High-power, high-energy diode-pumped Tm:YLF-Ho:YLF laser

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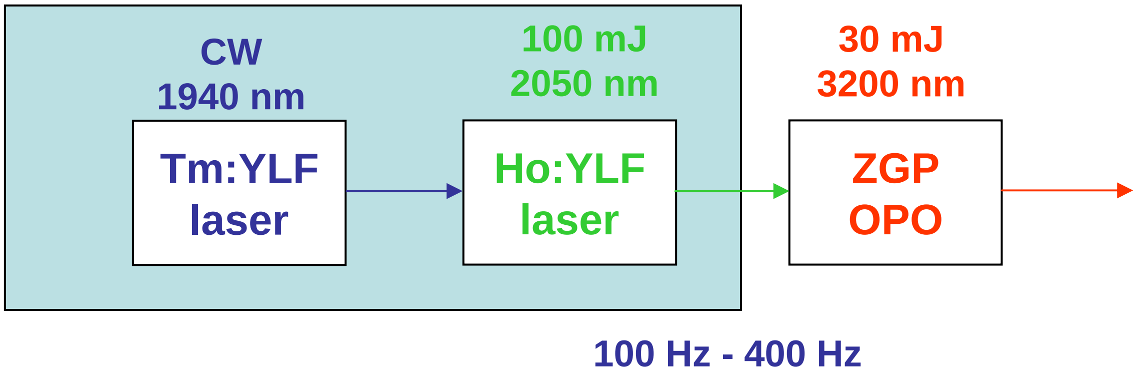
Outline

- Motivation
- Previous Results
- Tm:YLF Laser - Details
- Ho:YLF Laser – Details
- ZGP OPO ← New !
- Conclusions

Motivation

- Development of a 2-um laser source:
  - High-energy (up to 100 mJ)
  - High repetition rate (100-400 Hz)
  - High beam quality (TEMoo)



- Possible applications :
  - Pump source for other IR lasers
  - Industrial
  - Military

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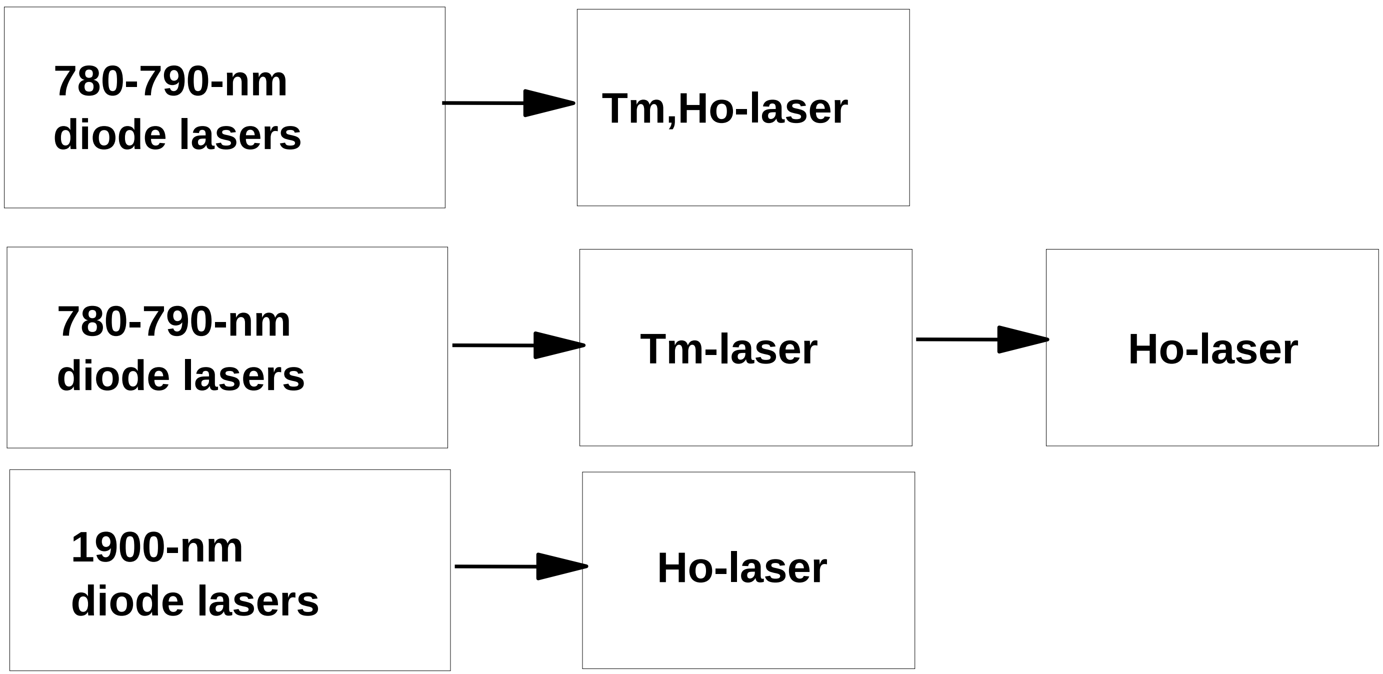
Approaches to diode-pumping of Ho-doped lasers



Advantages of Tm-pumped Ho-laser

- **Compared to diode-pumped Tm, Ho-co-doped laser:**
  - **Eliminates upconversion from Tm-Ho interaction that reduces efficiency and creates additional heating in crystal**
  - **Eliminates energy sharing between Tm and Ho that limits energy extraction in Q-switched mode**

- **Compared to direct-diode-pumped Ho-laser**
  - **Can operate at much higher power due to the availability of high-power diodes for Tm:YLF pumping**

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References on resonantly pumped Ho lasers

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P.A. Budni, M.L. Lemons, J.R. Mosto, and E.P. Chicklis, IEEE J. Sel. Topics in Quantum Electron. 6, 629 (2000).

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Previous results – Ho-lasers

- Tm:YLF pumped Ho:YAG

  P. A. Budni et al., "High-power/high-brightness diode-pumped 1.9-µm Thulium and resonantly pumped 2.1-µm Holmium lasers," IEEE J. on Selected Topics in Quantum Electron., 6, 629-635 (2000).

