Mercury Laser

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The FY-2001 goals are to build and characterize Mercury laser system with one amplifier and two pump modules

This will be accomplished through 6 objectives:

- **Build two pump delivery systems**
- **Fabricate Yb:S-FAP crystals**
- **Design and build wedged amplifier head**
- **Build injection and reverser hardware**
- **Integrated tests and code benchmarking**
- **Advanced Yb:S-FAP growth**

The budget allocation for these tasks is $8250k

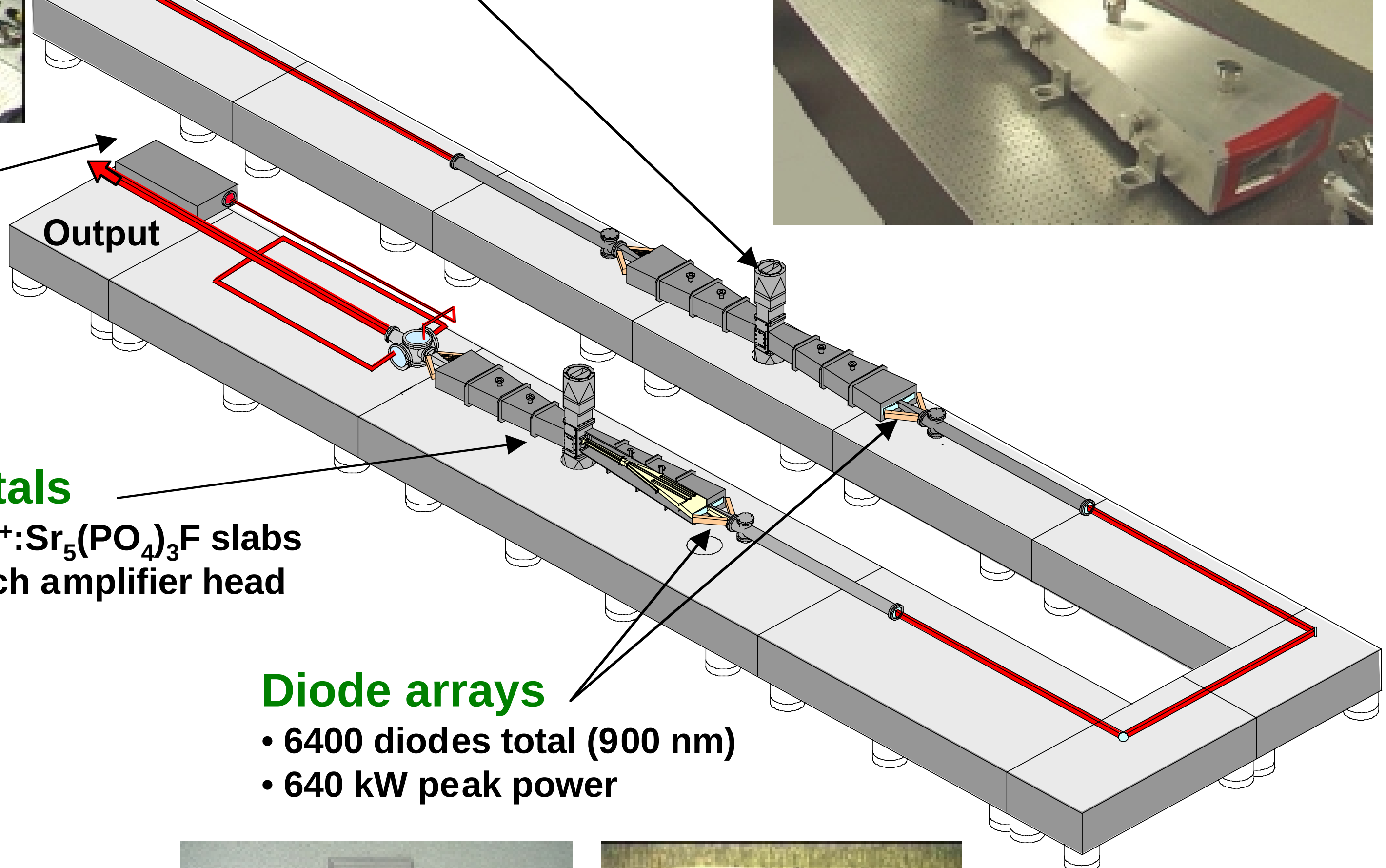
The short term goal is to develop a 100 J/1.05μm/10 Hz/10% laser capable of generating 2-10 ns pulses for IFE-related experiments for example: x-ray generation, rep-rate targets, beam-smoothing, optical damage, etc.

