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**Cr<sup>3+</sup>-SENSITIZATION OF THE 3 $\mu$ m Er<sup>3+</sup>: YAG LASER**

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**Abstract** – The laser parameters of flashlamp pumped Cr(2%),Er:YAG with Erbium concentrations of 30% and 50% were investigated and compared with unsensitized crystals. With short pulse durations ( $t_p < 500\mu s$ ) Chromium improves the lasing performance. Thresholds as low as 8J have been achieved.

**1.— Introduction**

Laser oscillation of Er<sup>3+</sup> in Y<sub>3</sub>Al<sub>5</sub>O<sub>12</sub> ( YAG ) was firstly reported in 1975 by Zharikov et al. /1/. Since then the laser characteristics of this system have been optimized. However in contrast to Gallium-garnets to our knowledge only one attempt to sensitize Er:YAG has been reported by Voron'ko et al. /2/.

Chromium which is a well known sensitizer in Nd laser materials can influence the output characteristics in three different ways:

- a) Its broadband absorption followed by an energy transfer to the laser ion is used to increase the pump efficiency.

Negative influence of a sensitizer can be caused by

- b) additional heat production within the laser rod or
- c) changes in the effectivity of energy relaxation processes like e.g. up-conversion or cross-relaxation (Fig.1). Especially in Erbium-doped 3 $\mu$ m solid state lasers these processes are of importance because the  $^4I_{11/2} - ^4I_{13/2}$  - transition is self-terminating. The lifetime of the lower laser level is longer than that of the upper laser level, which makes upconversion processes of type a) in Fig.1 necessary for long pulse operation.

In order to investigate the first point we determined the energy transfer parameters by measuring the fluorescence decay of Cr<sup>3+</sup>:YAG with different Er<sup>3+</sup>- concentrations. The very promising results urged us to grow large crystals of Cr(2%),Er(30%):YAG and Cr(2%),Er(50%):YAG to compare the laser performance of these materials with the unsensitized systems. The role of possible loss mechanisms will be discussed at the end of this paper.

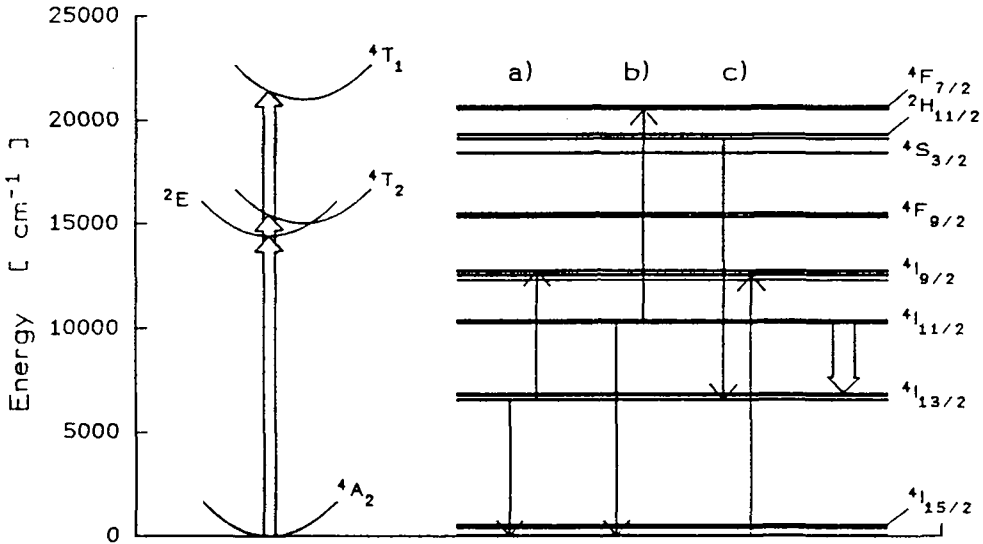


Fig.1 - Cr<sup>3+</sup> and Er<sup>3+</sup> energy levels in YAG

2.- Cr<sup>3+</sup>-Er<sup>3+</sup>-energy transfer

We excited the Chromium ions with 10ns pulses of a N<sub>2</sub>-laser pumped dye-laser (Rhodamin 6G) in Cr,Er:YAG samples with different Erbium concentrations and measured the Chromium fluorescence decay with a liquid Nitrogen cooled photomultiplier and a digital multichannel analyser. As Fig.2 shows, the Chromium lifetime in YAG of 1.7ms is shortened by a rapid non-exponential transfer with an onset 1/e-time of 10ns, totally quenching the Chromium fluorescence in less than 1ms. From the integrated decay curves in Fig.2 we estimate a Cr-Er transfer efficiency of 99% for Cr(2%),Er(30%):YAG.