  - Tm:YLF pump
    - 36 W CW output at 1.907 mm (σ-line)
    - Multimode, $M^2 \sim 2$
  - Ho:YAG
    - CW: 19 W
    - QCW: 16 W at 15 kHz

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Ho:YLF vs Ho:YAG

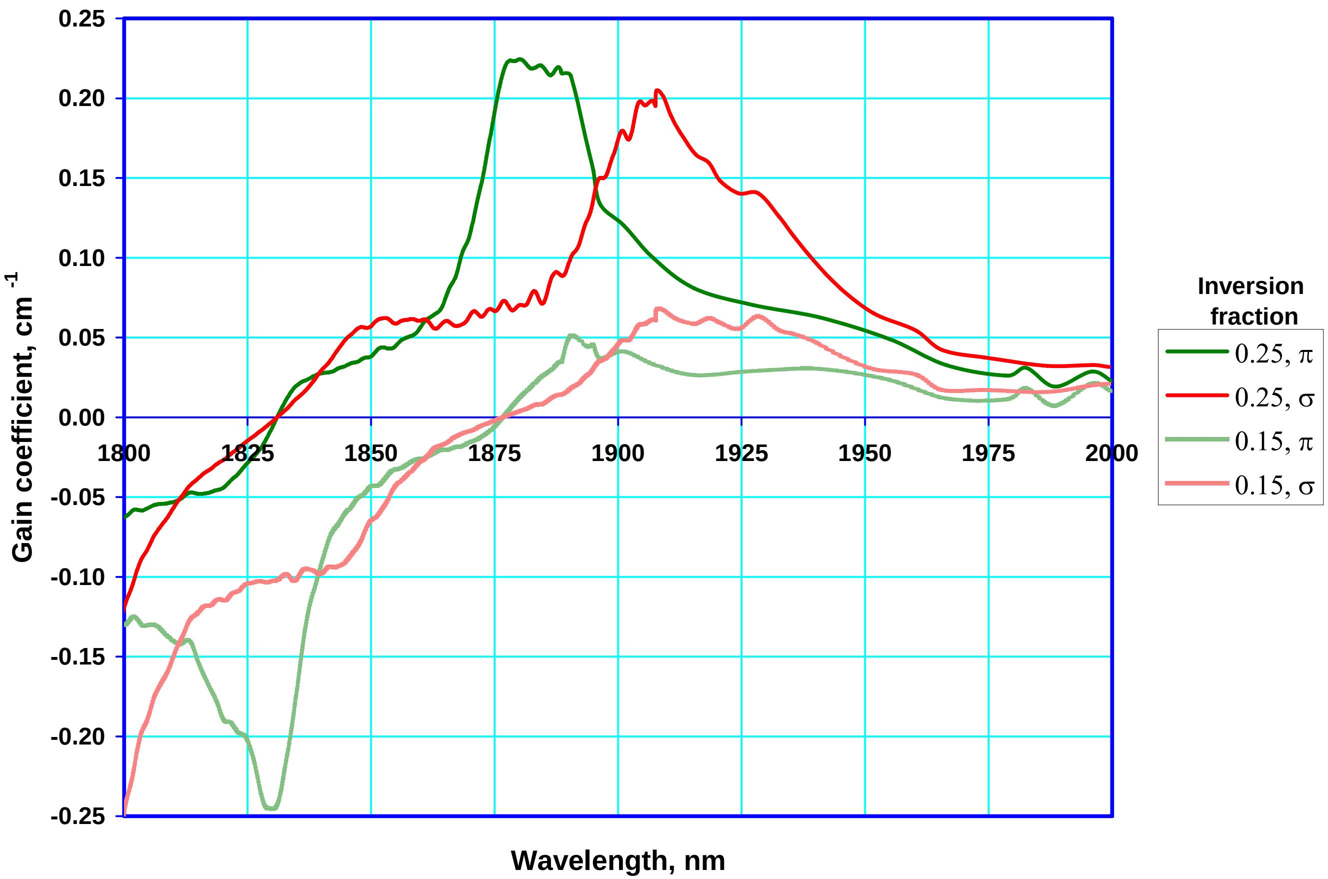
Why Ho:YLF?

- Long upper laser level lifetime ~ 15 ms
- Higher emission cross-section
- Naturally birefringent material
- Low dn/dT –> weak thermal lensing

Ho:YAG

- Isotropic
- Lifetime ($^5I_7$) 7 ms
- Strong thermal lensing
- Excellent thermo-mechanical properties

