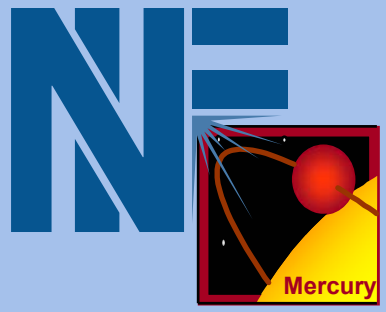
Progress Report for the Mercury Laser



Camille Bibeau

National Ignition Facility Directorate
Lawrence Livermore National Laboratory
Livermore, California 94550

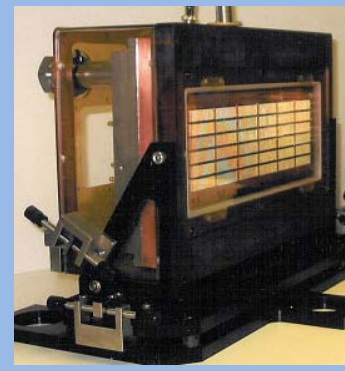
HAPL Review
Altanta, Georgia
February 5&6 2004

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

The facility upgrades have been completed and operations have commenced

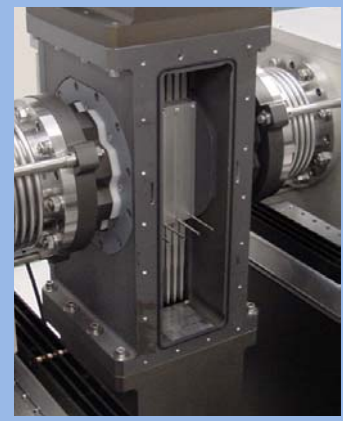
Flashlamps →diodes

Higher efficiency and reliability



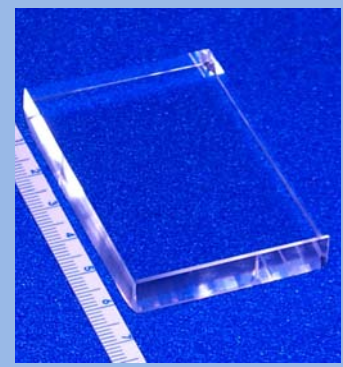
Radiative → forced cooling

Allows 10-Hz operation



Nd:glass → Yb:crystals

Increased energy storage and efficiency



Program goals:

- **100 J at 1.047 um**
- **10 Hz rep-rate**
- **5xDL beam quality**
- **3 nsec pulse length**
- **10 % efficiency**
- **10^8 diode reliability**

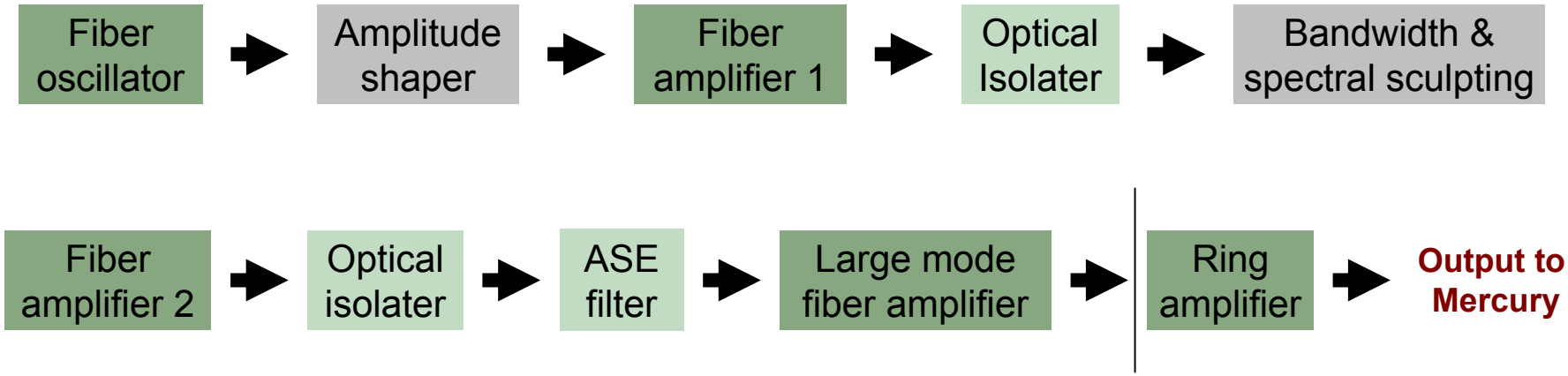
Cleanroom video

The enclosures now allow us to operate at cleanroom Class 100 levels

Class 100 = < 100 particles/ft^3 of <0.5 um size
Class 1000 = < 1000 particles/ft^3 of <0.5 um size

Front end video

Second generation Mercury front end will have enhanced capabilities of temporal and spectral sculpting



Component specifications

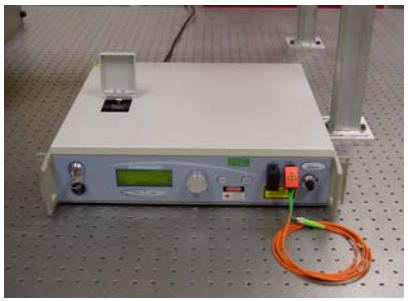
	Oscillator	Fiber amplifier 1	Fiber amplifier 2	Large mode fiber amplifier	Ring amplifier
Energy	NA	3 nJ	8 nJ	30 uJ	0.5 J
Rep-rate (Hz)	CW	960	960	960	10

The fiber-based front end will allow pulse-to-pulse stability and support the bandwidth needed for beam smoothing

Fiber oscillator → Amplitude shaper → Fiber amplifier 1 → Optical Isolater → Bandwidth & spectral sculpting

Fiber amplifier 2 → Optical isolater → ASE filter → Large mode fiber amplifier → Ring amplifier → **Output to Mercury**

Fiber oscillator



- 1047.7 nm
- SLM with 100kHz linewidth
- Polarized with 50:1 extinction

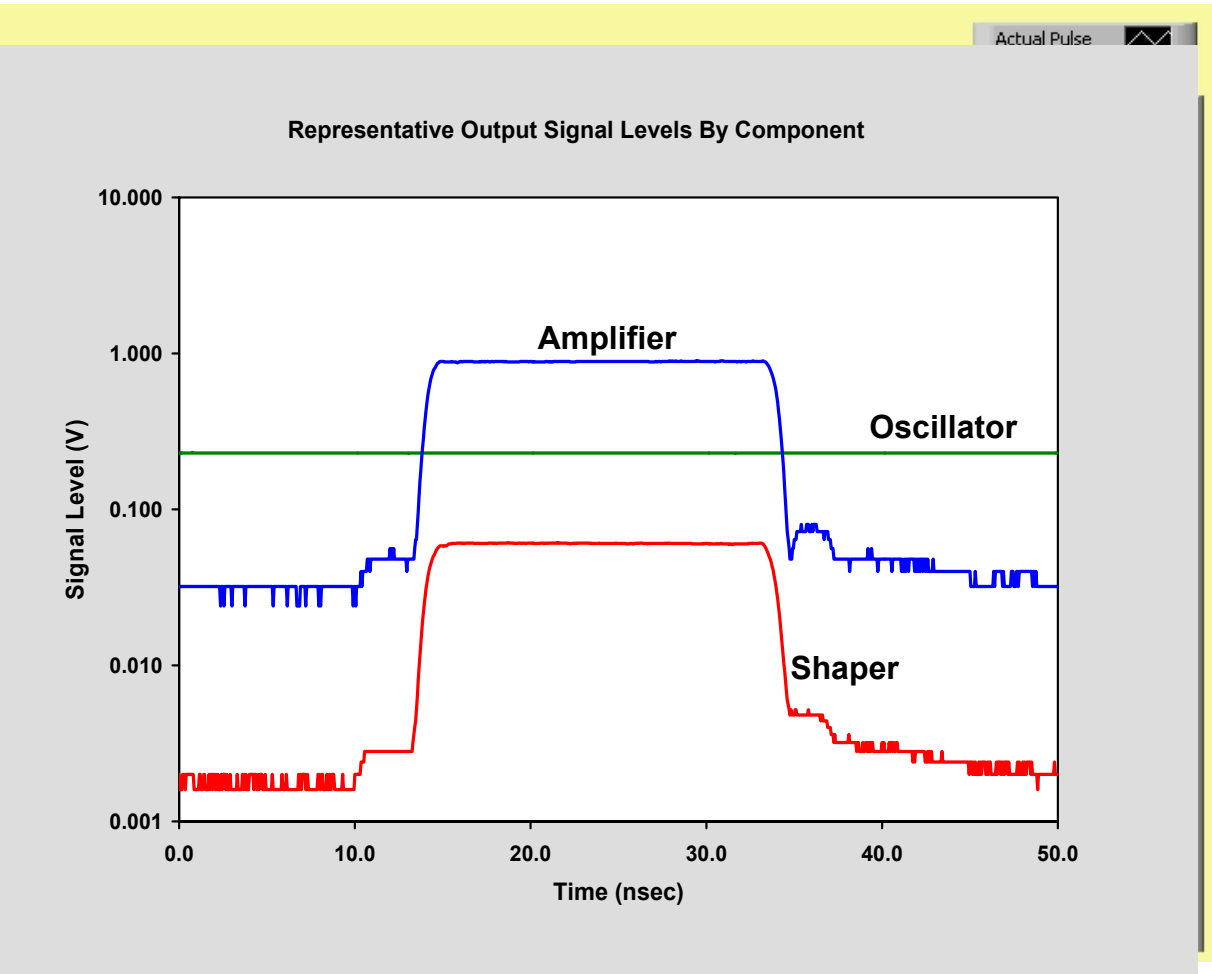
Amplitude shaper

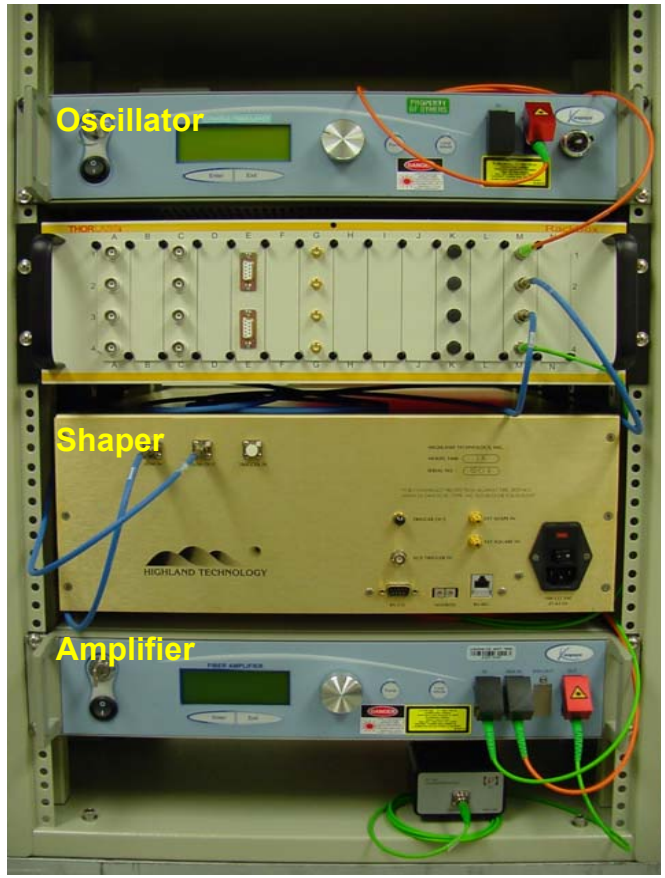
- Dual-stage EO modulator
- 96 adjustment points
- 250 psec resolution

