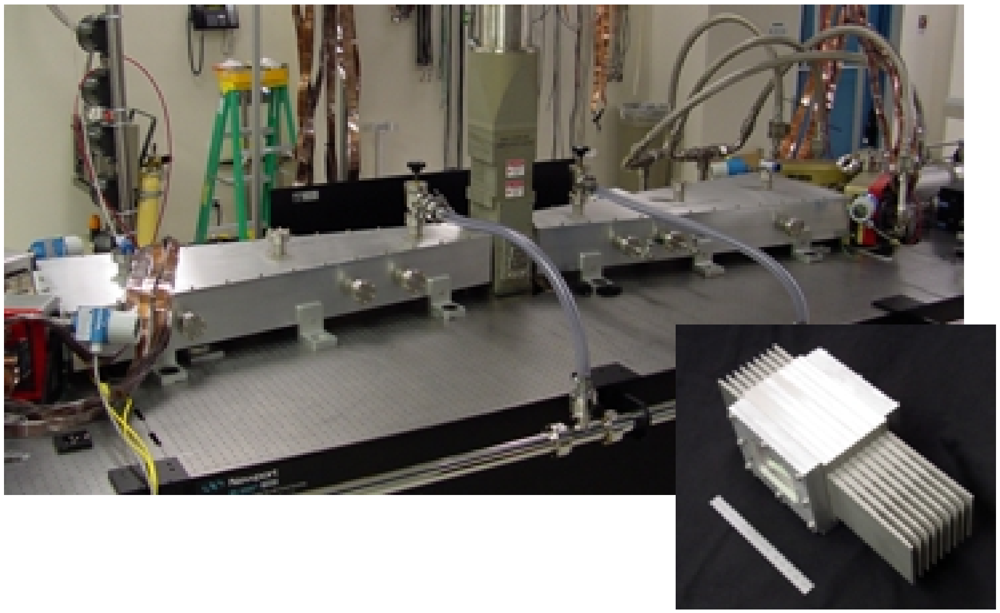
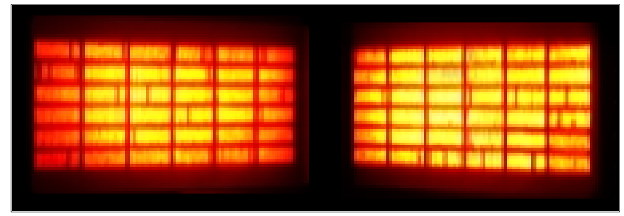
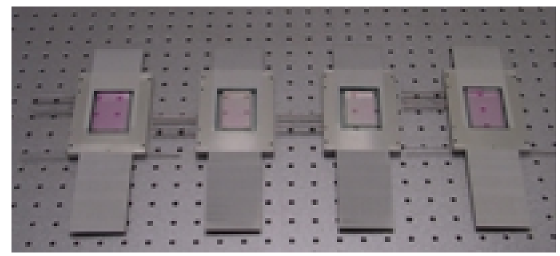
The Mercury Laser Project







Camille Bibeau
Project Leader
Laser Science and Technology

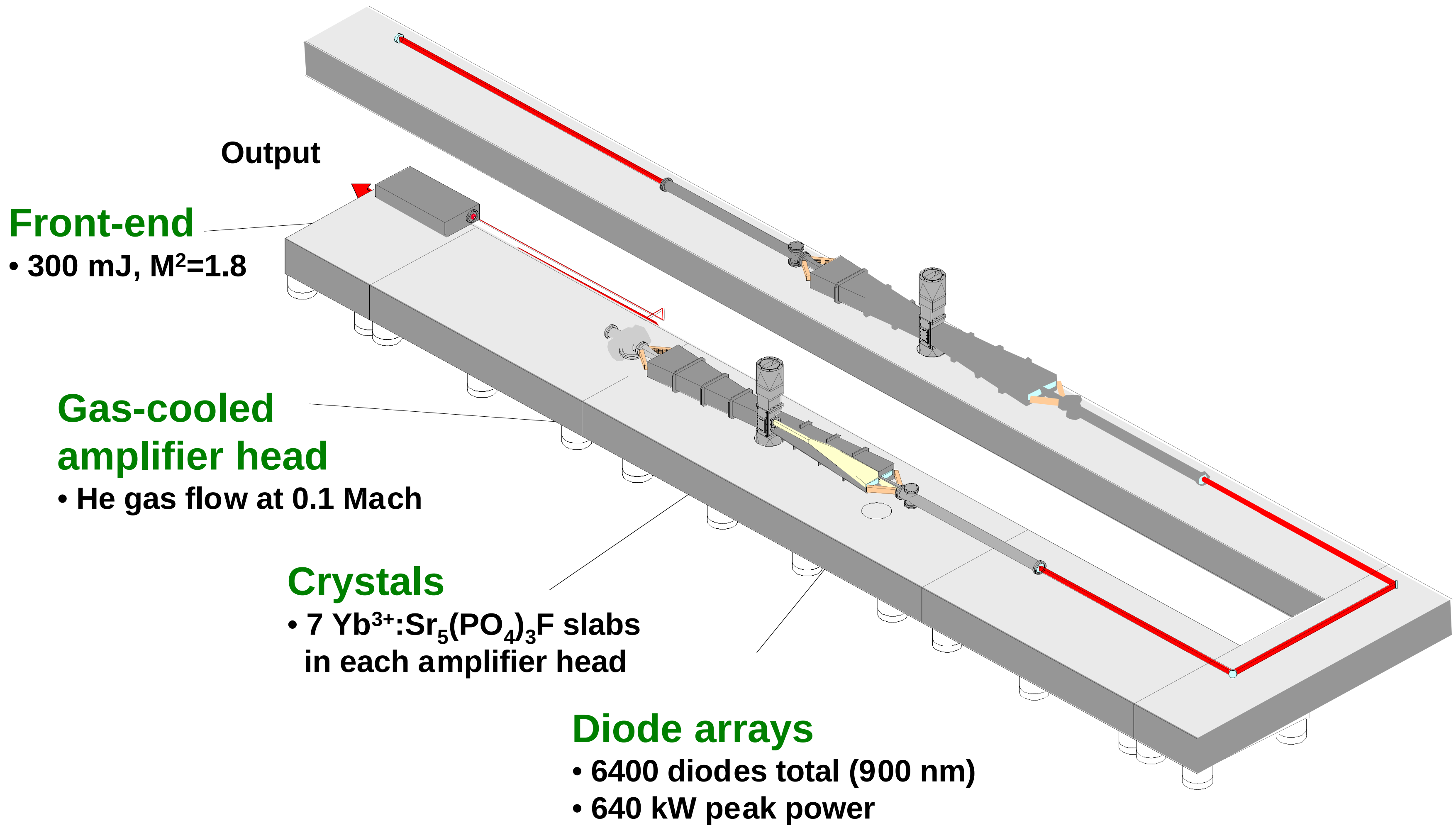
High Average Power
Laser Review
San Diego, California
April 4 & 5, 2002

We are planning for first light in this year

CY 2002 Objectives:

- Build pump diodes for 2nd amplifier
- Install 7 Yb:S-FAP crystals in 1st amplifier and grow 7 more for 2nd amplifier
- Build and install second amplifier head and utilities
- Build full aperture Pockels cell and install in reverser
- Perform experiments with one amplifier fully populated with Yb:S-FAP crystals
- Continue advanced Yb:S-FAP growth
- Facility Upgrades

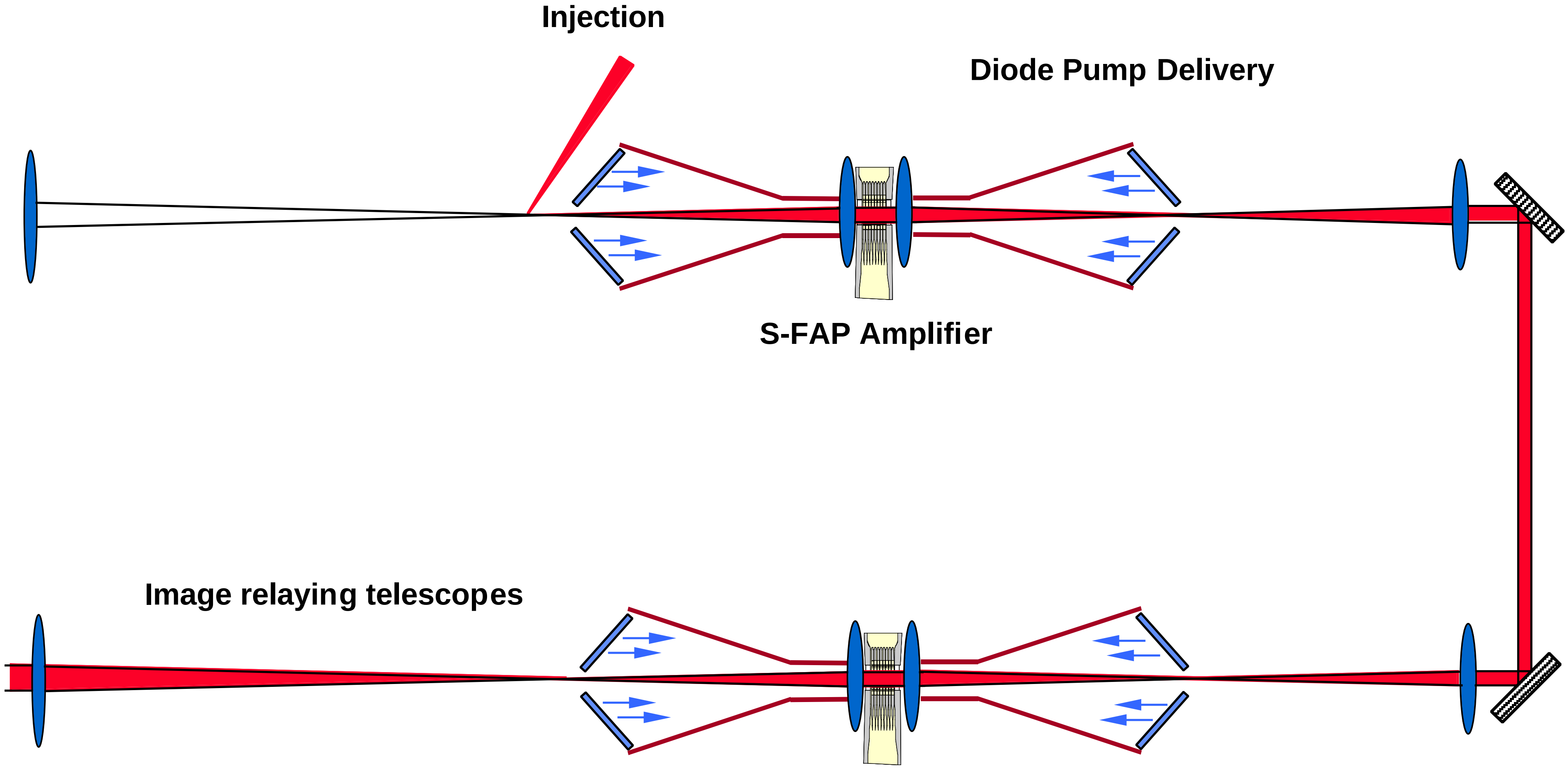
In 2002 we will have one amplifier fully populated with Yb:S-FAP producing up to 30 J of 1.047 um light and all diode arrays activated (640 kW)



