Status of High-Power Laser Development at Stanford

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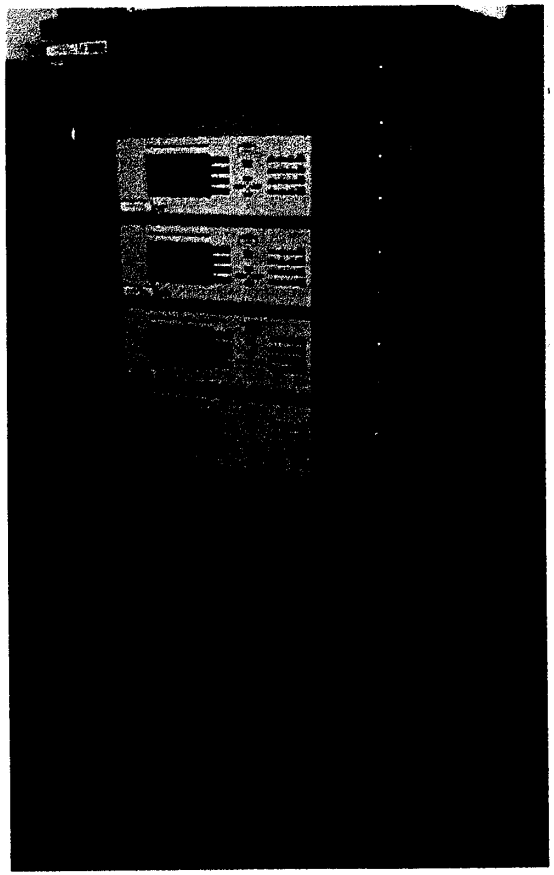
Outline

- Review
- Progress since last Hanford LSC
  - Completed Installation of new diodes
  - Preliminary experiments on Nd:YAG Amplifiers
  - (Near) Future Work

Laser diode upgrade

Laser diodes

- Manufacturer: Coherent
- 30 W each
- 808 nm
- Fiber coupled
  - 400 μm core
  - 0.2 NA
- 24 units
- 720 W total



Power Supplies

- Manufacturer: Newport
- 100 A, 14 V
  - Drive 6 bars in series
- Temperature Control
  - PID controllers
  - TEC drivers
- GPIB/RS-232
- Fault protection

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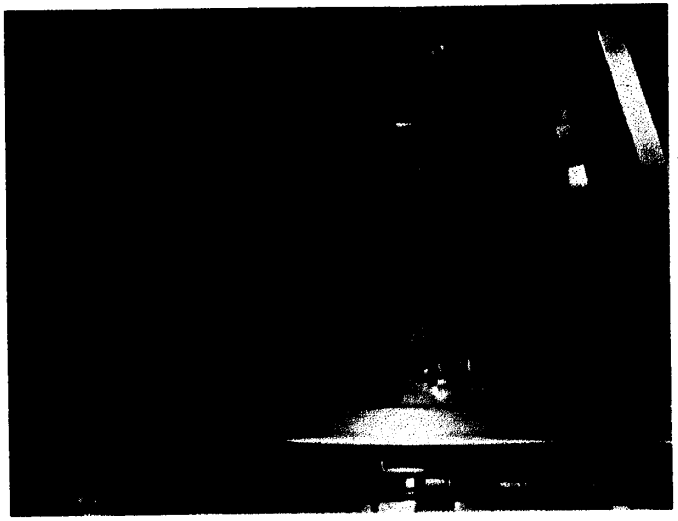
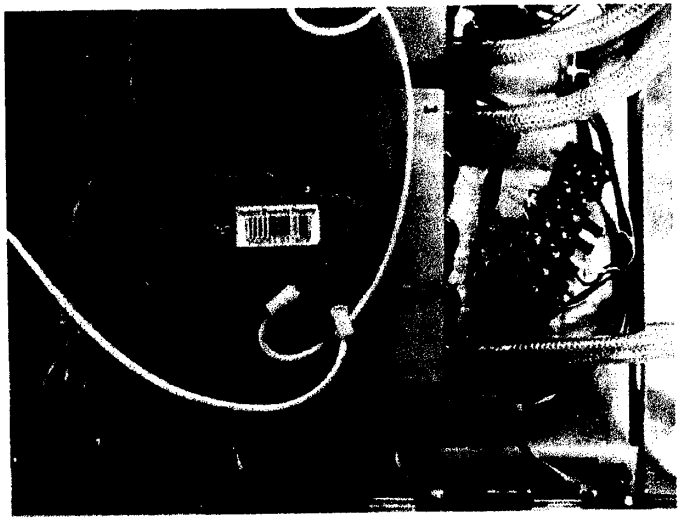
Installation Complete



-Labview control of diode:
  -Current
  -Voltage
  -Temperature
-Interlocks



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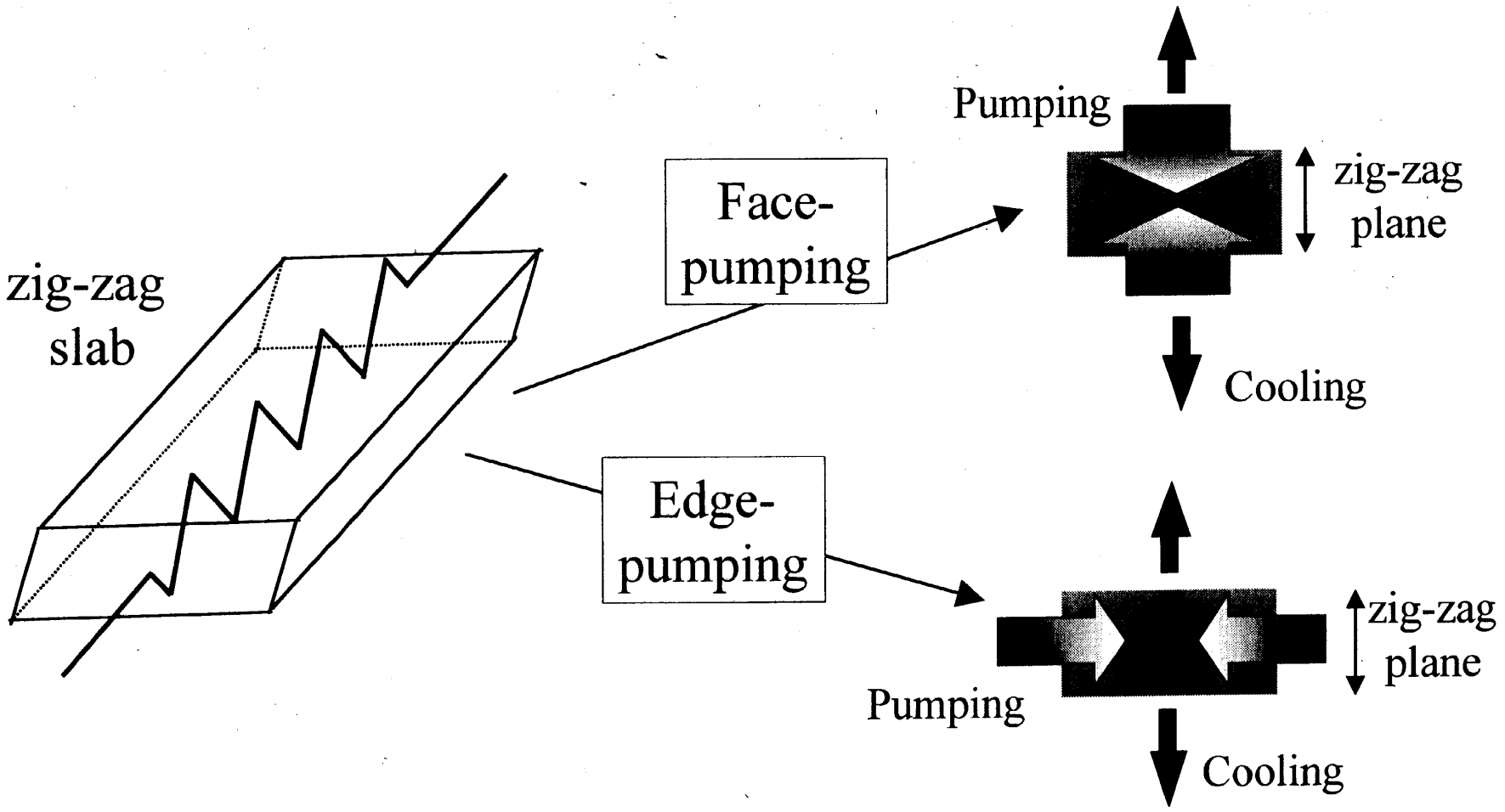
Amplification Goal: 100 W