Fiber amplifier

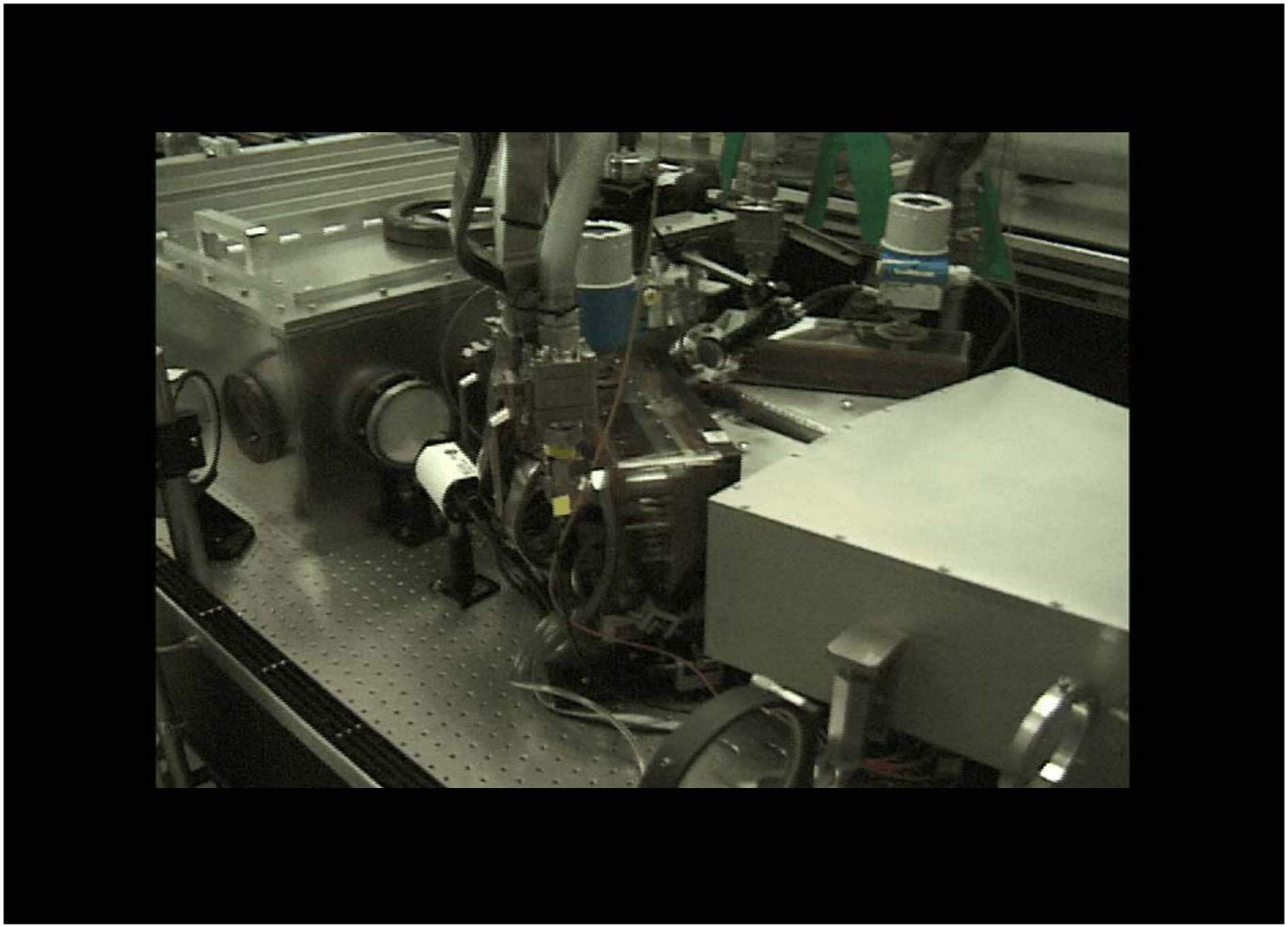
- Yb-doped fiber amplifier
- Polarization maintaining
- 30 dB gain

Several of the front end components are being assembled and tested





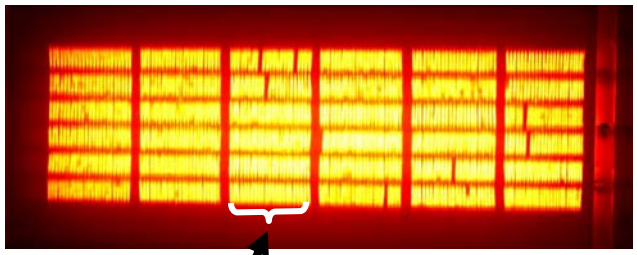
Diode array and pump delivery video

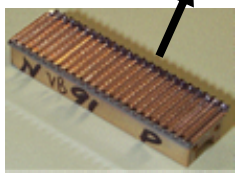


We have fabricated and qualified 80 kW diode arrays for a total of 320 kW of peak diode power

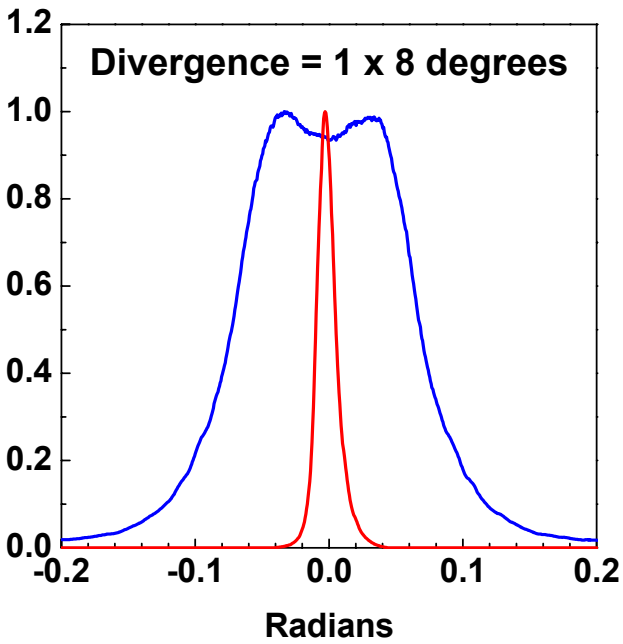
Operated at:

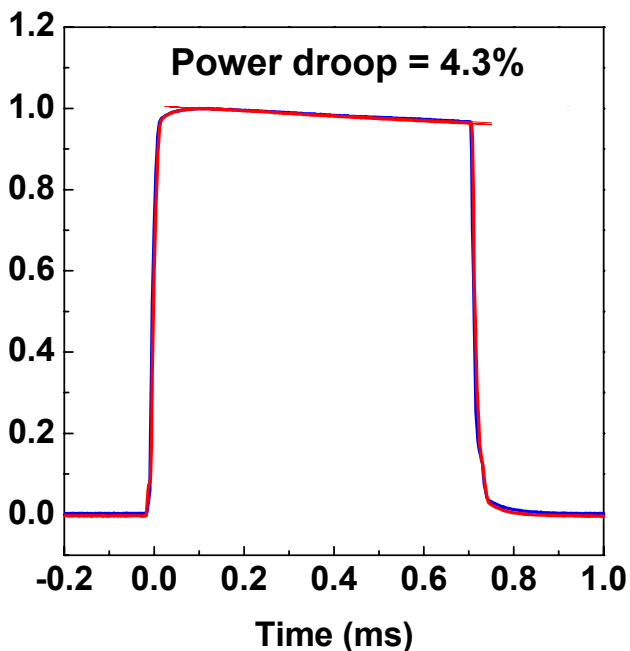
- 120 W/bar at 10 Hz
- 900 ms pulsewidth