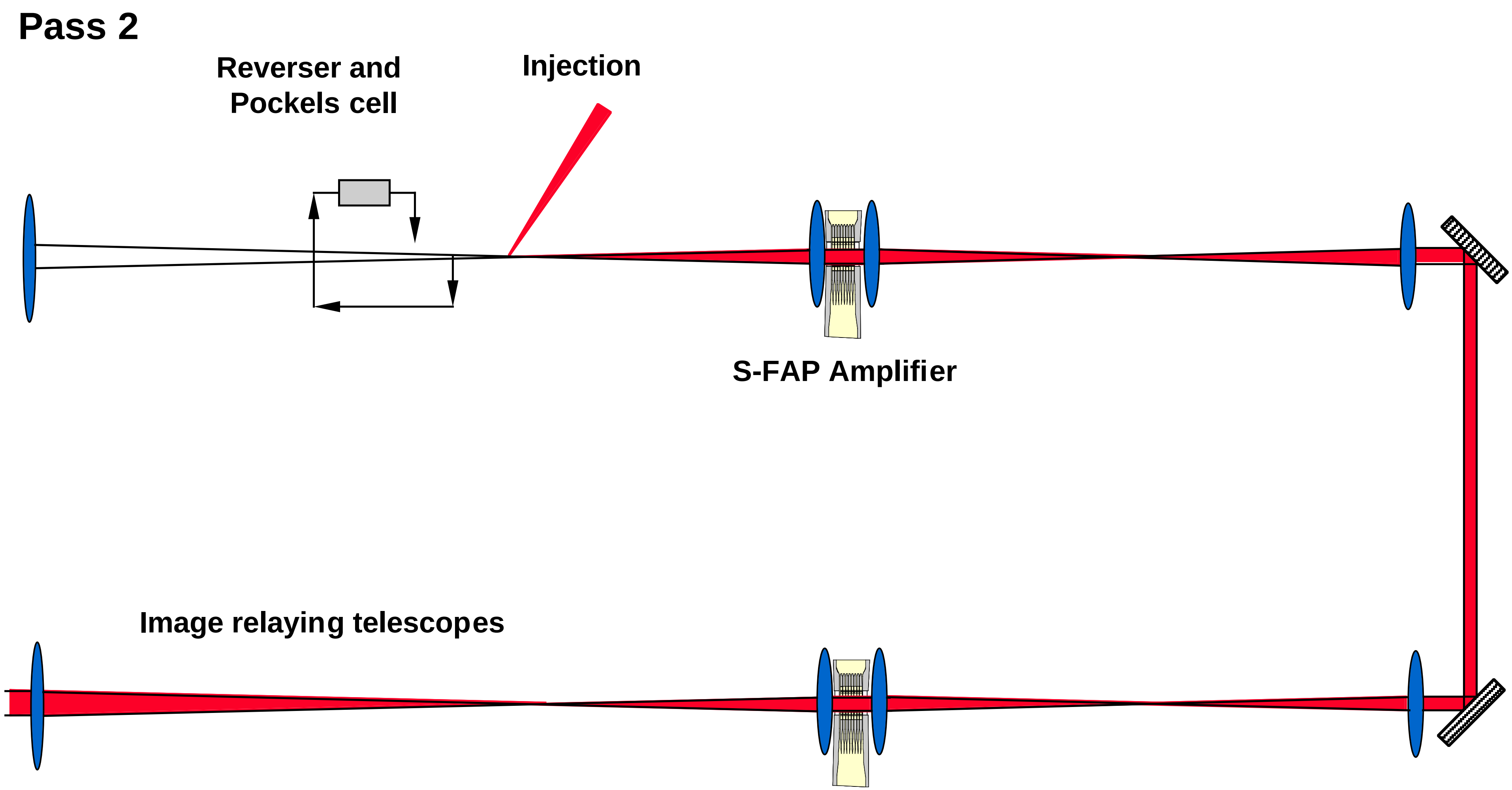
Output
Front-end
• 300 mJ, M^2=1.8
Gas-cooled
amplifier head
• He gas flow at 0.1 Mach
Crystals
• 7 $Yb^{3+}:Sr_5(PO_4)_3F$ slabs
in each amplifier head
Diode arrays
• 6400 diodes total (900 nm)
• 640 kW peak power

The Mercury laser system minimizes damage by arranging the lenses and amplifiers near relay planes

Pass 1

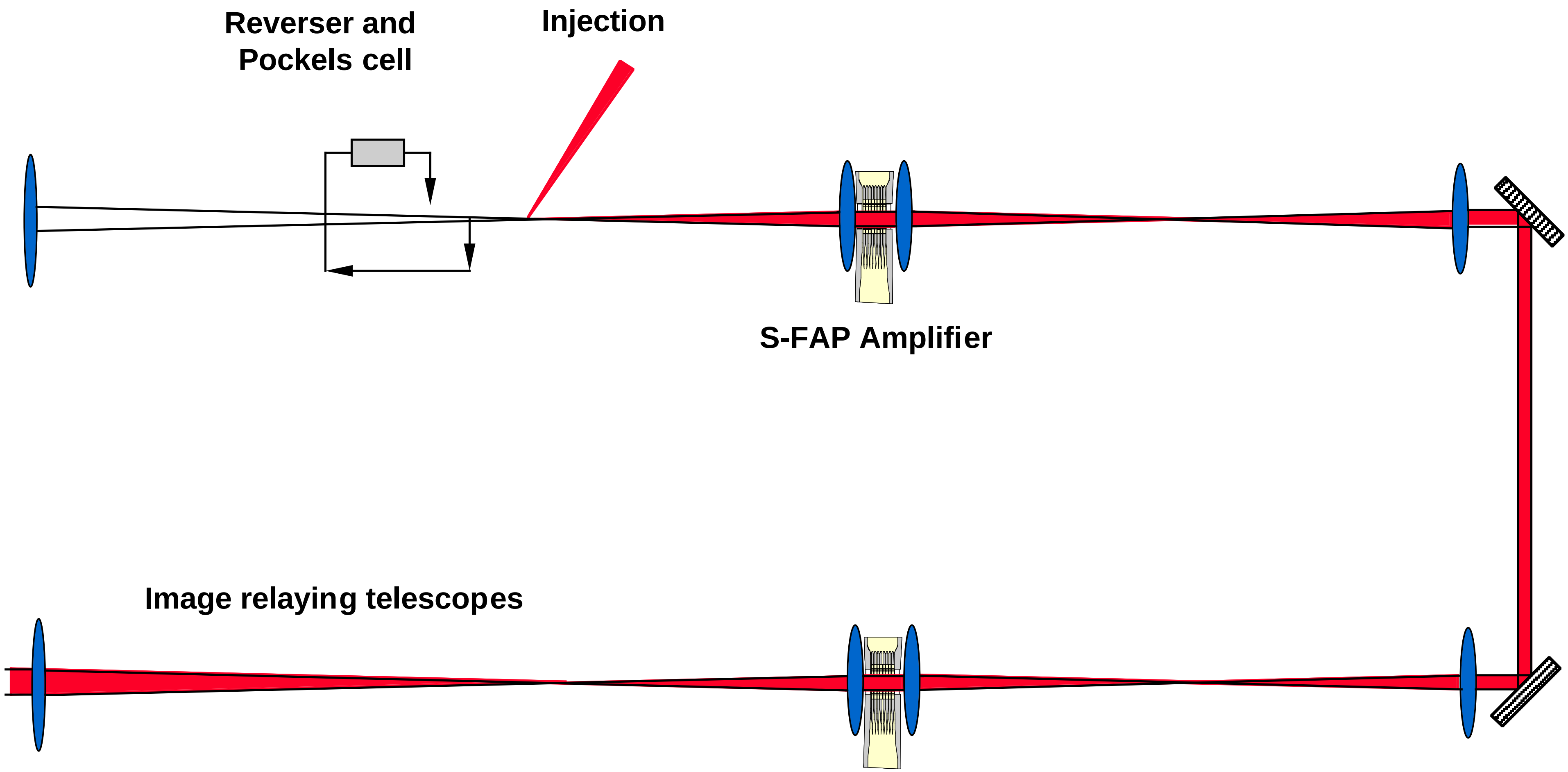


The Mercury laser system minimizes damage by arranging the lenses and amplifiers near relay planes

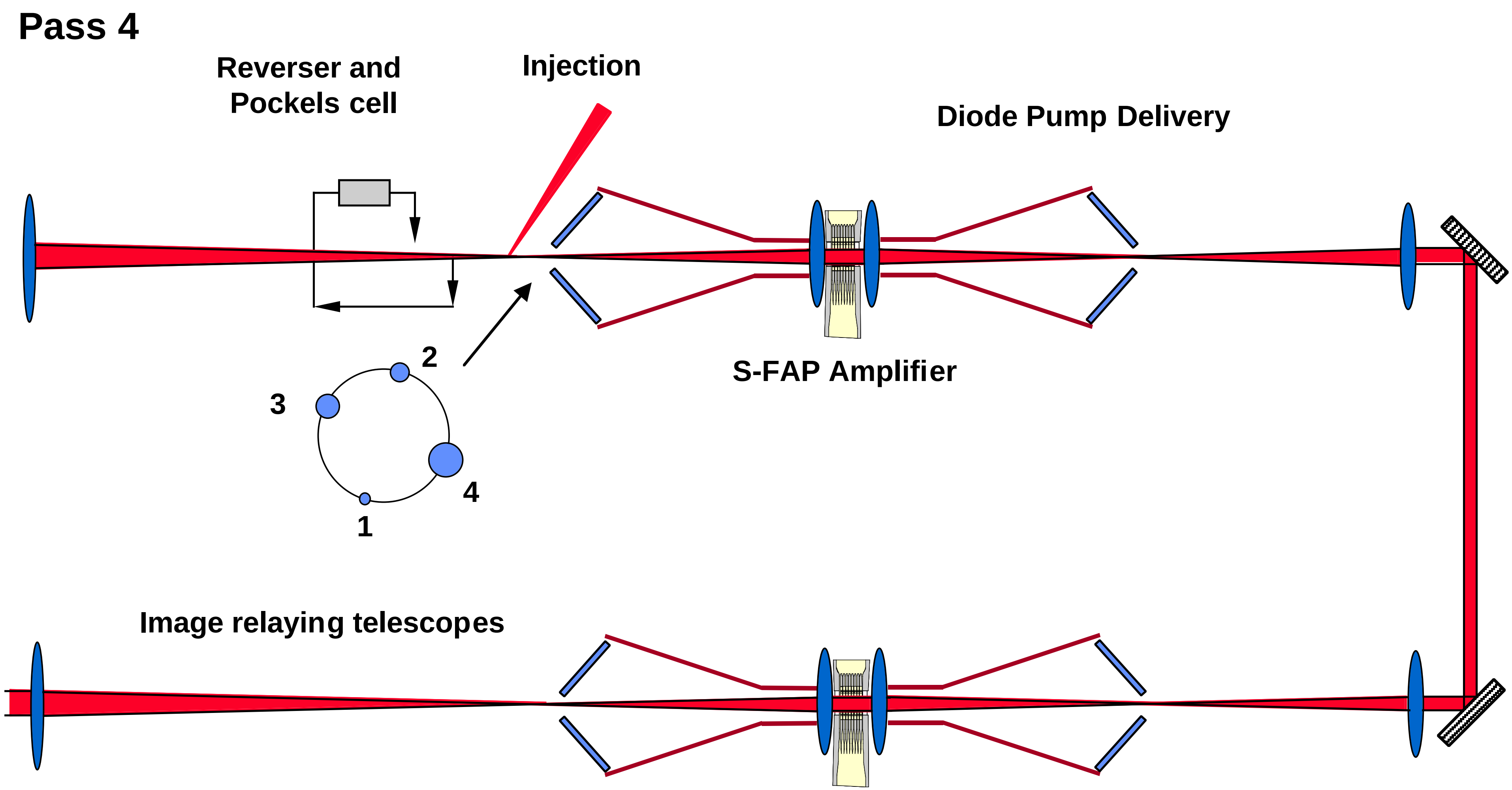


The Mercury laser system minimizes damage by arranging the lenses and amplifiers near relay planes