Gain Calculation – 3.5% Tm:YLF

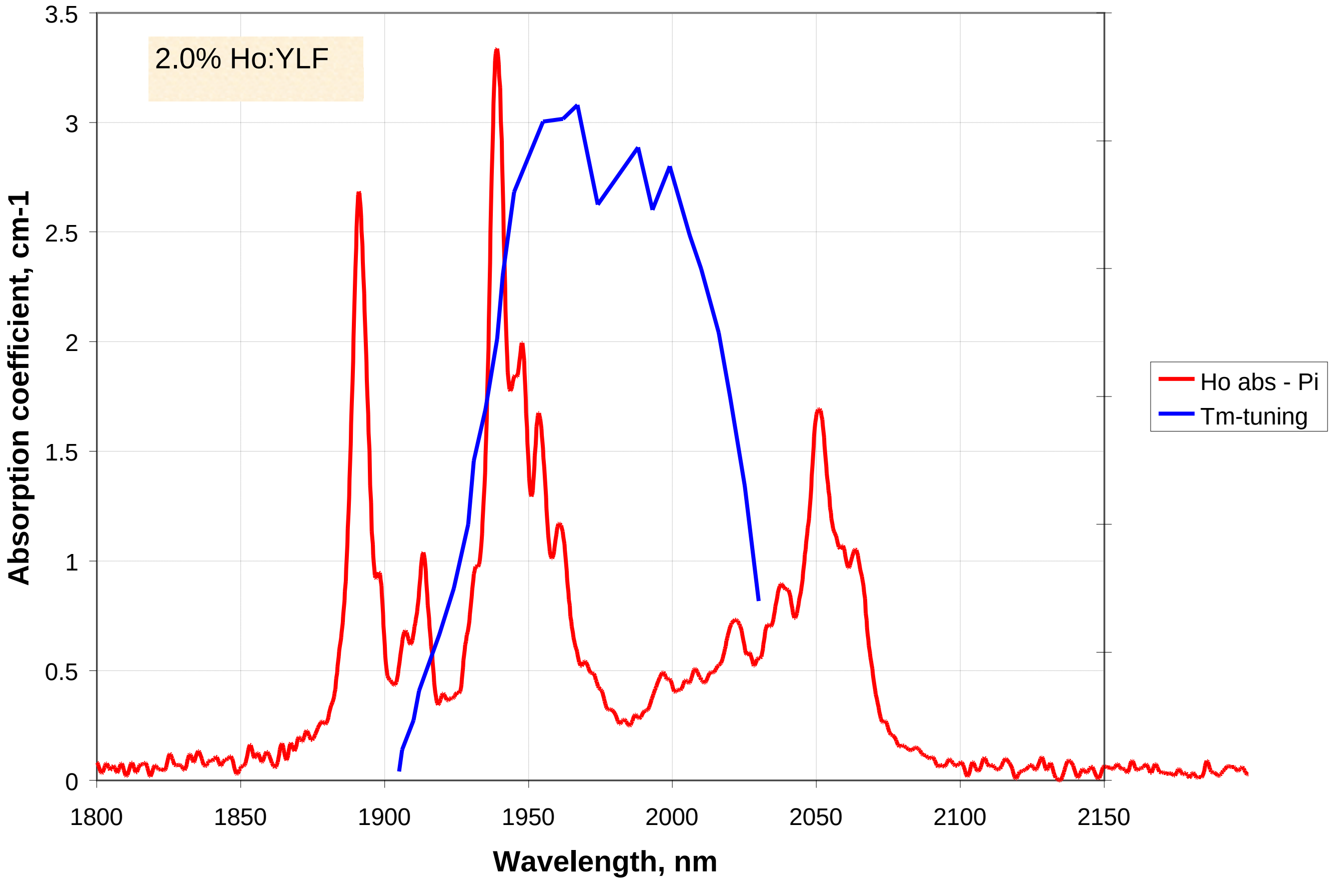


Polarized gain in Tm:YLF at two values of inversion fraction

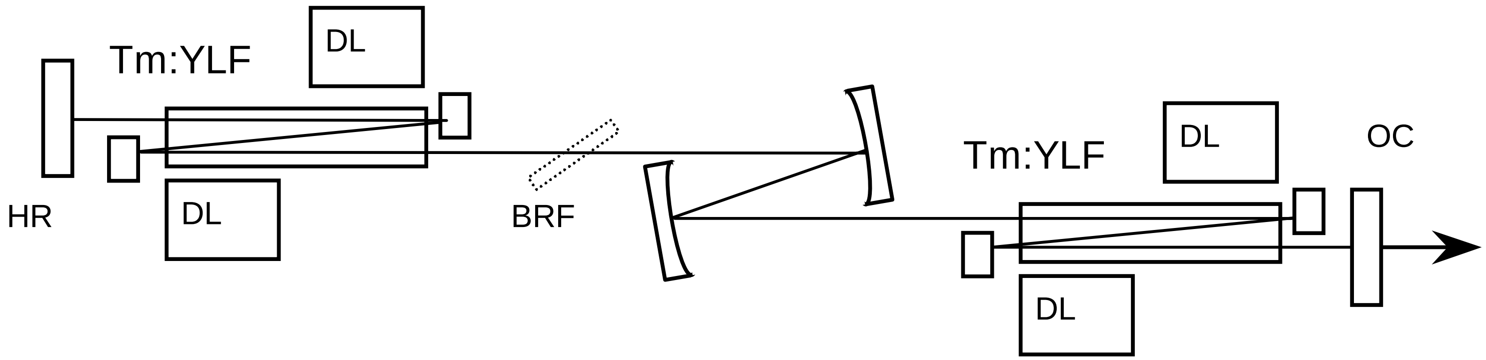
$g(\lambda) = N\,[\,p \cdot \sigma_{em}(\lambda) - (1-p) \cdot \sigma_{abs}(\lambda)\,],$

