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Multi-Pulses Behavior in a Erbium Glass laser Q Switched by Cobalt Spinal

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Abstract

Cobalt Spinal (Co^{2+}:MgO·Al_2O_3) has recently become one of the more popular 1.54um passive Q-switch materials. In this paper we examine the multi-pulse "pulse-train" behavior and its influence in time-of-flight laser range processing. This saturable absorber's performance is examined in terms of low gain erbium glass laser beam mode structure.

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Cobalt Spinal (Co^{2+}:$MgO{\cdot}Al_2O_3$) has recently become one of the more popular 1.54um passive Q-switch materials. In this paper we examine the multi-pulse "pulse-train" behavior and its influence in time-of-flight laser range processing. This saturable absorber's performance is examined in terms of low gain erbium glass laser beam mode structure.

Introduction

Miniature lamp-pumped eye-safe laser transmitters are used in numerous applications such as laser rangefinding and IR illumination. These small, low-cost, eye-safe laser transmitter designs are now being significantly improved with the use of 1.54um passive Q-switch materials such as Cobalt Spinel used in conjunction with erbium-ytterbium laser glass formulations such as QE-7S [1, 2]. *Cobalt Spinel (Co^{2+}:$MgO{\cdot}Al_2O_3$) has recently become one of the most popular 1.54um passive Q-switch materials due to increased availability and superior performance. In addition, recent QE-7S laser glass slope efficiency measurements show a 30% improvement in performance over current industry standards used in the MELIOS and M1A2 upgrade programs.* In this work we present a laser performance evaluation of passive Q-switch materials. Samples were obtained from various sources and tested with a standard lamp pumped erbium glass laser resonator setup.

Experiment setup

The Q-Switch sample test setup includes a 3mm diameter x 50mm long, uncoated erbium glass laser rod and a diffuse-reflector flashlamp-pumped laser cavity. The laser resonator consists of a planar HR mirror and a 3-meter concave output coupler with 85%

reflectivity. Test data includes laser pulse energy, pulse width, temporal & spatial mode structure, multi-pulse behavior, output energy stability and damage threshold.

Discussion

The laser "shot-to-shot" pulse energy stability is closely related to the output mode structure. At the 3~4 mJ energy level the output mode is TEMoo. Slight changes to the

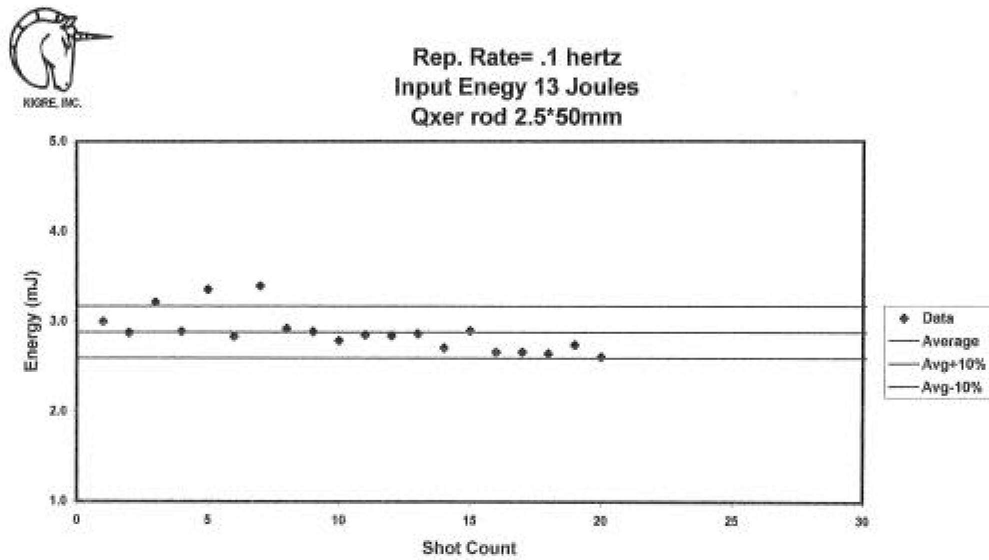
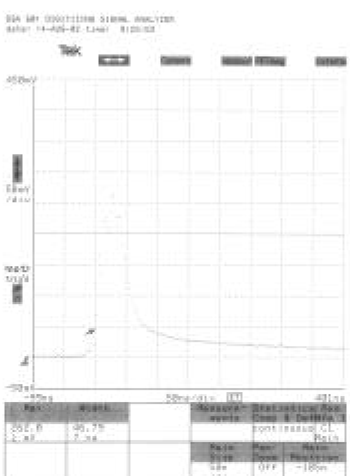
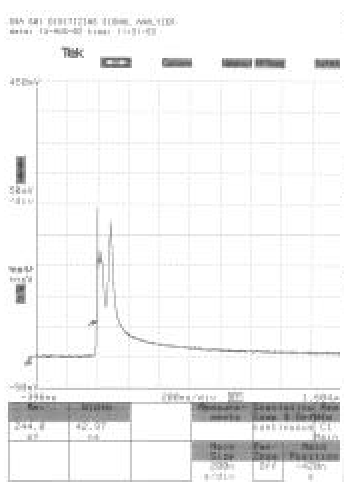


