Status of high power laser development for LIGO at Stanford

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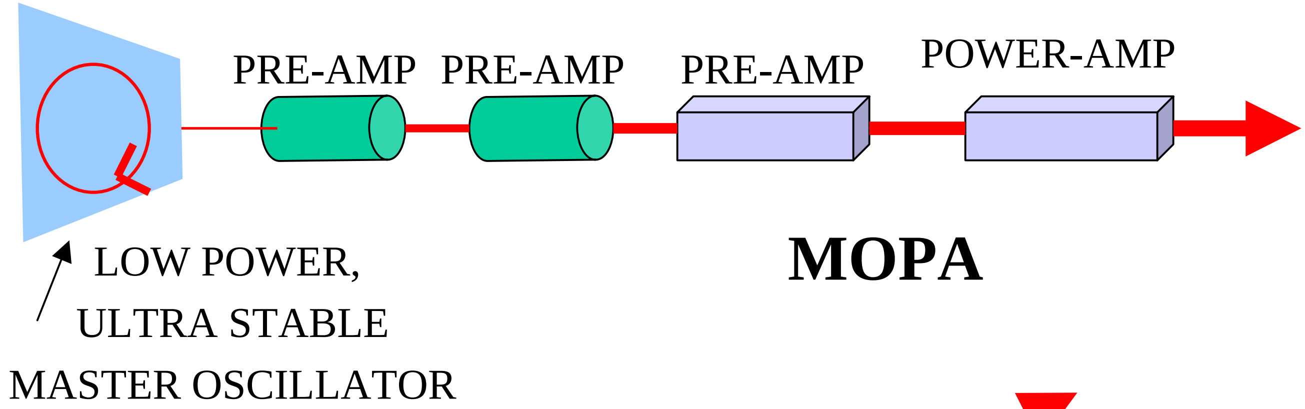
Outline

- Stanford approach to power scaling.
- Review of slab lasers.
- Experimental setup.
- 100W demonstration results.
- Scaling to 200W and beyond.
- Future work.

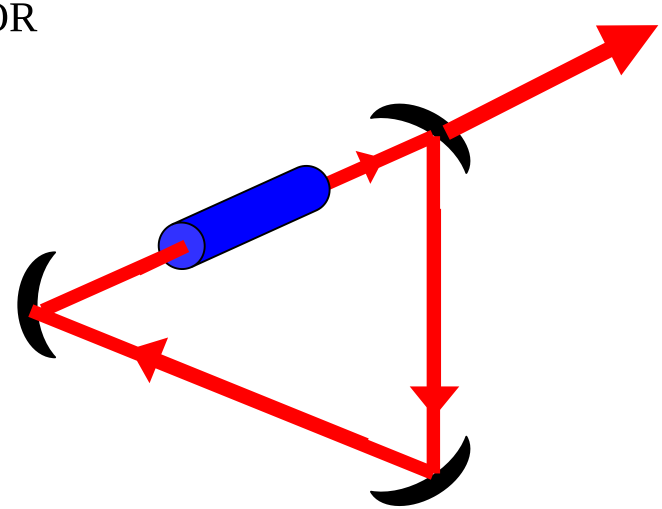
MOPA vs OSCILLATOR

- Rugged
- Scalable
- Single frequency
- Power available despite element failure.
- Less efficient.

- Difficult to control
- Single frequency operation involves injection locking.
- Element failure usually means zero power.
- More efficient.

