High power CW Tm:YLF laser with a holographic output coupler

Alex Dergachev, and Peter F. Moulton
Q-Peak, Inc.
135 South Road, Bedford, Massachusetts 01730
E-mail: dergachev@qpeak.com

Vadim Smirnov
Light Processing and Technology, Inc.,
4028 Laurel Branch Lane, Orlando, Florida, 32817

Leonid Glebov
School of Optics CREOL, University of Central Florida,
P.O. Box 162700, Orlando, Florida, 32816

Acknowledgements:
Lockheed Martin Corp., Laser Ultrasonic Technology Center

CLEO'2004

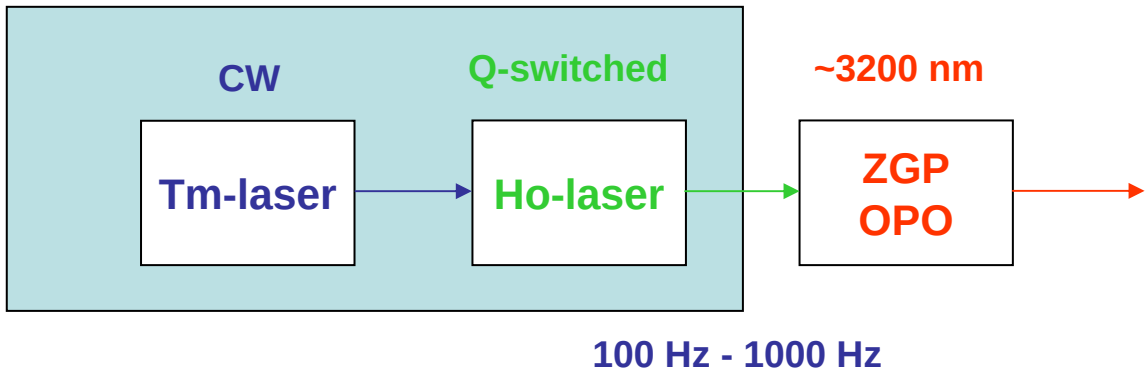
Outline

- Motivation
- Tm:YLF Laser – Details
- Volume Bragg Gratings (VBG) - Details
- Tm:YLF laser with VBG
- Conclusions

Qpeak APPLIED PHOTONIC SYSTEMS

Motivation

- Develop a 2-um laser system to pump OPO:
  - High-energy (up to 100 mJ)
  - High repetition rate (100-1000 Hz)
  - High beam quality (TEM_{oo})



- Immediate applications:
  - Complete system with OPO => Laser ultrasonics
  - High energy, high rep. rate Ho-laser:
    - ✓ Pump source for OPOs
    - ✓ Industrial
    - ✓ Military