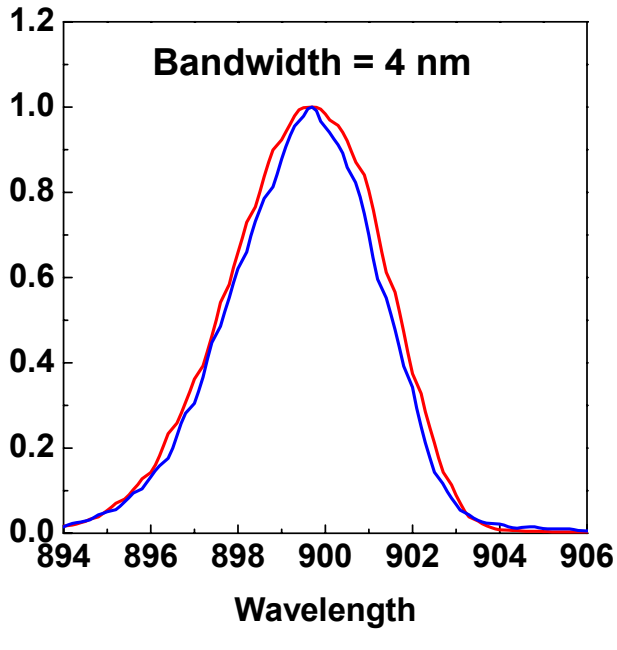




tile with 23 diode bars

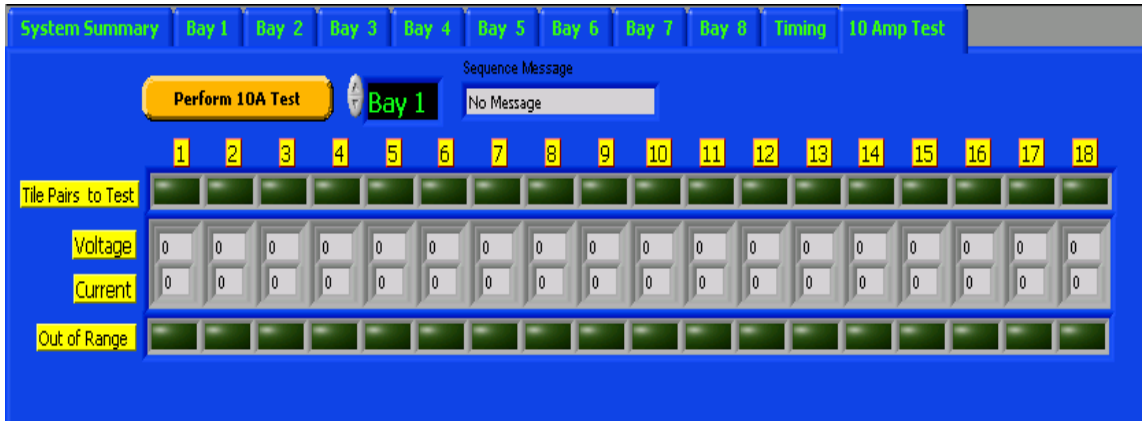




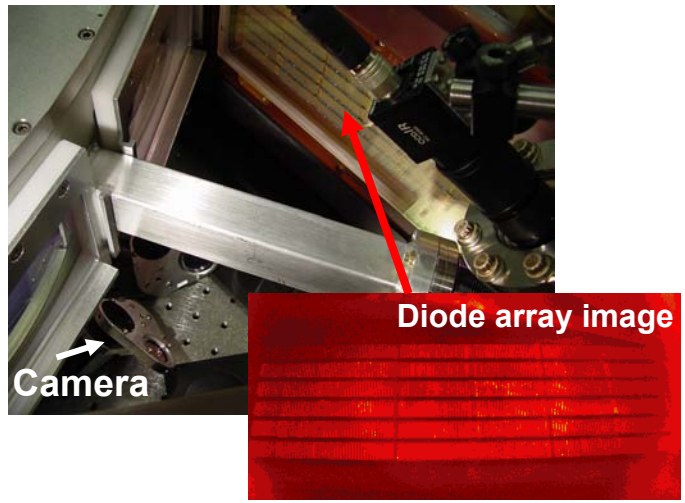


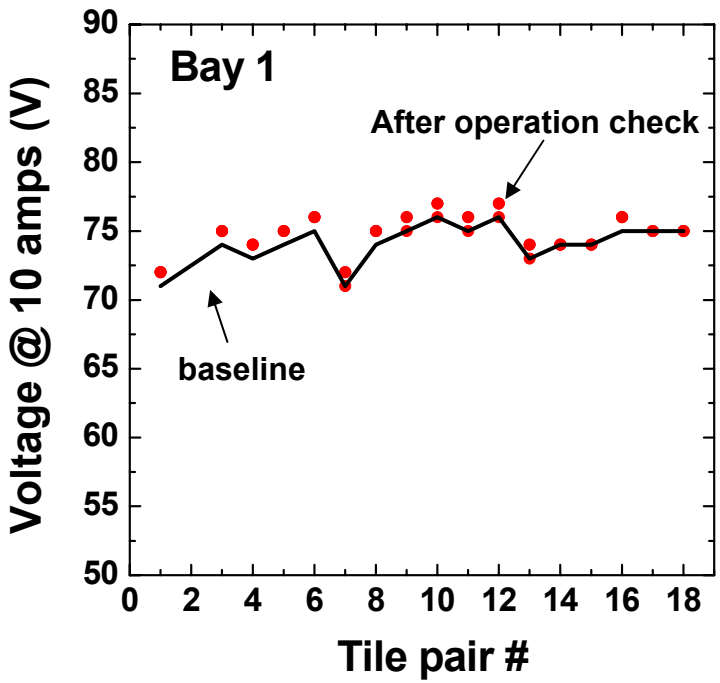
We have implemented diode array diagnostics to monitor tiles for failure

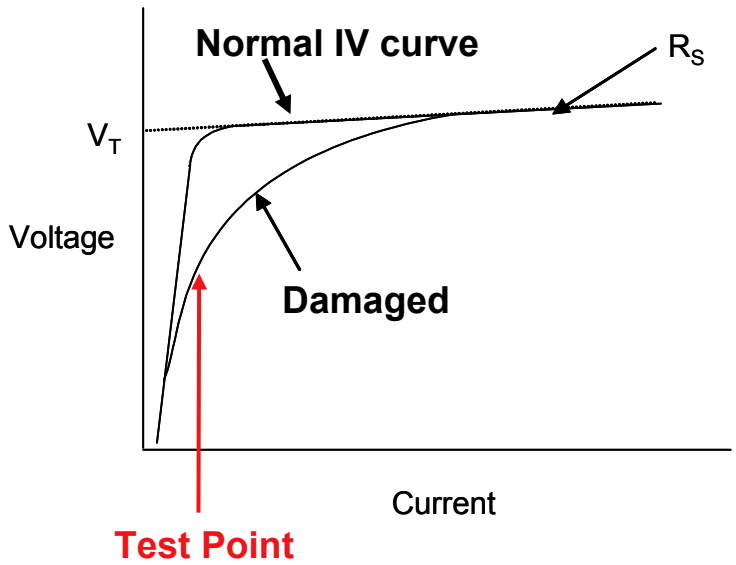
Automated computer monitoring of IV characteristics



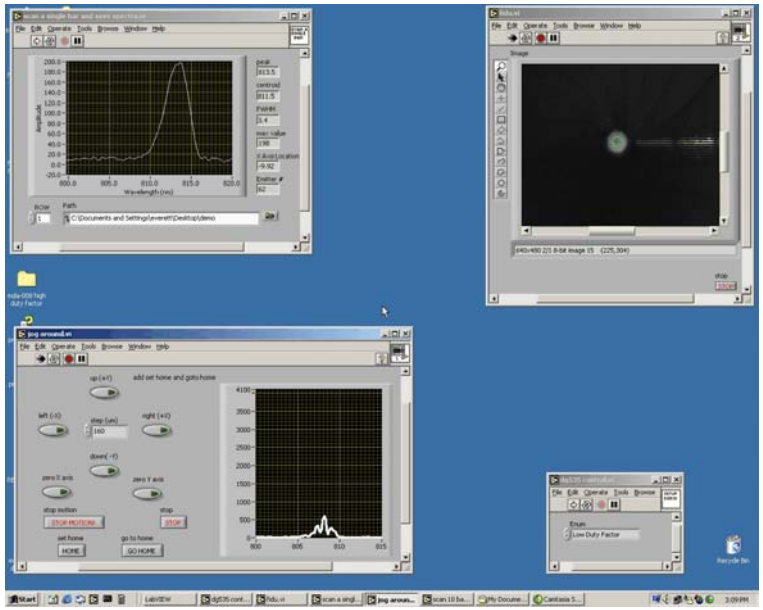
Cameras for real-time monitoring



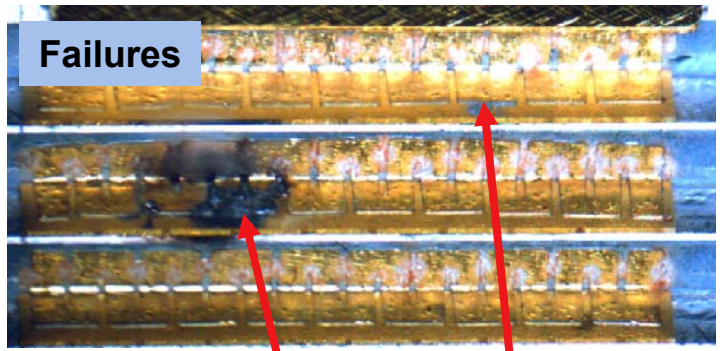


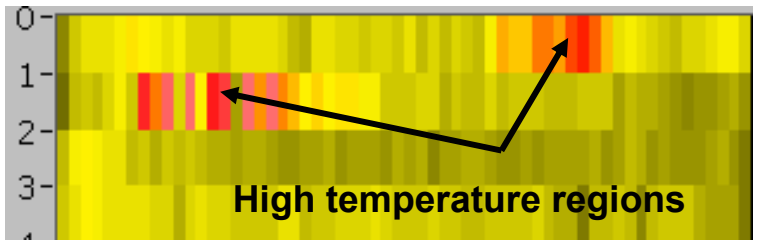


An experimental set-up has been built to observe anomalous, high temperatures that are precursors to diode failures

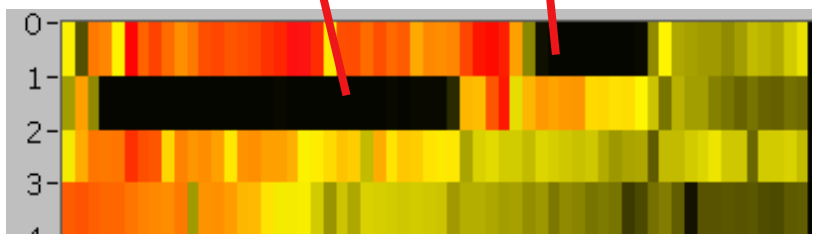


- Two “hot” regions identified
- Strong correlation between hot spots and eventual failures





Temperature (before burn-in)



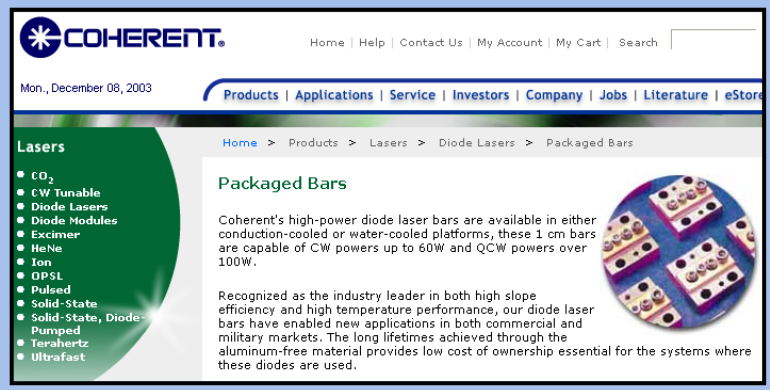
Power (after burn-in)

We anticipate the temperature field scan technology will be a useful diagnostic for eliminating weak diode bars and improving process-control

Qualified vendors will be assessing fabrication and licensing of V-BASIS technology

