

GODDARD SPACE FLIGHT CENTER

Failure Analysis Report

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Project:	ESSP	Part Type:	Laser Diode Assembly
Subsystem:	CALYPSO	Manufacturer:	SDL
Date:	03 September 2003	Part Number:	
	SDL-32-00881		
Investigator:	F. Felt 286-9634	Serial Number:	D172
Requestor:	H. Leidecker 286-9180		

Background

Subsequent to reports of gold-indium intermetallic growth on gold wires of other SDL laser diodes, the above device was forwarded by the CALYPSO program to the NASA GSFC Parts Laboratory for evaluation.

Part Description

The SDL-32-00881 laser diode array is manufactured by Spectra Devices Laboratory. The array consists of sixteen (16) repeating units sandwiched between anode and cathode blocks. Each repeating unit consists of an aluminum-doped GaAs laser diode bar soldered to a W-Cu submount; and with an alumina spacer also soldered to the submount. Each laser bar has ninety (90) one-mil diameter gold wires wedged between a gold film on the spacer and on the cathode face of the laser bar. Each of the sixteen (16) laser diode units is indium-soldered to a BeO substrate for heat-sinking, and to adjacent units for electrical continuity. The entire assembly rests on a mounting block with four (4) bolt holes and a removable safety shunt.

The following nomenclature is used for this analysis: Each repeating unit is numbered 1

through 16; beginning with the unit nearest to the cathode block. Each laser bar has six groups of fifteen gold wires. Viewing the laser diode top-down, the wire groups are labeled G1 through G6, from left to right on the laser bar, with the spacer bar oriented at the top of the view. In each group wires are labeled from left to right, W1 through W15.

Analysis and Results

The laser diode assembly was externally inspected and photo-documented. High-power optical inspection of the wires suggested the formation of gold-indium intermetallic. The mounting block was also inspected, finding extruded indium in two bolt holes. This problem, believed to be due to over-torquing of the bolts, was identified as a cause of electrical shorting in a previous laser diode investigation.

The cathode strap and cathode block were removed. Optical inspection showed that the entire assembly of sixteen (16) bars had lifted from the BeO substrate during removal of the cathode bookend.

Shear testing was attempted on the laser bar units, but the units were obviously not attached to the BeO, and several units separated in groups,

rather than individually. Nevertheless, the strength between the interface of the spacer and adjacent submount of six groups was measured between 355

and 870 grams-force. An additional seventh unit separated at 75 grams.

Optical inspection of the BeO heat sink with the laser bar units removed, found no evidence of indium, leading to the conclusion that the laser bars had not been properly heat-sunk. A single stripe of indium (each consisting of three segments) was found under the cathode, and anode blocks.

The laser diodes were inspected. Most wires exhibited gold-indium intermetallic formation. Many of these wires broke when the laser diode units were separated, because the massive intermetallic formation had effectively soldered the wires to the underside of an adjacent bar. On some laser diode units, most of the wires were broken and heavily encrusted with intermetallic. SEM inspection of several of these broken wires showed that the intermetallic growth had reduced the gold wire diameter by approximately one-third.

Composite images of laser bars were assembled using optical and SEM photographs. These images are found in Figures 17 through 34.

The wedge bonds on the gold wires at the spacer were inspected. Tool marks were found which had flattened wedge bonds and gouged wires. The close spacing of the wires and the repeating appearance of the marks strongly suggested the bonding tool dimensions exceeded the clearance between wires.

Conclusion

This evaluation found several major problems with the D172 laser diode assembly:

- (1) Massive gold-indium intermetallic was found on gold wires on many bars.
- (2) Extruded indium was found in two of the mounting bar bolt holes.
- (3) Indium solder was not found bonding any of the laser diode units to the BeO substrate.
- (4) Gold wedge bonds at the spacer exhibited evidence of tool mark damage.

GODDARD SPACE FLIGHT CENTER
Part Type Laser Diode Assembly
Manufacturer SDL

Part Number SDL-32-00881
Serial Number D172

Appended Photographs:

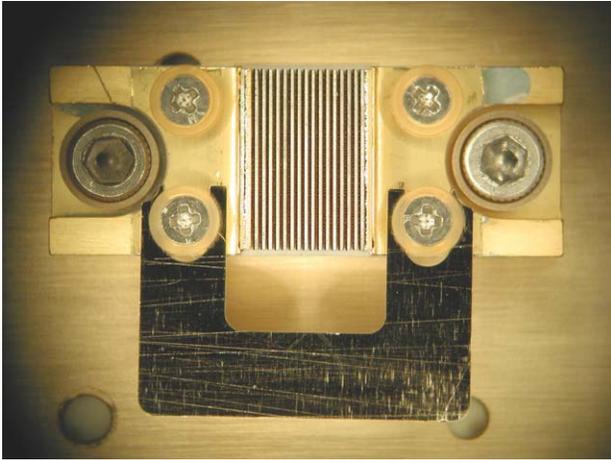


Figure 1. An overall top-down view of the D172 laser diode array with mounting bar, lugs, and safety shunt.



Figure 2. A close-up view of the sixteen (16) laser diode bars of the assembly.