- Two zig-zag edge-pumped slab amplifiers
  - Brewster ends
  - 3:1 aspect ratio (width/thickness)
- About 900 W total pump power
- Use 20 W injection locked GEO as master oscillator

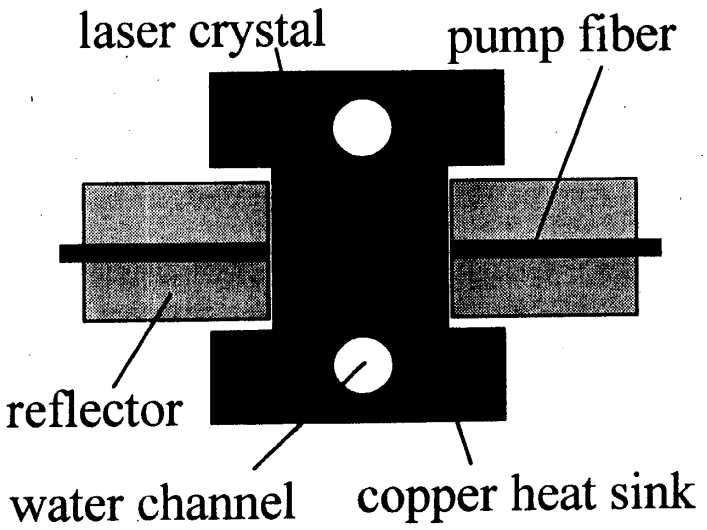
Face-pumping vs Edge-pumping



Edge-Pumping Pros and Cons

Advantages

- **Symmetric conduction-cooling**
- **Separate pumping and cooling interfaces**
- **Pump absorption and thermal characteristics both improve with width**
- **Power scales with area of cooled TIR faces**



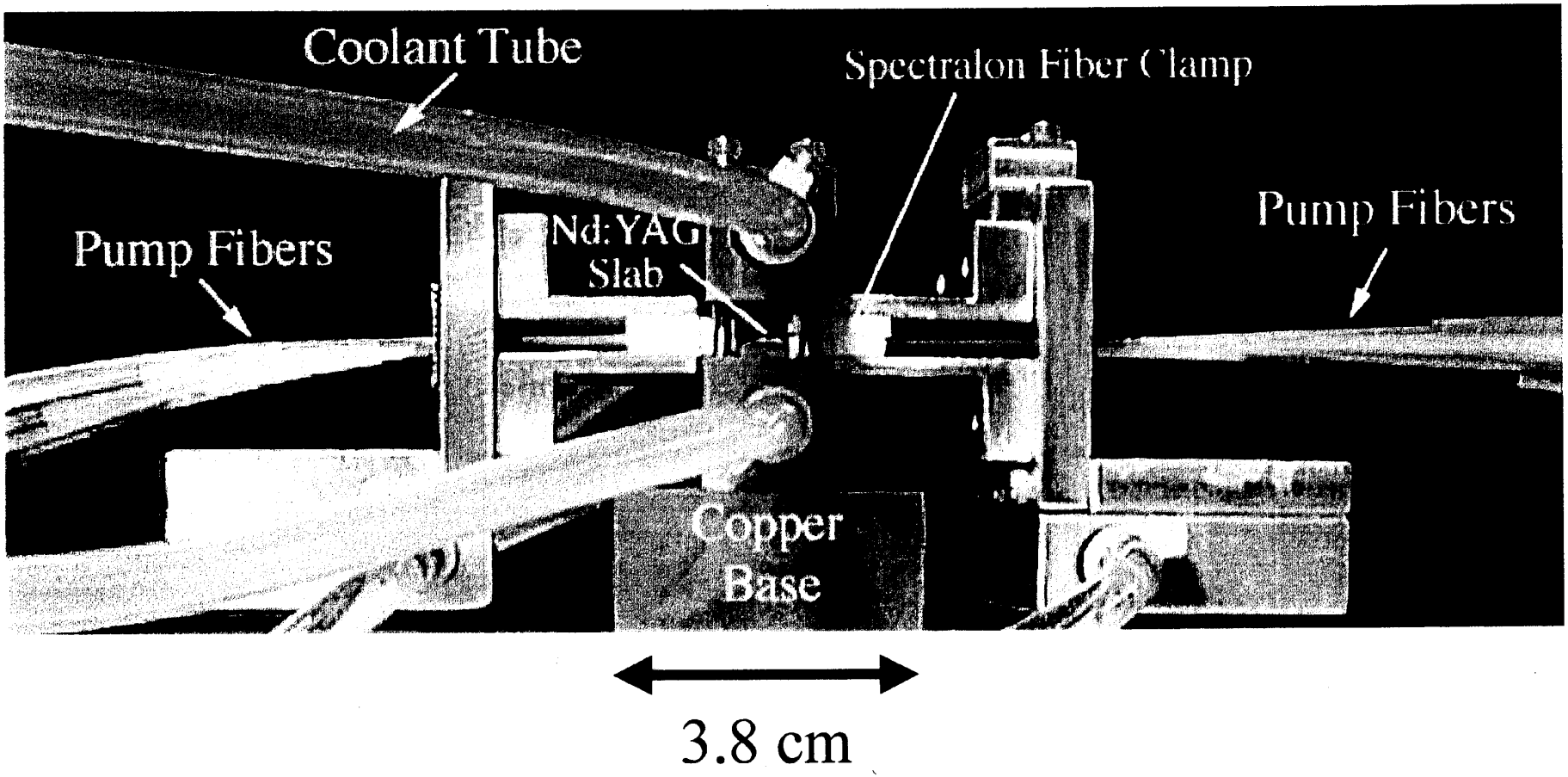
Disadvantages

- **TIR interface is also conduction cooling interface** → Protect with 2.5 μm thick SiO_2 coating
- **Small thermal gradient in pumping direction** → Small compared to other effects
- **Six polished faces: parasitic oscillations** → Correct choice of slab dimensions/angles