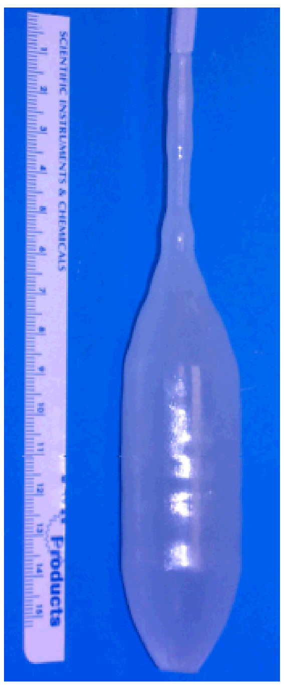
Gas-cooled amplifier heads

- He gas flow at 0.1 Mach

Front-end

- 300 mJ, M^2=1.8



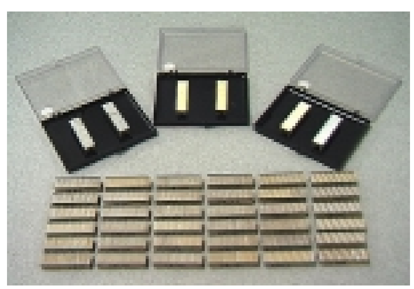


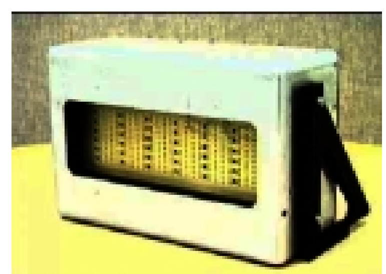
Crystals

- 7 Yb^{3+}:$Sr_5(PO_4)_3F$ slabs in each amplifier head

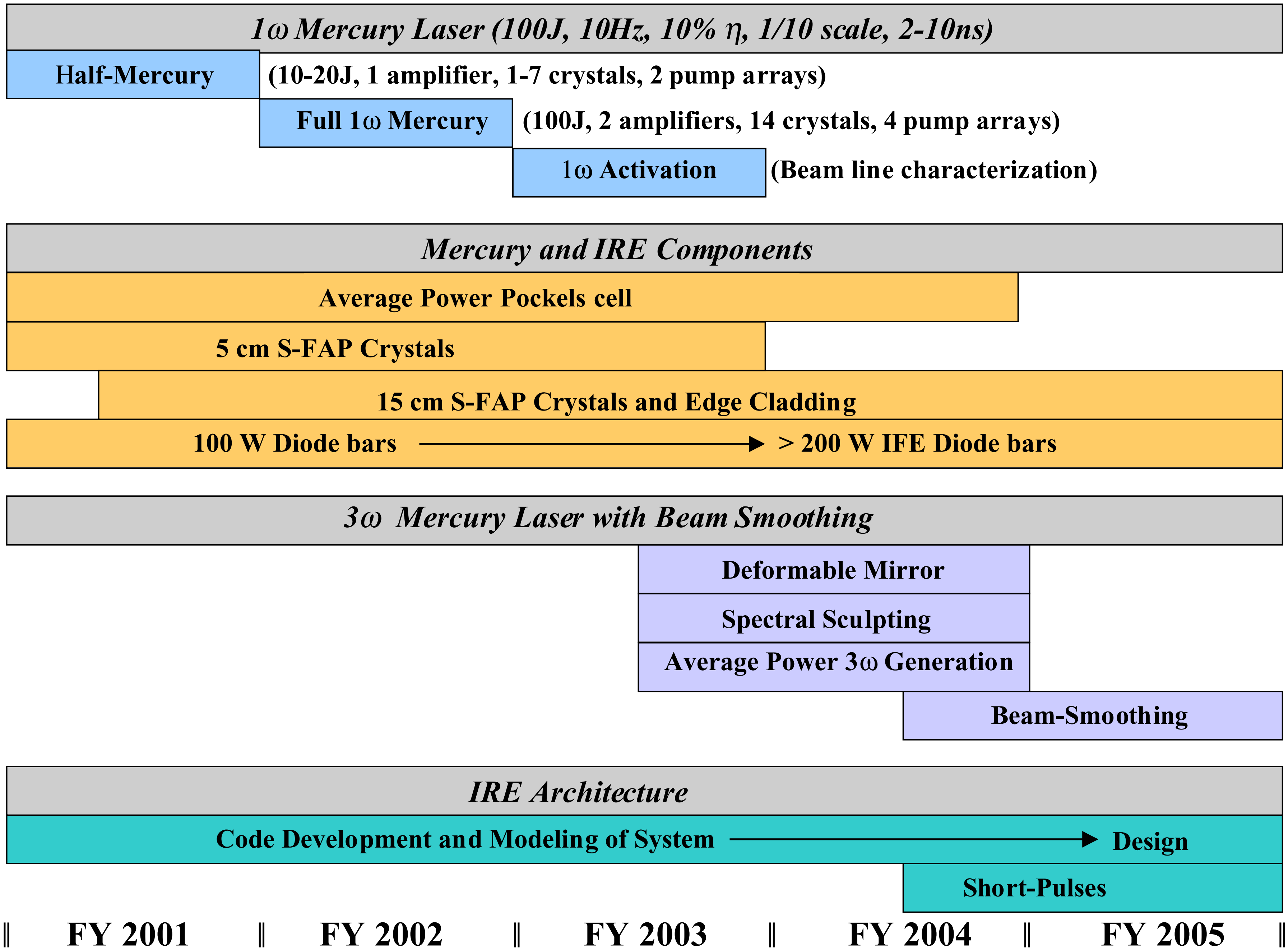
Diode arrays

- 6400 diodes total (900 nm)
- 640 kW peak power

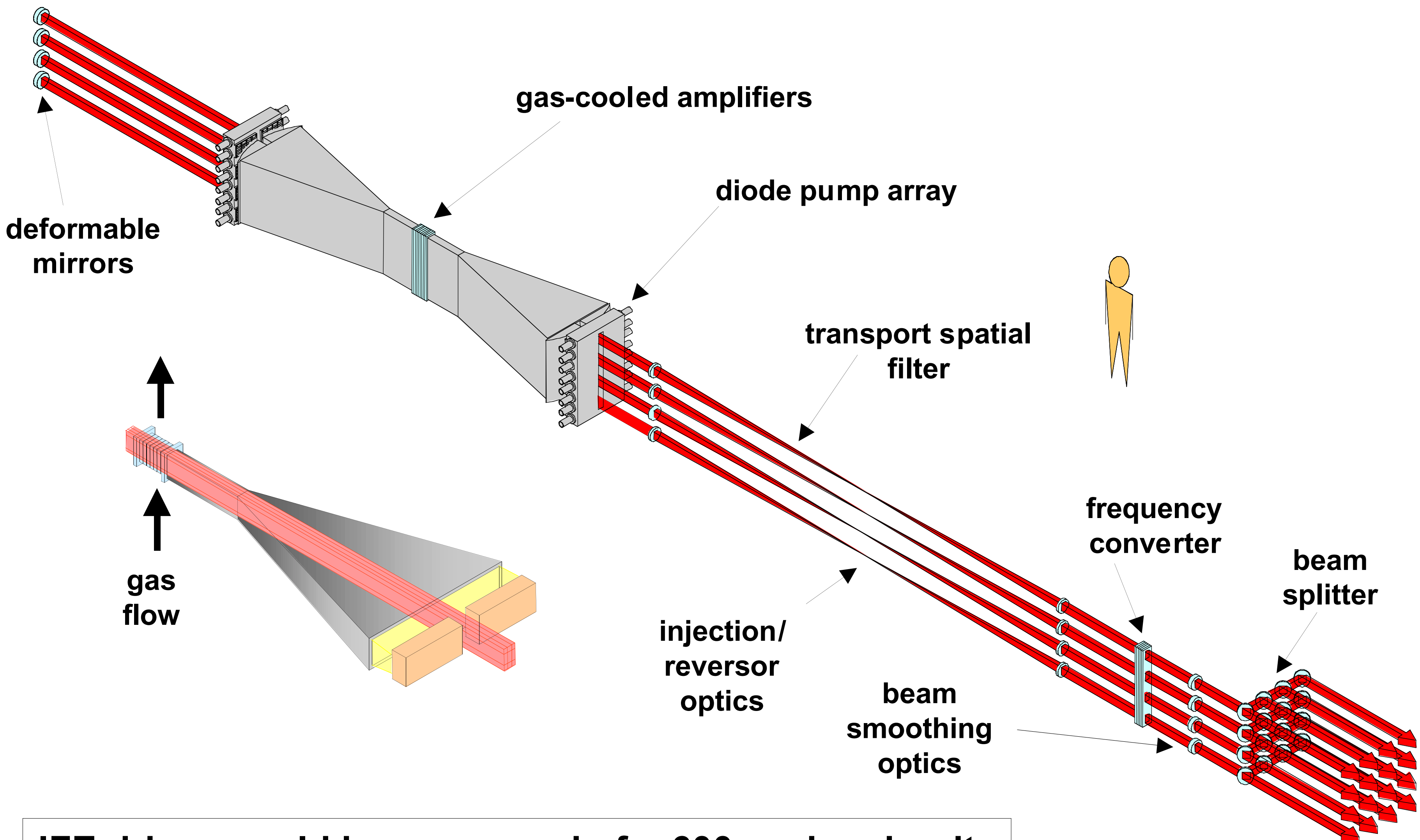




The 5 Year Plan for Mercury Laser Development



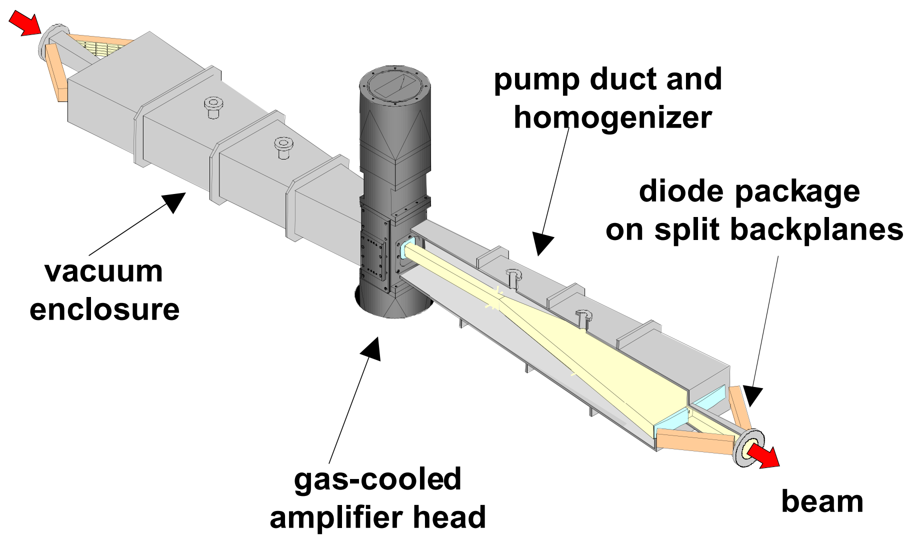
IRE laser is envisioned as a 4 x 1 beam bundle which is split after frequency conversion to a 4 x 4 beam array (~4 kJ)

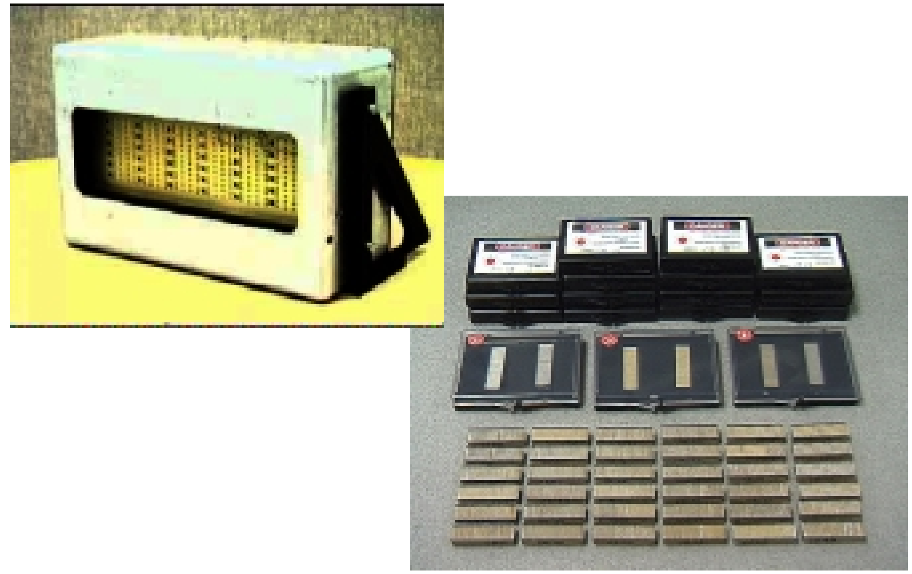


IFE driver would be composed of ~ 600 such subunits

Objective 1: Build two pump delivery systems

Goal

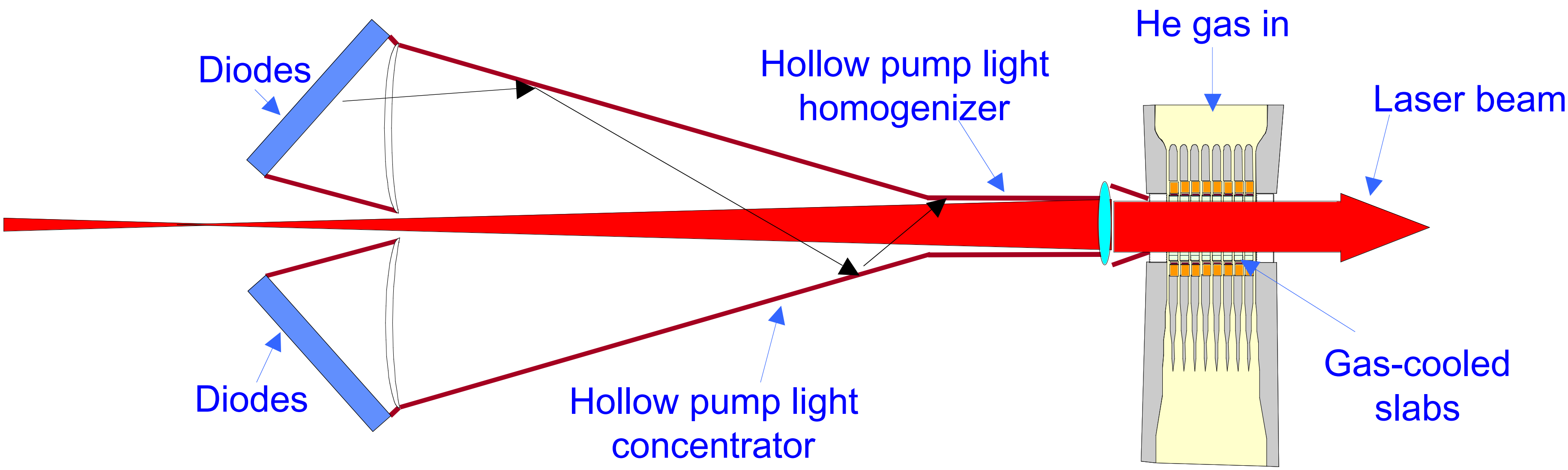


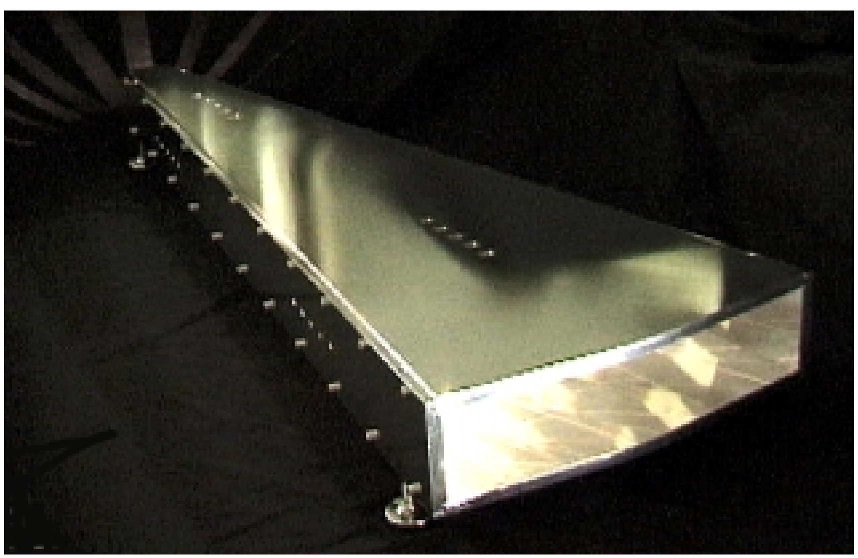


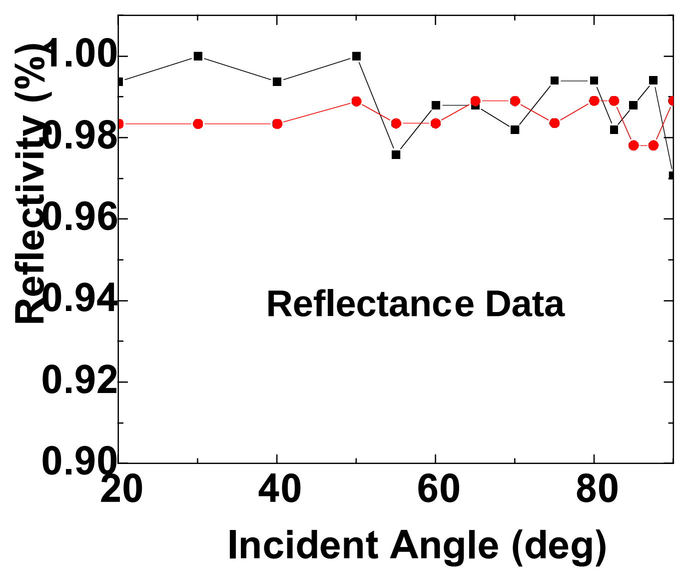
Status

- 80 V-BASIS 23-bar 900 nm tiles fabricated
- Two backplanes fabricated
- Remaining power supplies/pulsers purchased
- Pump delivery hardware being assembled
  - lens duct
  - homogenizer
  - telescope
  - vacuum enclosure

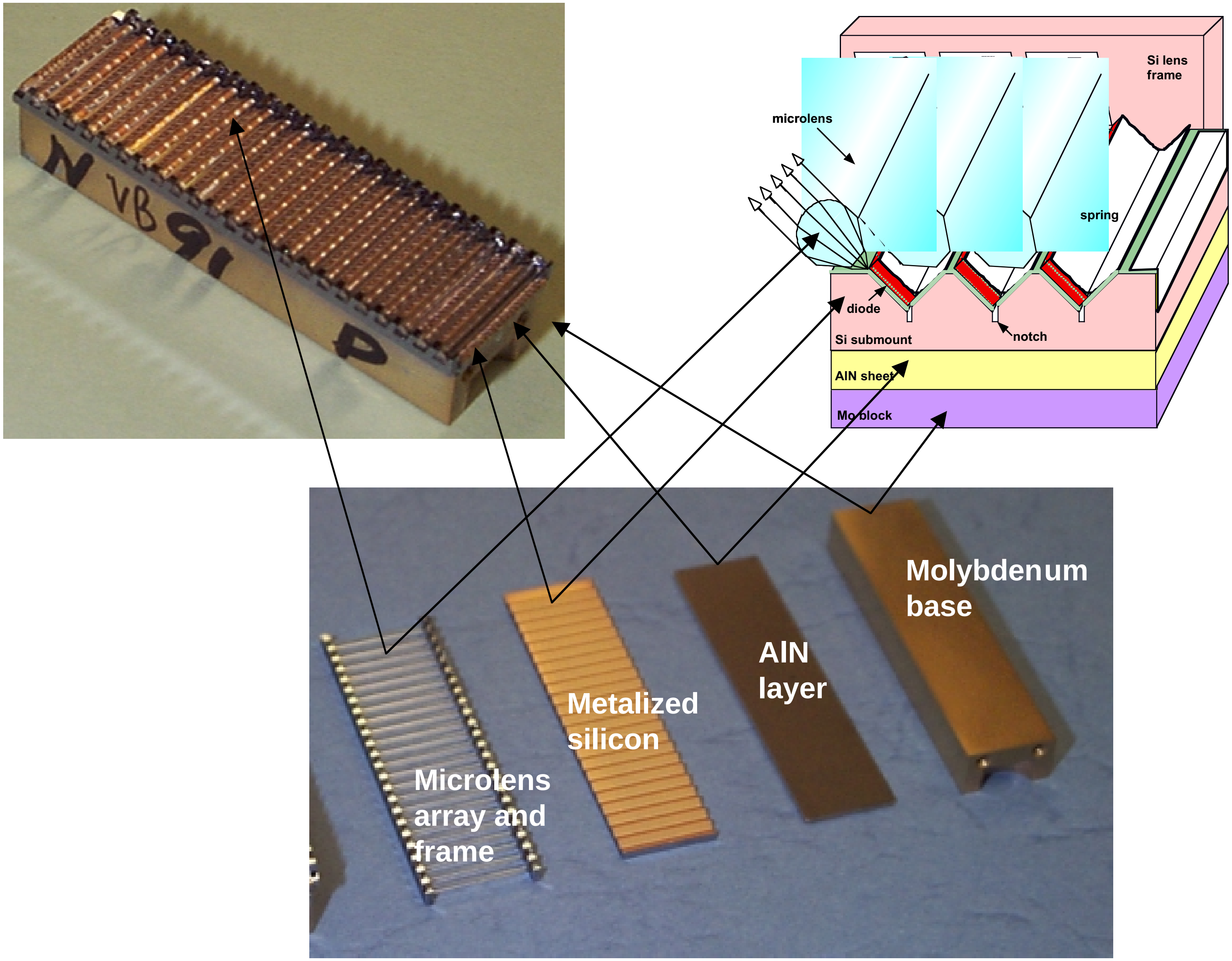
Reflectivity measurements of the silver-coated hollow lens duct show a >98% loss per bounce





