High-Power, Actively Modelocked Cryogenic Yb:YAG Laser

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Abstract

A high-power, actively modelocked, cryogenically cooled Yb:YAG laser has been demonstrated. At a repetition rate of 80 MHz, 214-ps pulses with 55 W of output power have been measured.

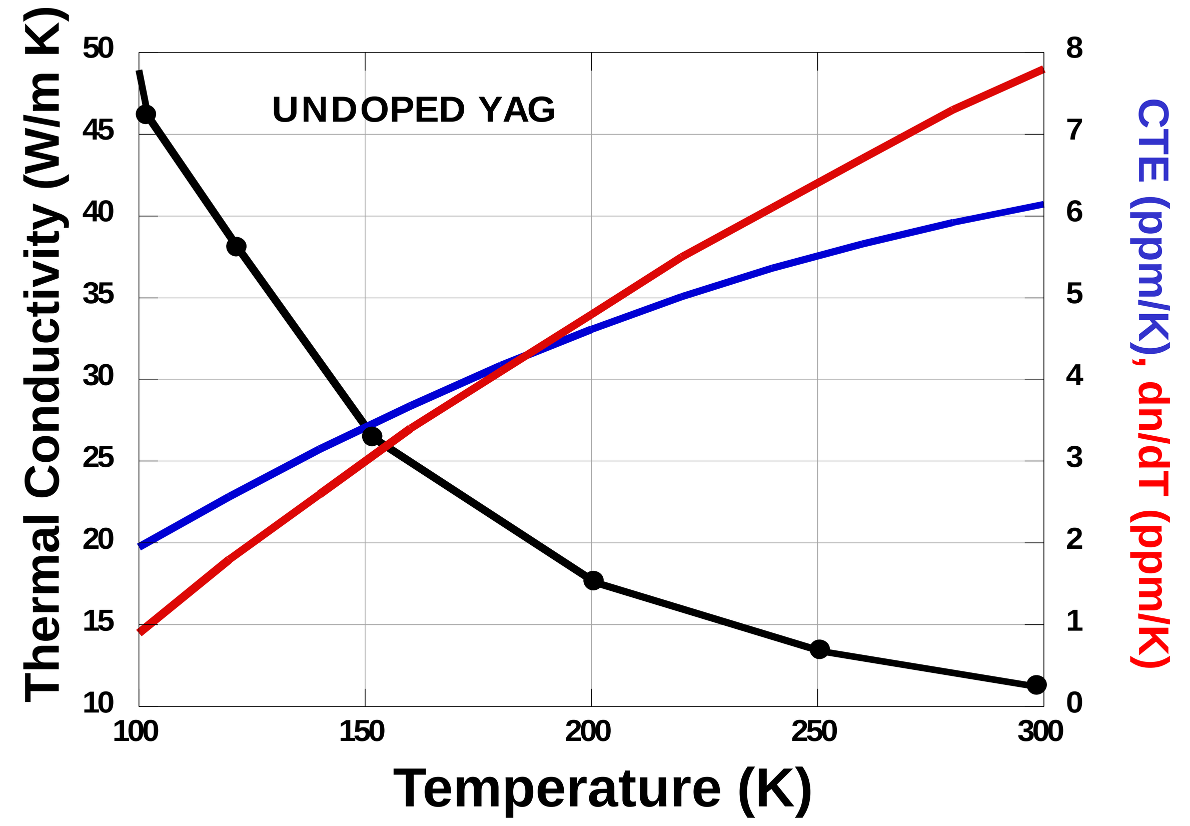
Motivation

- High-average-power pulsed lasers are required for:
  - State-of-the-art linear accelerators and free-electron lasers which necessitate high brightness photoinjectors
  - Extreme ultraviolet generation via high harmonic generation
- Solid-state lasers are attractive solution [1-2]
  - Room-temperature lasers often limited by thermo-optic distortion in output power

Cryogenic Yb:YAG is a promising high power pulsed source with excellent thermo-optic properties, low saturation fluence, and gain bandwidth [3-6]

Themo-optic Properties of Yb:YAG

Properties of Undoped YAG [3-6]