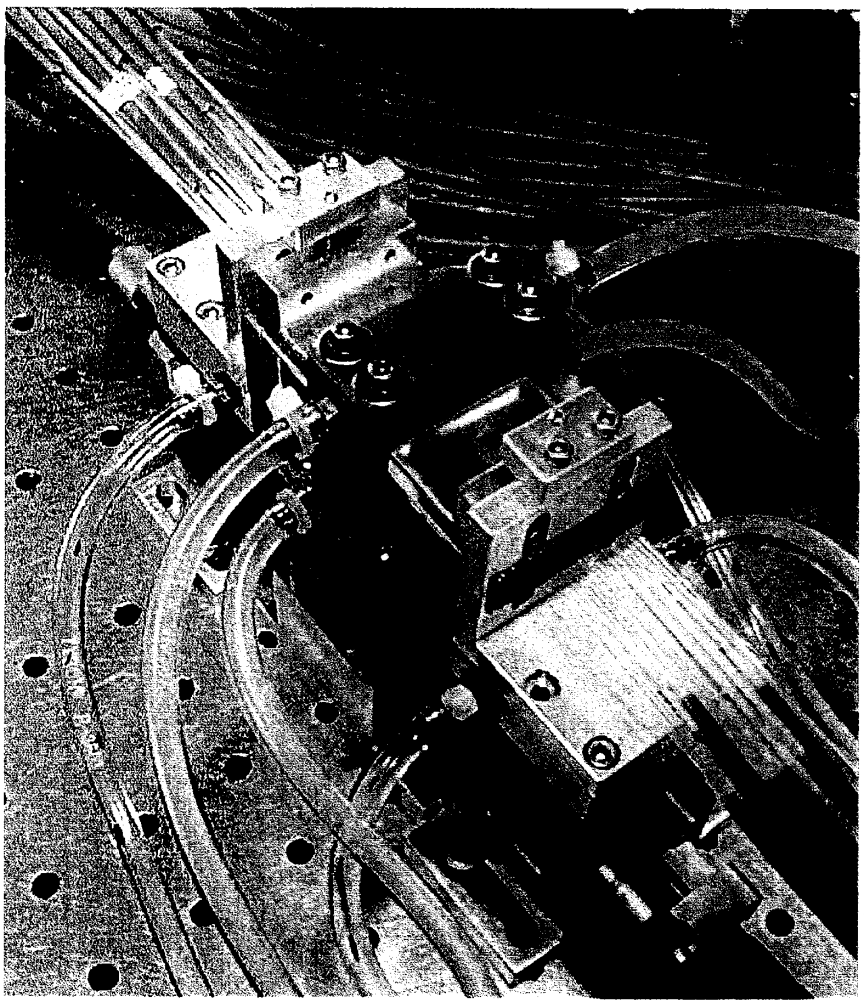
Power Scaling

- Slabs scale in power with the product of width and length
- Edge-pumped slabs
  - Reduce thickness without sacrificing pump absorption
  - Lower doping when width increases
    - Higher quality crystal growth
  - Symmetric cooling
- Constraints
  - ASE/parasitics
    - Limit length
  - Pump intensity
  - Thermal distortions
  - Stress fracture

