$Er:Y_2SiO_5$ Eyesafe Laser at 300 K

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Abstract

Laser action at 300K was demonstrated in $Er:Y_2SiO_5$ (Er:YOS) using a 1.53μm Er:glass laser pump. A single pulse of less than 300ns (full width half maximum) at 1.633μm was obtained.

Introduction

There is current interest in the development of solid-state laser materials centered at the 1.54μm eye-safe wavelength. New materials were investigated with the hope that they could outperform the commercially available Yb, Er:phosphate glass laser (for example, the KIGRE[1] QE-7 Yb,Er:glass).

Much of the relevant spectroscopy of $Er:Y_2SiO_5$ (Er:YOS) and Yb,Er:YOS was presented in 1992[2]. Recently, room temperature laser action at 1.57μm in 7%Yb, 0.1%Er:YOS pumped with a $Ti^{3+}:Al_2O_3$ laser at 791nm was reported[3].

In our studies, an Er:YOS crystal was pumped by a pulsed (flash lamp pumped) 1.53μm Er:glass laser and produced room temperature laser action at 1.633μm. In this respect, the Er:YOS laser was similar to Er:YAG[4] and Er:YSGG[5] lasers studied earlier in our laboratory.

Experiments

Laser action was obtained in an experimental arrangement similar to that utilized in references [4,5]. The 1% Er:YOS laser rod was grown by the Czochralski method at CREOL, University of Central Florida. The 1%Er:doped YOS laser crystal was 2.36 cm long polished flat and parallel and uncoated. The cavity was 4.5cm long consisting of a flat-flat resonator with a 5% output coupler transmissivity. An Er:glass laser operating at 1.532μm was utilized as the pump source in an end-pumped configuration. The Er:glass laser output was focused into the Er:YOS crystal using a 15cm focal length (FL) lens. Laser action was not obtained with a 10cm FL lens, nor when using the 15cm FL lens, if the pump light was focused at the crystal input end. The reported results were obtained when the focus of the 15 cm FL lens was near the center of the Er:YOS laser rod.

The 1.633μm laser radiation wavelength was measured using a Jarrell-Ash 0.25m monochromator. Using spectroscopic data[2] of Er^{3+}:YOS at 300K, we identified the lasing transition to be $^4I_{13/2}$:Y3(6551cm^{-1})$\Rightarrow$$^4I_{15/2}$:Z7(428cm^{-1}), at 1.633μm. The terminal

Proceedings on Advanced Solid-State Lasers, 1994, Vol. 20
Yee Fan and Bruce H. T. Chai (eds.)

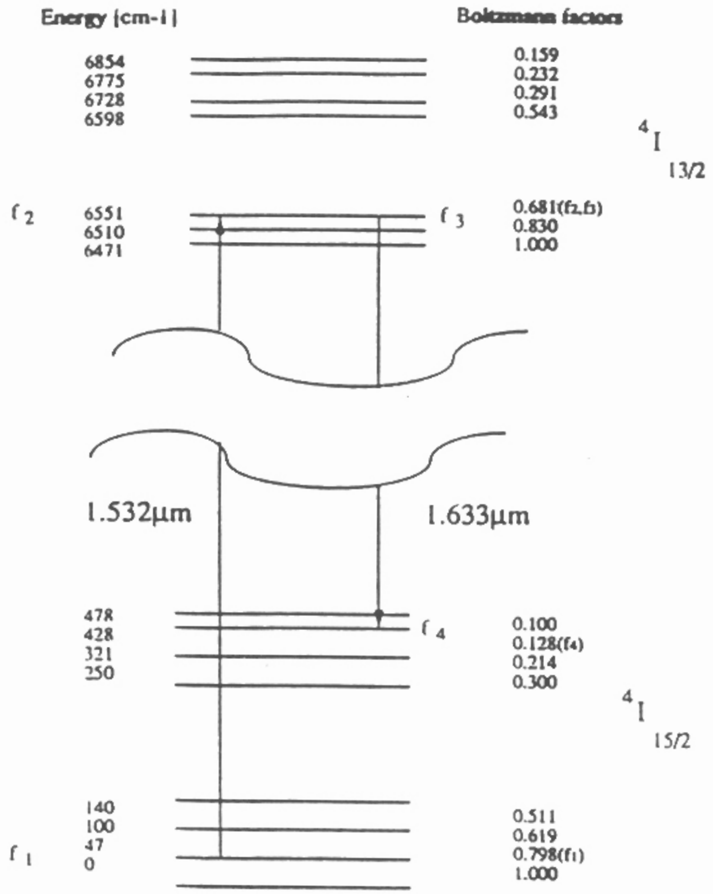

Figure 1. Er:YOS energy level diagram at 300K (after reference [2]).

state of the 1.633µm Er:YOS laser at $481 cm^{-1}$ has a fractional Boltzmann population of 0.13 (see Figure 1) and, thus, is a quasi-three level laser. According to the spectral data of reference [2], the laser output at 1.633µm occurs at a wavelength where the absorption is very low. In contrast, the laser action at 1.576µm described in reference [3] occurs at a wavelength of appreciable absorption.

