Diode-Pumped Er:Yb:Glass Mini-Transmitter

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Abstract

A miniature lightweight, diode-pumped, passively Q-switched Er:Yb:glass laser transmitter has been developed, capable of greater than 20 Hz operation at 1.53 µm.

Key Words

(140.3500) Lasers, erbium, (140.3480) Lasers, diode-pumped, Mini-laser, Uranium passive Q-switches.

Introduction

Low cost, miniaturized eyesafe lasers are needed for lightweight, battery-operated, precision eyesafe rangefinders in a variety of applications. We have developed a mini-laser transmitter consisting of a diffraction-limited Er:Yb:glass laser, pumped with a single InGaAs diode bar, and passively Q-switched using uranium-doped calcium fluoride.

Our mini-laser transmitter, shown in Fig. 1, puts out about 0.5 mJ in a 14 ns pulse, and weighs about 40 grams, including a visible diode aiming light (see Fig. 1). Raytheon, in conjunction with the University of Southern California, has developed two technologies which have made this possible: 1) a high efficiency diode pump cavity, and 2) a passive Q-switch at 1.5 µm.

Er:Yb:glass has several advantages over alternative technologies: 1) it lases at 1.53 µm, which is directly in the eyesafe wavelength band and therefore requires no OPO or Raman conversion, 2) Erbium possesses a long upper-laser-level lifetime (~ 8 ms) which allows significantly higher pump energy per diode bar, and 3) the Yb absorption feature is very broad which makes the system insensitive to diode wavelength shifts over temperature (see Fig. 2).

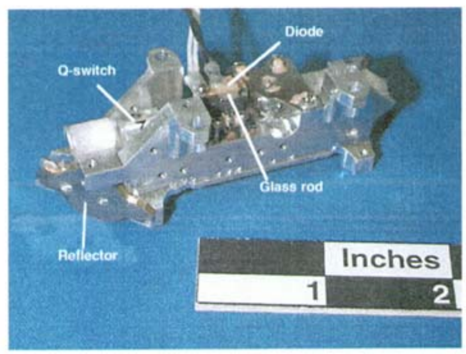


Figure 1. Mini-laser transmitter. Includes 1.5 µm laser resonator, InGaAs pump diode, receiver reflector, and visible diode aim light. Total weight is about 40 grams.

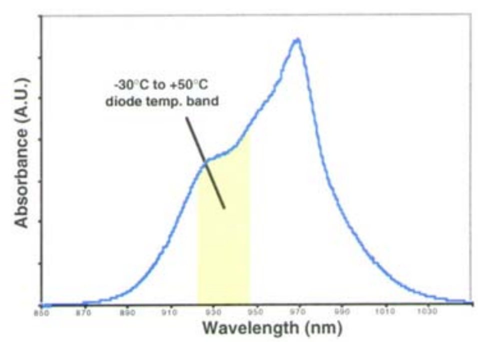


Figure 2. Yb^{3+} absorption, peaked near 970 nm, and the corresponding diode wavelength shift over temperature.

Transmitter components

The transmitter shown in Fig. 1 consists of an Er:Yb:glass rod, an InGaAs pump diode, laser resonator, receiver reflector, and visible wavelength aiming light diode.

The Er:Yb:glass laser rod (0.5 x 1 x 10 mm), consists of both doped and undoped Kigre phosphate glass, and is side-pumped at approximately 940 nm (nominal room temperature wavelength) with a QCW InGaAs diode bar supplied by Opto Power Corp. The rod is a type of integrating cavity, which permits several passes of the pump light through the active medium, yielding maximum absorption. The diode light pulses have a peak power of about 30 W. The pump energy is controlled by adjusting the pulse duration.

Representative laser rods and a U:CaF_2 passive Q-switch are pictured in Fig. 3.