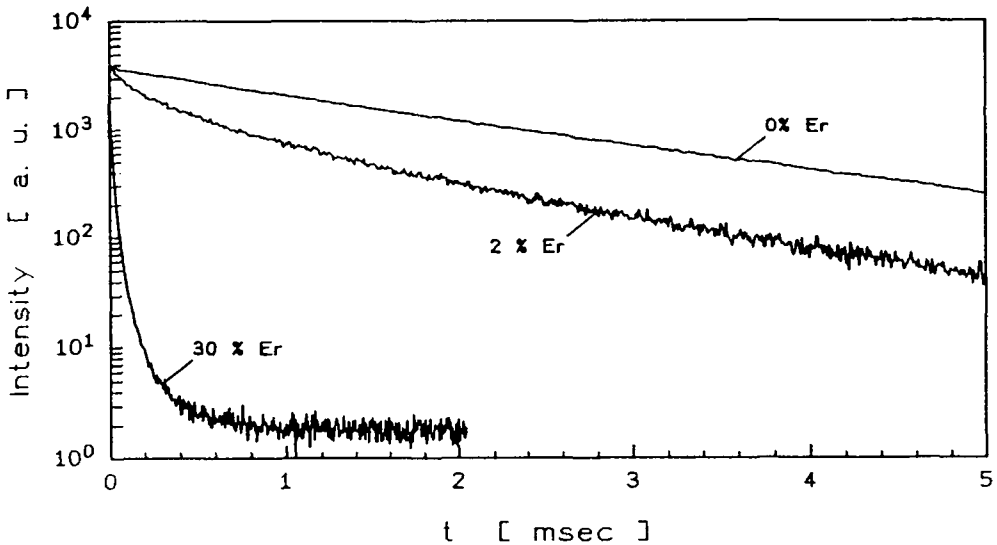


Fig.2 - Cr,Er:YAG fluorescence decay

### 3.- Laser experiments

Flashlamp pumped laser experiments were carried out with uncoated rods, a diffusely reflecting ceramic cavity, a linear Cerium-doped Xenon flashlamp, and a resonator consisting of a HR-mirror ( $r=1m$ ) and a flat output coupler ( $T=9\%$ ). The laser power was measured with a pyroelectric detector. Three different pulse durations of  $50\mu s$ ,  $200\mu s$  and  $1ms$  were chosen to compare the lasing behaviour with unsensitized rods.

### 4.- Results

The influence of Chromium additions on the output performance of  $Er^{3+}$ :YAG is presented in Figs.3+4 for the example of an Erbium concentration of 50%. Threshold energies and slope efficiencies at 3Hz repetition rate are listed in Table 1.

Table 1.- Lasing parameters of Er:YAG and Cr,Er:YAG

		Er(30%)		Er(50%)	
		Cr(0%)	Cr(2%)	Cr(0%)	Cr(2%)
50 $\mu s$	$E_{thr}$ [J]	/	15	12	8
	$\eta$ [%]	/	0.15	0.36	0.50
200 $\mu s$	$E_{thr}$ [J]	23	15	15	14
	$\eta$ [%]	0.40	0.56	0.60	0.75
1ms	$E_{thr}$ [J]	74	100	45	40
	$\eta$ [%]	0.33	0.26	0.53	0.47