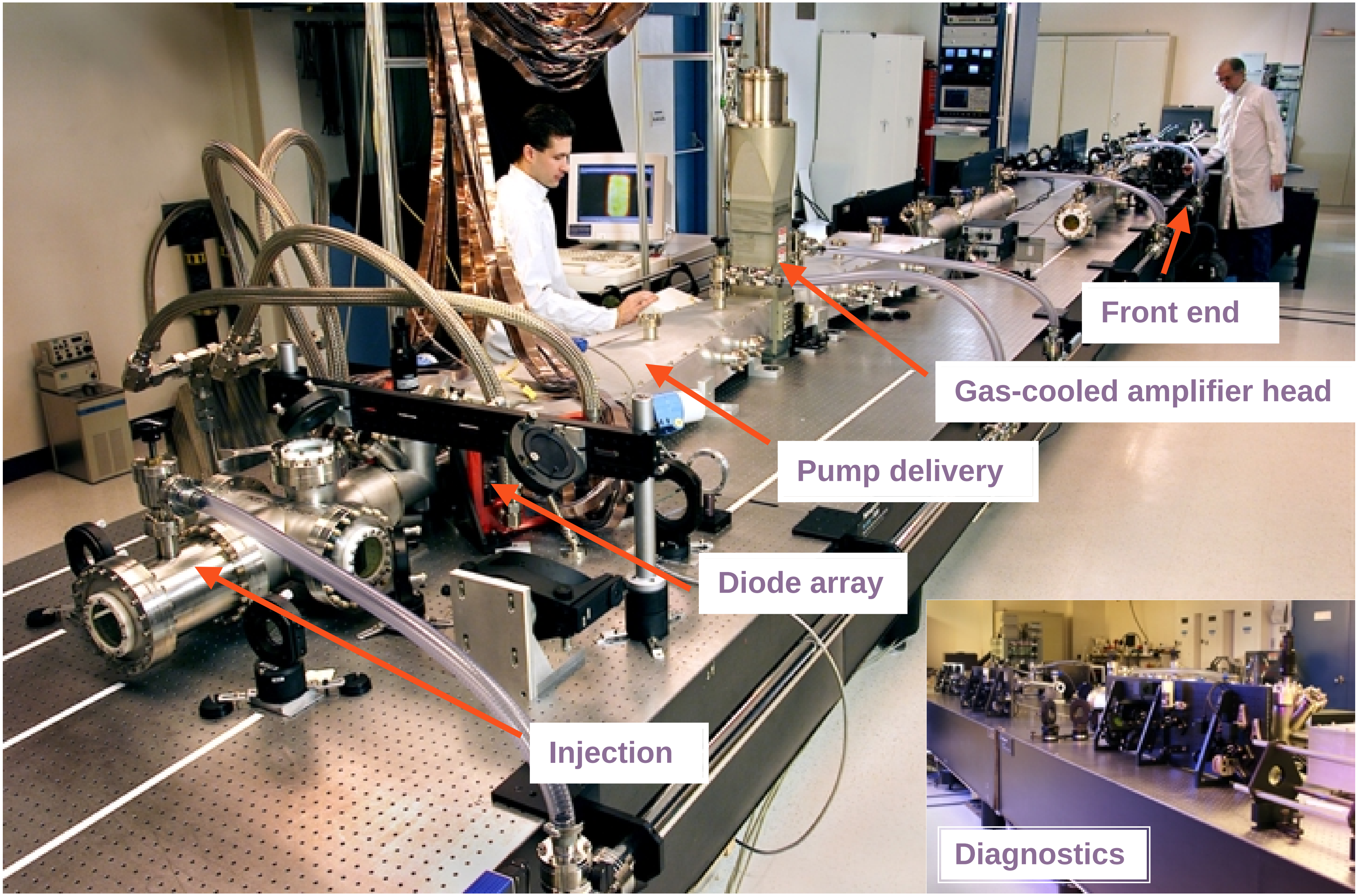
Pass 3



The Mercury laser system minimizes damage by arranging the lenses and amplifiers near relay planes



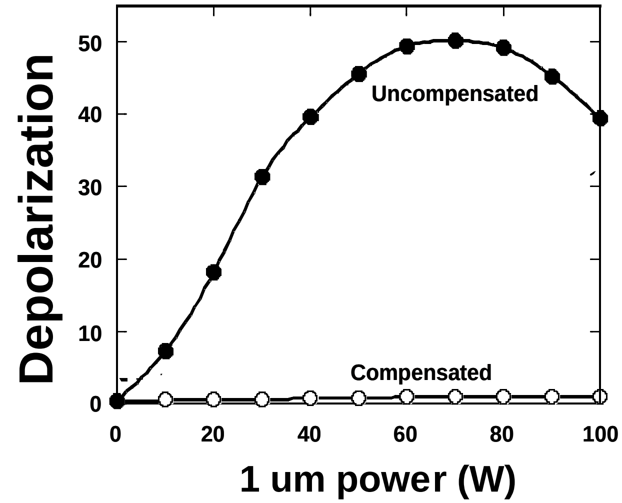
We are conducting experiments on the Mercury laser



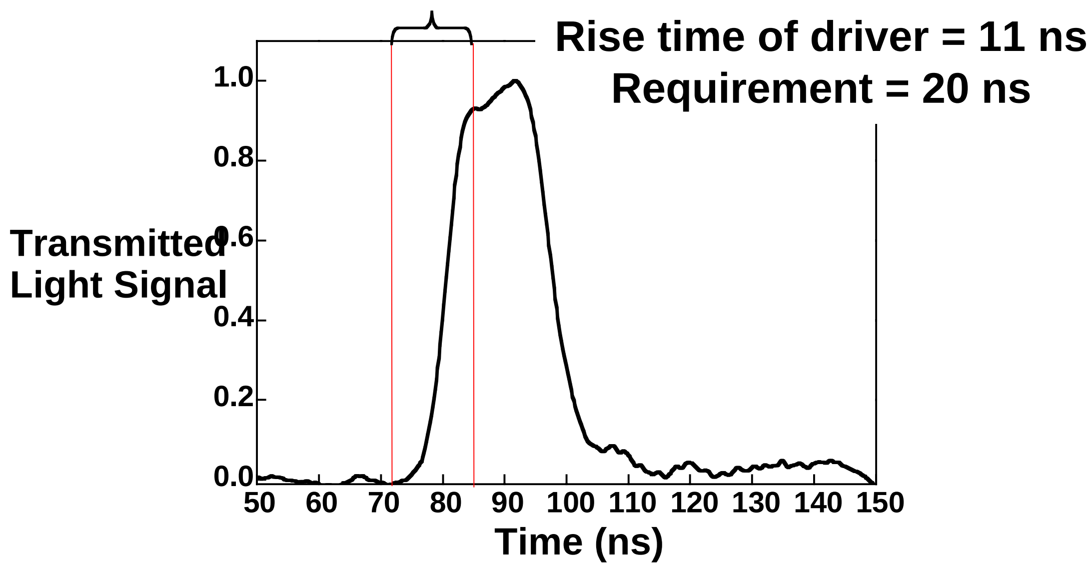
We have fully tested the half size Pockels cell and are ordering parts for the full size element

Previous Review:

2x3 cm^2 (1/2 size)



Update:

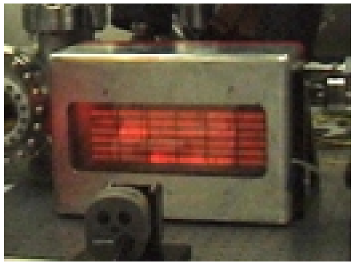


Optics for full aperture Pockels cell out for bid (polarizers, waveplate, KD*P)

We have installed four backplanes in the system and are building four more for the 2nd amplifier

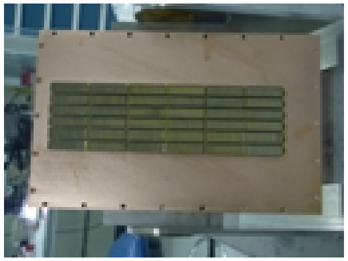
Previous Review:

23 Pulsers Activated



Backplane 1 (assembled and in system)

Backplane 2 (assembled and in system)

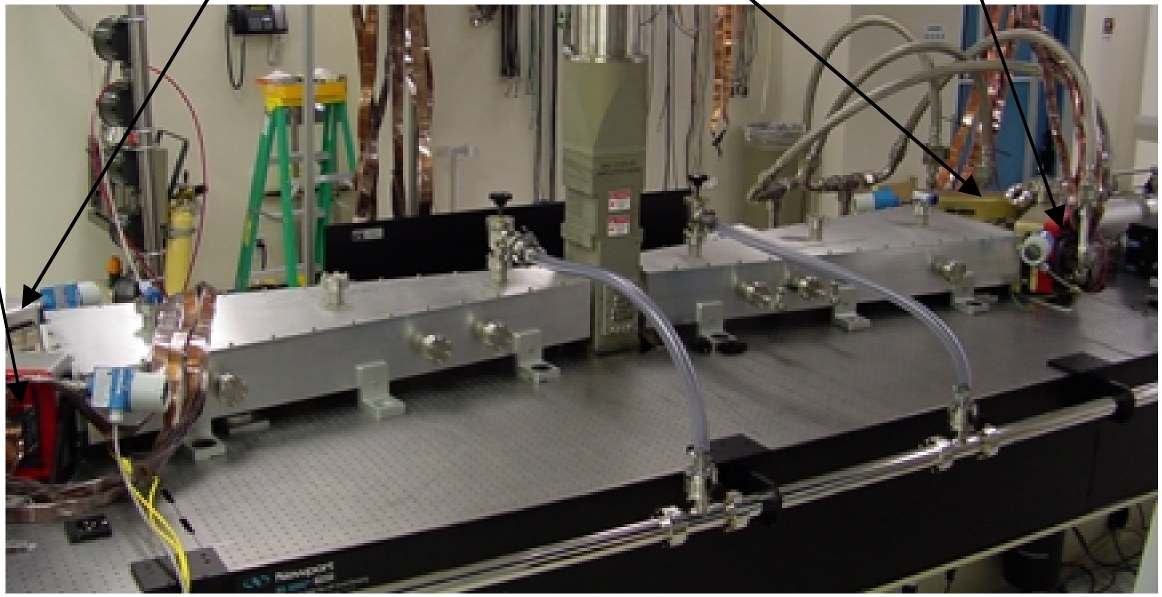


Backplane 3 (partially assembled)

