
Tunable CW Er:YLF diode-pumped laser

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Motivation

- ❑ Development of a directly diode-pumped tunable CW high-power (> 1 W) 3- μm laser
- ❑ Possible applications
 - Industrial
 - Medical

Previous results – Diode-pumped Er:YLF-lasers

Laser operation at 2.81 μm – end-pumped Er:YLF

□ Maximum slope efficiency :

- ~ 40% - Ti:Sapphire excitation (970 nm, longitudinal)
M.Pollnau et al., “Efficiency of Erbium 3-mm crystal and fiber lasers”
IEEE J. of Quantum Electronics, 32, 657-663 (1996)
- ~ 35% - Diode-Pumped (970 nm, longitudinal)
T. Jensen, A. Dening, G. Huber, and B.H.T. Chai, “Investigation of diode-pumped 2.8- μm Er:LiYF₄ lasers with various doping levels, Opt. Lett., 21, 585-587 (1996).

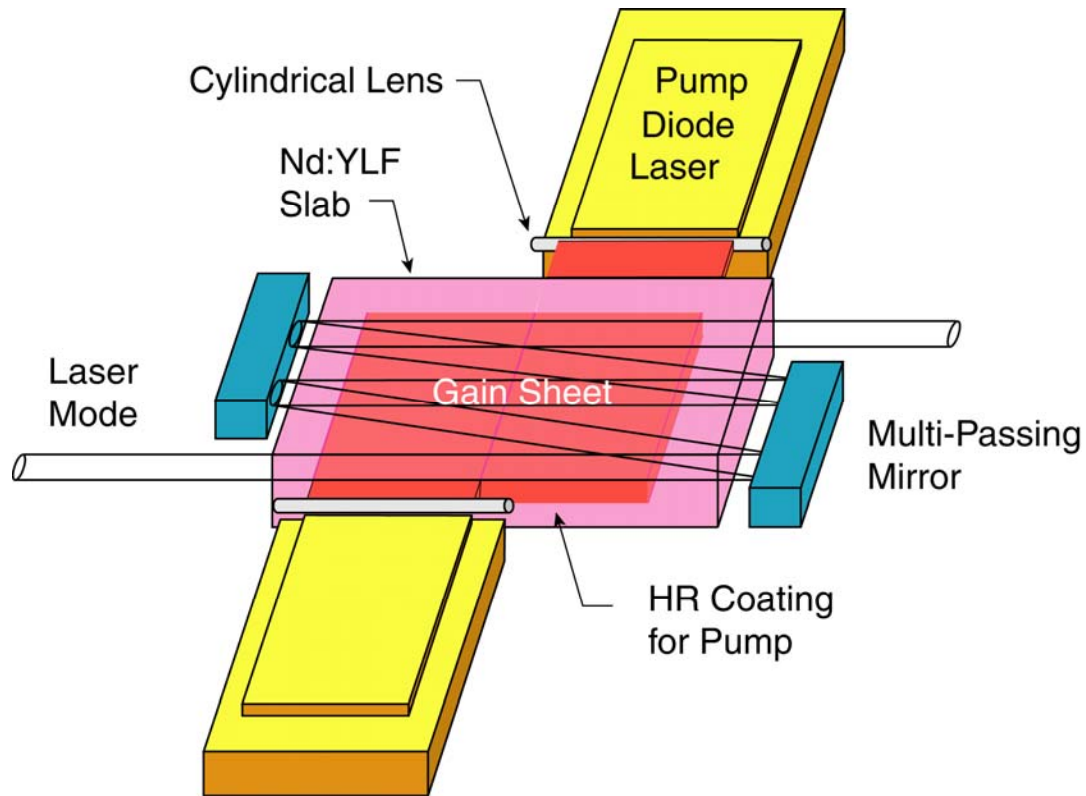
□ Maximum CW output:

- ~ 1.1 W Diode-pumped (970 nm, longitudinal, fiber-coupled diode laser)
T. Jensen et al. (see above)

□ Drawbacks:

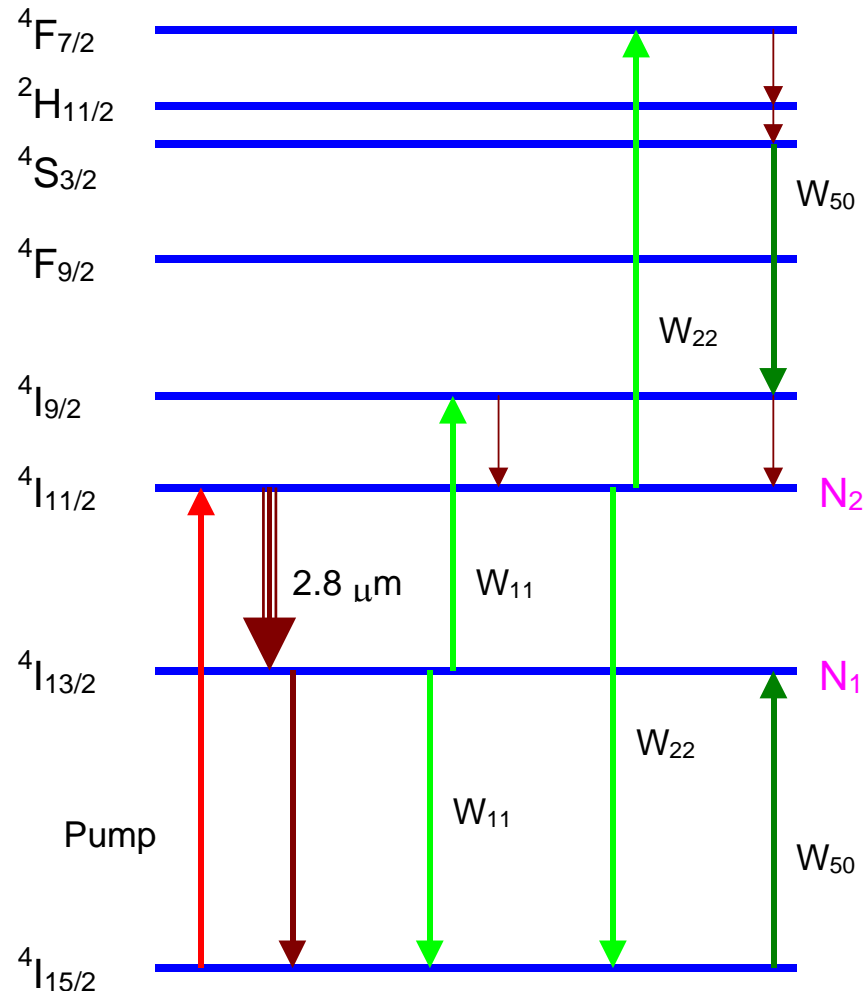
- difficult to scale to higher powers
- fracture of the laser elements at 4-6 W pump power (0.3-0.5 mm spot)

