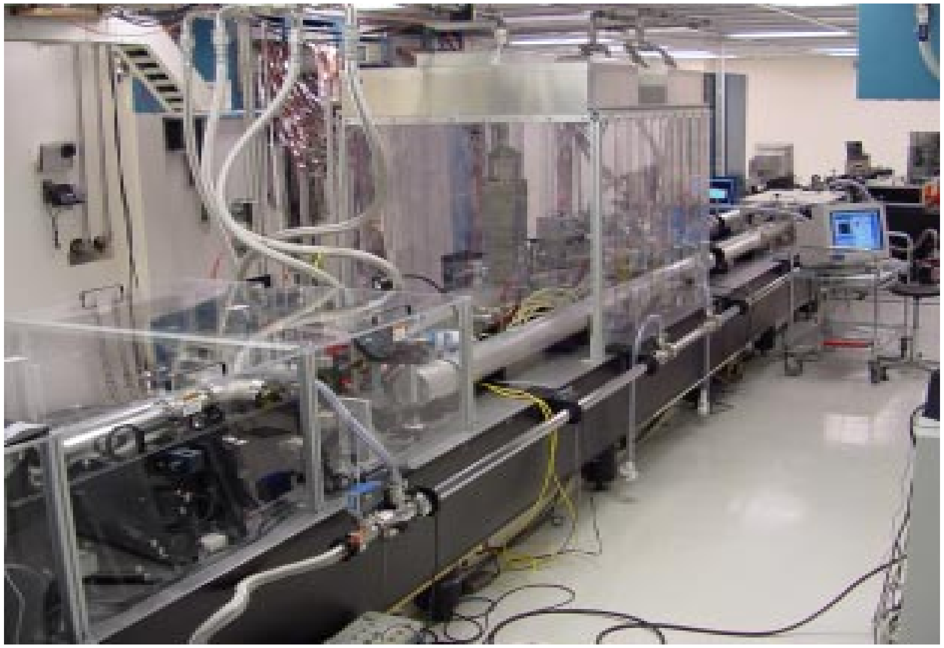
The Mercury Laser Facility (before and after)



May 31, 2003

September 20, 2003

Presented by:
Camille Bibeau

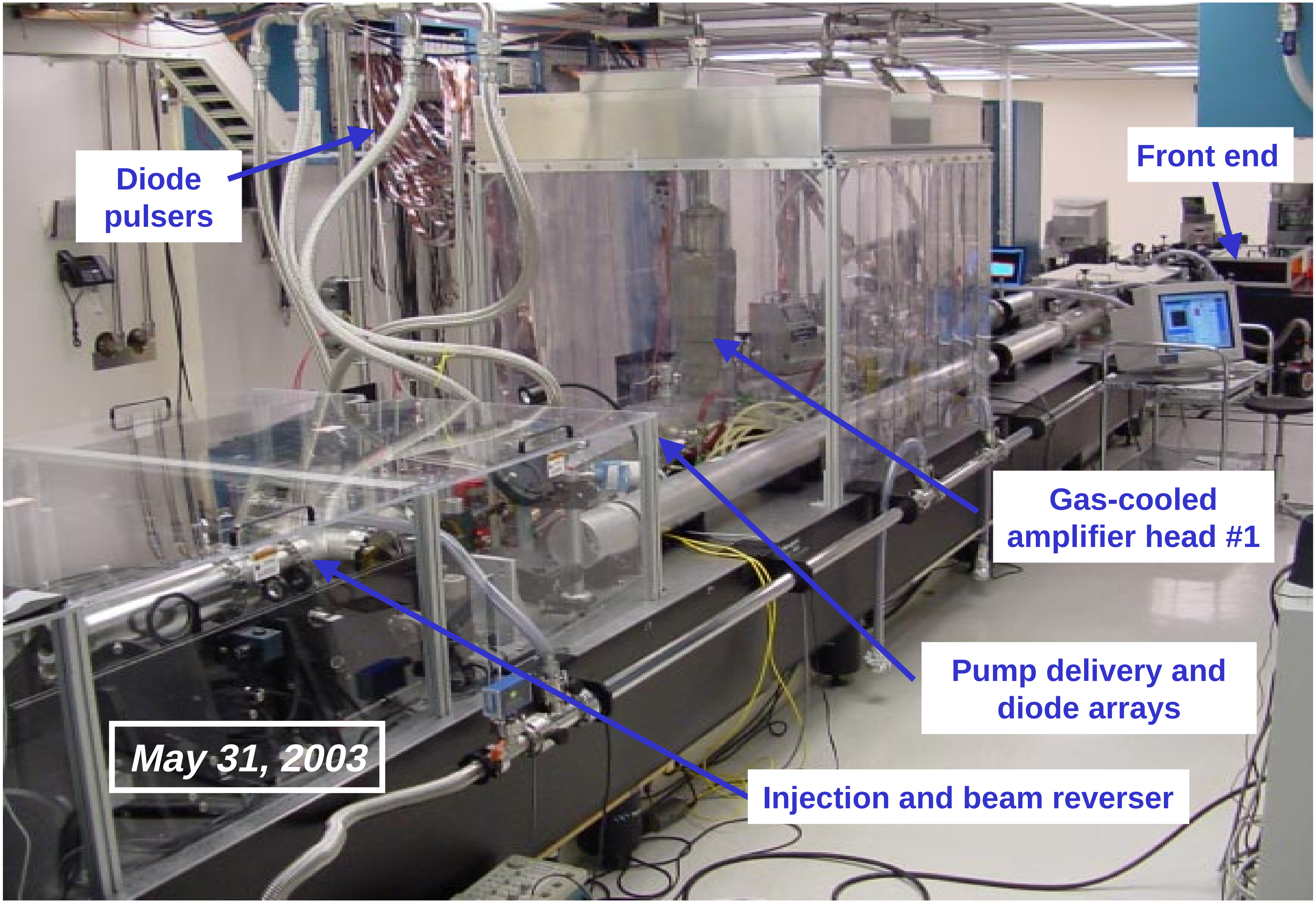
HAPL Program Review
September 24 & 25
Wisconsin University
Madison, Wisconsin

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.

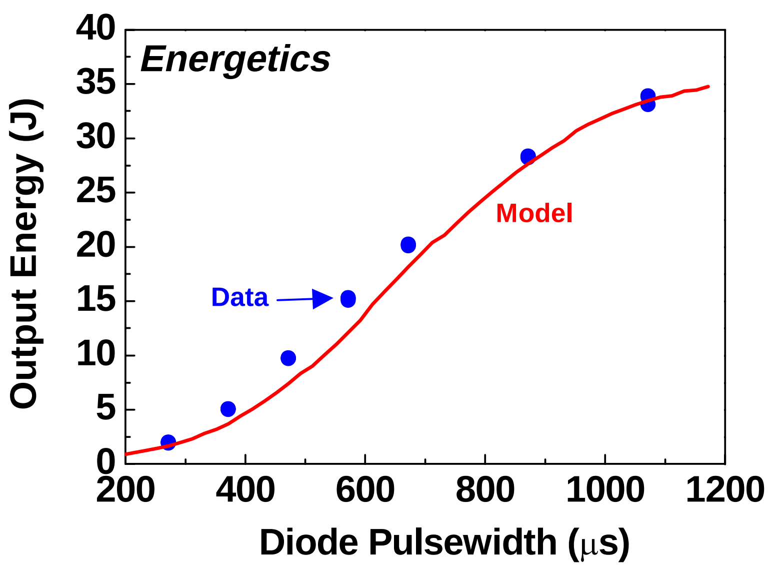
Mercury Team (2003)

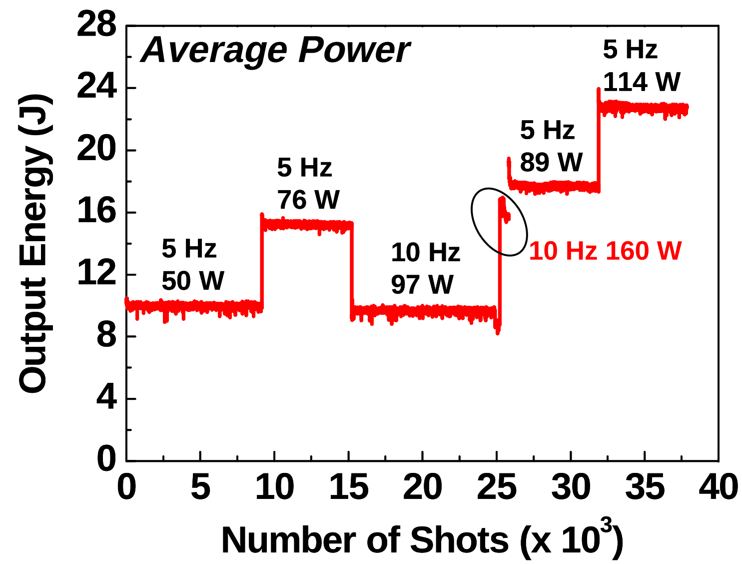
Management:	C. Bibeau, S. Payne
Crystal Growth:	J. Dawson, K. Schaffers, J. Tassano
Mech. Engineering:	W. Davis, B. Freitas, B. Kent, K. Klavuhn, J. Lang, S. Mills,
Laser System:	P. Armstrong, A. Bayramian, R. Beach R. Campbell, C. Ebbers, K. Kanz
Laser Diodes:	L. DiMercurio, K. Hood, D. Van Lue
System Controls:	R. Lanning, S. Telford, E. Utterback

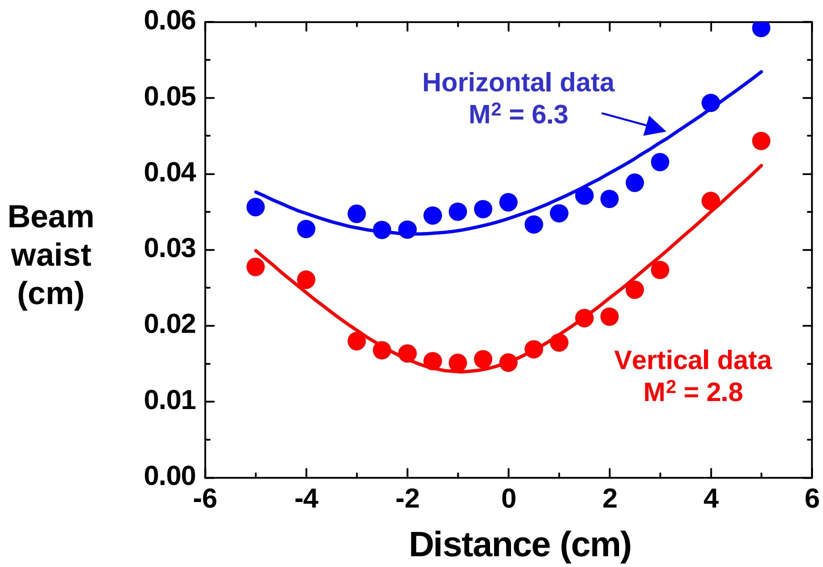
The system was operated with one amplifier to qualify subcomponents before building a two amplifier system

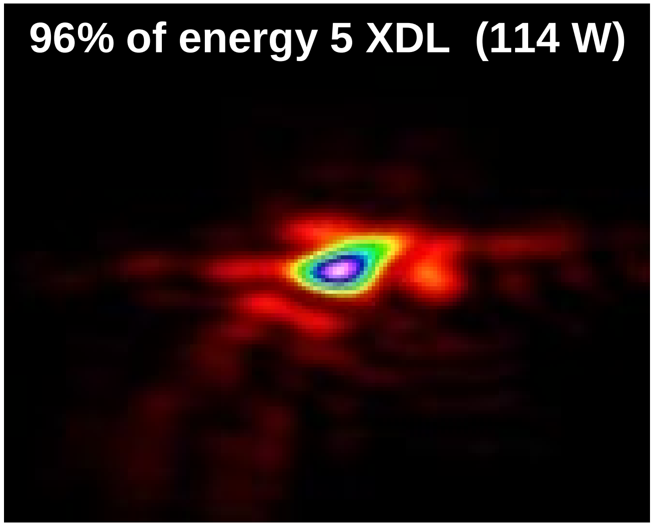


With the use of phase corrector plates, Mercury was operated at up to 34 J single shot, and 114 W average power at 5 Hz









The first amplifier was activated with the intention of exercising all high value components and testing functionality

Operations experience with the first amplifier has lead us to the following upgrades:

Front end
- Improved reliability

Reverser
- Elimination of non-essential optics

Pump delivery
- Improved pump uniformity

Amplifier head
- Accessibility of amplifier slabs without affecting alignment

Diode arrays
- Optical imaging and electronic feedback for diode monitoring

Controls and Diagnostics
- Faster response time and information to operator

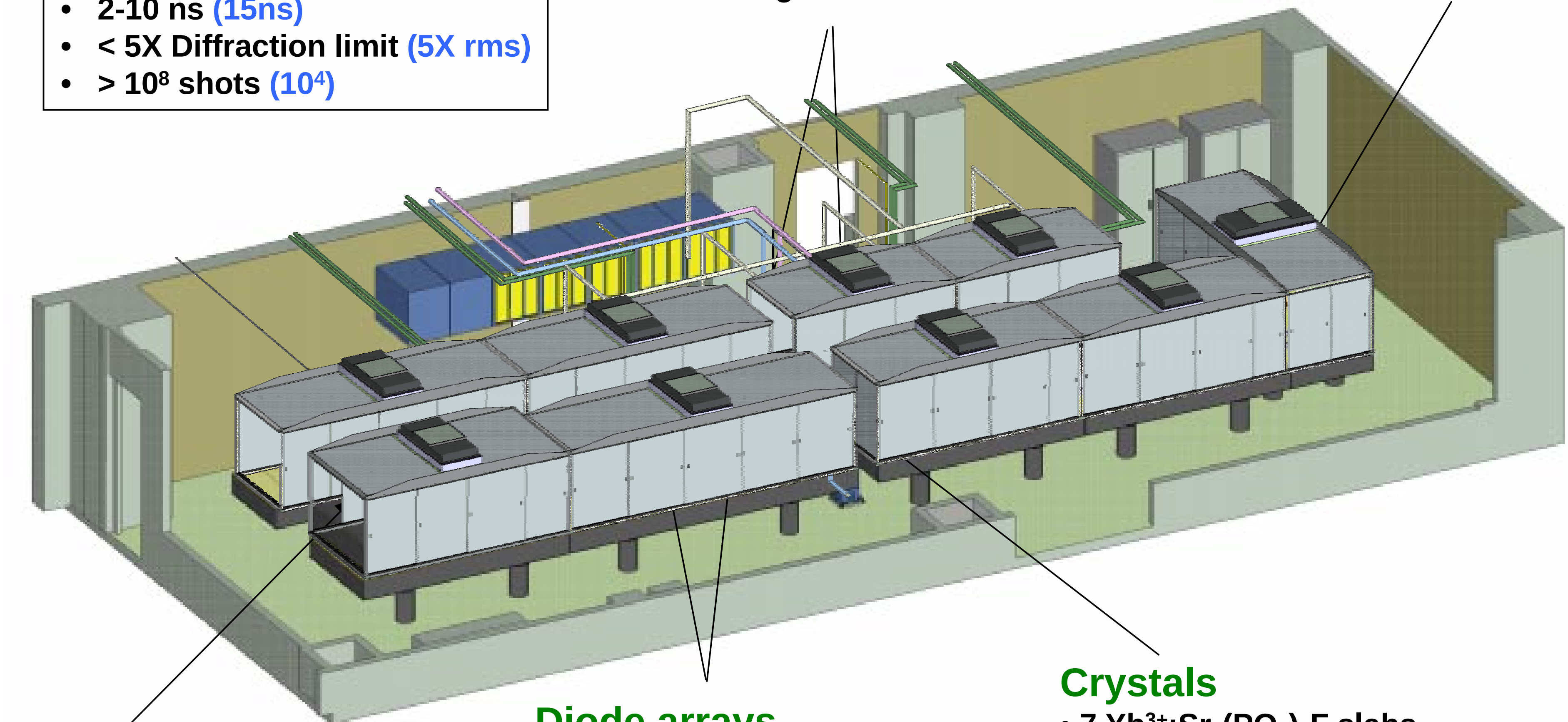
Cleanliness
- New class 1000 enclosures in beam paths

Crystal Growth
- First full slab fabricated

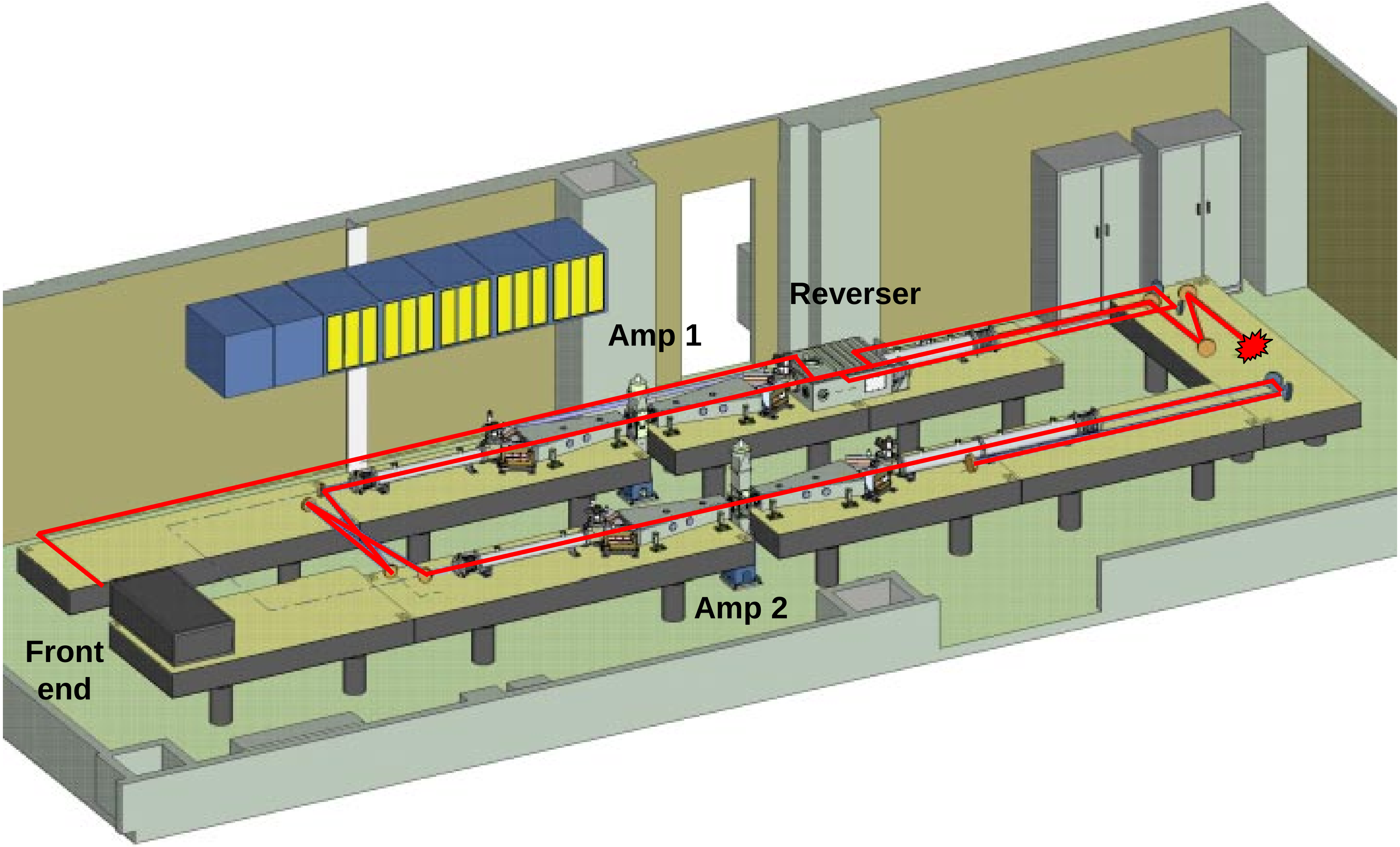
The second amplifier head has been built and the full 1ω laser system is being commissioned

The 2-amplifier system will enable 100 J operation

Goals:
- 100 J at 1ω (24J, 34J SS)
- 10 Hz (5-10Hz)
- 10% Efficiency (4%)
- 2-10 ns (15ns)
- < 5X Diffraction limit (5X rms)
- > 10^8 shots (10^4)

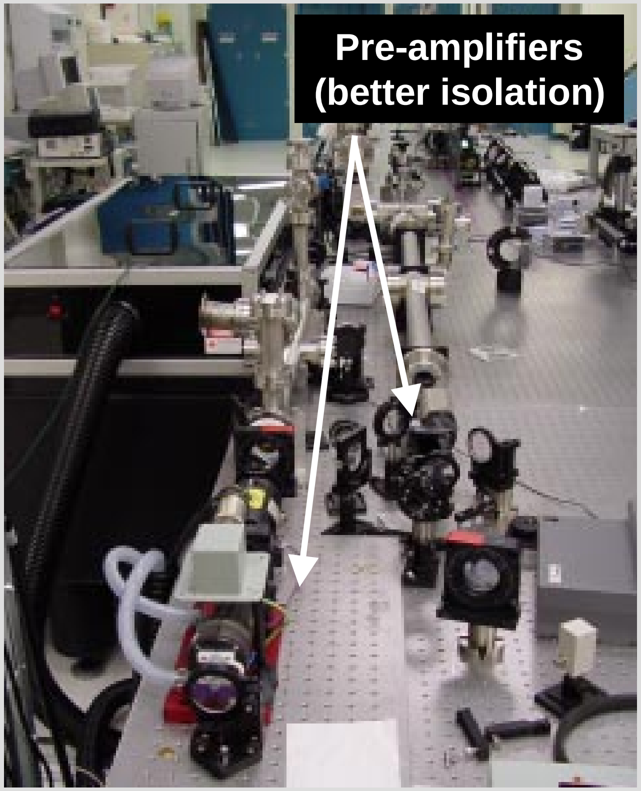


The 2-amplifier system will enable 100 J operation

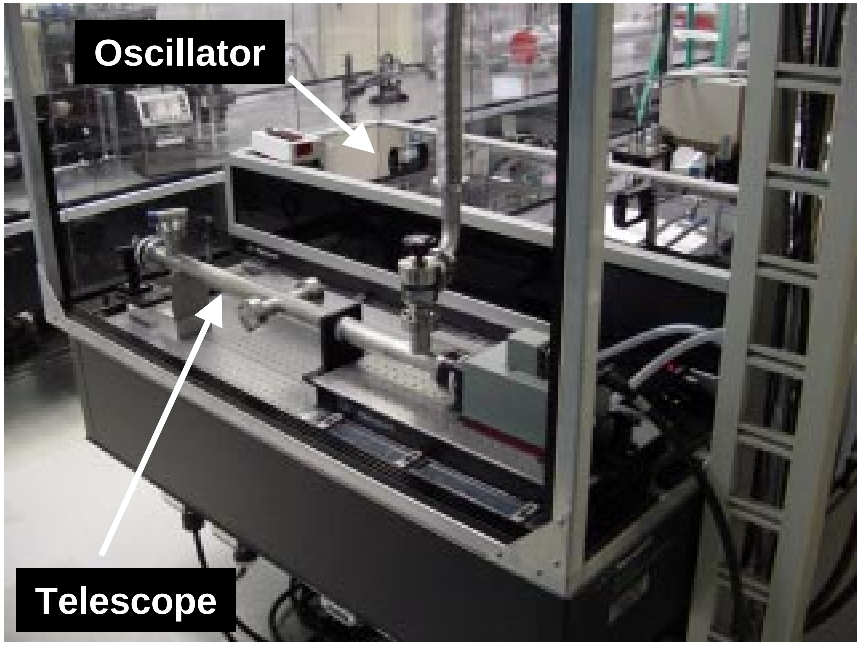


The front end has been reconfigured to allow for pulse shaping, parasitic suppression, and oscillator stability

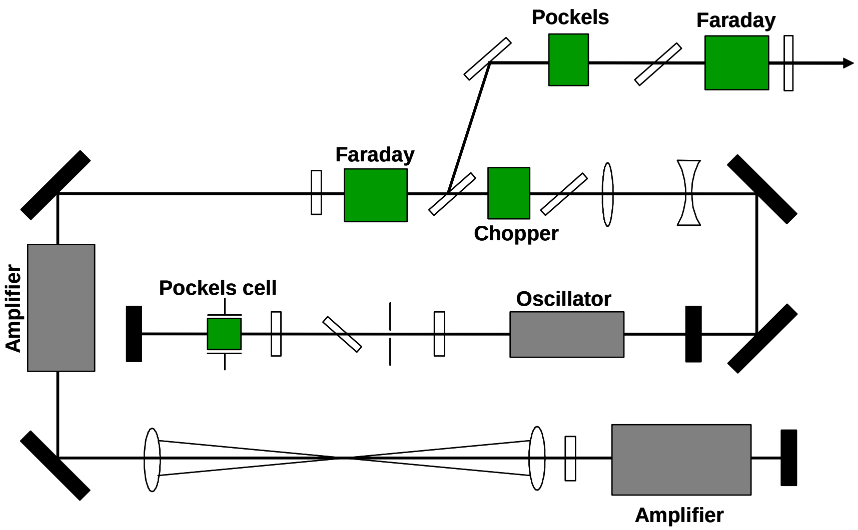
Before



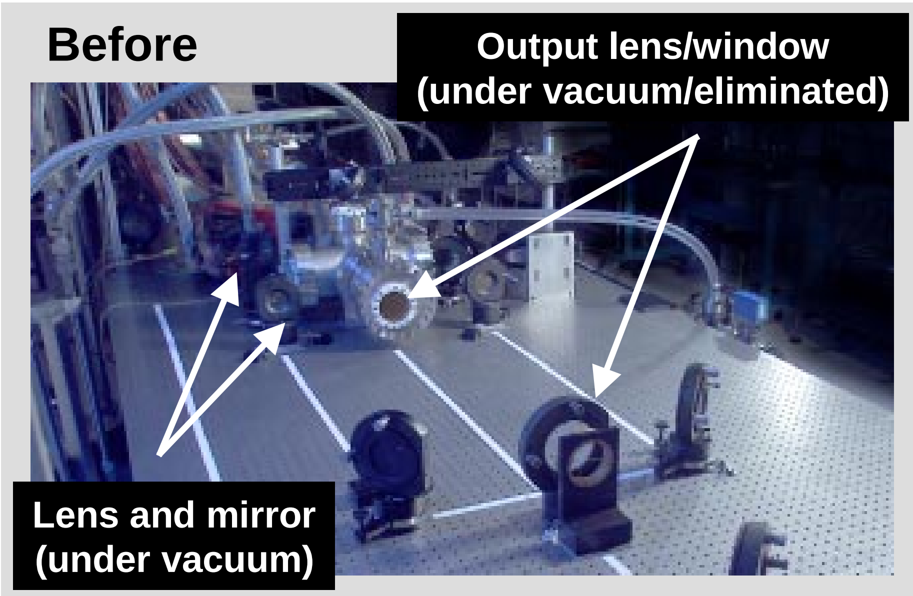
After

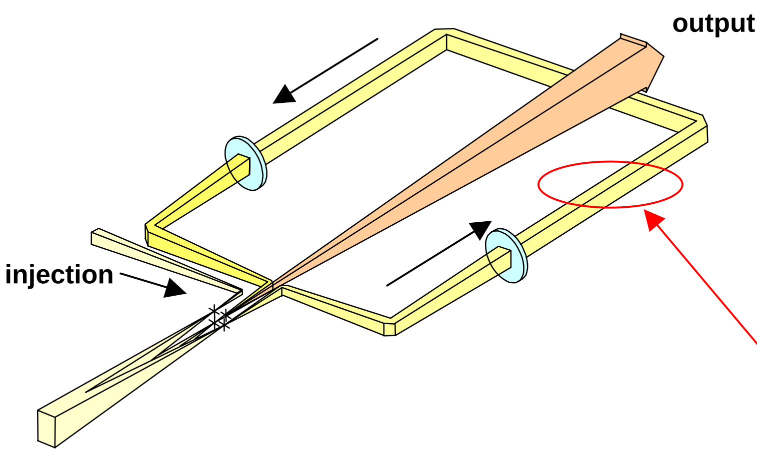


- Angular multiplexing for parasitic suppression
- Pulse slicer added for pulse length variability
- Energy increased to 0.9 J (before 0.5 J)