Backplane 4 (not yet assembled)

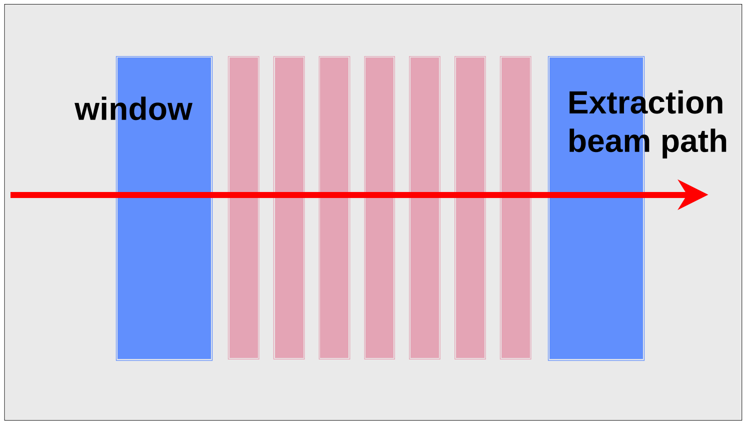
Update:

- 4 Backplanes in system
- 36 diode pulsers activated
- Diodes (5000), backplanes (4), pulsers (36), chillers (2) ordered for remaining pump systems
- Compliance difficulties with pulsers have slowed progress

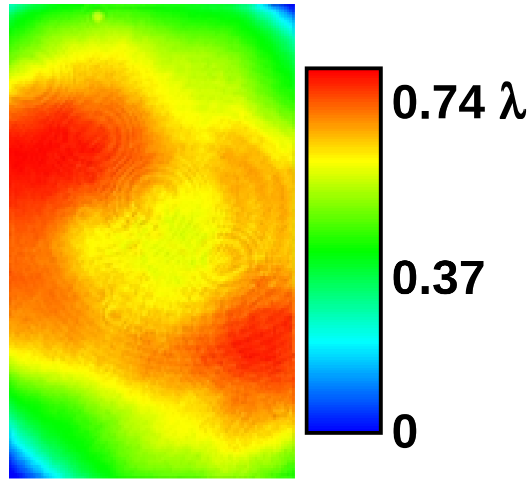


Interferometry with amplifier (Nd:glass, no wedge) were tested under full diode loading

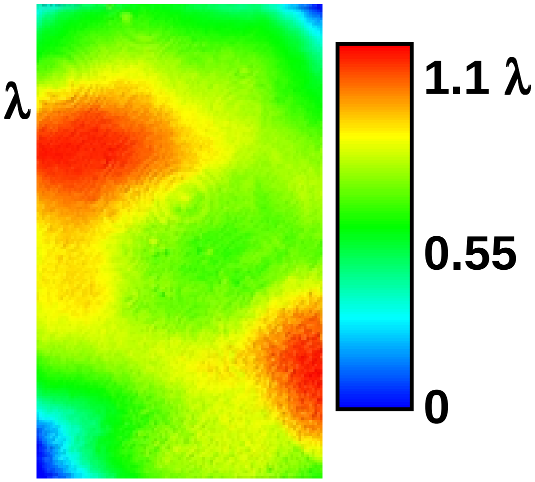
7 glass slabs with no wedge



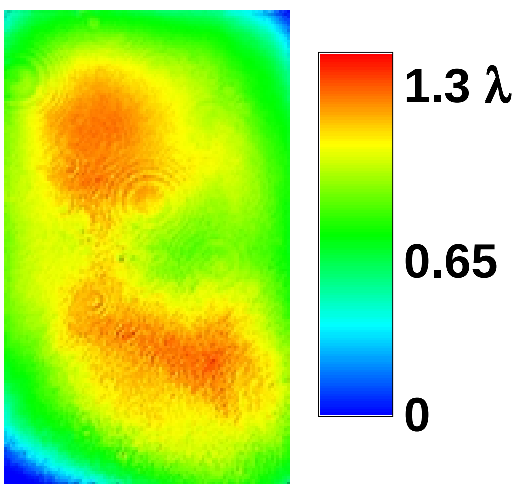
Static



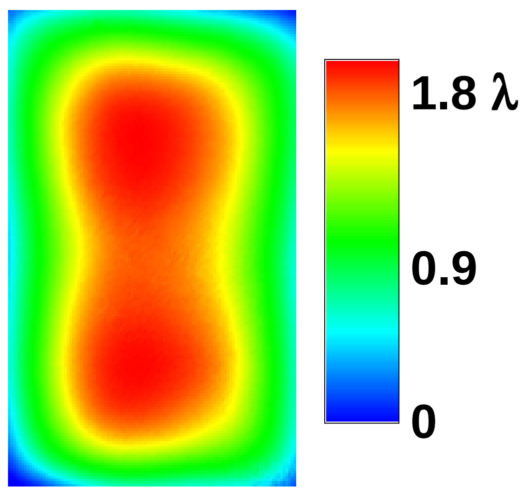
Gas Flow



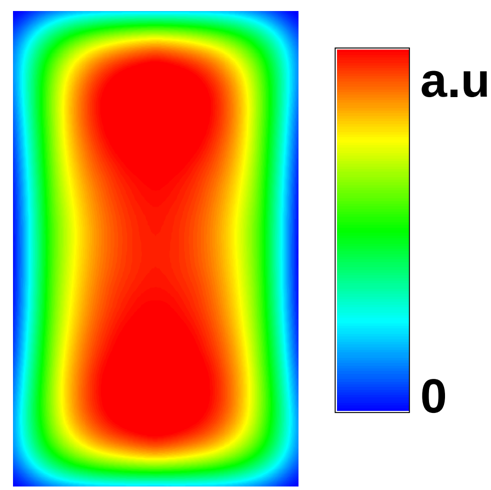
0.1 Hz diode rate



1 Hz diode rate



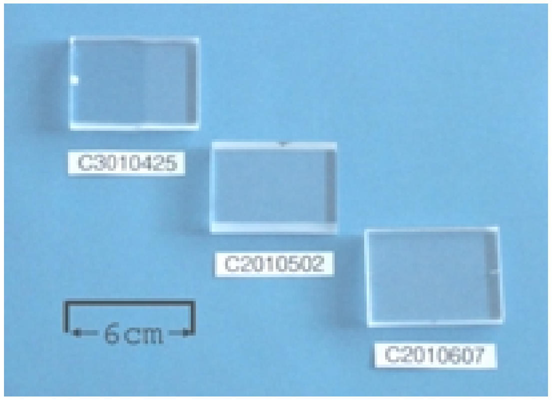
Model

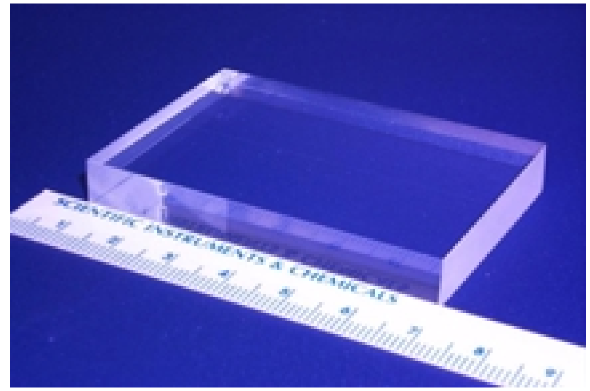


We have grown enough boules to install seven slabs in the 1st amplifier and four in the 2nd amplifier

Previous Review:

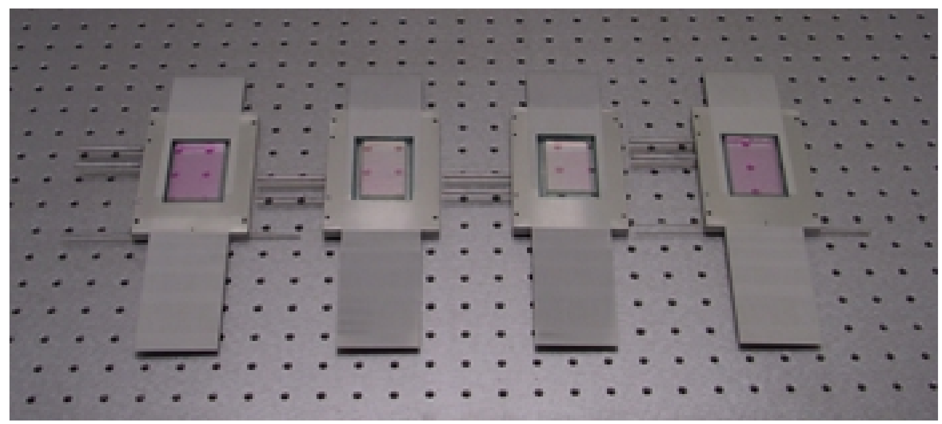
Four slabs were diffusion bonded



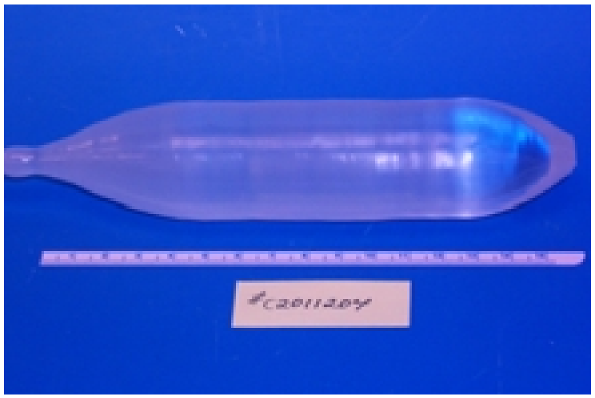


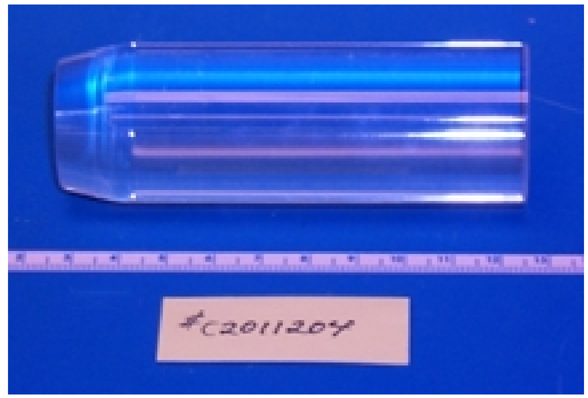
Update:

- 4 slabs have been mounted into vanes
- 7 boules await cutting
- Recent damage tests on uncoated material yielded 50 J/cm^2 at 10 ns
- Previous impediments to cutting slabs are resolved with either laser or water jet cutting
- Modeling of stress underway with UC Davis