The bleaching of the absorption of our Er:YOS crystal was studied and is shown in obtain the stimulated emission cross section ($\sigma_{1.633\mu m} \approx 6 \times 10^{-21}\ cm^2$), which was in good agreement with the data of reference [2]. The $^4I_{13/2}$ Er:YOS lifetime was measured using a Q-switched 1.532µm Er:glass laser. The Er:glass excitation laser was Q-switched using a U^{4+}:SrF_2 saturable absorber placed intra-cavity at the Brewster angle, thus, providing a plane polarized output of several mJ in a ≈60ns FWHM pulse. The ≈1.6µm fluorescence could be readily recorded following the pulsed excitation. The lifetime measurement results are shown in Figure 3. The $^4I_{13/2}$ 10.9ms lifetime is in agreement with the measurements of reference [2]. The somewhat faster initial decay (first ms in Figure 3), was attributed to the effects of upconversion. From Figure 3, we note that in our 1%Er:YOS laser crystal this upconversion effect appears to be small and is not expected to degrade appreciably the 1.633µm laser performance. Upconversion effects, as they pertain to the $^4I_{13/2} \Rightarrow {}^4I_{15/2}$ laser operation in Er(0.5%-4%):YAG, were studied in detail[6] and it was found that for low Er concentration (≤1%), upconversion losses were small.

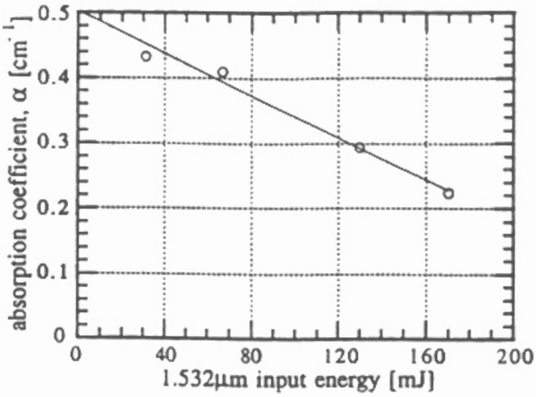

Figure 2. Absorption-bleaching of 1%Er:YOS laser crystal.

Self Q-switched Operation

The 1.633μm laser energy was measured directly using calorimeters. The measured output energy at 1.633μm was approximately 1 mJ (in a single pulse) for a 1.53μm absorbed pump energy of ≈75mJ. The threshold absorbed energy was estimated to be 40mJ. The time relationship of the pump and lasing signals are shown in Figure 4. The 1.633μm output consistently exhibited itself in a single "giant pulse" suggesting self Q-switched behavior of the Er:YOS laser. The temporally resolved 1.633μm pulse is shown in Figure 5. The full width half maximum (FWHM) was typically ≈280ns. The 1.633μm laser output sometimes exhibited random spiking after the initial giant pulse, but most frequently, an output such as that shown in Figures 4, and 5. Theoretical modeling using the slow saturable absorber model (see paper AThC3 of these proceedings) is in progress.