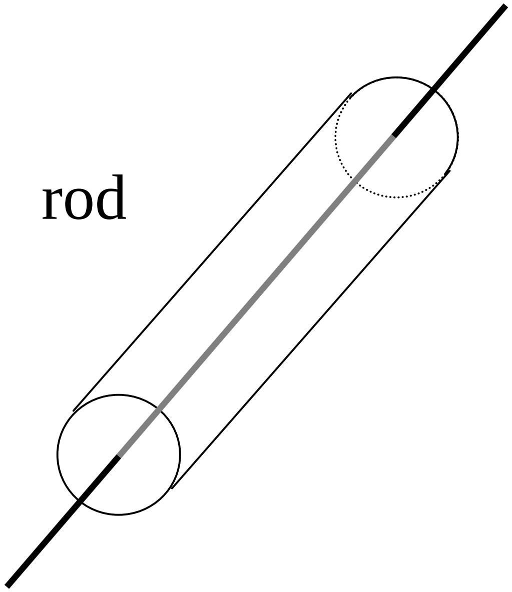


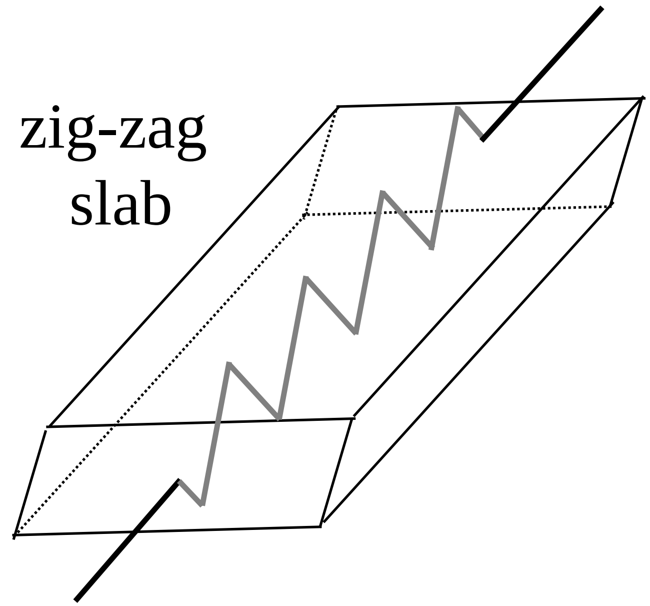
MOPA



OSCILLATOR

Rod vs Slab

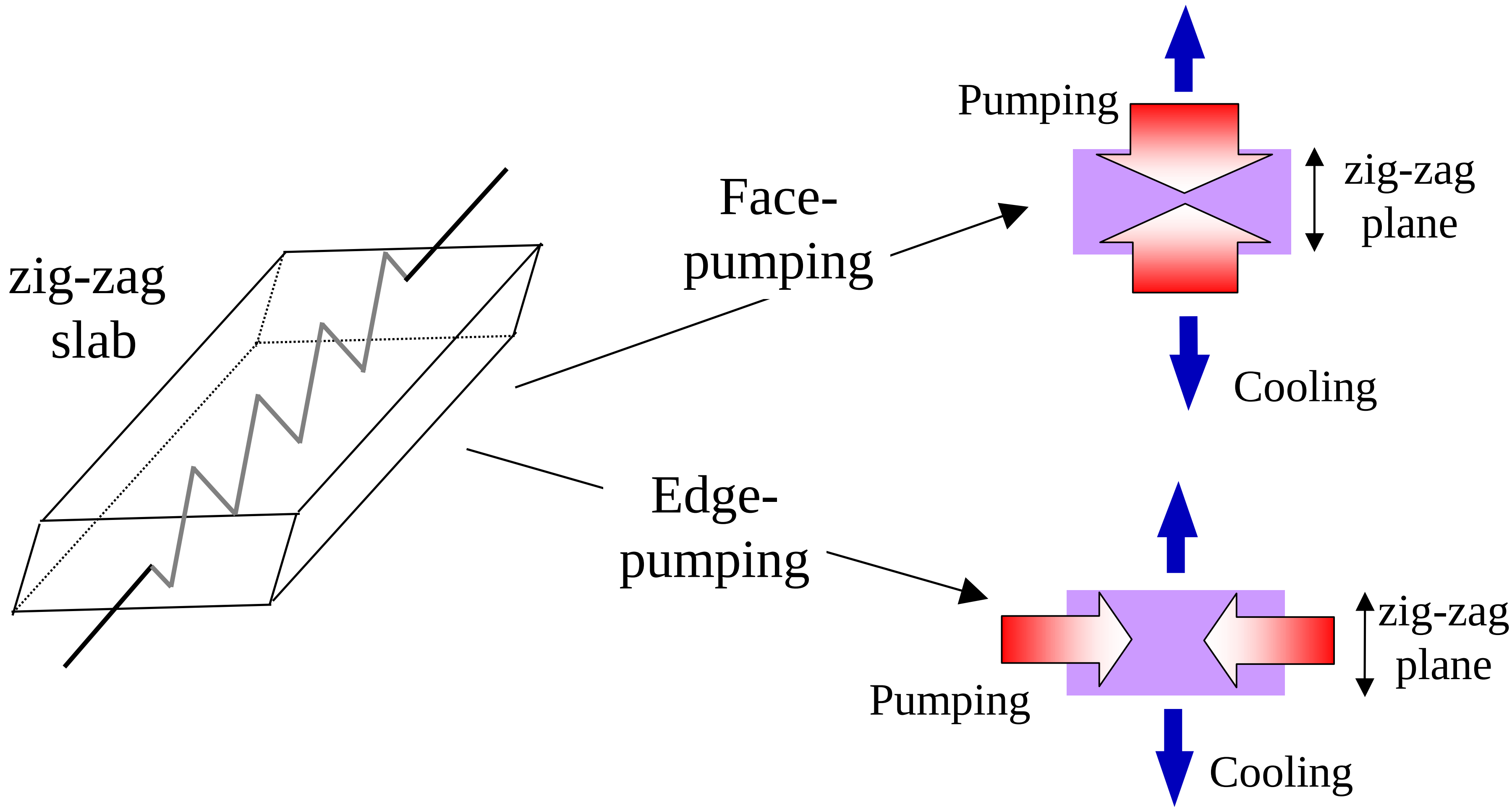




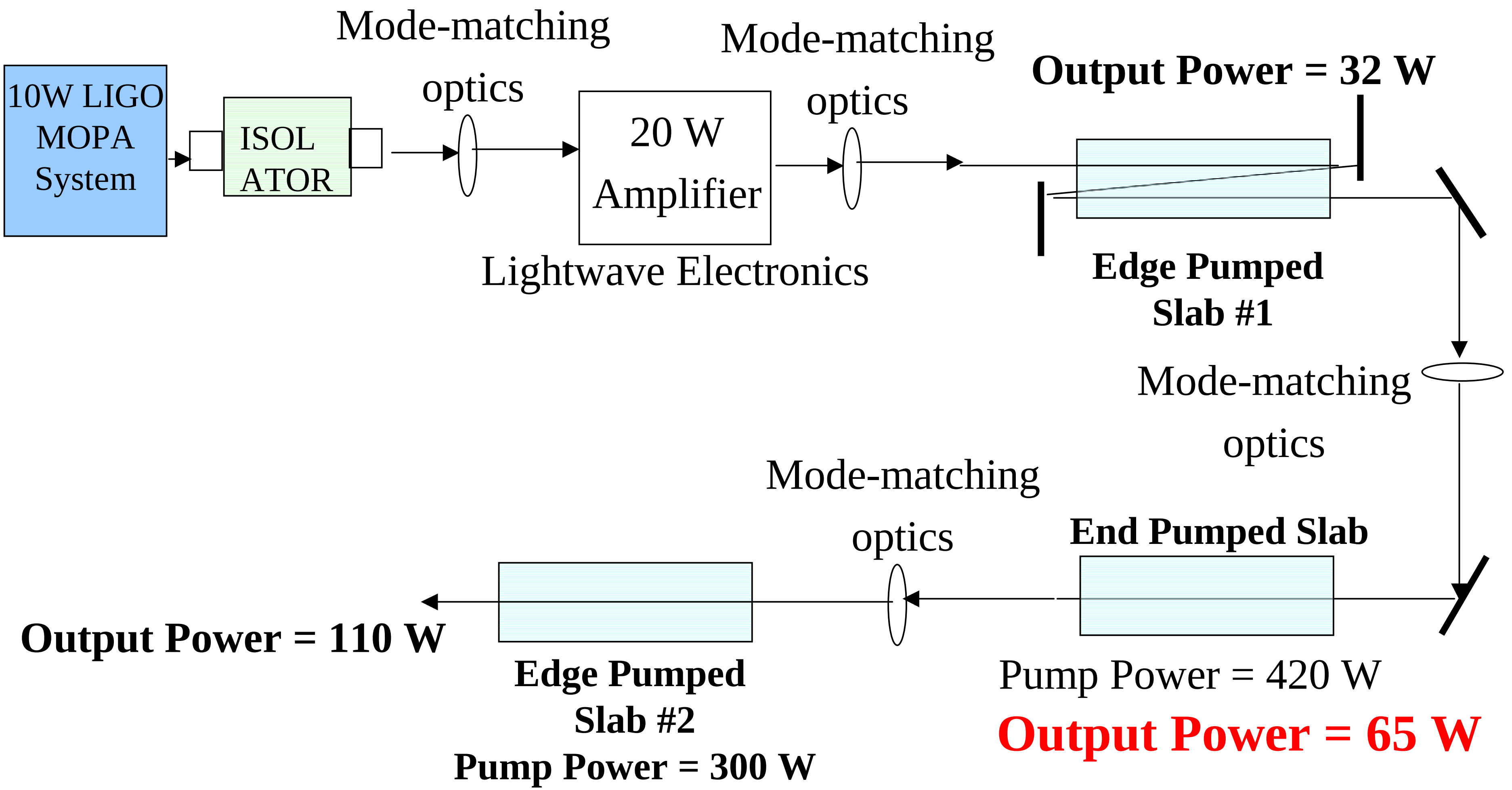
- 1^{st} order thermal lens
- Spatially dependent birefringence (depolarization)

- 2^{nd} order thermal distortions
- Slightly reduced mode-fill

Face-pumping vs Edge-pumping



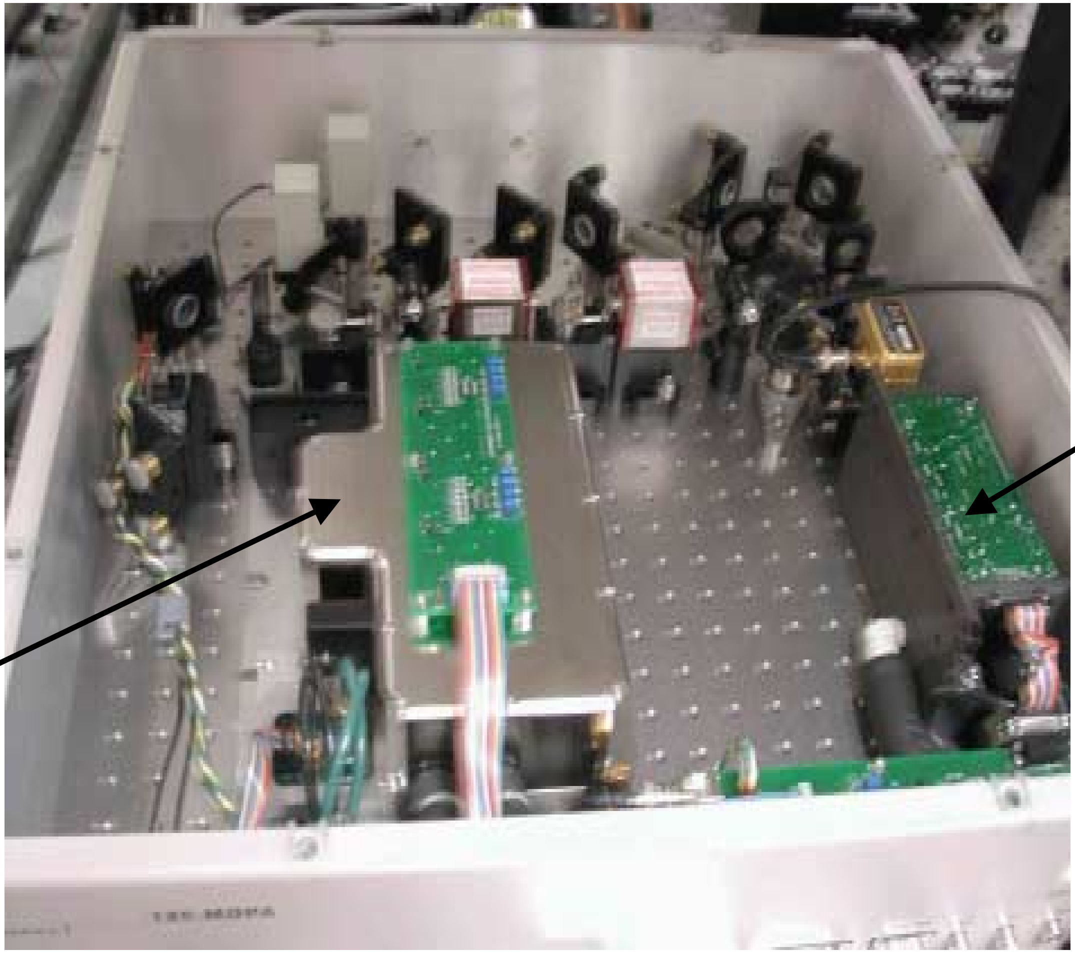
Experimental Setup for 100W demonstration



10W LIGO Laser

Characteristics:

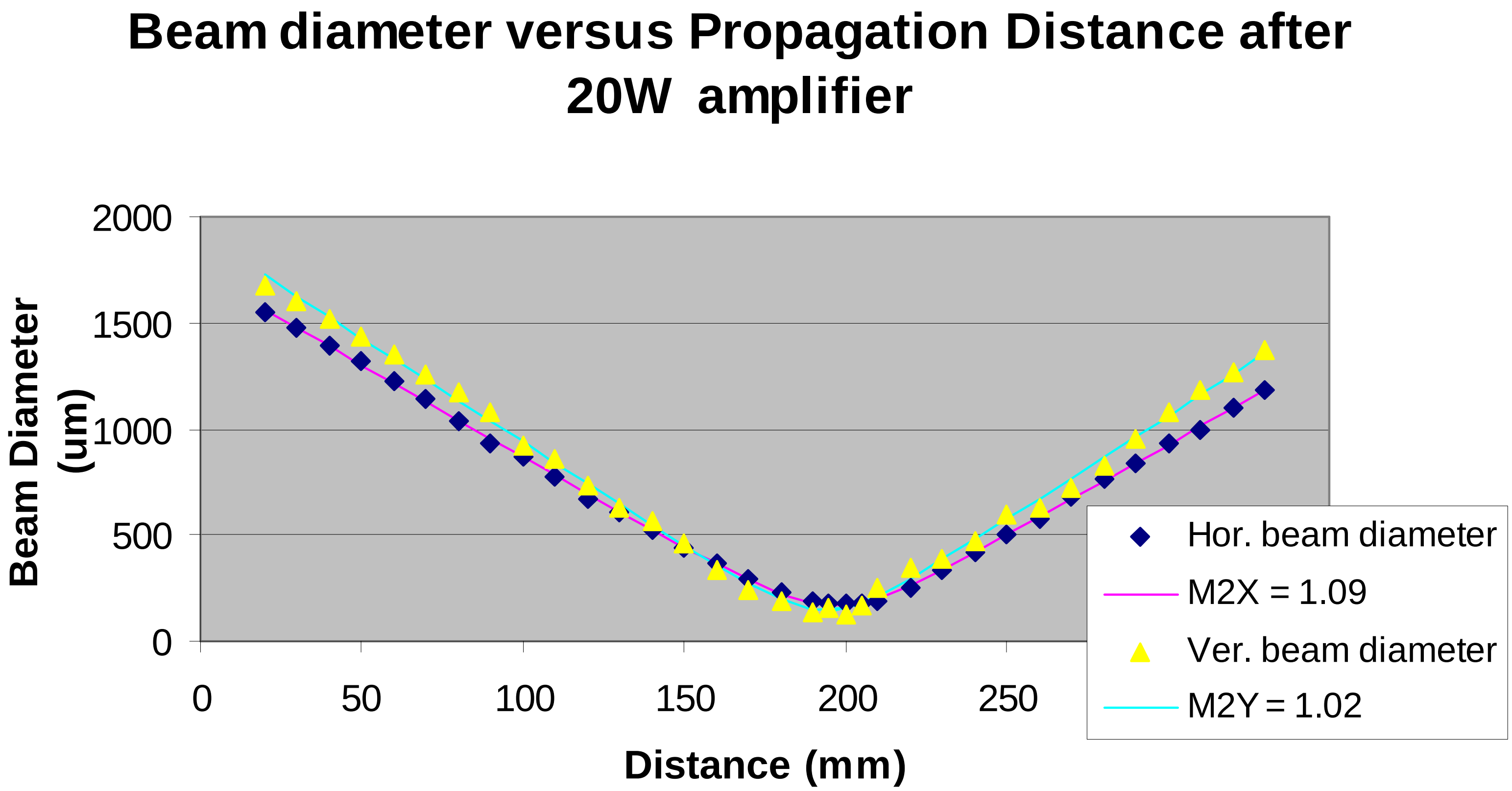
- Single frequency.
- TEM_{00}
- Narrow linewidth.
- Low frequency & amplitude noise.



10W Amplifier

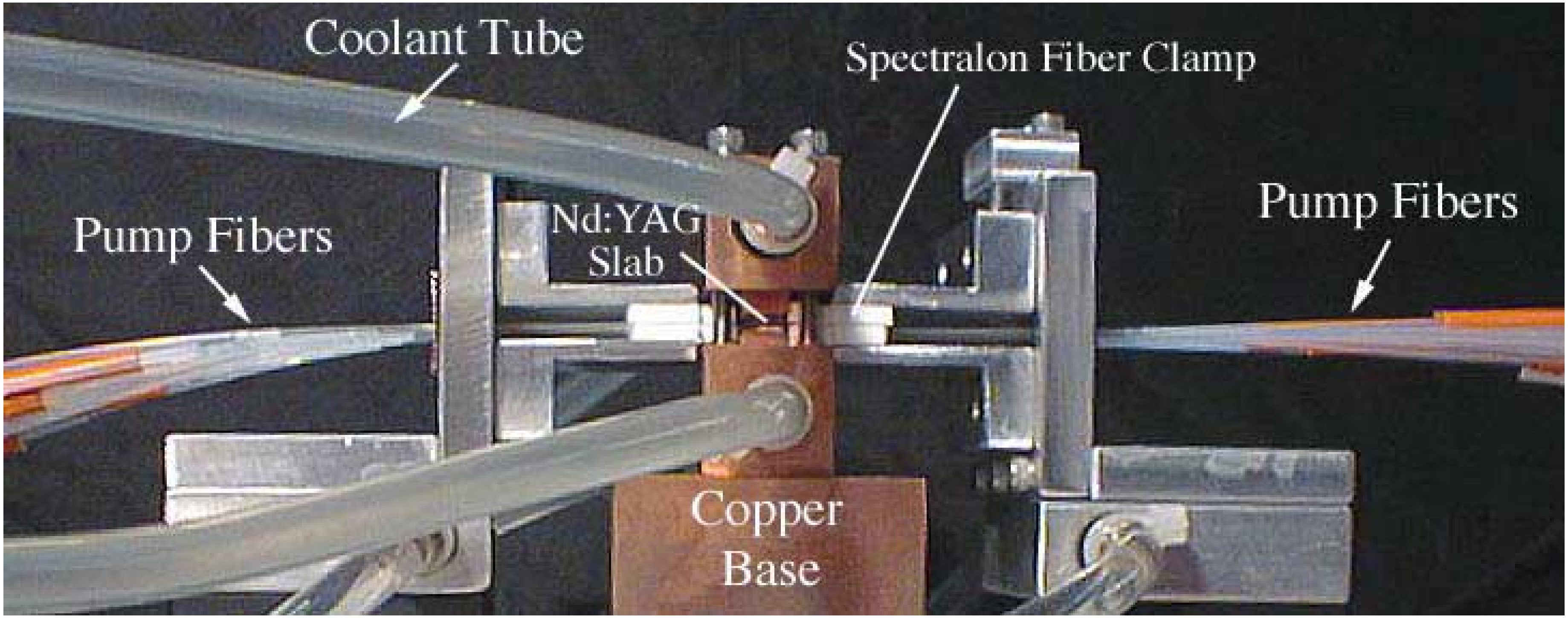
400mW NPRO

Beam quality after 20 W amplifier



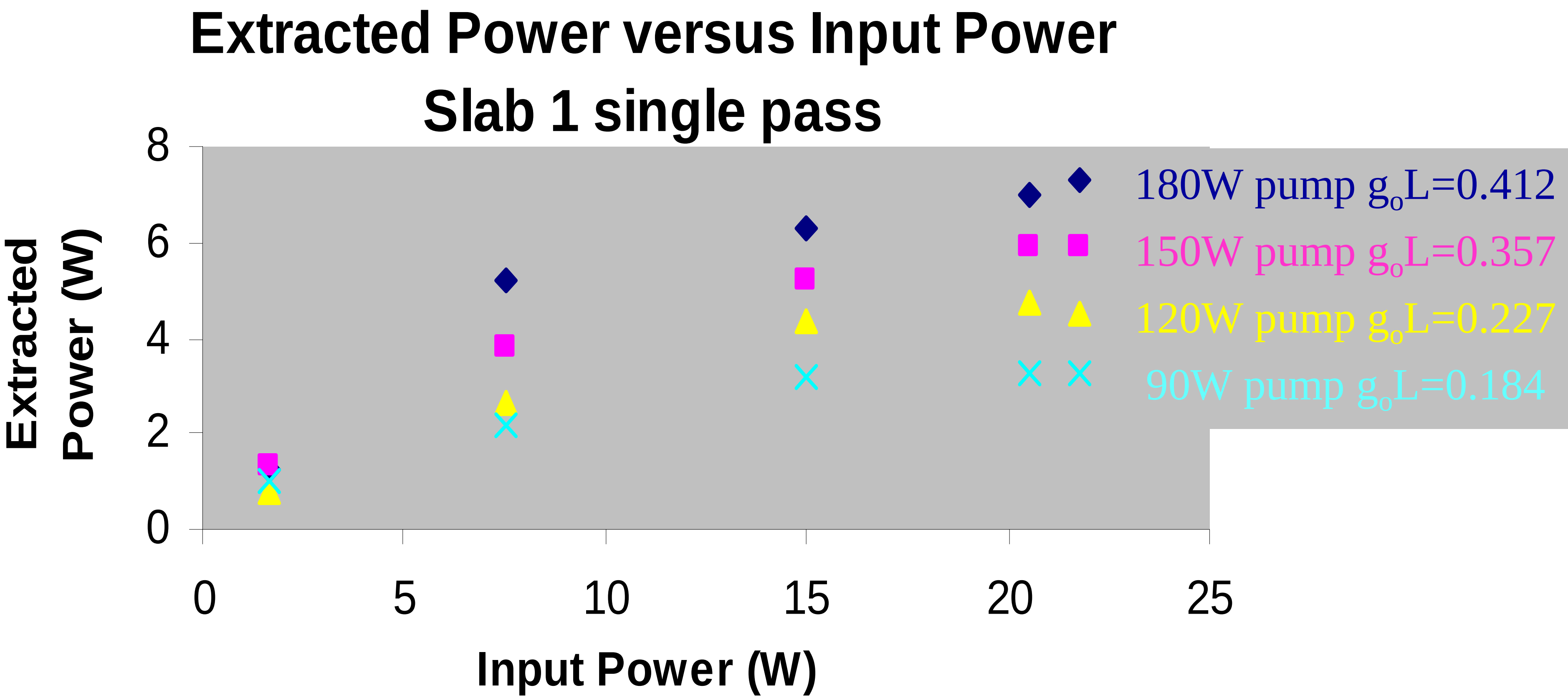
Measured output power ~ 23.5W.

