Diode-pumped, High-Power Nd:YLF and Nd:YVO_4 Lasers

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Outline

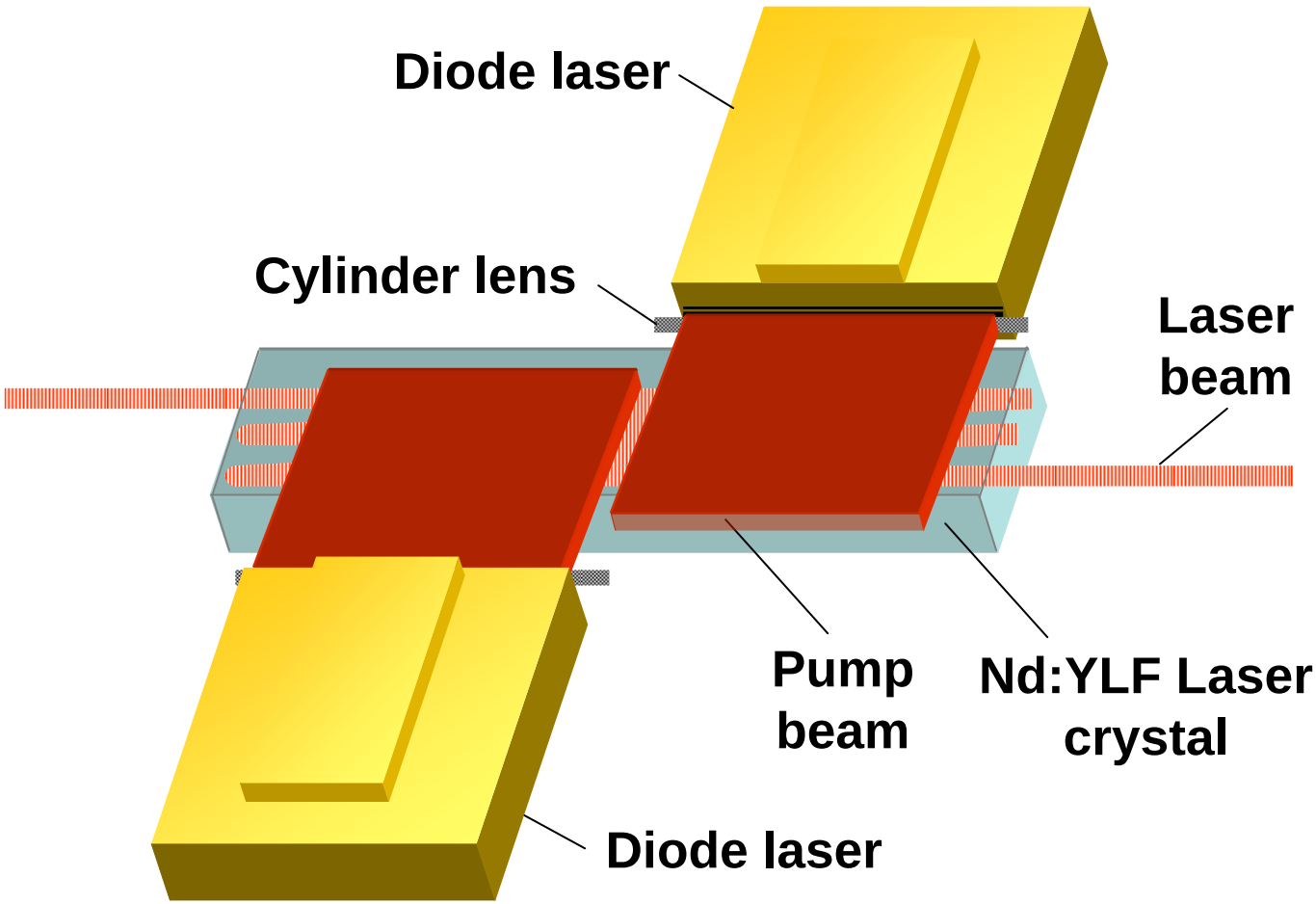
- Laser materials choices
- Basic Nd:YLF laser design and performance
- Basic Nd:YVO_4 laser design and performance
- MOPA systems
- Applications

Three Nd Laser Hosts As Choices

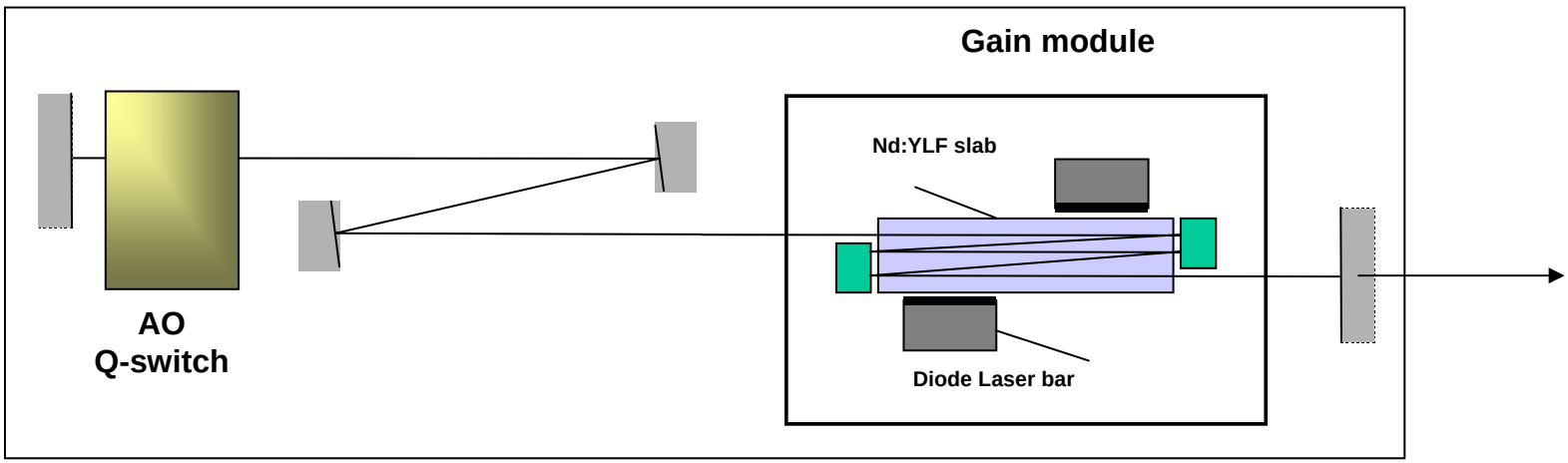
Crystal	Wavelength (nm)	Gain cross section (10-19 cm2)	Lifetime (μs)	Peak absorption (cm-1)
YAG	1065	3.3	240	10
YLF (π) YLF (σ)	1047 1053	1.9-2.3 π / 1.5	480-520	11
YVO4 (π)	1064	9.8-15.6	97	40

Crystal	Thermal conductivity (W/m K)	Expansion coeff. (10-6)	Thermal shock (W/m)	dn/dT (10-6)	Lensing
YAG	13	6.7	1450	+7.3	moderate
YLF	5.8 (c) 7.2 (a)	8 (c) 13(a)	240	-4.3 (e) -2.0 (o)	weak
YVO4	5.2	7.3 (a) ?? (c)	?	+2.9 (e) +8.5 (o)	strong