Q-Peak' MPS Gain Module Technology

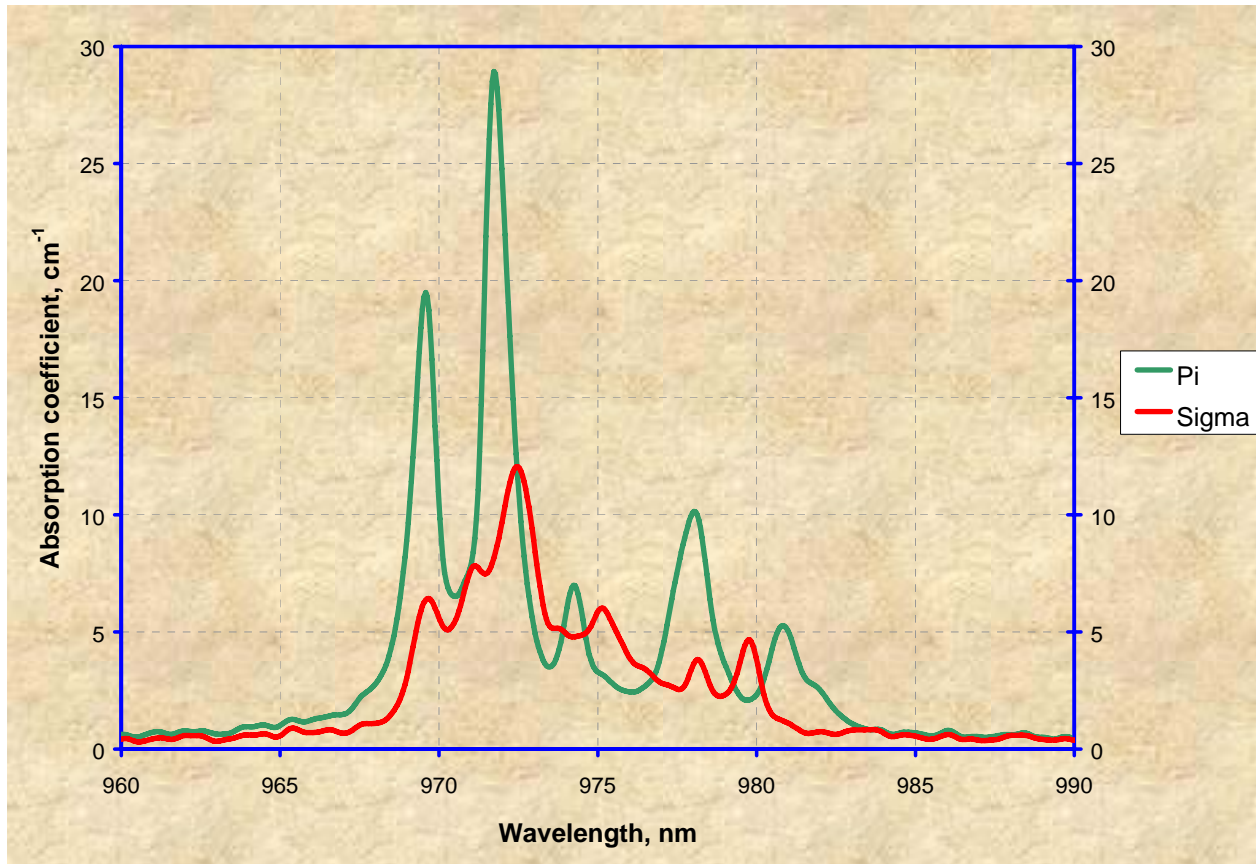


Er³⁺ Energy Level Diagram

- high Er concentration
- 980-nm pump
- strong up-conversion
- high heat generation



Absorption Properties of Er:YLF Laser Crystals



Polarized absorption spectra for 15% Er:YLF crystal at 300 K.

Pump Diode Lasers

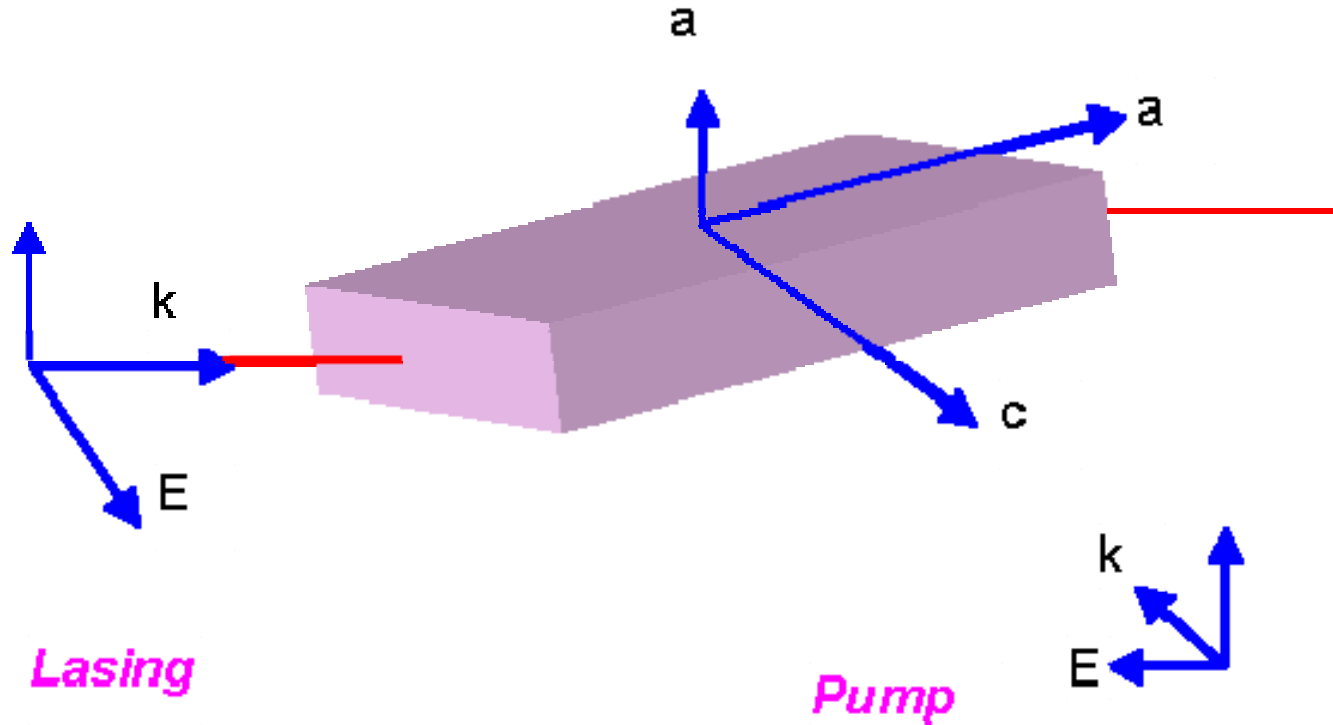
□ General case:

- Er:YLF can be pumped by the radiation of any laser or laser diode emitting in the 980 nm, 790 nm, or 1500-nm ranges.