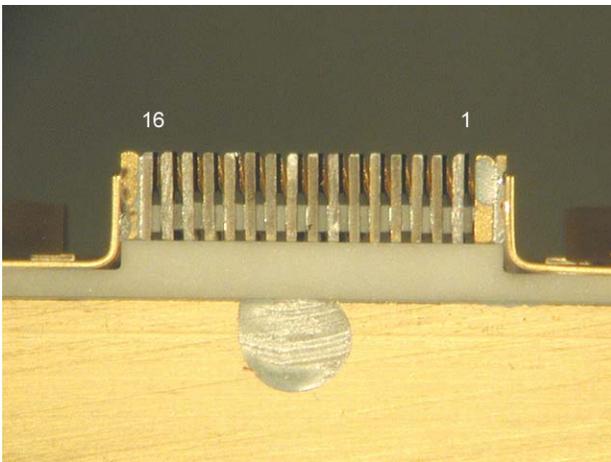


Figure 3. This image shows a side view of the D172 laser diode array. For the purposes of this analysis, the bars are numbered 1 through 16, as seen above.

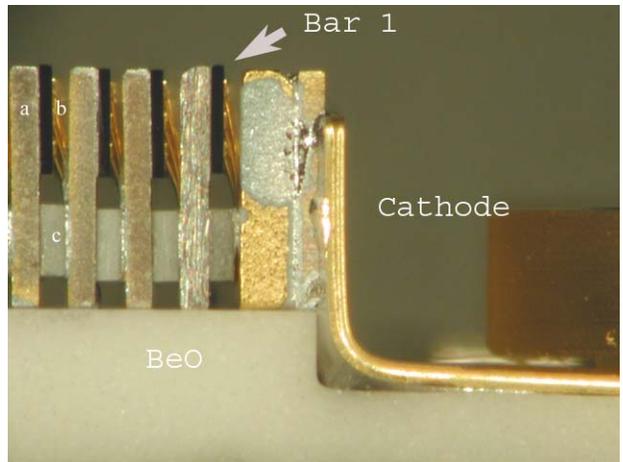


Figure 4. A detail side view of the cathode-end of the array showing the strap, bookend, BeO substrate, and four laser bars and submounts, beginning with Bar 1. The lettering identifies the submount (a), wires (b), and alumina spacer (c).

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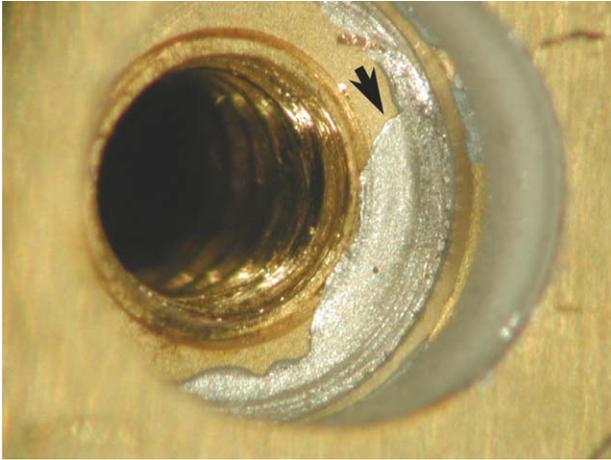


Figure 5. Extruded indium was found in a bolt hole on the mounting block. This anomaly, apparently caused by over-torquing of soft indium, can cause an electrical short.

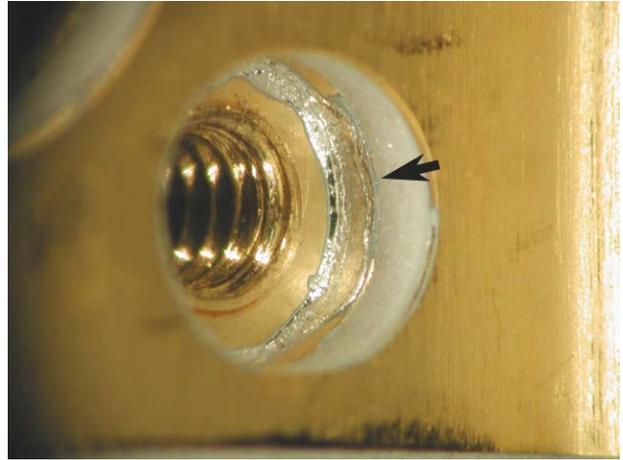


Figure 6. A second bolt hole with extruded indium is seen above.

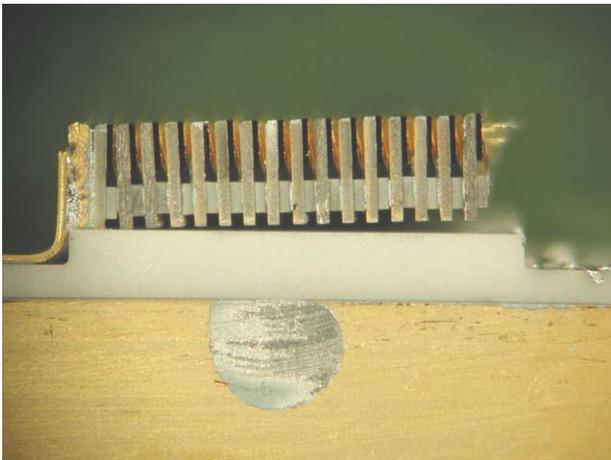


Figure 7. When the cathode bookend was removed from the assembly, all the laser bars 'floated', unattached from the BeO substrate.