Nd:YAG Laser Head



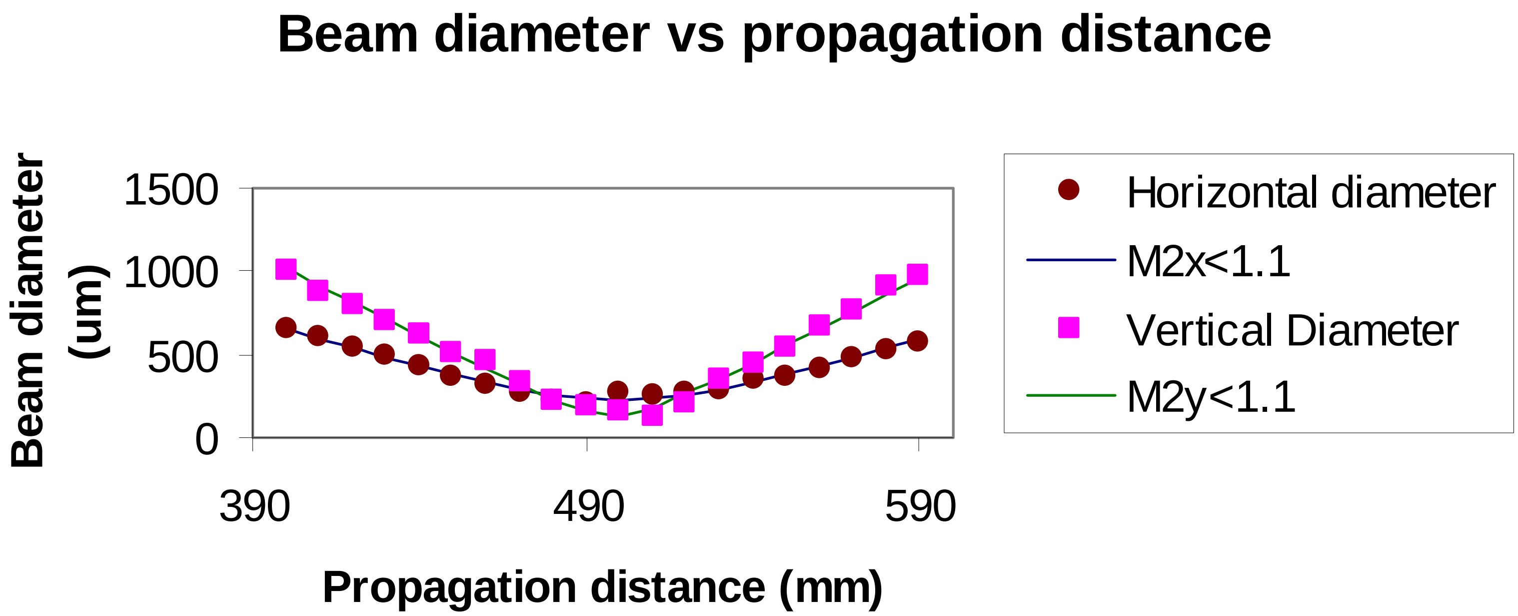
3.8 cm

Results for slab amplifier # 1



Output Power = Input Power + Extracted Power

Power and M^2 measurement after slab #1

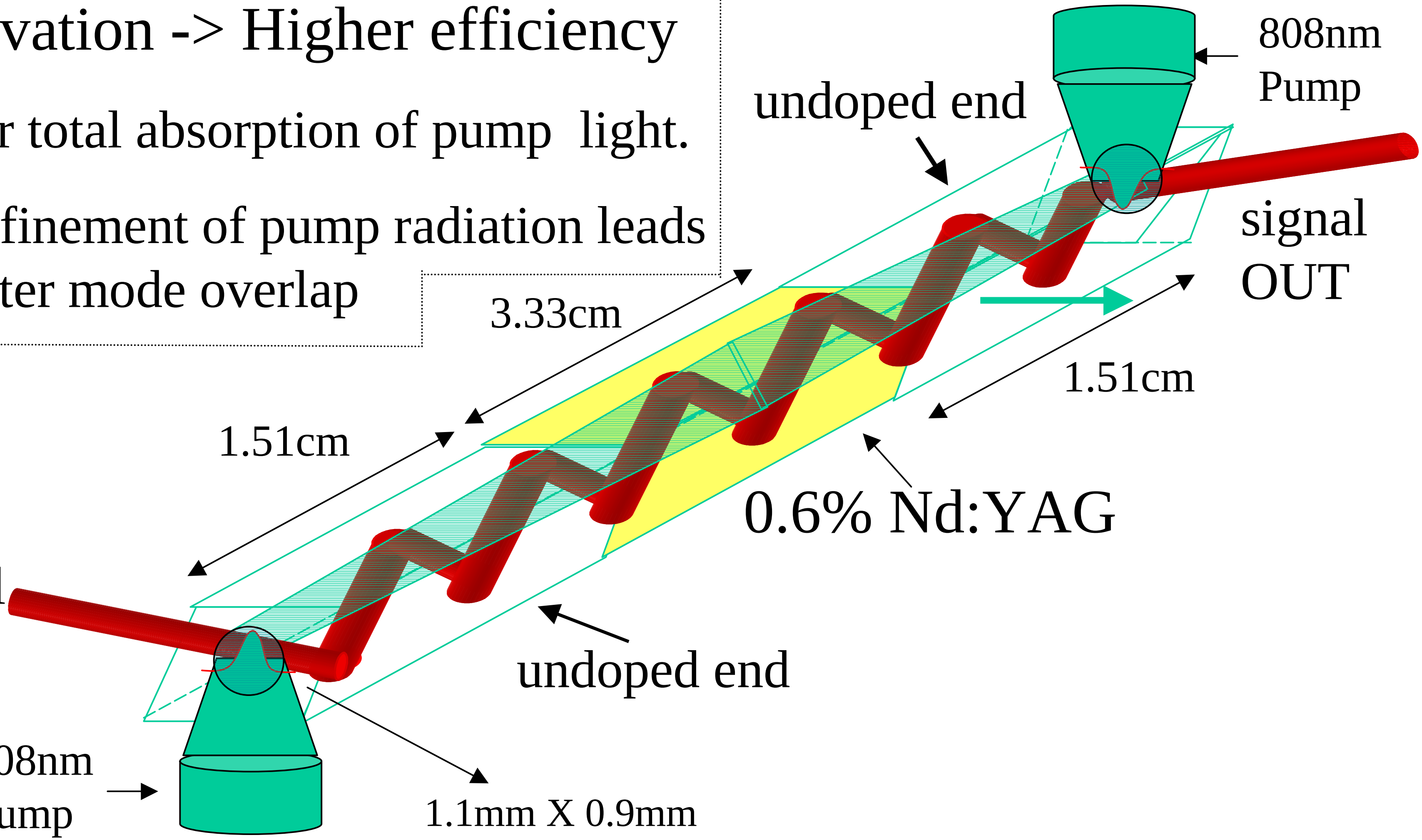


Output Power from triple passed slab #1 = 33W

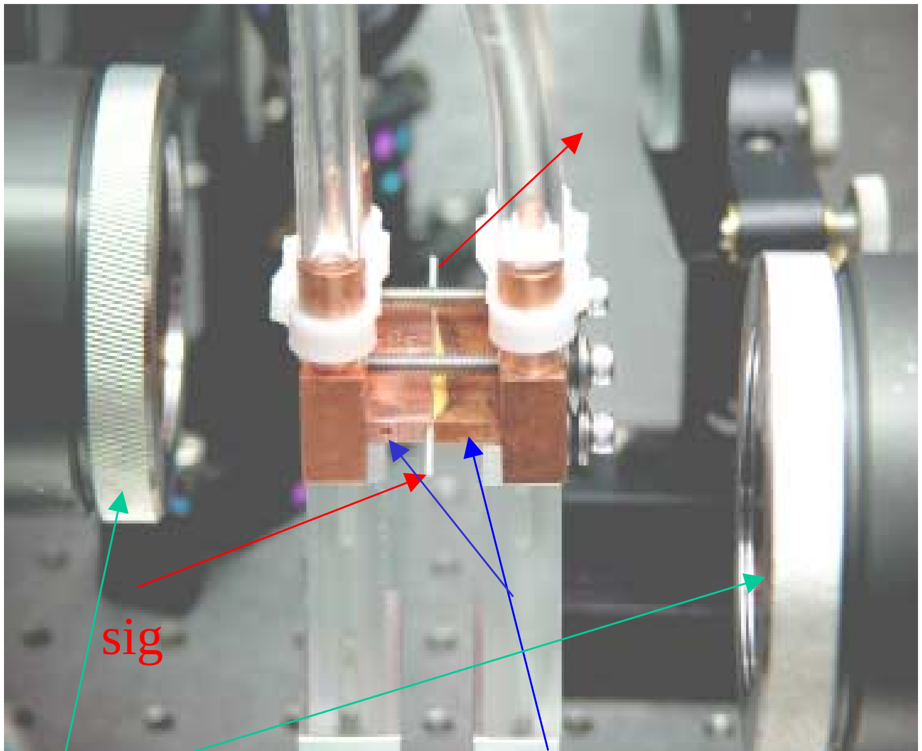
End pumped slab geometry