□ This work:

Pump laser	Wavelength, nm	CW power, W
Lensed diode bar (Coherent, Inc.)	980	up to 30

Laser Element Design – Er:YLF



Lasing: $E_L \parallel c$ – π -polarization

Pump: $E_P \parallel a$ – σ -polarization

Theoretical Model

Rate equations:

$$dN_2/dt = W + W_{11}(N_1)^2 - W_{22}(N_2)^2 - N_2/\tau_2,$$

$$dN_1/dt = \beta_{21} N_2/\tau_2 + W_{22}(N_2)^2 - 2 W_{11}(N_1)^2 - N_1/\tau_1,$$

The net gain coefficient:

$$g = \sigma_{21} (b_2 N_2 - b_1 N_1),$$

Definitions:

W_{11}, W_{22} - up-conversion rate parameters,

τ_1 and τ_2 - lifetimes for spontaneous decay and

β_{21} - the branching ratio.

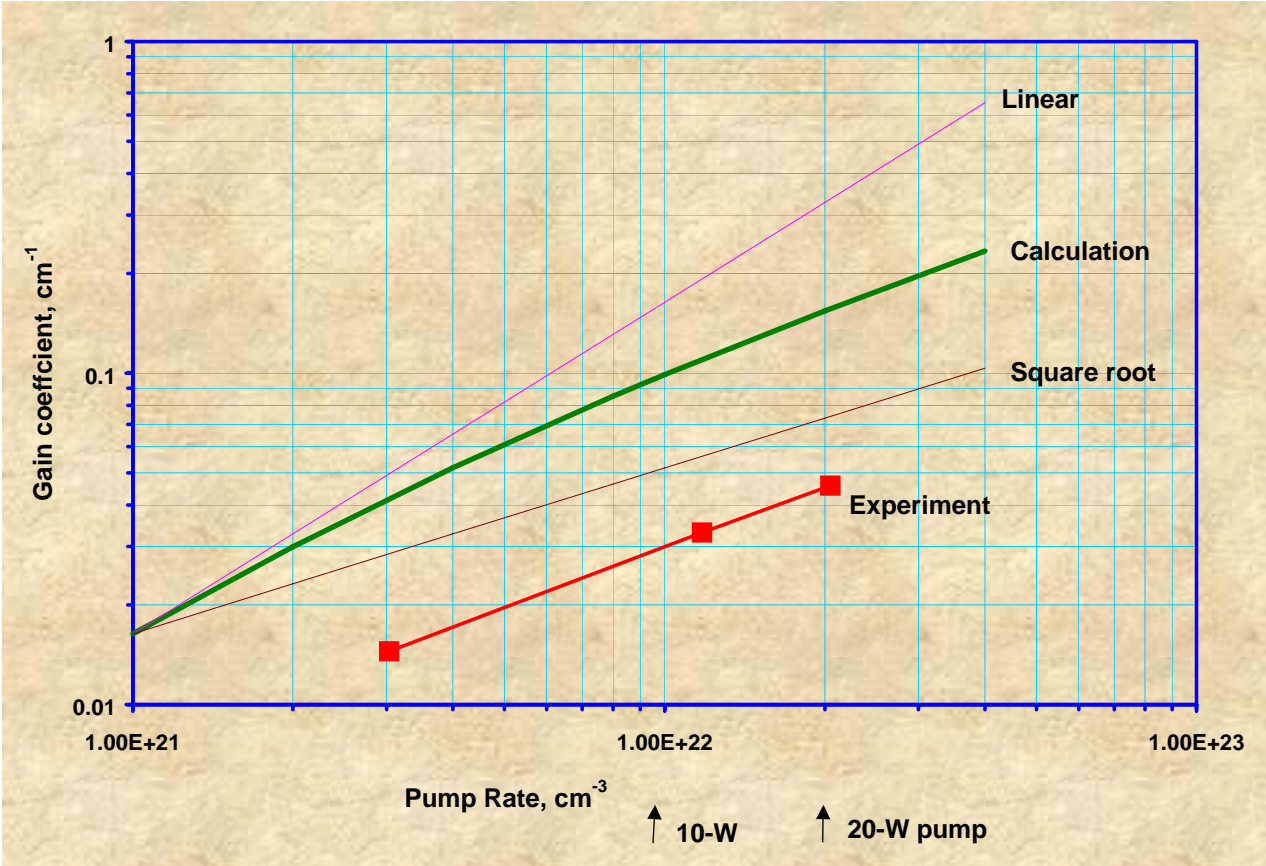
σ_{21} - spectroscopic cross section for the transition and