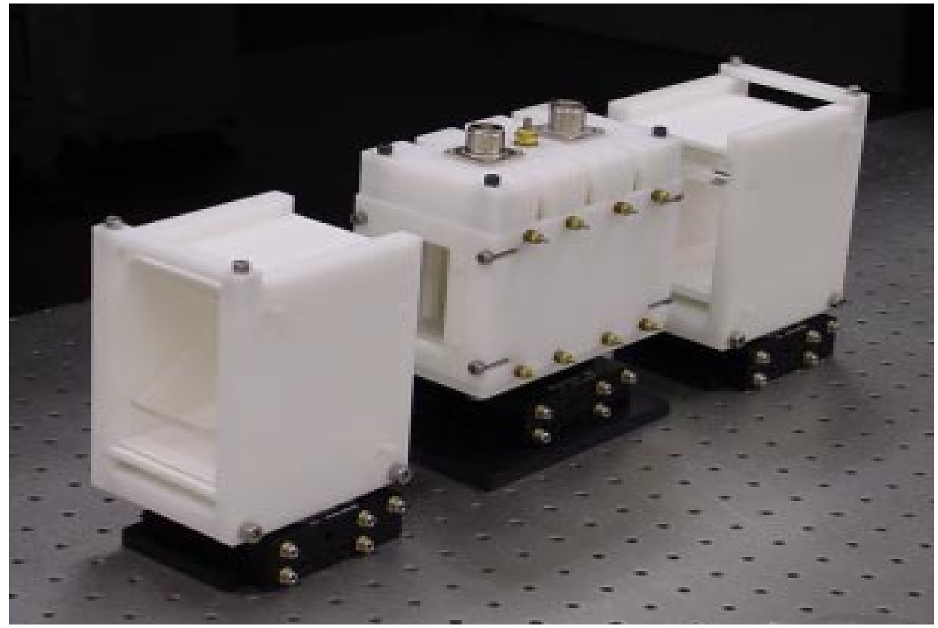
The reverser is now configured to full beam size, places critical optics under vacuum, and has better accessibility





- Reverser mirrors:
  - Qualified for 40 J/cm²
    (Exploring 70 J/cm² mirrors from France)
  - Expected peak fluence is 25-40 J/cm²
  - Adjustability has been added
- 3 windows have been eliminated
- Full scale eliminates beam overlap
- Full size Pockles cell

The 100 W Pockels cell developed for parasitic suppression in Mercury was awarded an R&D 100 Award

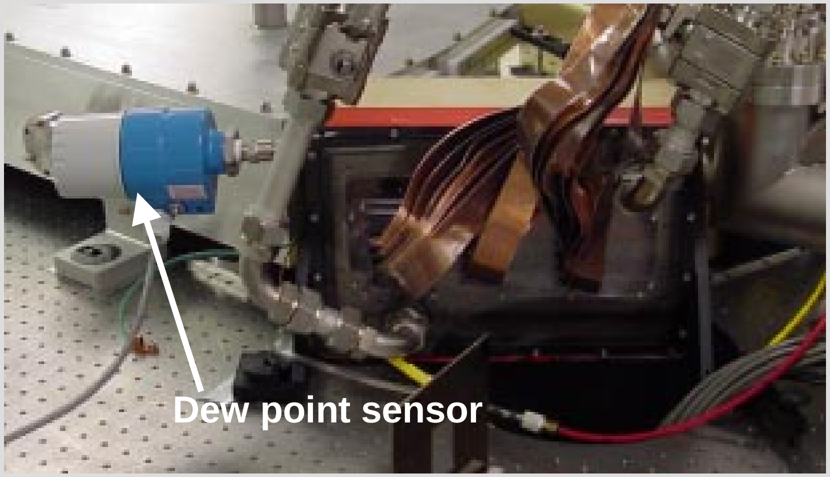


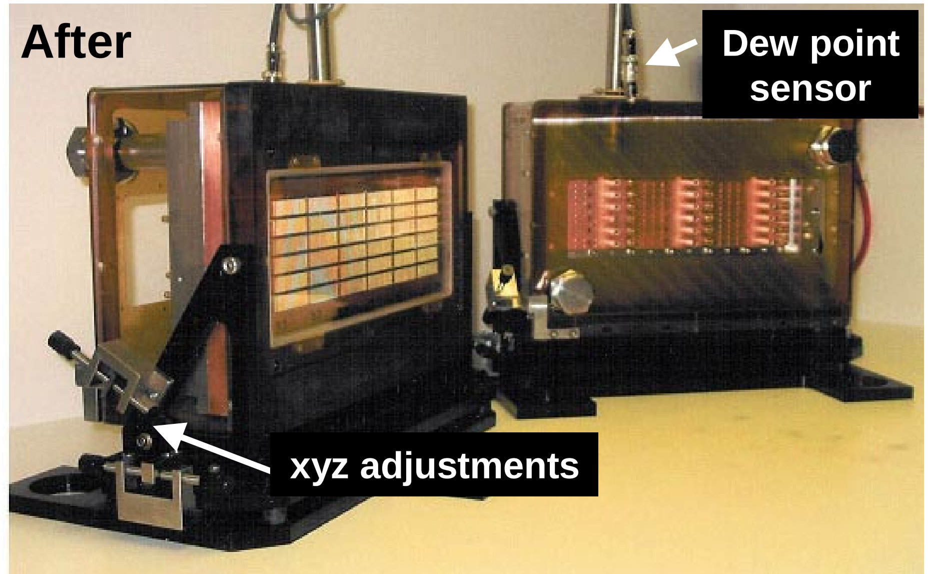
News clip:

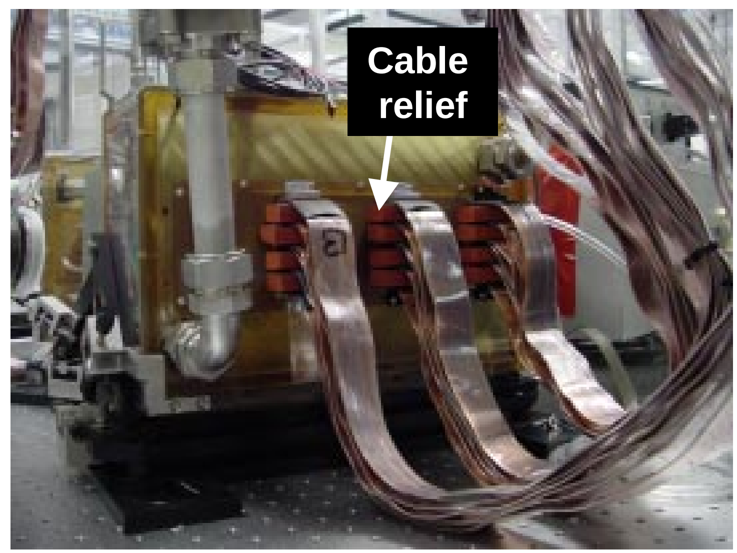
High-Average-Power Electro-Optic Q Switch …. will allow fast optical switching of high-average power lasers for machining, energy research, and national defense applications. The Q switch offers a ten-fold increase in the average power handling capability for lasers to 300 watts instead of only 30 watts. Members of the award-winning team … are: Christopher Ebbers, Vernon Kanz, and Hitoshi Nakano (Kinki University, Japan)

The new diode array hardware has been operated

Before

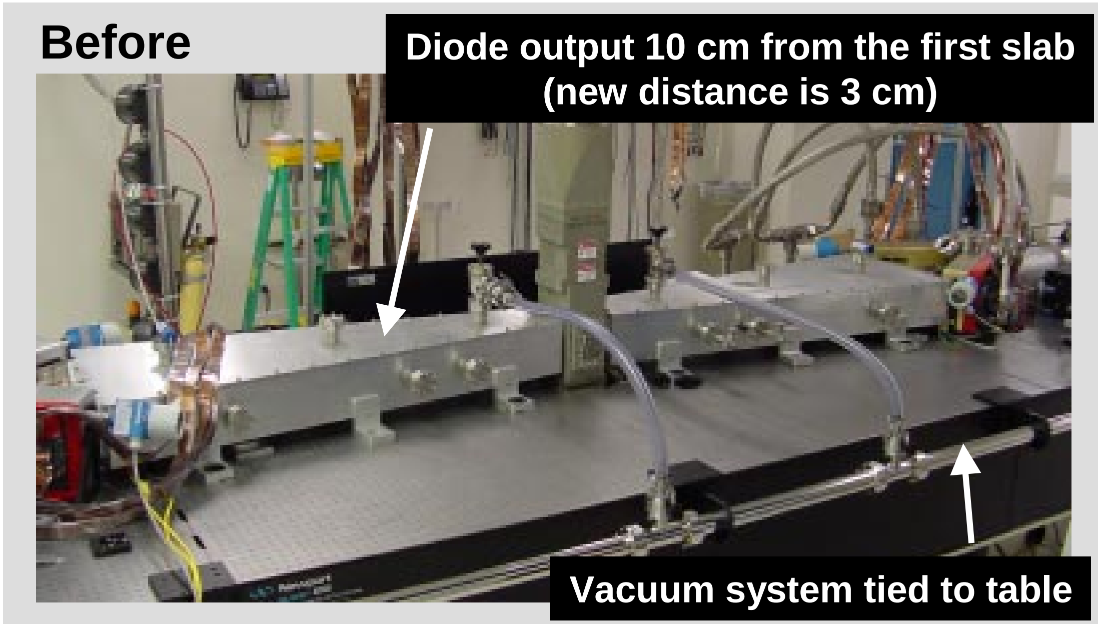




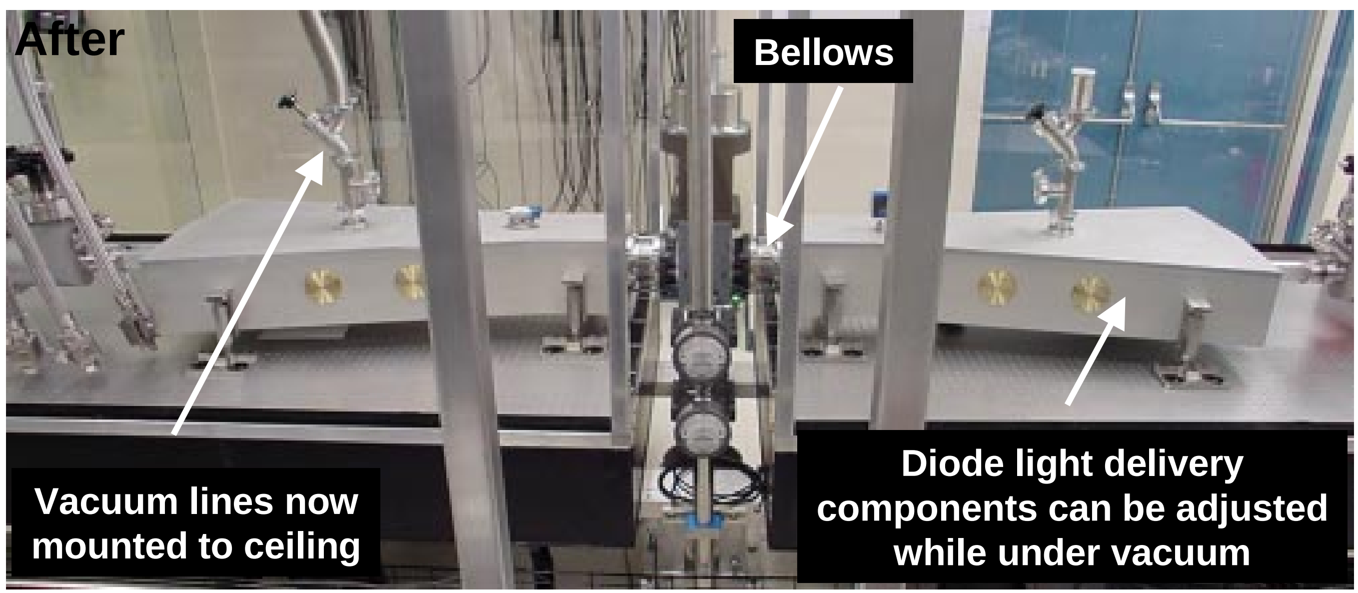


- Tip-tilt adjustment
- Smaller footprint
- Vibration isolation from the table
- Nitrogen purge relocated to eliminate condensation
- Strain relief on cables