Qpeak APPLIED PHOTONIC SYSTEMS

Tm:YLF Laser Characteristics and Requirements

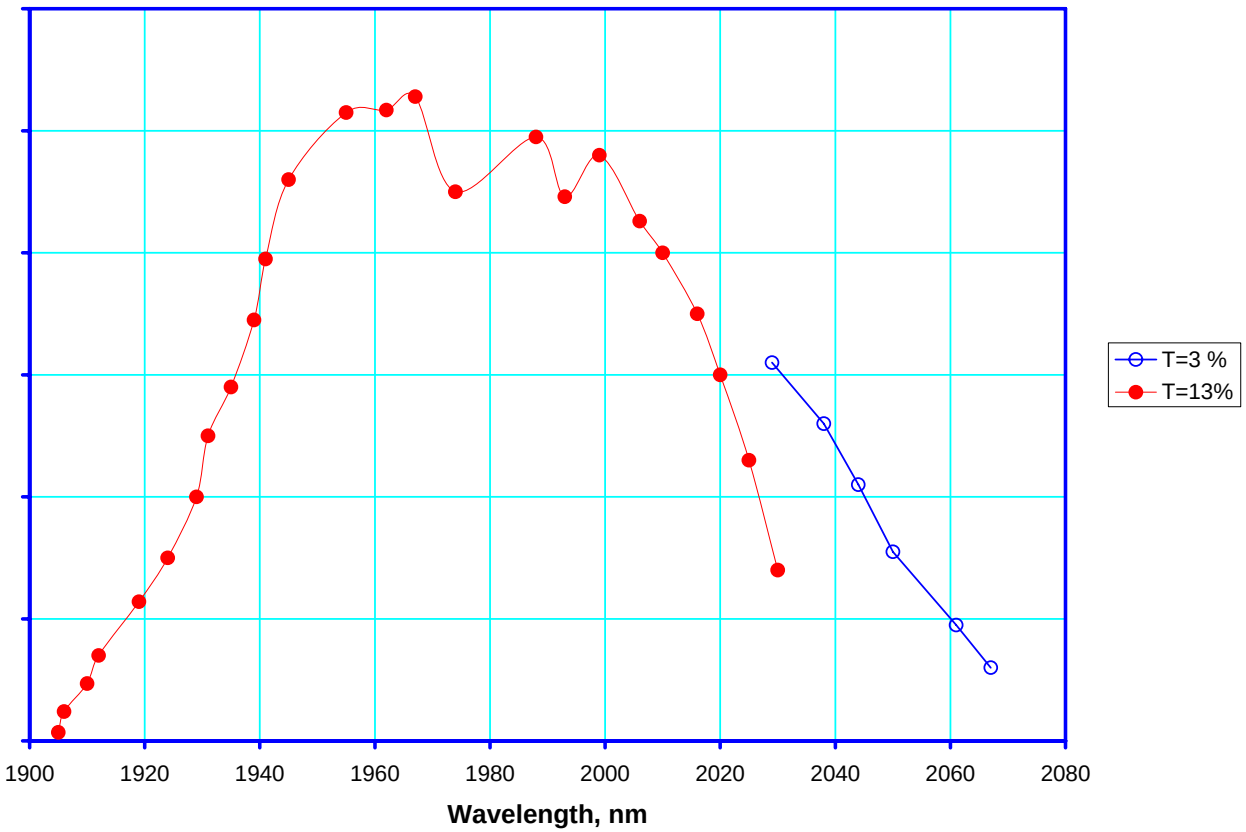
Operation regime	CW
Operational temperature	RT
Pump wavelength:	775-795 nm
Lasing wavelength range:	1905-2070 nm
Polarization:	Linear
Laser type	Quasi-4-level system

Specific requirements for Tm-laser as a pump source for Ho:YLF:

- Linear polarization (preferably)
- Lasing wavelength at ~ 1940 nm
- Linewidth < 6 nm

Qpeak APPLIED PHOTONIC SYSTEMS

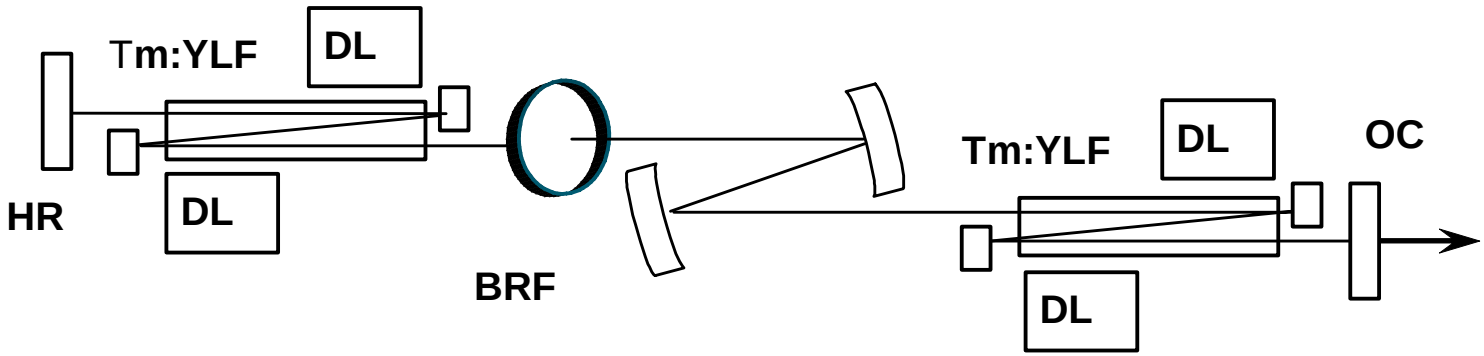
Tm:YLF CW Laser Operation – Wavelength tuning



Wavelength tuning with a 2-plate birefringent filter (TEM_{oo}) for two values of output coupler transmission.