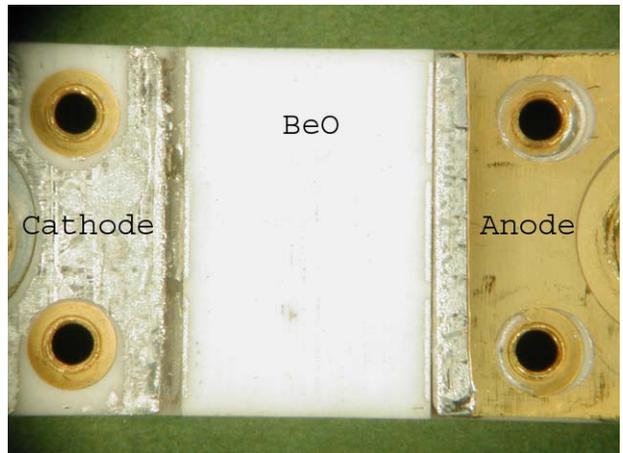


Figure 8. A top-down view of the BeO substrate after removal of all the bars shows no indium solder, except for three in-line segments at the cathode and anode.

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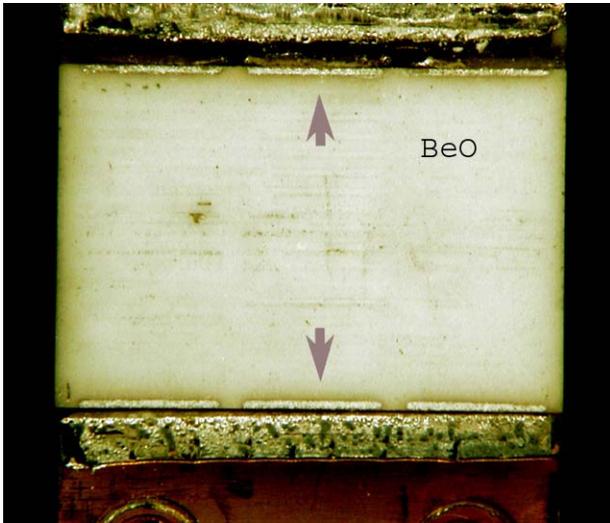


Figure 9. An enhanced view of the BeO substrate shows some striations from the bars. No evaporated indium was found, except for three segments indicated by arrows on both sides of the array.

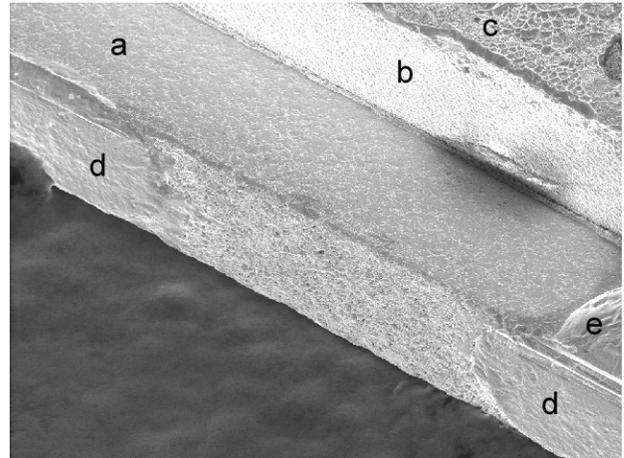


Figure 10. This view of the heat-sink side of Bar 13 shows the submount (a), the alumina spacer (b), and opposing ends of indium patches (d). A melted droplet of indium (e) is seen at lower right.

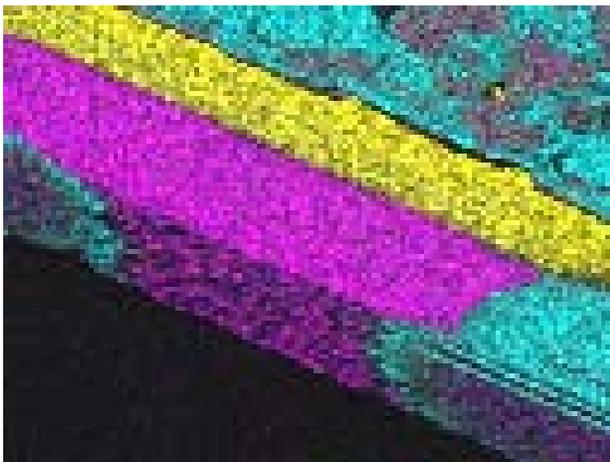


Figure 11. A matching EDS map of the image in Figure 10 shows indium (light blue), oxygen in the alumina (yellow) and gold film (purple) on the W-Cu submount.

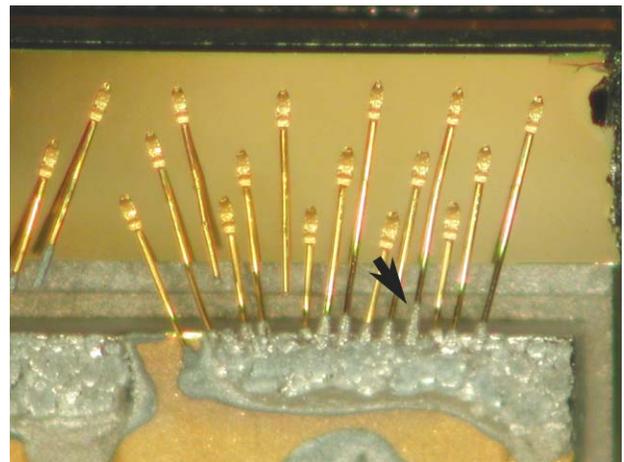


Figure 12. Low-power optical inspection of Bar 1 immediately found multiple gold wires affected by gold-indium intermetallic, one of which is indicated by the arrow.