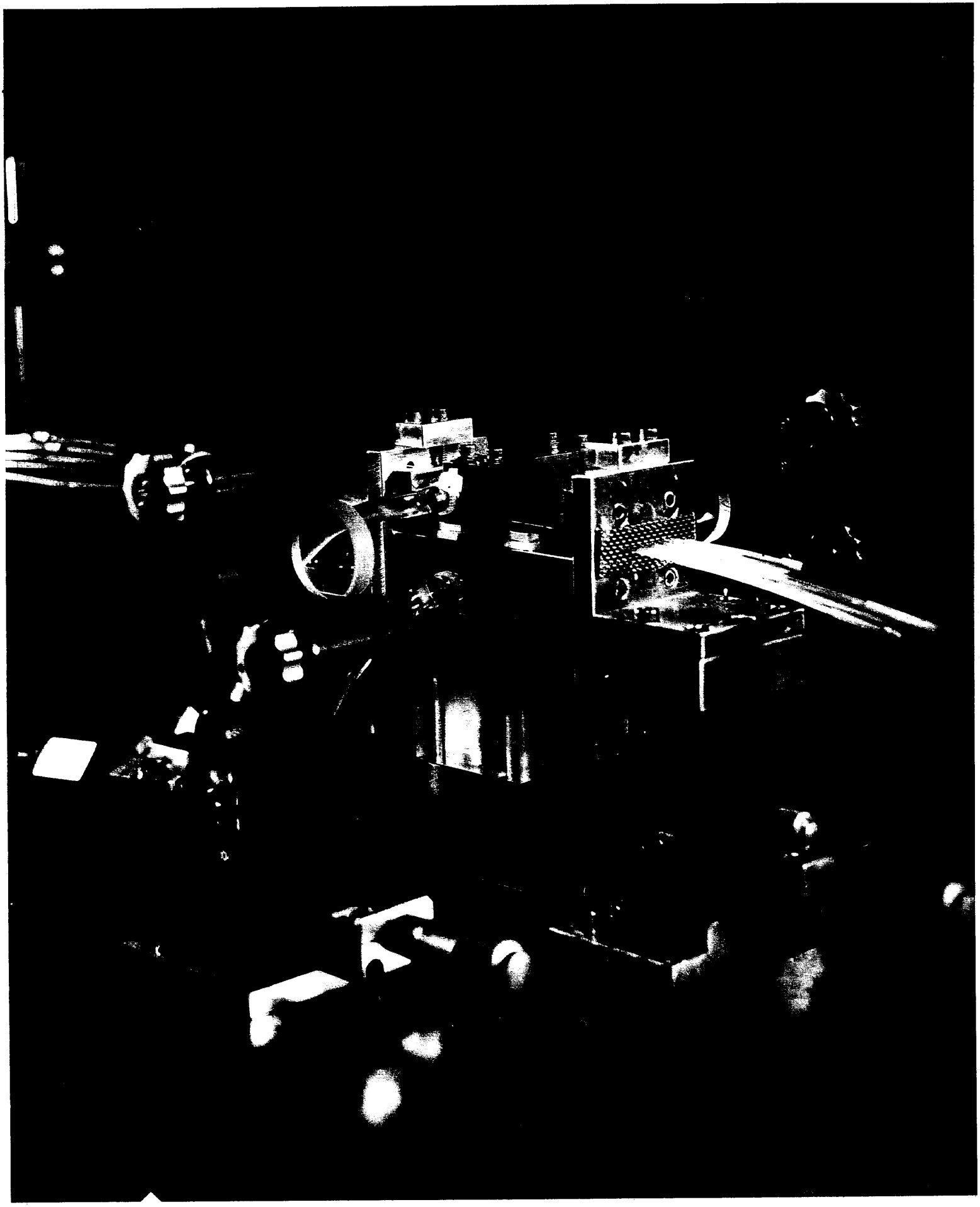
Nd:YAG testbed



Edge-Pumped Zig-Zag Slab Laser
3:1 Aspect Ratio

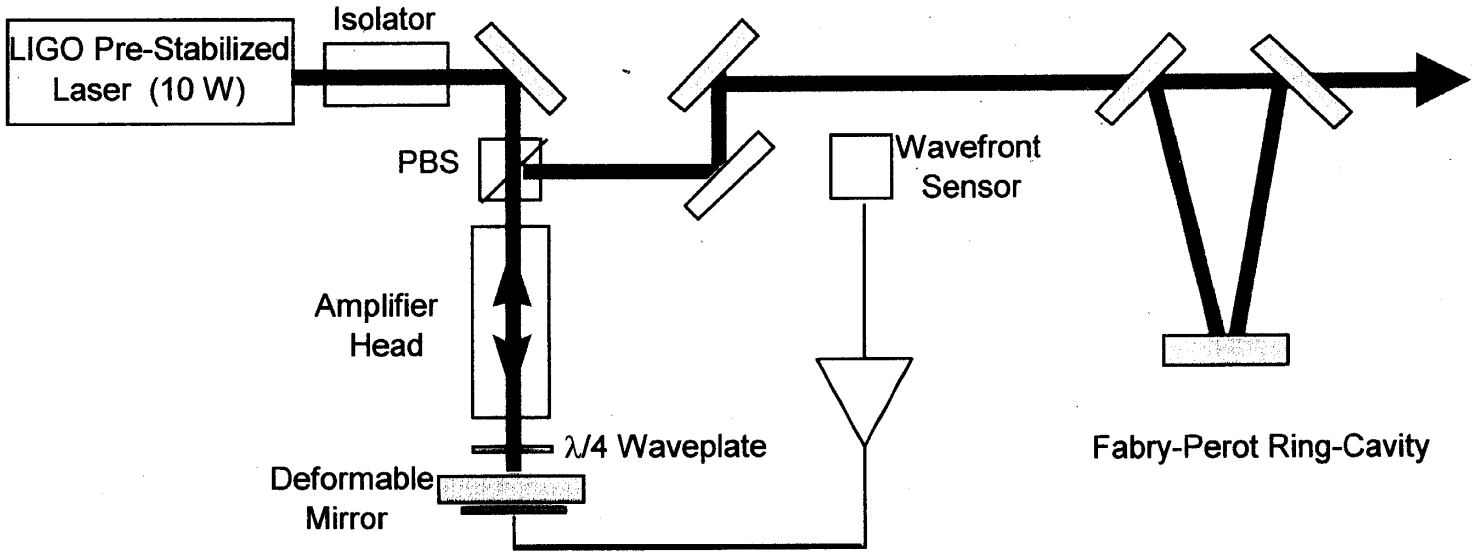


- 127 W Multimode Output
- 300 W Pump Power
- 55% Slope Efficiency



Stanford LIGO II - Prototype Laser Design

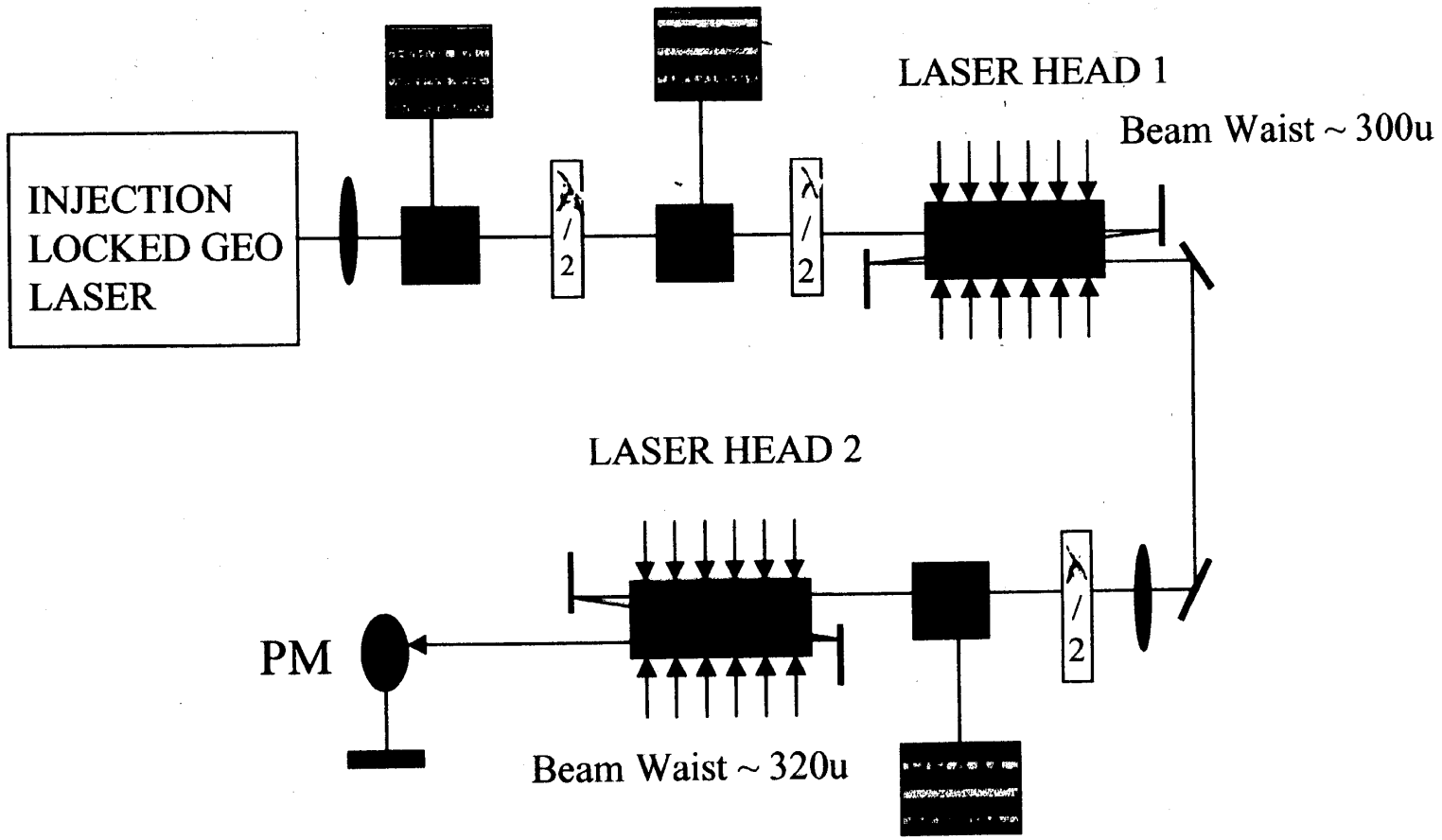
High Power Master-Oscillator Power-Amplifier