b_1, b_2 - Boltzmann factors for the lower and upper manifolds.

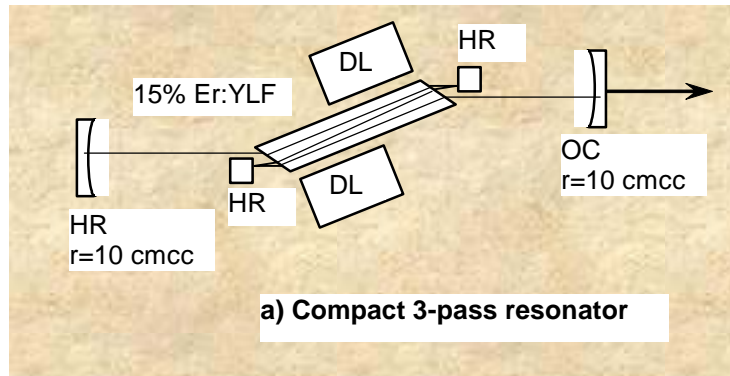
Table. Values for 15% Er:YLF used in the calculations (Based on the data from: M.Pollnau et al. IEEE J. QE, 321, 657-663 (1996)).

τ_1	10 msec
τ_2	4.0 msec
W_{11}	3×10^{-17} cm ³ /sec
W_{22}	1.8×10^{-17} cm ³ /sec
β_{21}	0.39
σ_{21}	3×10^{-20} cm ²
b_1	0.113
b_2	0.2