CLEO'2004

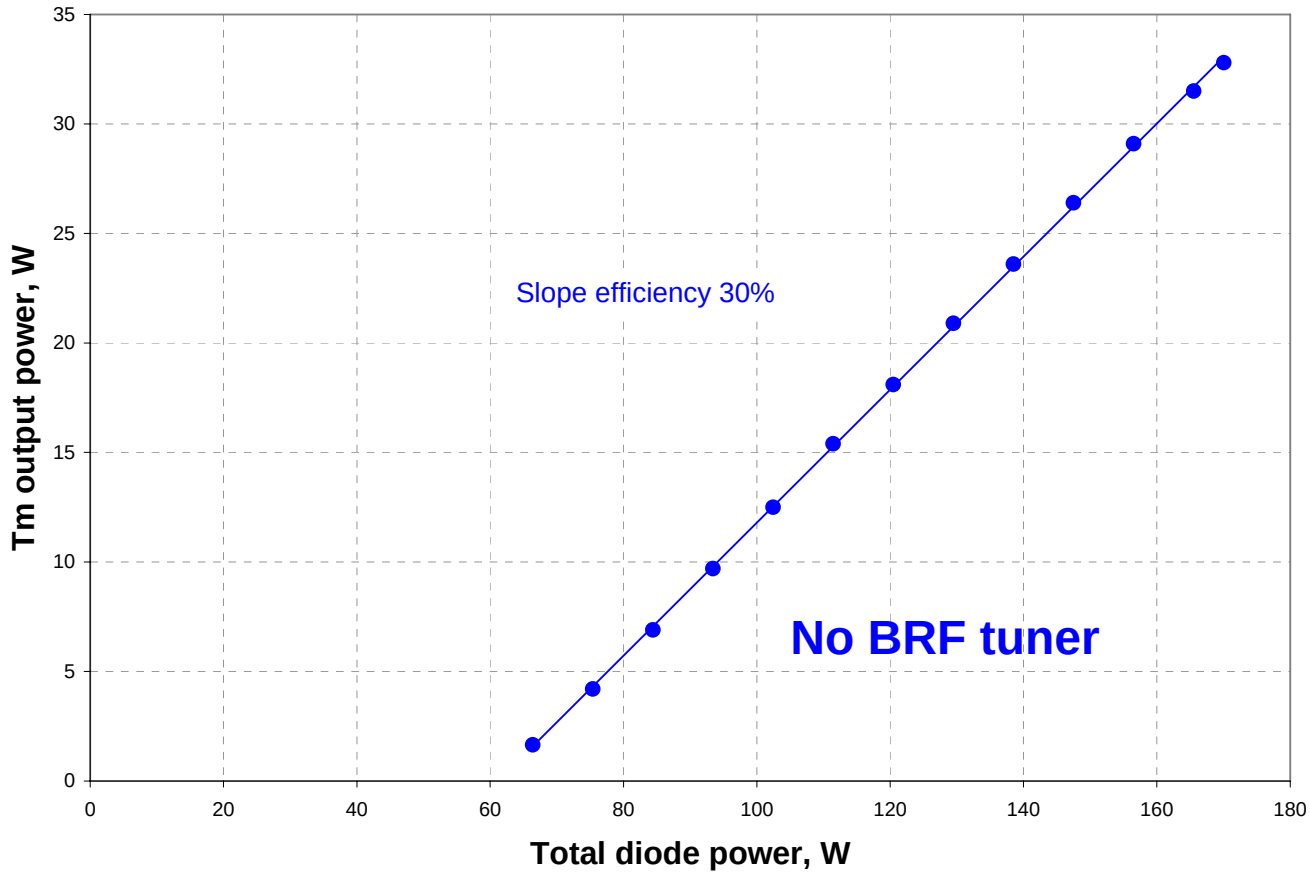
Experimental Set-Up – Tm:YLF Laser



- Dual-Gain Module oscillator
- Beam quality: M^2 ~ 1.05 x 7
- Wavelength tuning with BRF element

Qpeak APPLIED PHOTONIC SYSTEMS

Tm:YLF – Dual-GM Oscillator



Qpeak APPLIED PHOTONIC SYSTEMS

CLEO'2004

Application of BRF Element for Tuning

- Advantages
  - Continuous wavelength tuning
    - ⇨ Fine optimization of the pump wavelength
- Disadvantages
  - Temperature sensitive
    - ⇨ Wavelength drift
  - Precision rotational mount
- Major concern:
  - Wavelength stabilization !!!

- Alternatives:
  - Prism tuning ?
    - Complicated mechanical design
  - Gratings ?
    - Holographic surface gratings
      - Damage resistance ???
      - High enough reflectivity ???
    - Bragg gratings
      - Work with fiber lasers
      - Where do get bulk elements?