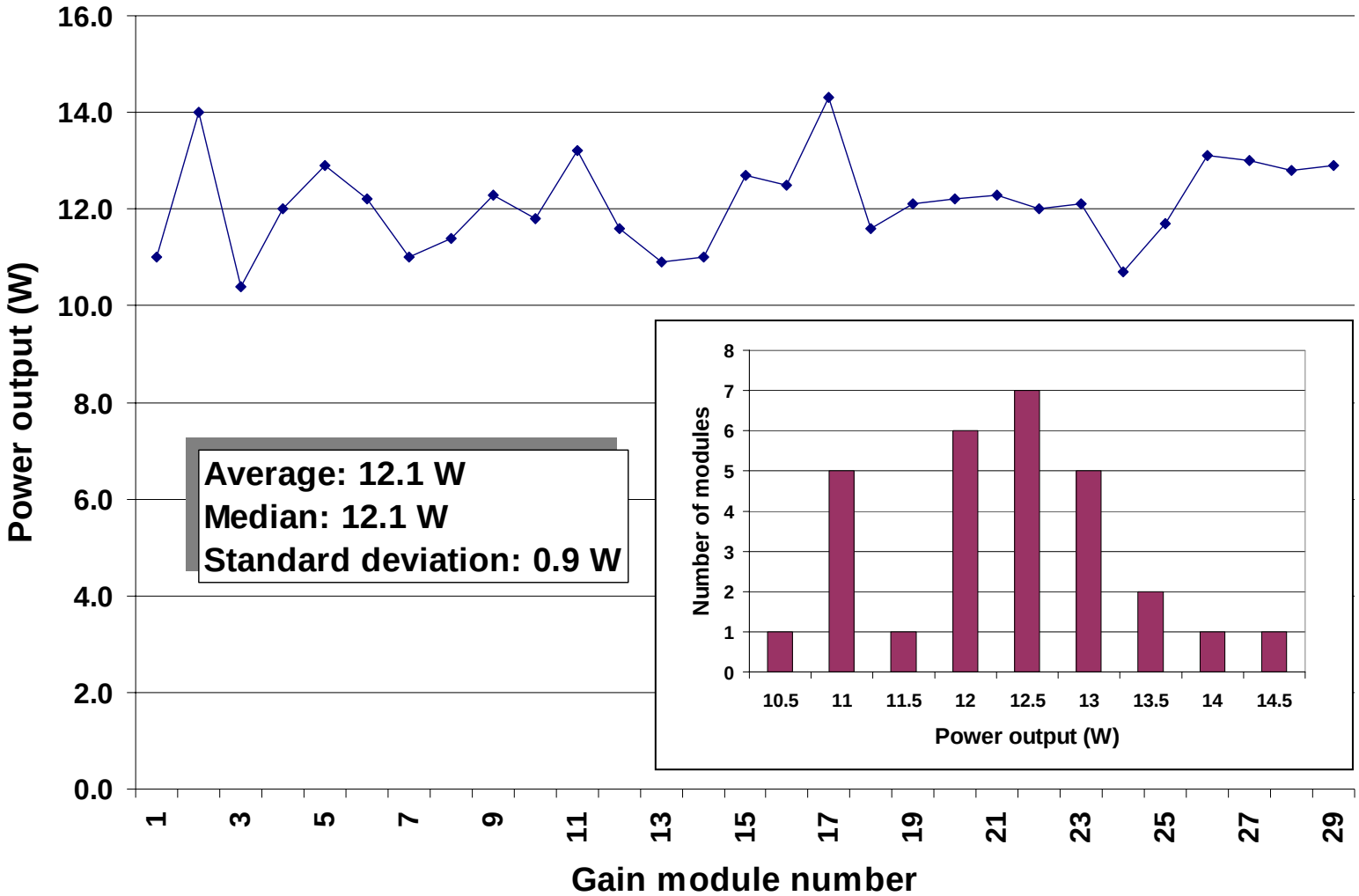
MPS Pumping Design



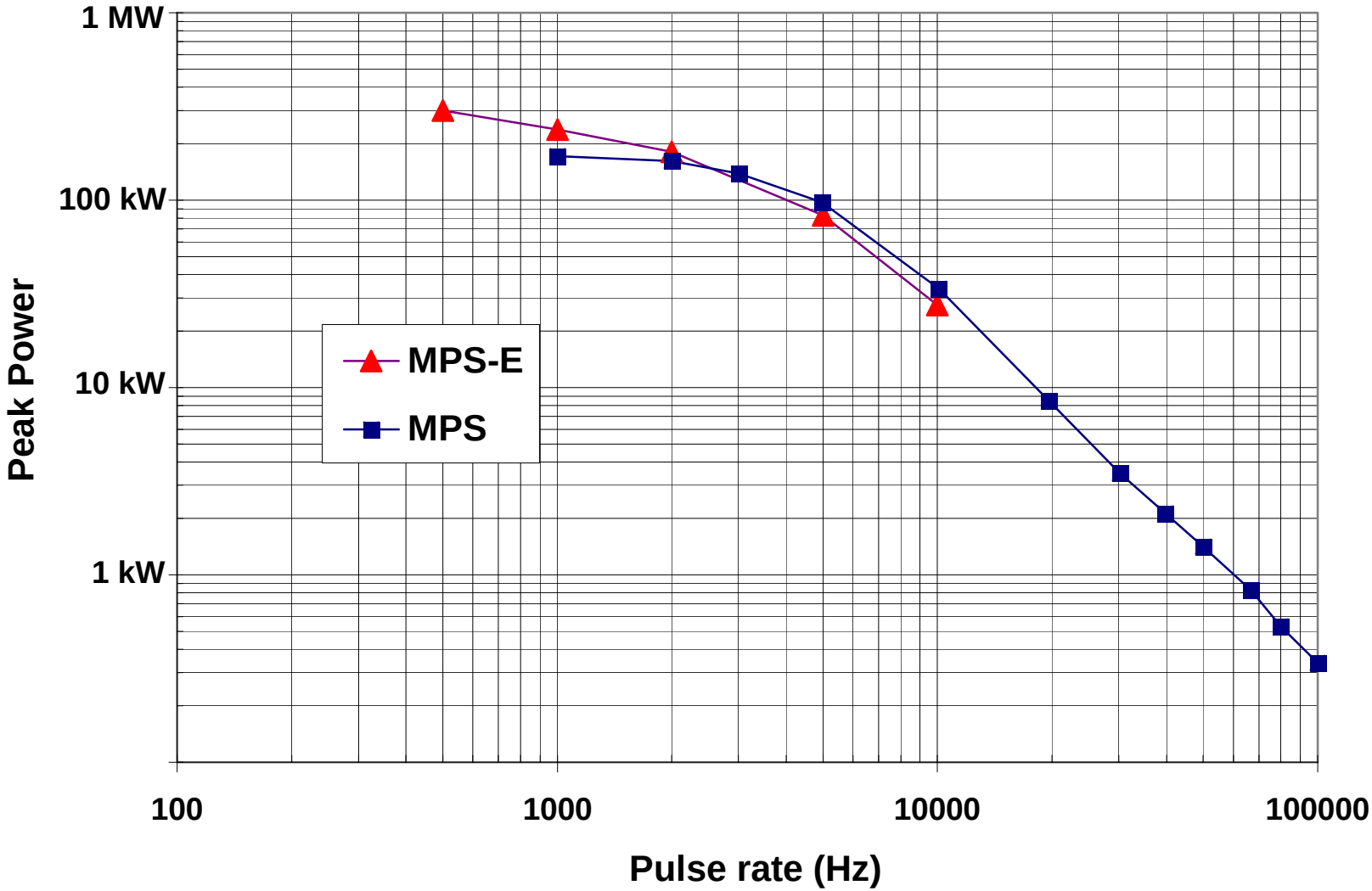
MPS gain module with resonator (MPS-1047)