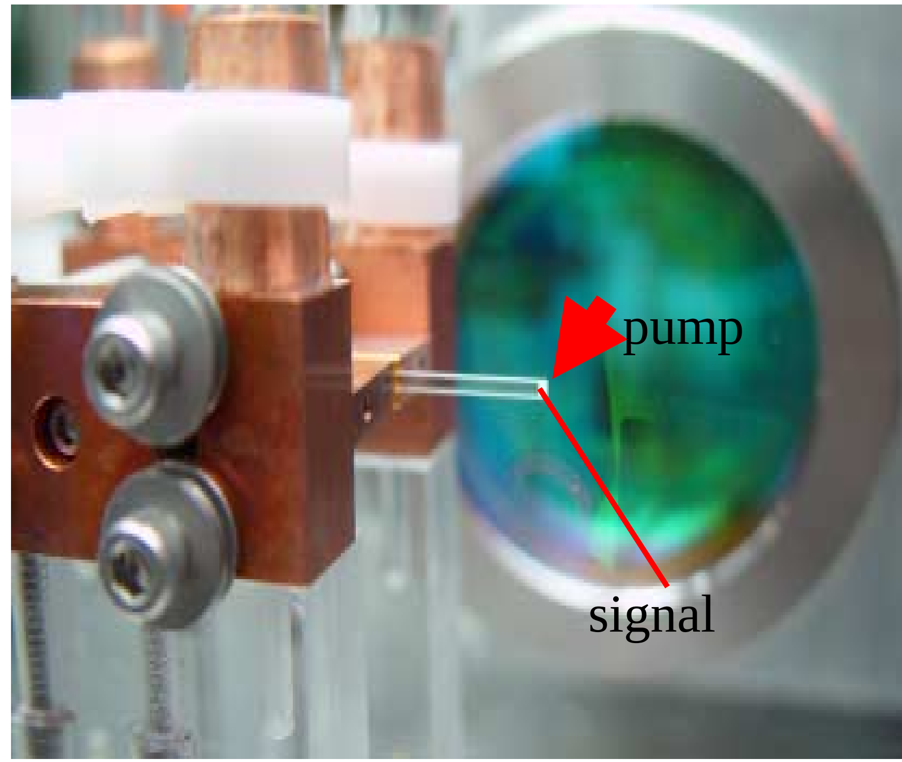
Motivation -> Higher efficiency

- Near total absorption of pump light.
- Confinement of pump radiation leads to better mode overlap



End pumped slab amplifier set up

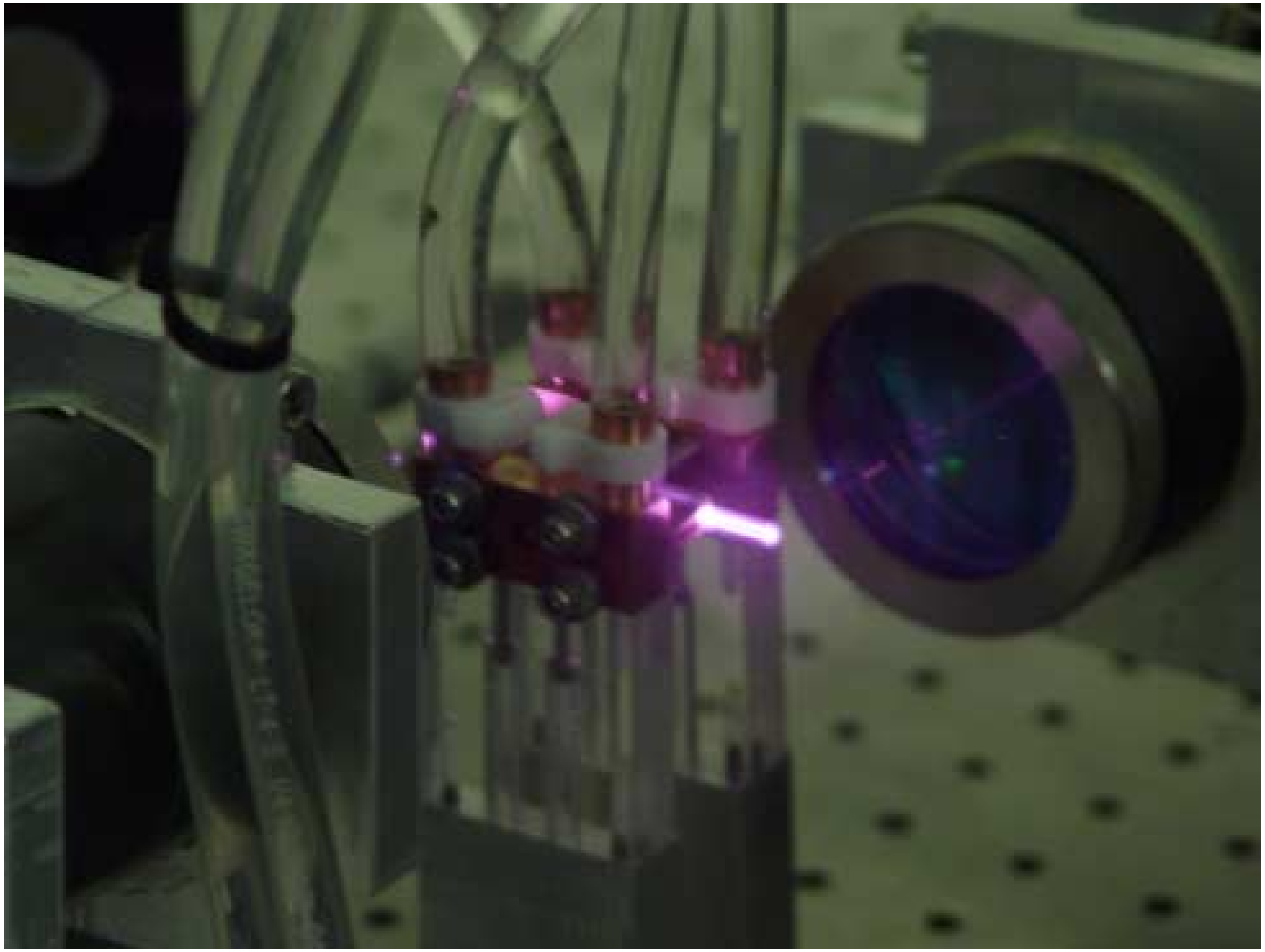




Pump diodes for end pumped slab

Each fiber coupled head delivers 300W at 808nm via a 600um fiber with a NA of .22.