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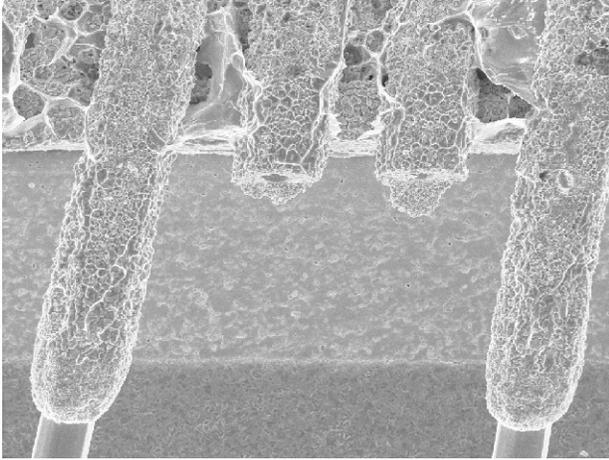


Figure 13. A view of four indium-affected gold wires on Bar 13. The two wires at center are broken because the wire was attached by intermetallic to the submount of the adjacent bar, and broke when the bars were separated.

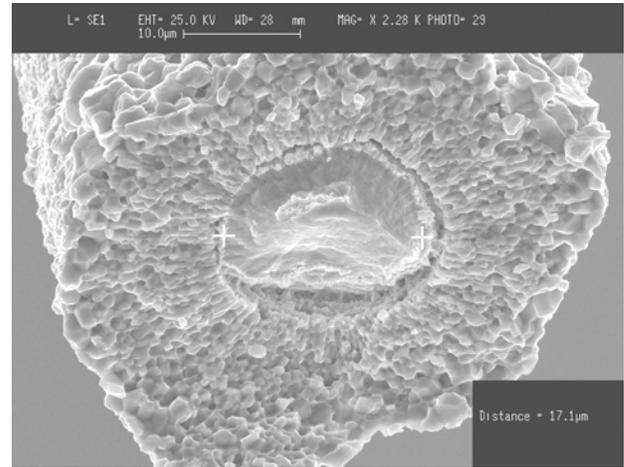


Figure 14. An end-on view of a broken wire from Bar 13 shows a gold wire at center measuring 17 μm .

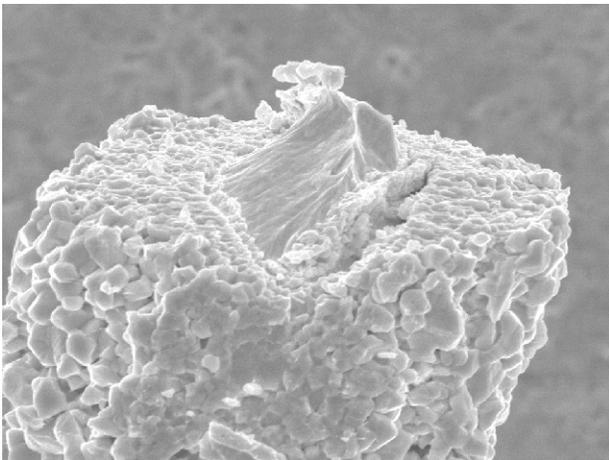


Figure 15. A side view of another broken wire shows evidence of tensile stress, presumably caused during disassembly because intermetallic had attached the wire to the adjacent submount.

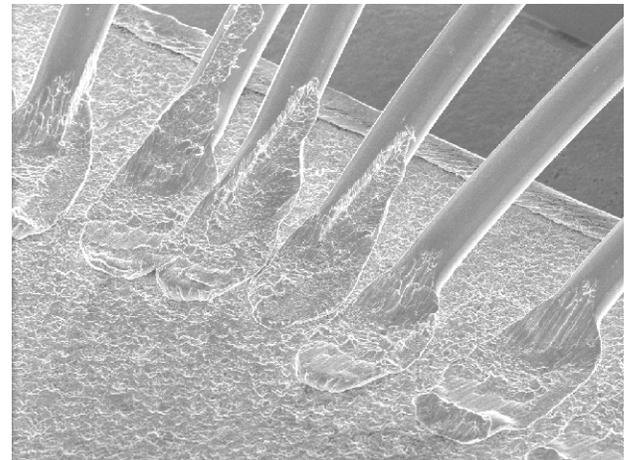


Figure 16. This image of some of the gold wedge bonds not affected by intermetallic shows evidence of damage by the bonding tool.

Appended Photographs:

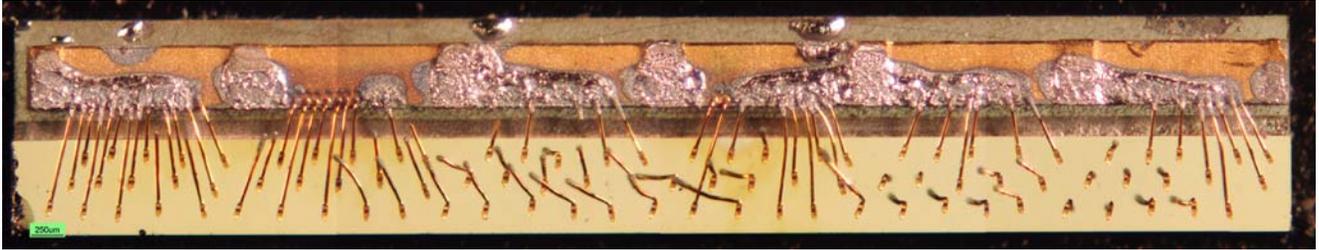


Figure 17. Bar 1

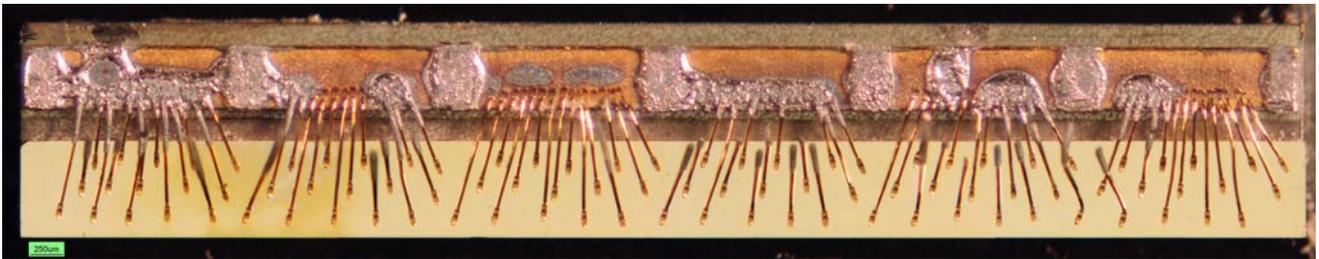


Figure 18. Bar 2.

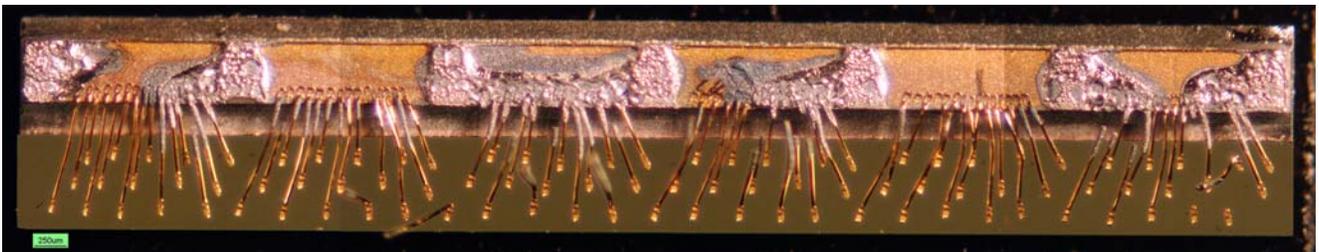


Figure 19. Bar 3.

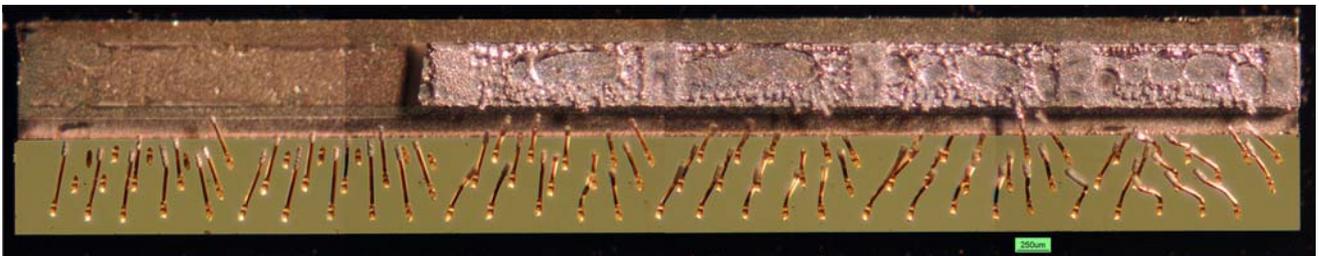


Figure 20. Bar 4.

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Manufacturer

SDL

Serial Number

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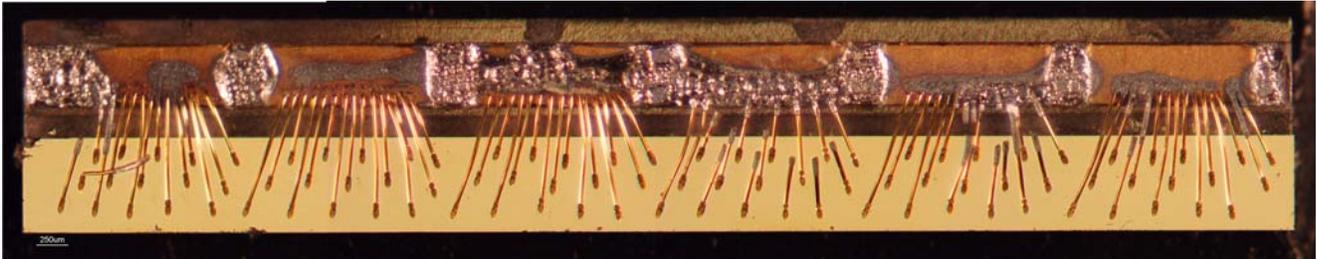


Figure 21. Bar 5.

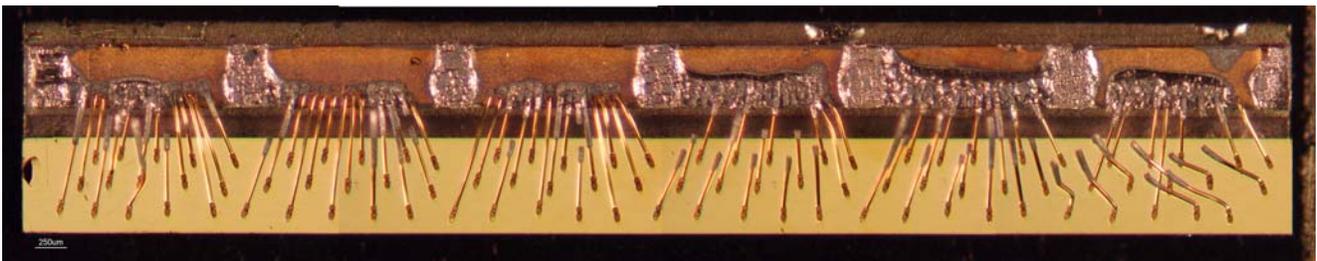


Figure 22. Bar 6.