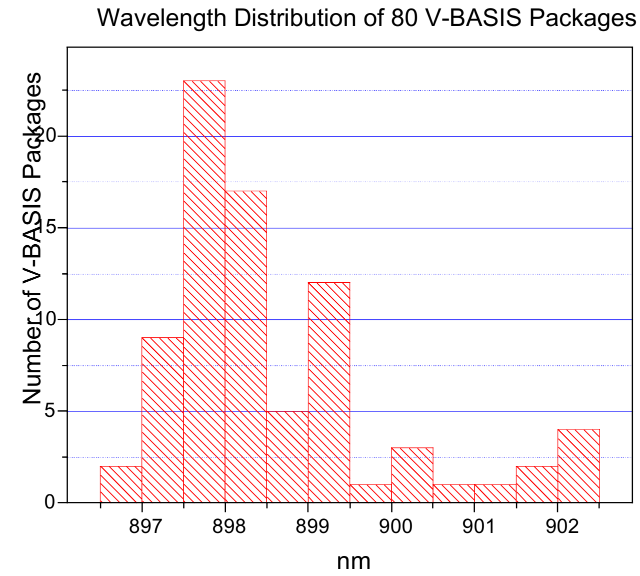


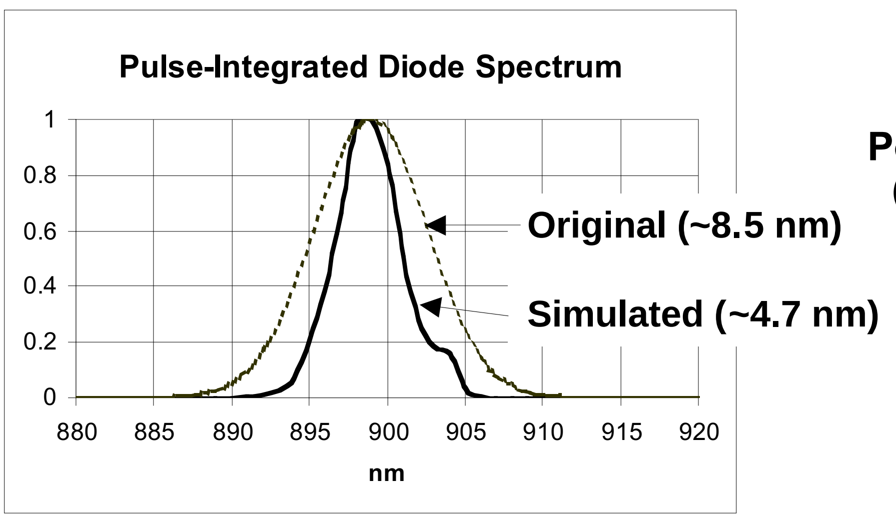
V-BASIS package components

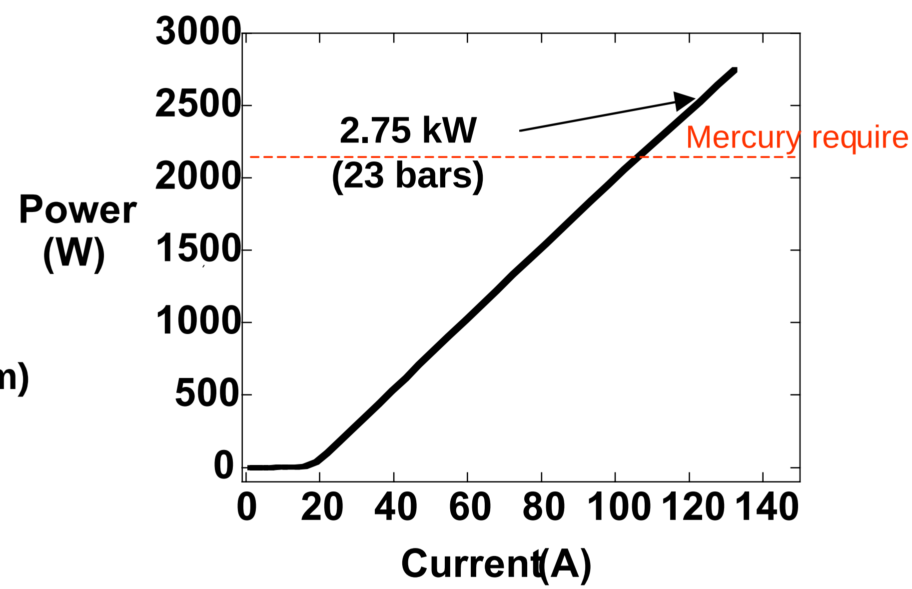


The V-BASIS packaged diode bars meet the optical specifications of the Mercury Laser System

Requirement	Status	
100 W_{peak} /1 cm bar	115 W_{peak} / 1 cm bar demonstrated with good lifetime	
Fabrication of 80 tiles	Completed	
45% electrical to optical efficiency	44% demonstrated	almost
Reliability of > 2x10 ^{8} shots	Testing is ongoing, but currently demonstrated 1.4x10 ^{8} shots without problems	
Power droop during pulse < 15%	5% droop demonstrated	
Assemble tiles on split backplane	Work is ongoing to finish 1 full backplane array (72 mounted tiles)	
Pulse-integrated linewidth < 8.5 nm FWHM	Demonstrated 4.7 nm FWHM on tiles for one split backplane	

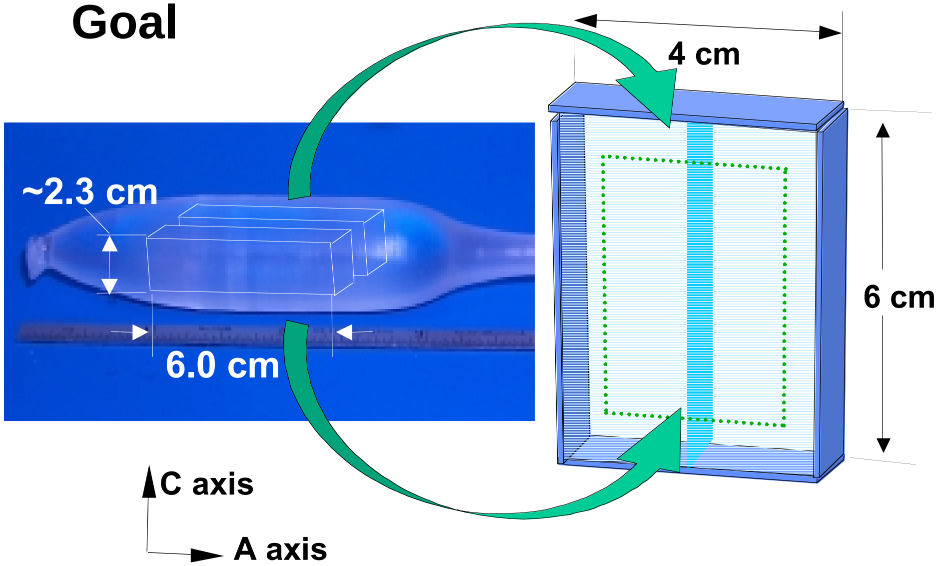




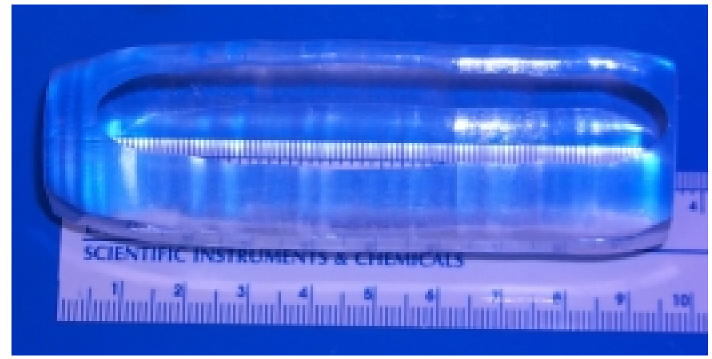


Objective 2: Fabricate S-FAP crystals

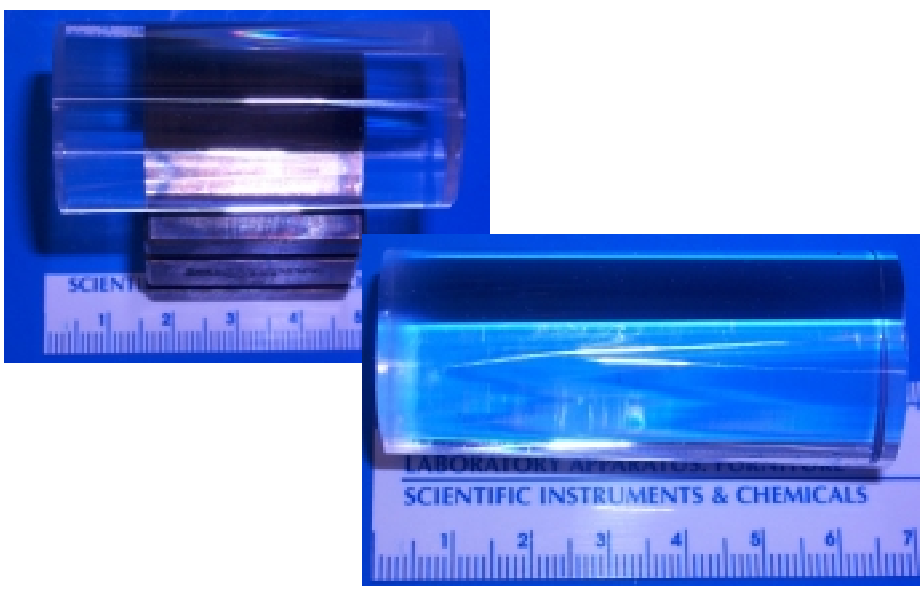
Goal



Litton boule (4x6 cm slab):



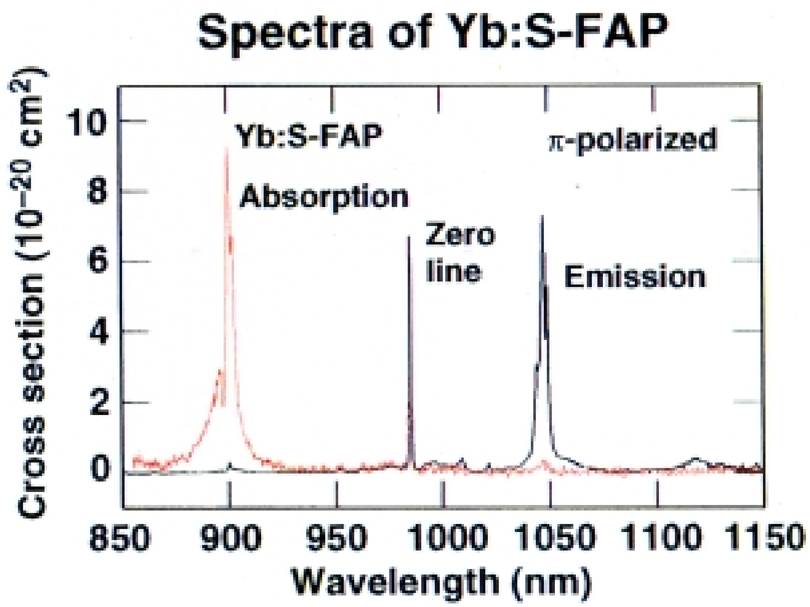
LLNL boules (3x5 cm slab):