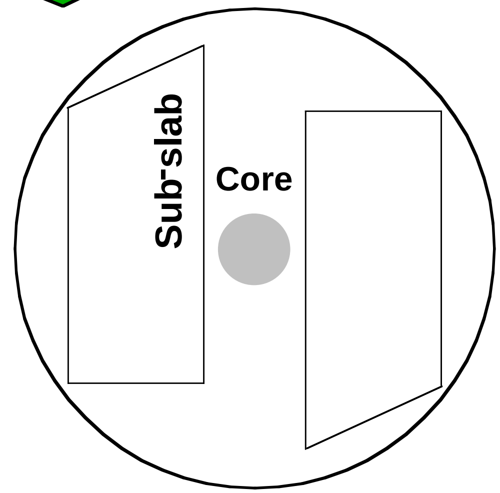


Several polishing and cutting steps are required to fabricate a full sized slab

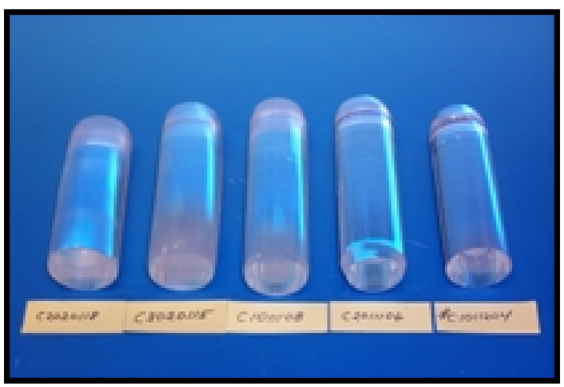


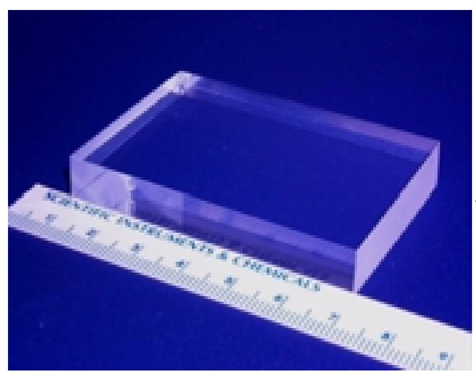


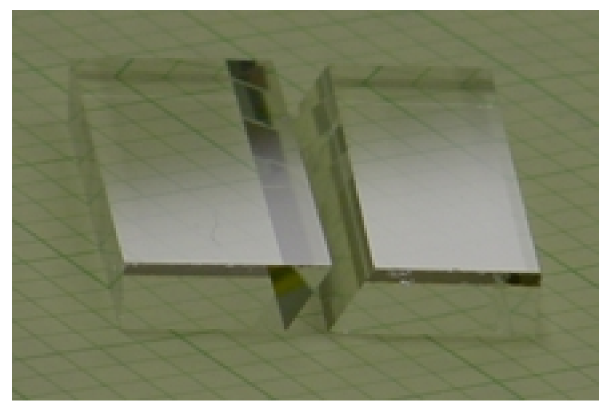
Boule cross section



Boules in waiting

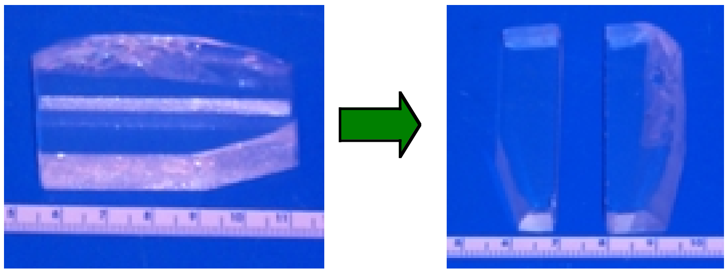






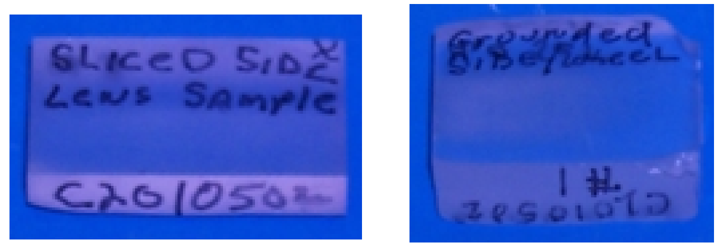
We have identified two cutting processes which appear to minimize the risk of cracking

Laser cutting
(fs laser at LLNL)



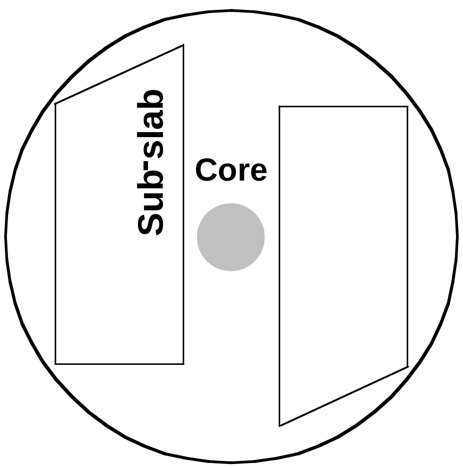
Advantage: fast, onsite process
Disadvantage: requires cleaving step

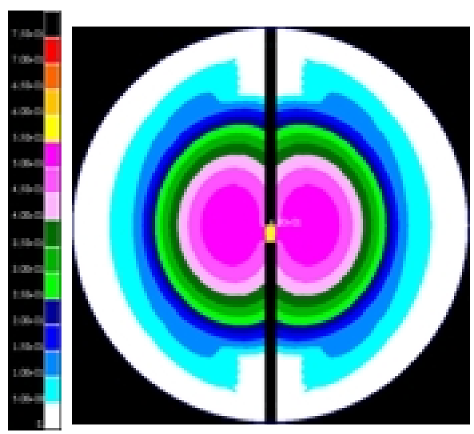
Water jet cutting
(Central Coast Gem Labs, Georgia)

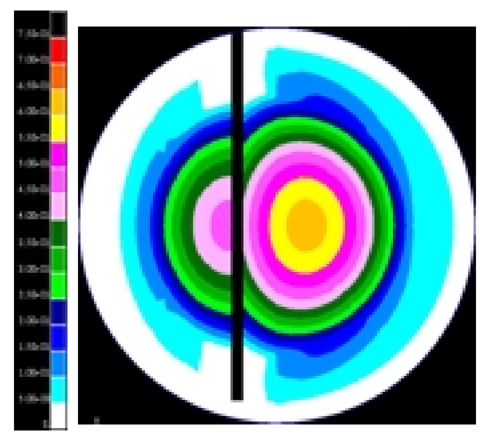


Disadvantage: proprietary offsite process
Advantage: inexpensive and provides cut slabs with smooth surfaces

Boule cross section



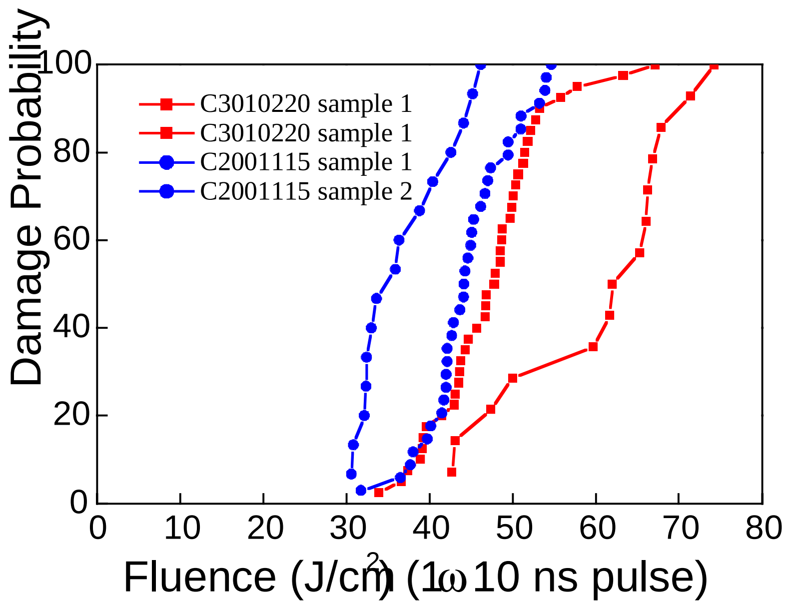




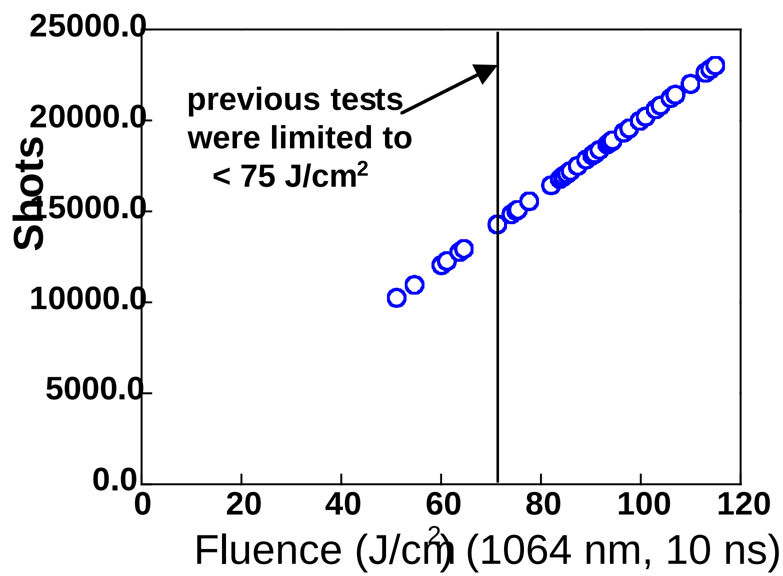
Stress analysis by UC Davis is helping to define how the boules should be cut

S-FAP damage threshold appears to be surface limited and is currently 25 J/cm^2 (coated) - 50 J/cm^2 (uncoated) for 10 ns pulses

Previous LLNL tests



New Big Sky tests

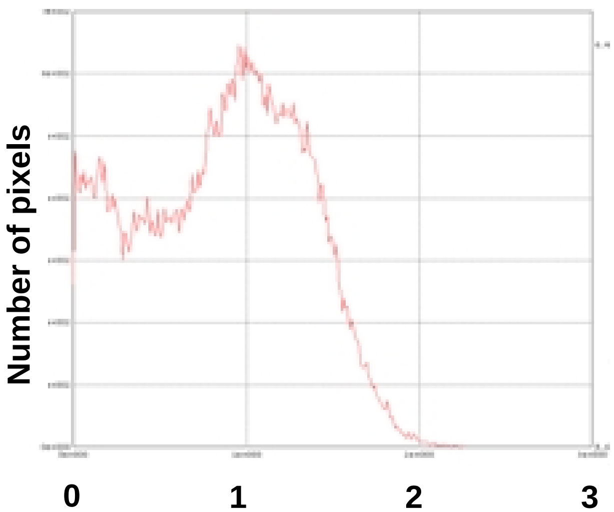


Additional damage tests are underway to improve statistics

Modeling of Mercury architecture indicates that 100 J operation can be achieved with low probability of amplifier damage

