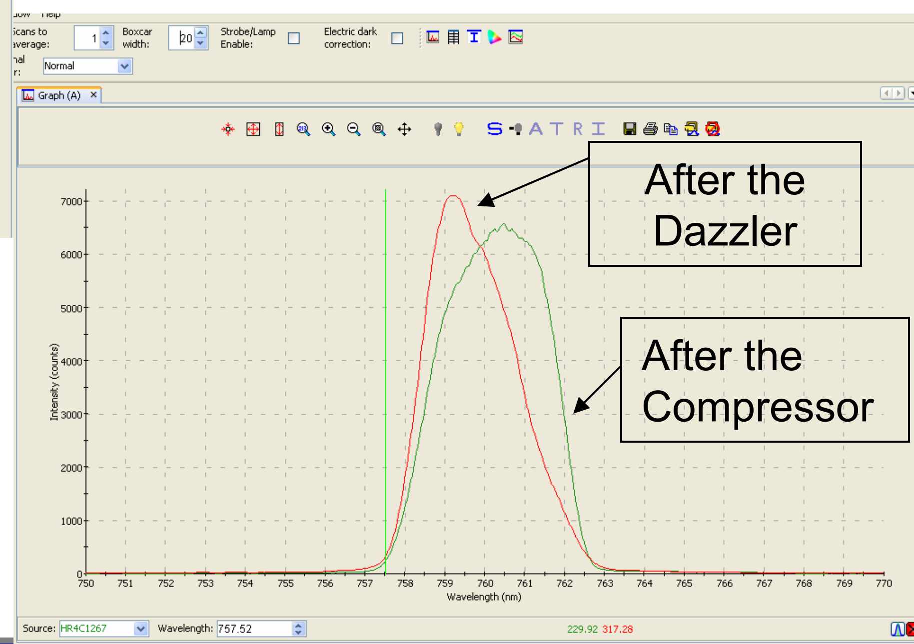
Temporal Shaping

- Dazzler 45mm long
- 2 passes in the Dazzler
- Beam size, collimation and alignment of the Dazzler are critical
- Resolution of the Dazzler should be 0.3nm