The new pump delivery system allows for better pump uniformity

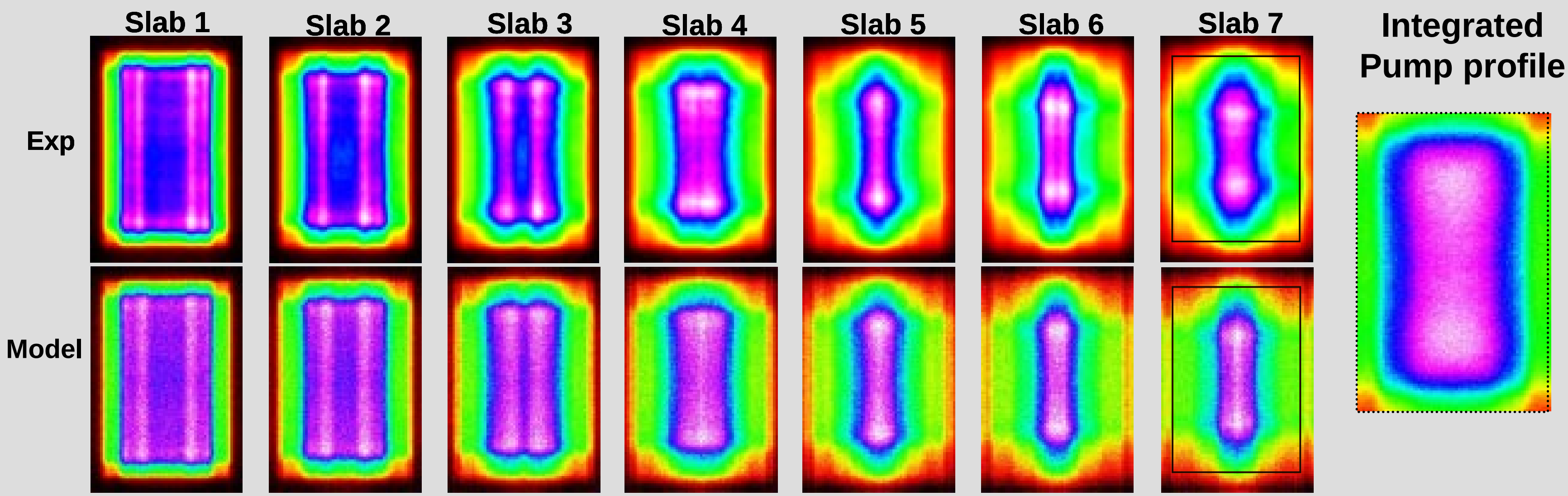


- Closer proximity to amplifier
- X, y, z, tip, tilt
- Higher optical quality components
- Bellows on lenses for collimation

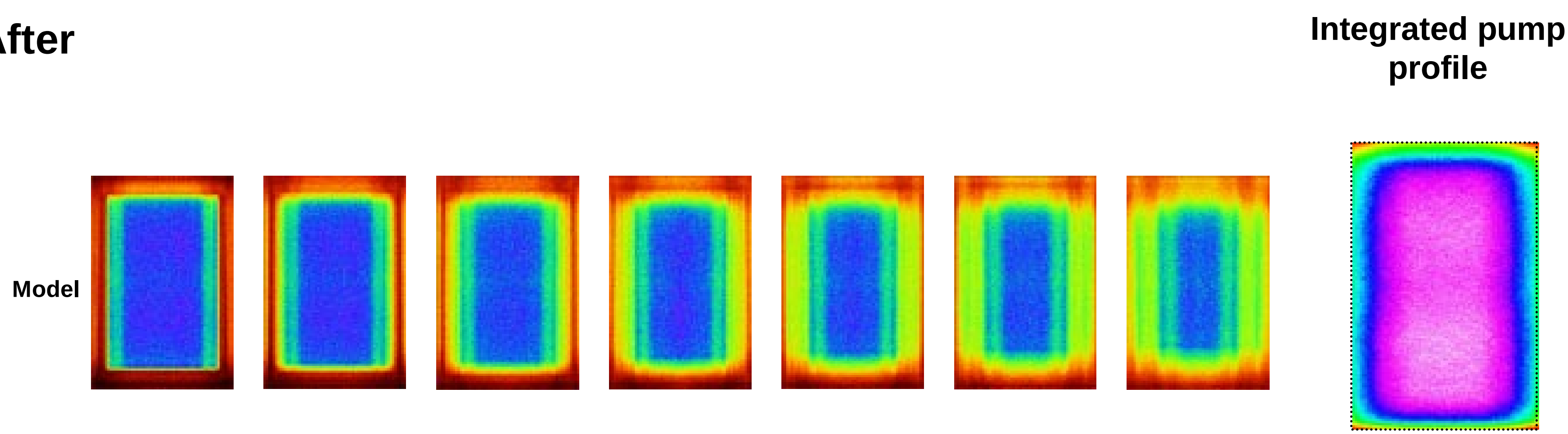


We have benchmarked the data to confirm ray trace codes

Before

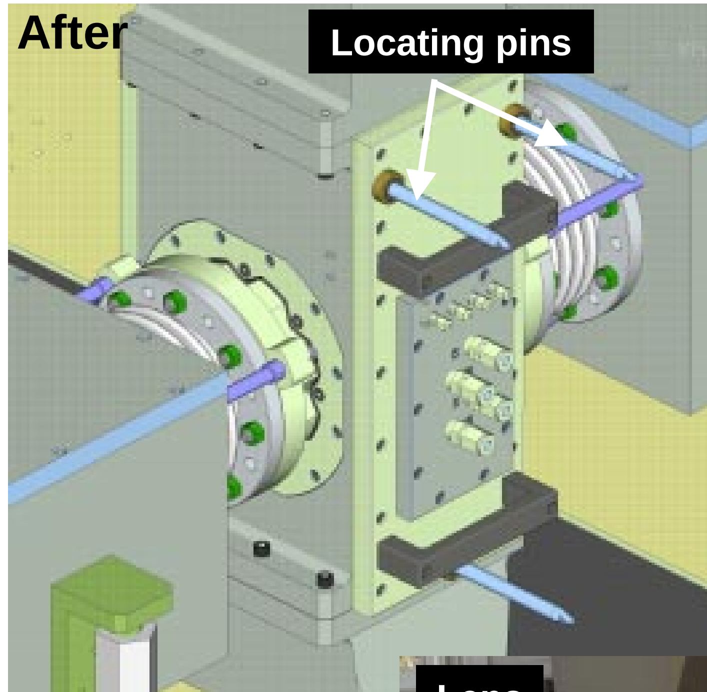


After

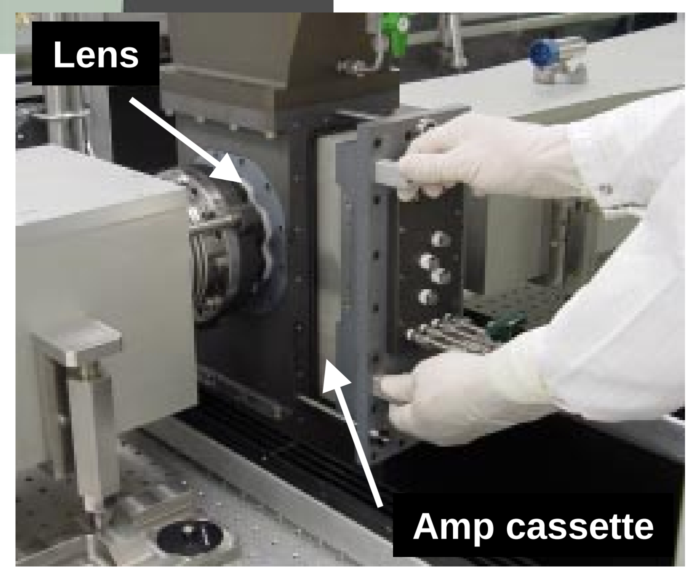


The new amplifier assembly will improve operations and beam quality

Before

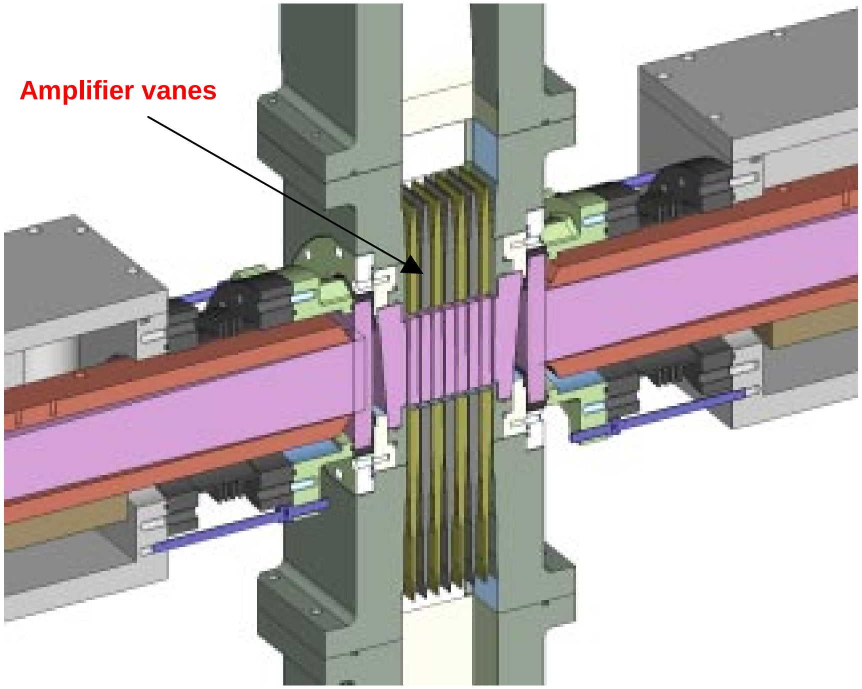


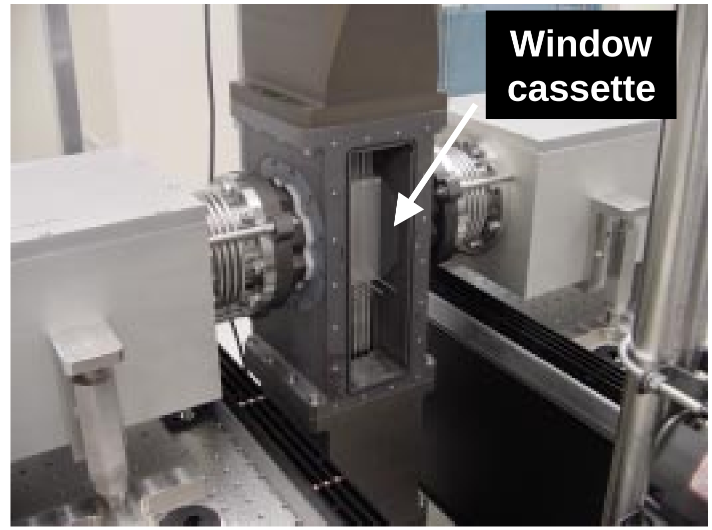
Window cassette

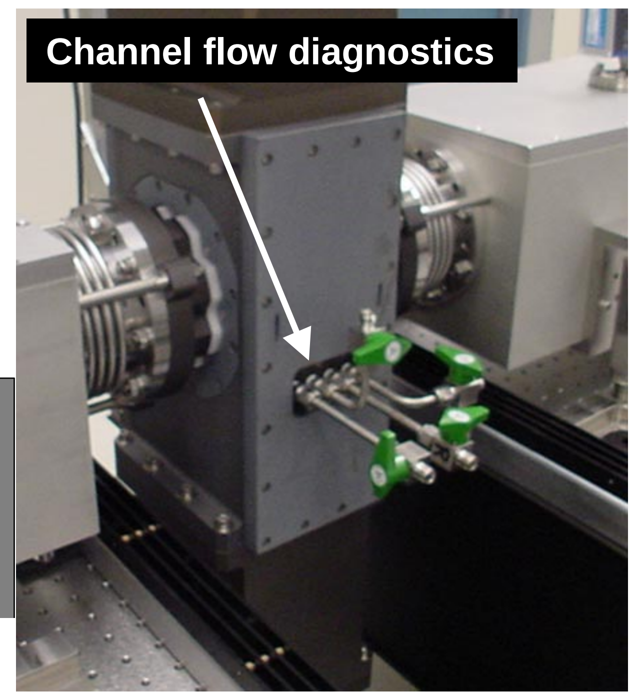


- Amplifier cassette is easily removable
- Laser and diode light remain aligned
- Windows located in an independently sealed cassette

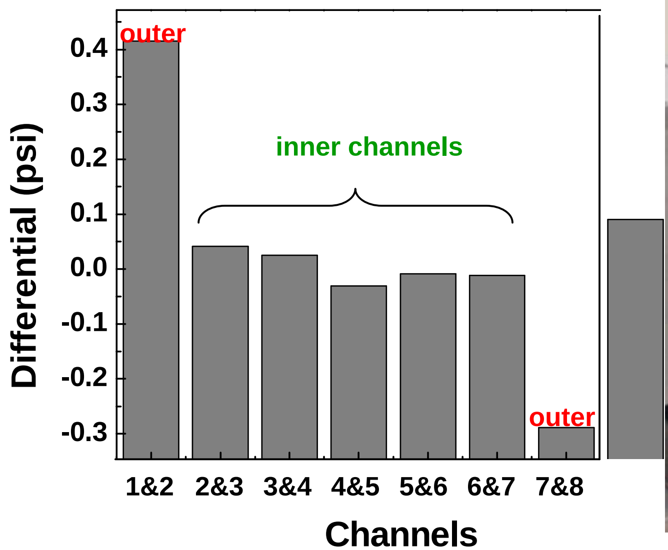
The new amplifier assembly was tested to verify adequate gas flow conditions between channels