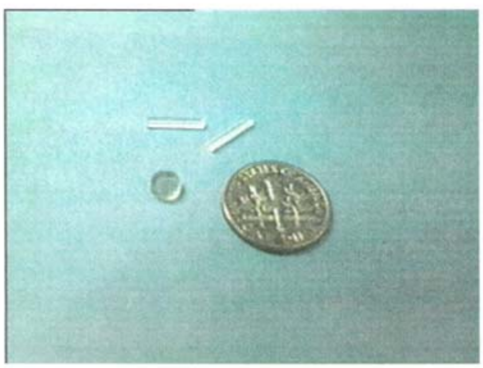


Figure 3. Er:Yb:glass rods and U:CaF_2 Q-switch.

Passive Q-switch

The mini-transmitter is passively Q-switched using a U:CaF_2 saturable absorber. The U:CaF_2 crystal absorption spectrum, from a crystal grown by Litton-Airtron, shows just the characteristic U^{4+} ion (active ion for the Q-switch) absorption features in the range 1 - 2 µm (see Fig. 4). The thin absorption lines due to U^{3+} are not present [1].

The Q-switch relaxation lifetime was measured with a fast InAs detector, with a Ge wafer to block the 1.53 µm pump light. The 2.6 µm fluorescence has a lifetime of about 4.8 µs. The absorption cross-section was measured using saturation methods and its value is roughly one order of magnitude higher than the stimulated cross-section of Er:phosphate glass [2,3].

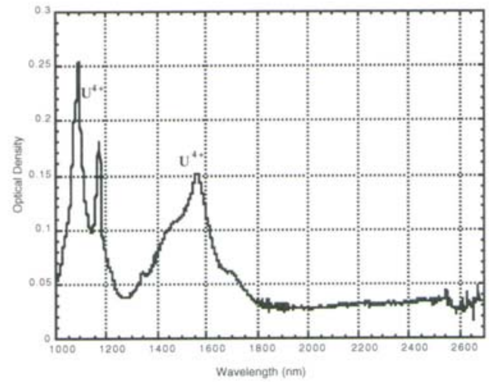


Figure 4. U:CaF_2 optical absorption spectrum.

Laser Beam Profile and 1.5 µm Fluorescence Measurements

Circular apertures were used to measure the beam size in the near and far fields. Energy through the apertures was measured with a calibrated Ge photodiode detector and recorded with a digital scope. A Hamamatsu 1.5 µm camera was utilized to observe the beam profile during the experiment. We quantified the beam quality using the equation:

$$M^2 = \frac{\theta \pi d}{4\lambda} \quad (1)$$

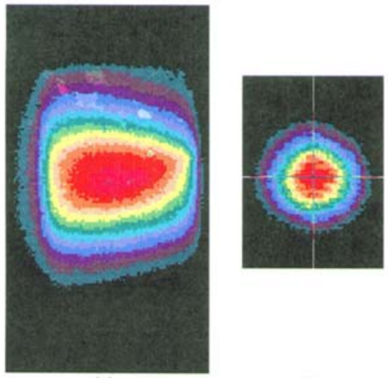
where: θ = far-field full-angle beam divergence at $1/e^2$ points; d = near-field beam diameter at $1/e^2$ points, and λ = wavelength (1.53 µm). θ and d values determined from the experiment, are shown in Table 1. Also shown is the resulting M^2 value from equation (1).

Table 1: Beam quality measurements.

Near-field dia (mm)	Far-field dia (mr)	M^2
1.17	1.86	1.12

The results, presented in Table 1 ($M^2 \approx 1$), indicate that the laser operates in the TEM_{00} transverse mode.

The 1.5 µm fluorescence ($^4I_{13/2} \rightarrow {}^4I_{15/2}$, Er^{3+}) intensity profile, and the far-fieldimage of the Q-switched laser beam profile are shown in Fig. 5.



(a) (b)

Figure 5. (a) 1.5 µm fluorescence profile, and (b) Q-switched laser far-field beam profile ($M^2 = 1.12$).