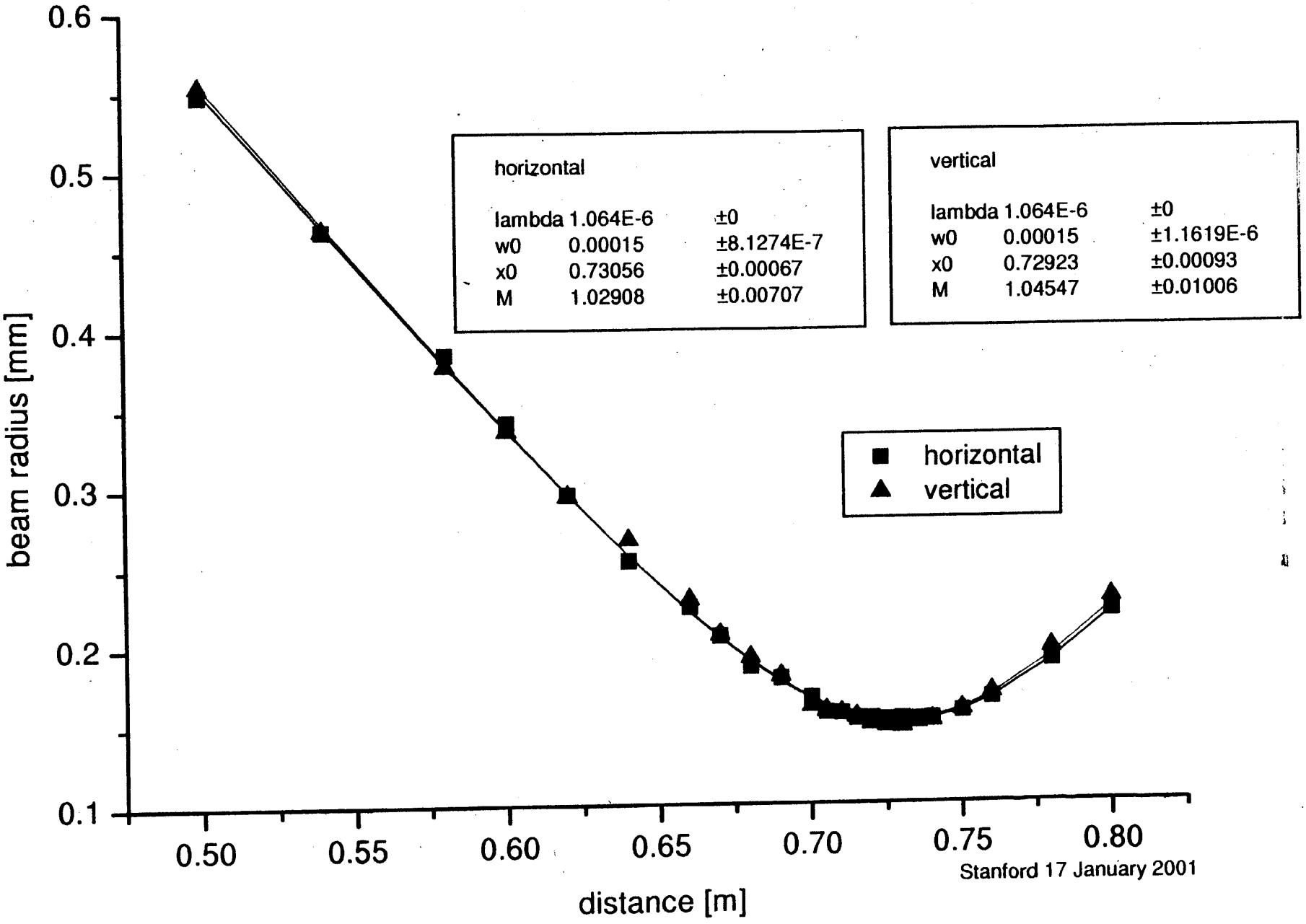
- Modular, easy to scale
- Coherence Control
- Spatial Mode Control
- Soft Failure Mode