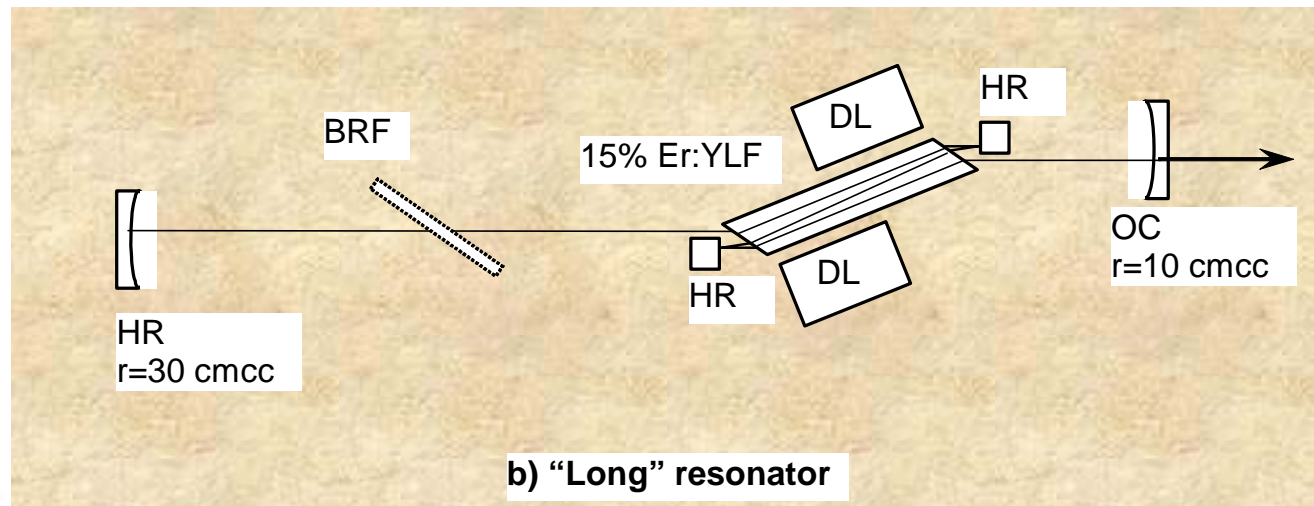
Gain Calculation



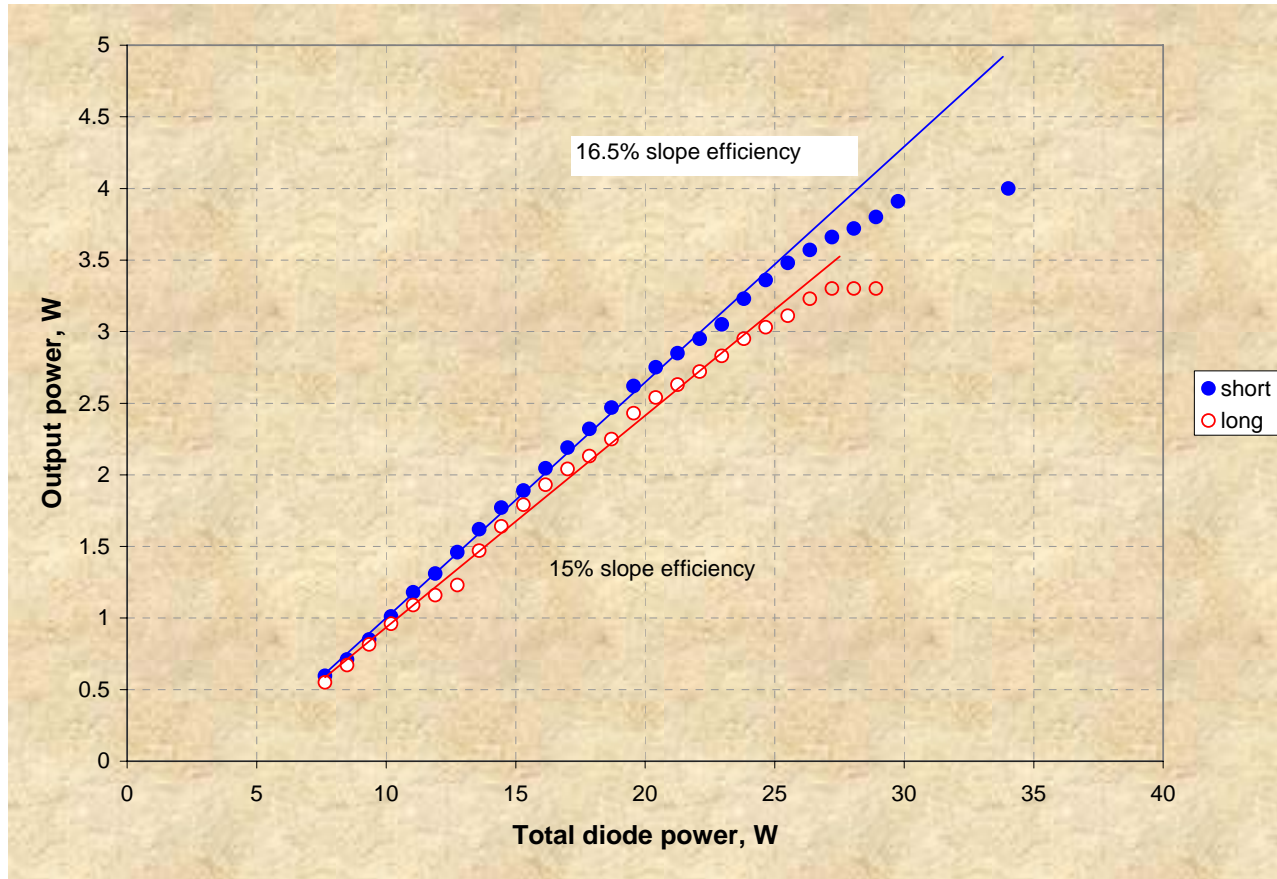
Experimental Set-Up



□ **Er:YLF Active Element:**
Brewster/Brewster-cut slab:
28-mm long
Clear aperture 1.25 x 6 mm.