Using Dazzler to Shape the Spectrum





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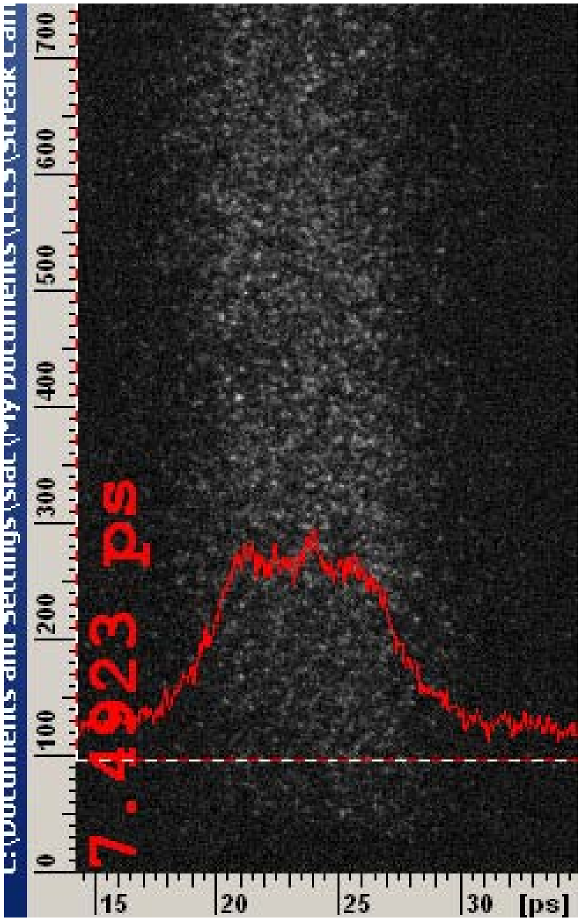
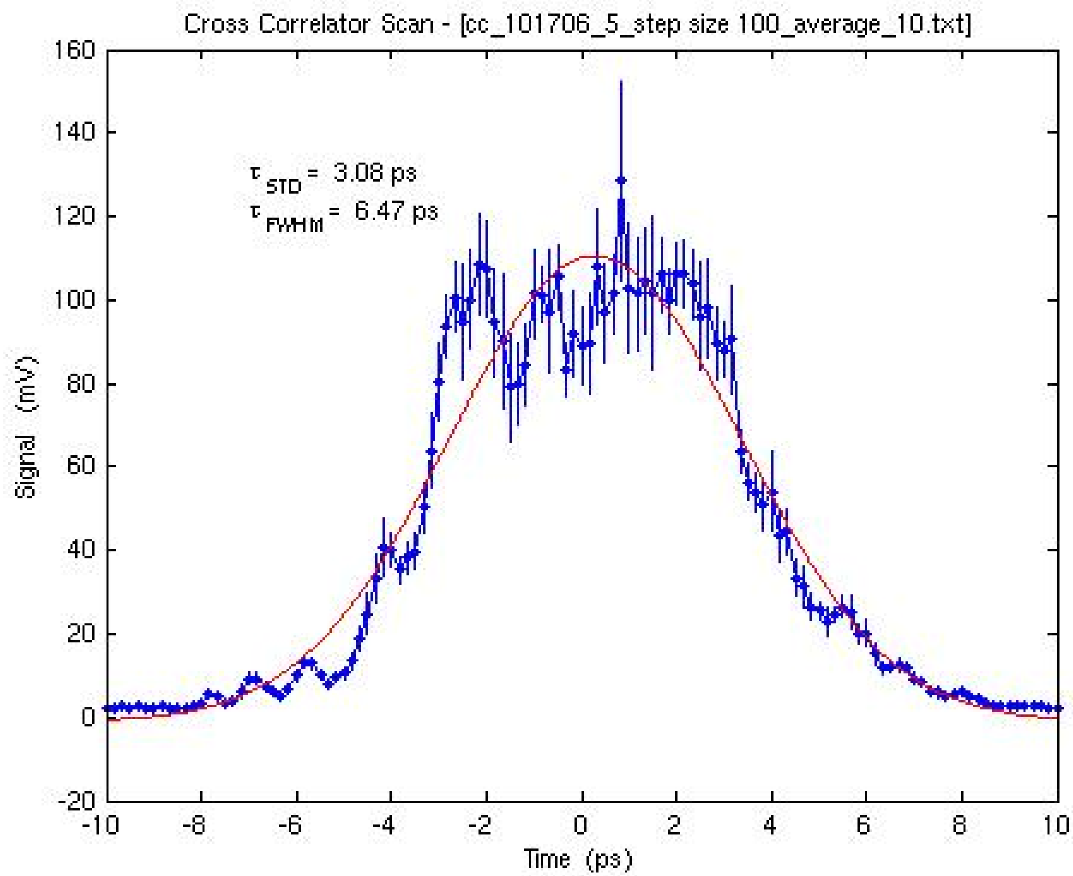
Temporal Pulse Shape