where *p* – inversion fraction, *N* - Tm-concentration

Pumping Ho:YLF with Tm:YLF laser



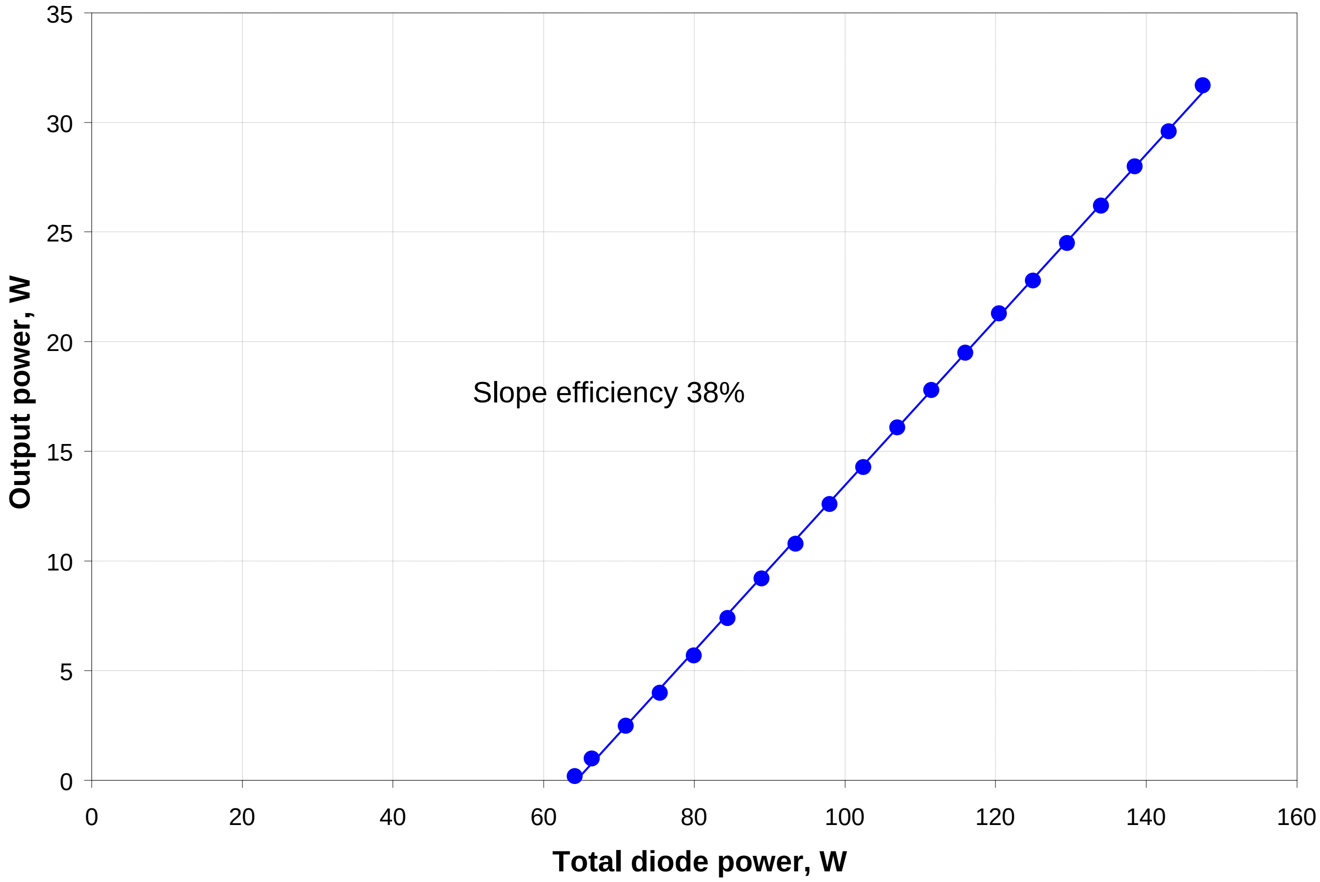
Experimental Set-Up – Tm:YLF Laser



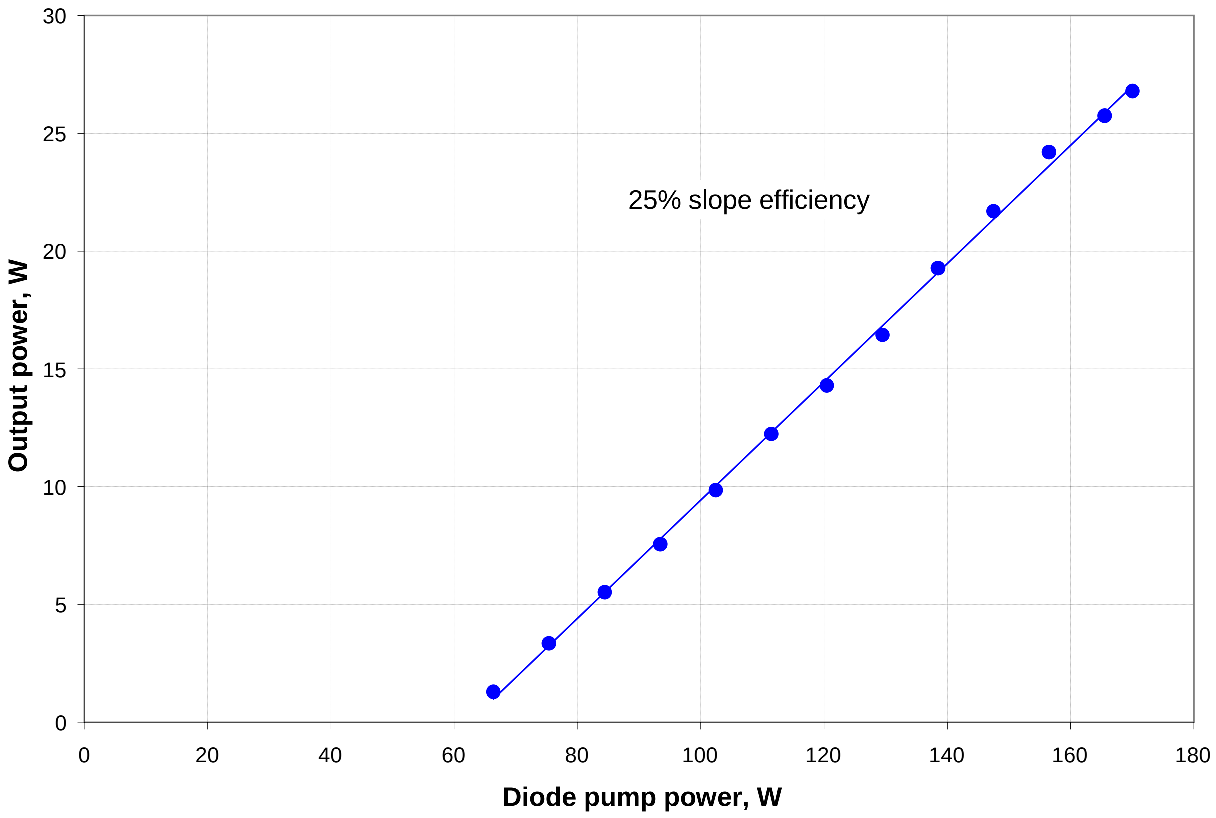
- **Tm:YLF Active Element:**

Rectangular slab:
22-mm long
Clear aperture 2x6 mm.

