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This Week's Citation Classic

Burns G & Nathan M I. *P-N* junction lasers. *Proc. IEEE* **52**:770-94, 1964.
[IBM Watson Research Center, Yorktown Heights, NY]

This paper is a review of the first year of the extensive studies of semiconductor injection lasers. The basic principles of lasers are presented as well as the application of these principles to *p-n* junction lasers. The bibliography including preprints is fairly complete. [The *SCI*® indicates that this paper has been cited over 110 times since 1964.]

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"In the November 1,1962 issue of two different, widely read physics journals, papers describing the first injection laser appeared. They came from the GE Research Laboratories[1] and my laboratory at the IBM Thomas J. Watson Research Center.[2] Injection lasers are made from small pieces of semiconducting crystal often too small for the naked eye to see. They are very efficient in converting electrical energy directly into light (laser light). One exciting aspect of the development of these lasers was that they resulted from the marriage of two important and intensely studied scientific fields, the semiconductor and laser fields.

"The interest in injection lasers was immediate and widespread. At IBM many of us started working seven days per week. It was a very exciting time, one I will always fondly remember.

"Even the most elementary microscopic aspects of how these lasers functioned were not understood. The lasers were *p-n* junctions made from GaAs. One laboratory claimed the light came from the p-side of the junction; the other laboratory was certain it emanated from the n-side. The relationship of the laser light to the donor and acceptor fluorescence in ordinary GaAs was not known. The mechanism of confining the light in what seemed like extremely narrow wave guides was not understood. These types of problems had never been encountered in the previous state of the art lasers which were made from large transparent crystals like ruby. Since the input power could be controlled very accurately by controlling the current of the *p-n* junction, the manner in which these lasers approached their thresholds could be studied. This was quite unlike what could be done in ruby type lasers.

"I was to leave for a sabbatical starting June 1963. As June approached I felt that there were many unknowns still to be determined. We had asked more questions than we had found answers and I began to wonder what we had really accomplished in these few months. I tried to summarize and piece together what had been found, what was understood, and what was not understood. In early June, therefore, I started the review article which has been cited often. Since every published paper and preprint in the field were at my fingertips, it was not difficult to pull them together in a modestly coherent manner. The review (finished on sabbatical) covered essentially every paper in the injection laser field (there are 162 references) as well as some of my unpublished work with my coauthor, Marshall Nathan. A more recent review has been prepared by Casey and Panish.[3]

"It apparently is highly cited because it is a useful summary of the early results. Normally a review paper written in a field only a year old would make no sense since so many issues are not settled. This paper seems to be an exception. The paper's success may also be due to the fact that it is easy to read since it only focuses on the simple problems one encounters in a new field."

1. **Hall R N, Fenner G E, Kingsley J D, Soltys T J & Carlson R O.** Coherent light emission from GaAs junctions. *Phys. Rev. Lett.* **9**:366-8, 1962.
2. **Nathan M I, Dumke W P, Burns G, Dill P H & Lasher G J.** Stimulated emission of radiation from GaAs *p-n* junctions. *Appl. Phys. Lett.* **1**:62-5, 1962.
3. **Casey H C, Jr. & Panish M B.** *Heterostructure lasers.* New York: Academic Press, 1978. 272 p.