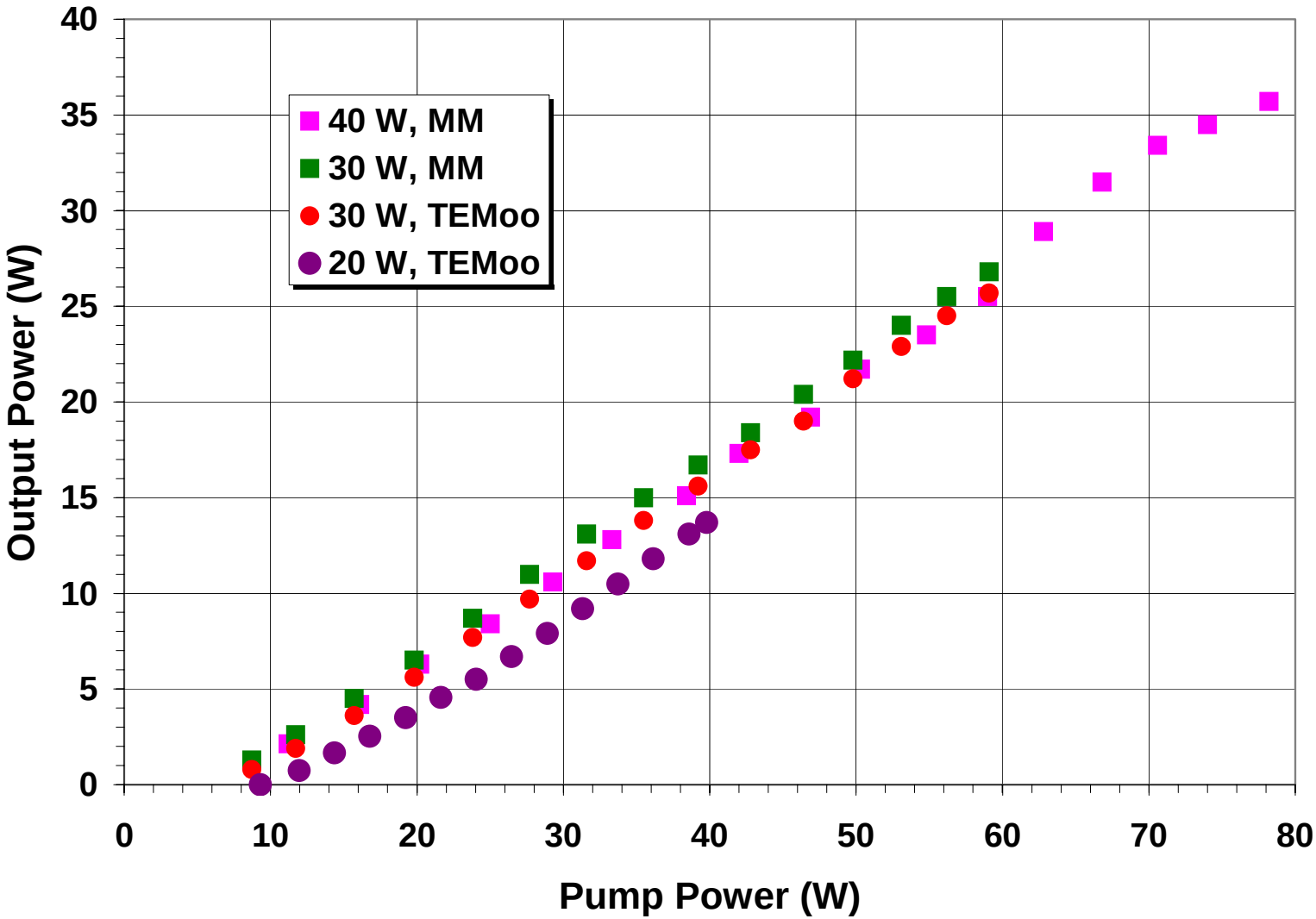
Production data on MPS gain module



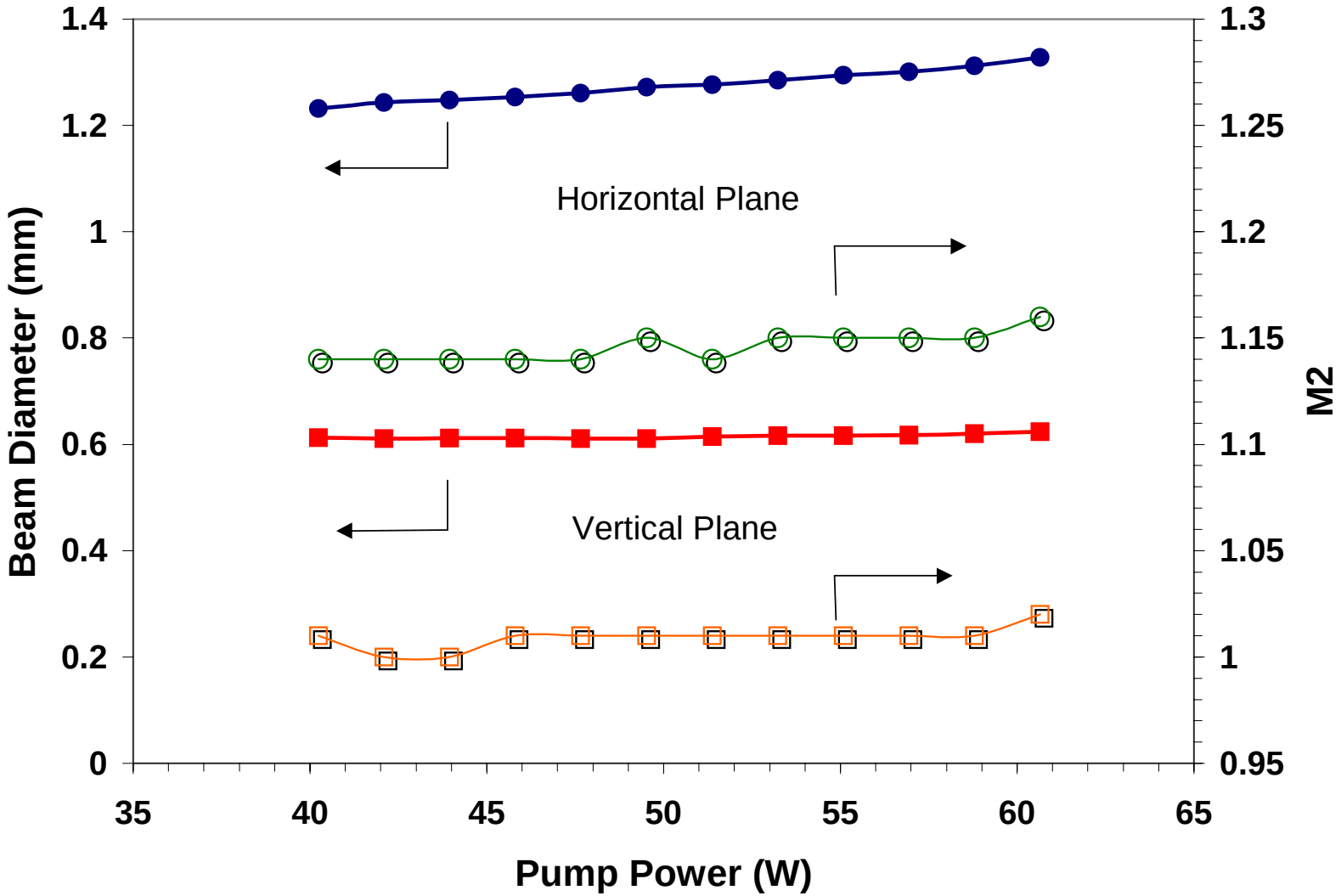
MPS Q-switching produces high powers



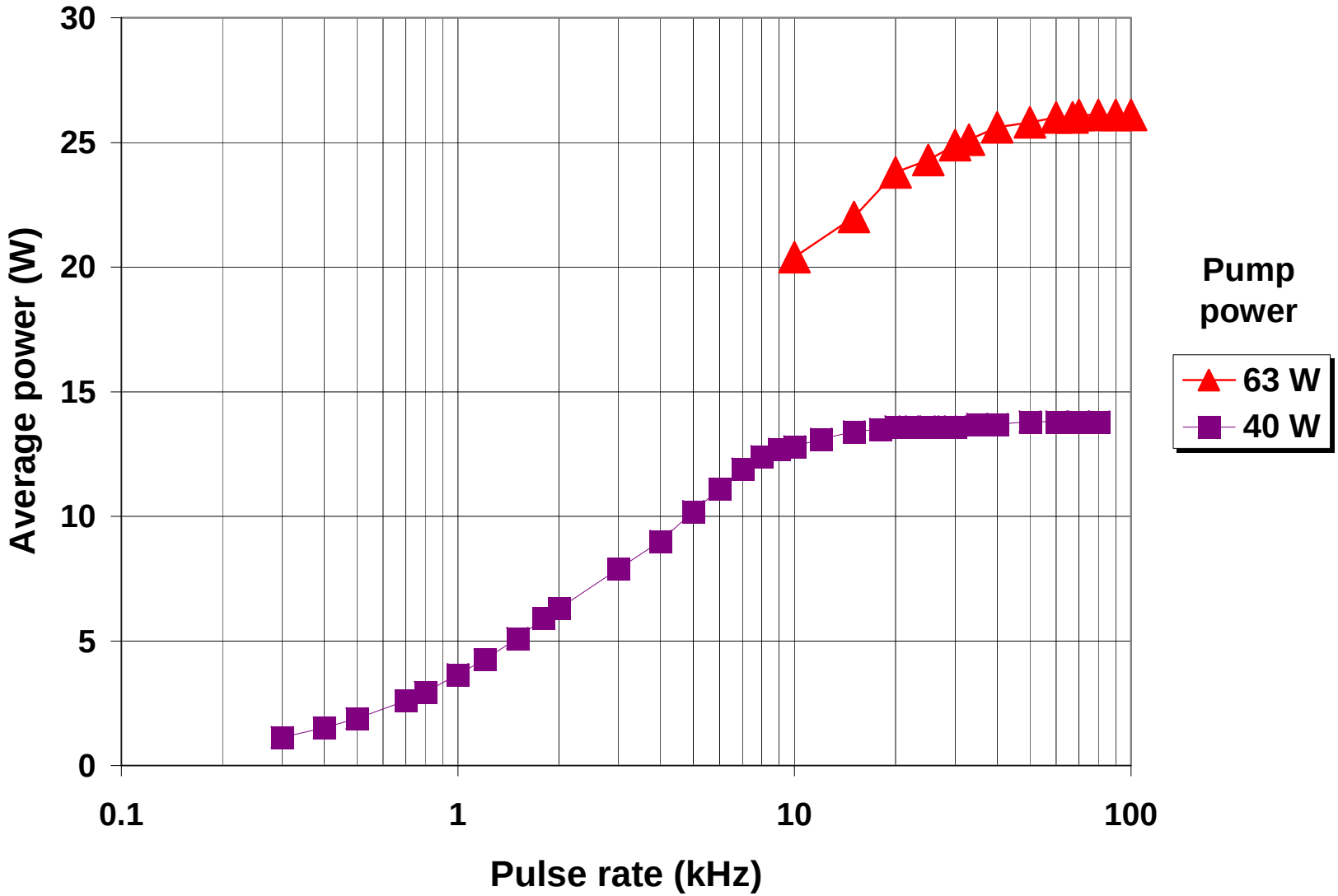
CW oscillator performance scales upward



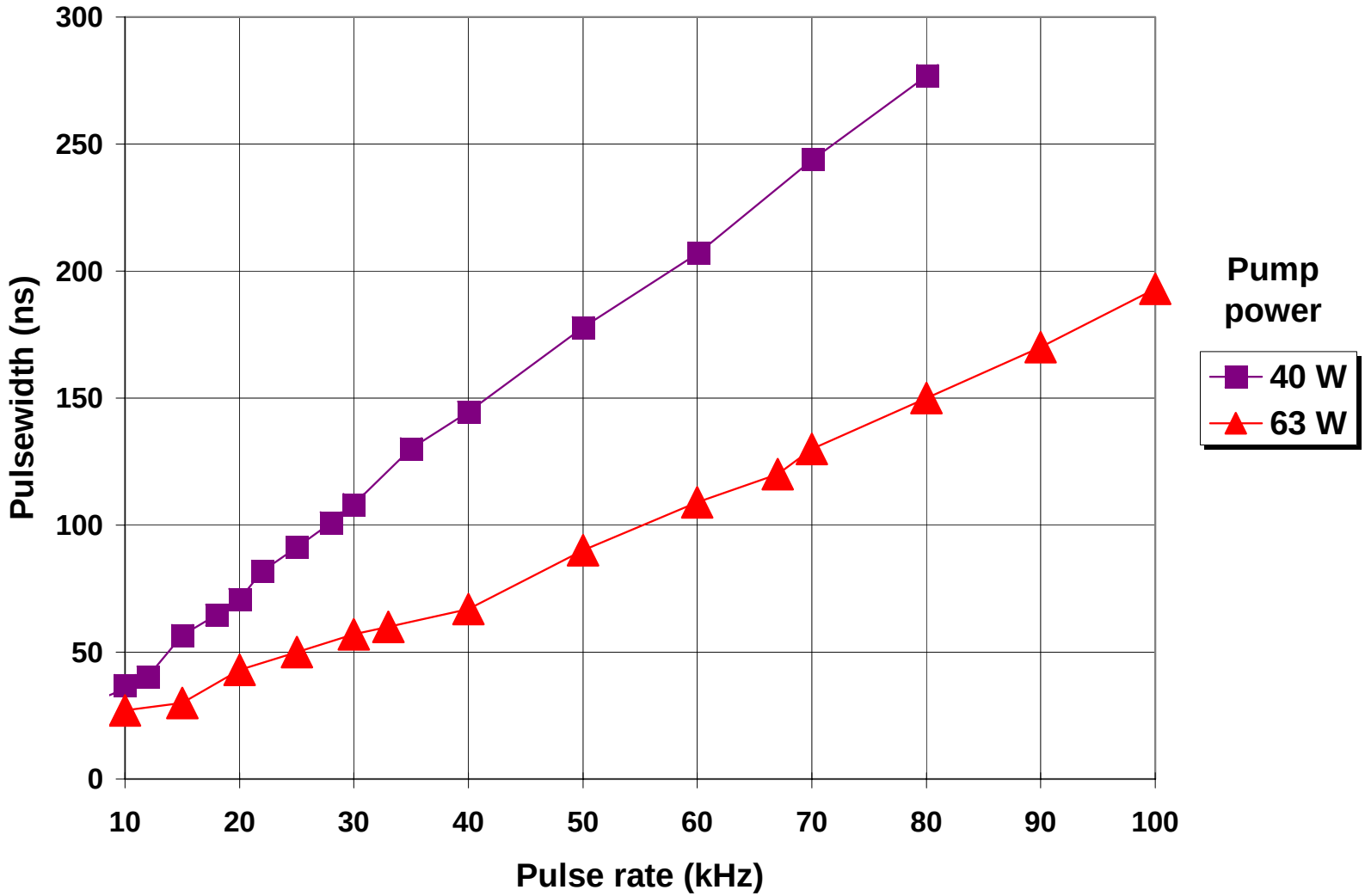
TEMoo properties are power-independent



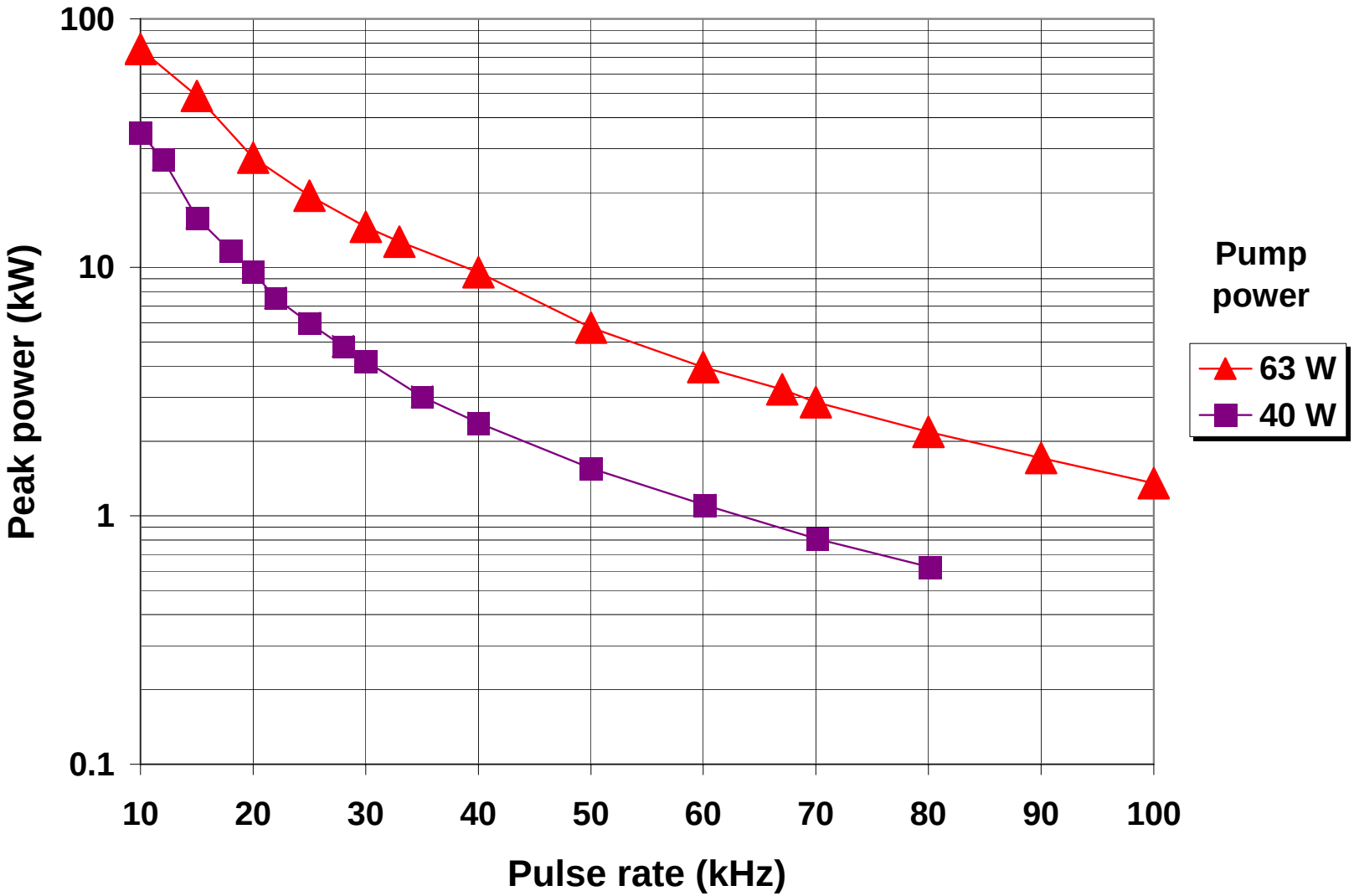
Q-switched average power is nearly doubled with 50% more pump power



