Co^{2+}:$MgAl_2O_4$ Crystal Passive Q-Switch Performance At 1.34, 1.44 and 1.54 micron

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Cobalt doped materials, such as Co^{2+}:ZnSe, Co^{2+}:YSGG, and Co^{2+}:$MgAl_2O_3$, have shown promise for use as high performance saturable absorber Q-switches for near infrared lasers. A good saturable absorber should exhibit relatively long excited-state lifetimes and a large absorption cross section. Divalent cobalt exhibits a large absorption cross section and extensive variations in excited-state lifetime when doped into different host materials.

The broad absorption band produced by Co^{2+}:$MgAl_2O_4$ (also known as cobalt doped spinal or magnesium aluminate) in the 1.3 to 1.5 micron region is due to the $4A_2$ to $4T_1$ transition. In this paper we report on the performance of GPI Co^{2+}:$MgAl_2O_4$ as a passive q-switch at 1.54, 1.44, and 1.34 micron.

A 1 mm thick Co^{2+}:$MgAl_2O_4$ sample with ~ 92%T @ 1.54um was evaluated in a diode pumped QX/Er Erbium glass laser resonator. A Cutting Edge Optronics water cooled pump chamber containing 30 (25W) 940nm diode arrays was employed. The CEO pump head contains five sets of linear six bar units in pentagon shaped configuration that side pump a 2.5mm dia. QX/Er laser rod with 6.5 cm of gain length. This pentagon head produces up to 750 watts of peak pump power with pump pulse widths up to 5ms.

One test-bed laser resonator was comprised of two plano/plano mirrors with a 70%R output coupler produced TEMoo mode 1.54um laser output pulses of 6.5 mj with a 35ns pulsewidth at 1Hz. The ratio of long pulse energy to Co^{2+}:$MgAl_2O_4$ Q-switched pulse energy is about 6.3. Table 1. shows q-switch performance data produced with 2 other CaF_2 passive q-switch samples.

Table 1. QS Performance Comparison

Passive Q-switch	GPI $Co^{2+}:MgAl_2O_4$	Spetrogen #1 CaF_2	Spetrogen #2 CaF_2
Thickness of sample	1 mm	1.25 mm	2.56 mm
Pump Current	47.3 A	45.4 A	52 A
Pump Energy	2.52 J	2.43 J	2.78 J
QS Output Energy	6.55 J	2.6 J	2.89 J
QS Pulse Width	35 nsec	526 nsec	198 nsec
Ratio of long pulse/QS	6.3	12.4	24.9

The test results show the Cobalt sample producing much better QS performance than the Spetrogen CaF_2 sample. Table 2 data shows the output energy verses with the repetition rate. Decreasing pulse energy corresponds to a decreasing TEMoo mode value as the repetition rate is increased.

Table 2. The Output Energy Verses Repetition Rate

Repetition Rate (Hz)	Output Energy (mj)	Pulse Width (nsec)
1	6.8	43*
2	5.3	43*
3	4.6	43*
5	4.0	43*

* For this data series the output coupler is 60% R.

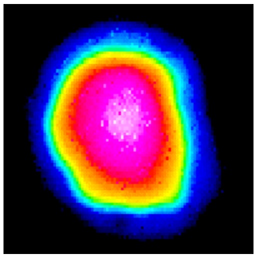
To allow for higher repetition rate operation, the resonator configuration was changed to plano/convex in order to compensate for thermal effects. The high rep-rate laser was operated in a multi-transverse mode in most cases. Multi-mode output pulses of 20mj, 35ns were demonstrated at 20Hz repetition rate. The Q-Switched output spatial mode profiles produced “beautiful” sharply defined multi-mode patterns which indicate that $Co^{2+}:MgAl_2O_4$ exhibits very low saturation losses. In a majority of the experiments we used a lower reflectivity output couplers of 60% and 70% R to insure that the AR/AR coating on the $Co^{2+}:MgAl_2O_4$ sample would not become damaged. With higher reflectivity output couplers we expect even better results may be obtain.

Table 3. High Repetition Rate Output Performances

Repetition Rate (Hz)	Pump Current (A)	QS Output Energy (mj)	QS Pulse Width (nsec)
7	58.5	9.7	42
9	58.5	12.9	40
12	59.0	16.7	39
15	59.0	14.3	39
17	59.5	14.0	38
20	60	20.0	38

The mode patterns at various rep-rates are shown in Fig. 1 The estimated absorption cross section for $Co^{2+}:MgAl_2O_4$ is much larger than stimulated emission cross section of QX/Er at 1535nm. Intracavity focusing optics were not required for QS action.

7Hz 9.7mj

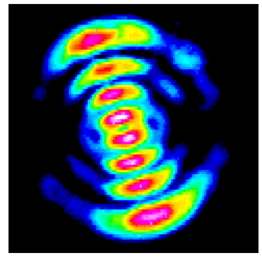


42nsec
single pulse

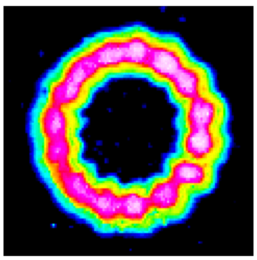
9Hz 12.9mj

40nsec
single pulse

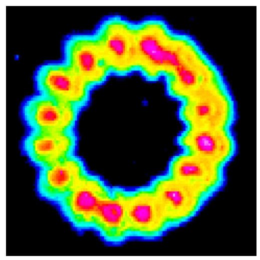
12Hz 16.7mj



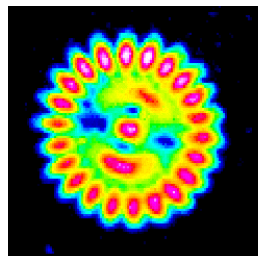
39nsec
single pulse



15Hz 14mj
39nsec
single pulse



17Hz 14mj
38nsec
single pulse



20Hz 20mj
38nsec
double pulse

Fig.1 Mode patterns for different pulse repetition rates

A flashlamp pumped Nd:YAG laser resonator with a 6 x 100mm rod and a 80% R output coupler was operated at 1.44 um. Q-switching was accomplished with a plate of GPI $Co^{2+}:MgAl_2O_4$ exhibiting 90%T @ 1.44um. This laser produced multiple output pulses or a “pulse train” with ~3 mj /pulse and 100ns pulsewidth. In this simple resonator configuration no intracavity focusing was required to help reach laser QS threshold.

A flashlamp pumped $Nd^{3+}:KGd(WO_4)_2$ (Nd:KGW) laser resonator with a 5 x 50mm rod and a 80% output coupler was operated at 1.34 um. Q-switching with a thin plate of $Co^{2+}:MgAl_2O_4$ (~0.3mm thick, 85%T @ 1.34um) produced 17 mj, 300 ns multi-mode pulses at 5 Hz pulse repetition rate The absorption cross section of Co^{2+} in spinal is comparable to the emission cross section of Nd^{3+} in KGW and intra-cavity focusing of laser beam was required. The intracavity beam waist at the spinel plate was 2.5 mm diameter.