Distortion (OPD)

$$FOM_d = \frac{\kappa}{\eta_h \left|\frac{dn}{dT}\right|}$$

Depolarization

$$FOM_b = \frac{\kappa}{\eta_h |\alpha|}$$

η_h fractional thermal load
κ thermal conductivity
α thermal expansion
dn/dT refractive index change with temperature

- Larger material FOM's give less OPD and less stress-induced birefringence
- Key material properties (κ, α, dn/dT) scale favorably at lower temperature in bulk single crystals

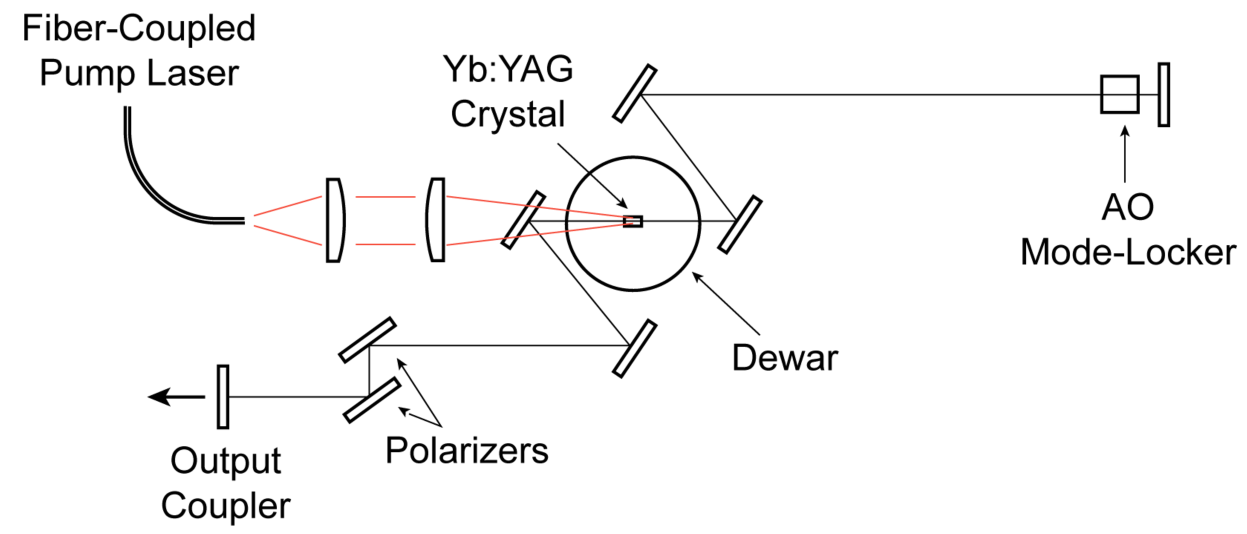
Themo-optic Properties of Yb:YAG

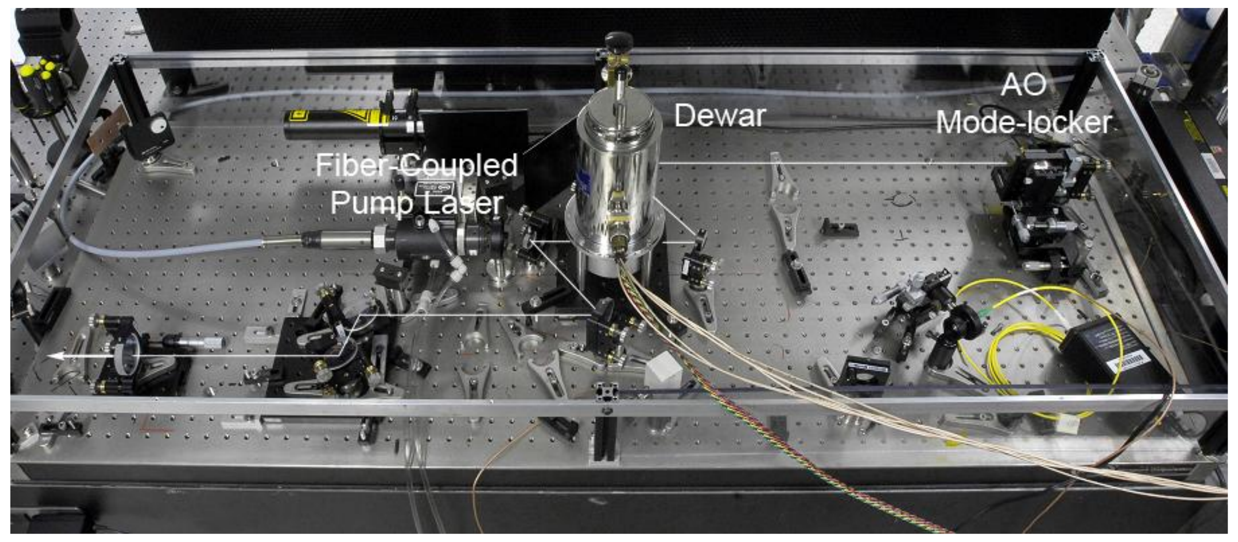
Un-doped YAG Figures of Merit [3-6]