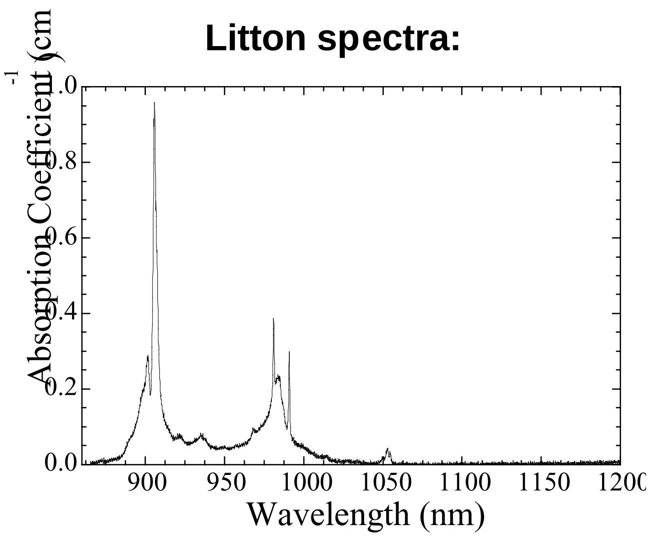
Status

- 3 boules are being cut and polished in preparation for diffusion bonding and slab fabrication
- One LLNL furnace converted to Litton design
  - improve control of:
    - atmospheric growth conditions
    - thermal gradients
  - anticipated first growth 2/11
- Alternative bonding methods being explored:
  - Stanford
  - LETI and Crystal Laser, France

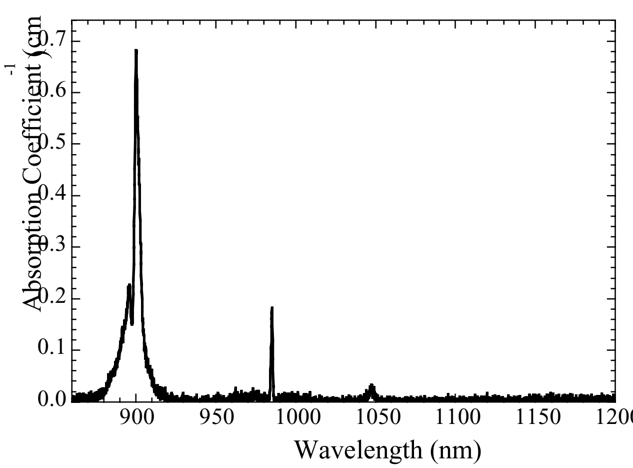
The emission cross section and doping have been measured for the LLNL and Litton crystals



Litton spectra:



LLNL spectra:

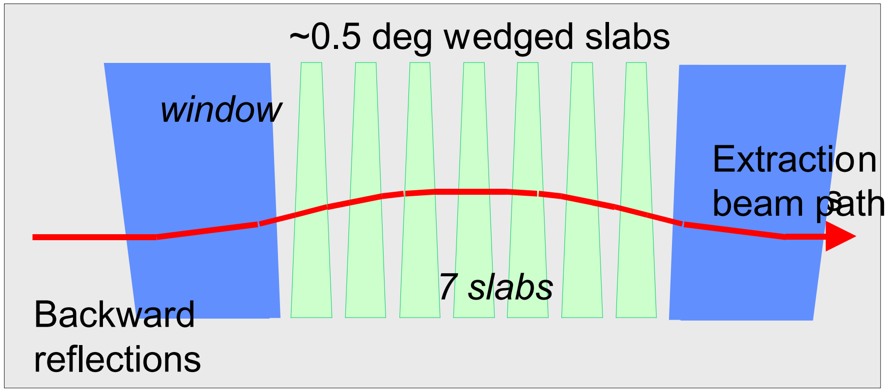


A pathway for producing 3.2 cm diameter crystals has been defined

Issue	Fundamental Cause	Resolution	Roles	
			LLNL	Airtron
Cloudiness	Precipitation on line defects	〈 excess SrF_2 in melt 〈 annealing over melt	Under control	Under control
Anomalous absorption	Yb^{3+} in a different site	〈 c-axis along growth direction 〈 thermal gradients of <70°C/cm	Under control	Nearly resolved
Grain boundaries	Dislocations from the seed	〈 seed extensions to grow out boundaries	Under control	Under control
Bubble Core	Constitutional supercooling	〈 growth stability 〈 maximize thermal gradients	Under control	Under control
Cracking	Internal stresses	〈 cool crystals attached to melt	Under control	Nearly resolved
Size	Control of defects	〈 diffusion bond half-size slabs	Under control	Under control
Sparkle inclusions	Limited Yb solubility in melt	〈 Yb-doping of <0.75 At% in melt	Nearly resolved	Under control
R&D		...	Lead	Backup
Production		. .	Backup	Lead

Objective 3: Design and build wedged amplifier head

Goal

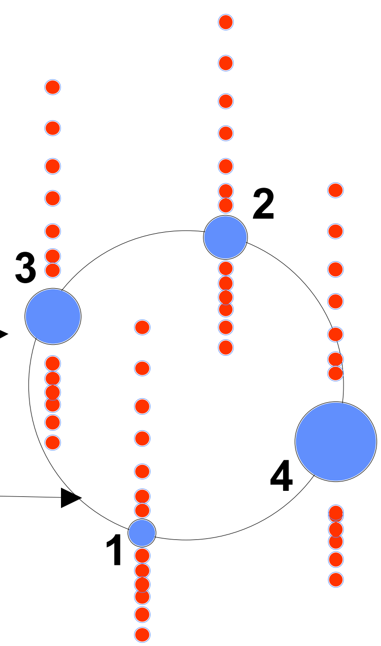


Wedging elements of amplifier head vertically distributes reflections away from the extraction beam

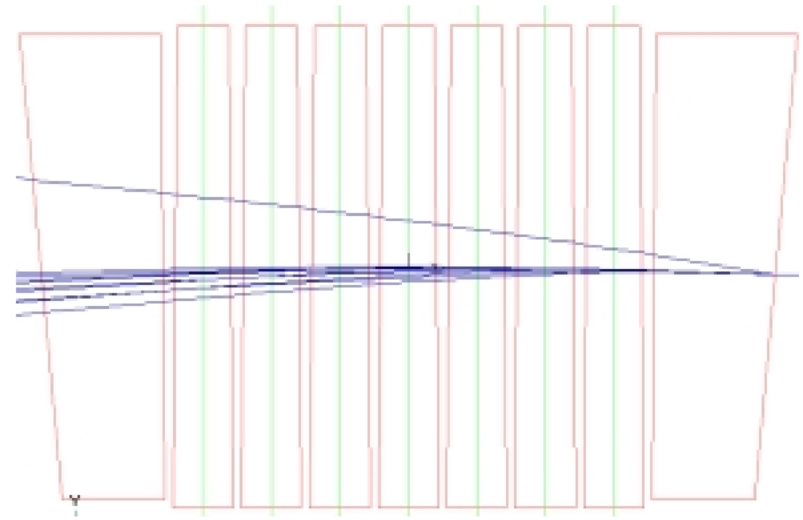
Backward and forward reflections from slabs, windows, lenses,...

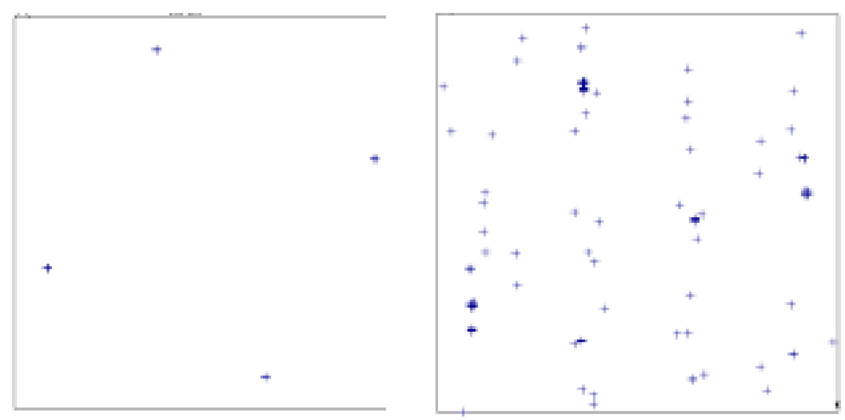
0.7, 1.05, 1.4 and 1.75 mm diameter pinholes

1.75 cm (10 mrad) dia. circle



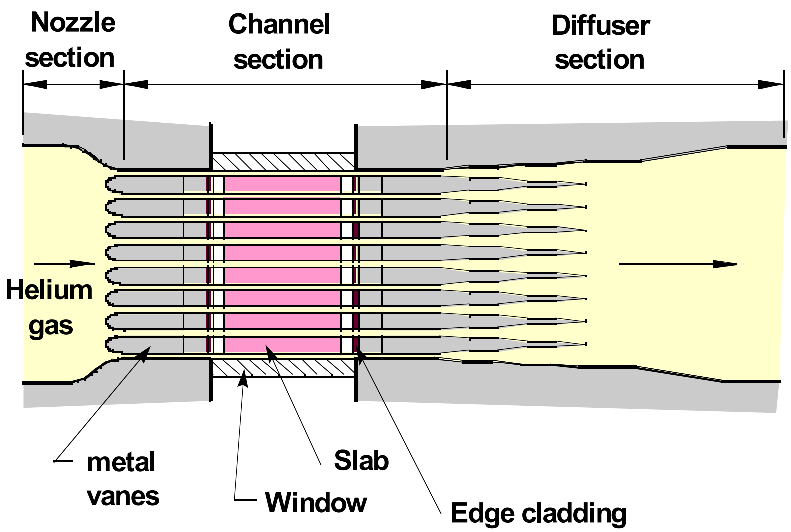
Status

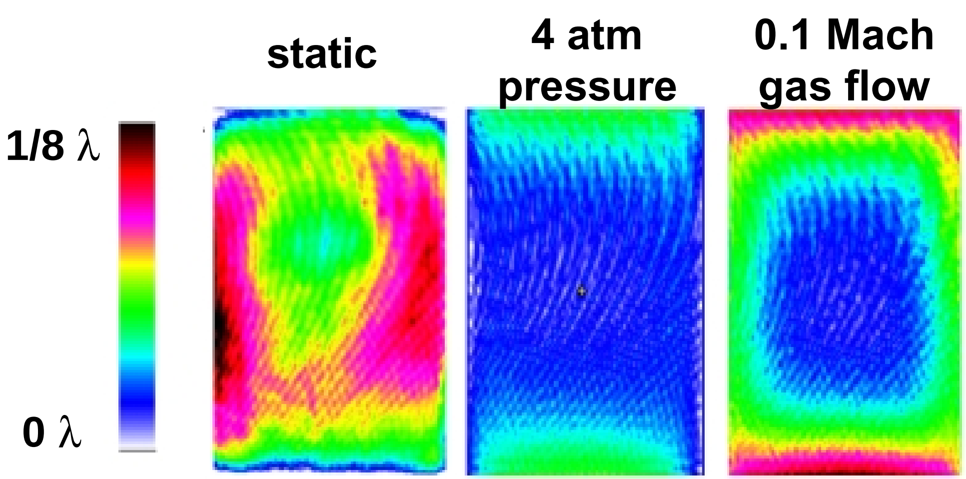




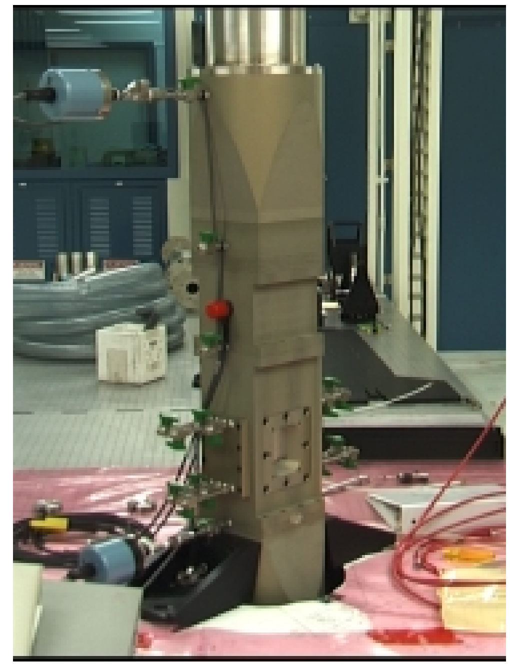
- **Ray trace code written in OPTICAD**
- **0.5 degree slab wedge amplifier design in progress**