Packaging house

Diode bars

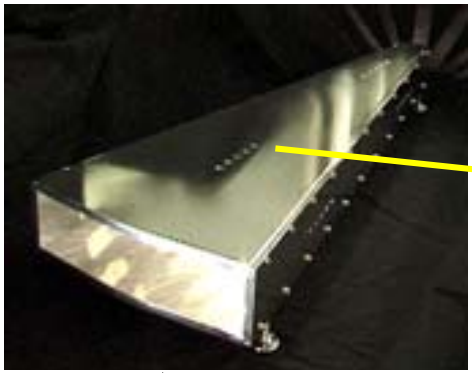


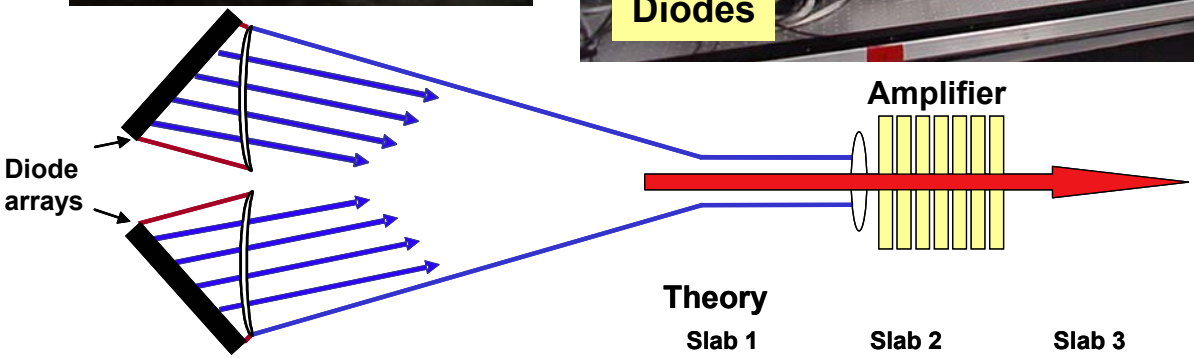
FBO Announcement

LAWRENCE LIVERMORE NATIONAL LABORATORY SEEKS PARTNERSHIPS WITH INDUSTRY TO SUPPLY SEMICONDUCTOR LASER DIODE ARRAYS FOR THE MERCURY LASER FACILITY

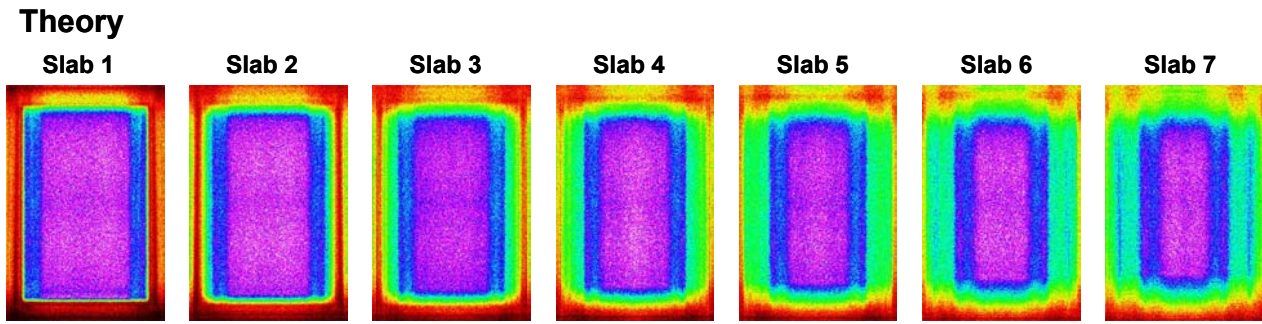
The Lawrence Livermore National Laboratory (LLNL), operated by the University of California under contract with the U.S. Department of Energy (DOE), is seeking potential industrial partners and participants who are interested in, and capable of, supplying laser diode arrays in support of the Mercury laser project now underway at LLNL. The Mercury laser will be the first all diode-pumped inertial confinement fusion laser and will produce 100 Joules/pulse with an emission wavelength of ~ 1 μm. The current 23-bar LLNL arrays or "tiles" used on the system operate at an peak power of 2.3 kW at 10 Hz with an emission wavelength of 900 nm and 1ms long pulses. The tile consists of bars mounted on a silicon heatsink with microlens conditioning to reduce the divergence of the fast axis to 10 mrad.

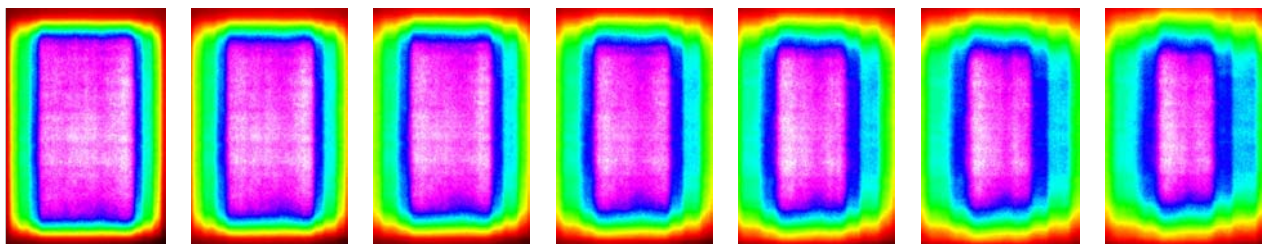
System had been reactivated with two amplifiers and improved pump diode delivery





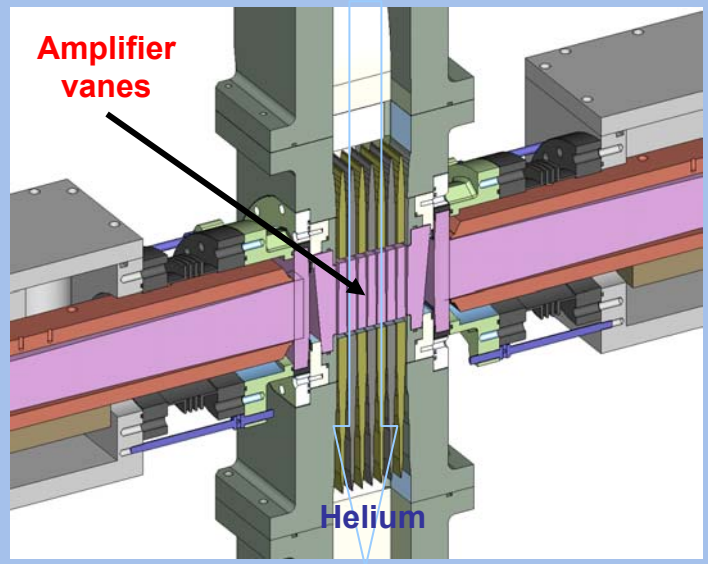
Pump profiles



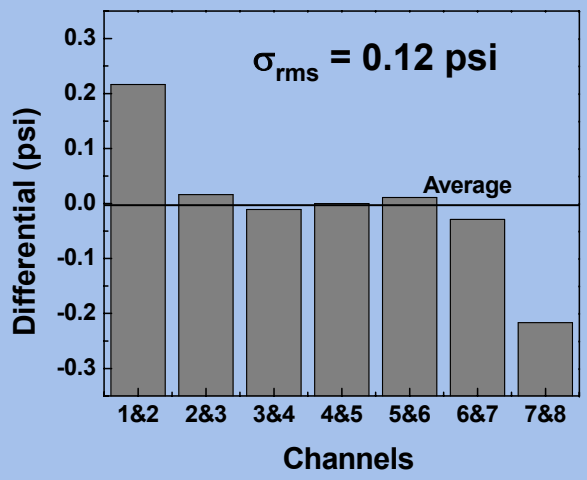


Amplifer video

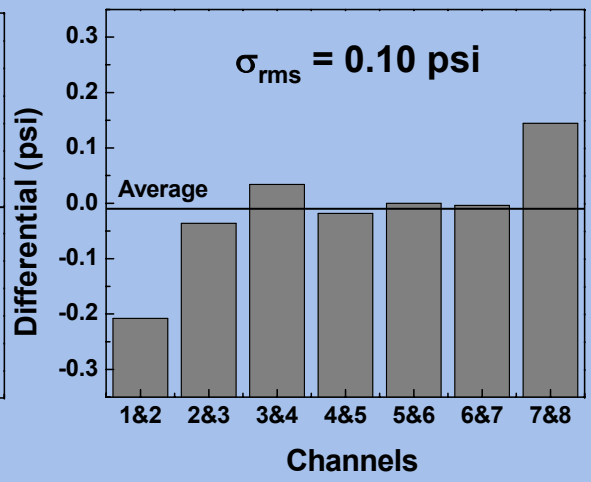
Helium gas is now flowing between two amplifiers; flow tests confirm adequate balance between channels

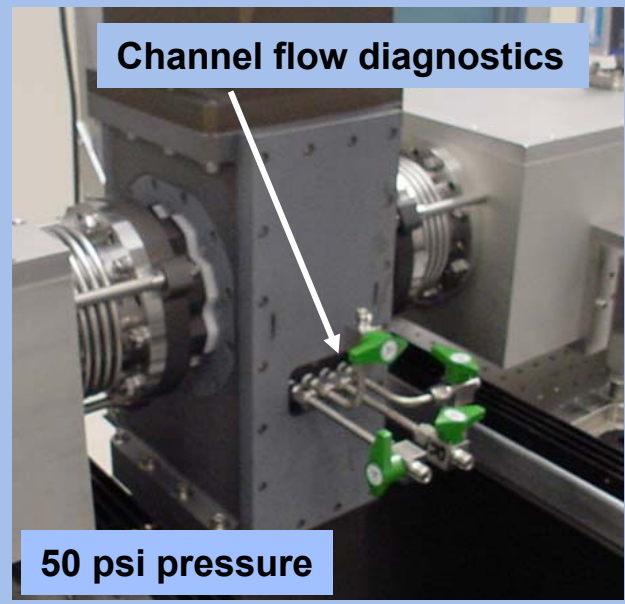


Amplifier 1



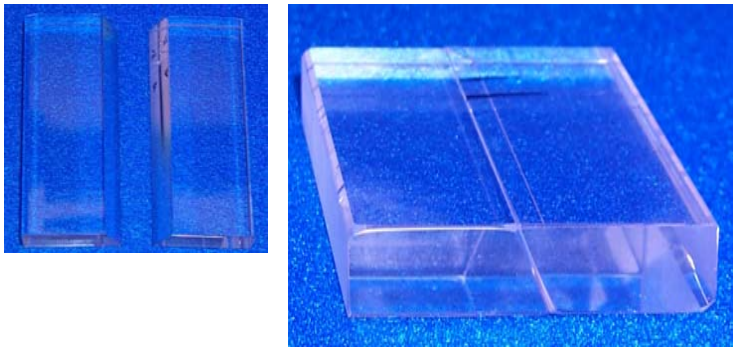
Amplifier 2



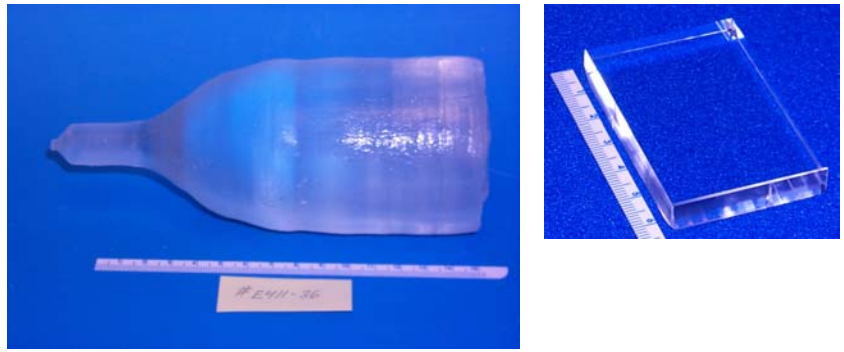


Many processes are involved with fabricating and qualifying amplifier Yb:S-FAP slabs