Figure 1

TEMoo value of mode were observed due to thermal loading effects resulting from changing pulse repetition rates. The stability of the Q-switched TEMoo output mode under such these conditions was found to be about +/- 10% as shown in Figure1.





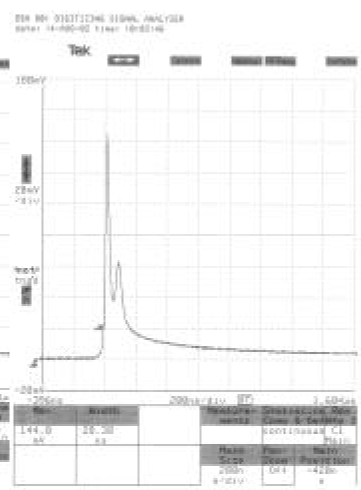


Fig.2 **Fig.3** **Fig.4**

When the laser resonator was configured to produce more than 3mJ the output was typically found to be multi-mode in structure. This is due to the fact that this resonator structure limits the mode diameter of a TEMoo mode to not more than 1mm, which also limits the amount of stored energy. We observed three occurrences of multiple pulsing in this configuration, all of which were multi-mode.

A). The output may include two or three different pulses with tens of nanosecond separation.
B). The output may include two or three different pulses with hundreds of nanoseconds separation
C). The output may be consistent with "normal" multiple pulse operation and exhibit output pulses with tens or hundreds of microseconds of separation.

For situation A; the laser is running in two or three modes, which have similar mode volumes, but see slightly different gain regions. The result is that the pulse build-up time is slightly different for different modes. Thus, two or three pulses overlap and form a broaden pulse. Figures 2 to 4 shows typical pulses. In Figure 2 three pulse peaks still can be seen in a pulse with 46.79ns pulse duration. The total pulse-width and energy is quite unstable, depending upon which modes are activated. This situation occurs at Cobalt transmission values higher than 92% and outputs of from 5 to 8 millijoules. At lower transmission values of about 83%, the output reaches the 10 to 15 millijoule level with pulse widths of 17 to 30 nanoseconds. All are in the “A” category.

For situation B; the output is multi-mode. However, the different modes see a relatively large difference in gain. Correspondingly, the mode build-up time difference is now several hundred nanoseconds. The output consists of two or three pulses separated by hundreds of nanoseconds. This type of output is not qualified for the rangefinder applications; however, it may be useful in radar applications. See figures 3 through 5.

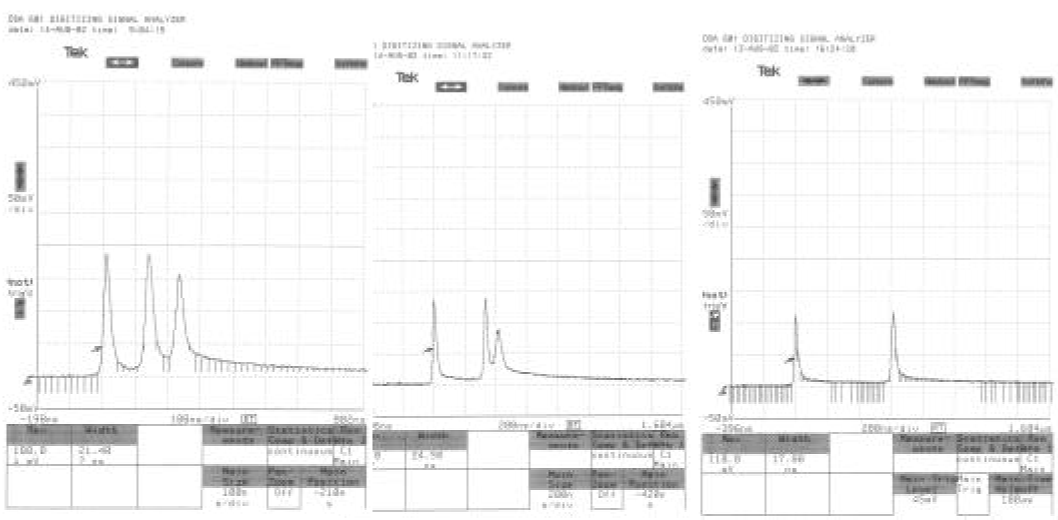
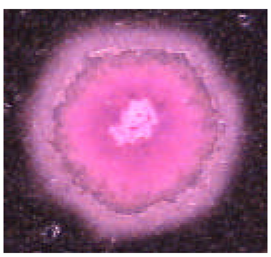
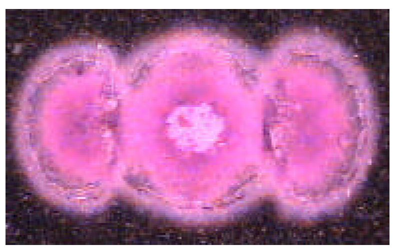