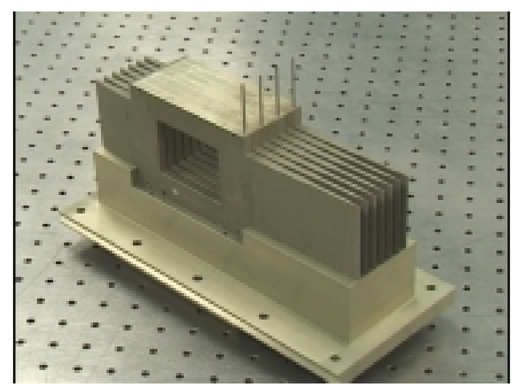
Pressure and gas flow contributes 1/16 wave to wavefront distortion





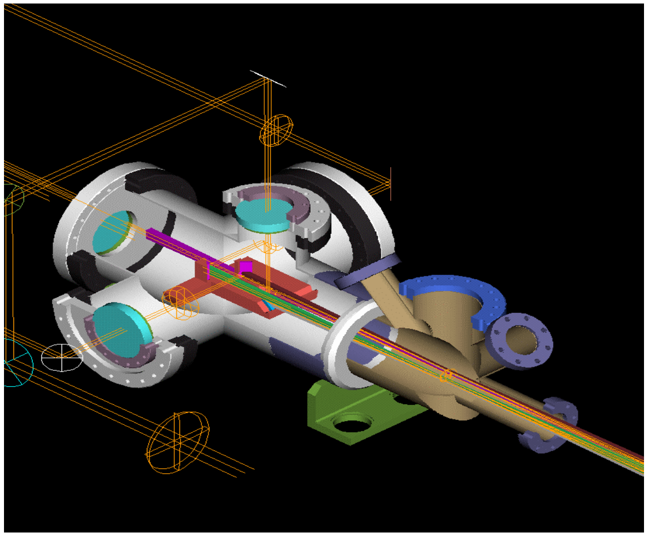
Gas cooled head and vanes

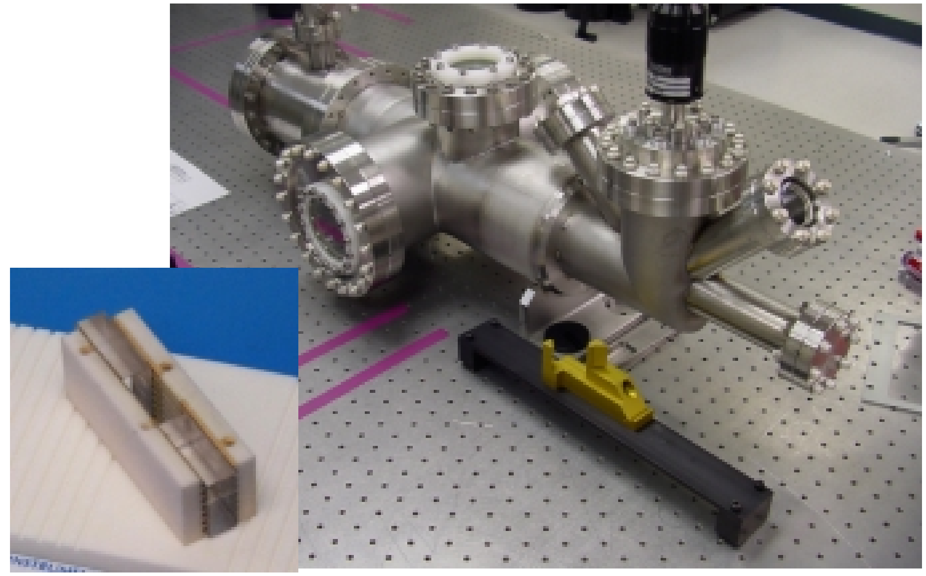




Objective 4: Build reverser and injection hardware

Goal

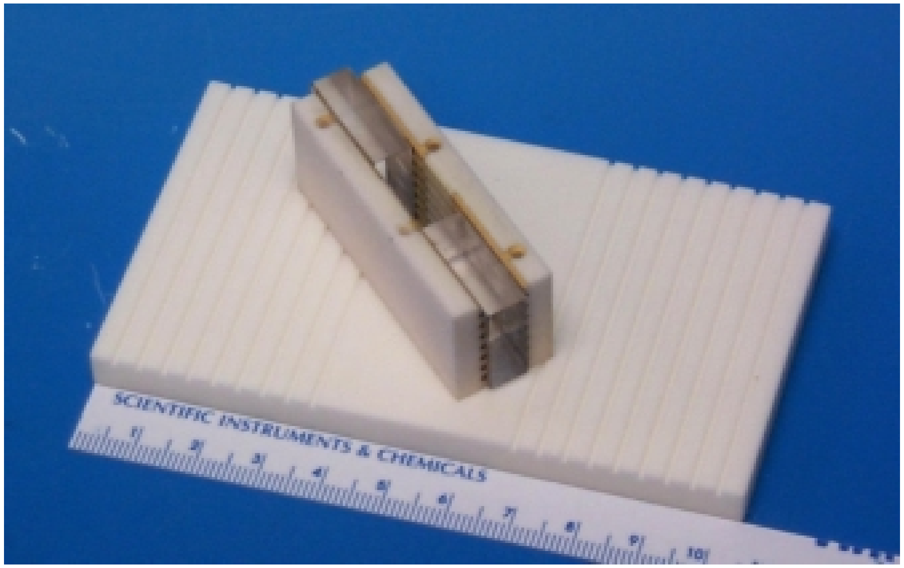




Status

- Injection hardware fabricated
- Half aperture Pockels cell being tested
  - $1.5 \times 2.5 cm^2$
  - Full aperture parts on order
  - 100 W goal (10J, 10Hz, $<1J/cm^2$)
- Front end assembled
  - YLF oscillator and two amplifiers installed
- Vacuum transport telescopes assembled

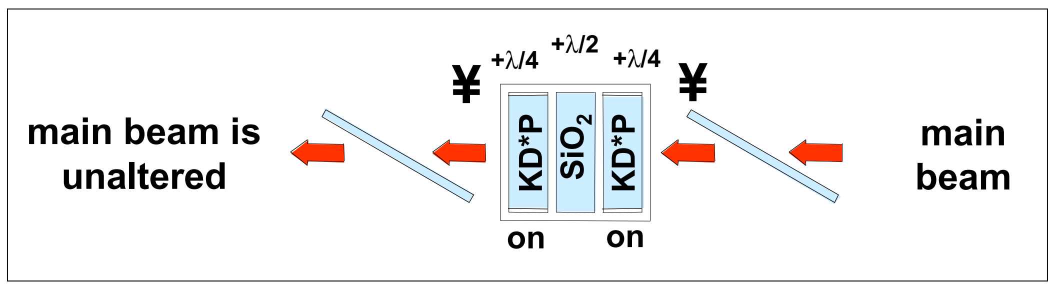
A half aperture (1.5 x 2.5cm^2) average power Pockels cell is being assembled and tested

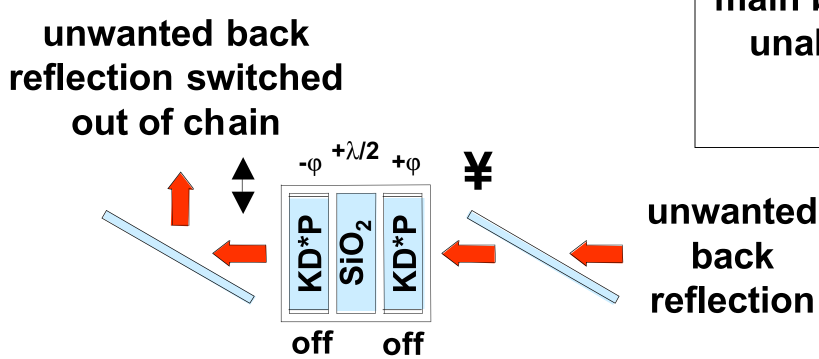


¥ Dual crystal configuration allows compensation for thermally-induced birefrigence

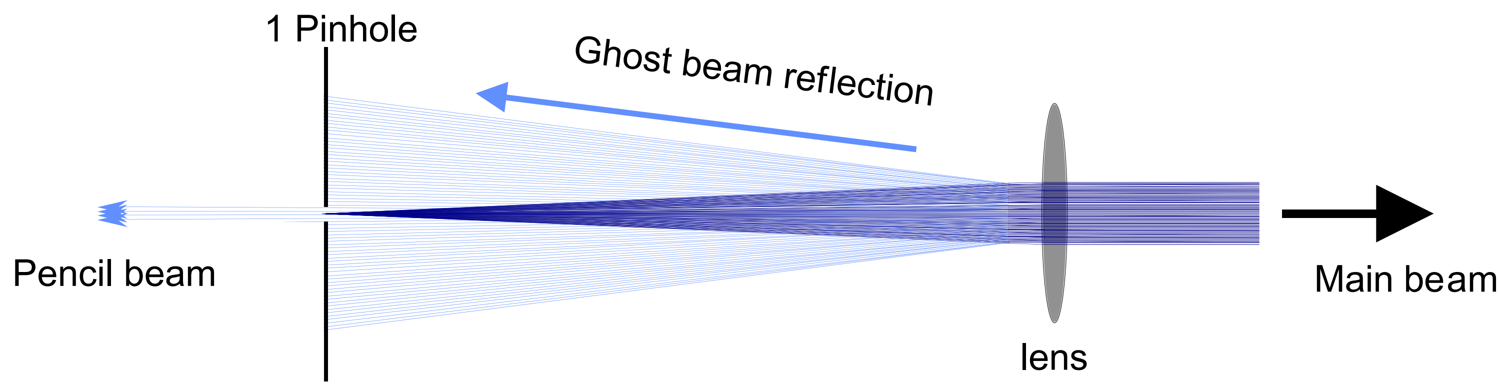
¥ Operating fluence of 0.5 J/cm^2 is below damage limit