Tm:YLF – Dual GM Oscillator – 1 pass



Tm:YLF – Dual GM Oscillator – 3 passes



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Calculations for Tm:YLF-pumped Ho:YLF laser at low pulse rates

Crystal doping (%)	0.5
N_0 (cm^{-3})	7×10^{19}
Crystal length (cm)	3.6
Scaled pump fluence	1.6
Pump pulsewidth (msec)	15
Pump power (W)	20
average inversion fraction	0.44
η_s pumping efficiency	0.52
F_p (J/cm^2)	21.1
Pump energy (J)	0.3
Pump-beam radius (cm)	0.048
Stored energy in crystal (J)	0.16
g_0, Gain coefficient (cm^{-1})	0.36
G, Single-pass gain	3.7

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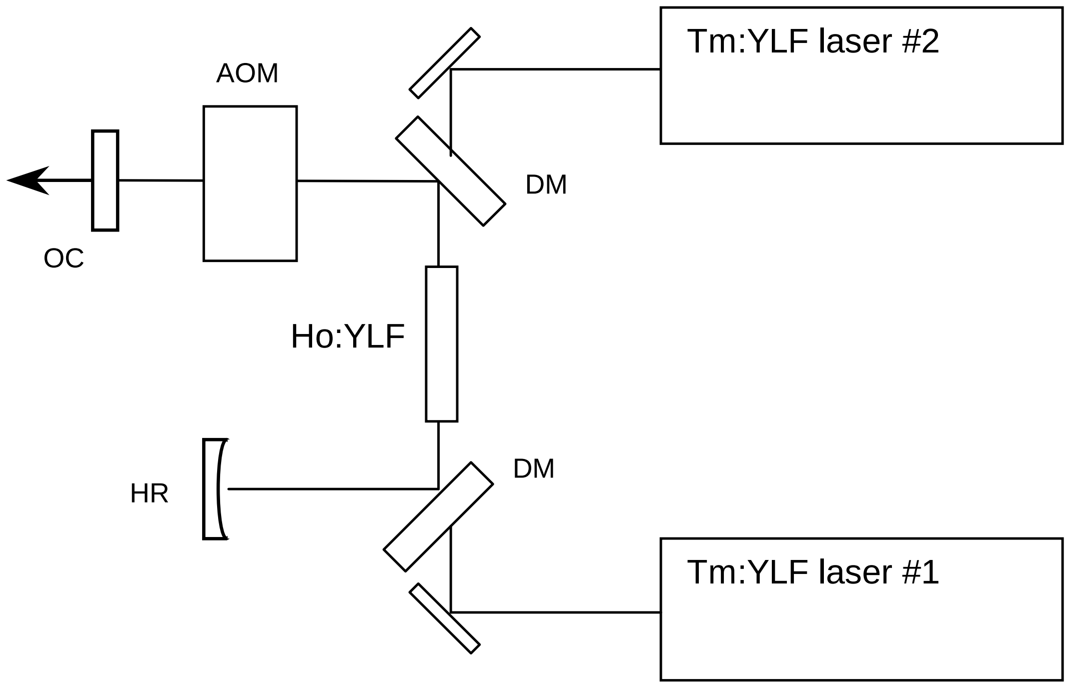
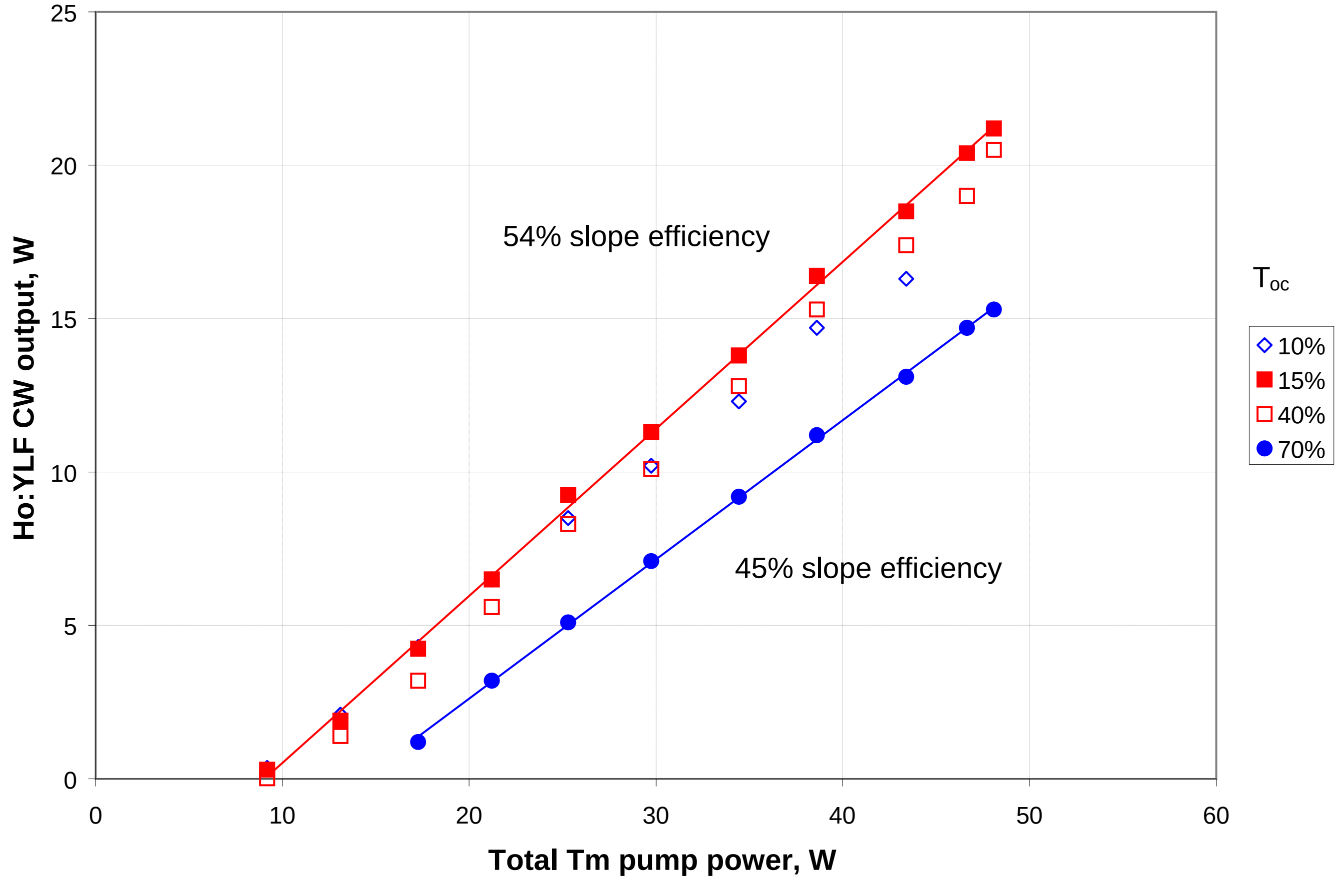
Calculations are based on work by W.F. Krupke and L.L. Chase, Optical and Quantum Electron. 22, S1 (1989).