Laser performance

The slope efficiencyfor the Er:Yb:glass free-running laser (i.e. without the Q-switch) is shown in Figure 6. The laser threshold is about 25 mJ of diode pump energy, and the slope efficiency is nearly 13%. With the passive Q-switch installed, the output is 0.5 mJ per pulse, with a 14 ns pulsewidth, at a 2 Hz repetition rate. The laser (Q-switched and free-running) always operates in a single transverse mode (TEM_{00}).

The Q-switched laser has been operated at higher repetition rates from 10 to 20 Hz, continuously, with an output pulse energy and pulsewidth similar to the 2 Hz rate. We have also obtained preliminary results at a 50 Hz continuous rate.

The mini-laser can also be operated in a different mode where the pump diode is left on for longer times, allowing repetitive Q-switching. Fig. 7 shows an 11 pulse burst at greater than a 1 Khz repetition rate.

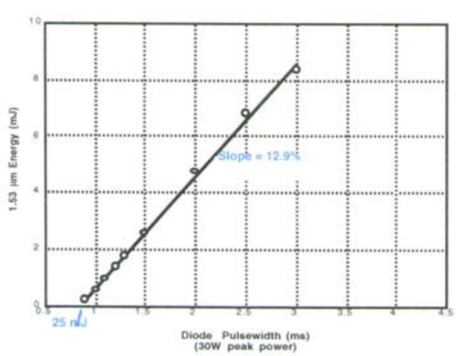


Figure 6. Slope efficiency and threshold of the free-running laser at 2 Hz.

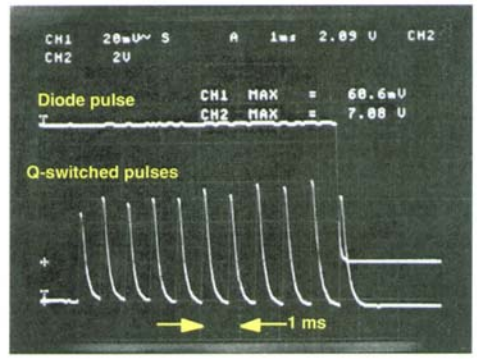


Figure 7. Repetitive Q-switch mode. The start of the diode pulse is not shown.

Glass Fiber Technology

We are currently working on manufacturing techniques to support low cost, high-rate production of the mini-laser. One important area is the fabrication of the miniature glass rods. Toward this end, we have demonstrated the feasibility of manufacturing the rods from a fiber-pull.

A test fiber-pull has been conducted using Nd:phosphate glass. A glass preform (see Fig. 8) was made and pulled. Approximately sixty rods were fabricated from this fiber-pull (ten of these are shown in Fig. 8).

We are now preparing to conduct a fiber-pull using an Er:Yb:phosphate glass preform.

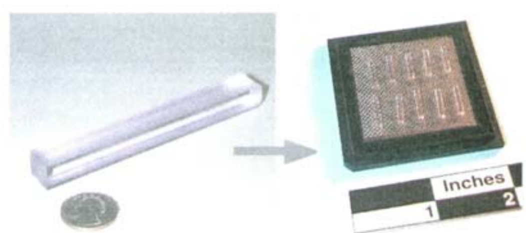


Figure 8. Ten rods (right) fabricated from test fiber-pull using a Nd:phosphate glass preform (left).

Conclusions

In conclusion, a diode-pumped, passively Q-switched, Er:Yb:glass technology has several distinct advantages for mini and micro-lasers. A low cost, lightweight, eyesafe mini-laser transmitter has been developed, for use in manportable rangefinder systems. This transmitter is now in production at Raytheon. In addition, the design is scalable to significantly higher repetition rates and energies, to support a wide range of additional rangefinder applications.

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References

1. W. A. Hargreaves, Phys. Rev. B 44(10) 5293-5295 (1991)
2. R.D. Stultz, M. B. Camargo, S. T. Montgomery, M. Birnbaum, and K. Spariosu, Appl. Phys. Lett. 64 948-950 (1994).
3. R. D. Stultz, M. B. Camargo, and M. Birnbaum, J. Appl. Phys. 78(5) 2959-2961 (1995).