Streak Camera



Cross correlator

Temporal Pulse Shaping

- The achieved temporal pulse shape meets physics requirements for the injector commissioning
- Plan to improve the temporal shape
  - Replace the Lyot filter in the regen amplifier by the edge mirrors – this will reduce oscillations
  - Continue working on the Dazzler settings and the optimum UV conversion crystals lengths
  - Thales engineers are coming back in December-January to continue working on shaping
- Plan B – to use stacking of Gaussian pulses
  - Design and parts for pulse stacking are in place

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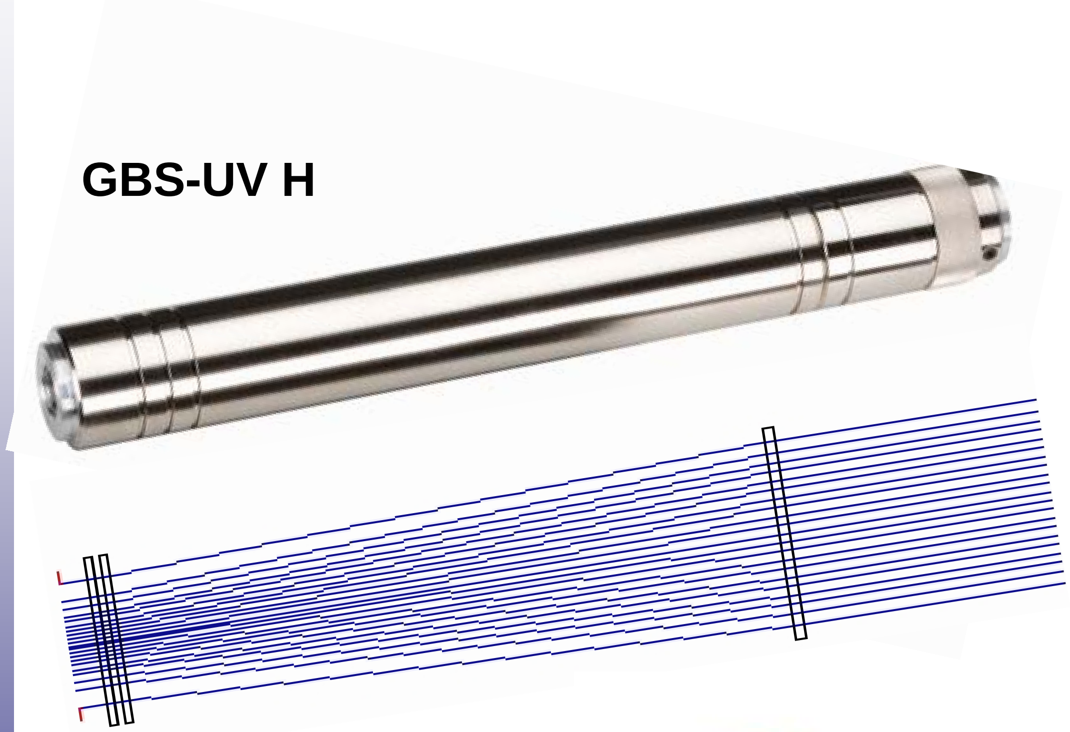
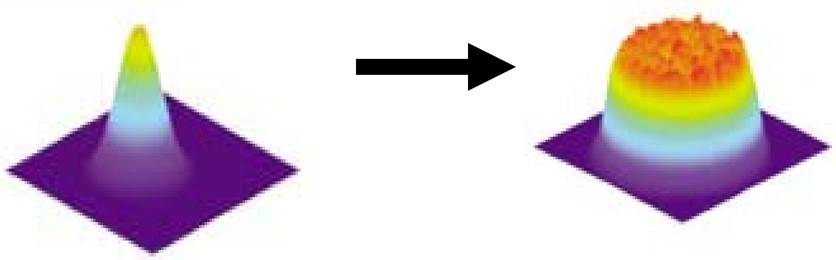
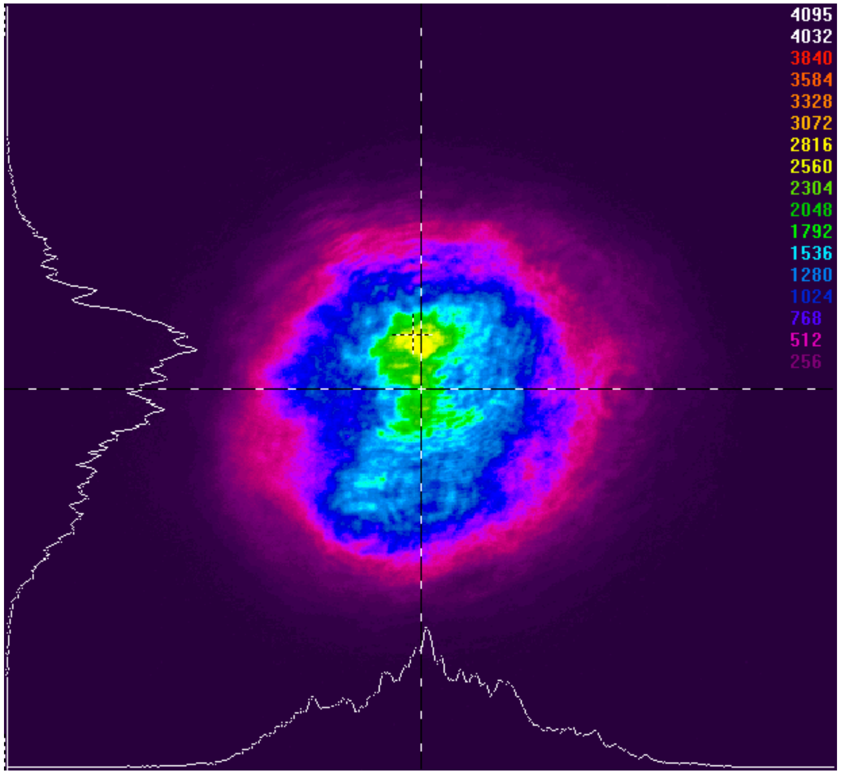
Spatial Beam Shaping – Newport Shaper