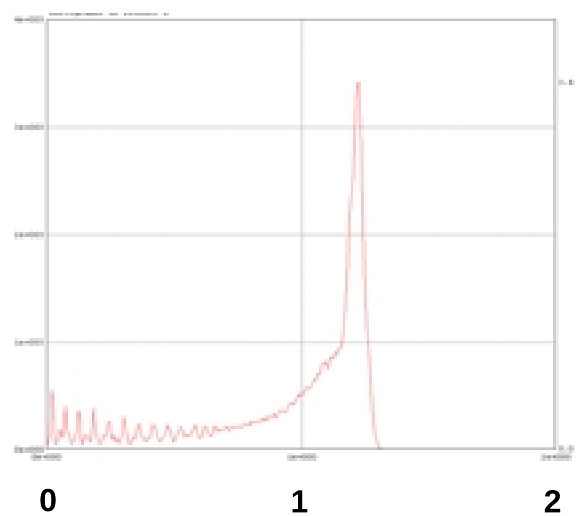
Fluence histograms at critical optics

Reverser Mirror
F_{AVE} = 9.38 J/cm^2



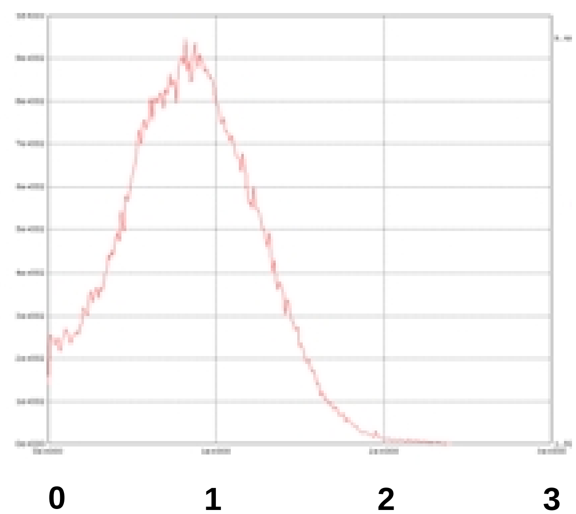
F_{AVE} multiplier

Amplifier (relay plane)
F_{AVE} = 5.75 J/cm^2



F_{AVE} multiplier

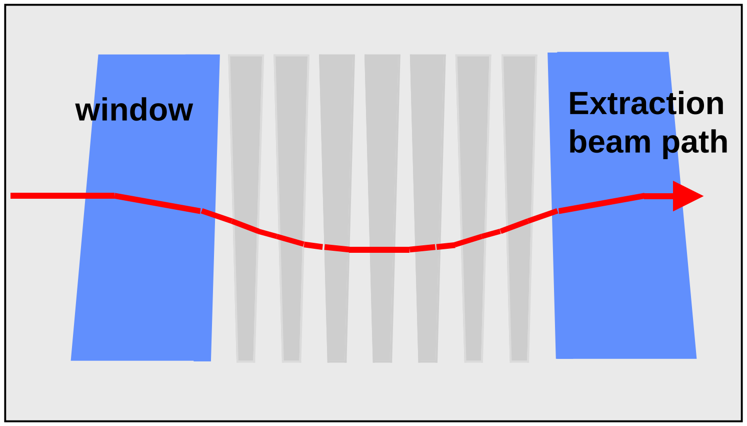
Output Lens
F_{AVE} = 2.75 J/cm^2

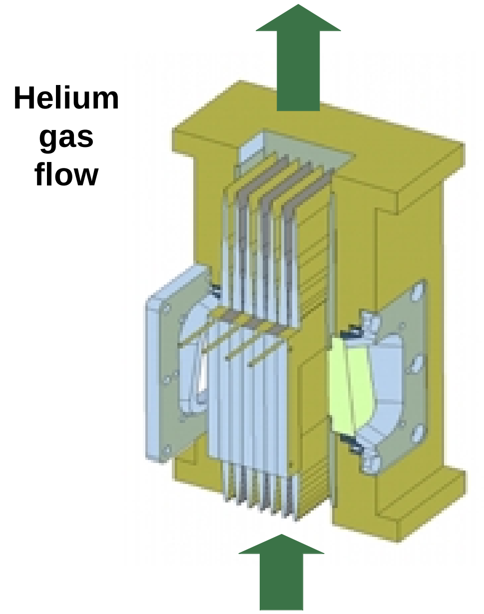


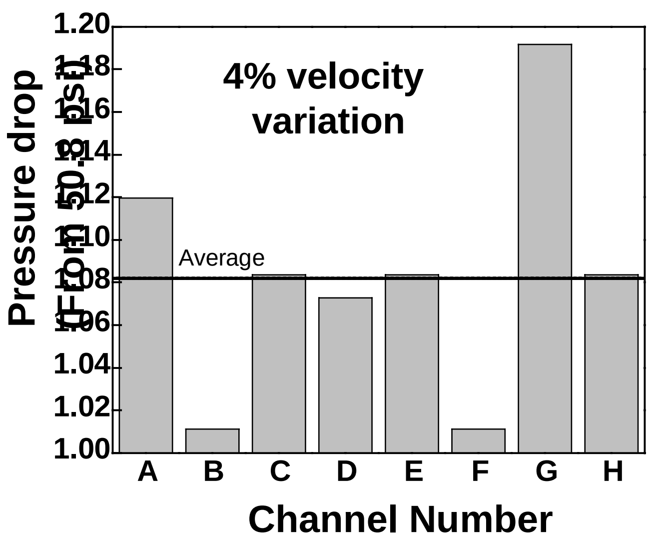
F_{AVE} multiplier

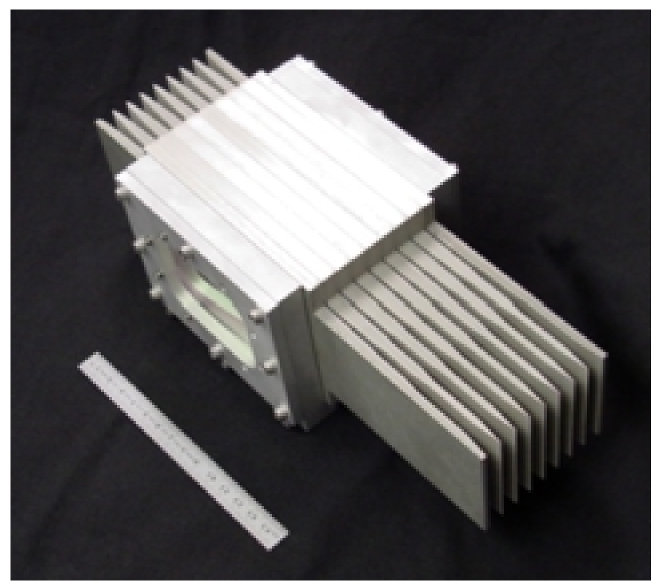
We have successfully flow tested the new wedged slab amplifier

7 slabs with 1° wedge angle





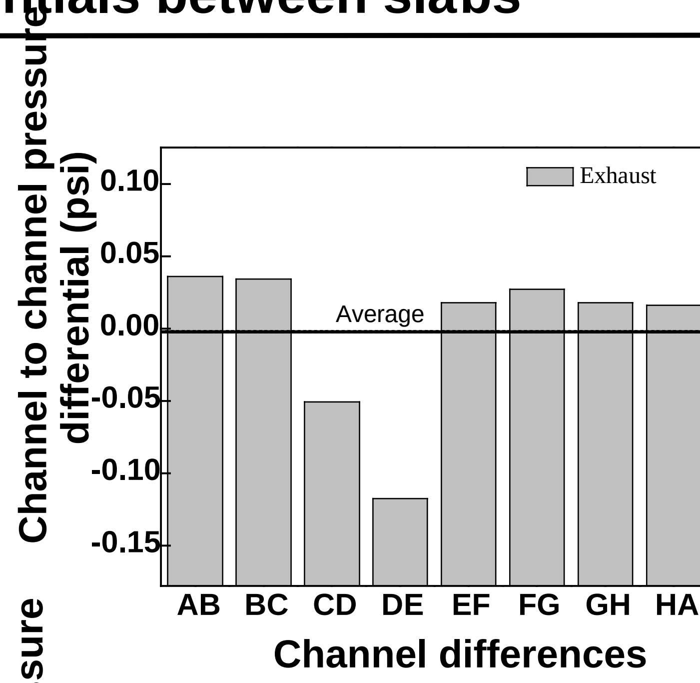




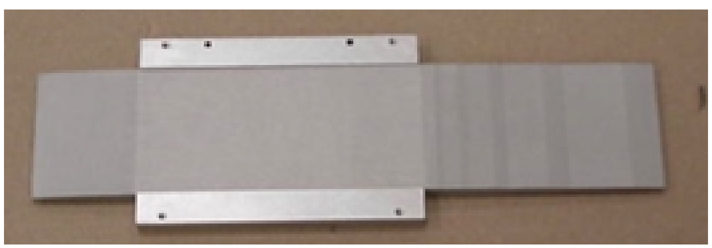
Flow tests with potted vanes show acceptable channel to channel pressure differentials between slabs

Potted vane

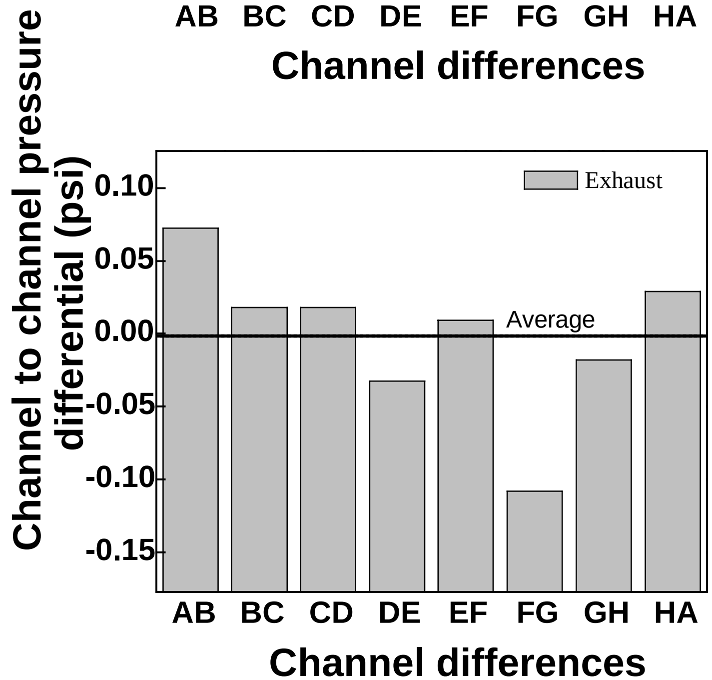
$\sigma_{rms} = 0.054$



Solid vane

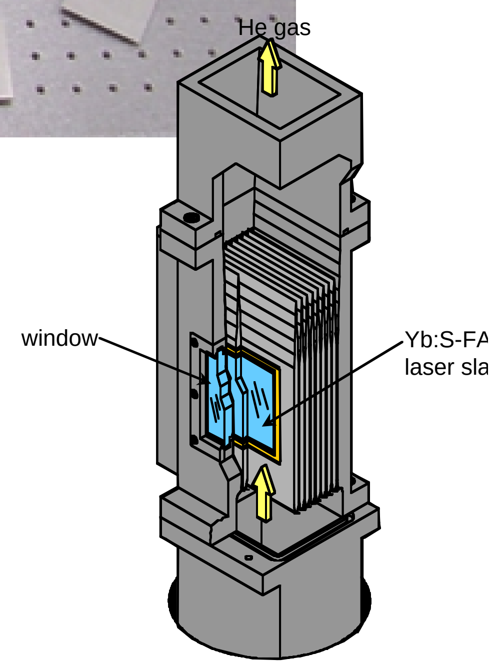


$\sigma_{rms} = 0.058$



We are already performing experiments with one amplifier populated with four Yb:S-FAP crystals