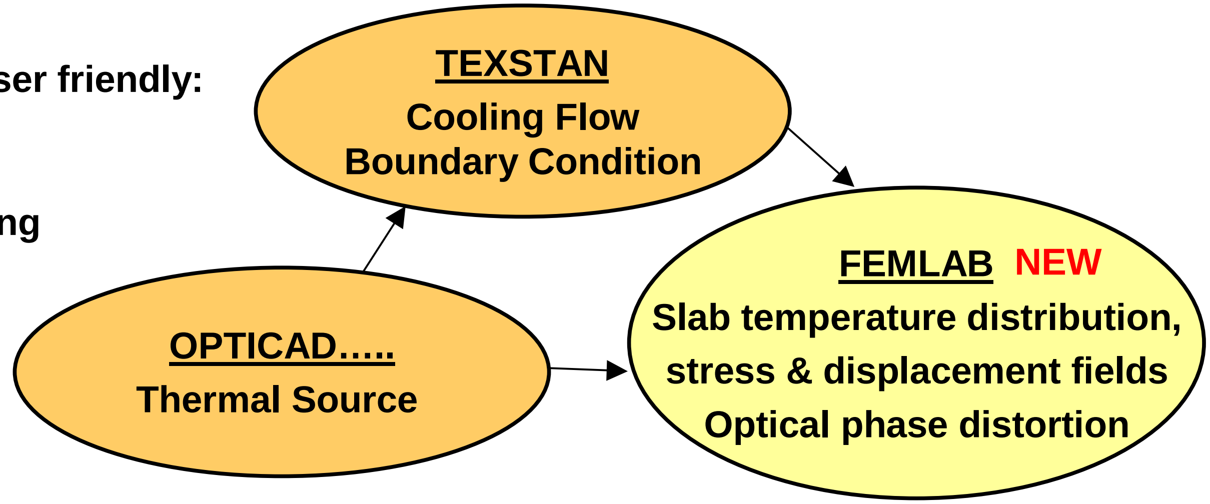


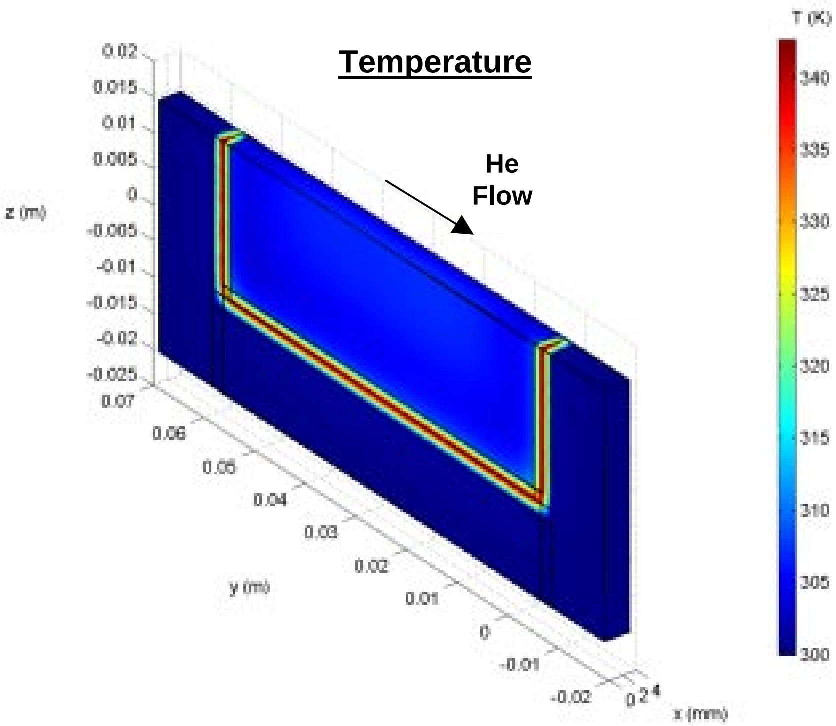
- Pressure differential in inner channels allowable
  - 0.030 psi rms
- Outer vanes require more secure mounting
  - 0.207 psi rms
- Previous measurements
  - 0.058 psi rms total

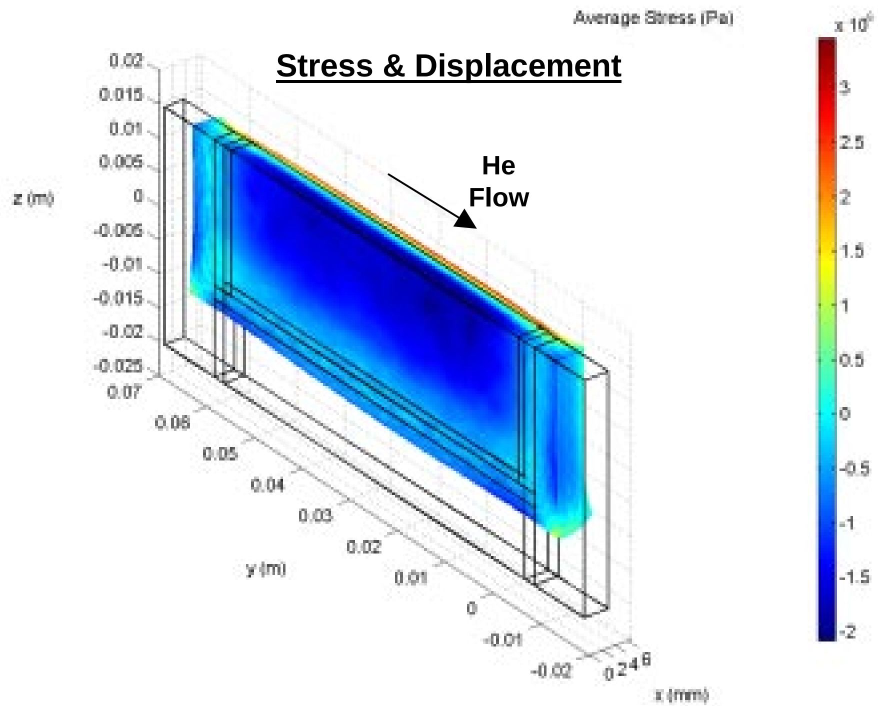


FEMLAB is now being used to model the optical wavefront distortions in Mercury

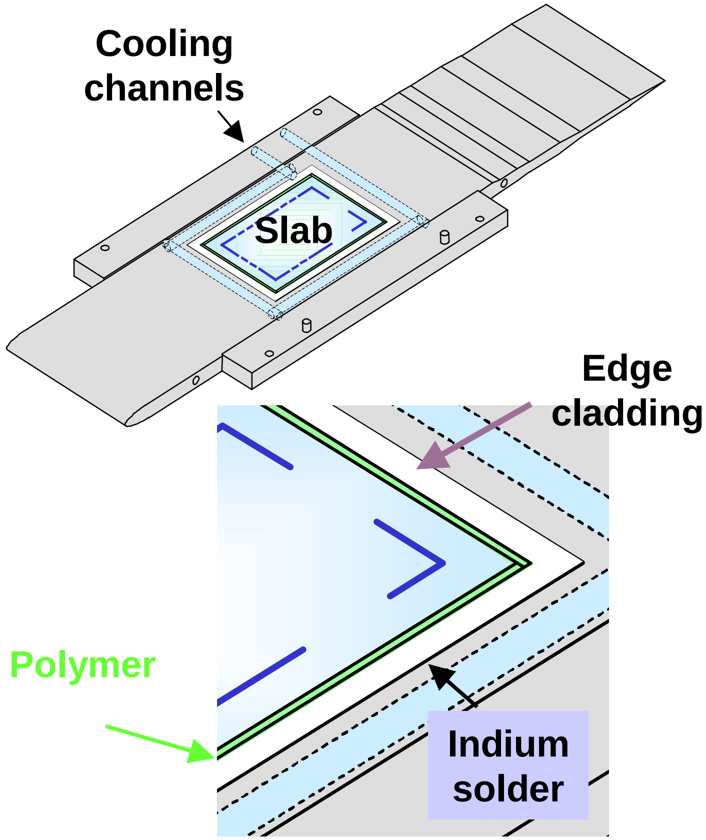
- **Graphical user interface more user friendly:**
  - **CAD modeling**
  - **Automatic mesh generation**
  - **Visualization & post processing**
  - **Full integration with MATLAB**





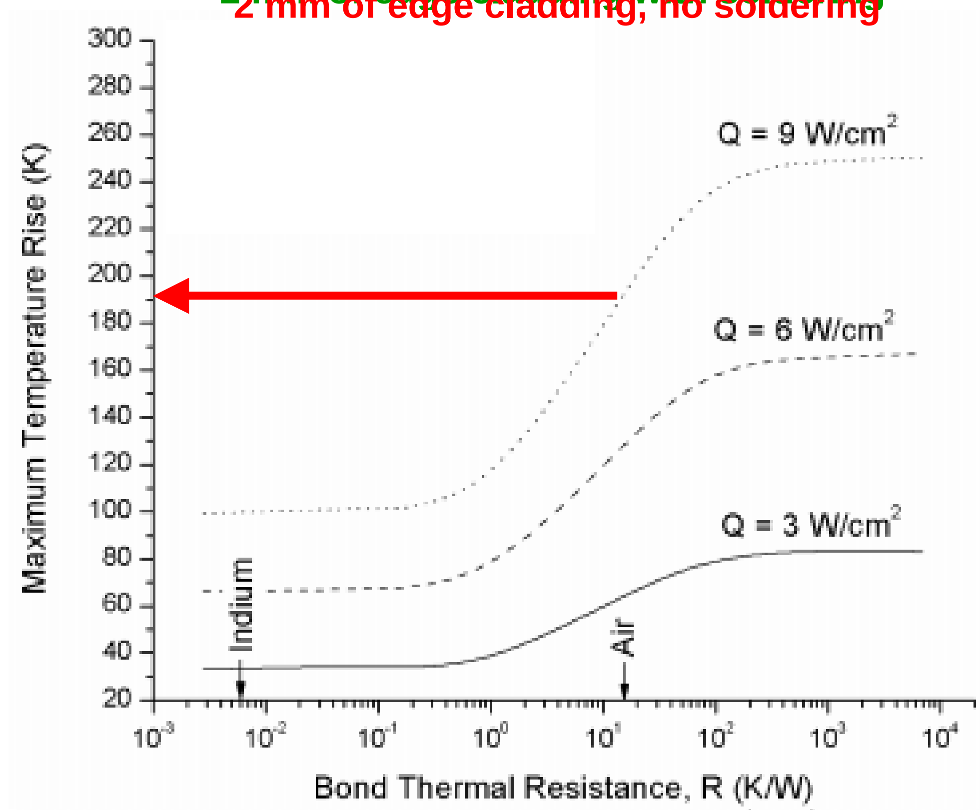


We can now operate at rep-rate without overheating the polymer



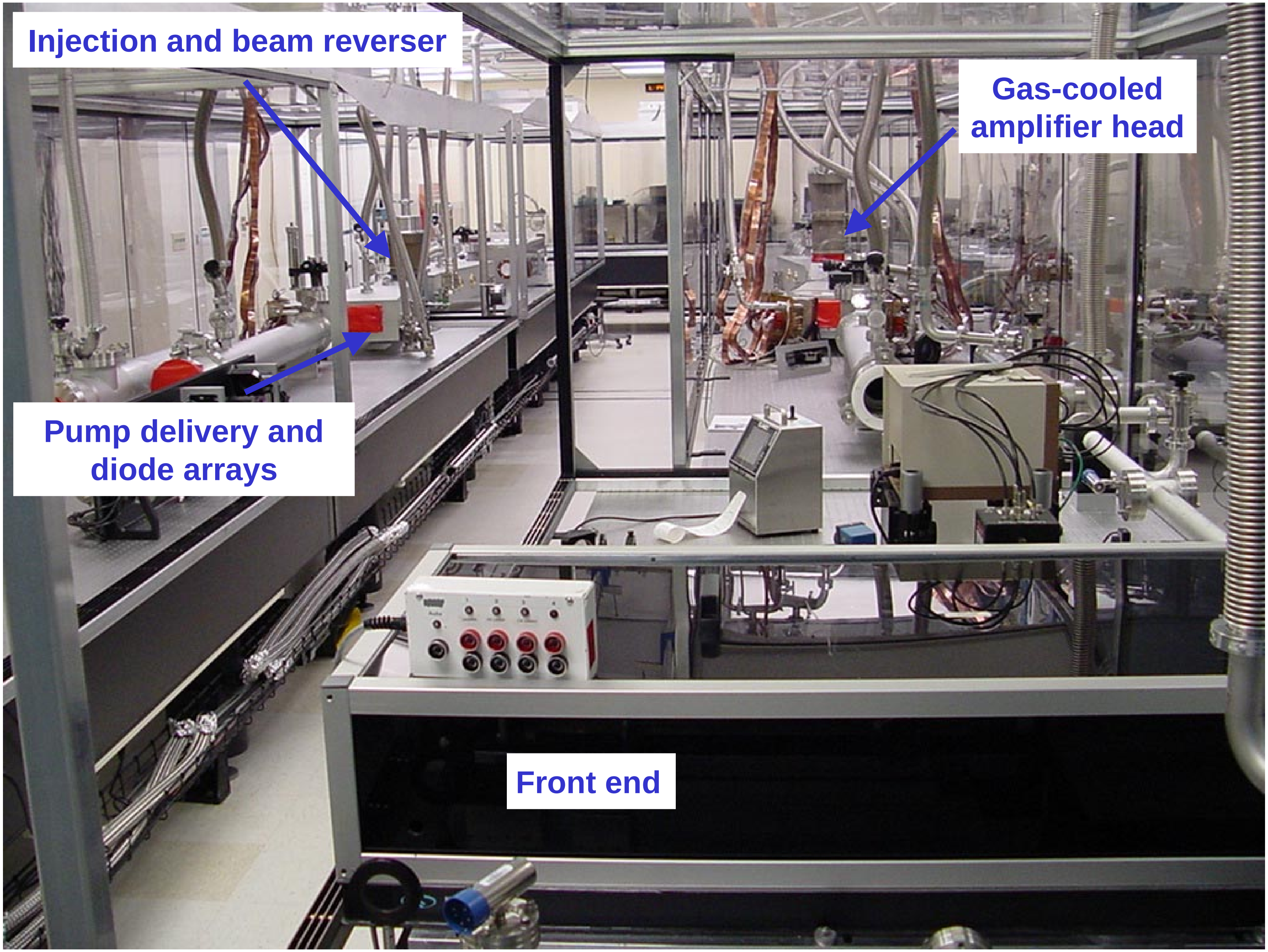
After:
2 mm of edge cladding with soldering