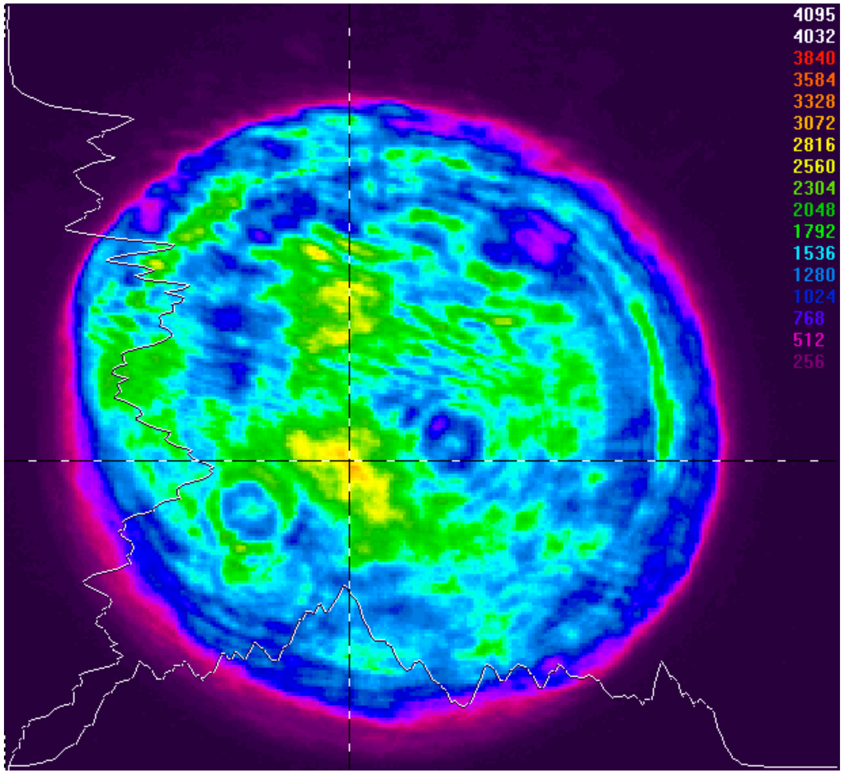


- Converts Gaussian beam input to flat top output
- Transmission >97%
- High profile uniformity - 78% of input power is directed into the flat top with 15% RMS power variation
- Collimated output beam allows use of conventional optics after beam shaping
- Provides performance over large wavelength ranges

Spatial Shaping – work in progress



Laser Output



Spatial Shaper Output

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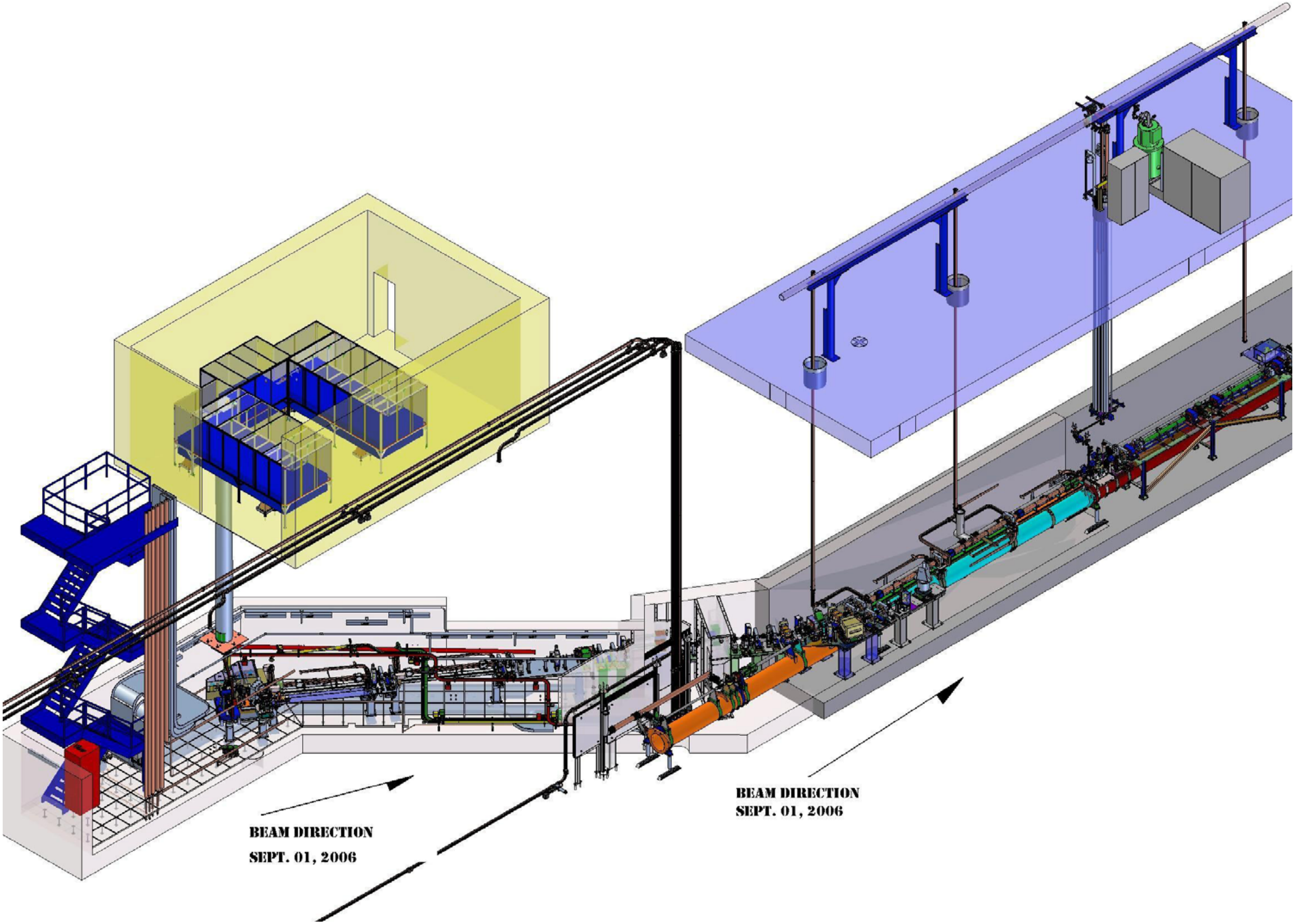
Laser Commissioning