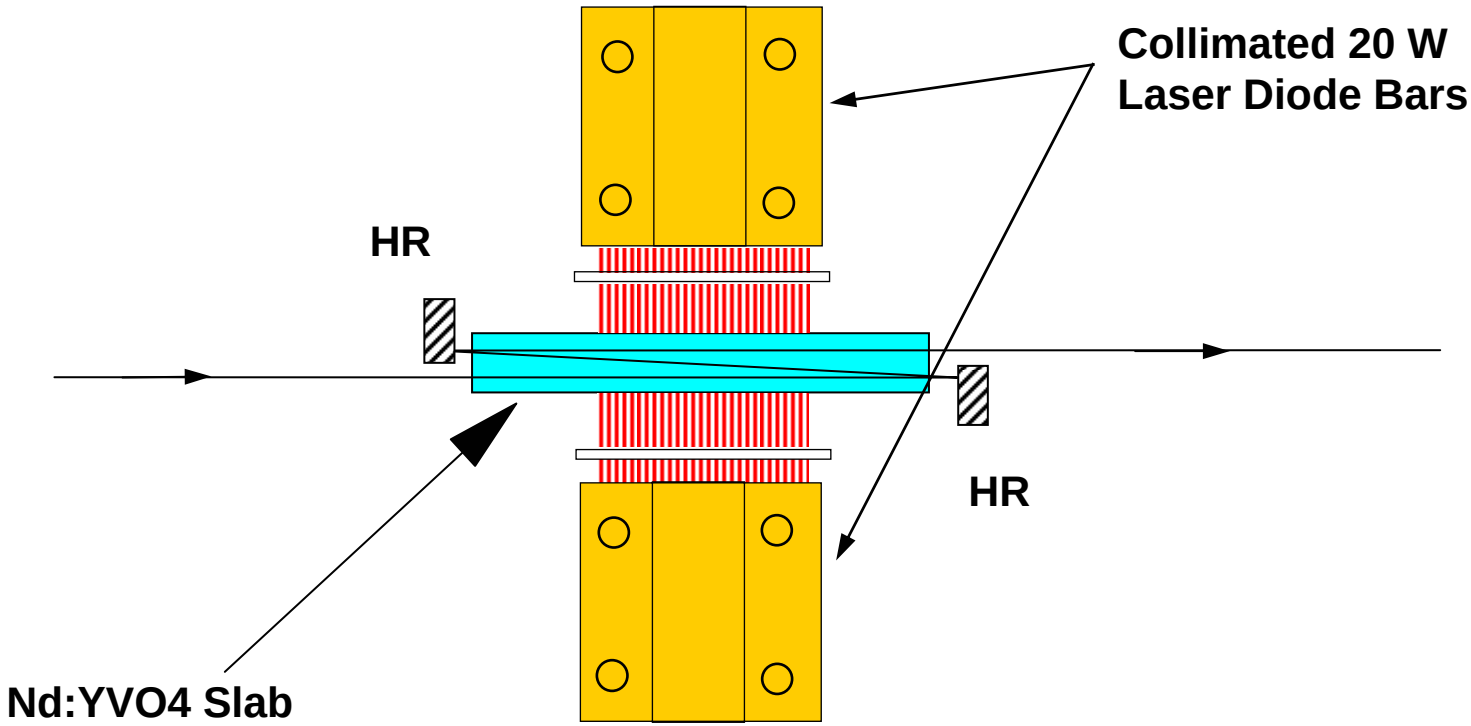
Higher gain yields shorter pulses



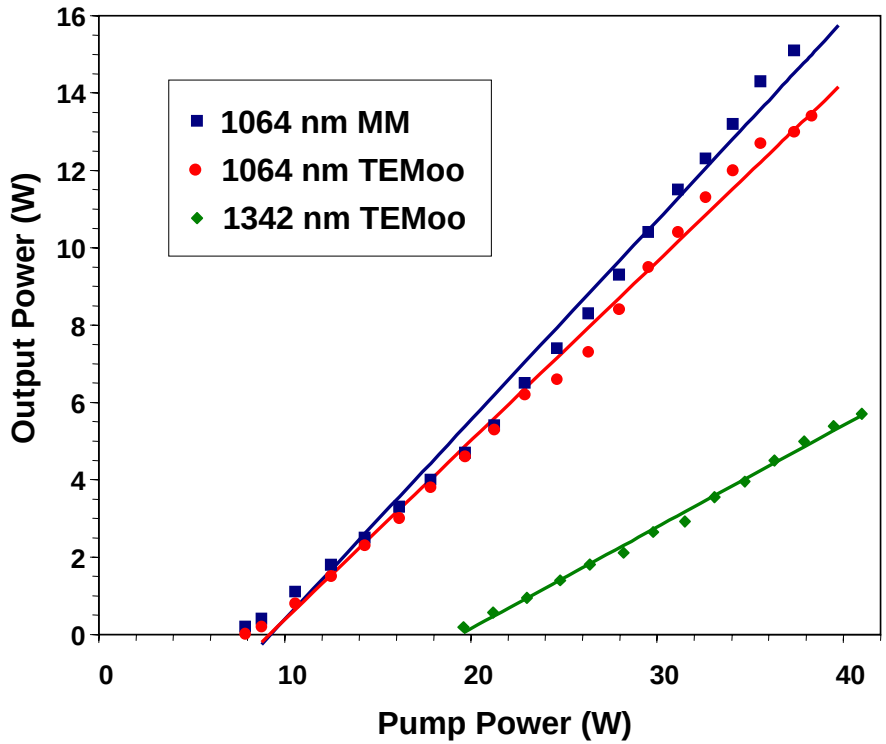
Peak power is increased at high PRR



High-power, MPV ($Nd:YVO_4$) gain module

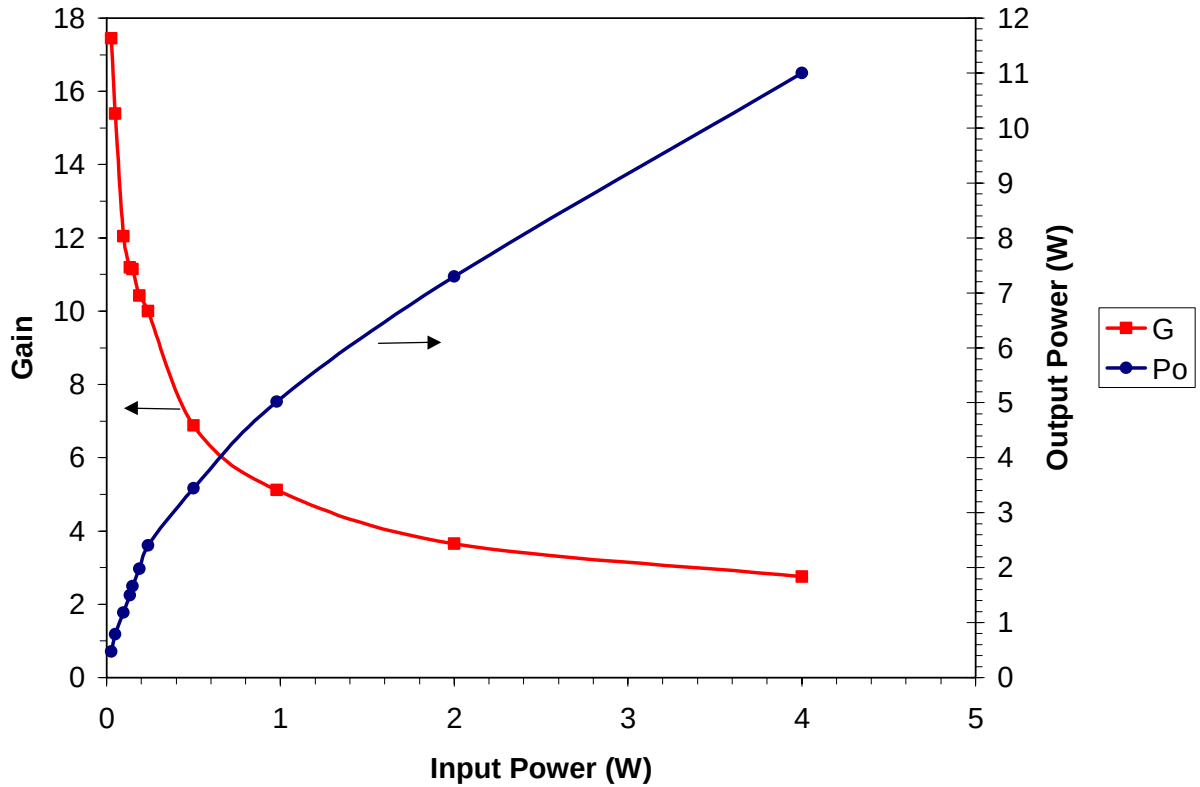


MPV (Nd:YVO_4) Oscillator CW Efficiency



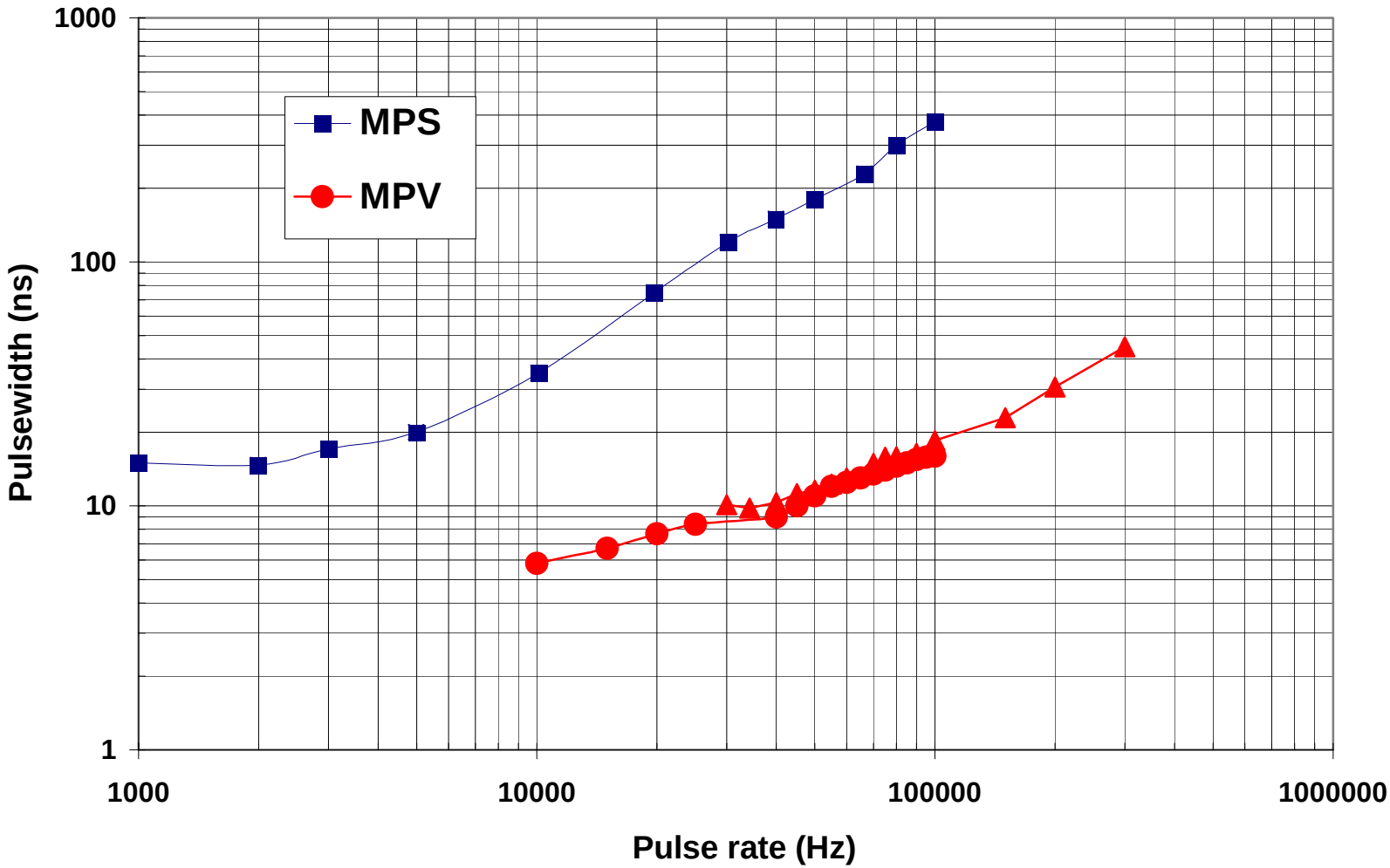
- 1064 nm, >15 W multimode, >13 W TEM_{00}, 46.3% slope, 35.0% optical and 13% electrical efficiency.
- 1342 nm, >6 W TEM_{00}, 26% slope, 15% optical and 6% electrical efficiency.

MPS CW Amplifier Performance

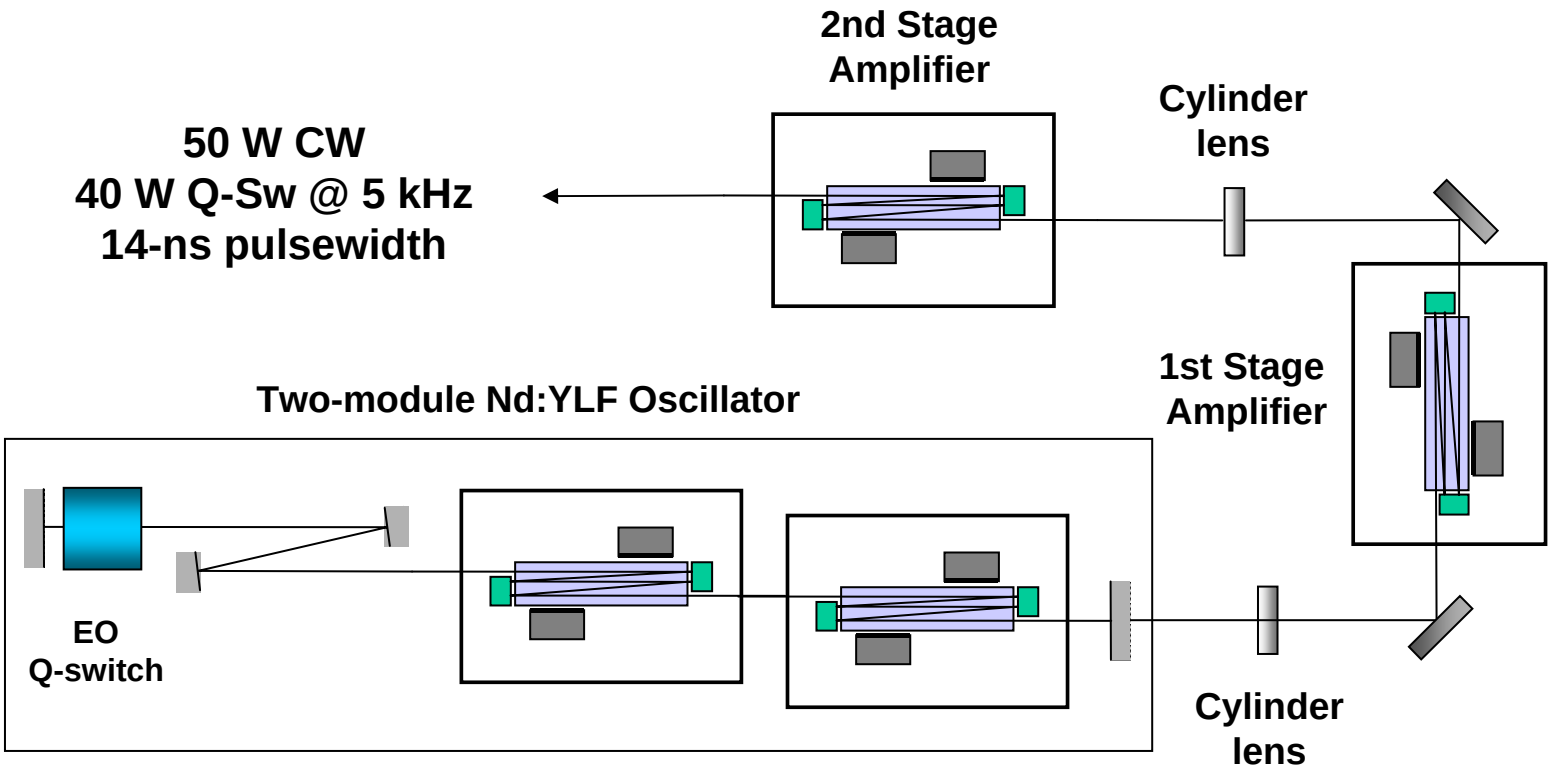


- **Gain of 17 with 27 mW input at a pump power of 38.7 W. 3-pass small signal gain >30 based on later single-pass measurements.**