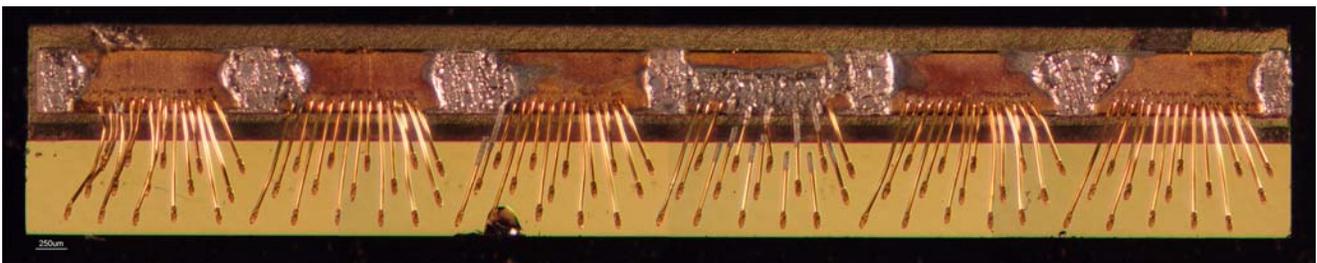


Figure 23. Bar 7.

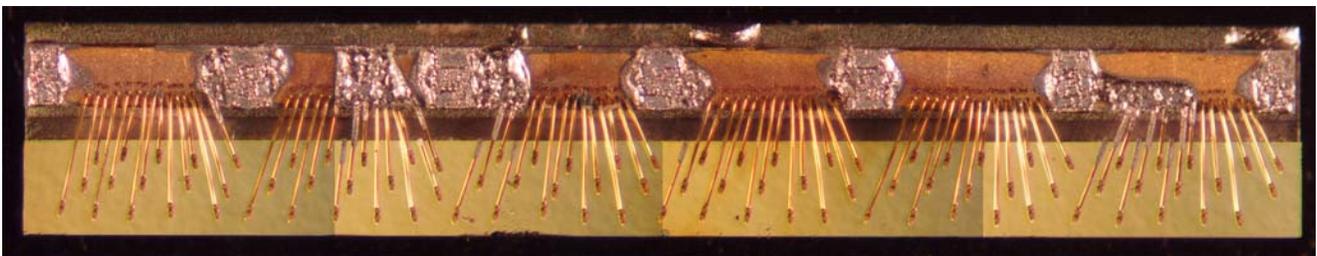


Figure 24. Bar 8.

Appended Photographs:

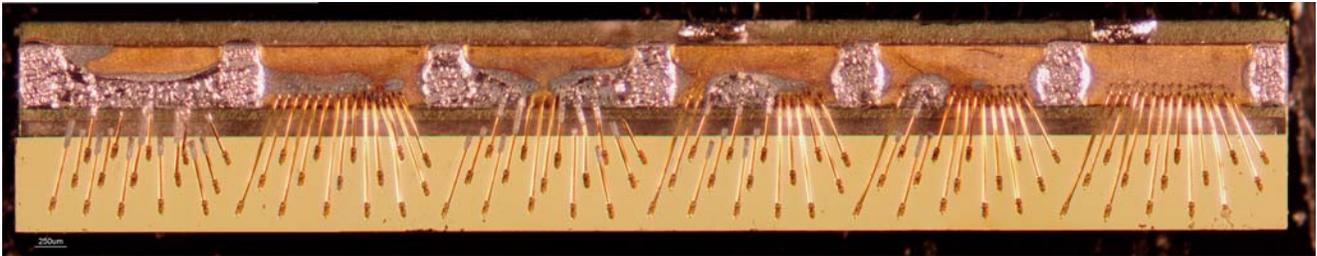


Figure 25. Bar 9.

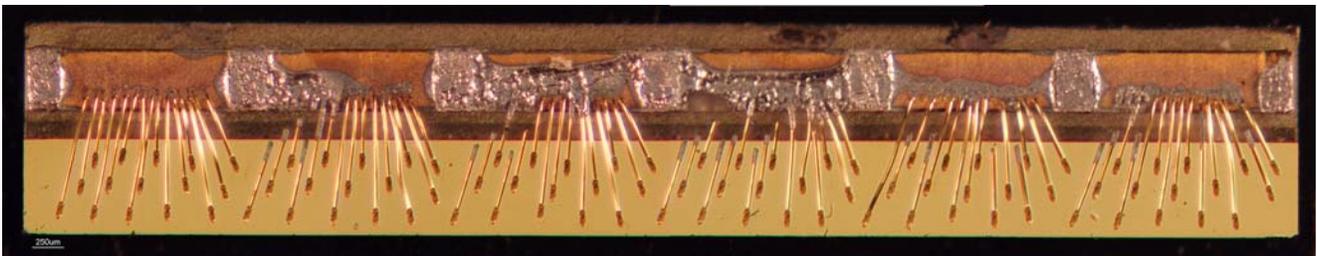


Figure 26. Bar 10.