- Transport
  - Shaper
  - Diagnostics
  - Pointing Lock Loops
- Characterization
  - Calibration of diagnostics
  - Virtual Cathode



BEAM DIRECTION
SEPT. 01, 2006
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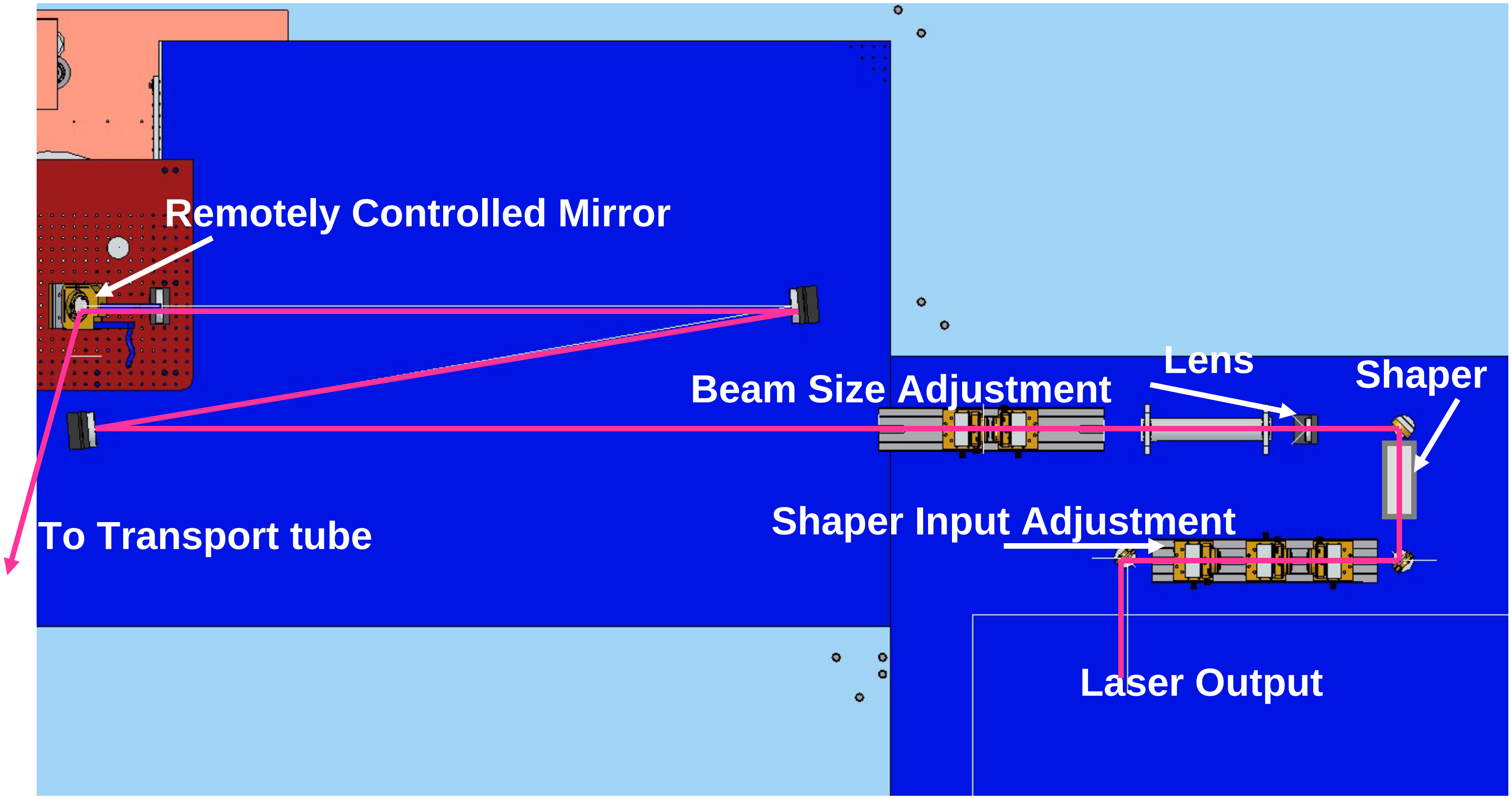