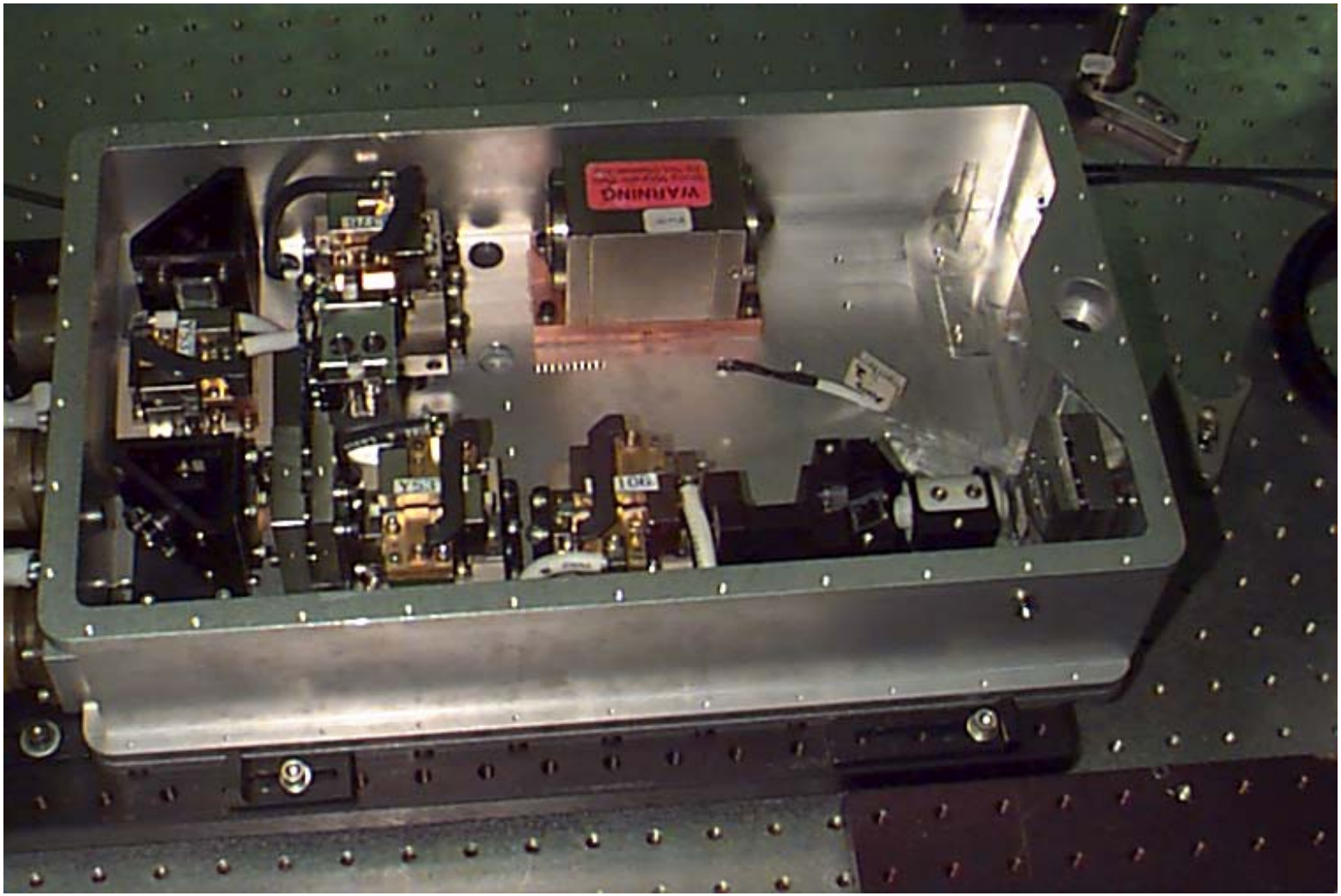
MPS and MPV pulsewidth vs. rate



MPS MOPA system #2 generates 50 W cw

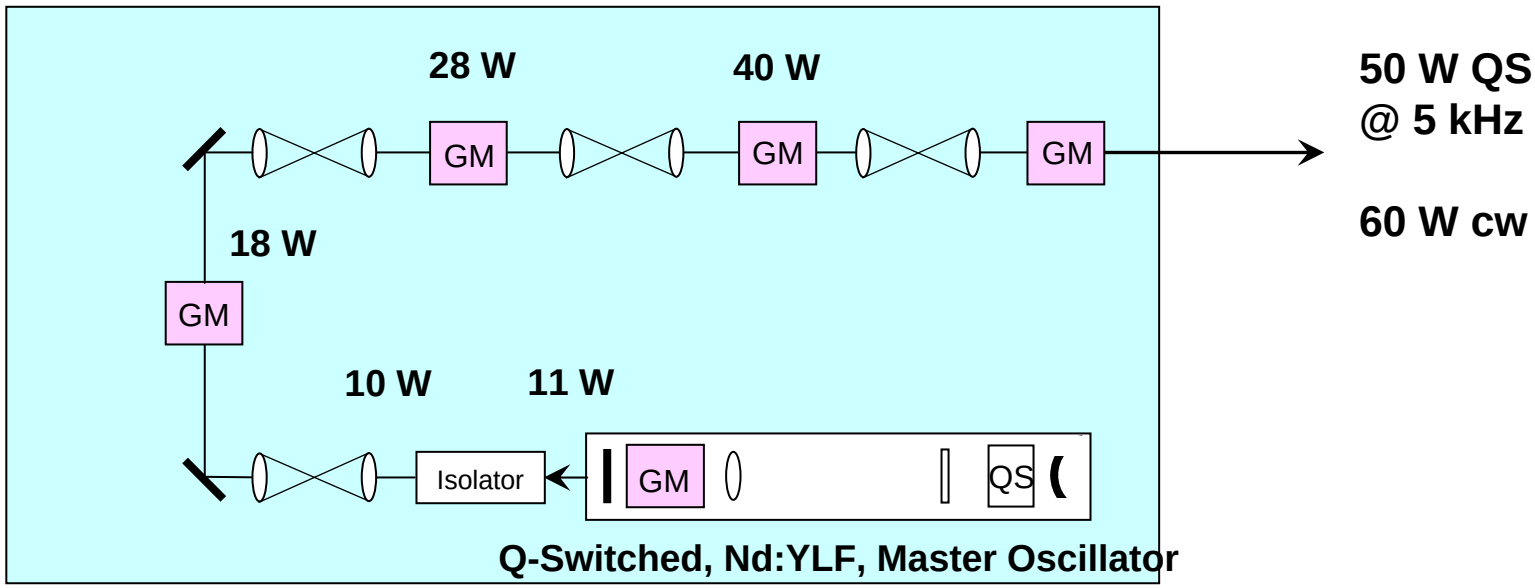


MOPA #2 laser head



MOPA design allows scaling to 60 W cw

(20-W pump lasers)



Relay Optics

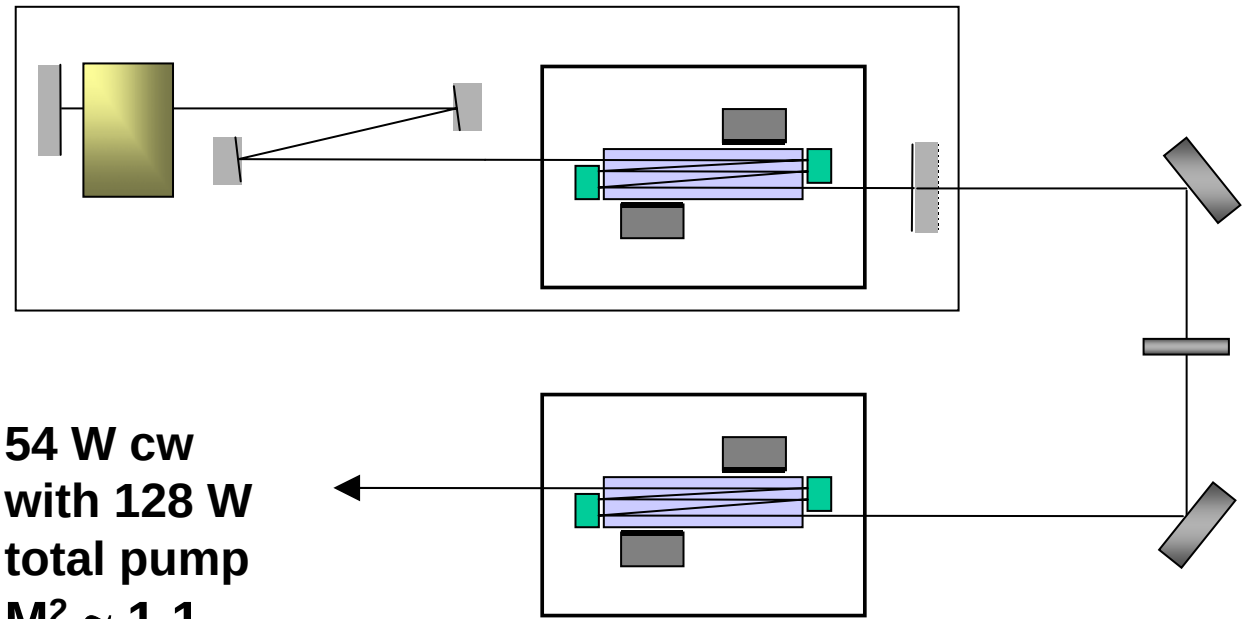
GM Gain Module

Mirrors

QS AO Q Switch

MOPA generates 54 W cw with one amplifier

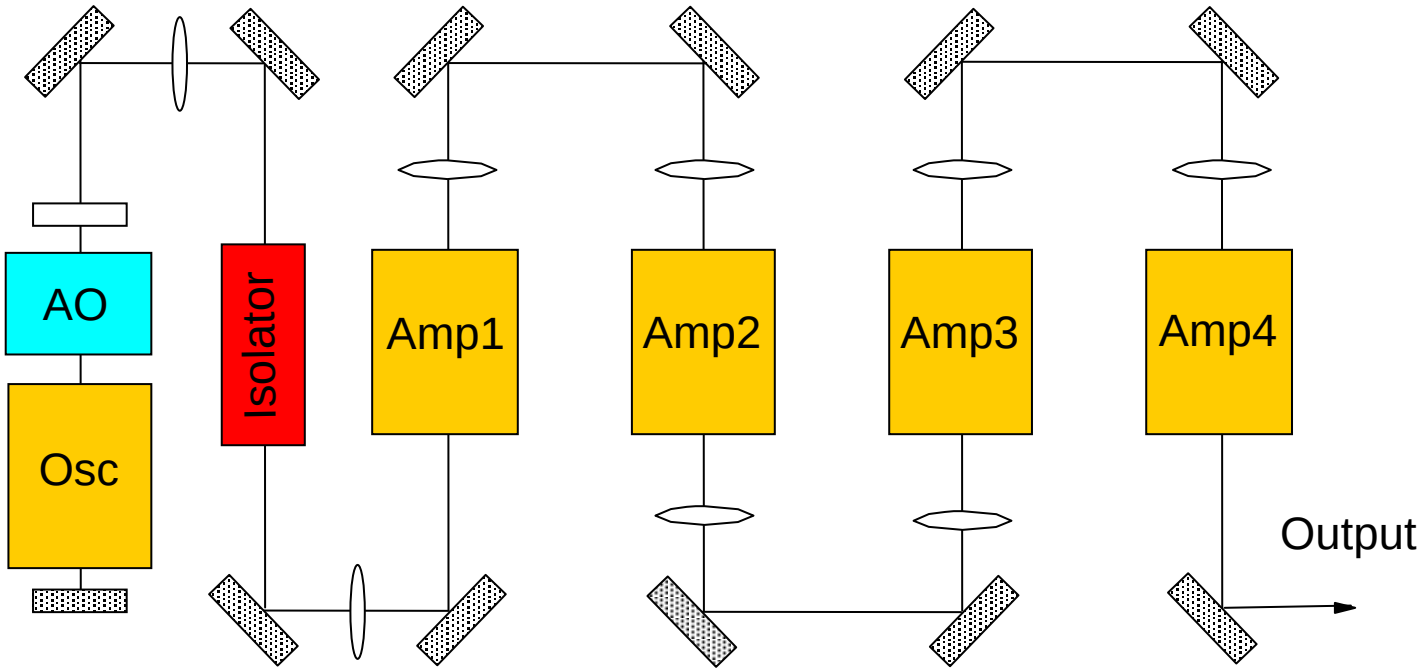
(40-W pump lasers)