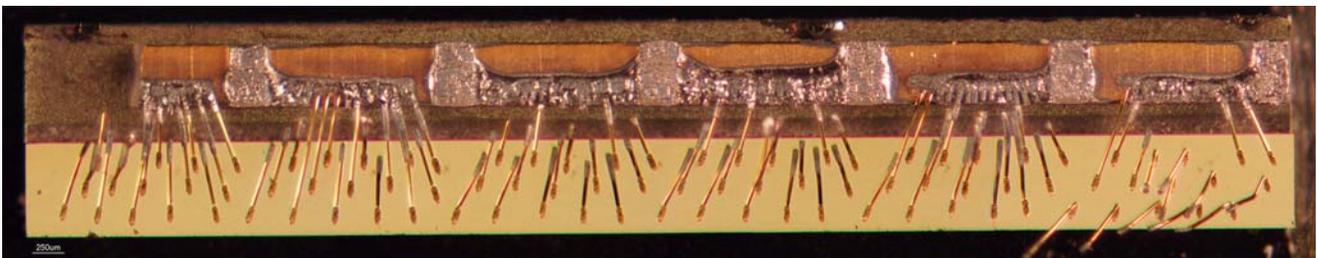


Figure 27. Bar 11.

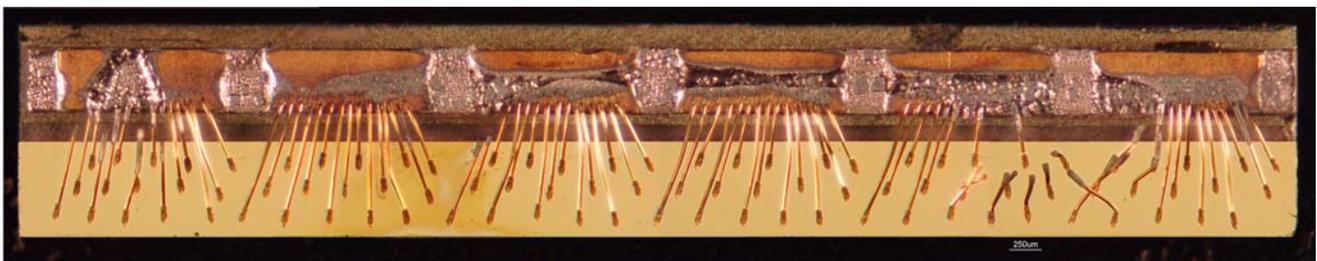


Figure 28. Bar 12.

Appended Photographs:

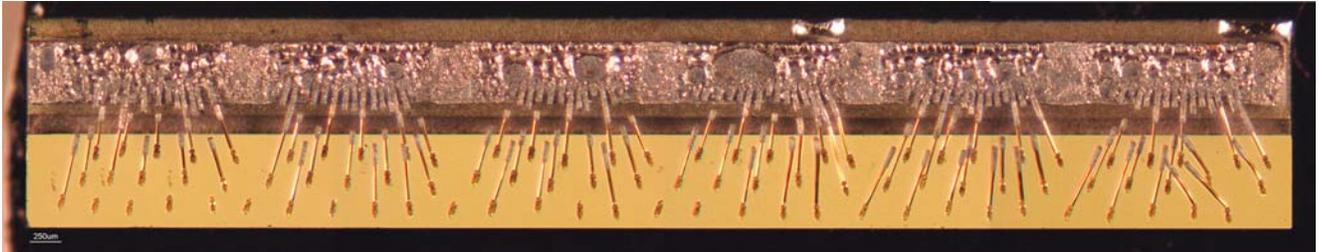


Figure 29. Bar 13.

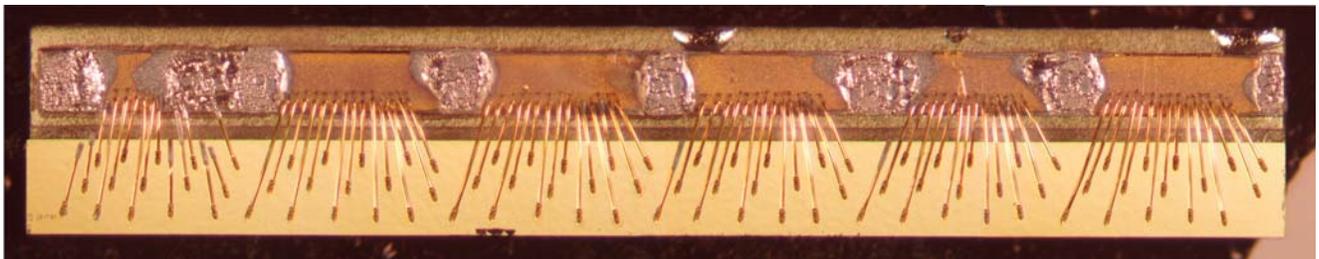


Figure 30. Bar 14.

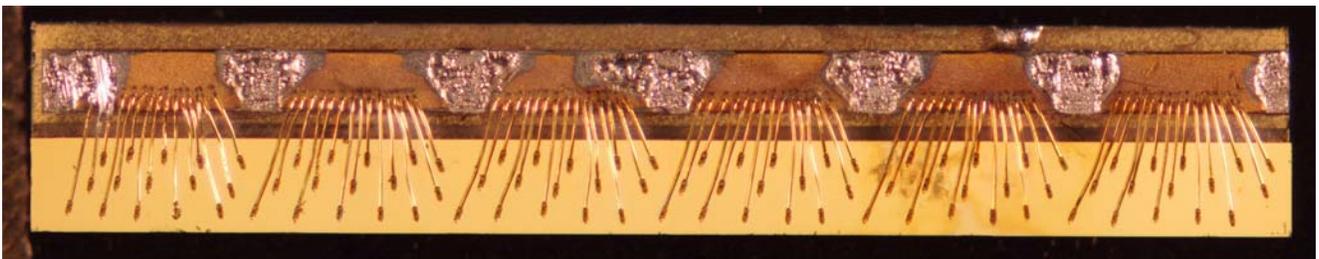


Figure 31. Bar 15.