Figure 5 **Figure 6** **Figure 7**

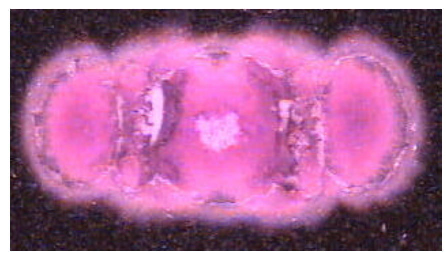
If the working voltage is further increased, situation C will result. This situation is what is normally considered to be multi-pulse operation. The double pulse separation is about 400 to 500 microseconds. The two pulses can be either single or multi-mode as described by above situation A or B. The separation of pulses is normally in the range of several hundreds micro-seconds, as seen in YAG laser Q-switched by Cr^{4+}:YAG. However, there are differences. For example, the second Q-switched pulse seems repeatedly to occupy a different mode than the first one, Beam patterns P1, P2 and P3 and corresponding scope traces Fig.8-Fig.10 demonstrate the pulse patterns. P1 is single mode with energy 3.0 mj in TEMoo mode. P2 is obviously consists of one TEM_{00} plus TEM_{01} mode. P2 is a double pulse with total energy 6.95mj. It demonstrates that the second pulse is in TEM_{01} mode. P3 is a triple pulses output with total energy 9.47 mj. Upon careful examination of the pattern it was determined that the first pulse is TEM_{00} mode, the second pulse is TEM_{30} mode and third pulse is TEM_{01} mode. It means that those pulses utilize different gain volumes, inferring that the gain recovery in a quasi-three level system is longer than in a four level system.



P1



P2



P3

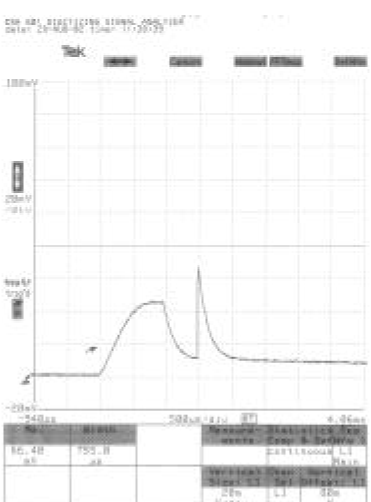


Fig.8

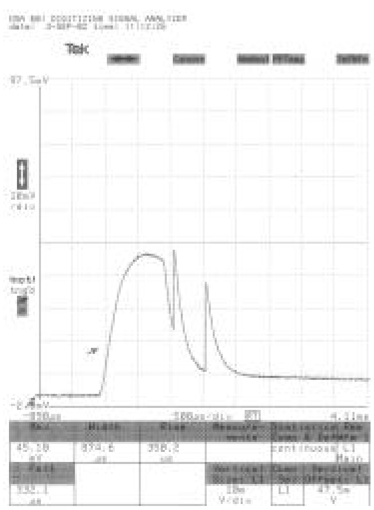


Fig.9

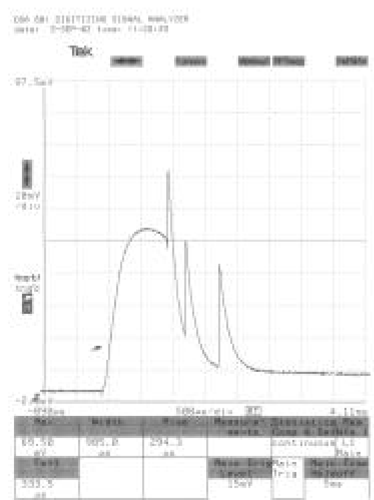


Fig.10

Conclusion

As expected, because of the restrictions imposed by the mode diameter required for single mode operation, it is difficult to maintain the TEMoo mode without an aperture with a 3mm diameter of laser rod. With a minor adjustment, the aperture will force the laser operate in single mode and also can widen the single pulse range.

References

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