Schematic layout of the end-pumped Ho:YLF laser



DM – Dichroic Mirror,
AOM – Acousto-Optic Modulator,
OC – Output Coupler,
HR – High Reflector

CW Ho:YLF Laser Operation (TEM_{oo})



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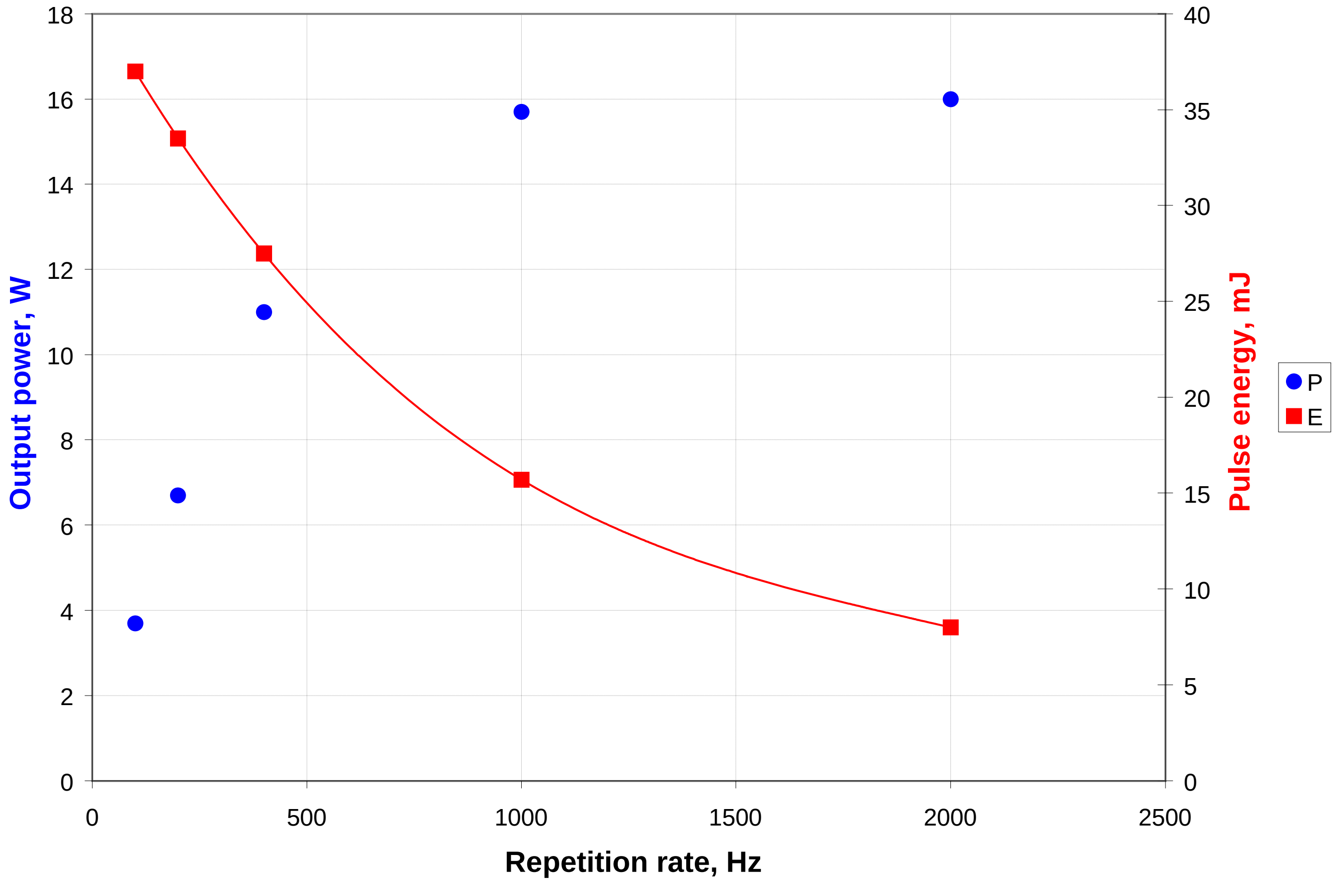
Ho:YLF – Q-Switched Operation (TEMoo)