Er:YLF CW Laser Operation Three-Pass Geometry

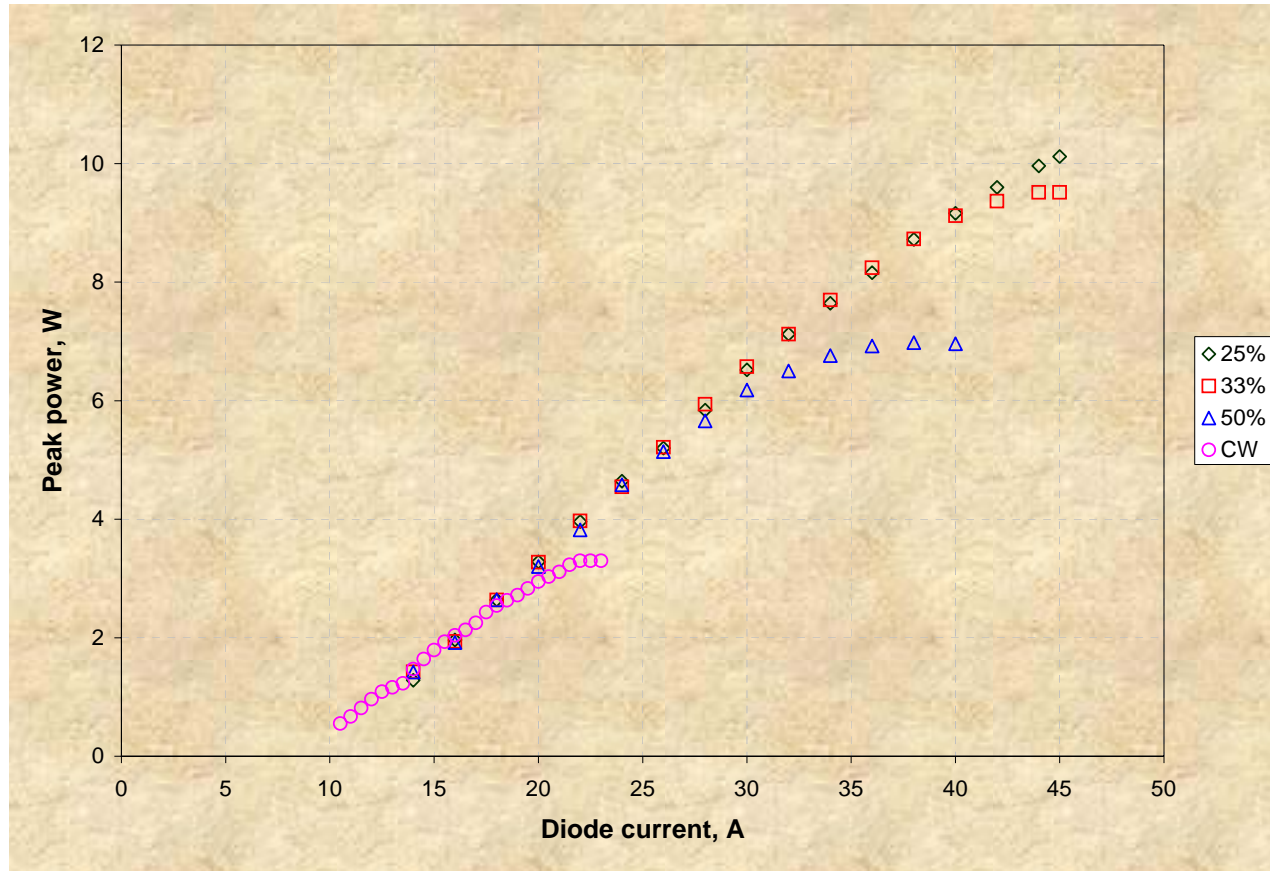


	Compact	Long
HR mirror	2600-3000 nm	
Output coupling	T ~ 4% at ~ 2600-2900 nm	T ~ 4% at 2600-2900 nm
Resonator length	~ 20 cm	~ 40 cm