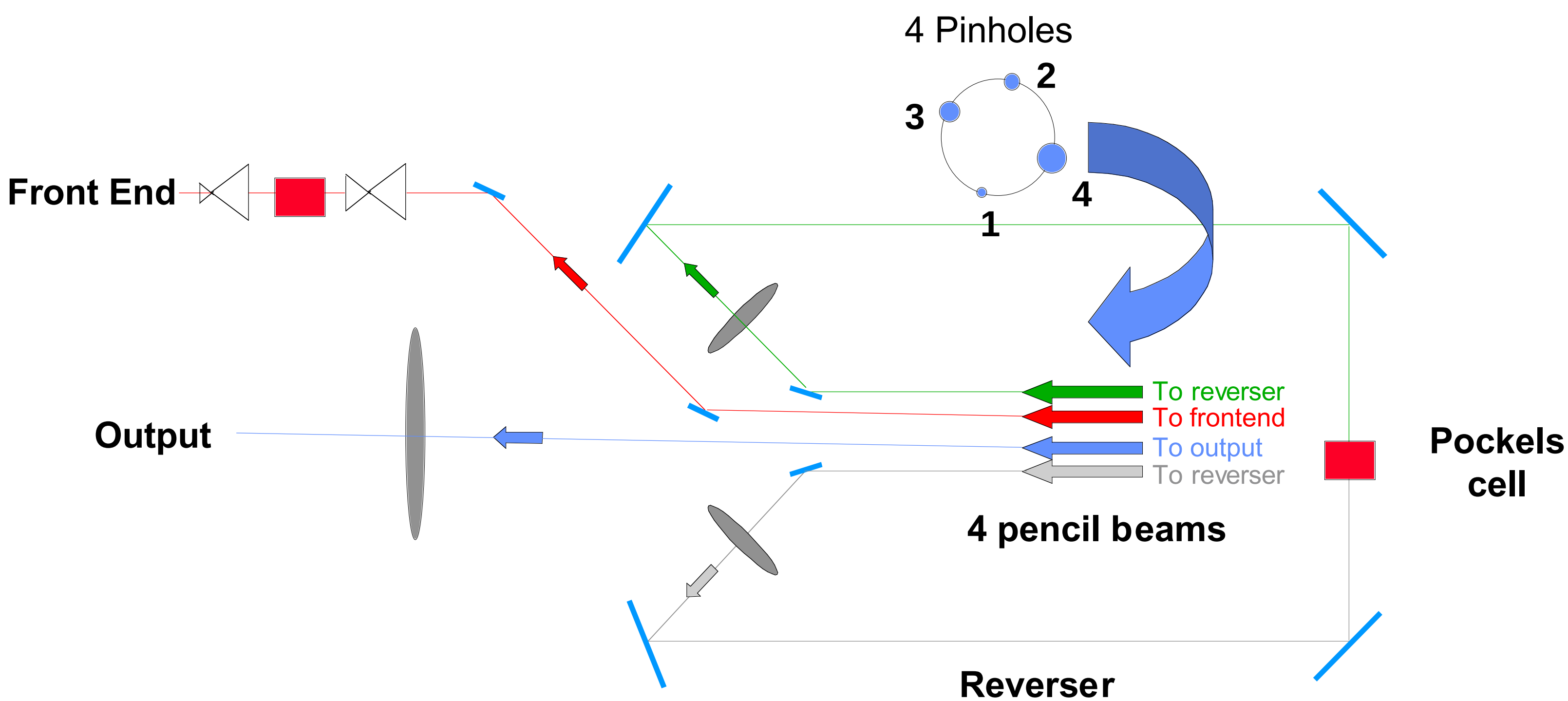
¥ Water coded housing will be employed



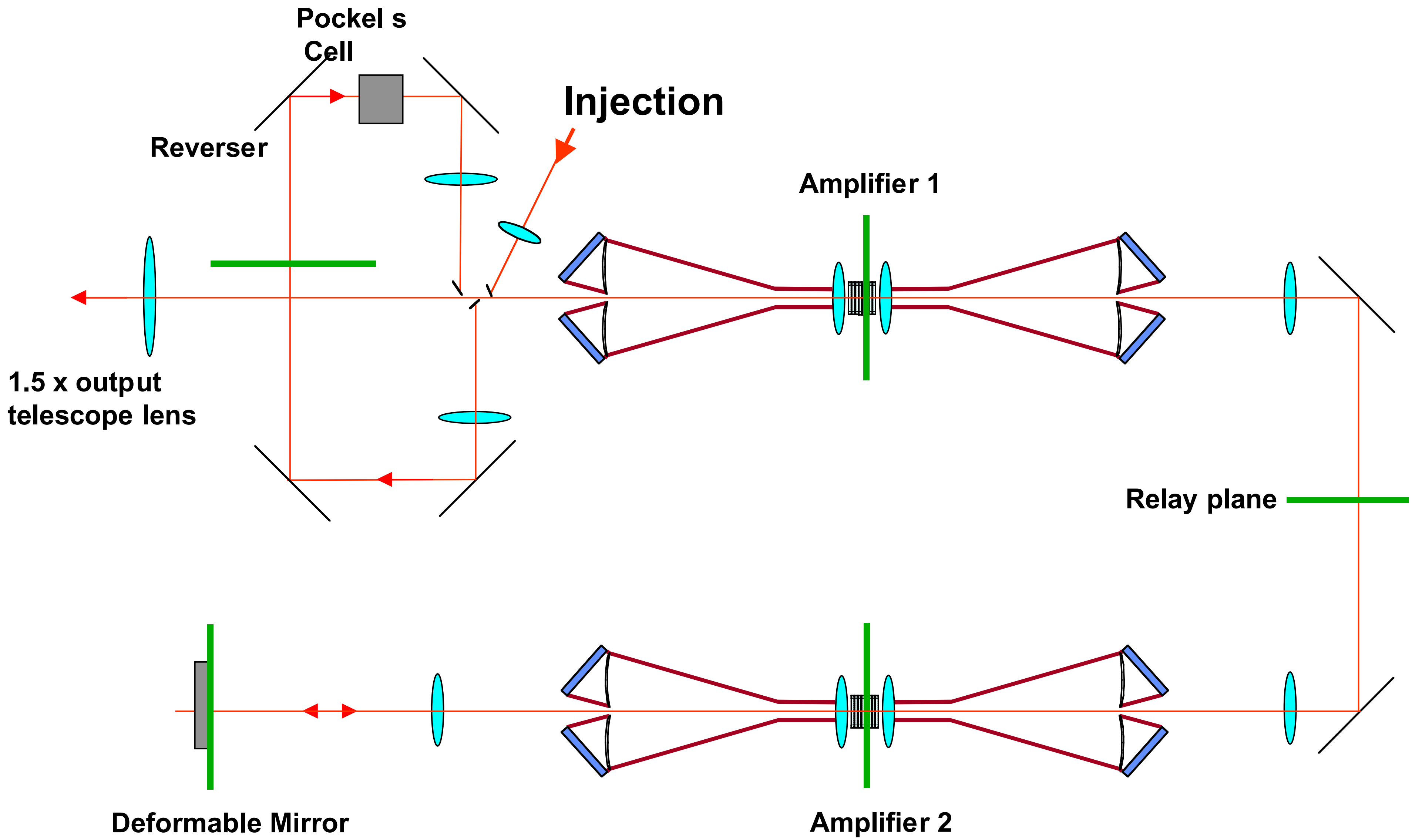


Pencil beams are generated at every lens and will require isolation to control their growth

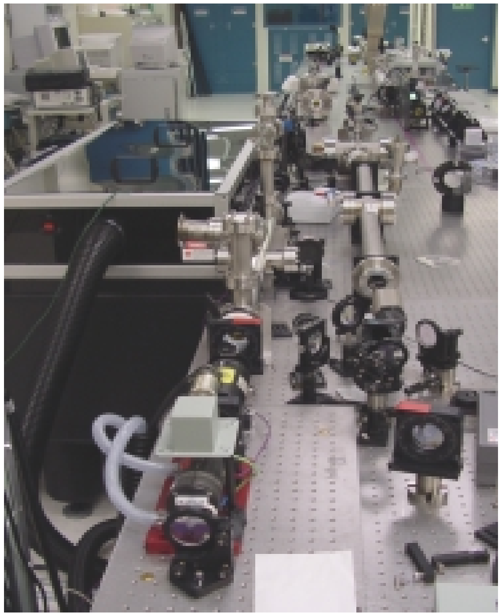




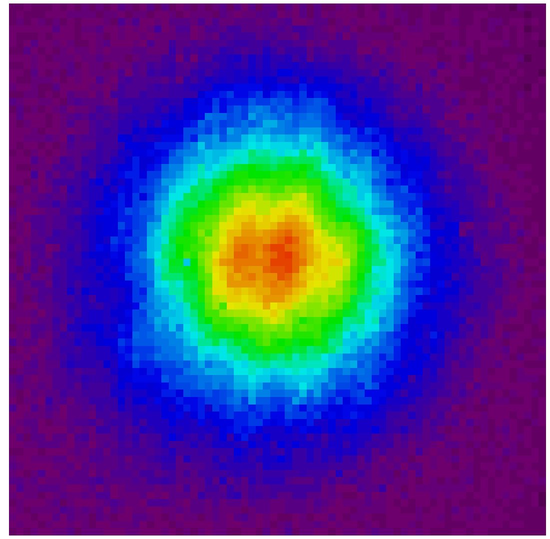
The Mercury laser system minimizes damaging fluences by maximizing the number of amplifiers and optics near the relay plane



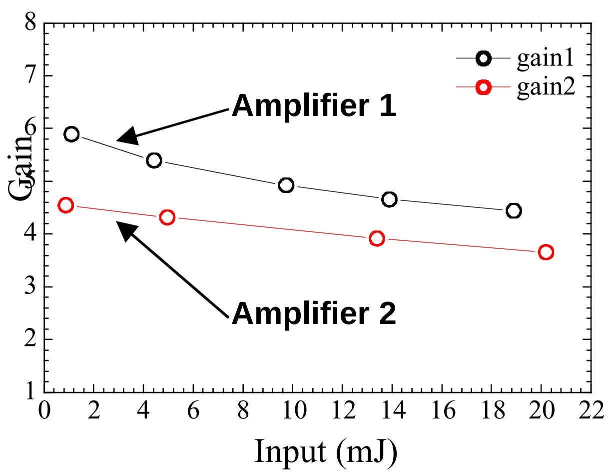
The front end currently produces 300 mJ with a beam quality of $M^2 < 2$