54 W cw with 128 W total pump

$M^2 \approx 1.1$

MPV Nd:YVO_4 MOPA System



- **5 Gain Modules; 1 Oscillator, 4 Power Amplifiers. Same design for both 1064 nm and 1342 nm.**
- **Relay-imaged between master oscillator and amplifiers to preserve optimum beam size throughout the MOPA chain.**

Nd:YVO_4 MOPA Results

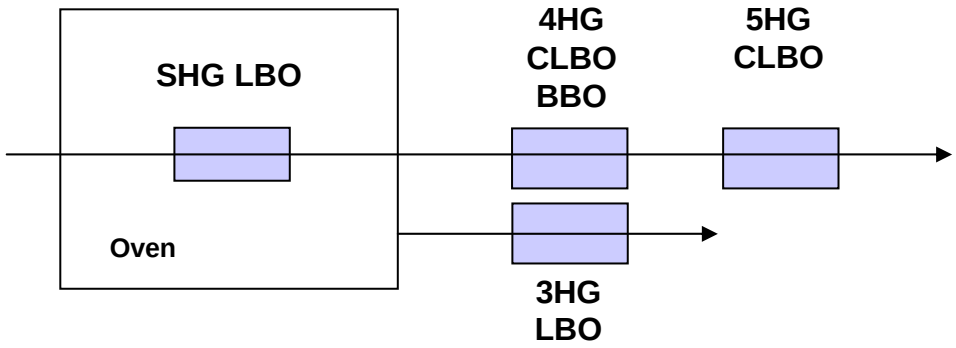
1064 nm

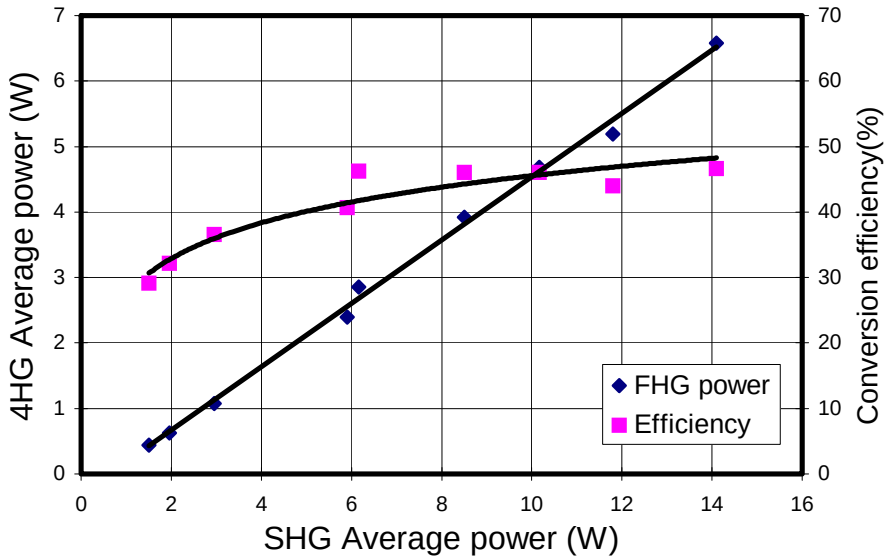
- **Outputs CW/Q-Switched @ 50 kHz**
  - **Oscillator: 11.4 W /10.5 W, 10 ns FWHM**
  - **Output: 53.5 W / 50.7 W, 10 ns FWHM, 1.01 mJ/pulse**
    101.4 kW Peak
- **200 W pump power → >25% optical, >10% electrical efficiency.**

1342 nm

- **Outputs CW/Q-switched @ 50 kHz**
  - **Oscillator: 11 W /9.6 W, 22 ns FWHM (Double crystal)**
  - **Output: 26.5 W / 25.0 W, 22 ns FWHM, 0.5 mJ/pulse**
    23 kW Peak
  - **240 W pump power → 10.4% optical, 4% electrical efficiency.**

Nd:YLF harmonic conversion generates high visible, UV powers (with Ushio)





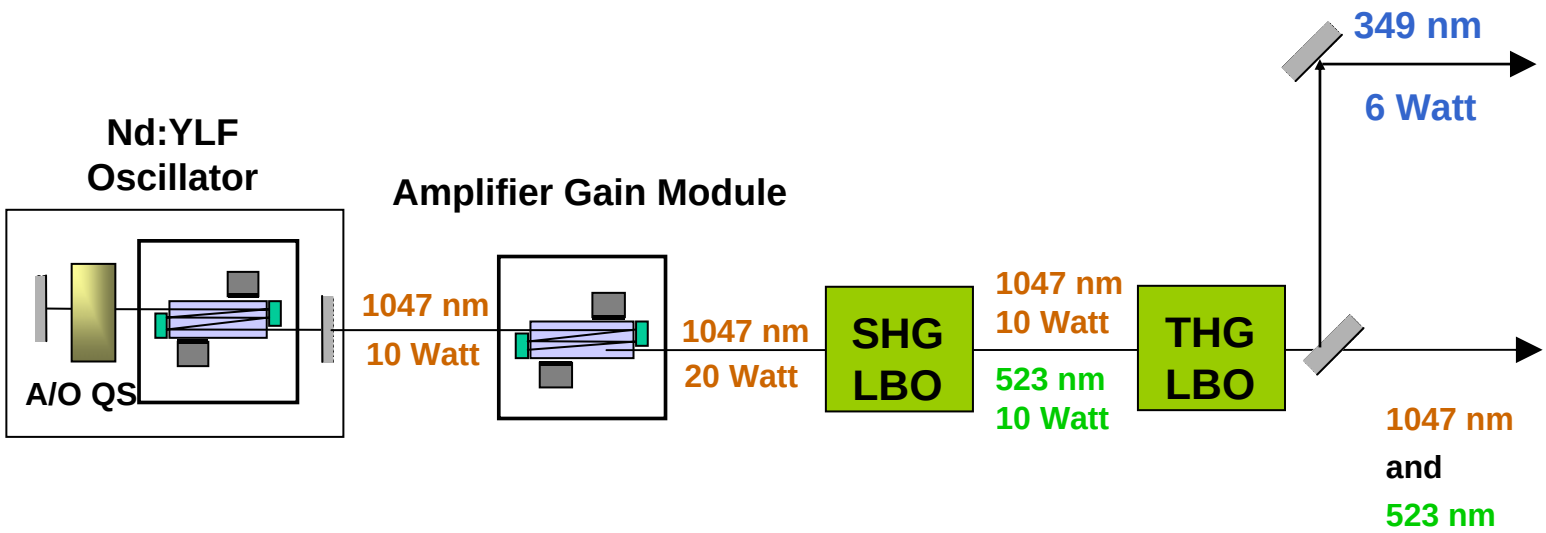
SHG (523.5 nm):
30 W at 67 kHz
and 60-68% conversion in LBO

3HG (349 nm):
6 W at 10 kHz (30%)
15 W at 5 kHz in LBO

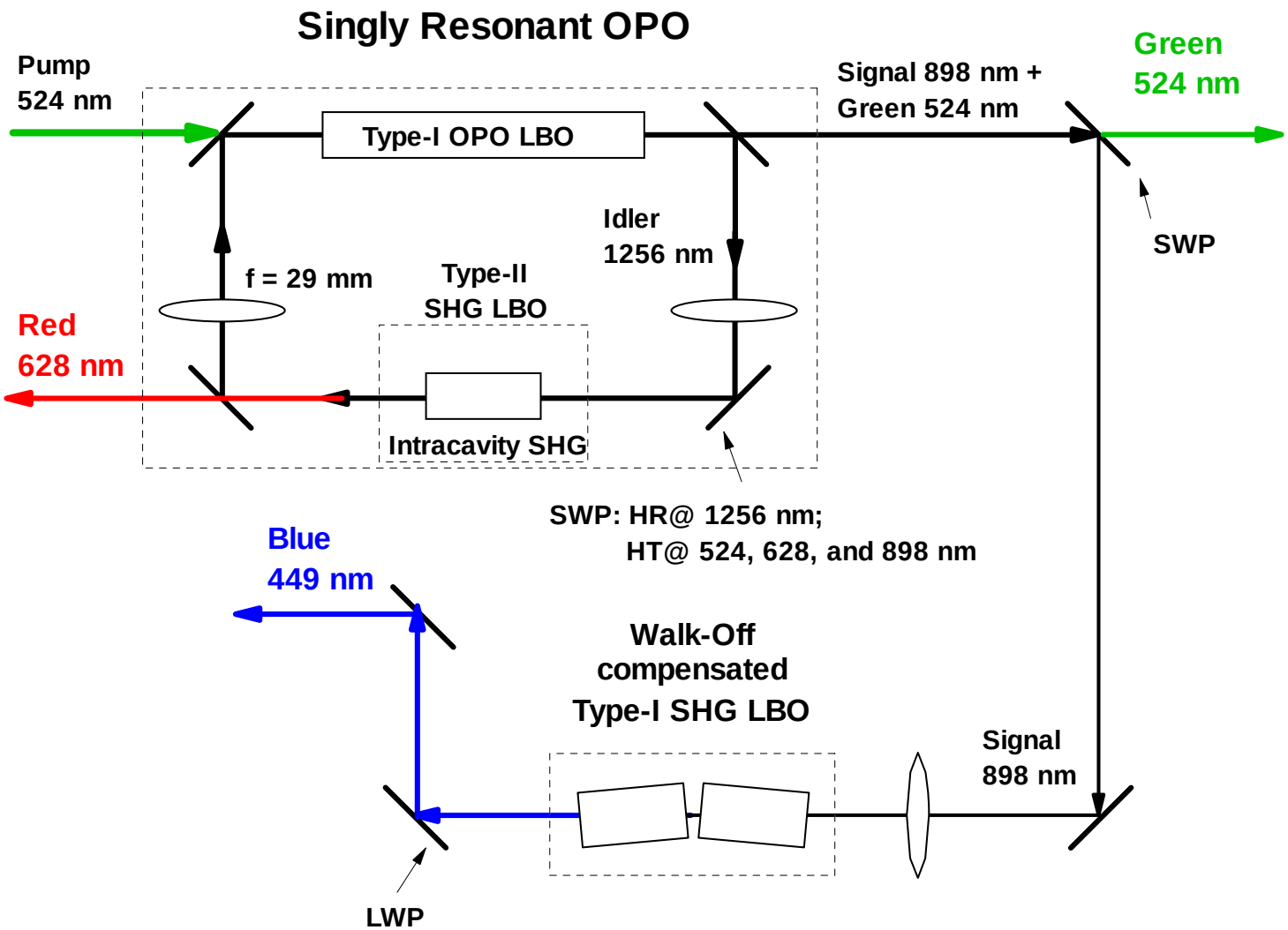
4HG (262 nm):
10 W at 5 kHz with CLBO
2.5 W at 10 kHz in BBO