Qpeak APPLIED PHOTONIC SYSTEMS

Volume Bragg Gratings

Minimum requirements:

• Damage threshold	>100 kW/cm^2
• Center wavelength accuracy	+/- 1 nm
• Bandwidth	< 3 nm
• Reflectivity	>90%

Qpeak APPLIED PHOTONIC SYSTEMS

VBG Fabrication - Material

- Photo-thermo-refractive (PTR) glass
  - Sodium-zinc-aluminum-silicate glass doped with Ag, Ce, and F
  - Proprietary technology (CREOL and LPTI)
    - US Patents 6,586,141 B1 and 6,673,497 B2
  - Wide transparency range 300-4000 nm
  - Low parasitic absorption (< 0.01 cm^{-1} at 600-2700 nm)
  - Highly homogeneous material

Bragg Mirror Design

All optical properties of a Bragg grating such as:

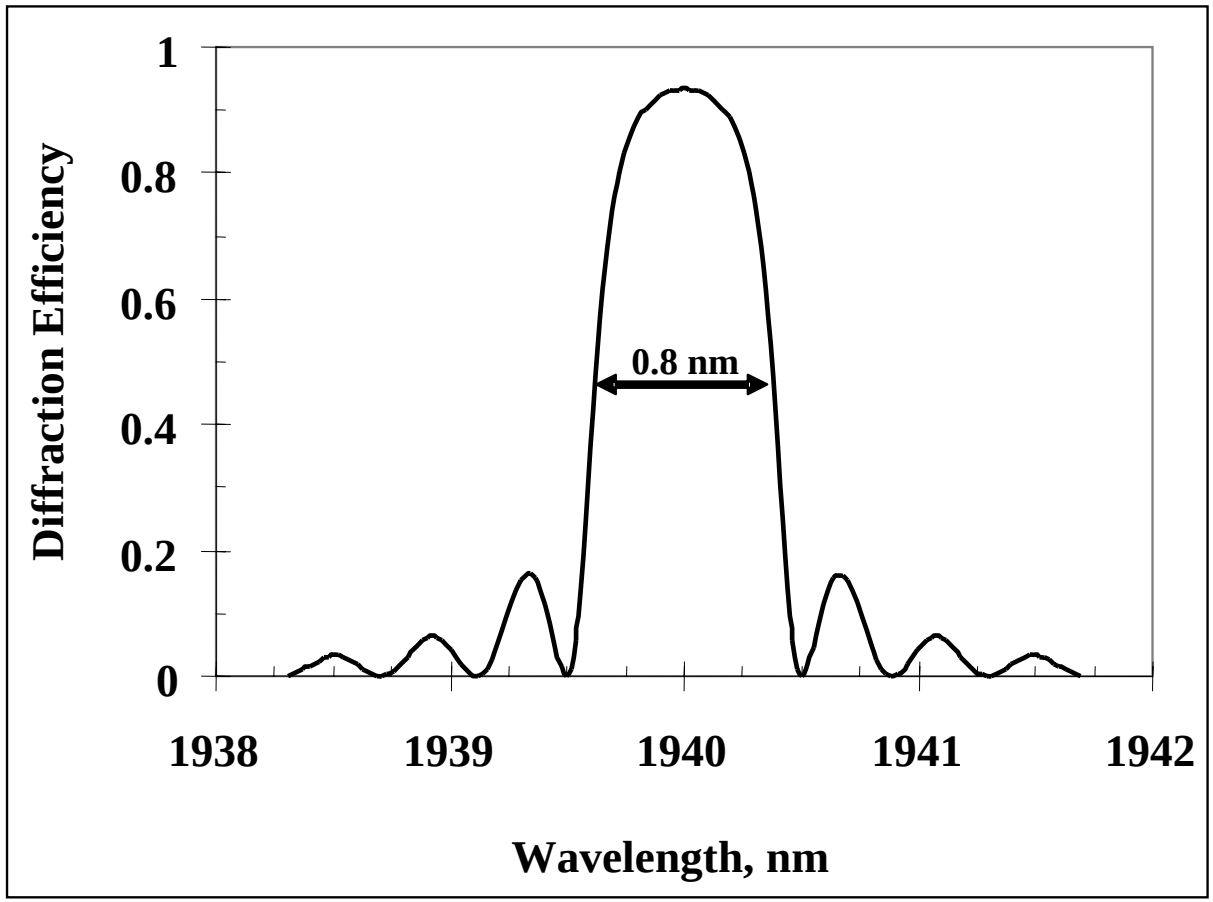
- Bragg angle
- Diffraction efficiency
- Spectral and angular selectivity

are defined by:

- *refractive index modulation (n_1)*
- *grating period (d)*
- *grating thickness (t)*

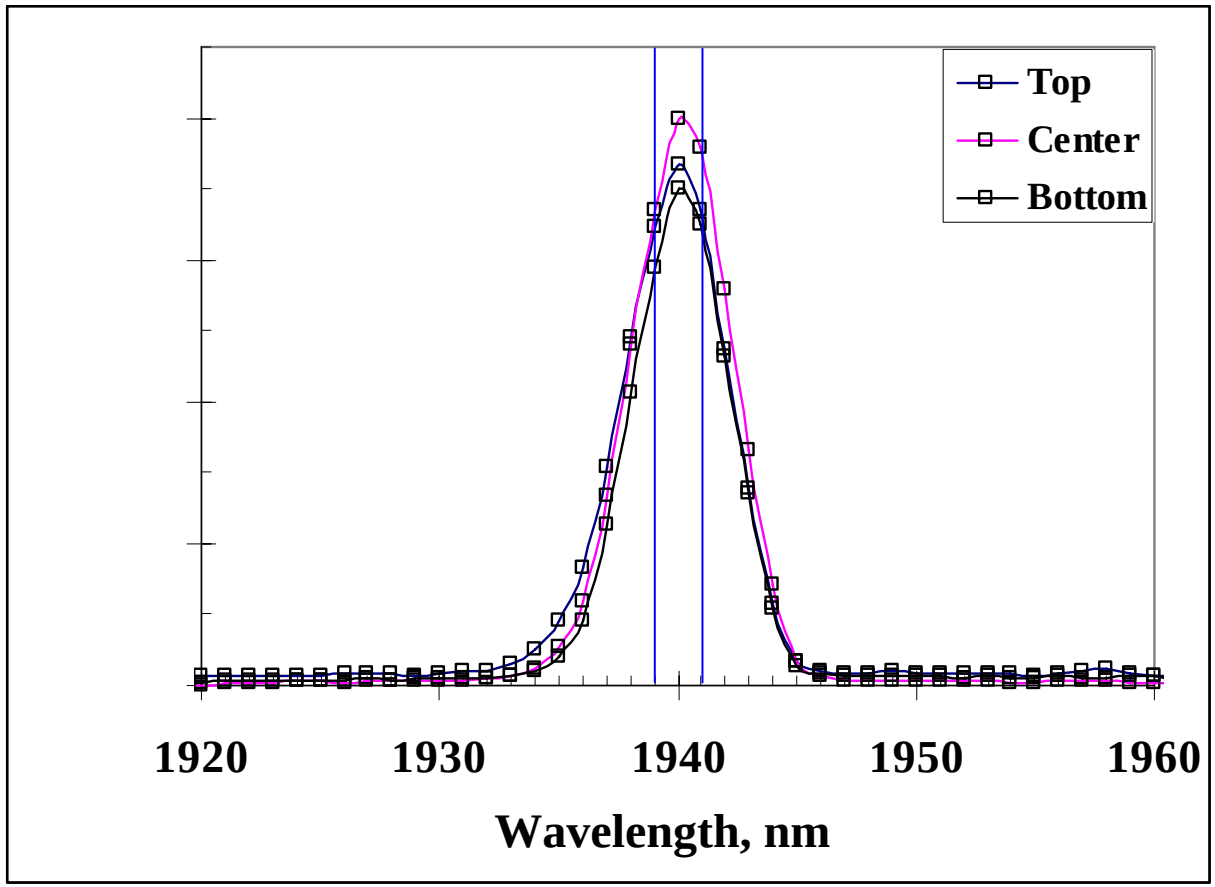
Qpeak APPLIED PHOTONIC SYSTEMS

Calculated spectral profile of Bragg reflector



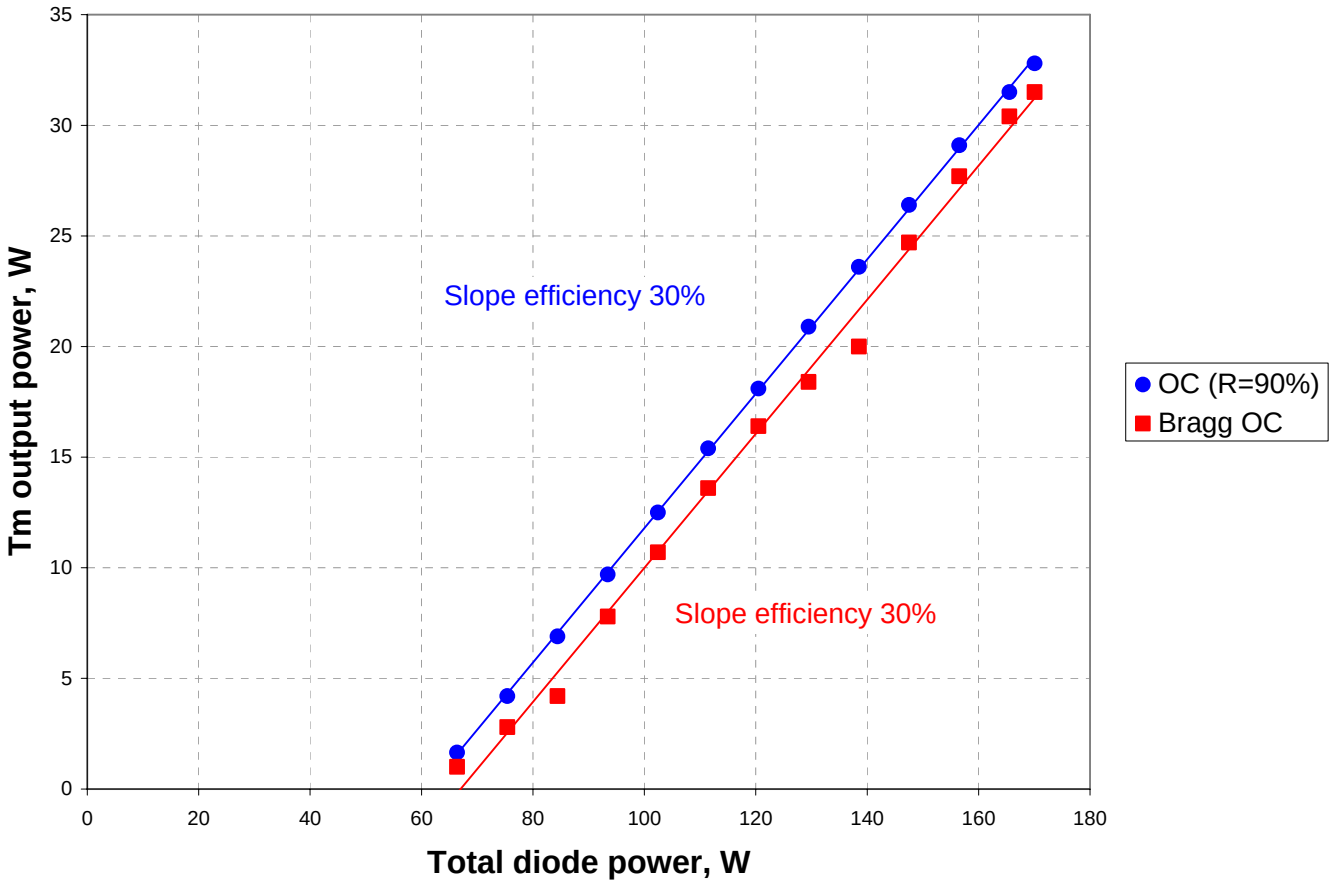
Qpeak APPLIED PHOTONIC SYSTEMS

Spectral characterization - Experiment



Qpeak APPLIED PHOTONIC SYSTEMS

Tm:YLF–Laser with a Bragg mirror



Qpeak APPLIED PHOTONIC SYSTEMS

CLEO'2004

Conclusions

- Successful application of a single holographic element in a Tm-laser:
  - Output coupler with required reflectivity of ~ 90 %,
  - Narrow-band wavelength selector
  - Damage-free operation

- Tm-laser:
  - High CW output power exceeding 30 W
  - Operational laser wavelength insensitive to
    - Temperature variations
    - Output laser power
  - Narrow linewidth

- To the best of our knowledge this is the first demonstration of a *bulk* laser of any type (non-fiber) with a *bulk* holographic output coupler, in general, and
  - First demonstration of a bulk 2-um Tm-laser with a bulk holographic OC, in particular

Qpeak APPLIED PHOTONIC SYSTEMS