End pumped slab looking "cool"

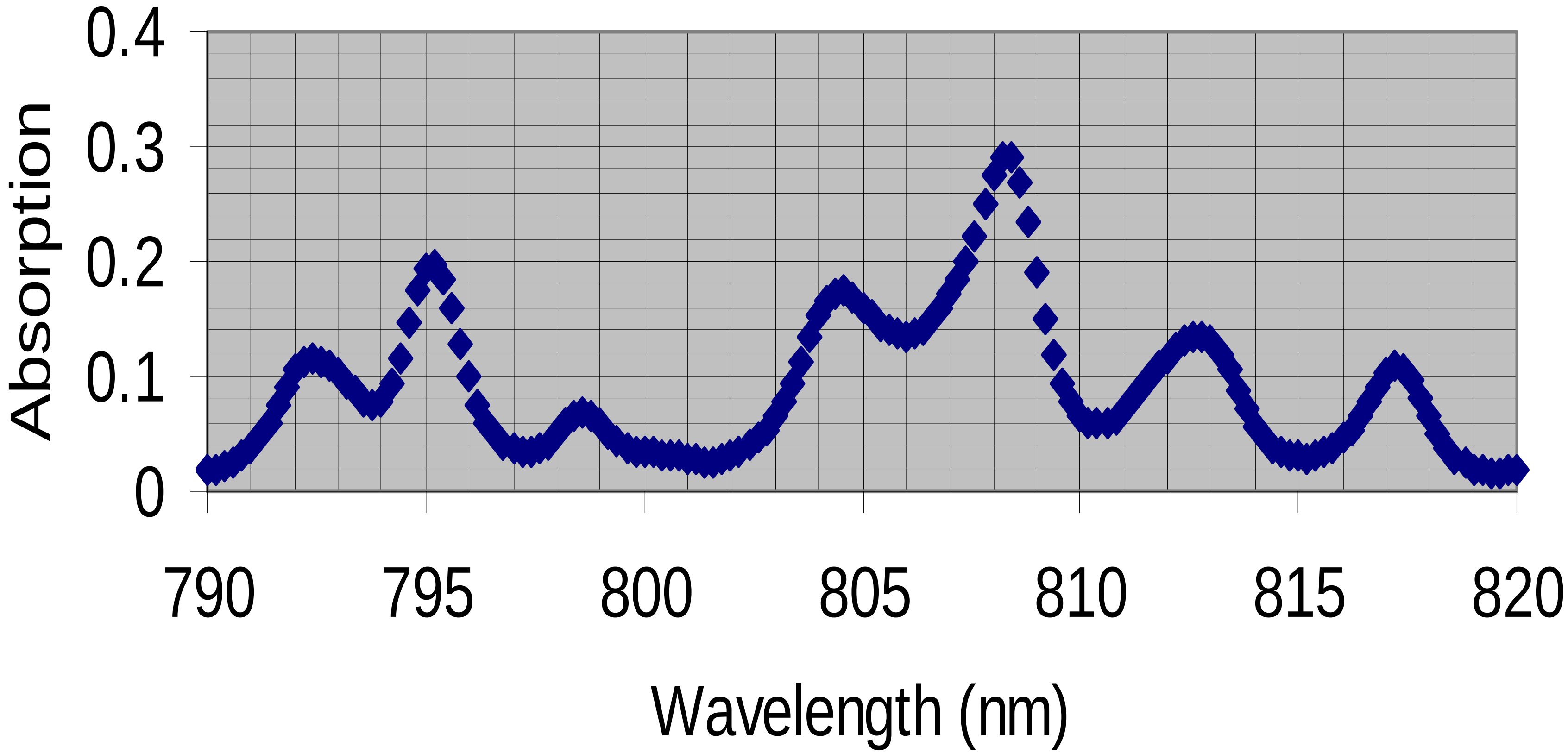


Problems encountered with pump diodes

- Power supplies shipped at European 3-phase voltage standards. Necessitated installation of custom transformer => DELAYS!

- Wavelength under normal operating conditions ~ 800nm. Need to “cook” the diodes (36ºC) and operate at full power (300W) to move wavelength into absorption range of Nd:YAG. Replacement stacks details being worked out => DELAYS!

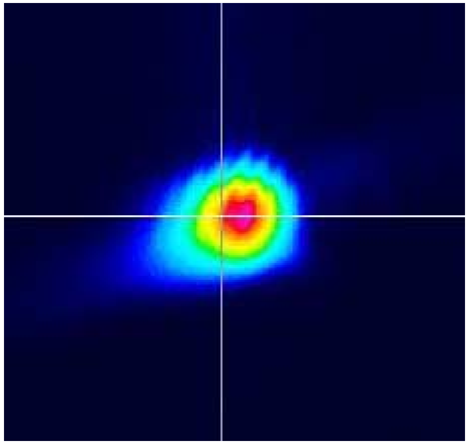
End pump slab pump wavelength detuning



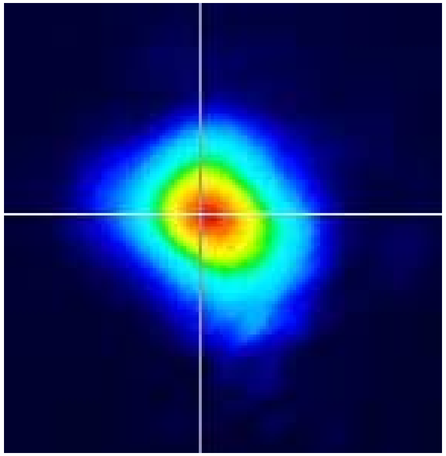
Operating at 805nm to improve diode lifetime and provide longer absorption length

Results of 100W experiment

- Power output ~ 65W
- Single passed end pumped slab extracted 35W.
- Depolarization ~ 1.5%.
- M2 < 1.1