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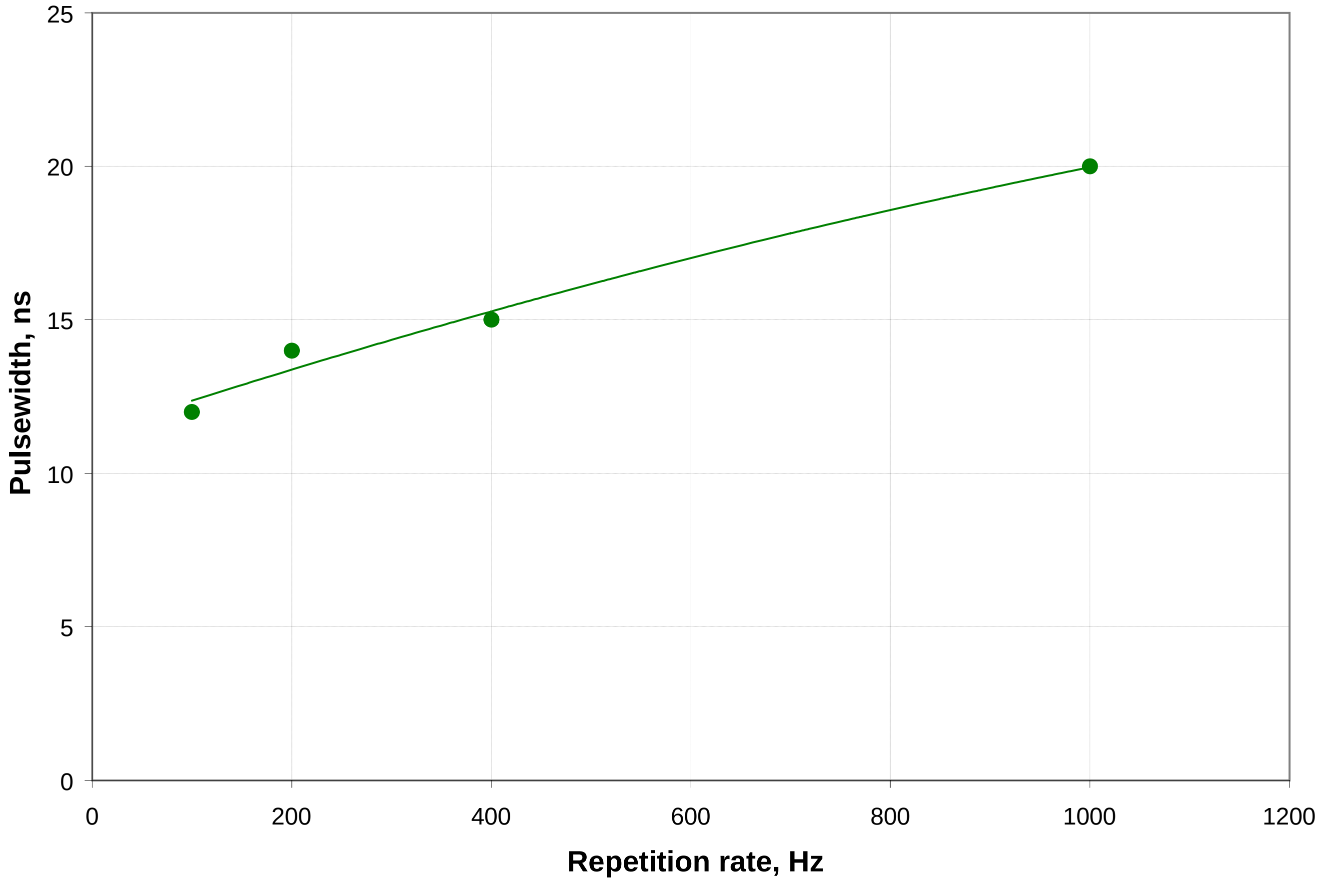
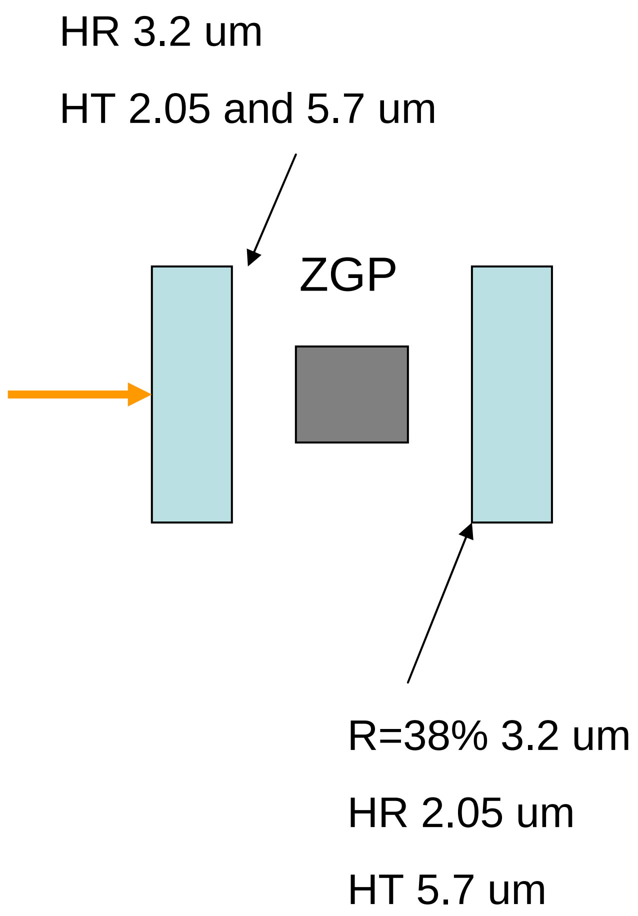
Ho:YLF – Pulsewidth vs repetition rate