Before:
2 mm of edge cladding, no soldering

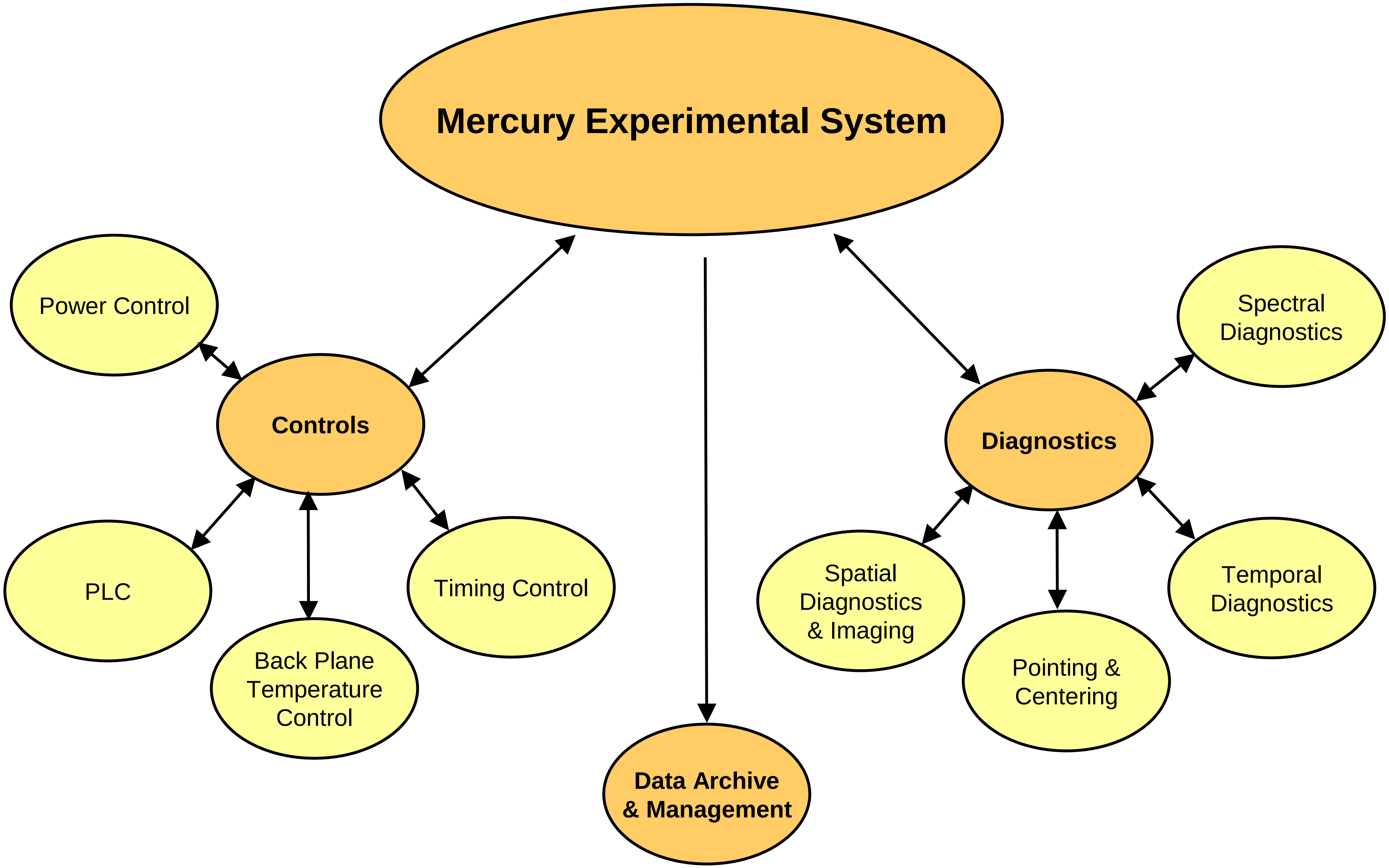


- New potting hardware
  - flatness is down to <100 um
- Edge cladding is soldered onto vane
  - 10 nm Titanium - adhesion
  - 100 nm Nickel - adhesion
  - 100 nm Gold - oxidation
  - 15 μm Indium - solder

We are currently testing all new components for functionality



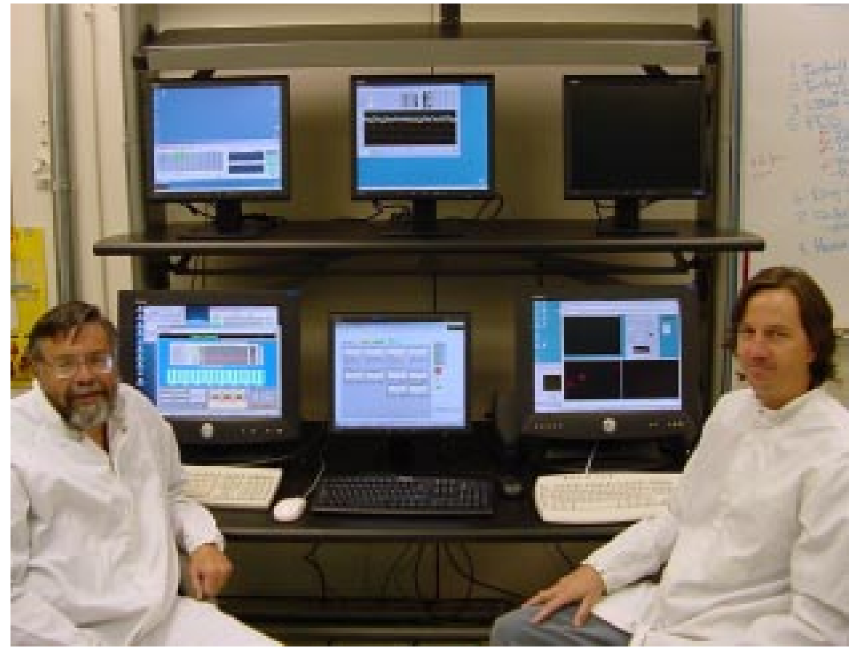
We have reconfigured the Mercury controls and diagnostics

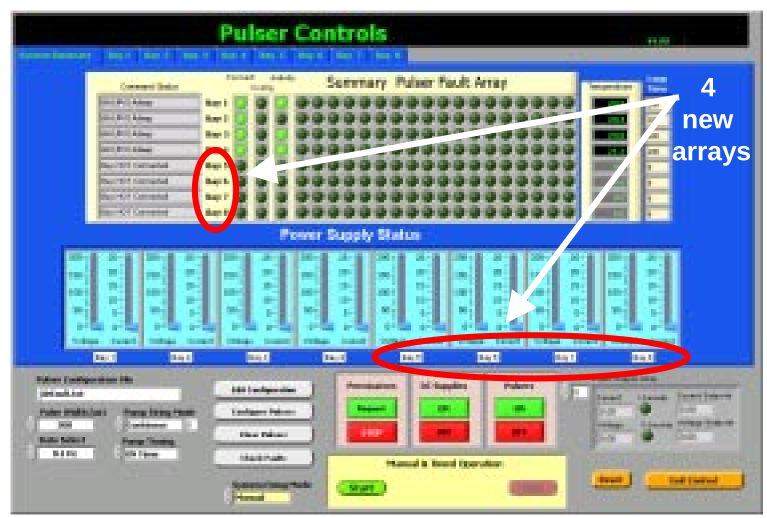


The control panels to the system have been upgraded to allow for 8 diode array operation

Before

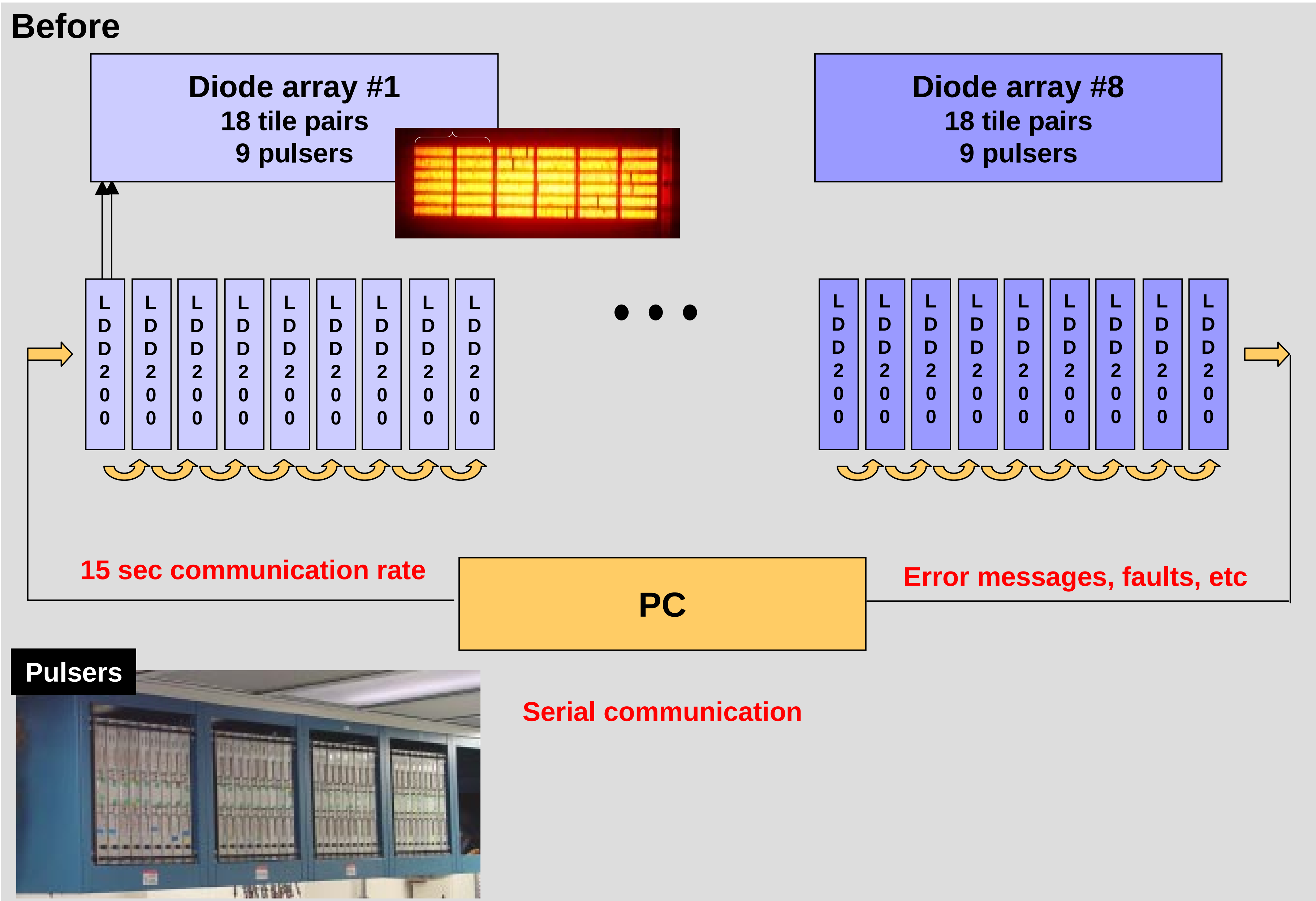
After





- **PXI controllers added**
  - **parallel communication**
- **Timing hardware (12 DG 535's) replaced with FPGA**
  - **simplification**
  - **flexibility**
  - **reliability**
  - **reduce timing jitter**
- **User interface improved**
  - **faster and comprehensive system monitoring**

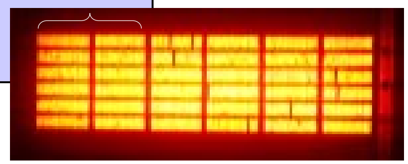
The previous serial communication methods had slow response time and error checking



The new system allow for faster communication and more detailed information to be communicated to the operator