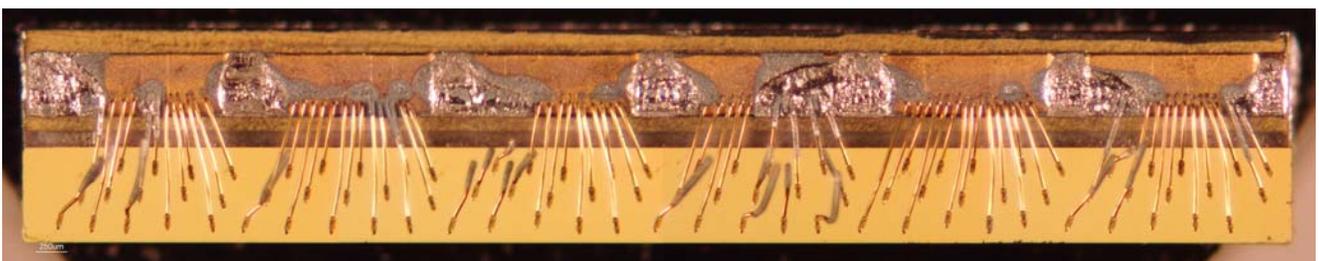


Figure 32. Bar 16.

Appended Photographs:

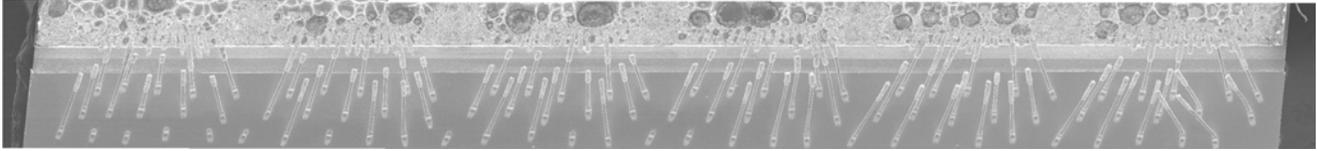


Figure 33. Bar 13.

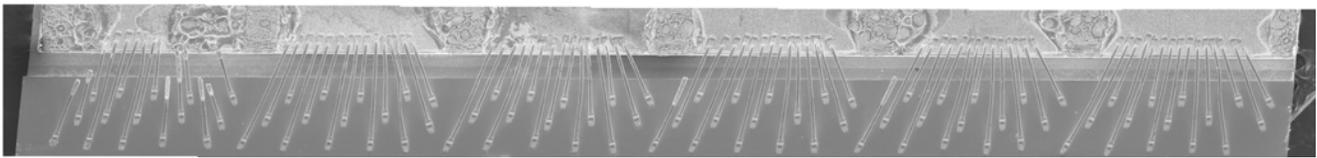


Figure 34. Bar 14.

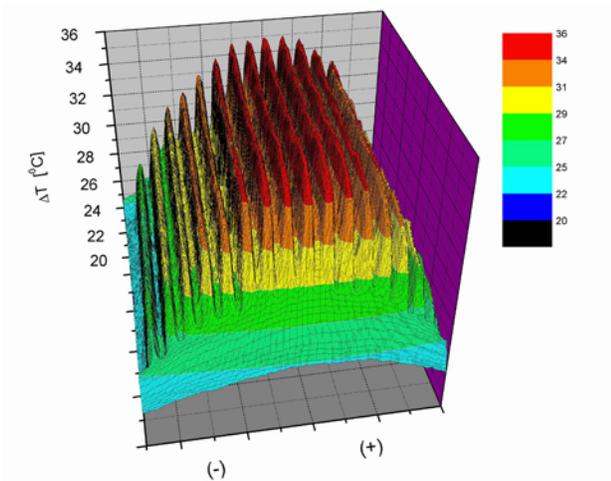


Figure 35. A 3-D infrared view of the D172 laser diode array, taken top-down. The parabolic distribution of temperatures across the array with higher temperatures at the center, is evidence that the laser diode units were not properly heat-sunk. When disassembled, no evidence of indium stripes was found on the BeO substrate under the laser diode submounts. (See Figures 8 and 9.)

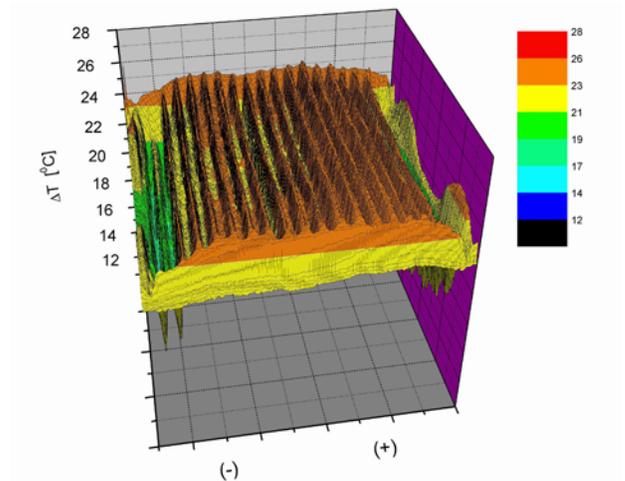


Figure 36. Compare to the Figure at left. The 3-D infrared view of the D243 laser diode above shows a much flatter temperature distribution across the array, presumably because the laser diode submounts were properly connected by indium to the BeO substrate.