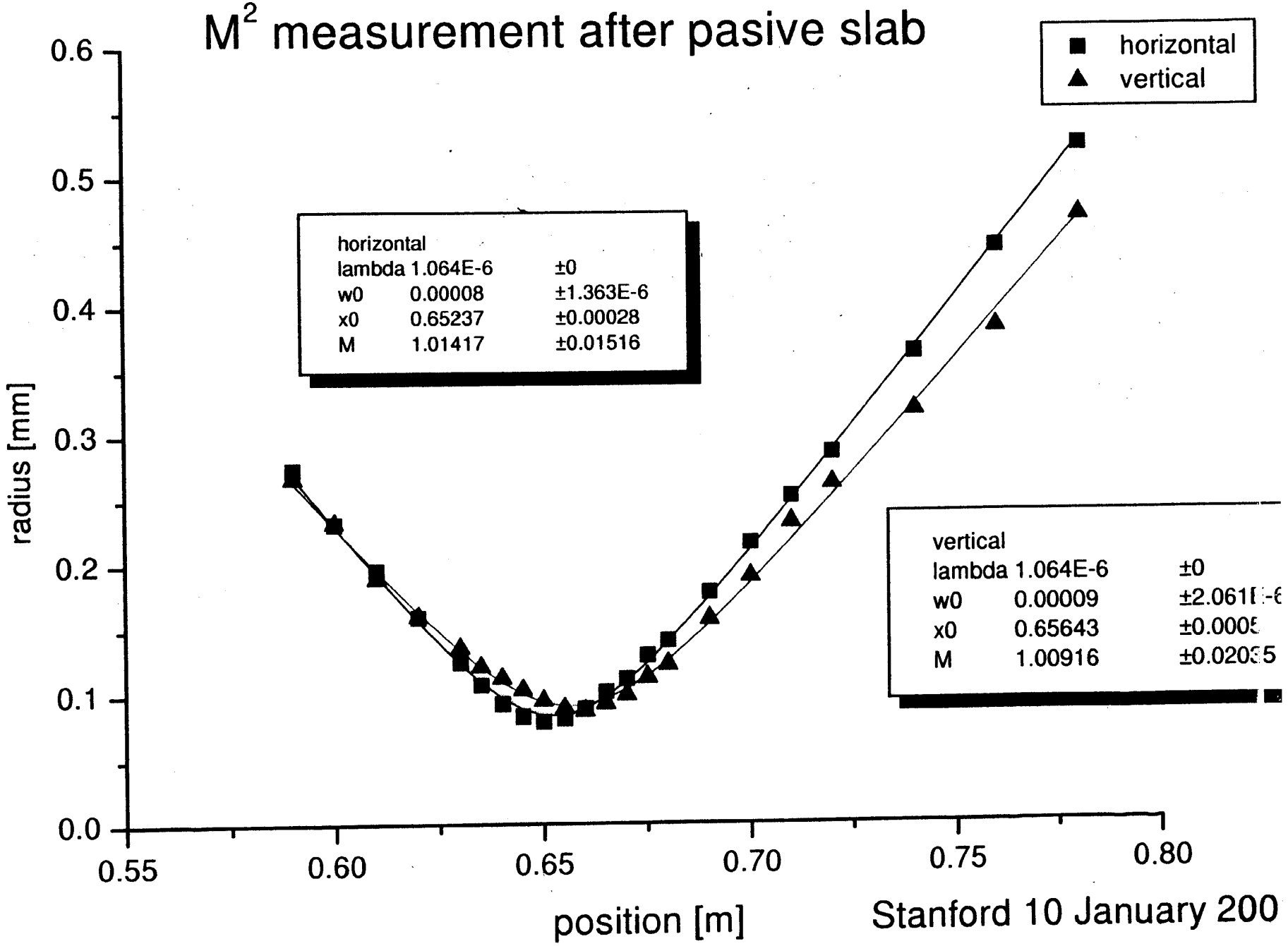
- **Amplifier Power Noise**
- Extraction Efficiency
- Mode Distortion

