

# This Week's Citation Classic

CC/NUMBER 1  
JANUARY 4, 1982

De Loach B C, Jr., Hakki B W, Hartman R L & D'Asaro L A. Degradation of CW GaAs double-heterojunction lasers at 300 K. *Proc. IEEE* 61:1042-4, 1973.  
[Bell Laboratories, Murray Hill, NJ]

Identification of a major failure mechanism in stripe-geometry proton-bombarded double-heterojunction lasers is reported. This mechanism consists of the formation of localized 'dark lines' in the optical cavity, coinciding with a decrease in light output. The dark lines are aligned in  $\langle 100 \rangle$  crystallographic directions. [The SCI® indicates that this paper has been cited over 110 times since 1973.]

B.C. De Loach, Jr.  
Bell Laboratories  
Murray Hill, NJ 07974

November 3, 1981

"This paper had its origins in a program being carried out at Bell Telephone Laboratories to improve the reliability of semiconductor lasers. At the time, there was a lot of speculation concerning potential fiber-guide systems and how they might some day revolutionize telecommunications. Unfortunately, the lasers of the day (the obvious choice for the transmitter) had lifetimes of minutes to at most a few hours. If the promise of these systems was to be realized, laser lifetime had to be improved by orders of magnitude. We decided to tackle the problem.

"Back of the envelope calculations indicated that none of the usual failure mechanisms for semiconductor devices was likely to be operative for lasers dying so quickly and that something new was likely involved. I was aware of some earlier work on light emitting diodes<sup>1</sup> that had evidenced a peculiar failure mechanism wherein dark lines developed in the photoluminescence of these devices. Although the structure was quite different, the more I thought about this phenomenon the more likely a candi-

date it seemed for a laser killer. I discussed it with members of my department and almost immediately Basil Hakki managed to get a dead laser partly dissected and obtained a crude photo of its luminescence pattern. The dark lines were there! Bob Hartman and Art D'Asaro had made a window laser structure intended for these measurements and obtained excellent photographs of what everyone has come to call dark line defects. The key observation here was that the dark lines started in the stripe and grew outward, making these defects unique in semiconductor literature.

"In my opinion it was this discovery and its association with strain and lattice defects that became the cornerstone of today's reliable laser technology, which is why the paper is often cited. A considerable body of work has ensued on the subject to date with the transmission electron microscope work<sup>2</sup> of Pierre Petroff and Hartman first revealing the true 'nature of the beast' to be a dislocation tangle. The detailed physics of the development of the dislocation network under the influence of device operation has to date proved difficult to nail down. There is no doubt that matter is moving under the influence of energetic carriers but a consensus has not developed on the nature of the point defects involved or indeed whether point defects are generated by the process or are consumed by it. This problem is still being studied today, in part due to the perception that it has import for other semiconductor devices as well as for lasers.

"It was an exciting time for those of us involved in the laser effort. I think we were all convinced of the importance of what we were doing and at that time we had the best of all worlds for a technical team: 1) an important job, 2) a job involving not only engineering but good science as well, and 3) adequate funding and moral support from our management."

1. Biard J R, Pittman G E & Leezer J F. Degradation of quantum efficiency in gallium arsenide light emitters. (Stickland A C, ed.) *Gallium arsenide: proceedings of the international symposium organized by the Institute of Physics and the Physical Society in co-operation with the Avionics Laboratory of the US Air Force, Reading, September 1966*. London: Institute of Physics and the Physical Society, 1967. p. 113-17.
2. Petroff P M & Hartman R L. Defect structure introduced during operation of heterojunction GaAs lasers. *Appl. Phys. Lett.* 23:469-71, 1973.