5HG (207 nm):
2 W (internal)
at 5 kHz with CLBO

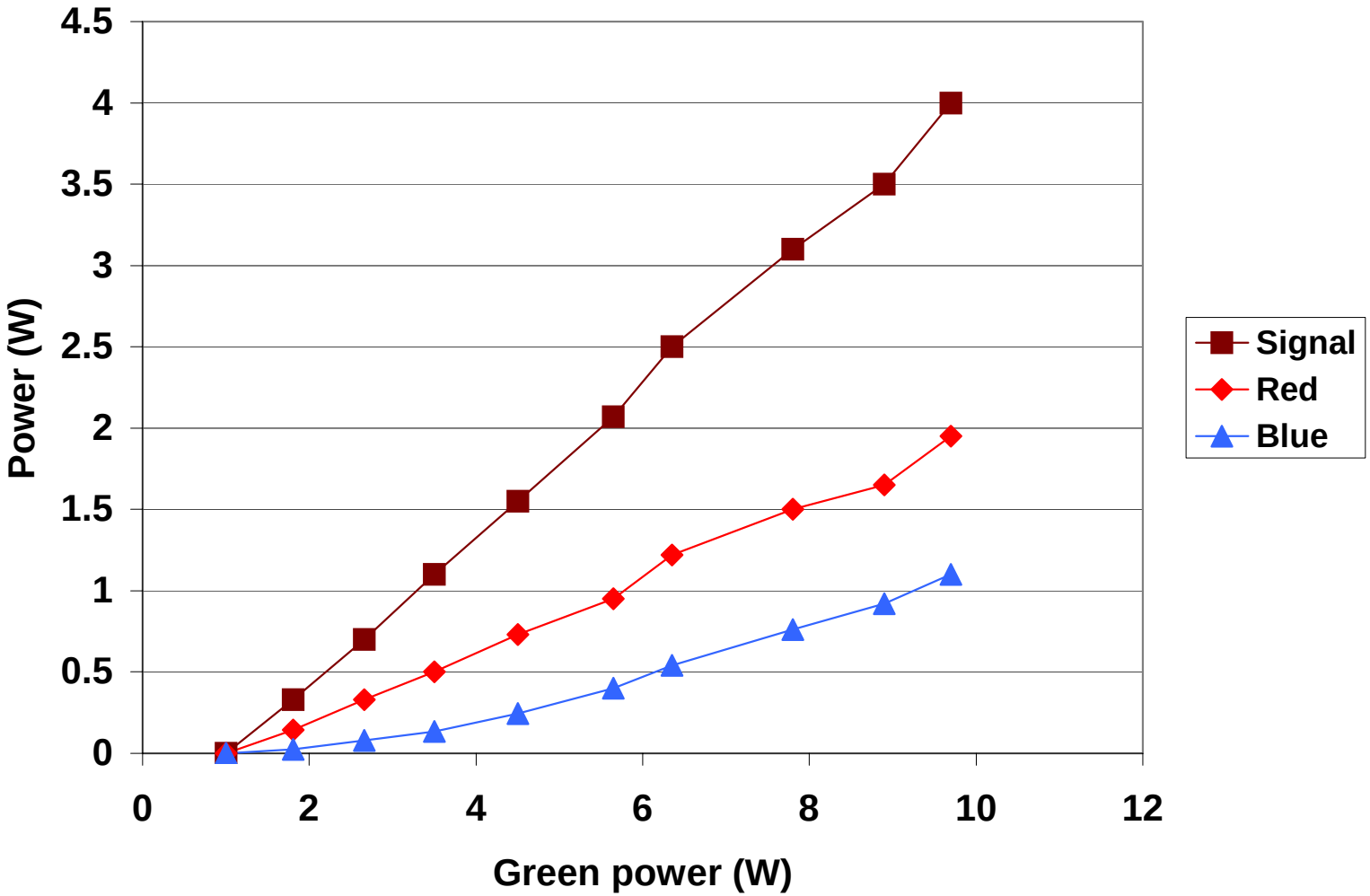
MPS-based 349-nm commercial product



Schematic of RGB OPO

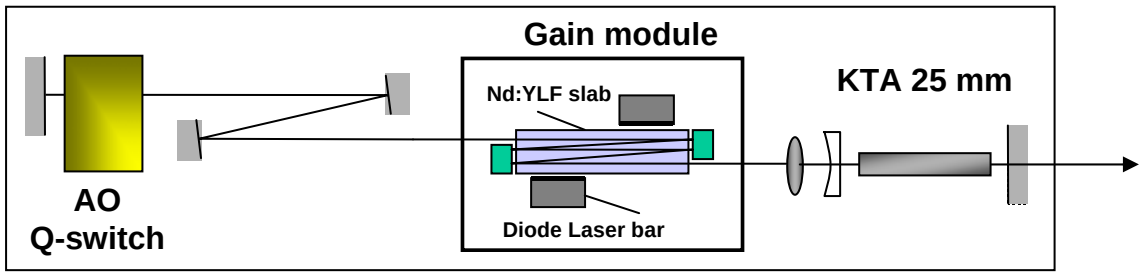


Watt-level doubled OPO outputs at 10 kHz



IR parametric oscillator systems

Intracavity OPO



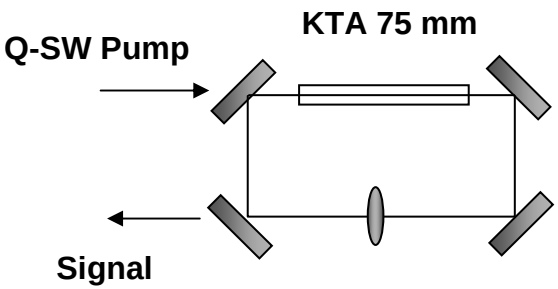
1 W output

at 1507 nm

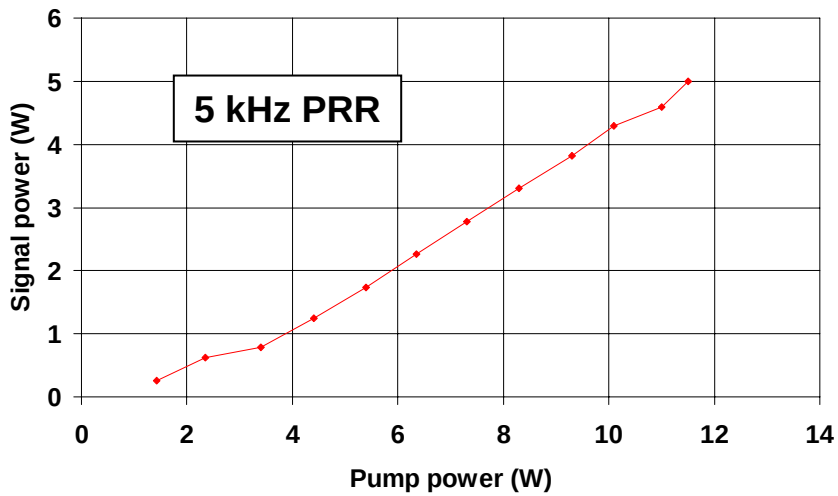
12.5 kHz PRR

6 ns pulsewidth

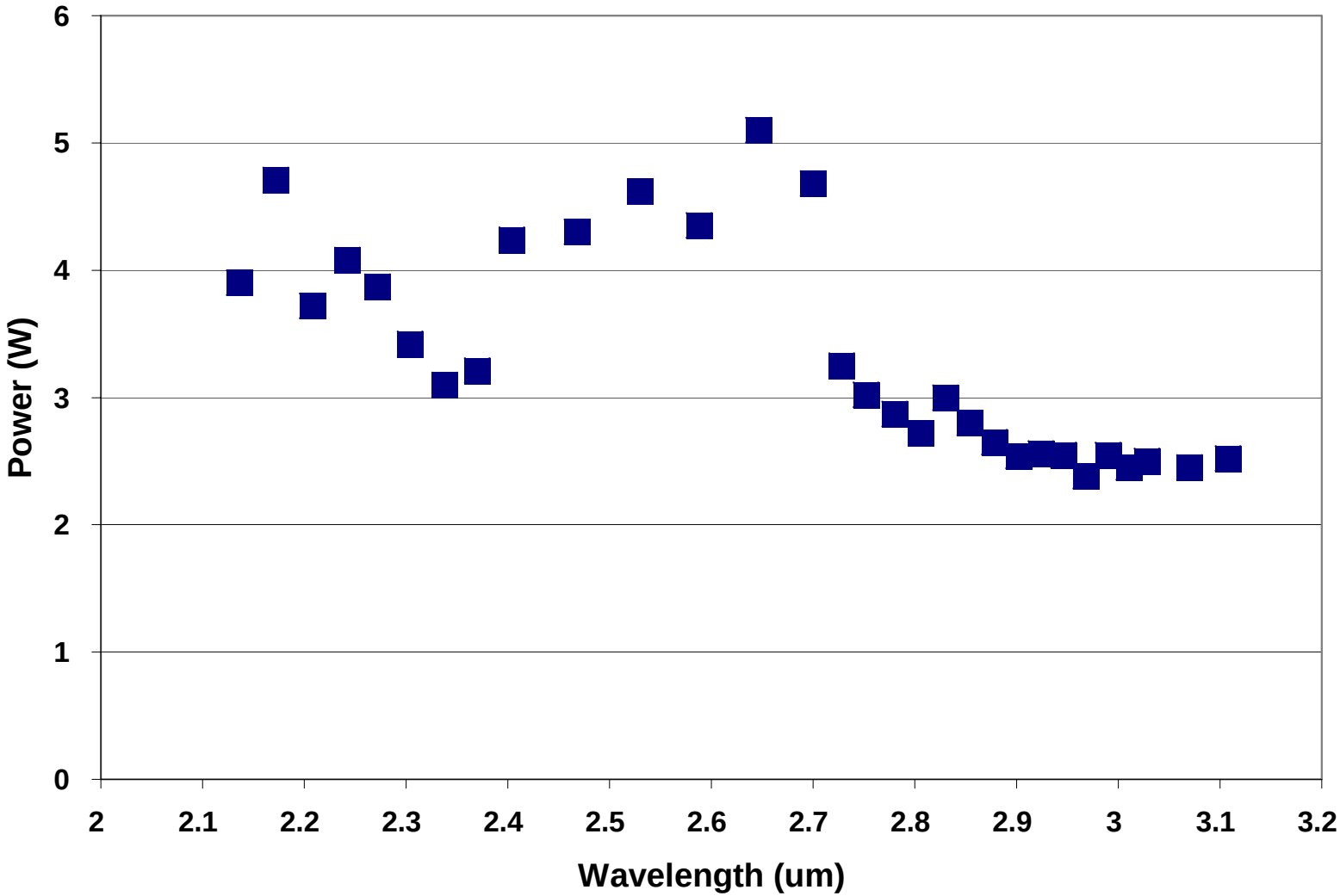
External OPO



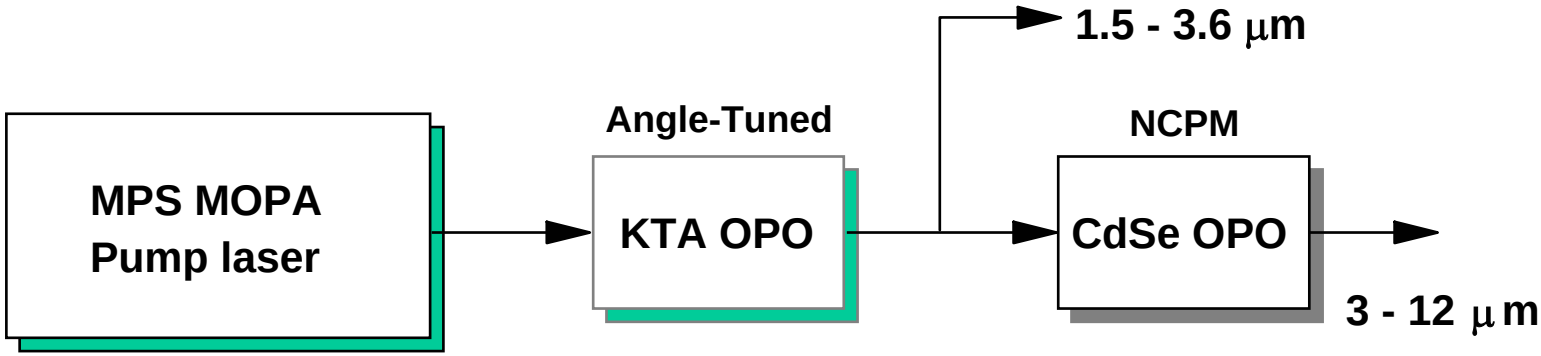
43% conversion to 1507 nm



Tuning curve for MPS-driven KTA OPO



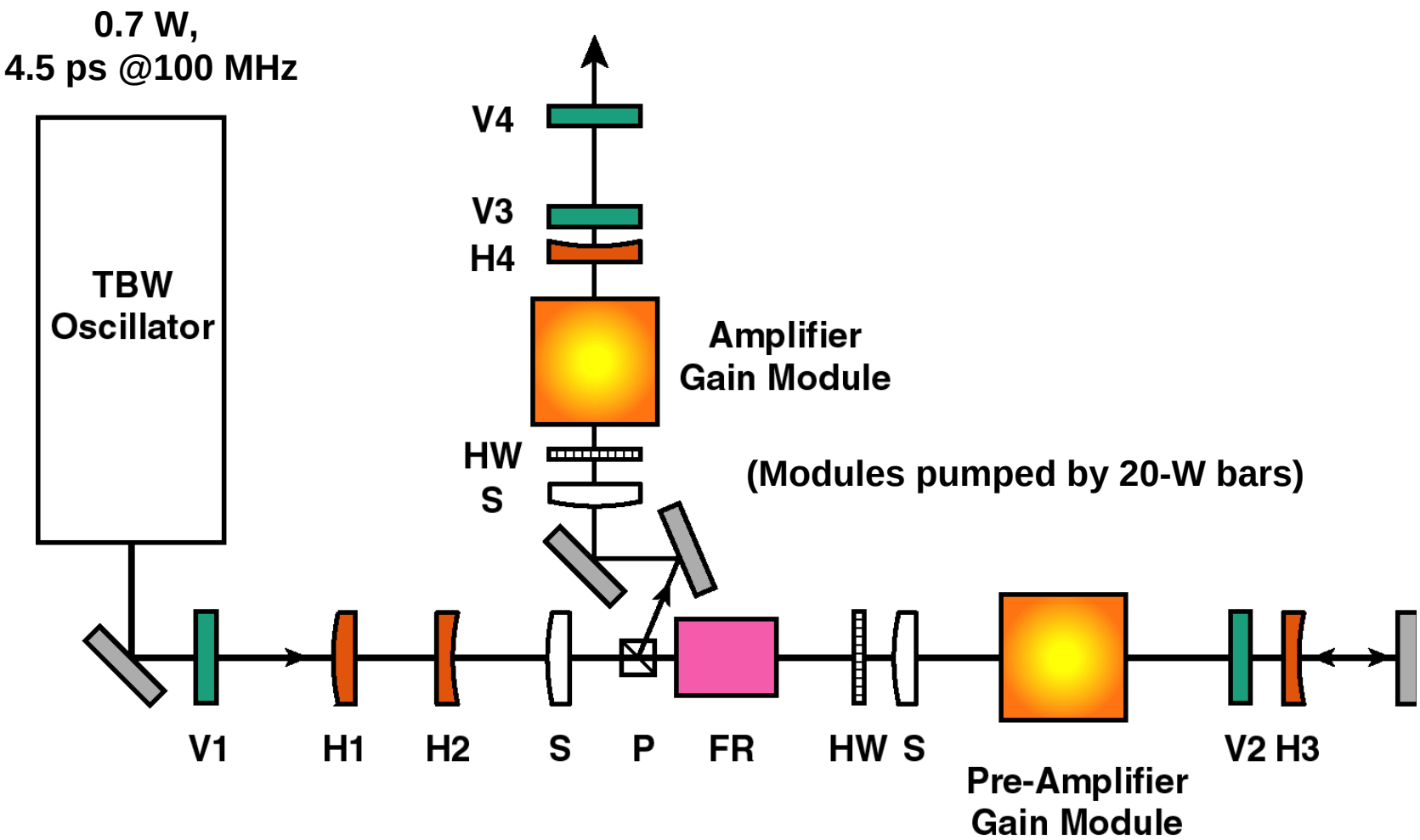
Tandem OPO design gives full IR coverage



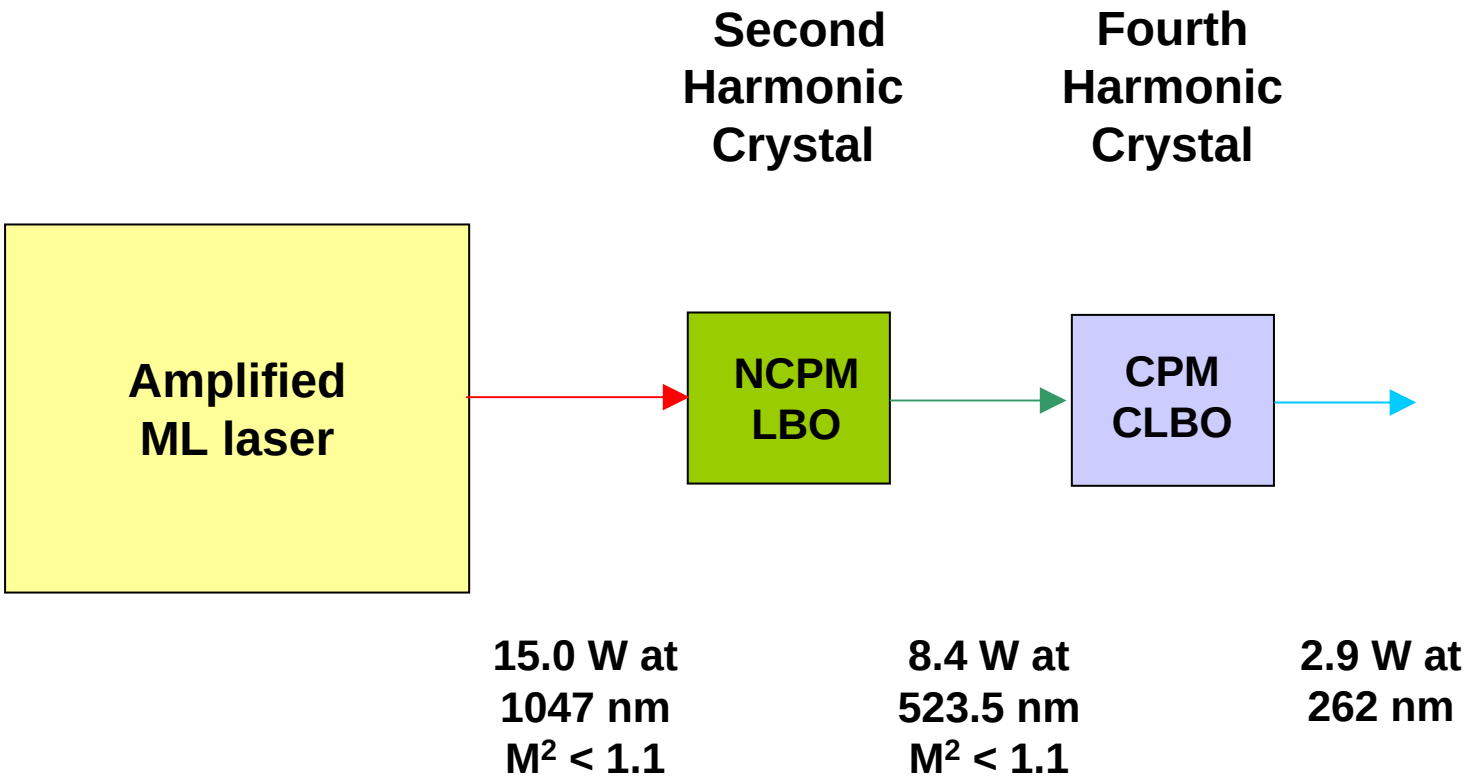
Results to date:
(At 4 kHz pulse rate, 30-W pump power)

- **KTA signal at 1514 nm: 6.5 W**
- **KTA idler at 3450 nm: 5 W**
- **CdSe signal at 5120 nm: threshold**