Resonator
properties



Er:YLF quasi-CW Laser Operation Three-Pass Geometry



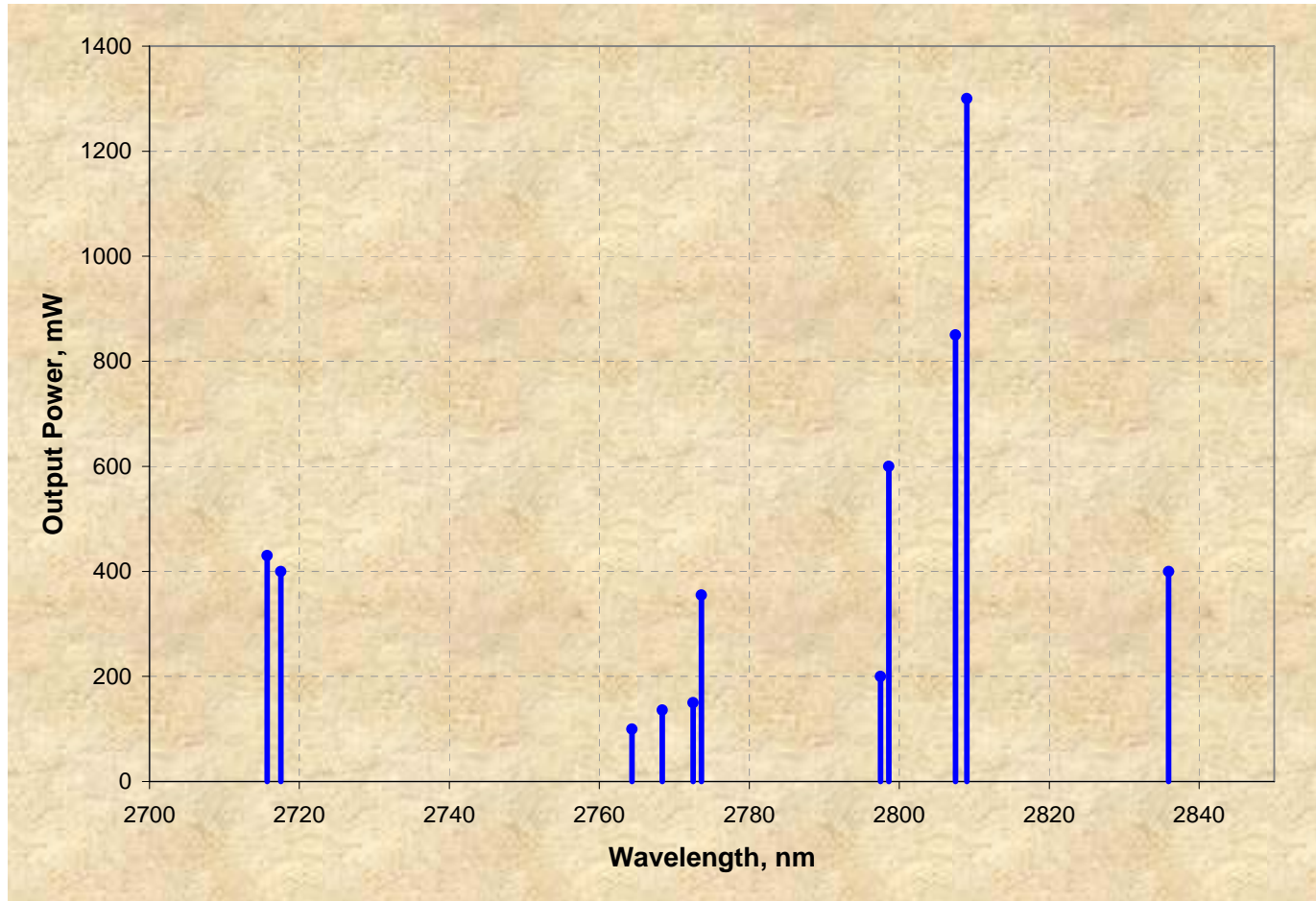
	Long
HR mirror	2600-3000 nm
Output coupling	T ~ 4% at 2600-2900 nm
Resonator length	~ 40 cm

Calculated Wavelengths for Transitions Between $4I_{11/2}$ and $4I_{13/2}$ Manifolds in Er:YLF

Manifold	Level	Energy, cm-1	4I/11/2				
			1	2	3	4	5
			10222	10235	10283	10289	10315
			nm	nm	nm	nm	nm
4I13/2	7	6738	2870.3	2859.6	2820.9	2816.1	2795.6
	6	6724	2858.8	2848.2	2809.8	2805.0	2784.7
	5	6697	2836.9	2826.5	2788.6	2784.0	2764.0
	4	6674	2818.5	2808.2	2770.9	2766.3	2746.5
	3	6579	2745.0	2735.2	2699.8	2695.4	2676.7
	2	6539	2715.2	2705.6	2670.9	2666.7	2648.3
	1	6535	2712.2	2702.7	2668.1	2663.8	2645.5

Note: Bold numbers indicate wavelengths for which lasing has been obtained in prior work.

Er:YLF CW Laser Operation Wavelength tuning



Conclusions

Development of an efficient side-pumped CW Er:YLF laser:

- ❑ First demonstration (to the best of our knowledge) of a tunable CW side-pumped 3- μm Er:YLF laser
- ❑ Wide tuning range: 2716-2836 nm
- ❑ Record output CW power for a diode-pumped Er-laser ~ 4 W