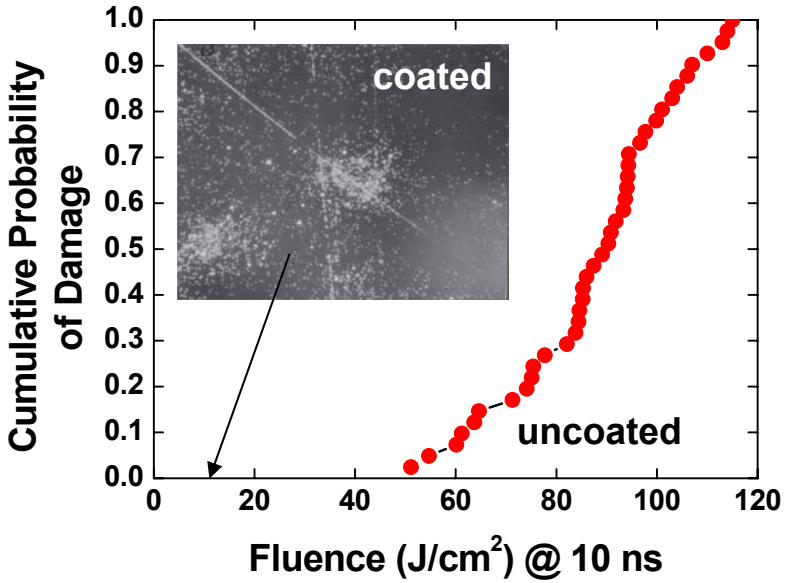
3.5 cm boules require bonding to form slabs



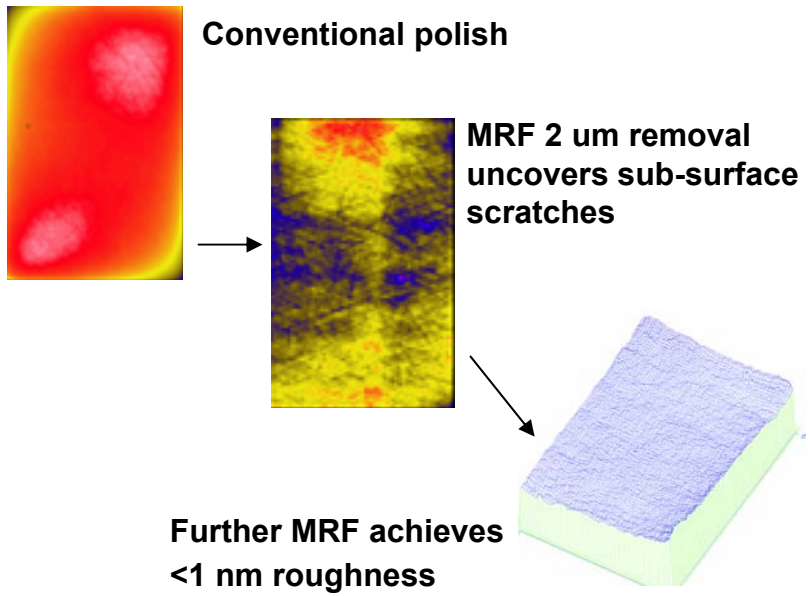
6.5 cm boules directly yield two full-size slabs



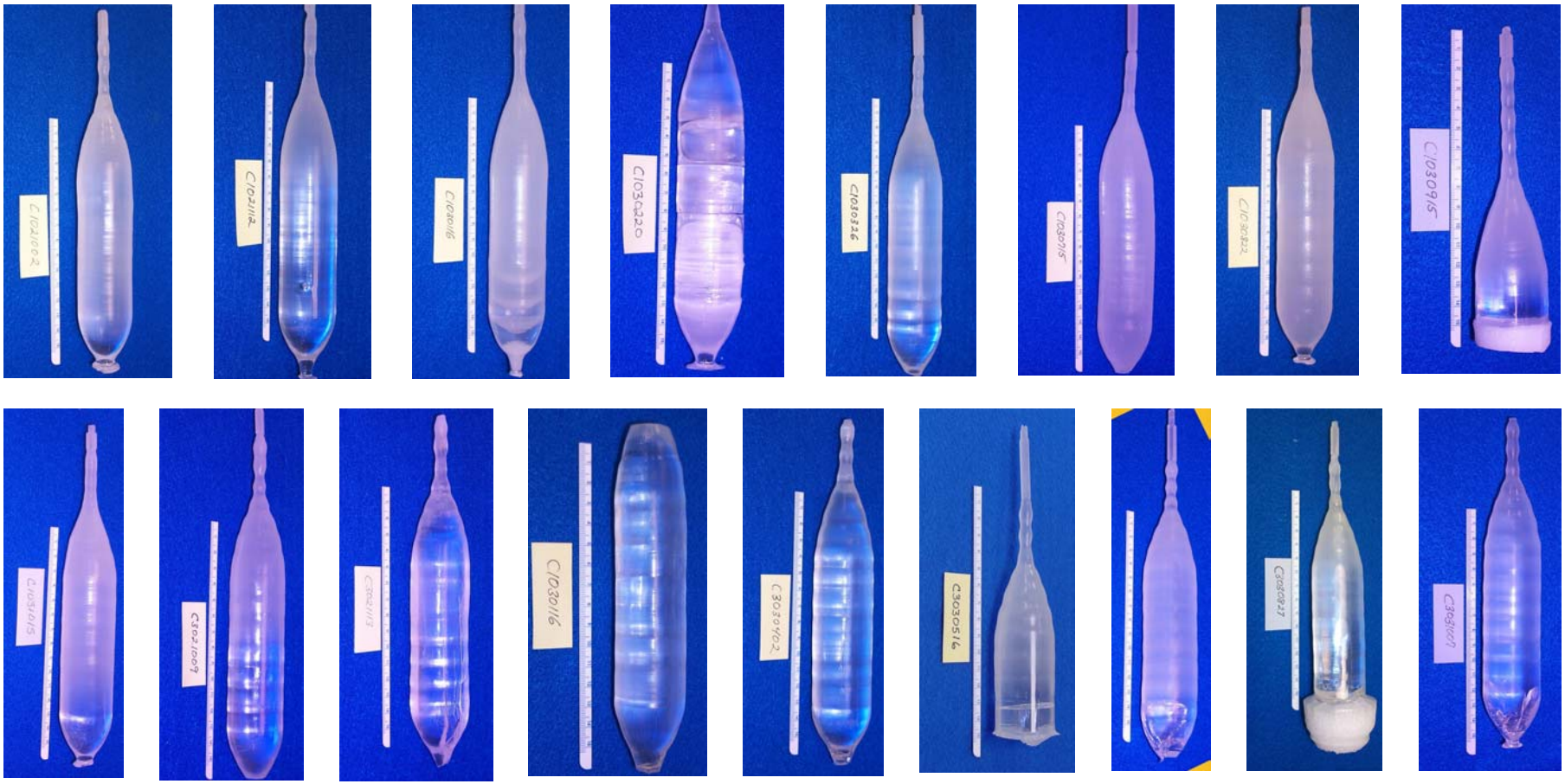
High damage threshold coatings requires high quality surfaces



Magneto-rheological finishing (MRF) removes sub-surface damage



Over 18 boules have been grown from LLNL Czochralski furnaces in FY03

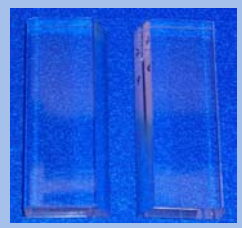


A reproducible process has been developed for the growth of small diameter boules, although the bonding process has been time-consuming

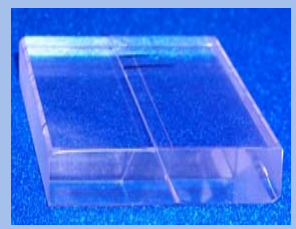
We are investigating two bonding processes for Yb:S-FAP

Boules

Half Slabs

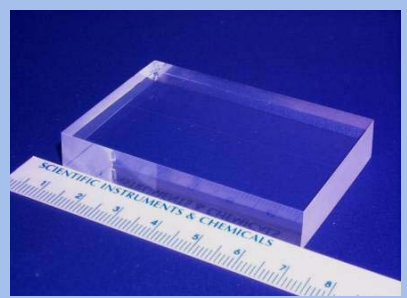


Bonded



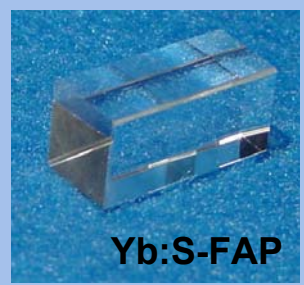
Onyx

- High temperature bonding
- Bond time 8 weeks
- Flatness: ~λ/10
- Roughness: ~25 A
- Possible residual stress in bond
- No index matching requirement
- No material embedded in bond
- Minimal scattering from bond region



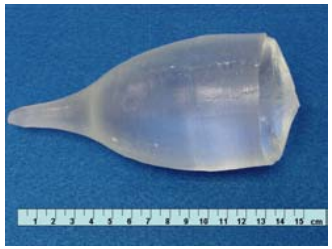
Schott

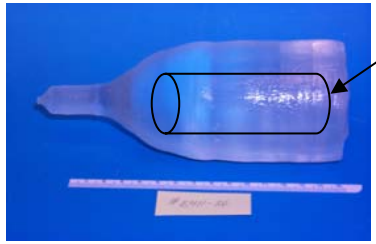
- Low temperature "glue" bonding
- Bond time 1-2 weeks
- Flatness: ~λ/3
- Roughness ~250 A
- Index matching requirement
- Material embedded in bond
- Environmental durability
- Optical clarity