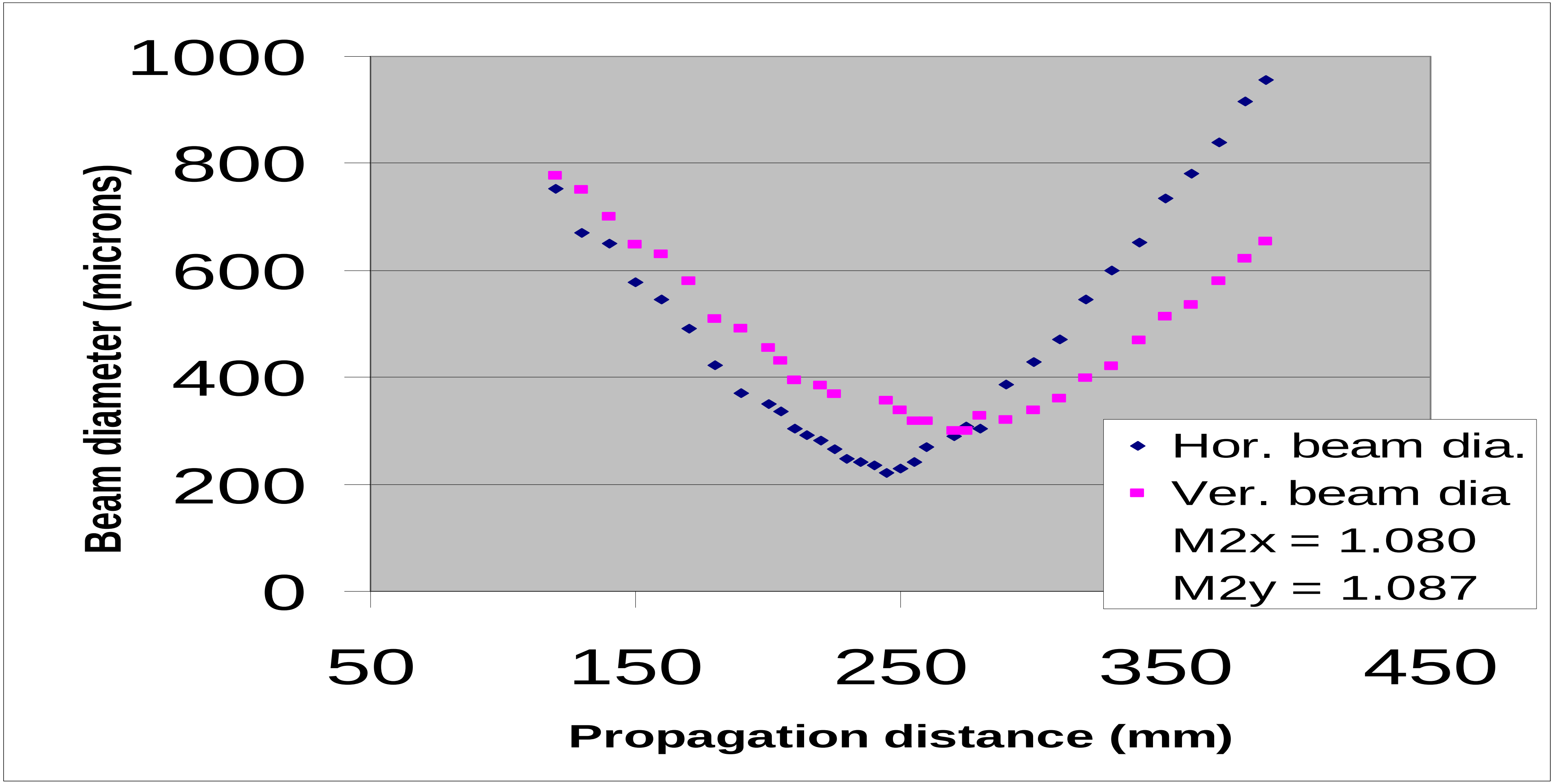


COLD SLAB
OUTPUT 30W

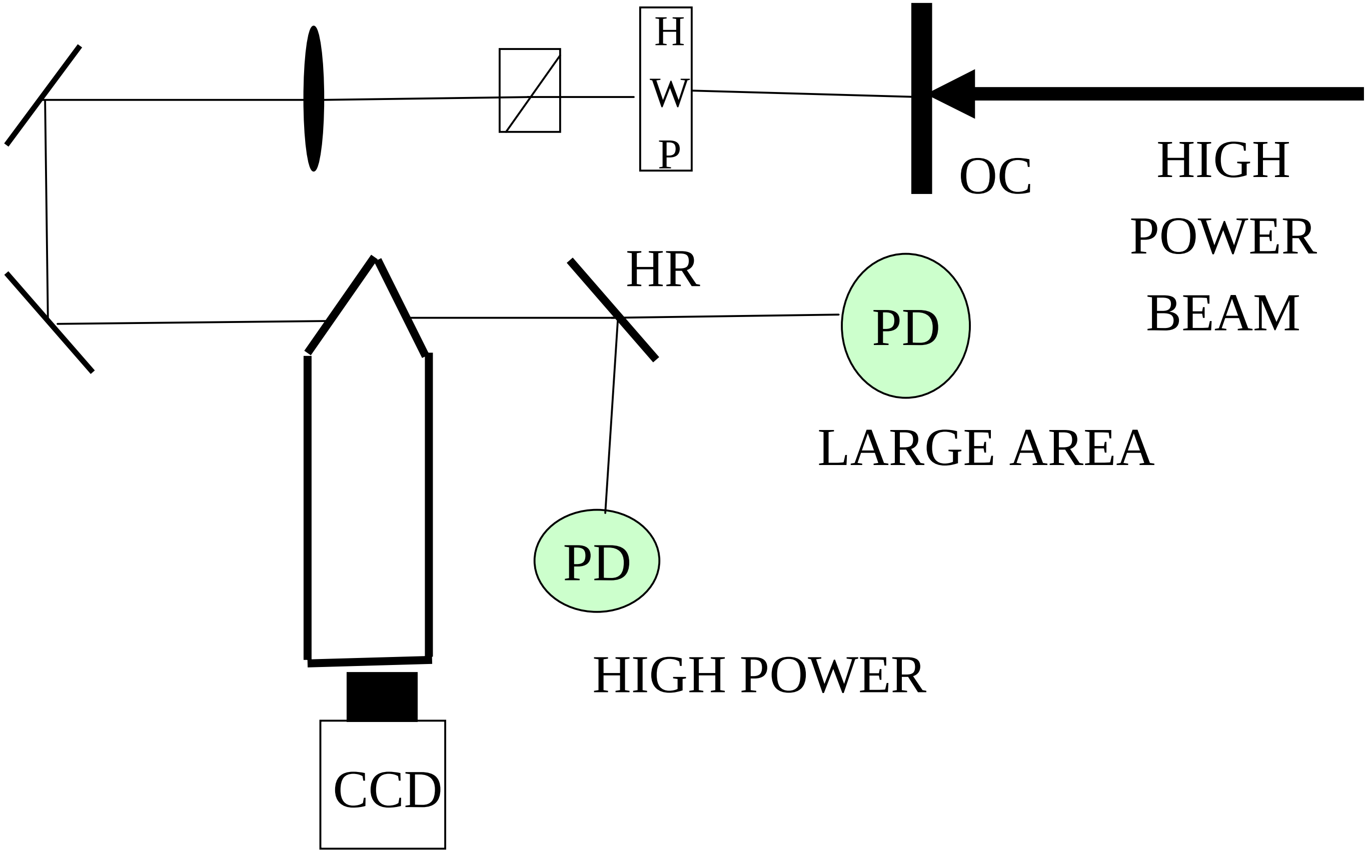


PUMPED SLAB
OUTPUT 65W

Final beam quality at full power

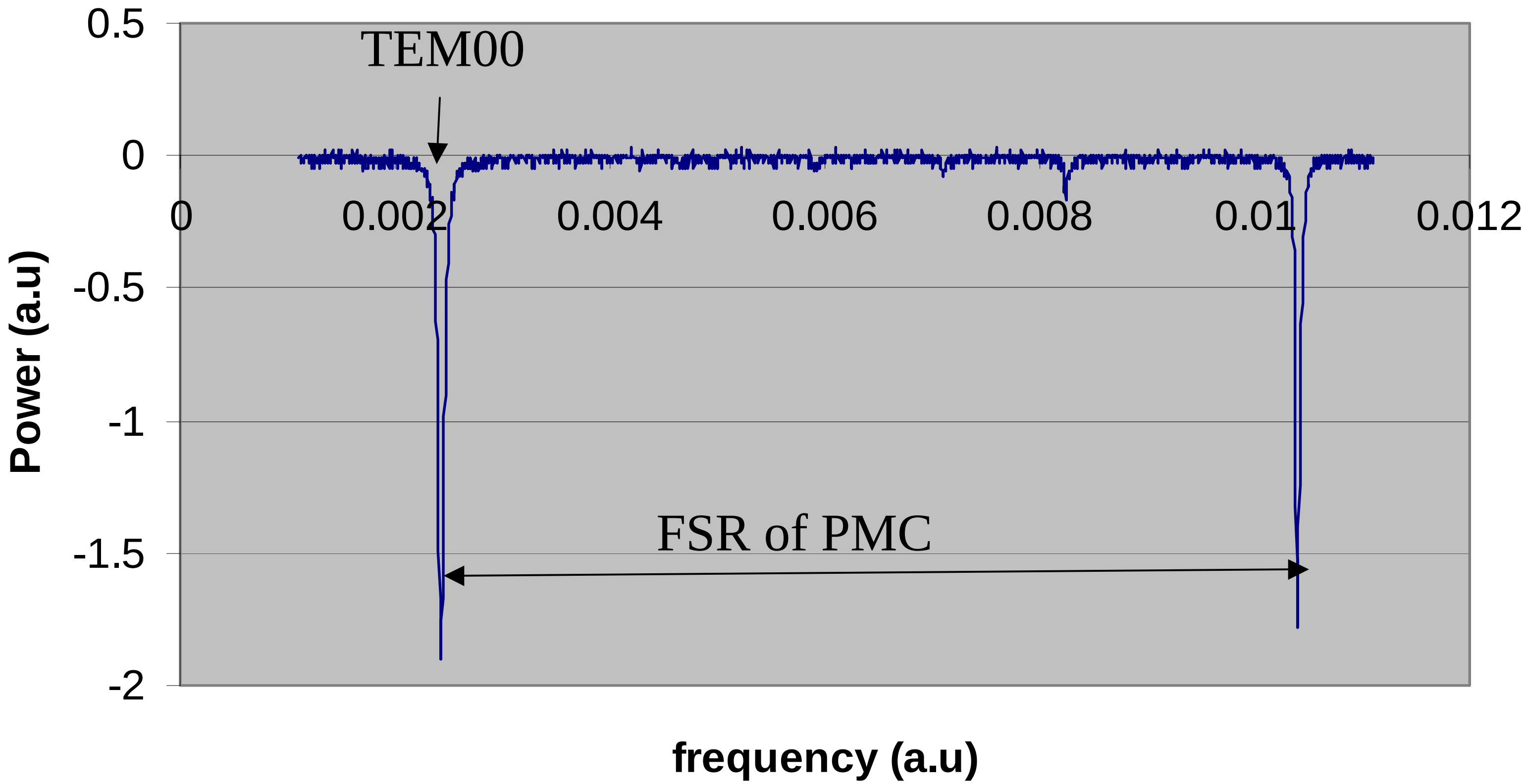


Mode Cleaner setup



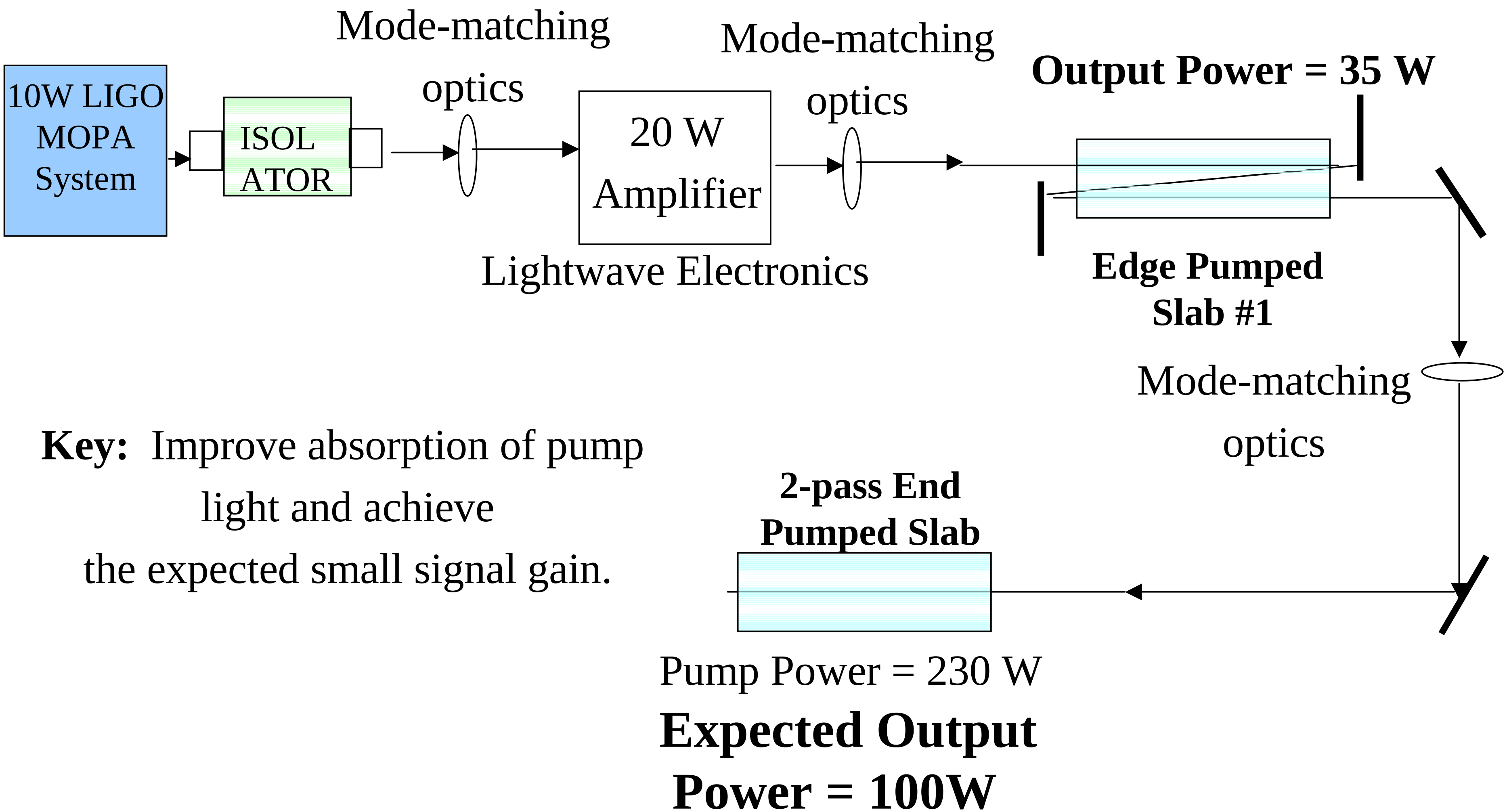
- Peak to peak intensity fluctuations after mode cleaner over 10 seconds = 7.3%

Mode content of 65W beam



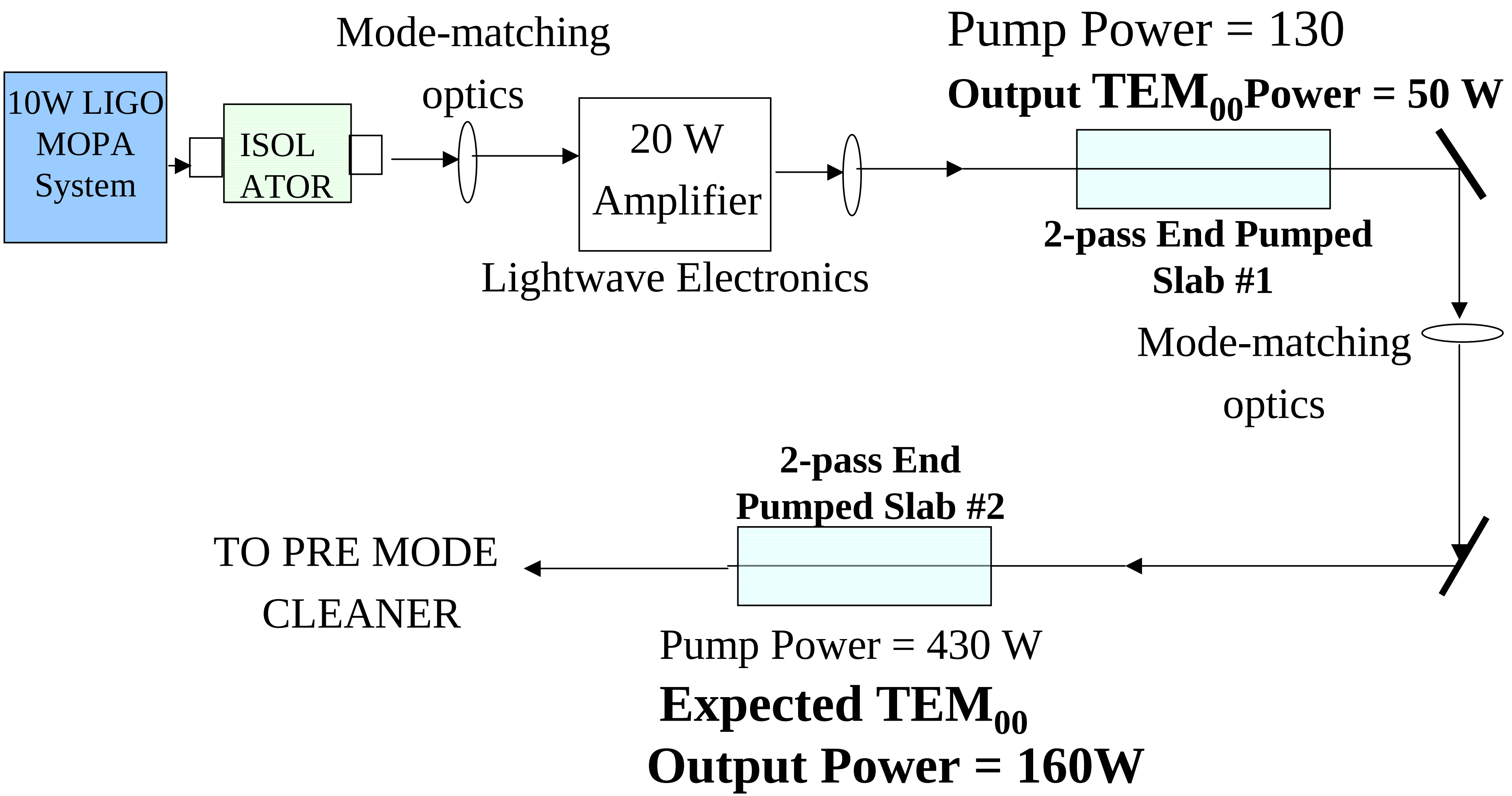
74% mode content in TEM00.

What next for the 100W experiment?



Key: Improve absorption of pump light and achieve the expected small signal gain.

Scaling to 200 W : Experimental Plan



Expected MOPA System Performance

Amplifier	Input Power	Multi-mode Output	Output TEM_{00}
End-pumped (P_{pump} = 130W)	20 W	60 W	50 W
End-pumped (P_{pump} = 435W)	50W	200W	160W
Edge-pumped (P_{pump} = 1400W)	160W	500W	400W

- Edge pumped design chosen for final stage because of heat extraction requirement and simpler engineering design without sacrificing much pump absorption.

(Near) Future Work

- Double pass end pumped slab to reach 100W.
- Better mode matching into PMC to demonstrate higher coupling of TEM00 mode.
- Characterization of frequency noise with Benno Wilke's assistance.
- Switch preamplifer after 20W stage from edge pumped to end pumped topology to achieve 200W with better mode quality.

Conclusion

- MOPA architecture as demonstrated by Stanford is ideal for power scaling while maintaining the spatial mode quality.
- The architecture is simple, modular and requires no complicated electronics.
- Finally, the architecture is reliable and has a soft failure mode.

Technology transfer

- Stanford will work closely with final LIGO laser manufacturer to ensure transfer of knowledge of MOPA technology.

Acknowledgements

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Stanford High Power Team