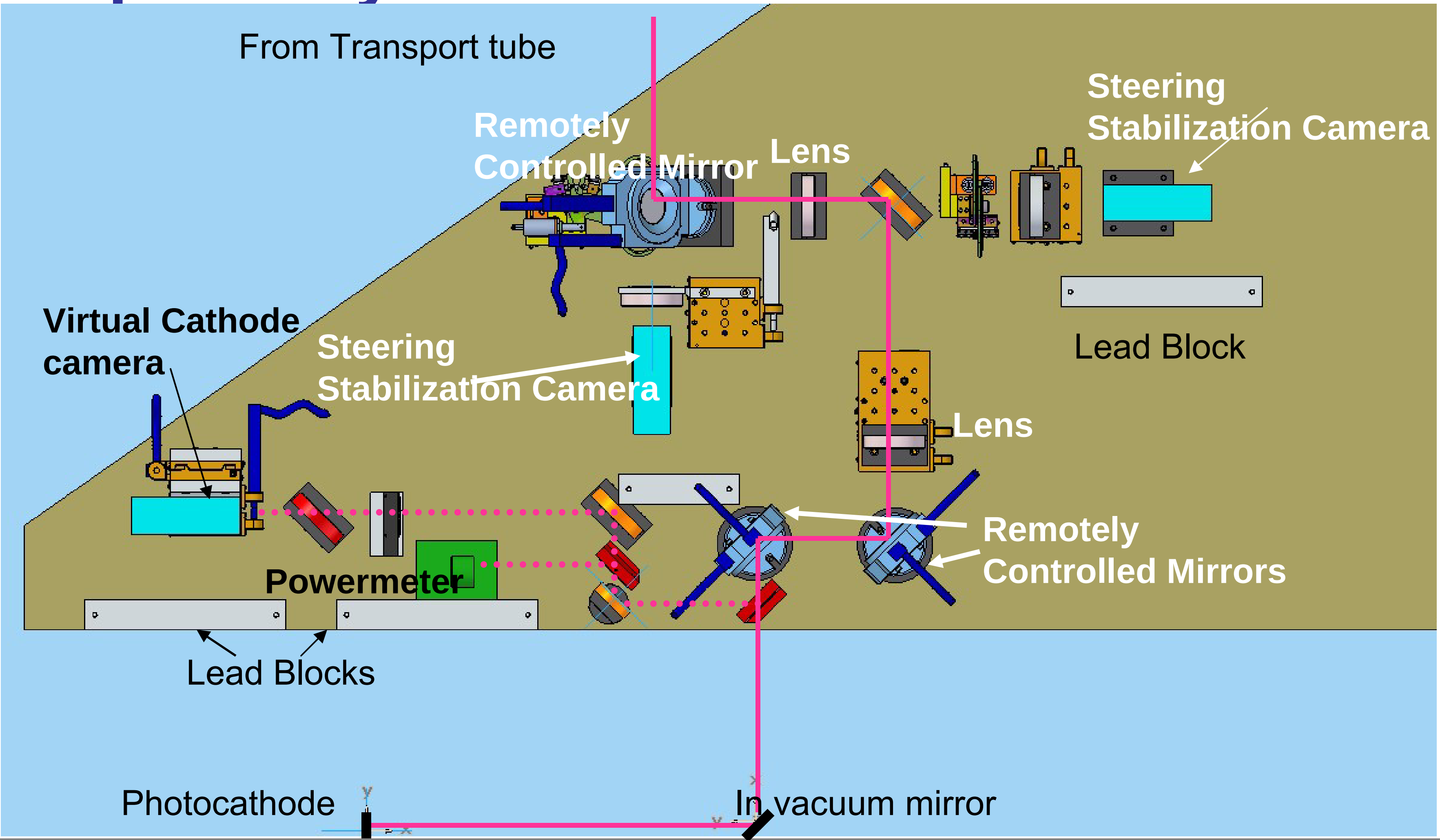
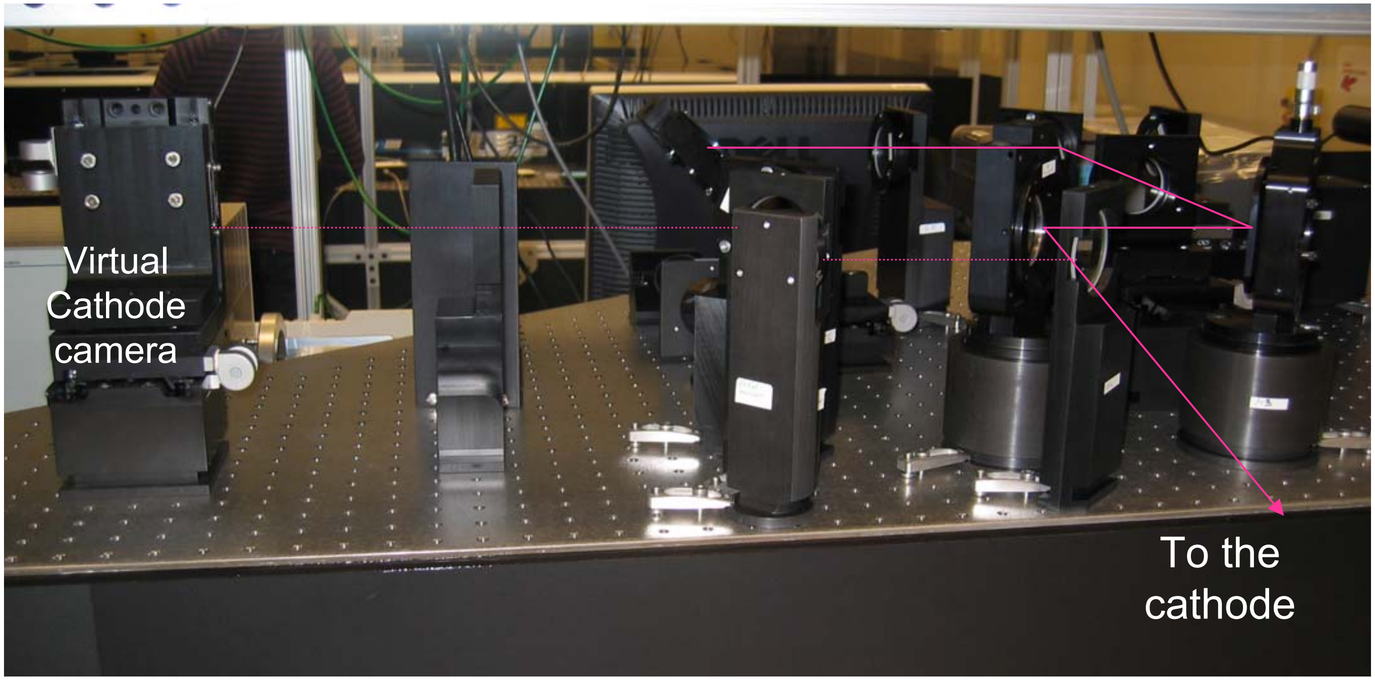
Transport System in the Laser Bay