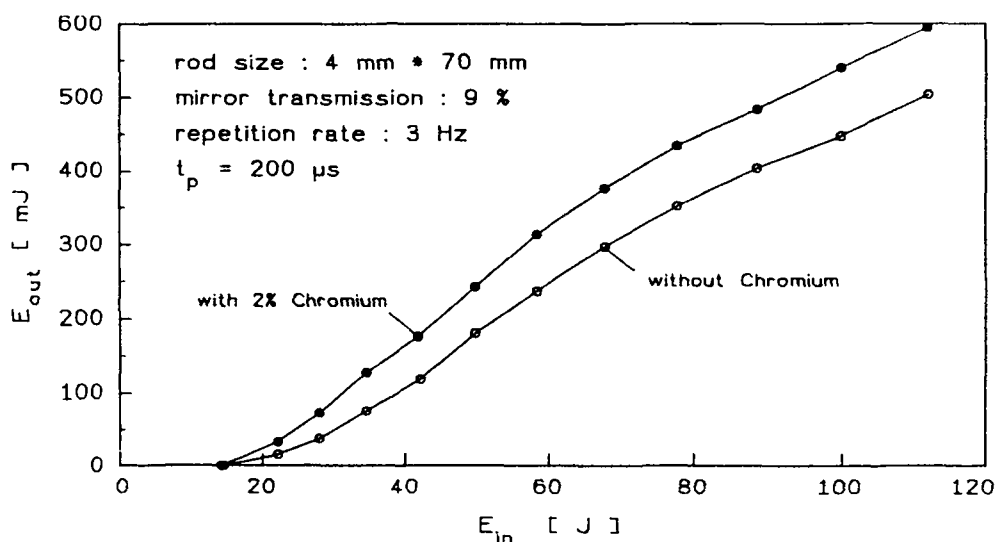


Fig.3 - Er(50%):YAG and Cr(2%),Er(50%):YAG at  $200\mu s$  pulse duration

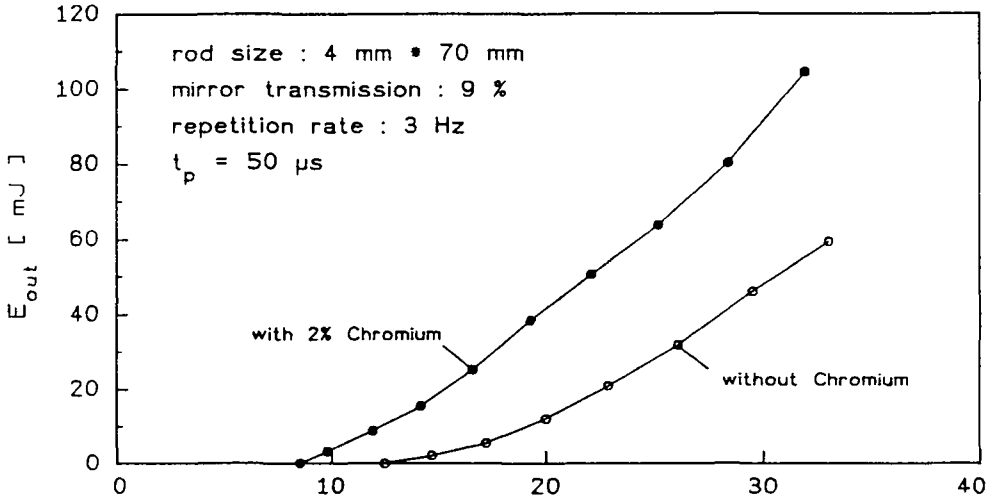


Fig.4 – Er(50%):YAG and Cr(2%),Er(50%):YAG at  $50 \mu s$  pulse duration

Significant improvement of the  $3 \mu m$  Er:YAG laser performance was achieved by codoping with Chromium, especially for short pulse durations. For  $t_p=200 \mu s$  the improvement compared to the unsensitized system was 50% in Er(30%):YAG and 25% in Er(50%):YAG. At shorter pulses the advantages are even higher. Threshold pump energies of less than 10J could be obtained.

At long pulse durations and high average output power additional losses caused by Chromium lead to a reduction of the slope-efficiency. The reason for this loss is not yet clear. We assume that high pump energies produce an increasing probability for upconversion and excited state absorption effects into high Erbium levels. A subsequent back transfer from Erbium into the Chromium  $^4T_1$ -level may be the reason for thermal problems in the Chromium sensitized system.

## References

- /1/ E.V.Zharikov, V.I.Zhekov et al., Sov.J.Quantum Electr.4(1039),1975
- /2/ Yu.K.Voron'ko, S.B.Gessen et al. Sov.J.Quantum Electr.20(8),Aug.1990