Yb:S-FAP Yb:S-FAP Nd:Glass Nd:Glass Nd:Glass Yb:S-FAP Yb:S-FAP

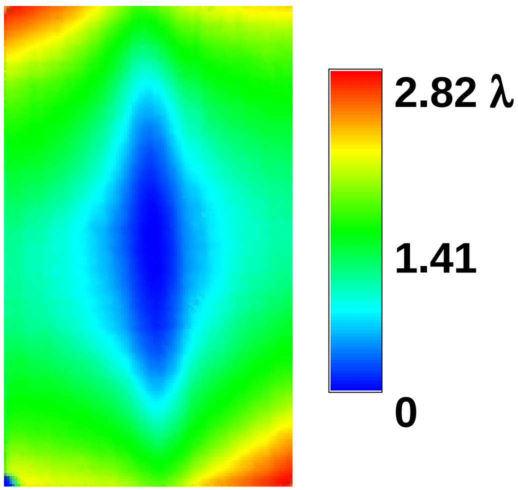


A mixture of Yb:S-FAP and Nd:Glass will be used to conduct:

- **flow tests**
- **gain experiments**
- **interferometry measurements**

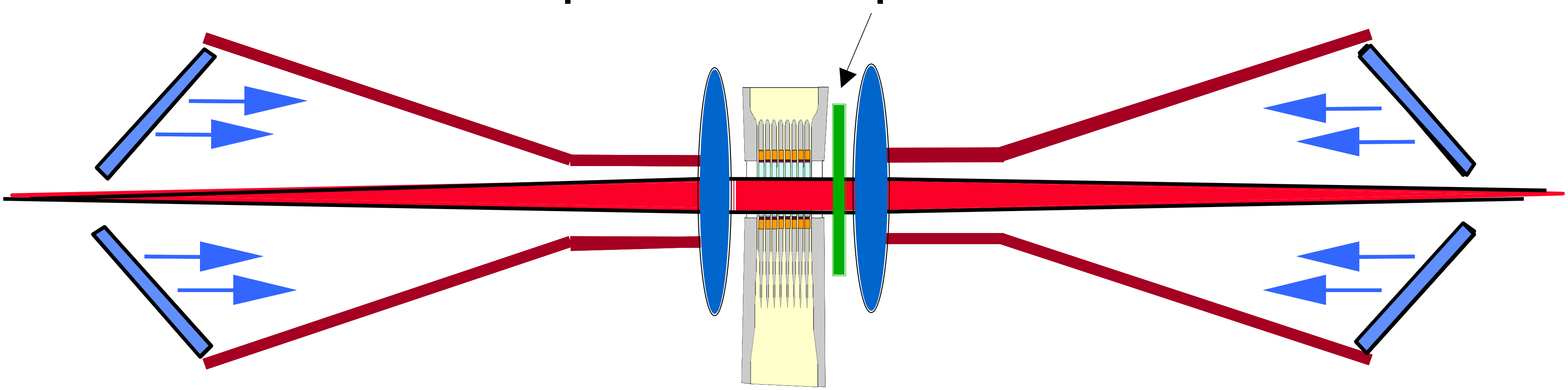
We plan to use a phase plate to correct for the low order of distortion in the amplifier slabs

Wavefront distortion with helium gas flowing (3 glass and 4 S-FAP slabs)

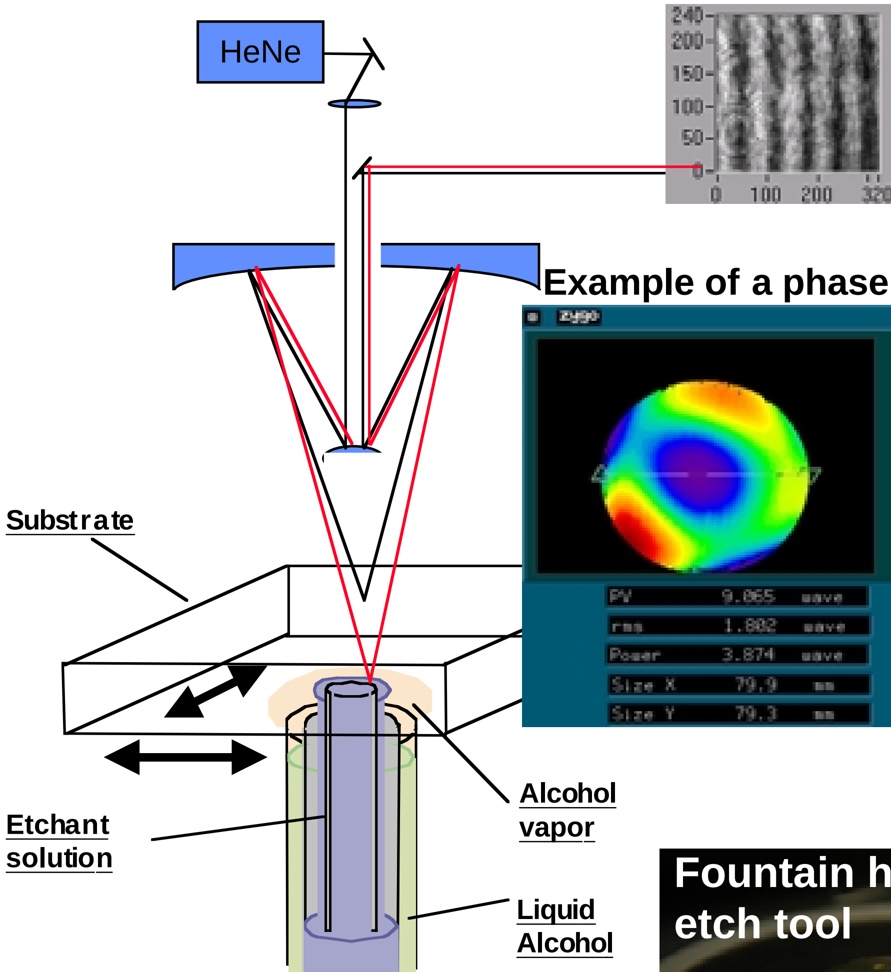


- Primary distortion is due to bonding
- These are the "first" full size S-FAP slabs fabricated
- Improvements in progress
  - LLNL: annealing
  - ONYX: polishing
  - Schott: developing room temp "glass glue"
- Phase plate offers correction and remove distortions near the source

phase corrector plate

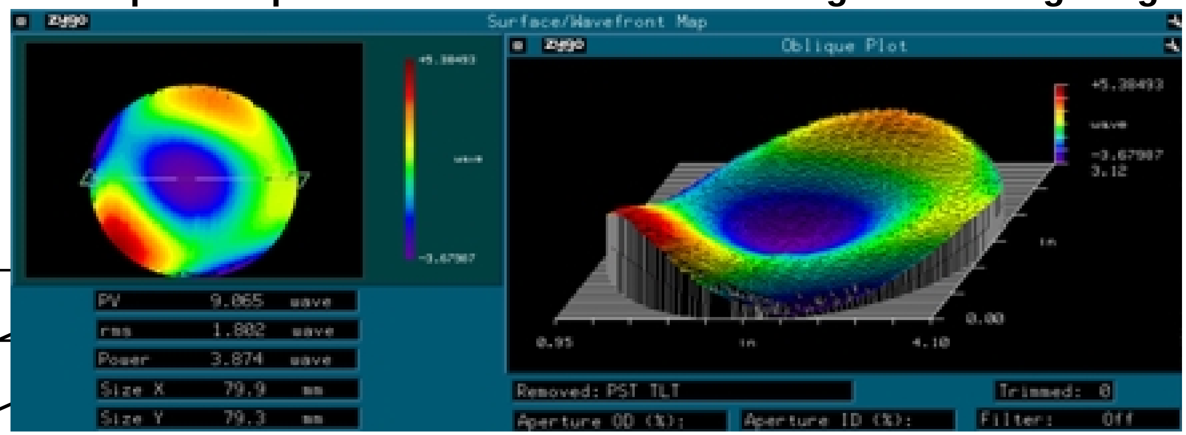


Wet-etch figuring can be used to fabricate the phase corrector for Mercury

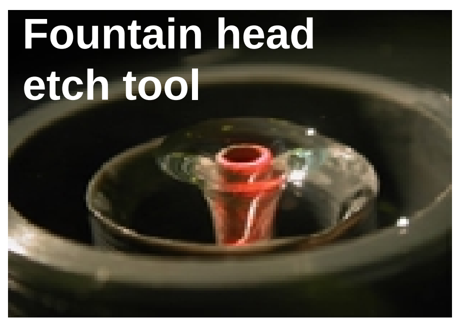


Real-time etch monitoring Removes many of the Parametric sensitivities

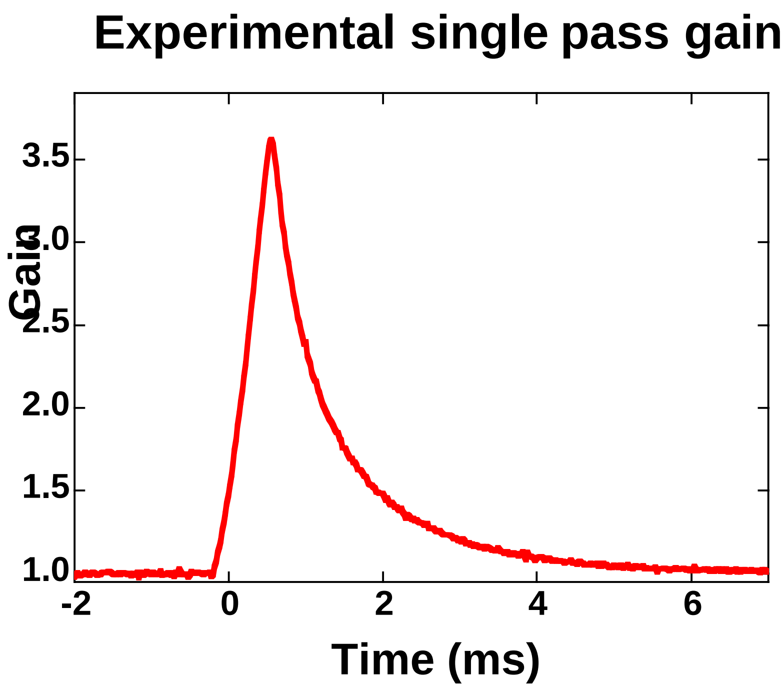
Example of a phase corrector fabricated using wet-etch figuring