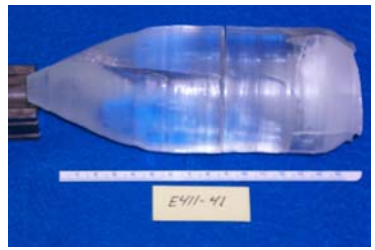


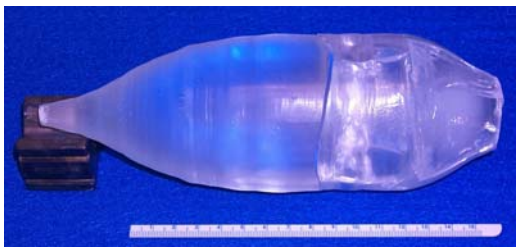
>30 J/cm^2 damage threshold

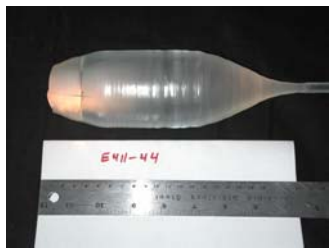
Numerous large, 6.5 cm diameter crystals of Yb:S-FAP have been grown at Northrop-Grumman (Charlotte, NC)







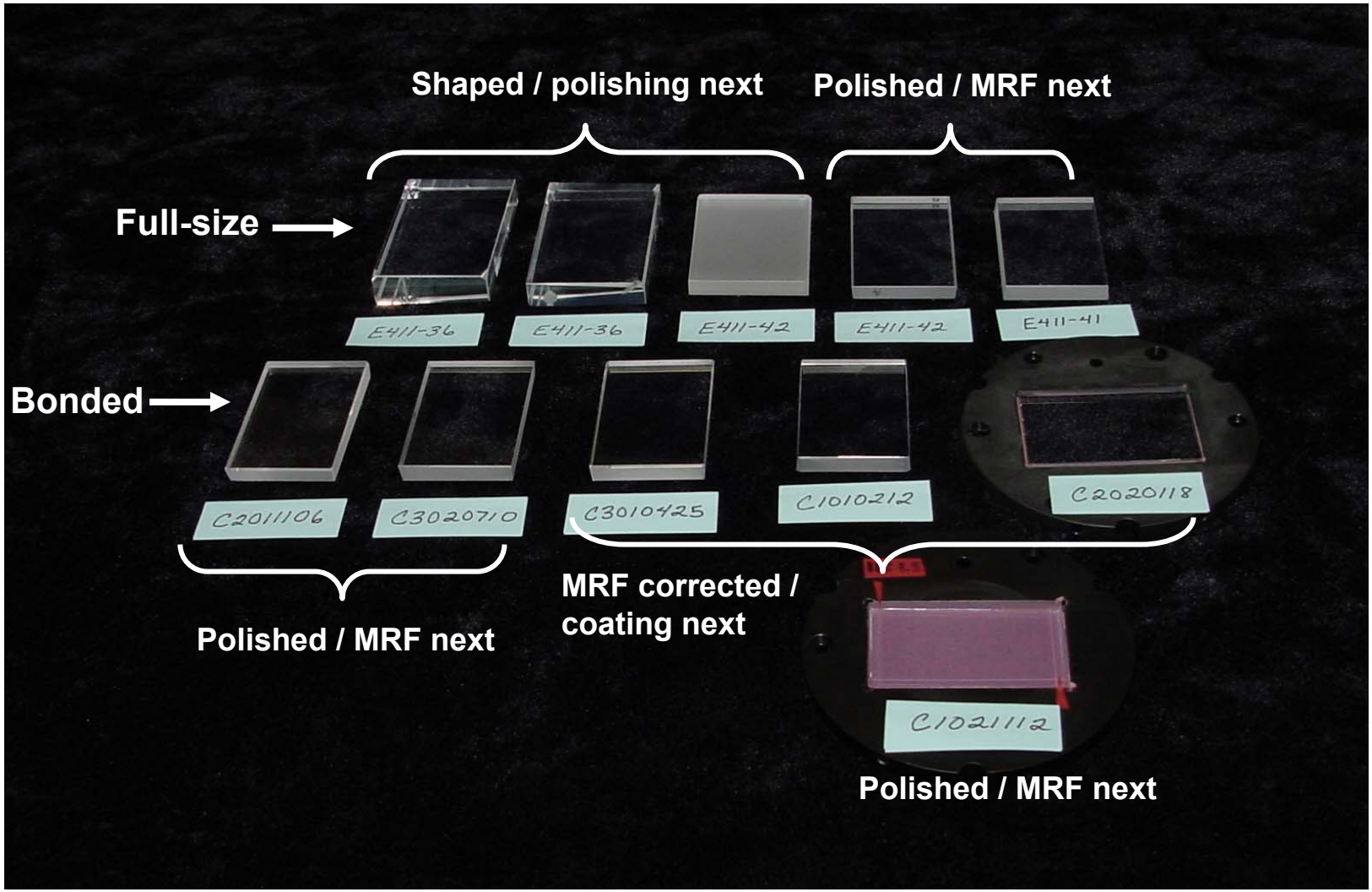




Using a high pressure water jet cutting process, we have been able to harvest four full size slabs

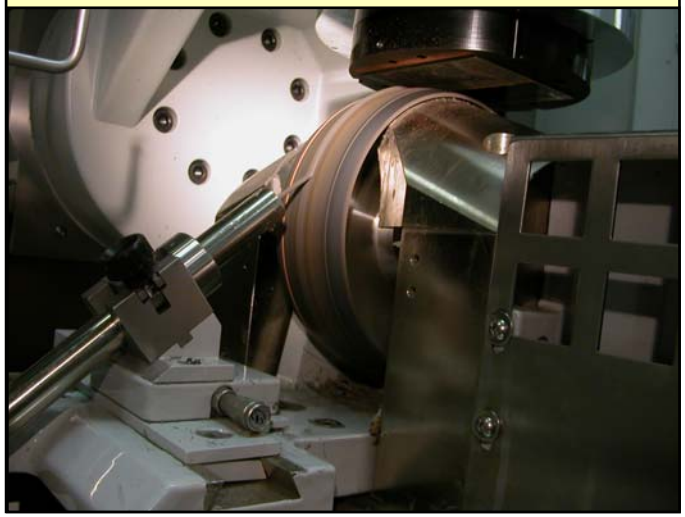
We have 11 slabs in various stages of fabrication that might be installed in the amplifiers over the next few months

Bond → Shape → Polish → MR Finishing → Coating

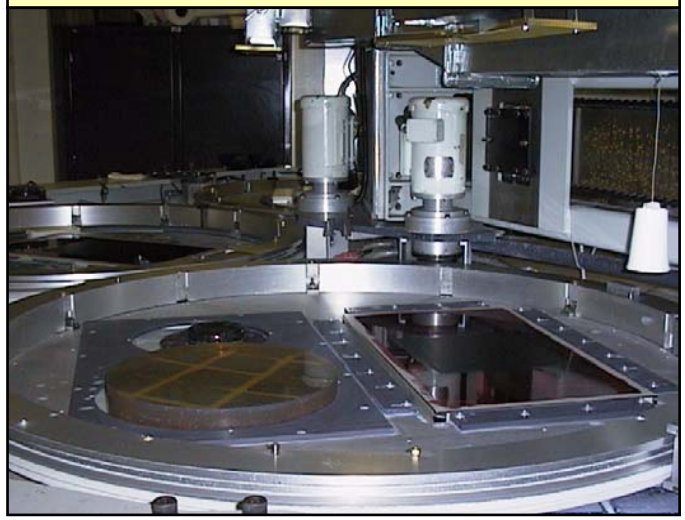


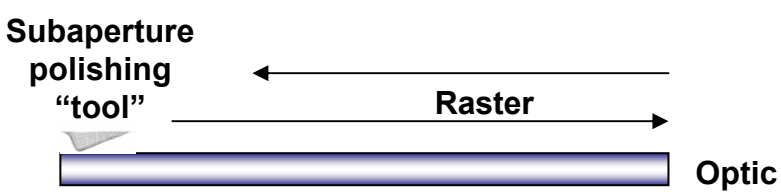
The Magnetorheological Finishing (MRF) machine at LLNL is being used to improve the wavefront of Yb:S-FAP slabs

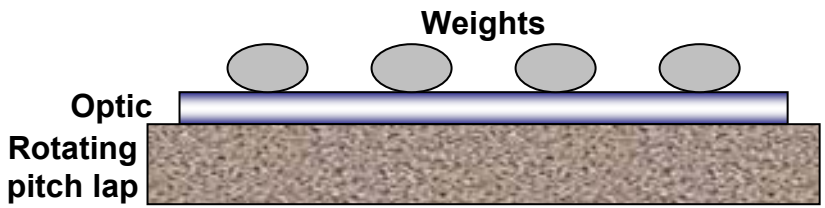
Deterministic finishing



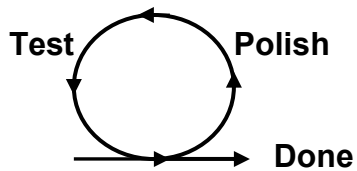
Conventional polishing







Test → Polish → Test → Done



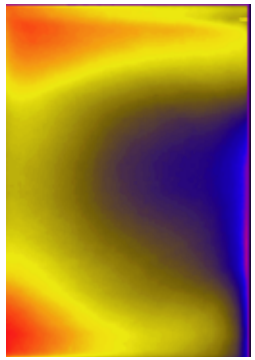
The removal function is held constant during polishing and material removal is controlled by varying the residence time over the optical surface

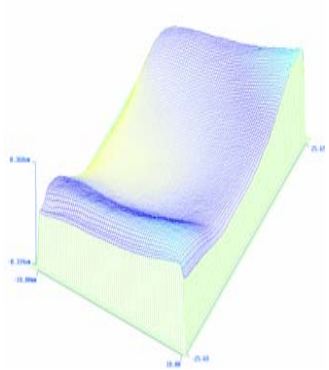
MRF process steps are outlined in movie

Slab number C1010212 has been refurbished and is ready for coating

Before

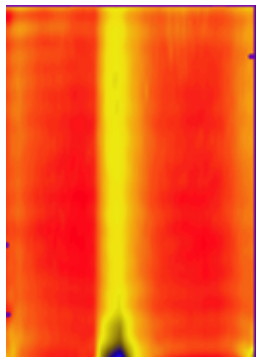
Surface wavefront

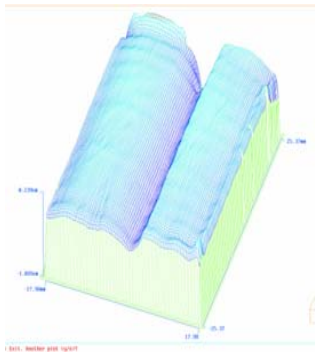




PV: 0.702 um
Rms: 0.127 um

Transmitted wavefront

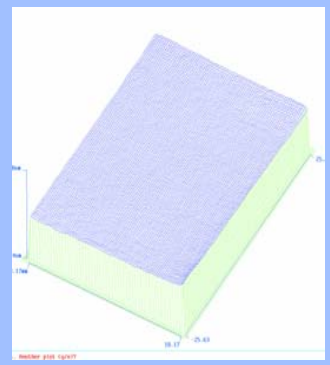




PV: 1.338 um
Rms: 0.130 um

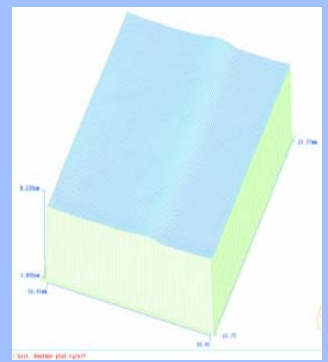
After

Surface wavefront



PV: 0.0775 um (10x)
Rms: 0.0071 um (18x)