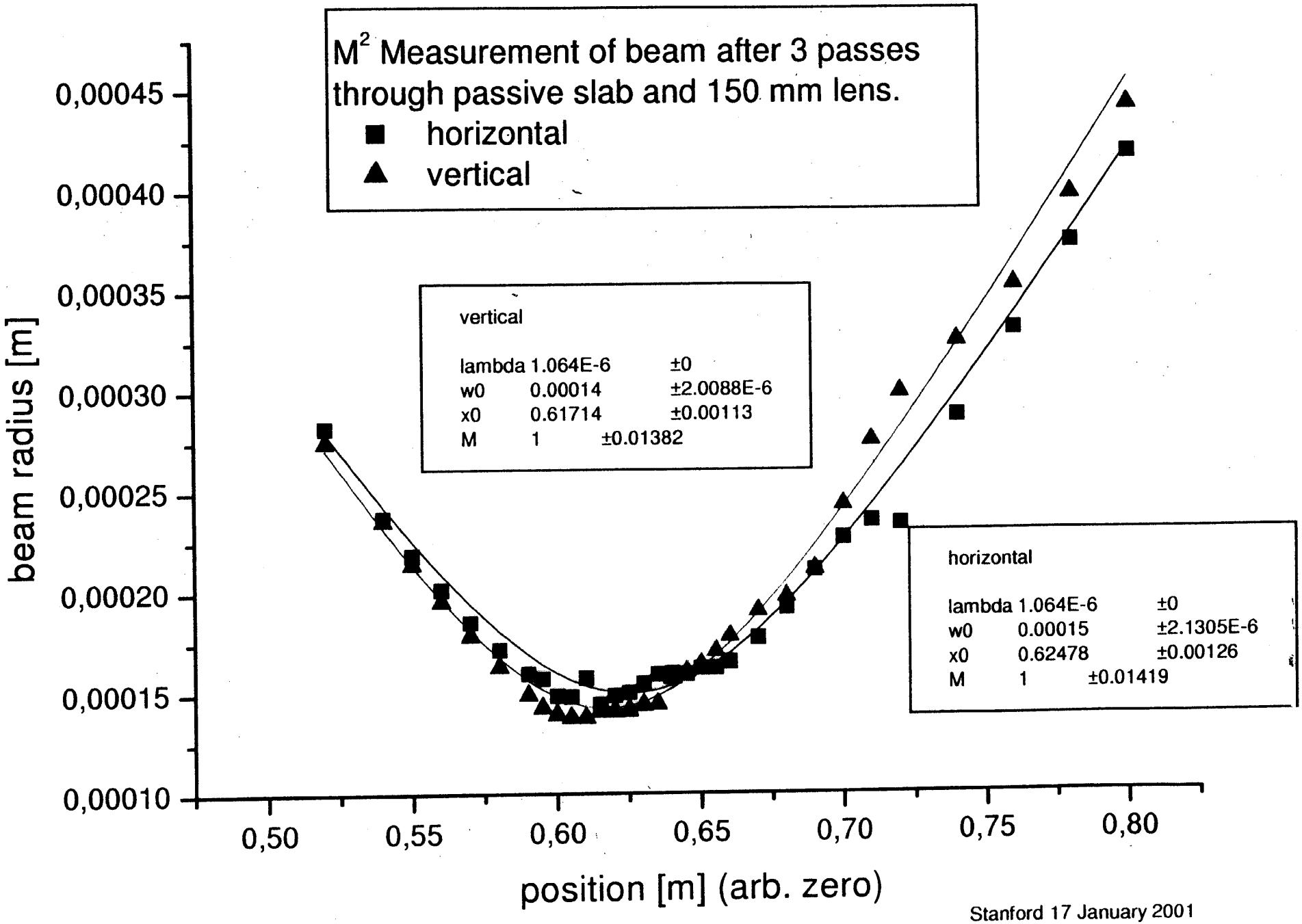
EXPERIMENTAL SETUP

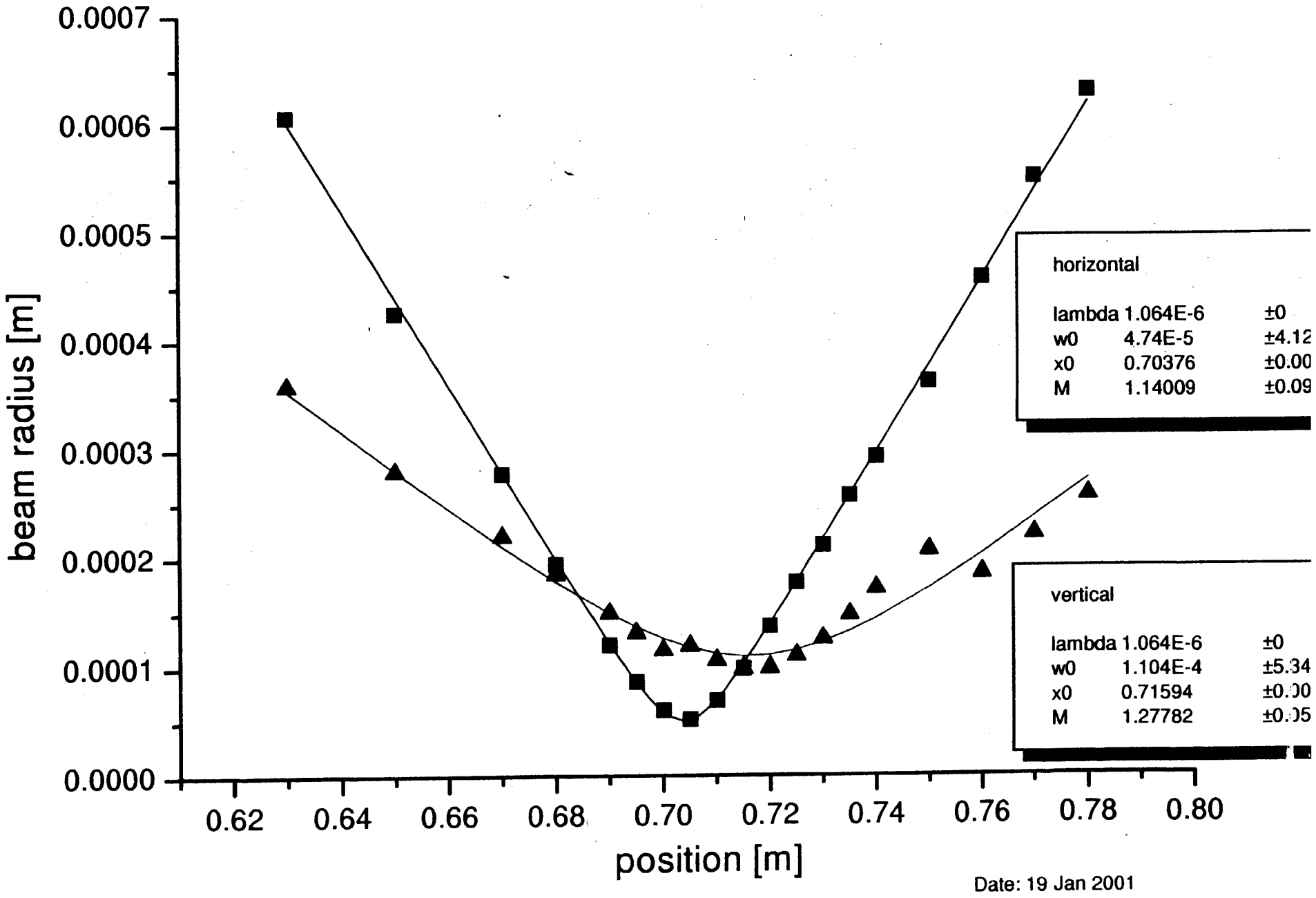


Stanford High Power lasers lab.

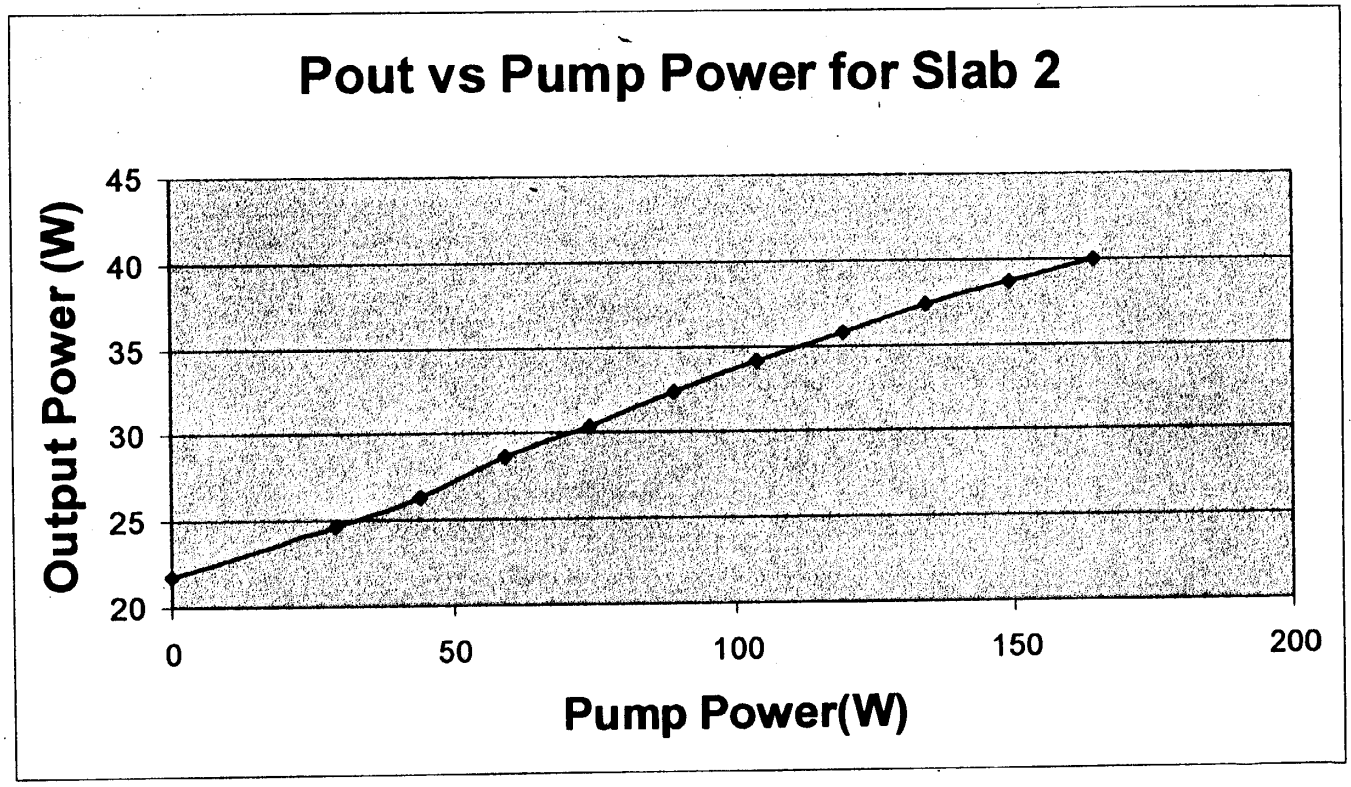

M² measurement of GEO ILO
horizontal
lambda 1.064E-6 ±0
w0 0.00015 ±8.1274E-7
x0 0.73056 ±0.00067
M 1.02908 ±0.00707
vertical
lambda 1.064E-6 ±0
w0 0.00015 ±1.1619E-6
x0 0.72923 ±0.00093
M 1.04547 ±0.01006
horizontal
vertical
beam radius [mm]
0.6
0.5
0.4
0.3
0.2
0.1
0.50
0.55
0.60
0.65
0.70
0.75
0.80
distance [m]
Stanford 17 January 2001


