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**CONTRACT CRYSTAL GROWTH  
AND  
FABRICATION SERVICES**

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Quarterly Technical Report # 3

Period: November 1989 through January 1990

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## SUMMARY

This program is intended to give the scientists at the Naval Research Laboratory the ability to evaluate new solid state laser crystals. During the third quarter of this contract five growth runs were performed and three spectroscopic cubes were fabricated.

## CRYSTAL GROWTH

The five crystals grown were gadolinium scandium gallium garnet (GSGG) doped with erbium and / or thulium. The presumed congruent composition for undoped GSGG is  $Gd_{2.96}Sc_{1.9}Ga_{3.14}O_{12}$ . The melt compositions are listed in Table 1. If it is assumed that the distribution coefficients are unity then the crystal compositions will be the same. We have assumed that erbium has a unity value and that thulium has a value of 1.2. Therefore, the nominal doping of Tm in the crystal will be approximately 20% higher than in the melt. The melts for NRL-6 and 7 were targeted to be 30%Er and 5%Tm, but the growth engineer miscalculated the composition. The compositions in Table 1 are the actual ones formulated.

KEYWORDS: SOLID STATE LASERS, CRYSTAL STRUCTURE, CRYSTAL GROWTH, FABRICATION, GADOLINIUM, SCANDIUM, GALLIUM, OXYGEN, ERBIUM, THULIUM

TABLE 1: Compositions

Growth Run	Melt composition	Nominal Doping (at%)
NRL-4	$Gd_{2.06}Er_{0.9}Sc_{1.9}Ga_{3.14}O_{12}$	30 % Er
NRL-5	$Gd_{2.91}Tm_{0.05}Sc_{1.9}Ga_{3.14}O_{12}$	2 % Tm
NRL-6	$Gd_{2.045}Er_{0.9}Tm_{0.015}Sc_{1.9}Ga_{3.14}O_{12}$	30 % Er, 0.6% Tm
NRL-7	$Gd_{2.045}Er_{0.9}Tm_{0.015}Sc_{1.9}Ga_{3.14}O_{12}$	30 % Er, 0.6% Tm
NRL-8	$Gd_{1.935}Er_{0.9}Tm_{0.125}Sc_{1.9}Ga_{3.14}O_{12}$	30 % Er, 5.0% Tm

The growth conditions are listed in Table 2. Runs NRL-4 and -5 were grown with a flat interface to eliminate the central core strain associated with deep interface growth. They were free of inclusions and NRL-5 was low in strain. NRL-4 on the other hand had an irregular strain pattern in a polariscope. It was not clear

whether this strain was caused by the large amount of erbium substitution or by some other growth factor. However, runs NRL-7 & 8 which also had 30% Er substitution had very little strain and thus the high Er content does not seem to be an intrinsic problem. The strain in NRL-4 may have been caused by a non-planar interface or by a large number of dislocations. The boules are not routinely etched and a dislocation count is unavailable.

Run NRL-6 did not produce a crystal. Attempts to dip a garnet seed and to initiate growth resulted in opaque, pink, polycrystalline material on the seed. The frozen melt also had this appearance, rather than the characteristic glassy surface of garnet melts. The level of the melt in the crucible was not as high as expected and a weighing error was suspected. The melt was removed from the crucible and a sample sent for spark source mass spectrographic analysis. The results of the analysis are inconclusive. Gd, Sc, Ga, and Er are listed as "major" elements which means that the concentration is greater than roughly 1000 ppmw. The Tm concentration was 650 ppmw. Therefore, these elements were not completely omitted from the batch, but it is still possible that the full amount was not added. Further analysis was not performed because a second run of this composition behaved normally.

TABLE 2: Growth Conditions

<u>Fraction</u> <u>Growth Run</u>	<u>Pull Rate</u> mm/Hr	<u>Rotation</u> RPM	<u>Oxygen</u> %	<u>Average Length</u>		
				<u>Diameter</u> mm	<u>at Diam</u> mm	<u>Crystallized</u> %
NRL-4	1.5	50	1.5	26	25	6
NRL-5	1.5	48	1.7	33	52	17
NRL-6	no crystal produced					
NRL-7	1.5	45	1.5	33	36	11.5
NRL-8	1.5	45	1.8	33	55	20

## FABRICATION

Spectroscopic cubes 5x5x5 mm were cut and polished from runs NRL-4, -5 and -7. The residual boule sections were polished and delivered. A spectroscopic cube from NRL-8 is in process.

## PERSONNEL CHANGES

Two of the contributors to this report are no longer with Litton Airtron. Bob Metz's crystal growth duties will be absorbed by John Creamer and Don Murrell's fabrication duties by Robert C. Acklin.

## PLANS FOR NEXT QUARTER

At this time a run is in progress of Cr:Tm:YALO for Dr. Quarles and no further runs have been scheduled.

STATEMENT "A" per C. Marquardt  
NRL/Code 6551  
TELECON 2/14/90

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