Transmitted wavefront

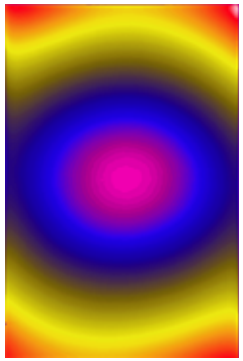


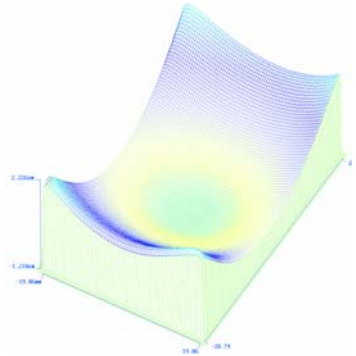
PV: 0.0922 um (14.5x)
Rms: 0.0191 um (7x)

Slab number C3010425 has been refurbished and is ready for coating

Before

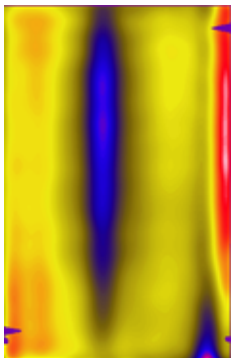
Surface wavefront

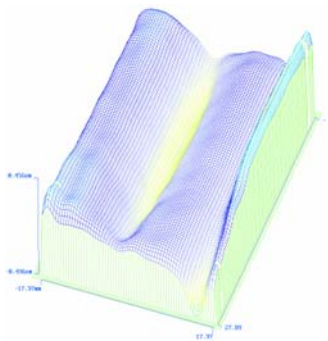




PV: 3.437 um
Rms: 0.815 um

Transmitted wavefront

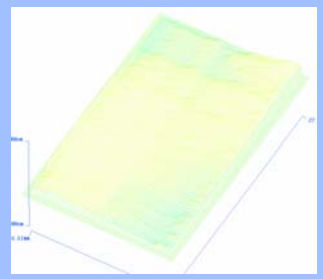




PV: 0.952 um
Rms: 0.160 um

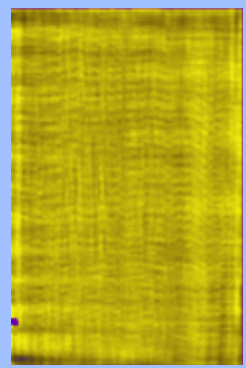
After

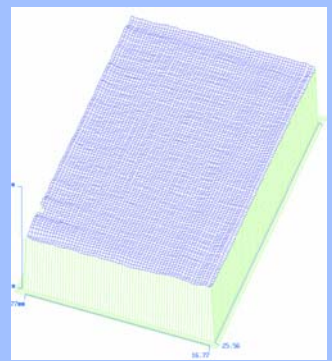
Surface wavefront



PV: 0.0682 um (50x)
Rms: 0.0140 um (58x)

Transmitted wavefront

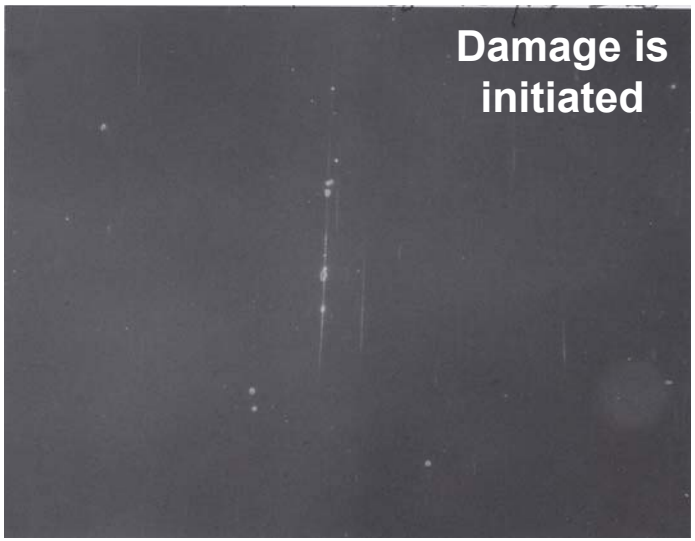


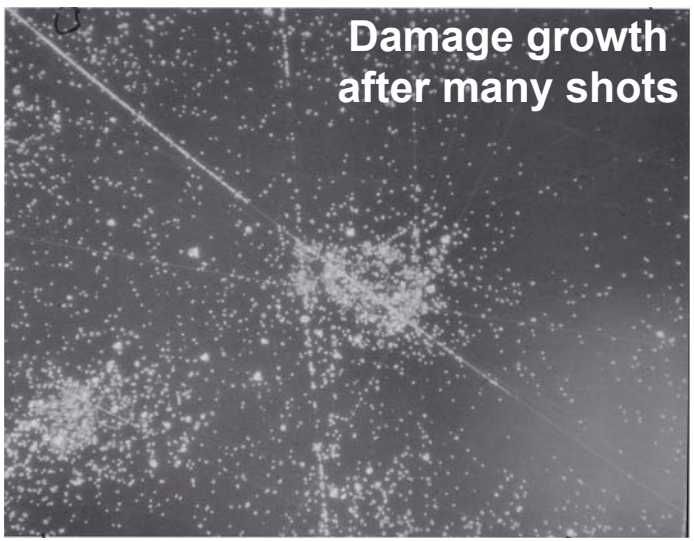


PV: 0.0755 um (13x)
Rms: 0.00695 um (23x)

Coating damage can attributed to surface scratches

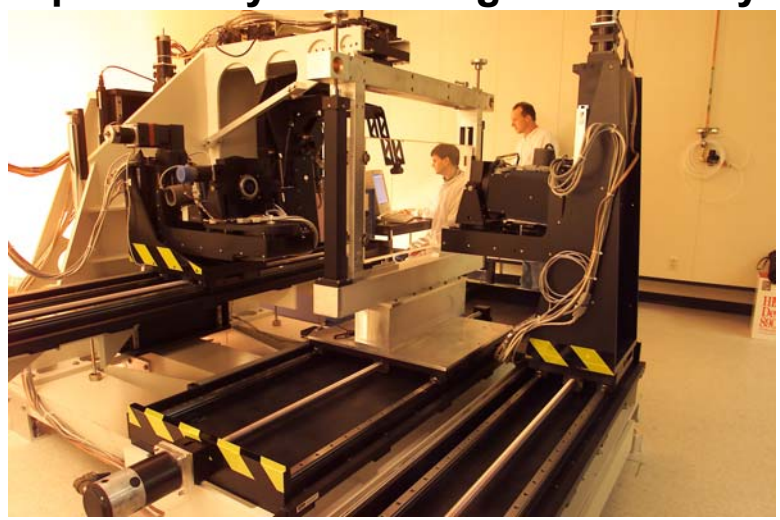
Coated Yb:S-FAP damage
(5-10 J /cm^2 at 10 ns)