	100 K	300 K
κ (in W/mK)	47	11
dn/dT(ppm/K)	0.9	7.9
α (ppm/K)	2.0	6.2
Relative FOM_d (300-K Nd:YAG = 1)	87 (Yb:YAG)	1 (Nd:YAG)
Relative FOM_b (300-K Nd:YAG = 1)	31 (Yb:YAG)	1 (Nd:YAG)

Experimental Setup

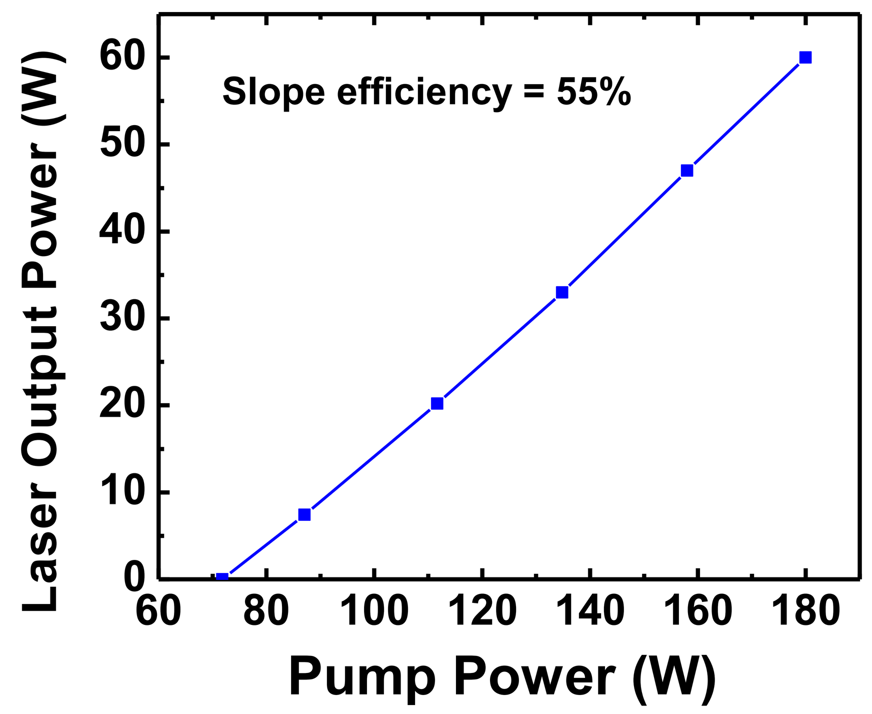
- 2 at.% Yb-doped 5x5x23 mm YAG crystal
- 80 MHz cavity