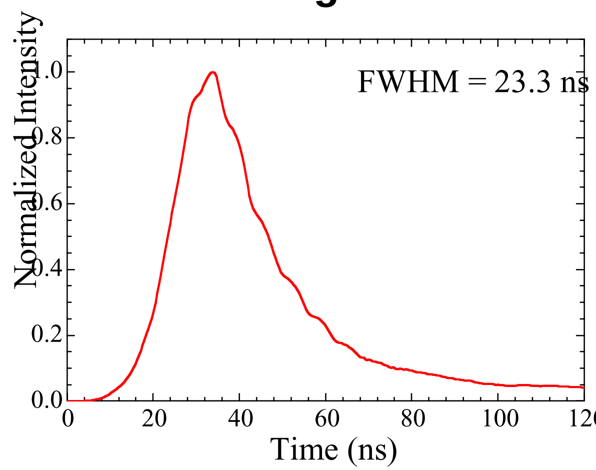
Beam Quality $M^2 = 1.8$



Gain measurements

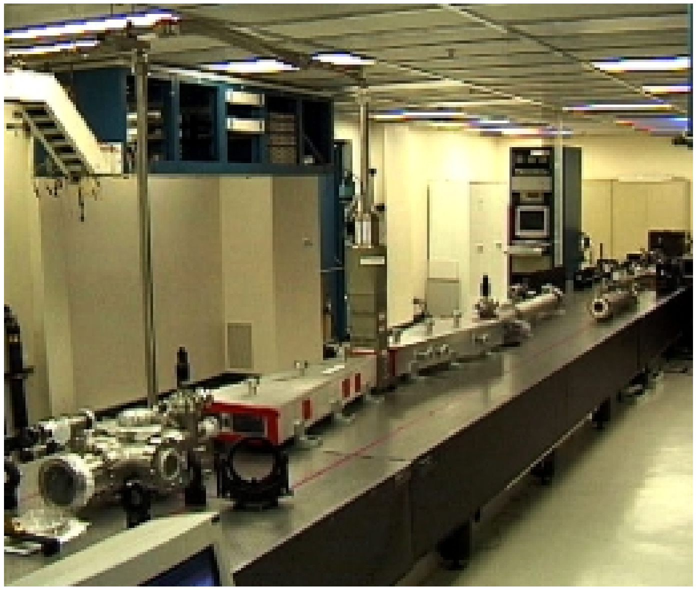


Pulse length = 23 ns

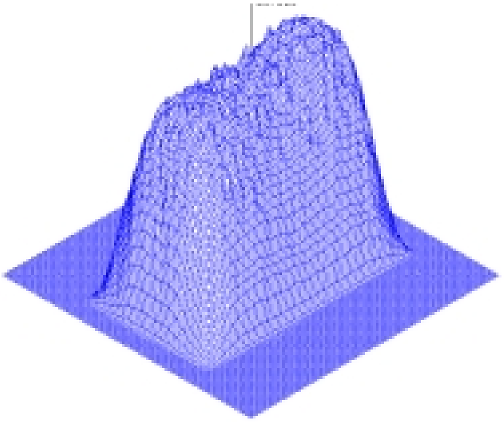


Objective 5: Integrated tests and benchmarking

Goal



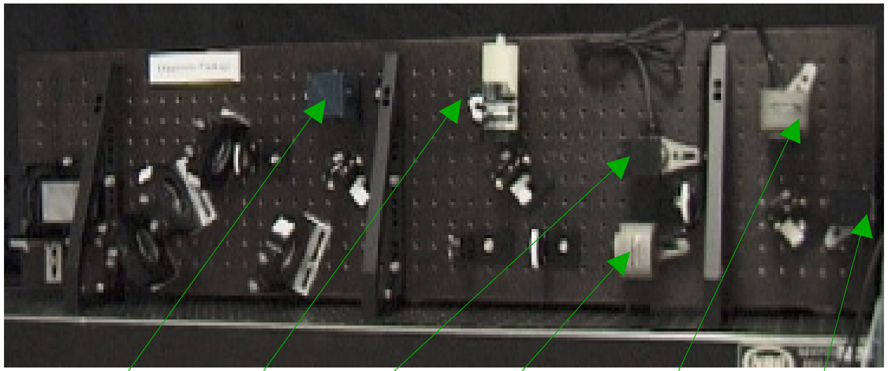
MIRO propagation code



¥ 96 % light in 5x diffraction limited beam

¥ 37% light in a 1x diffraction limited beam

Diagnostics

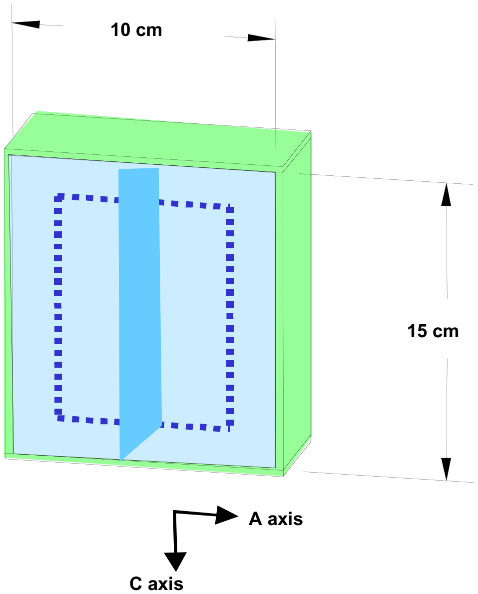


Status

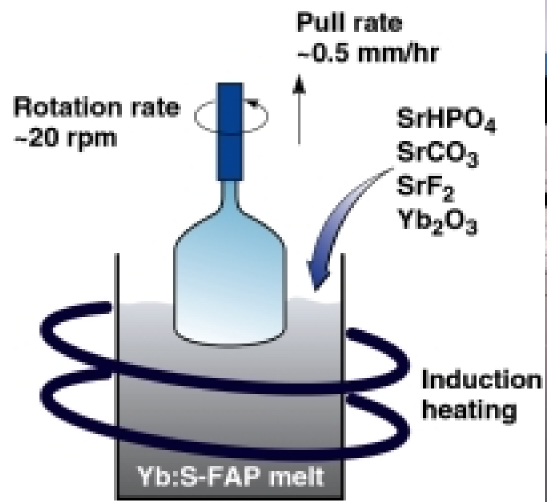
- Backplane and pump delivery tests: 4/1
  - Power, droop, chirp, polarization
  - efficiency, far/near field, uniformity
- One of two diagnostics packages built
- Miro prop. code written to model half Mercury
  - measured wavefront files
  - gain files from ray trace code
  - angular multiplexing
  - 4 unequally sized pinholes

Objective 6: Advanced S-FAP growth

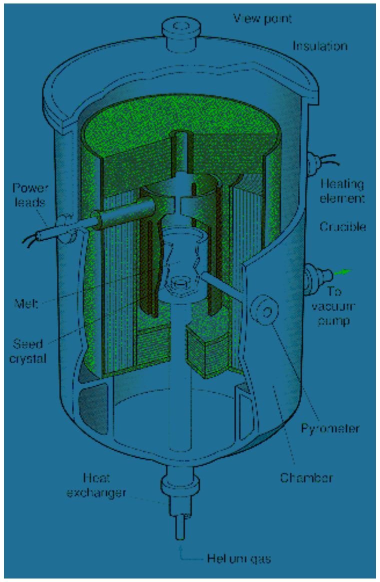
Goal

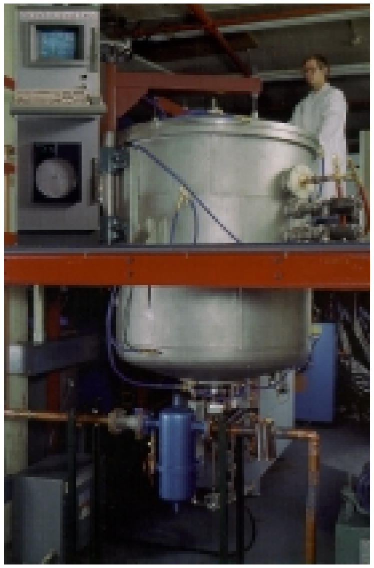


Czochralski: LLNL/Litton Airtron



HEM: Crystal Systems



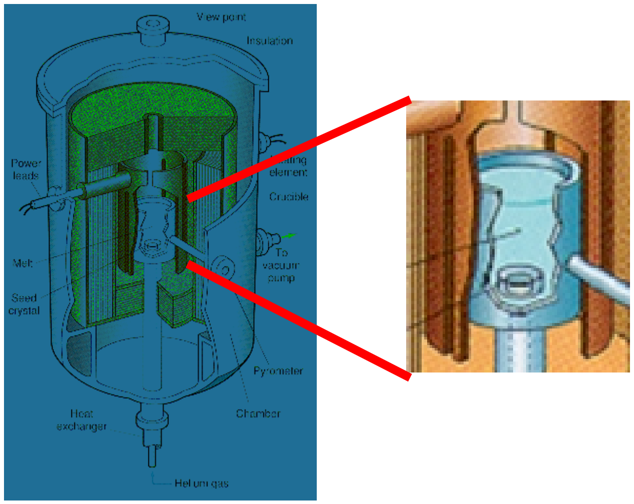


Status

- Contract written and to be awarded to Crystal Systems to demonstrate feasibility of growing large diameter Yb:S-FAP crystals by heat exchanger method (HEM)
- LLNL/Litton will investigate feasibility of flat interface growth

Objective 6: Advanced S-FAP growth cont.

Heat Exchanger Method



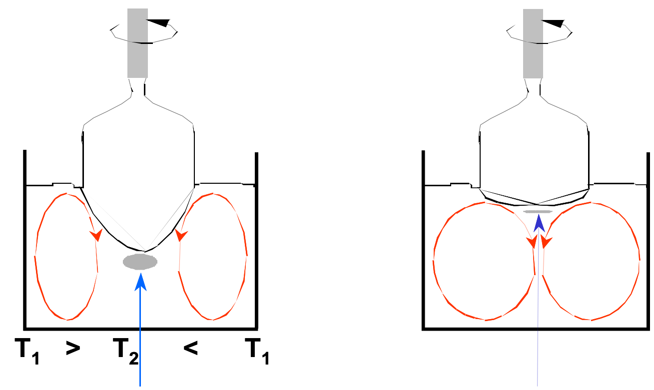
Growth is controlled by cooling the seed and slowly lowering the furnace temperature to maintain a stable interface

13 inch diameter Sapphire crystal

Large Diameter, Flat-Interface Method

Convex Interface

Flat Interface

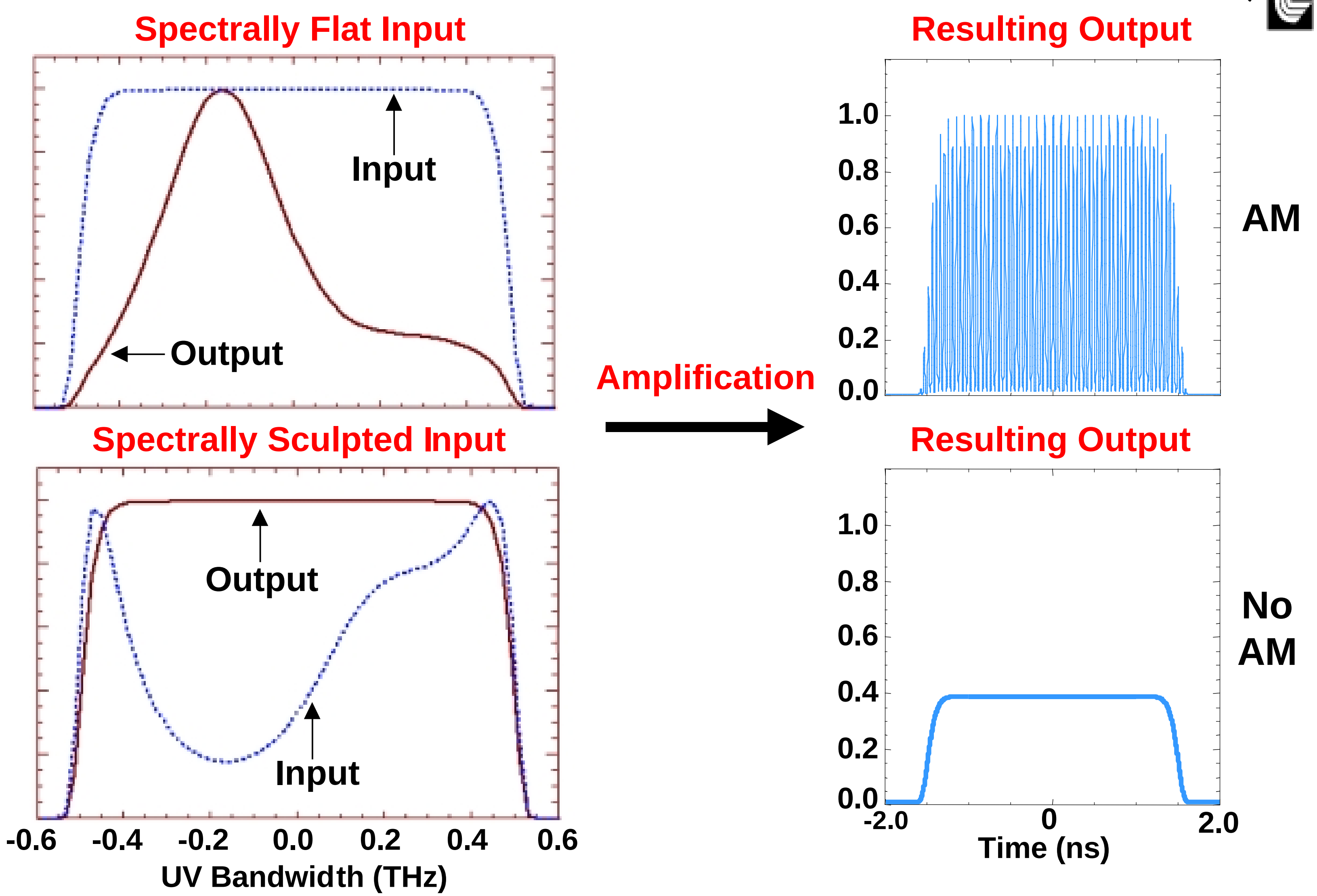


Dead Zone
Core Generation

Minimal Dead Zone
No Core Generation

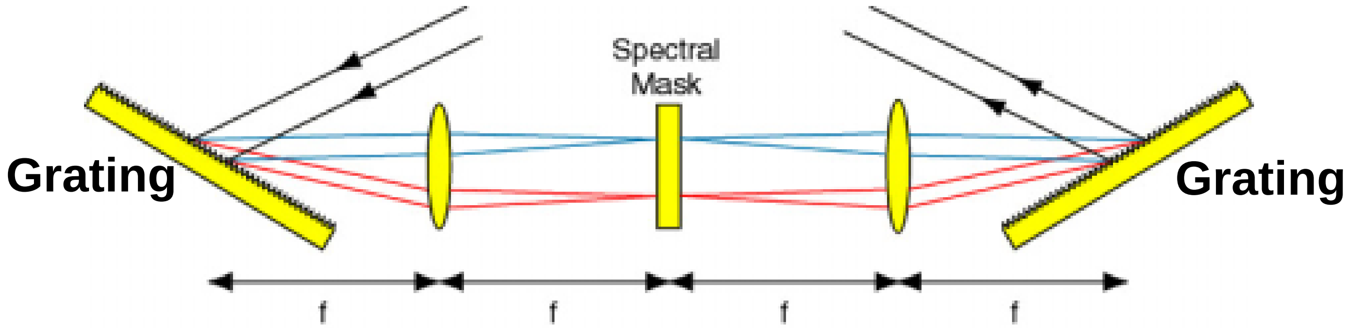
5 inch diameter Nd:GGG crystal grown by the flat interface method.