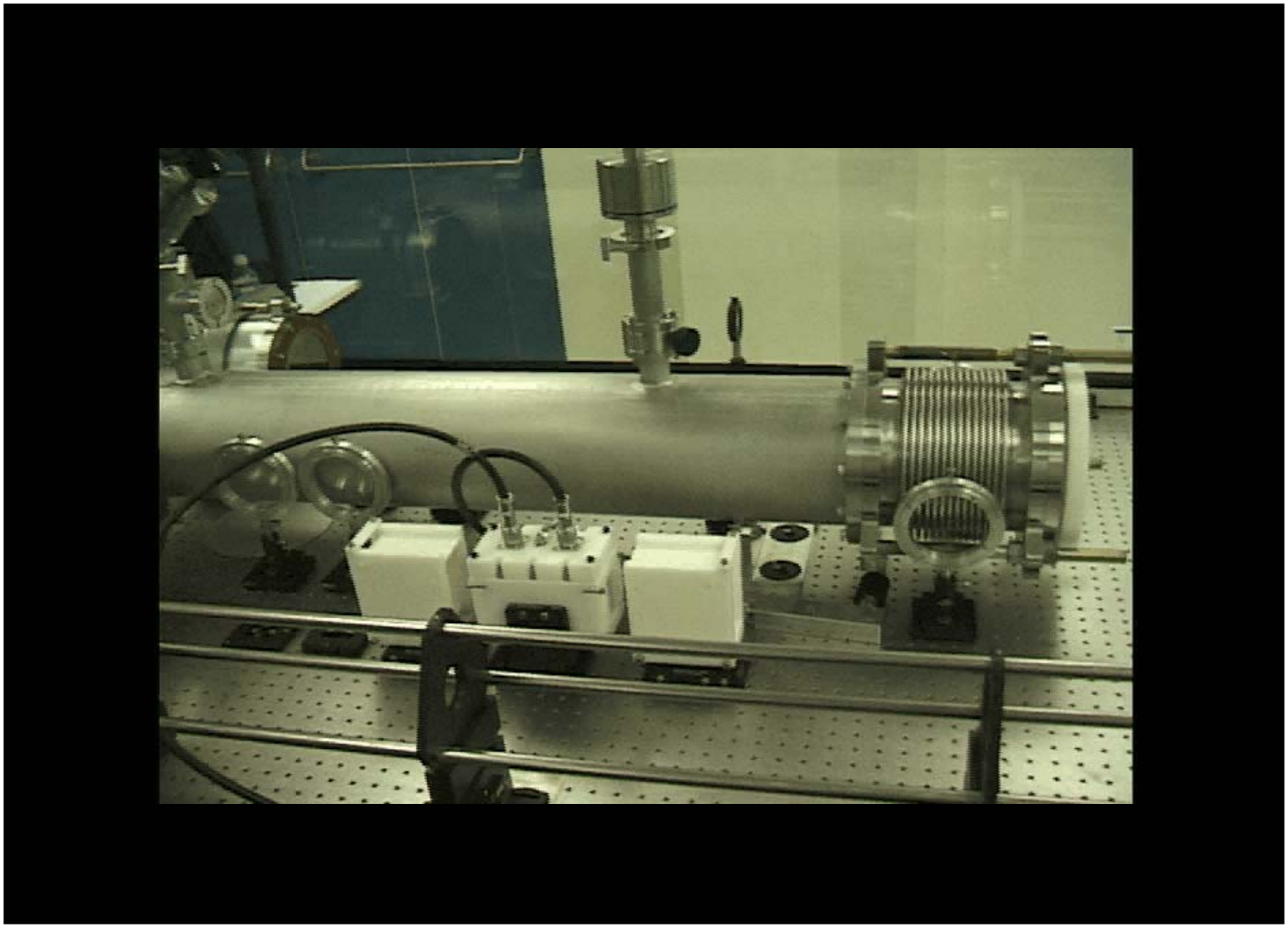


Spectra Physics coating chamber

Spectra Physics damage test facility



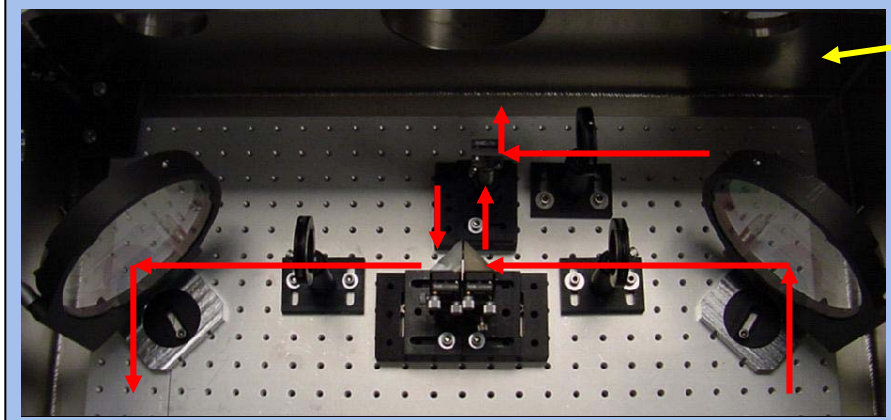
Reverser and Pockels cell video



The full scale reverser has been activated and now includes pre-qualified mirrors to allow longer operation run times

Reverser
(Allows two additional passes)

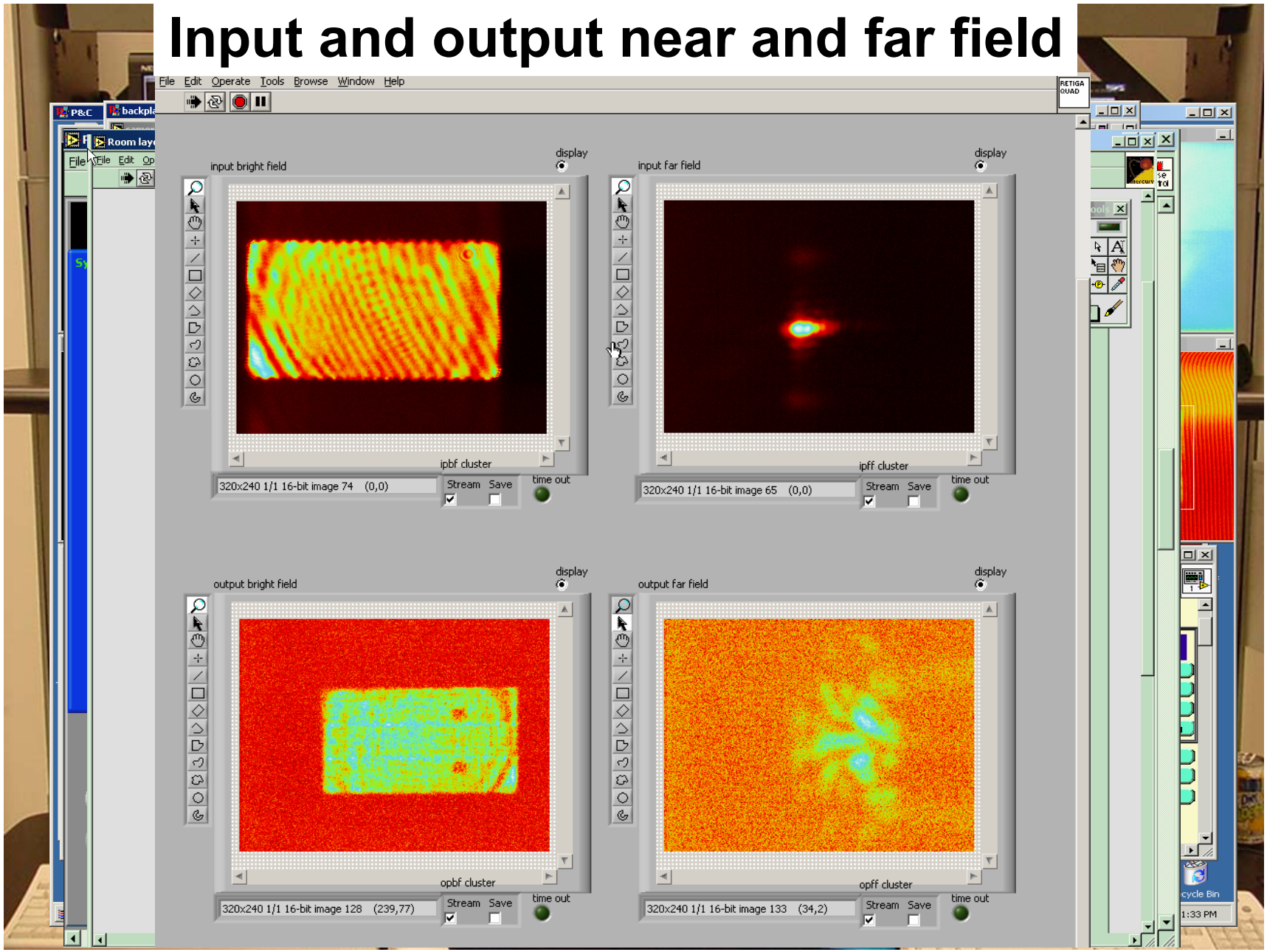
- Full size optics
- Pre-qualified mirrors (20 J/cm^2 at 10 ns)
- Motion control on all optics
- More optics in vacuum for cleanliness



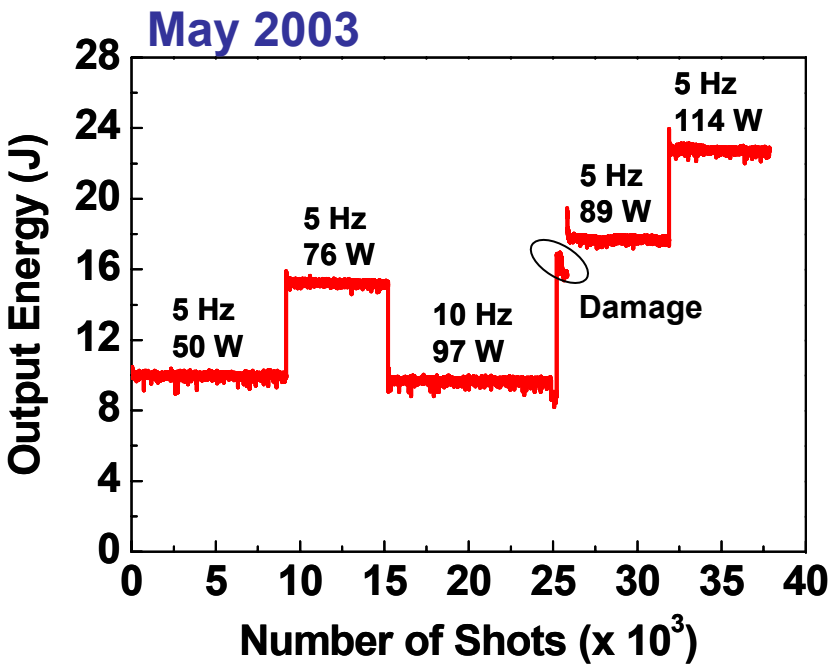
Pockels cell
(Prevents amplification of parasitics)

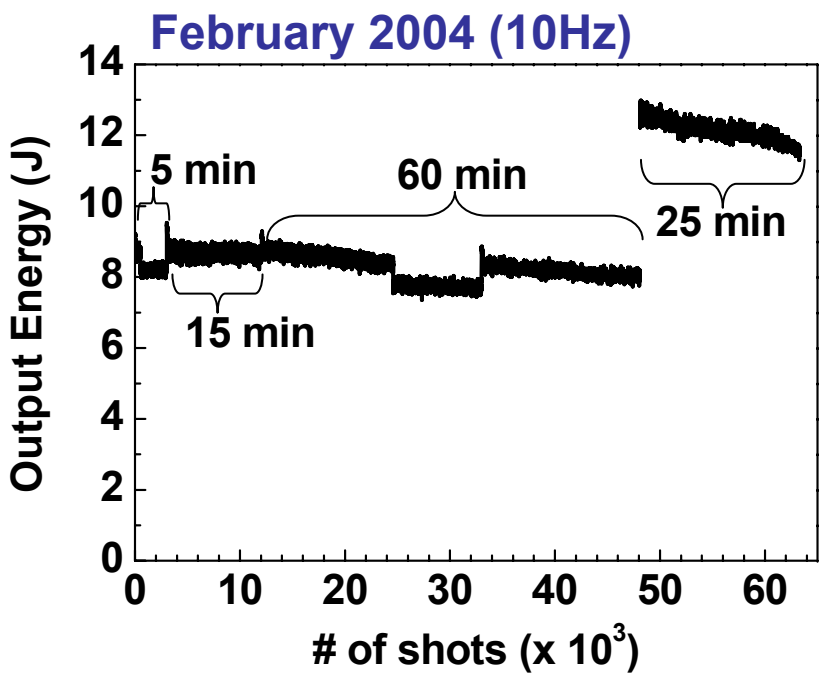
- Average contrast: 200:1
- Rise/fall time: 8.2 ns / 14 ns
- Wavefront distortion: 0.15λ
- Pulsed operation with no EMI

Input and output near and far field



Reactivation of the upgraded laser facility commenced last week, and the power is being ramped up slowly





System upgrades include:
- second amplifier
- phase plate co-located with slabs
- distributed control system
- damage resistant reverser
- second set of utilities
- class 100-1000 cleanroom

Slab fabrication:
- 3 ready for coating
- 5 in MRF cue
- 3 in shaping

Amplifier # 1 (4 slabs)
- 12 J, 10 Hz (2/04)

Amplifier # 2 (7 slabs)
- 50 J, 10 Hz (5/04)