Experimental Results

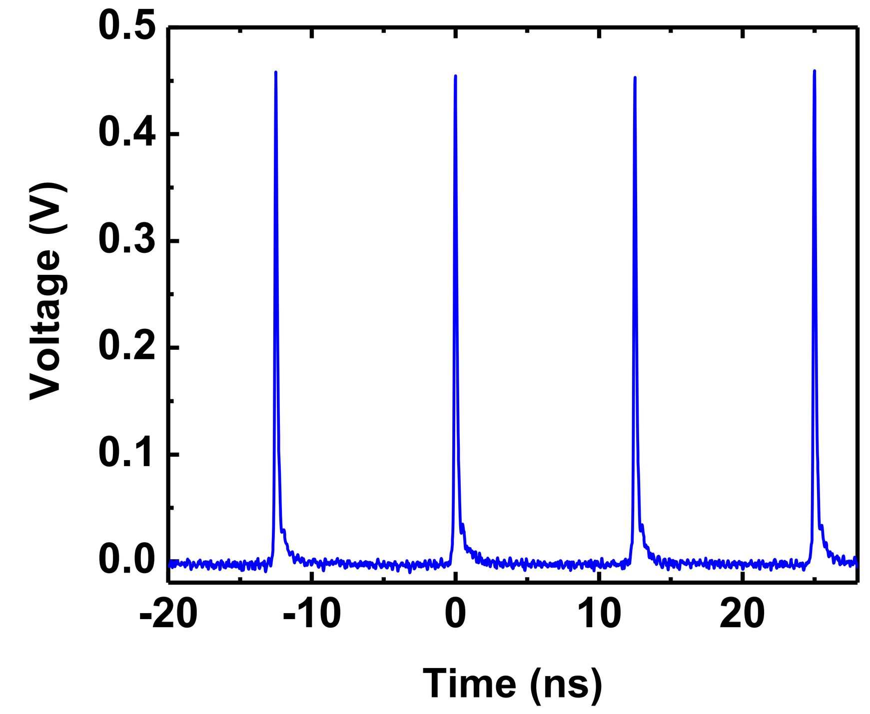
CW operation of laser



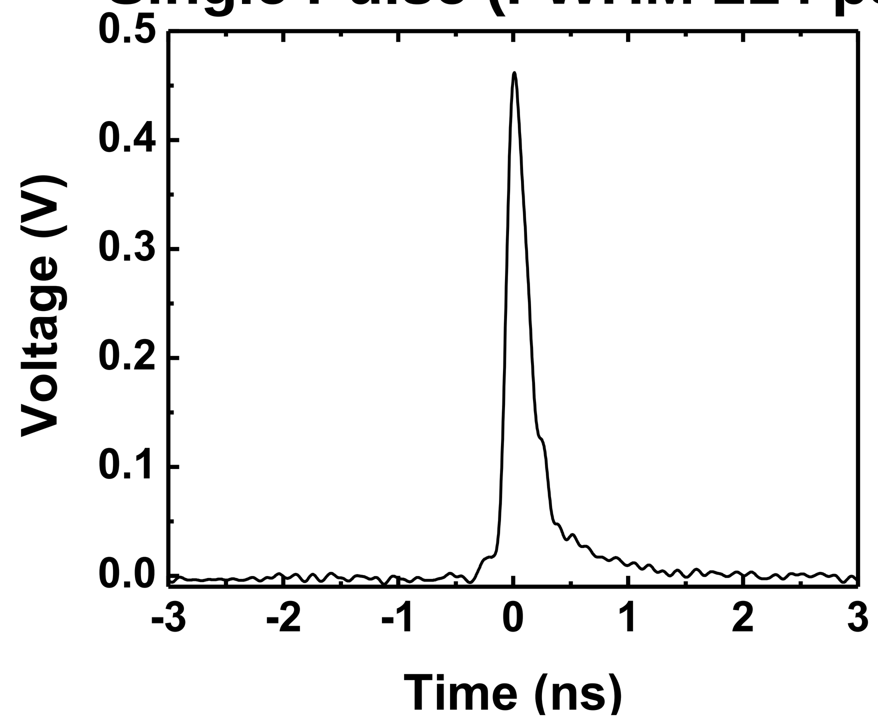
Experimental Results

- **Modelocked operation with 55 W average output power**

80-MHz Pulse Train



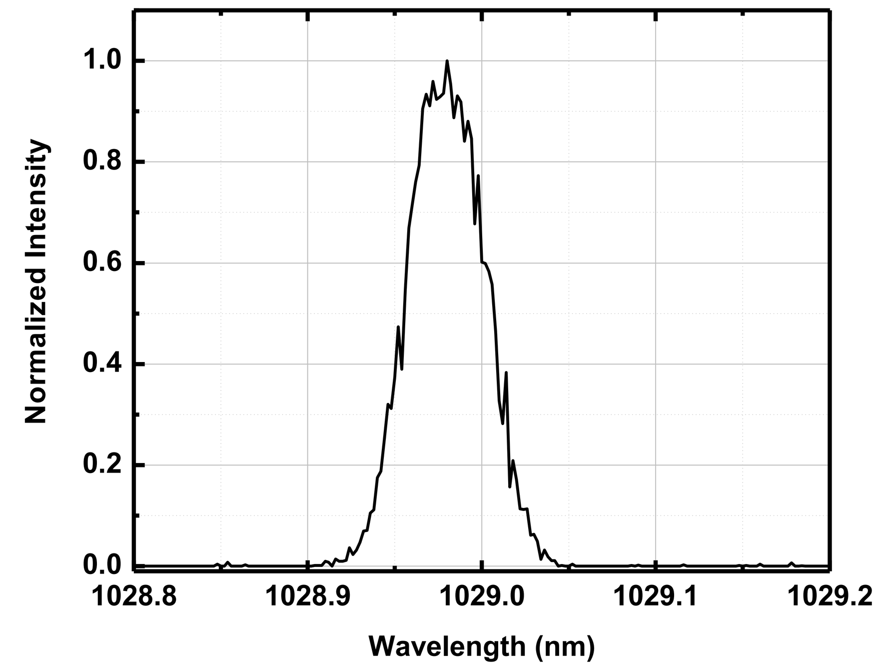
Single Pulse (FWHM 214 ps)



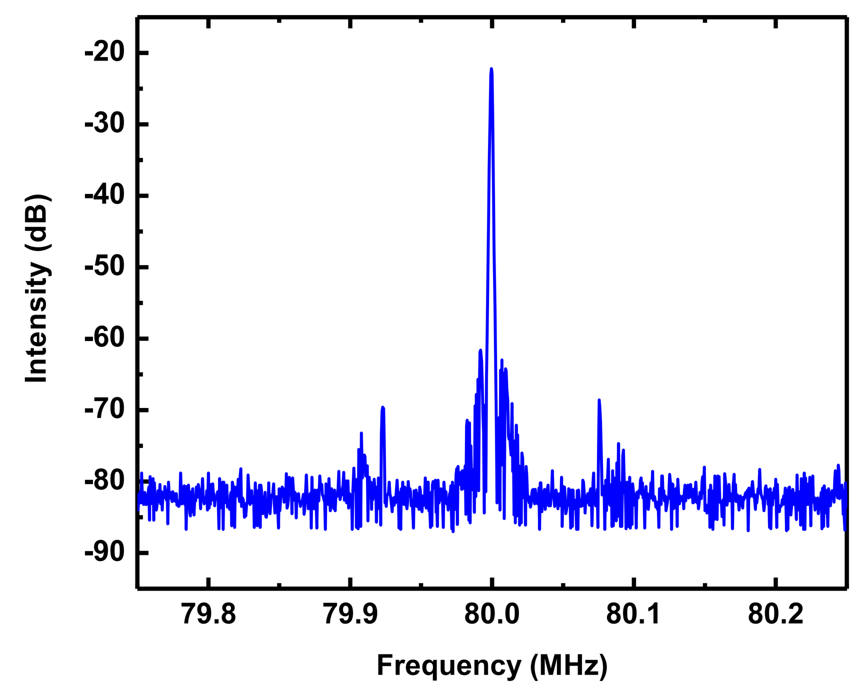
Experimental Results

Optical Spectrum

- FWHM of 0.05 nm
- Time-bandwidth product = 3.35



RF Spectrum



Conclusions

- **Actively modelocked cryogenic Yb:YAG laser demonstrated with 55-W of output power, 214 ps pulse-train at 80 MHz**
- **No fundamental limit on output power**
- **Potential for shorter, transform-limited pulses with incorporation of modelocker with greater modulation depth, spectral filter, or saturable absorber**

References
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