Optical System next to the Photocathode



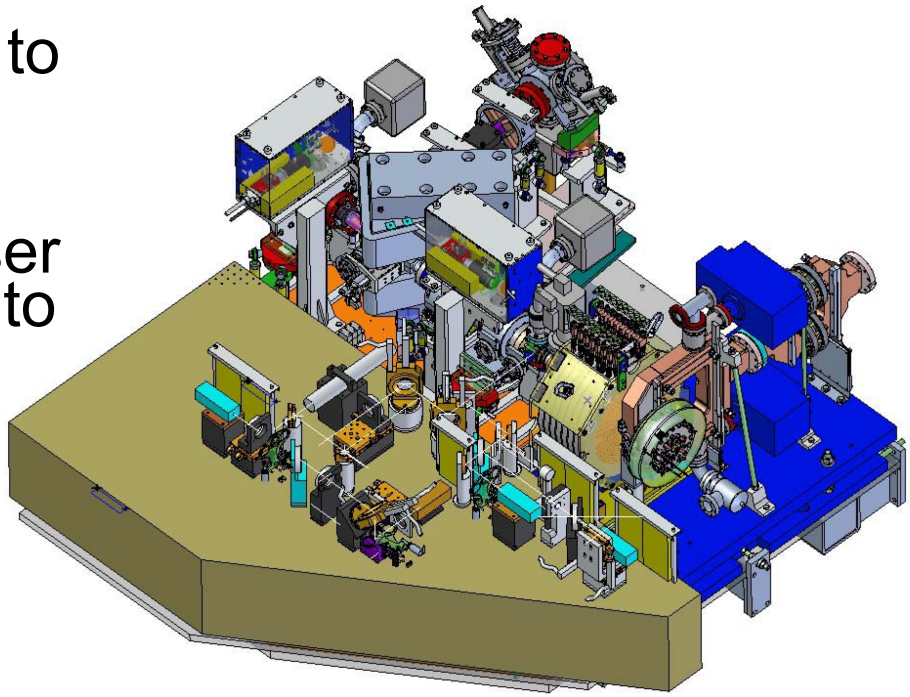
Photocathode Launch System



- Photocathode launch system has been assembled in the laser bay
- The system will be tested before it goes into the vault

What's Next - Laser Commissioning

- Laser table and LSS in Vault
  - Laser door installed prior to transport – Nov 20
  - Components will be installed and tested in laser bay prior to table moving to vault
  - Support for laser table should be ready for table installation on Nov 28th



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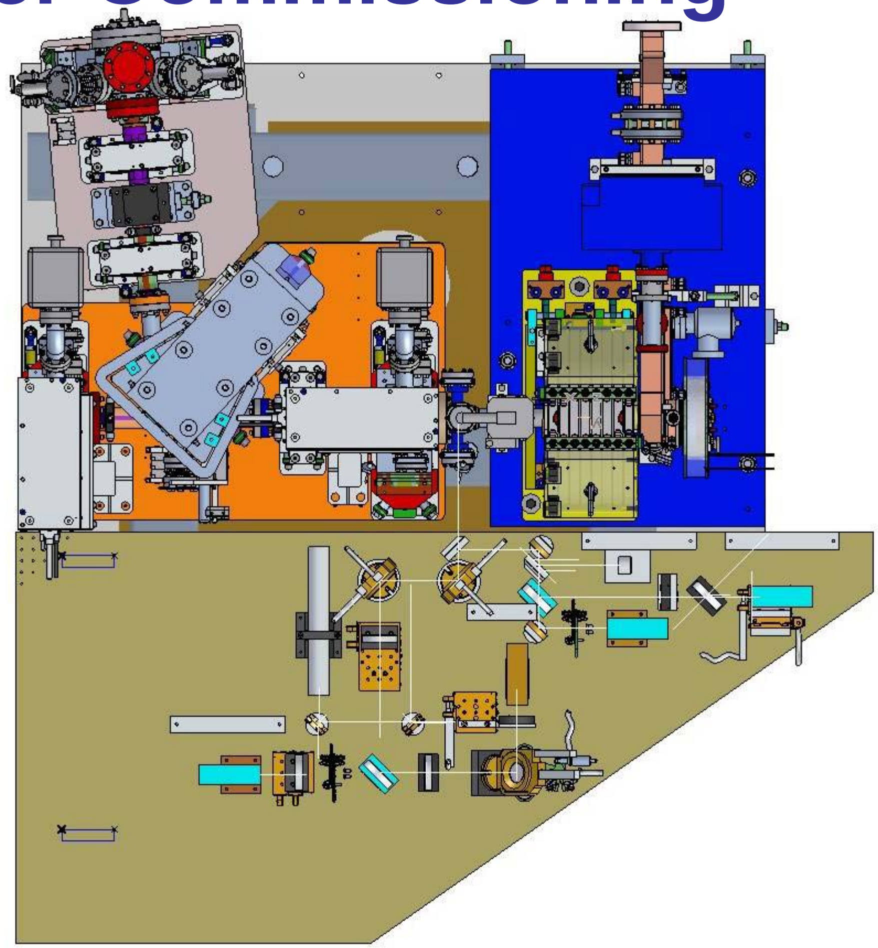
What's Next - Laser Commissioning

- **Virtual cathode work requires GTL.**
- Gun can be installed two weeks after GTL installation
- UV on cathode one week later.
- Laser optimization (temporal profile, stability, automation, etc) will continue until GTL is installed.



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Injector Commissioning

- UV on Cathode scheduled mid-March
  - Laser group operates the laser
- Some laser commissioning will continue in parallel
  - Characterization
  - Automation
  - Refine Operation Procedures
  - Refine Maintenance Schedules
- August 07 Down
  - Train Ops Group
  - Hand off laser in Jan 08

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Hand Over to Ops

- August 07 Down
  - Train Operations Group on typical Operation Procedures
  - Hand off laser by Jan 08
- Laser Group will support Ops
  - Scheduled Maintenance
  - Issues that arise outside of the typical operation envelope

End