M2 measurement after pasive slab
horizontal
vertical
horizontal
lambda 1.064E-6 ±0
w0 0.00008 ±1.363E-6
x0 0.65237 ±0.00028
M 1.01417 ±0.01516
vertical
lambda 1.064E-6 ±0
w0 0.00009 ±2.061E-6
x0 0.65643 ±0.0005
M 1.00916 ±0.02035
radius [mm]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.55
0.60
0.65
0.70
0.75
0.80
position [m]
Stanford 10 January 200


M² Measurement of beam after 3 passes through passive slab and 150 mm lens.
horizontal
vertical
vertical
lambda 1.064E-6 ±0
w0 0.00014 ±2.0088E-6
x0 0.61714 ±0.00113
M 1 ±0.01382
horizontal
lambda 1.064E-6 ±0
w0 0.00015 ±2.1305E-6
x0 0.62478 ±0.00126
M 1 ±0.01419
beam radius [m]
0,00045
0,00040
0,00035
0,00030
0,00025
0,00020
0,00015
0,00010
0,50
0,55
0,60
0,65
0,70
0,75
0,80
position [m] (arb. zero)
Stanford 17 January 2001


M² measurment after hot slab
@ 60% pump and full input (102° polarizer corr. 12.2 W cold troughp.)
beam radius [m]
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
0.62
0.64
0.66
0.68
0.70
0.72
0.74
0.76
0.78
0.80
position [m]
horizontal
lambda 1.064E-6 ±0
w0 4.74E-5 ±4.12
x0 0.70376 ±0.00
M 1.14009 ±0.09
vertical
lambda 1.064E-6 ±0
w0 1.104E-4 ±5.34
x0 0.71594 ±0.00
M 1.27782 ±0.05
Date: 19 Jan 2001

Power Measurements after second slab



Fitted data to $G = G_0 \times \exp[-(I_{out}-I_{in})/I_{sat}]$
Isat ~ 3.5KW/cm2 close to published values for Nd:YAG.

PROBLEMS ENCOUNTERED

- Grease/contamination problems with the second slab caused power loss and unstable operation in the second slab.
- Beam Scan broke down.
- Experiment interrupted by ASSL.
- Slab 2 coating damaged in a couple of spots due to fiber burn.

Near term future work

- Restart amplification experiments and demonstrate 100 W, diffraction limited power using 2 edge-pumped slab amplifiers, and upgraded 10 W Lightwave LIGO laser.

- Place orders of slabs for end-pumped pre-amplifiers to 160 W of output power

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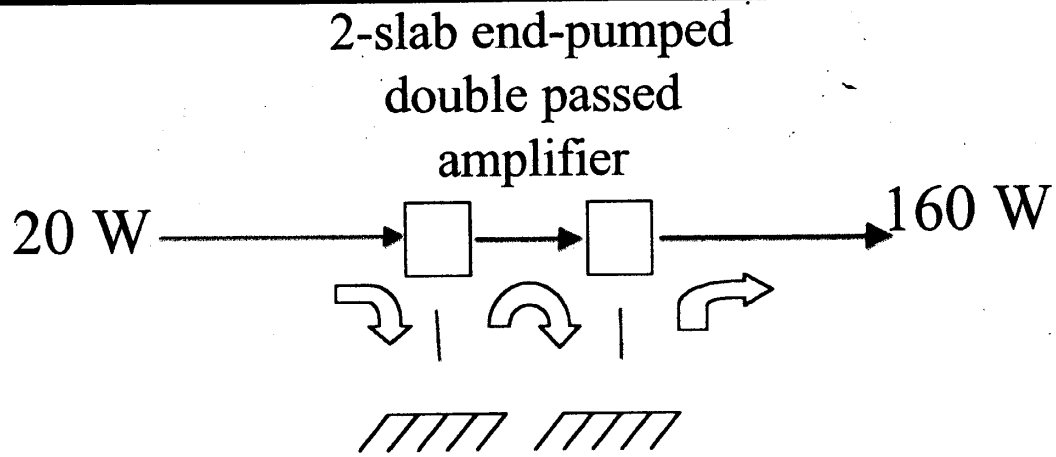
Pre-amplifier Design : End-pumping

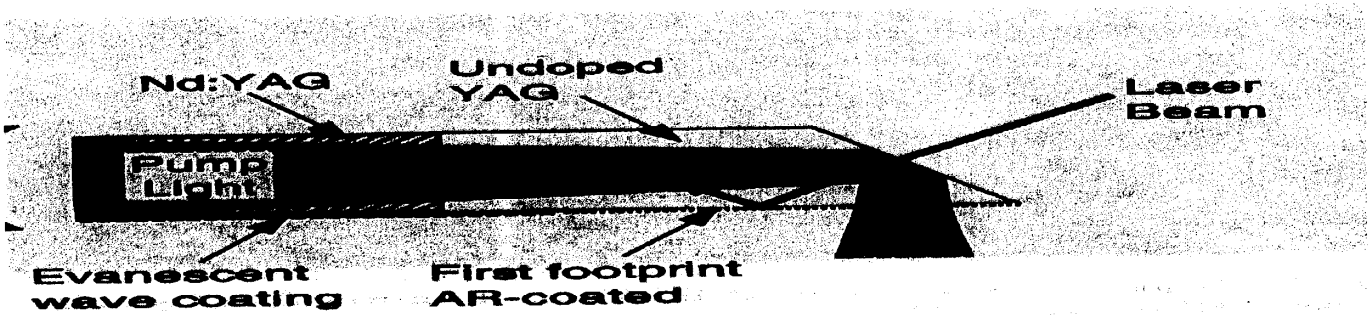


Slab Design Issues

1. Parasitic suppression
2. Pump light coupling and absorption

Crystal Dimensions

Width = 1.05 mm,
Length = 4.4 cm,
Thickness = 1.05 mm



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Expected MOPA System Performance

	Amplifier Pumping topology	*Pump Power (W)*	*Input Power (W)*	*Multi-mode Output Power (W)*	*TEM00 Output Power (W)*
Amplifier 1	*End-pumped slab*	*100*	*20*	*60*	*48*
Amplifier 2	*End-pumped slab*	*400*	*48*	*200*	*160*
Amplifier 3	*Edge-pumped slab*	*1400*	*160*	*500*	*400*

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