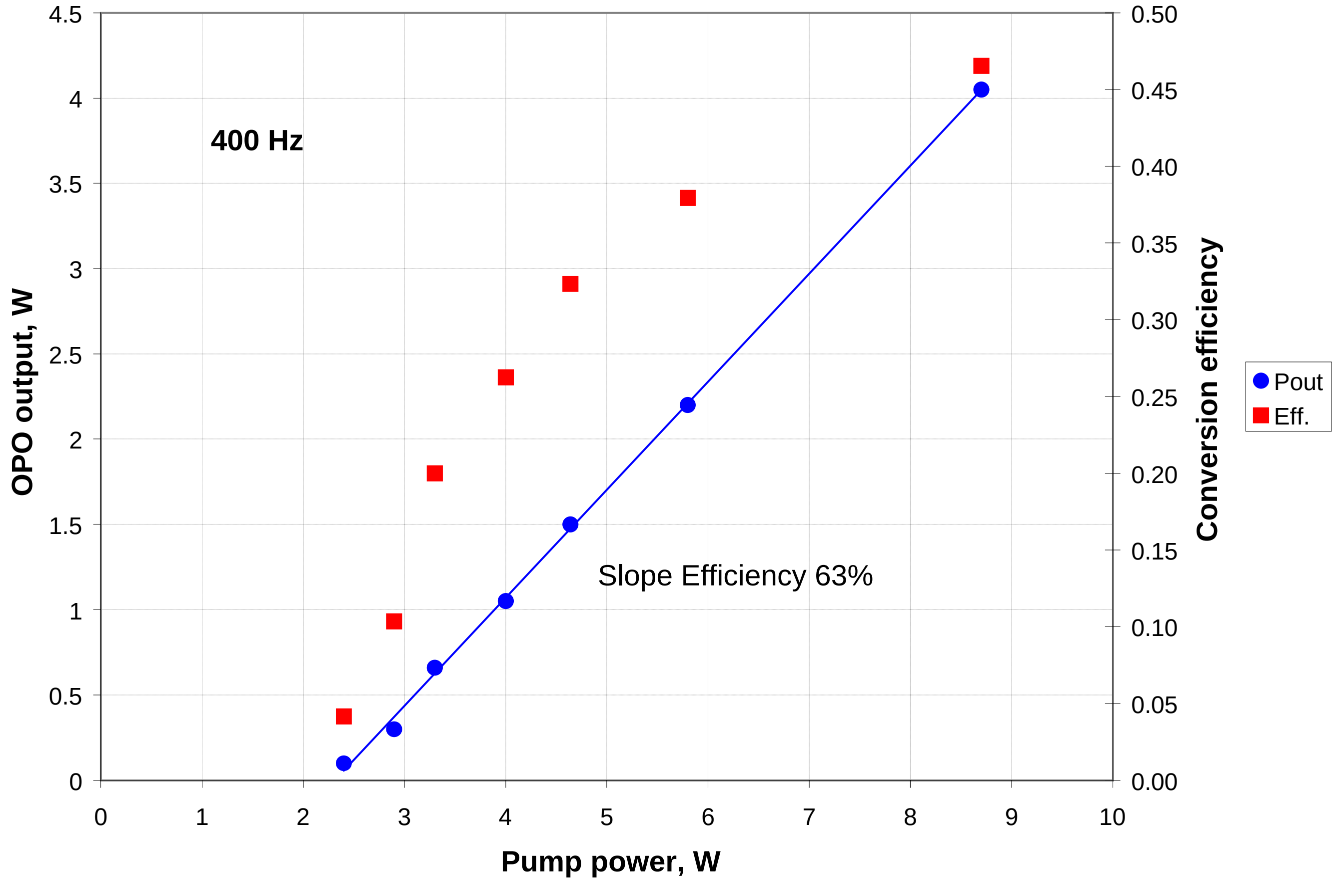


ZGP OPO - Layout

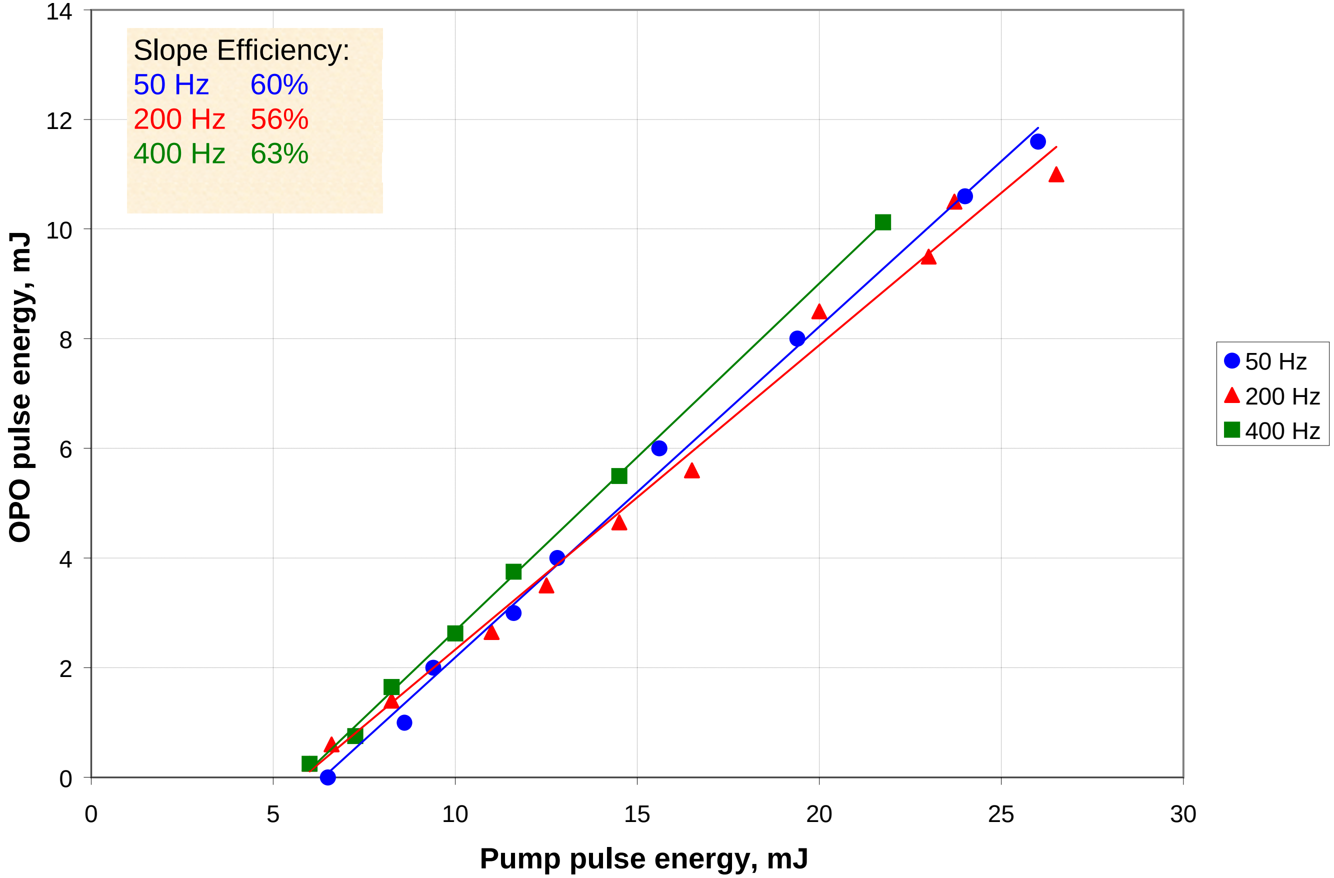


- ZGP OPO:
  - ZGP 1 cm-long
  - Type I, 53°-cut
  - Flat/flat resonator
  - Singly resonant cavity
  - Pump – double pass
  - ~6 cm-long resonator
  - OC 38% at 3.2 um

ZGP Operation – 400 Hz



ZGP OPO Operation – Pulse energy



Conclusions

Development of an efficient Tm:YLF - Ho:YLF – ZGP laser system:

- Ho:YLF laser:
  - Highest (to the best of our knowledge) CW output of 21 W for 2-μm Ho:YLF laser
  - Efficient Q-switched operation (up to 37 mJ per pulse)
  - Repetition rates in wide range from Hz to kHz, particularly, in 100-400 Hz
  - High beam quality TEMoo beam
- ZGP OPO
  - Demonstrated > 10 mJ (total) output at 50-400 Hz rep. rates