- **CdSe idler at 10570 nm: threshold**

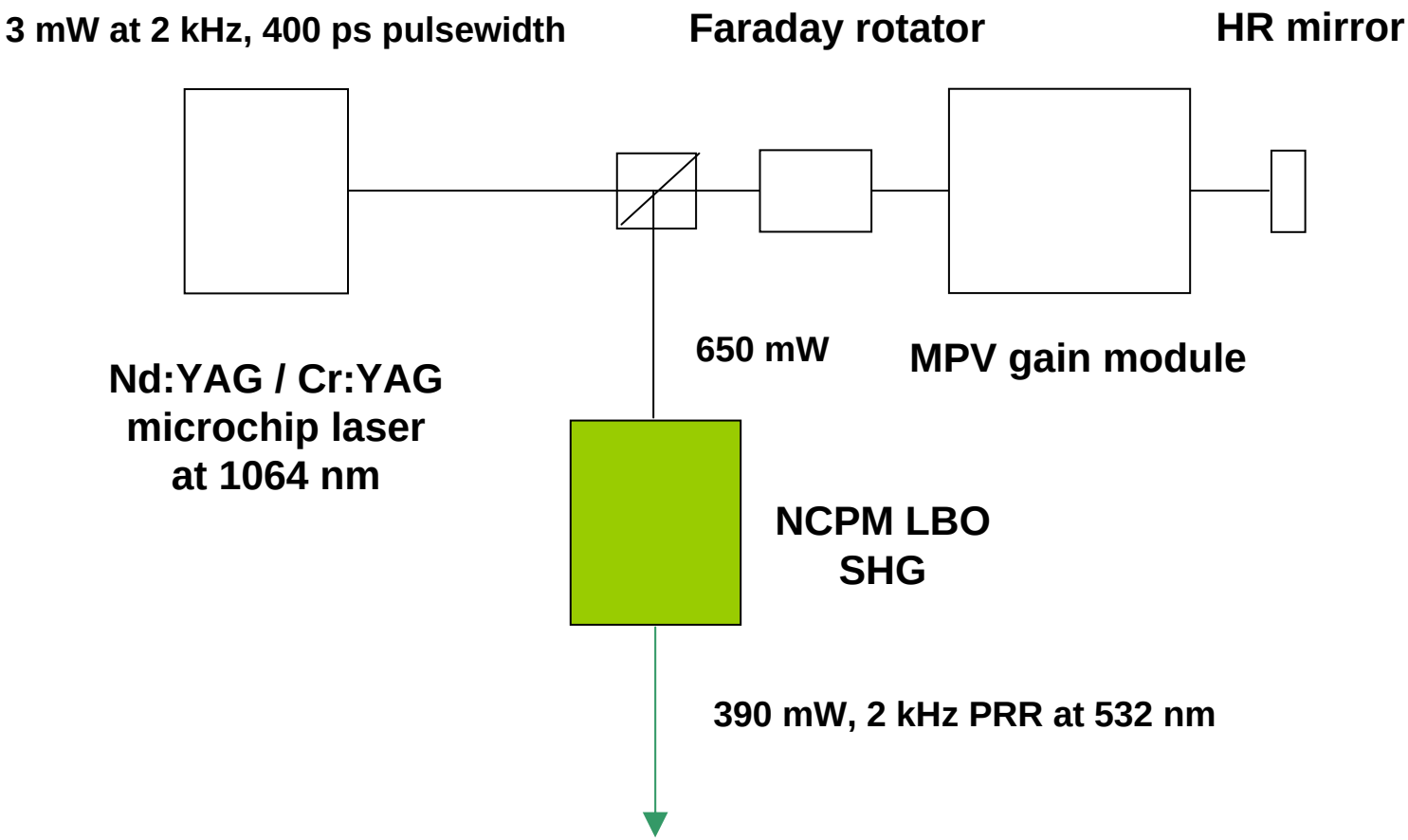
MPS modules amplify a mode-locked laser



Amplified ML laser converts efficiently



MPV amplifies a micro-chip laser



Summary

- Side-pumped Nd:YLF MPS and Nd:YVO_4 MPV designs combine simplicity, scalability of side pumping with the high-efficiency, TEM_{00}-mode performance of fiber-coupled, end-pumping designs.
- Recent availability of 40-W bars has more than doubled the output of MPS Nd:YLF "gain module" to > 25 W and increased peak power at high pulse rates. Nd:YVO_4 performance may improve as well, but strong thermal lensing will be a challenge.
- CW-pumped, Q-switched systems can efficiently drive nonlinear optics to generate tunable, vis-UV and IR wavelengths.
- Systems designers should consider cw-diode-pumped systems instead of pulsed-pumped systems for cost and reliability reasons.