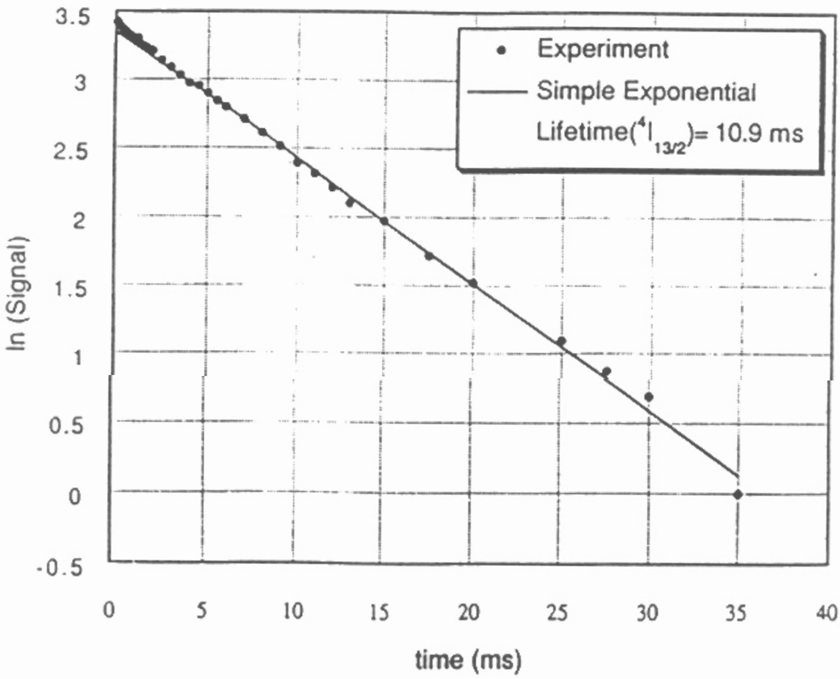

Figure 3. Lifetime of the $^4I_{13/2}$ Er:YOS energy level at 300K using Q-switched 1.532μm laser excitation.

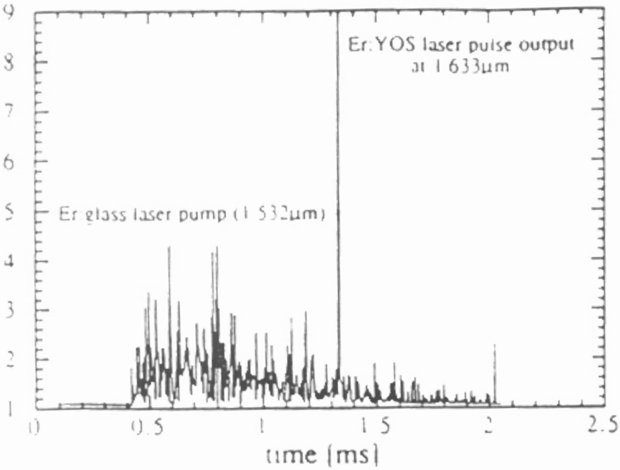

Figure 4. 1.633µm Er:YOS laser action (giant pulse) compared to the 1.532µm randomly spiking Er:glass pump laser.

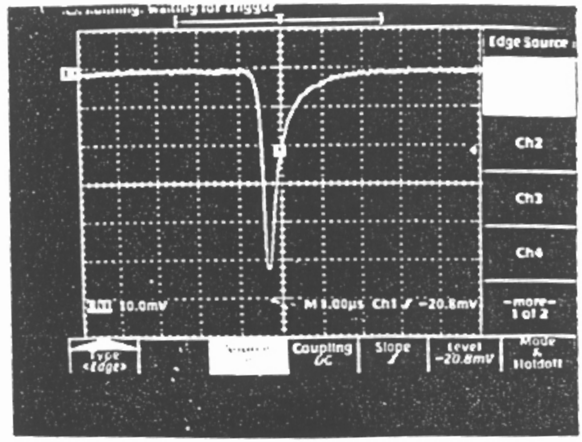

Figure 5. 1.633µm Er:YOS laser pulse (FWHM≈280ns) showing the typical fast rise time and the slower decay.

References

1. Kigre, Inc. 100 Marshland Rd., Hilton Head, SC 29926, President: John D. Myers.
2. C. Li, C. Wyon, and R. Moncorge, "Spectroscopic Properties and Fluorescence Dynamics of Er^{3+} and Yb^{3+} in Y_2SiO_5", IEEE J. Quantum Electron. **28**(4), 1209-1221 (1992).
3. C. Li, R. Moncorge, J. C. Souriau, C. Borel, and Ch. Wyon, "Room temperature CW laser action of Y_2SiO_5:Yb^{3+},Er^{3+} at 1.57 µm", Opt. Comm. **101**, 356 (1993).
4. K. Spariosu and M. Birnbaum, "Room Temperature 1.64 micron Er:YAG lasers pumped by an Er:glass laser", in Advanced Solid-State Lasers Technical Digest 1992 (Optical Society of America, Washington, D.C., 1992), pp 69-71.
5. K. Spariosu, M. Birnbaum, and M. Kokta, "1.643µm Er^{3+}:$Y_3Sc_2Ga_3O_{12}$ (Er:YSGG) laser at 300K", Accepted for publication in the IEEE J. Quantum Electron.
6. K. Spariosu, M. Birnbaum, and B. Viana, "Er^{3+}:$Y_3Al_5O_{12}$ laser dynamics: Effects of Upconversion", Accepted for publication in J.O.S.A.-B.