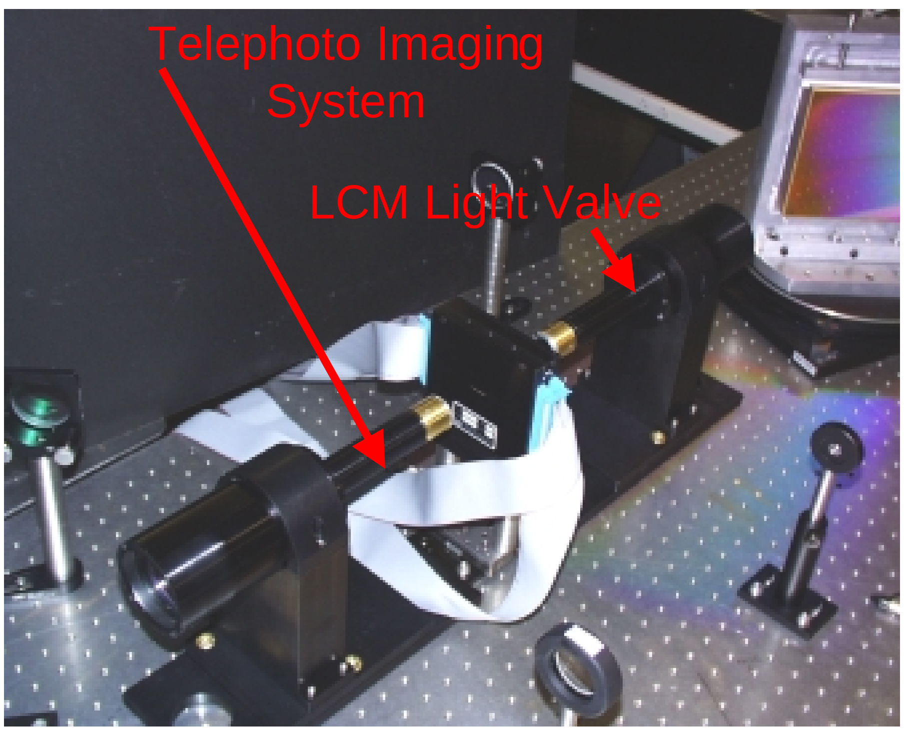
LLE: Spectral Sculpting progress



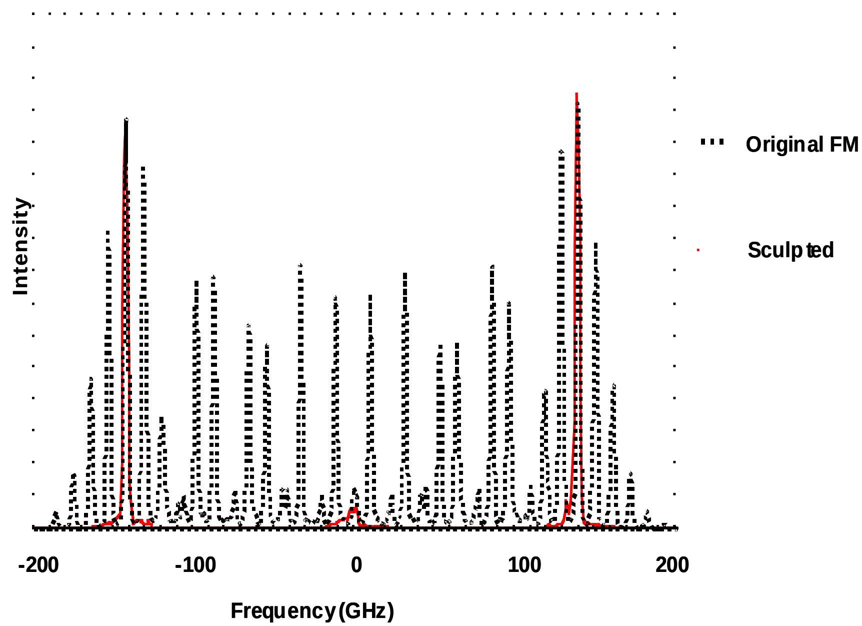
By sculpting the input spectrum, Yb:S-FAP can generate 1 THz UV bandwidth without AM

A compact spectral sculptor using a liquid-crystal modulator light valve has been demonstrated





- **Gratings: 1740 grooves/mm**
- **Telephoto imaging system EFL ~ 800 mm**



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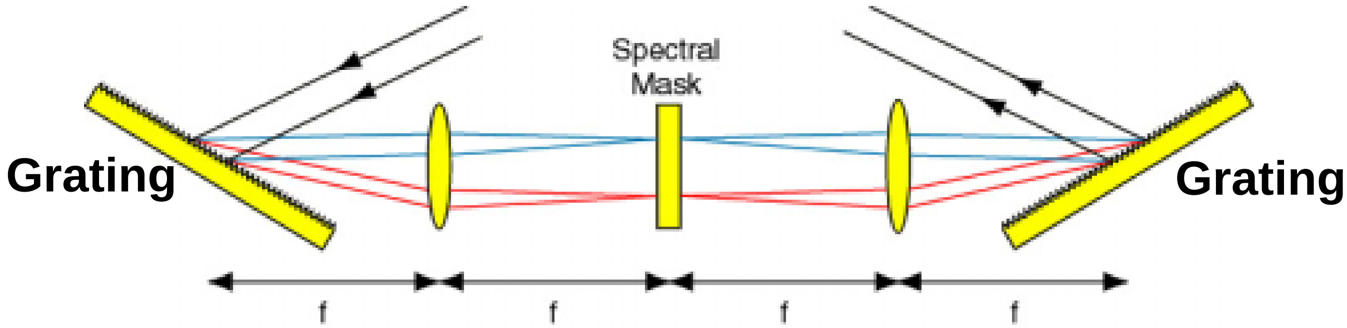

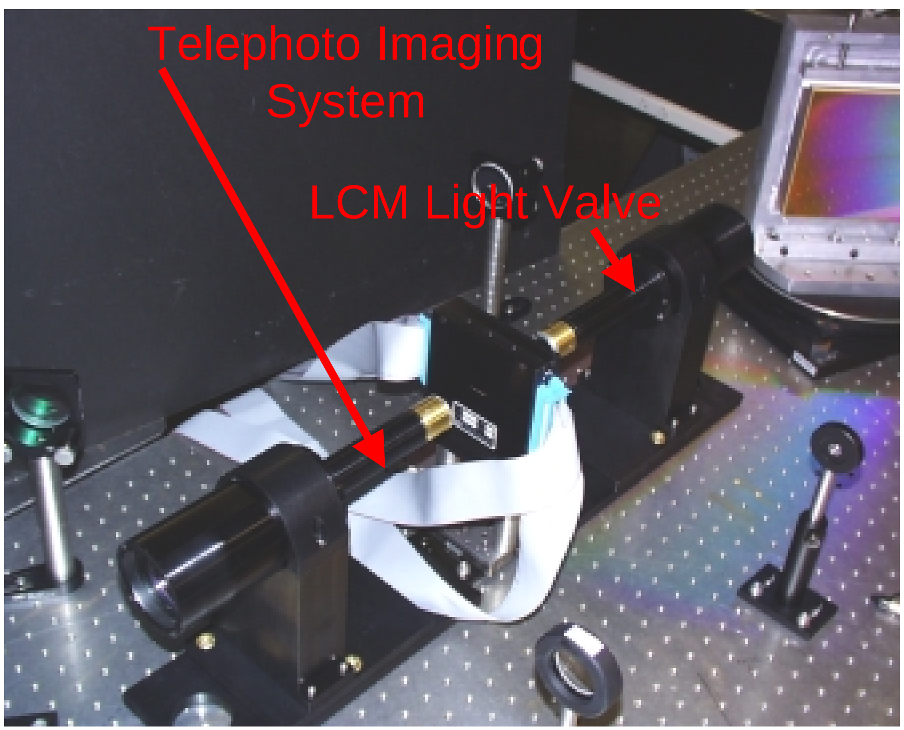

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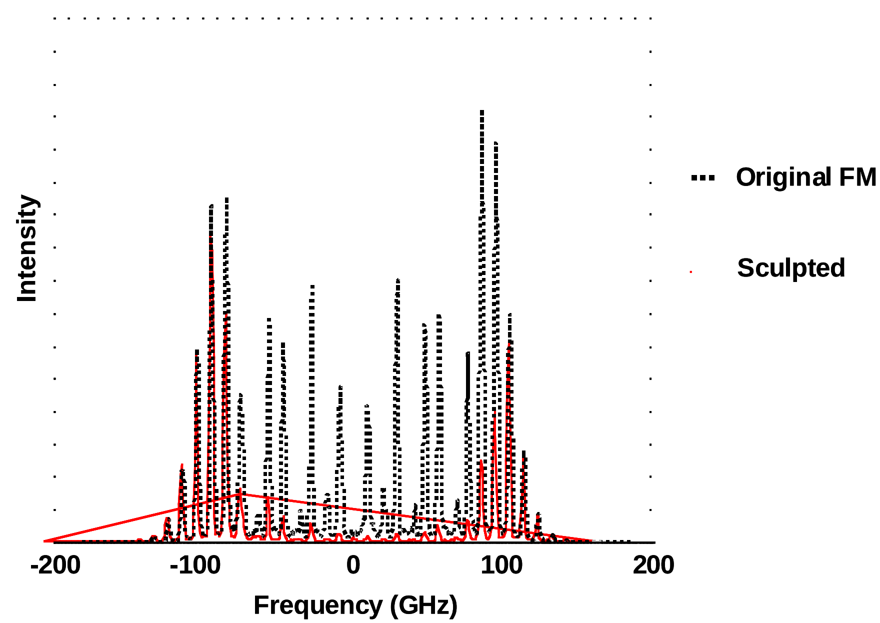
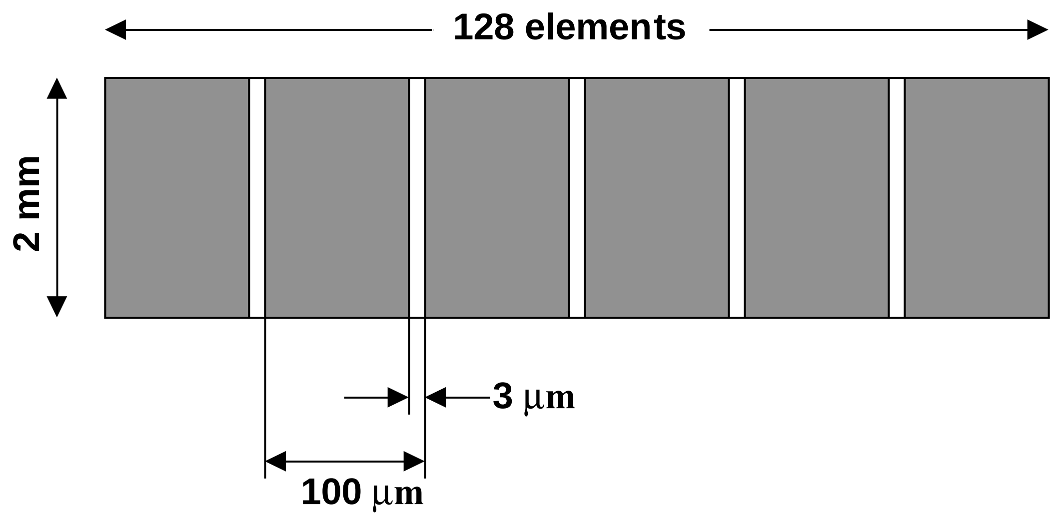
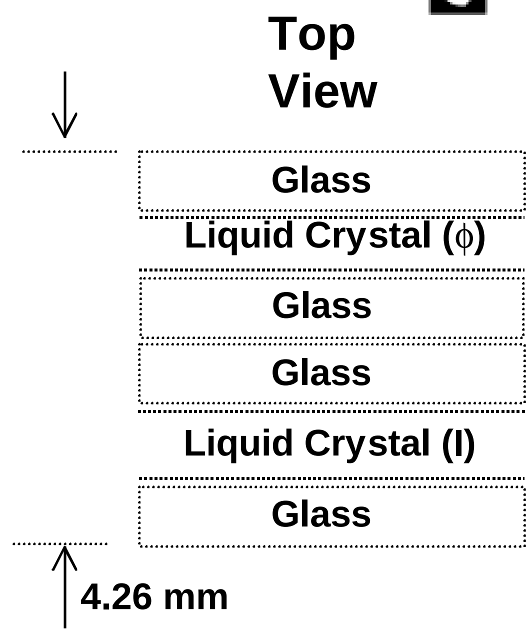
- Telephoto imaging system
  EFL ~ 800 mm



The spectral sculptor uses a liquid-crystal modulator light valve





- Commercially available unit uses two 128 pixel liquid-crystal modulators.
- Each pixel serves as a computer controllable amplitude and phase mask for a single FM sideband.

Summary

Milestone budget breakout:

• $3030k	Build two pump delivery systems
• $1800k	Fabricate Yb:S-FAP crystals
• $825k	Design and build wedged amplifier head
• $1025k	Build injection and reverser hardware
• $1270k	Integrated tests and code benchmarking
• $300k	Advanced Yb:S-FAP growth
• $350k	(LLE) Spectral sculpting experiments and evaluation of average-power frequency conversion design

We are on schedule to build half Mercury in FY01