After

Diode array #1
18 tile pairs
9 pulsers



Diode array #8
18 tile pairs
9 pulsers

LDD200 | LDD200 | LDD200 | LDD200 | LDD200 | LDD200 | LDD200 | LDD200 | LDD200

• • •

LDD200 | LDD200 | LDD200 | LDD200 | LDD200 | LDD200 | LDD200 | LDD200 | LDD200

Error messages, faults, etc

Diskless/Headless PC

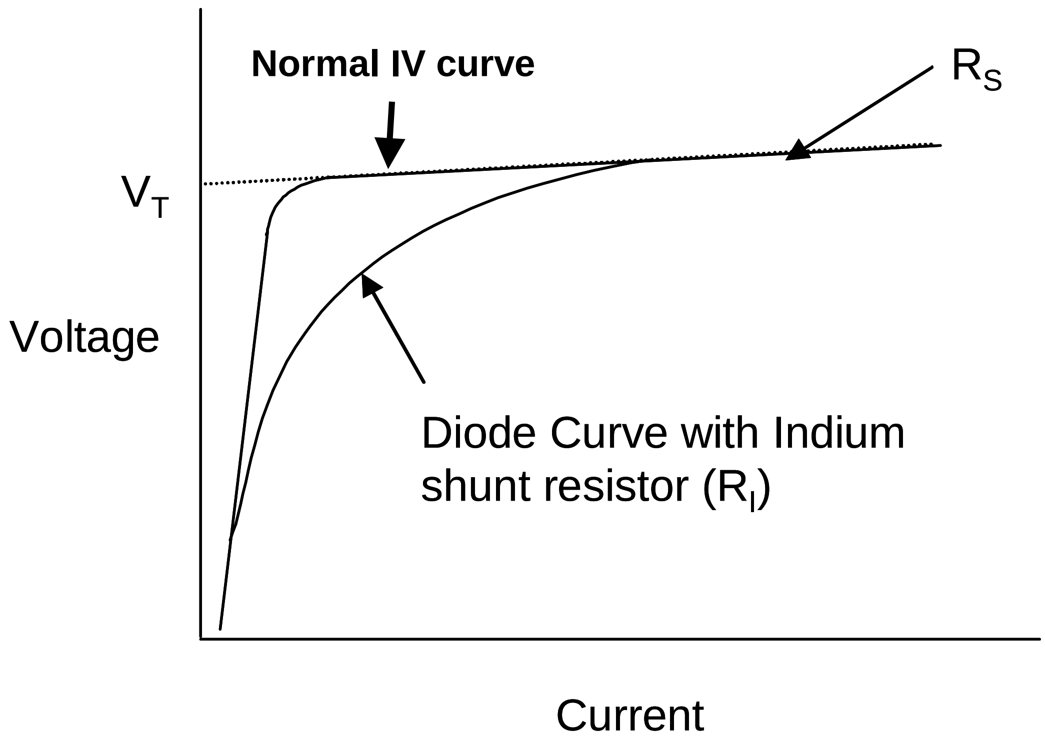
• • •

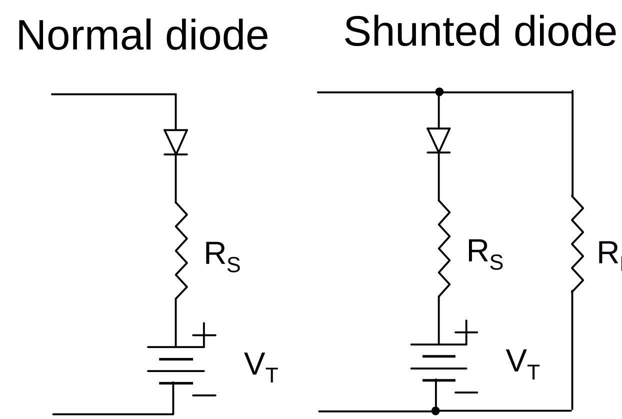
Diskless/Headless PC

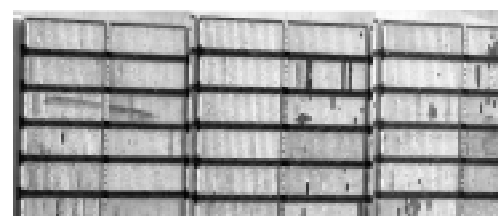
0.2 sec communication rate to operator

PC

Some tiles were damaged on backplanes 3 and 4 from a 1 μm parasitic



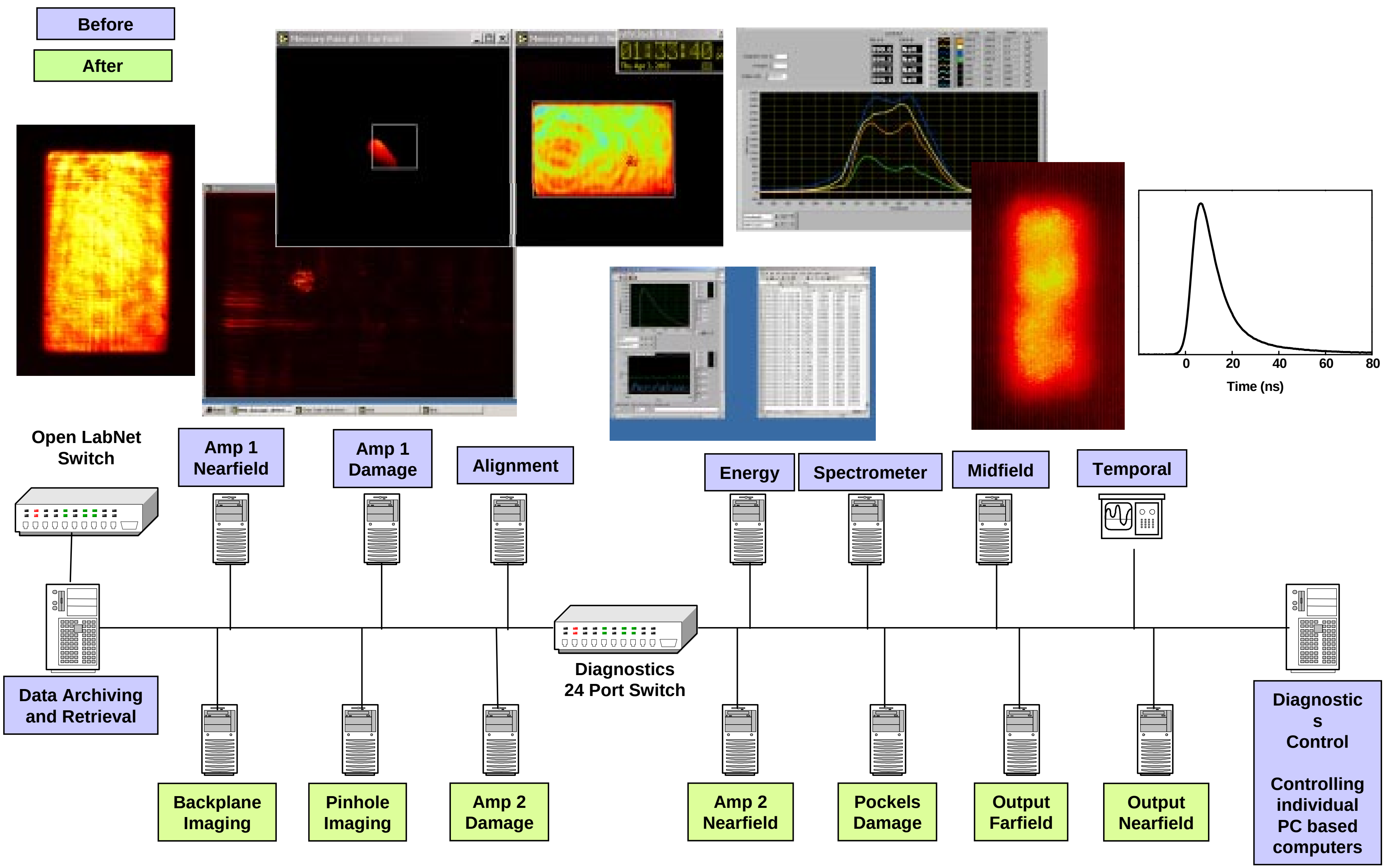




Improvements to the system include:

- **Daily electrical monitoring of the IV curve**
- **Optical imaging on all eight backplanes to detect power level drop**
- **Dichroic optics to reduce laser intensity on arrays by 1e-6**

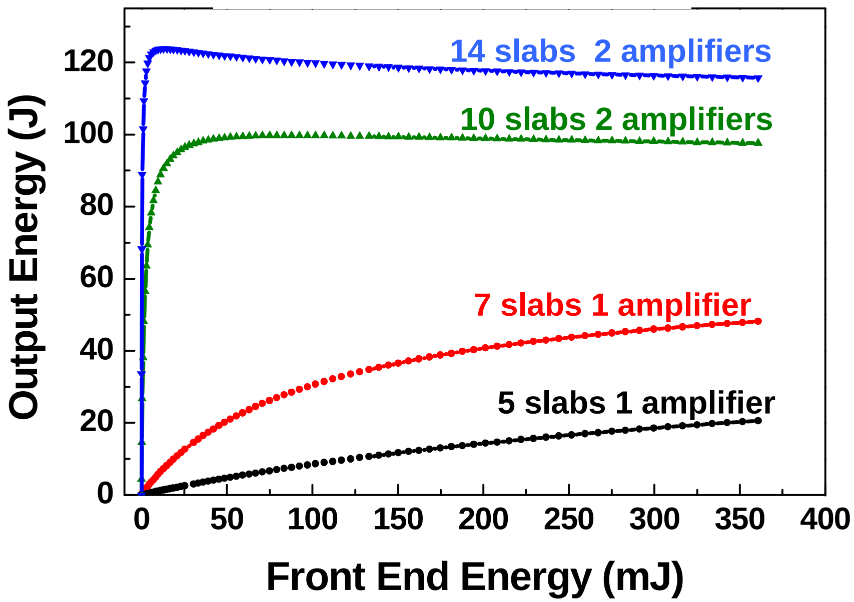
The diagnostics network was upgraded to add second amplifier components

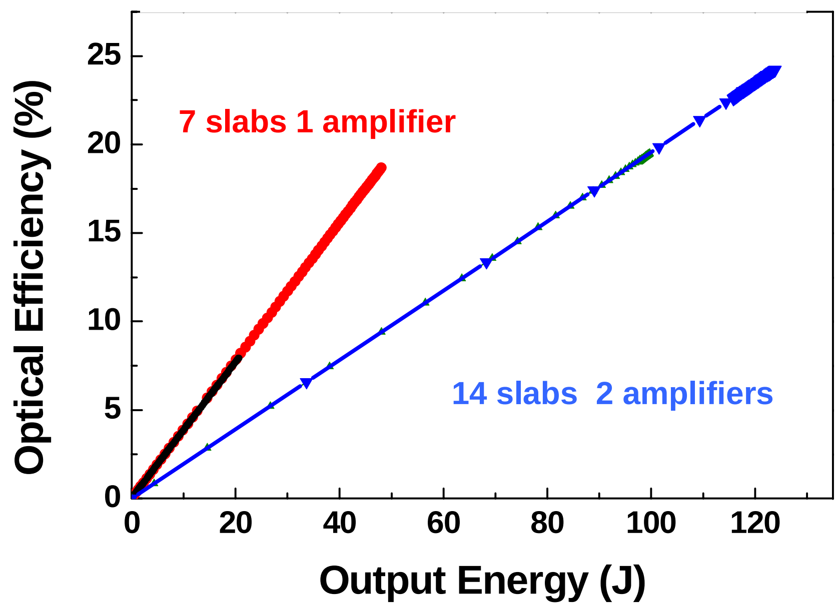


The second amplifier and more slabs will allow us to reach our energy and efficiency goals

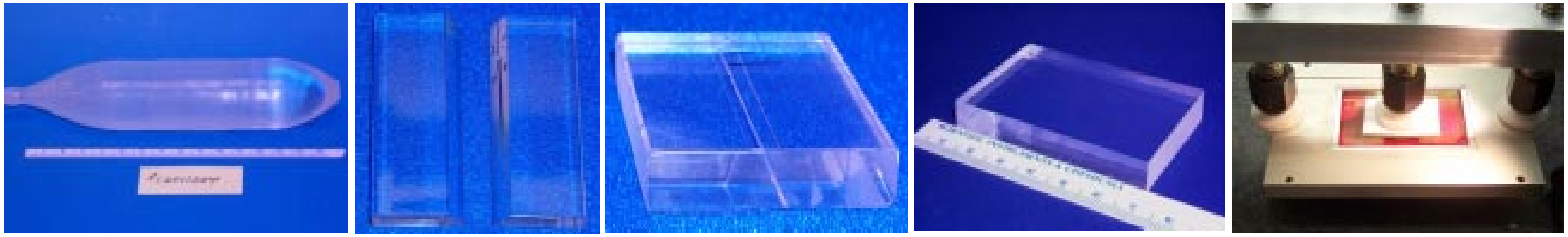
Model assumes:

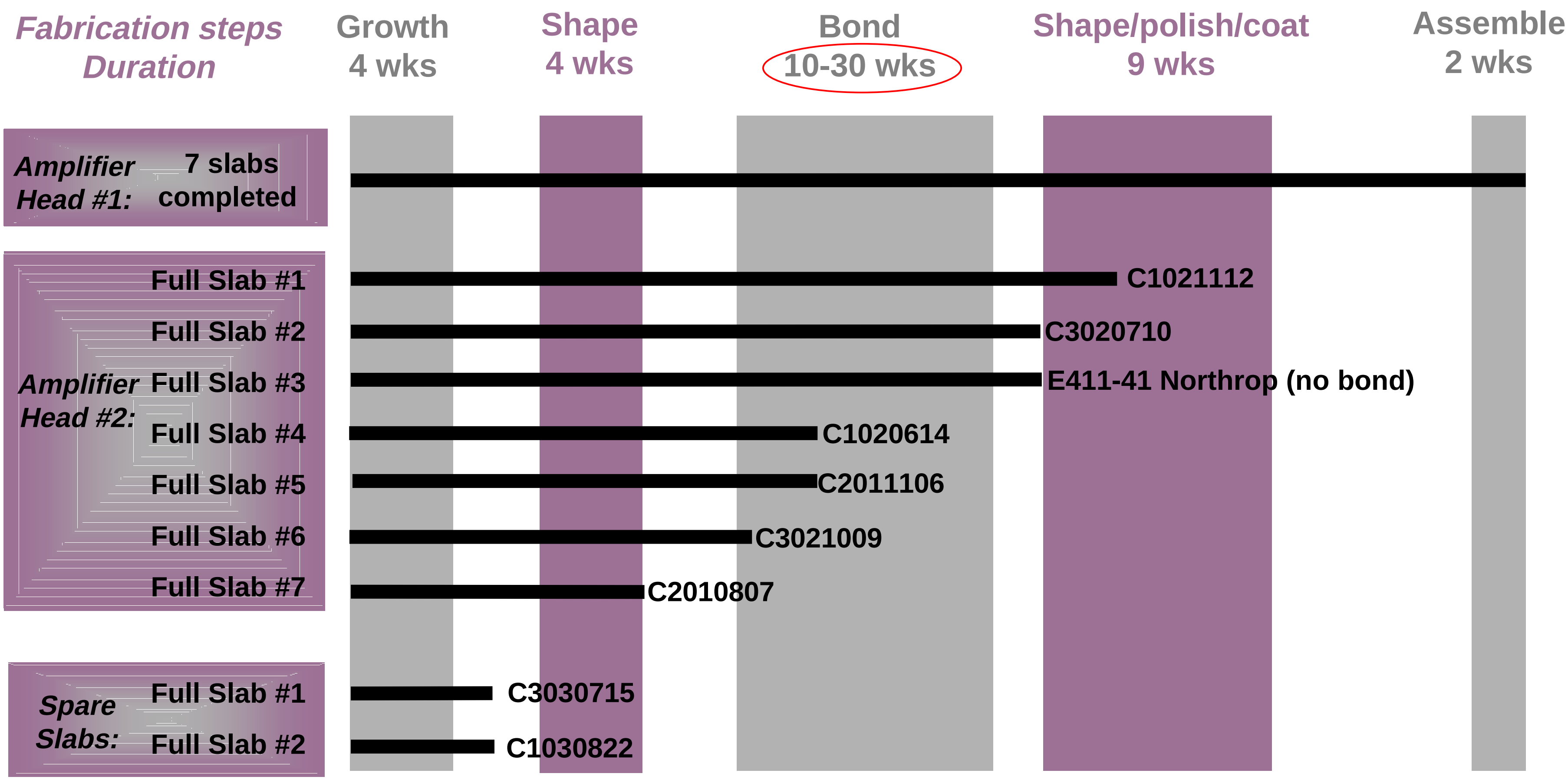
- **750 usec diode pulse length,**
- **120 W/bar**
- **1.3 x 10^{19} cm^{-3} doping**



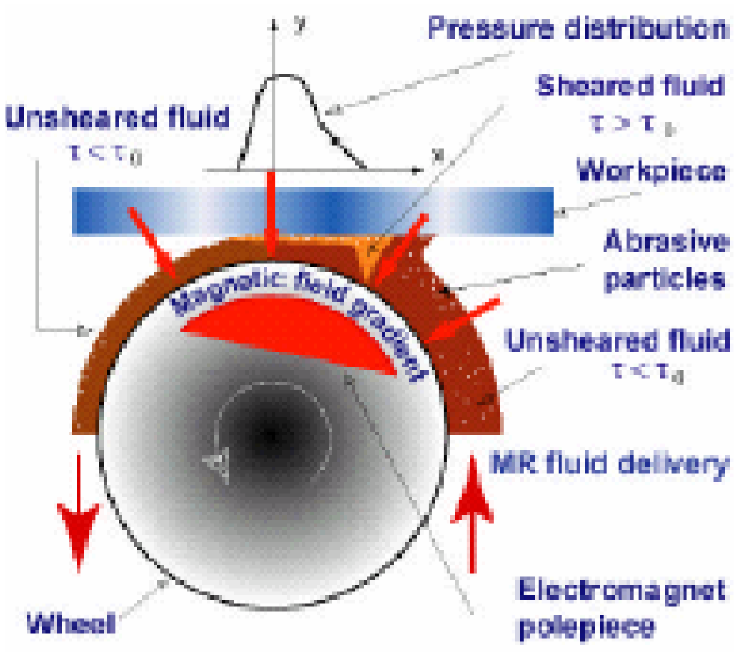


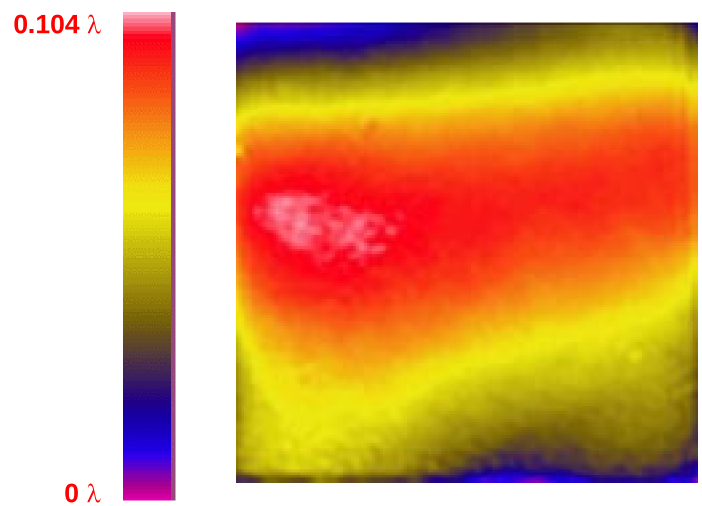
We have fully populated one amplifier with 7 slabs and are working toward completing the second head





The Magnetorheological Finishing (MRF) machine at LLNL is being used on S-FAP samples





It appears that we may be able to polish out the bond distortion

Process:

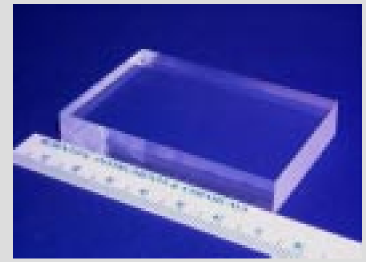
- **A polishing process dominated by shear loading**

Capabilities:

- **Minimum 1 mm feature size**
- **Fast turn around – hours for (10 cm^2 parts)**
- **Depth > 10 mm**
- **Gradient capabilities > 400 nm/mm**

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

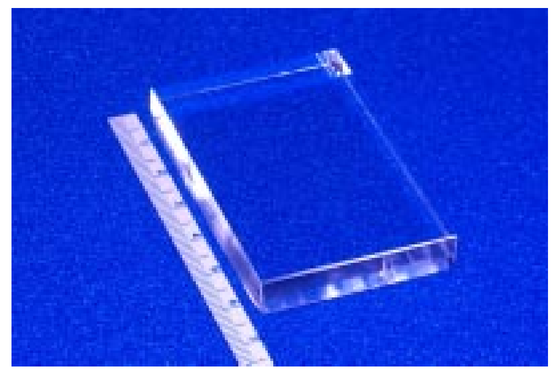
Before



After

Grow 6.5 cm crystal

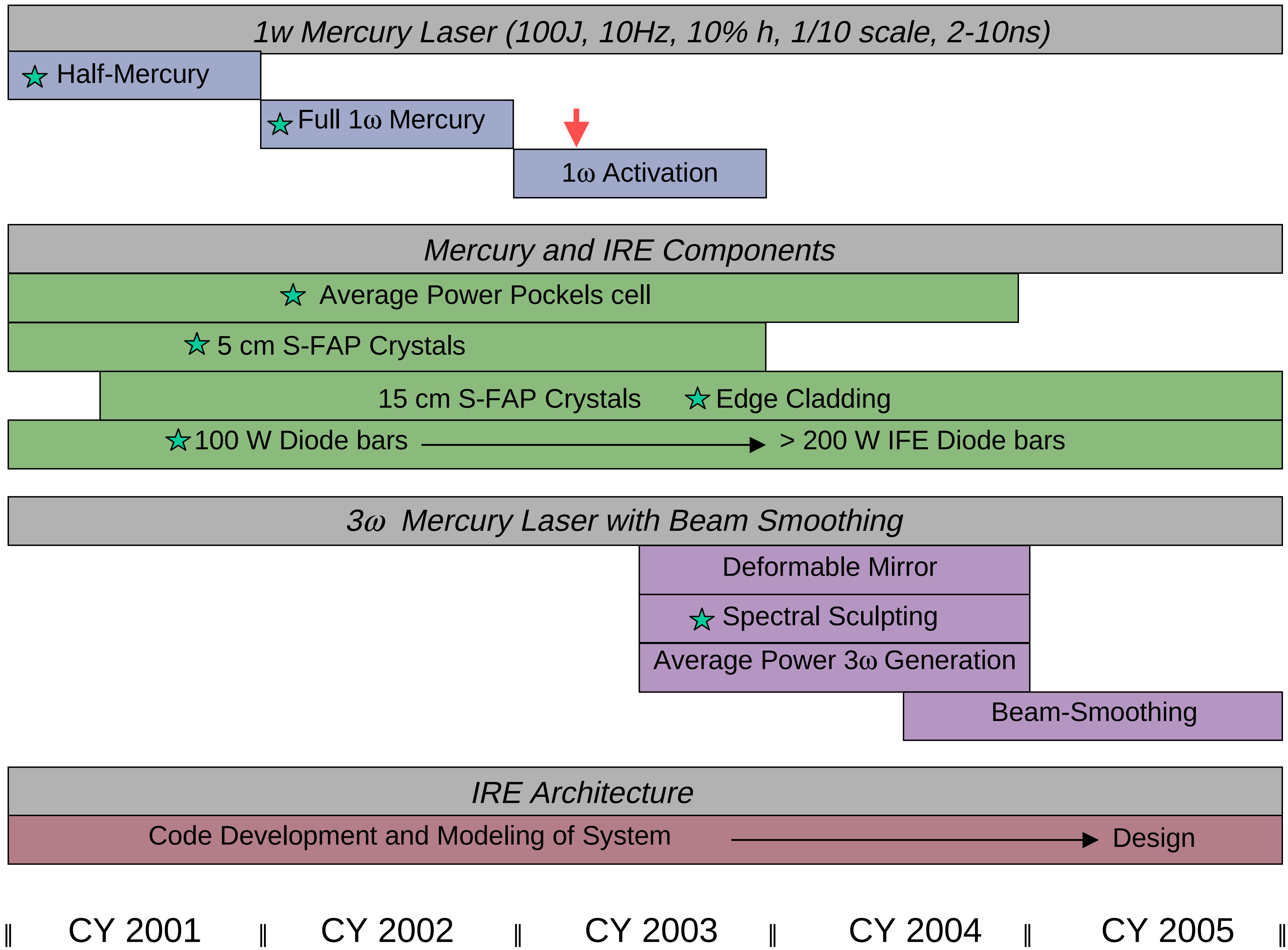
Cut into slabs



Final polish

- **Some boules are large enough to harvest full size slabs (no bonding)**
- **Currently developing processes to cut, grind and polish large boules**
- **High thermal gradients required to reduce defects (cracking more prevalent)**

The 5 Year Plan for DPSSL Development *(Where are we?)*



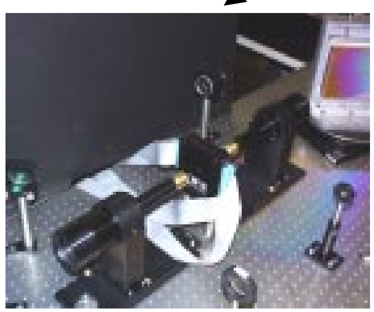
We have designed a front-end laser that offers the attributes needed for full Mercury

- **Present system is a commercial unit, on-loan for temporary use**
- **New system is designed to spectrally, temporally, and spatially tailor the pulses to meet our IFE goals**

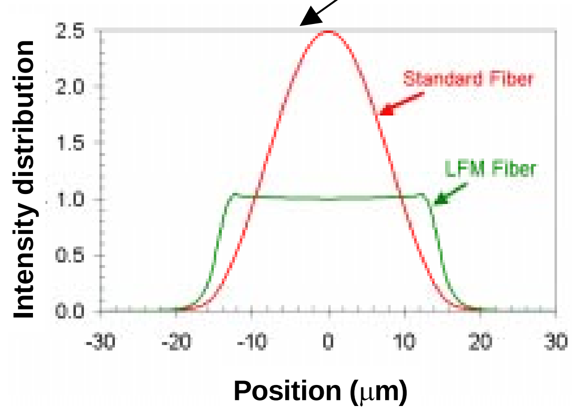
Basic layout (*see poster for details*)

Fiber oscillator → **Pulse shaping** → **Bandwidth** → **Fiber amplifiers** → **Yb:S-FAP multipass amplifier**

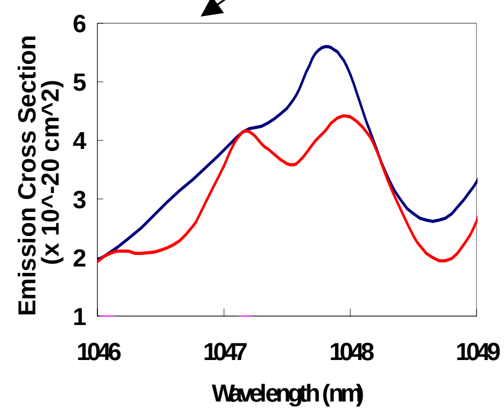
Highland Box



Spectral sculpting Univ. Rochester



Large-Flattened Mode Fiber (2.5X intensity)



Gain flattening with intra-cavity etalon