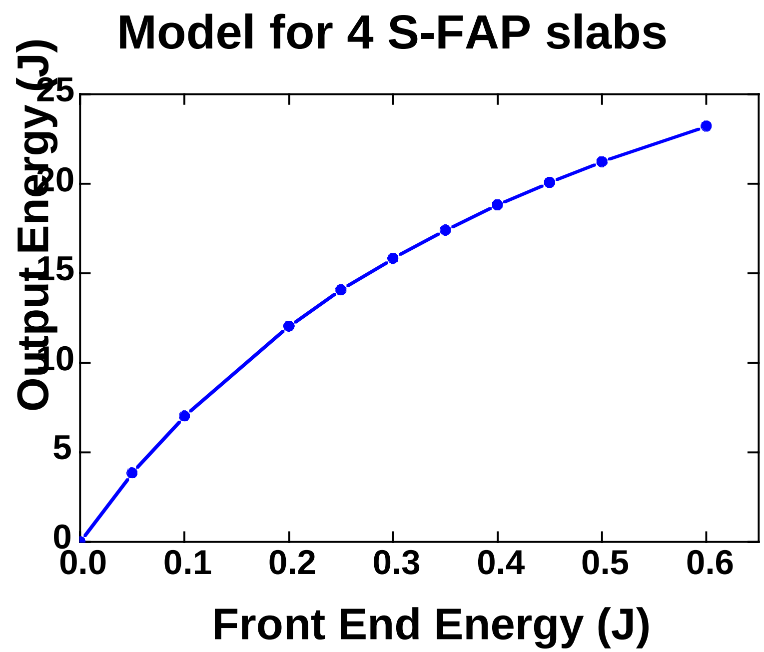


80 mm diameter optic, 380 um thick
P-V material removal depth ~ 10 µm



We have measured gain for the "mixed" amplifier with 4 Yb:S-FAP and 3 Nd:Glass slabs



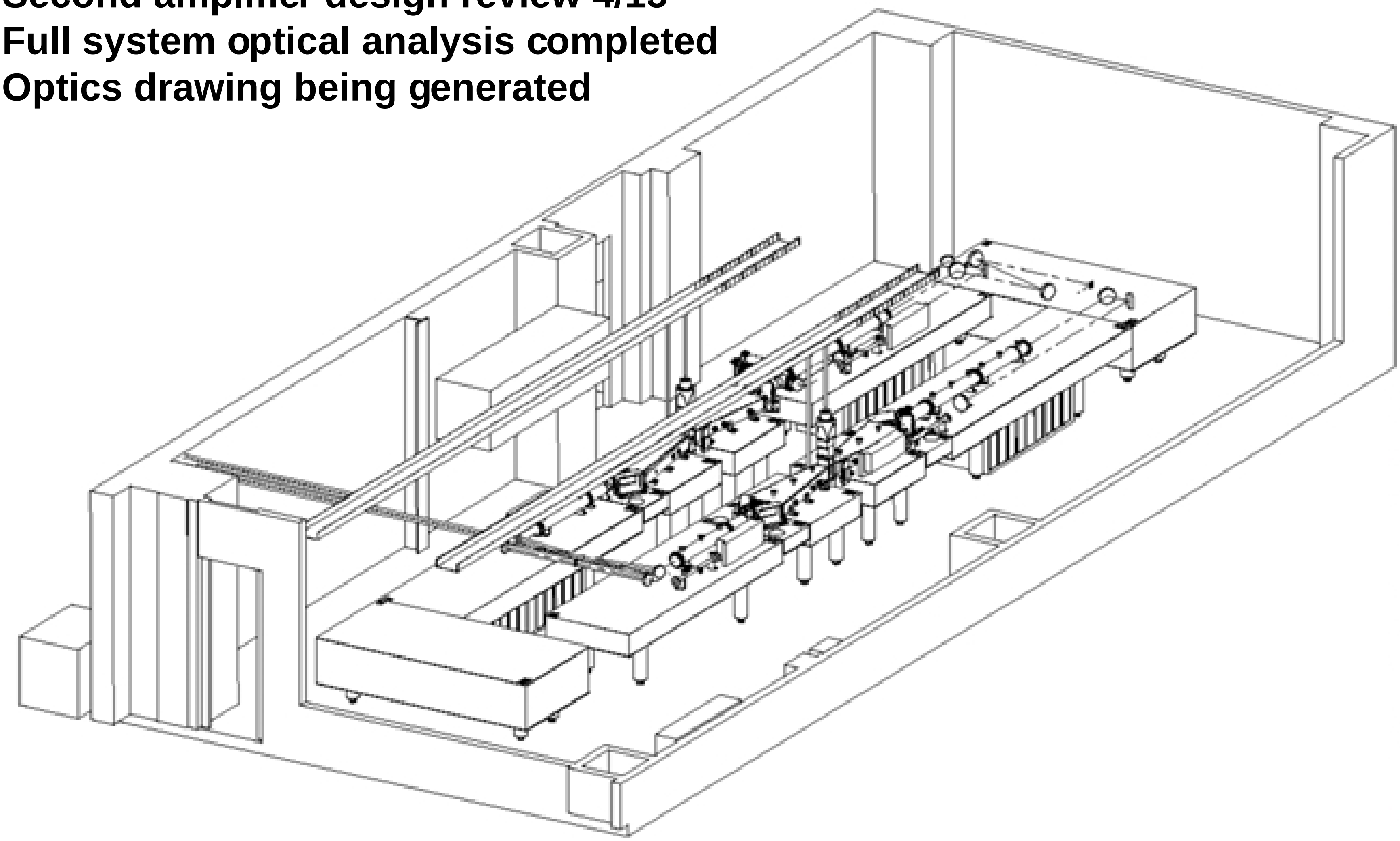


- For single pass measurements:
  - Experimental gain: G = 3.5
  - Modeling predicts: G = 2.9
- 4 pass gain experiments next and testing of phase corrector concept
- Seven S-FAP slab amplifier experiments scheduled later this year

We are preparing to upgrade the facility in order to build and install 2nd amplifier head and utilities

Update:

- **Room layout completed**
- **Utilities ordered**
- **Second amplifier design review 4/15**
- **Full system optical analysis completed**
- **Optics drawing being generated**

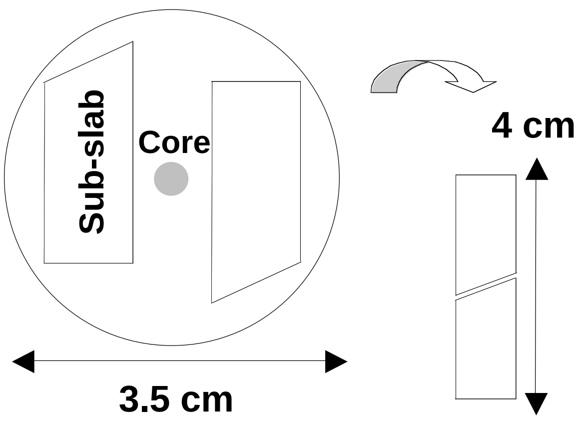


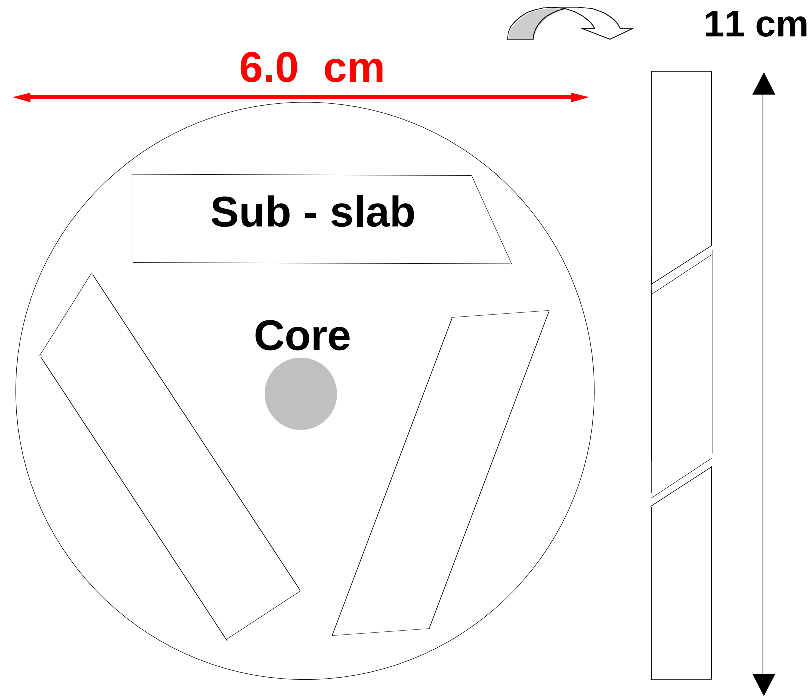
We are on schedule to produce first light with one amplifier this year

CY Months	1	2	3	4	5	6	7	8	9	10	11	12
• Build pump diodes for second amplifier						✓ array 5		✓ array 6		✓ array 7		✓ array 8
• Install 7 Yb:S-FAP crystals in amplifier			✓ 4 slabs					✓ 7 slabs				
and grow 7 boules for 2nd amplifier				✓ 4 boules						✓ 7 boules		
3 Build and install second amplifier head and utilities										✓ complete		
4 Build full aperture Pockels cell and install in reverser			✓ optics bid						✓ assemble			
• Perform experiments with Yb:S-FAP crystals			✓ 4 slabs					✓ 7 slabs				
• Continue advanced Yb:S-FAP growth					✓ first growth							
• Facility Upgrades									✓ complete			

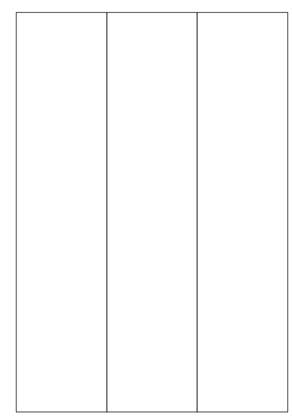
We are working with Schott Glass Technologies to develop a glass glue for Yb:S-FAP

Boule cross section





- We are investigating “glass glue” as an alternative means to bonding crystal segments
- Less stressful process
- Requires only 2x boule diameter scale-up for final kJ aperture



11 x 16 cm^2
is kJ aperture

The 5-year plan for DPSSL development has several parallel efforts in place

CY 2001	CY 2002	CY 2003	CY 2004	CY 2005

Mercury Laser (100 J)

Component Development → Build laser → 1ω Activation

- Wavefront Correction
- Spectral Sculpting
- Average Power Frequency Converter

Beam-Smoothing

3ω Activation

IRE Component Development (multi-kJ system)

15 cm S-FAP Crystals and Edge Cladding →

Pockels Cell and Driver →

> 200 W Diode bars →

IRE Architecture

Code Development and Modeling → IRE Design