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# This Week's Citation Classic

**Dyment J C, D'Asaro L A, North J C, Miller B I & Ripper J E.** Proton-bombardment formation of stripe-geometry heterostructure lasers for 300 K CW operation. *Proc. IEEE* **60**:726-8, 1972. [Bell Telephone Laboratories, Inc., Murray Hill, NJ]

**A new stripe geometry semiconductor laser structure is reported in which the active region of the junction is defined by proton-bombardment-induced high-resistivity layers. The method yields more reproducible mode patterns, lower threshold currents, and CW operation at heat-sink temperatures up to 110°C. [The *SCI*® indicates that this paper has been cited in over 120 publications since 1972.]**

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"The years 1970 and 1971 were very exciting ones for all the researchers who were involved with those temperamental but wonderfully mysterious semiconductor junction lasers. At Bell Laboratories, CW operation of semiconductor lasers at room temperature had been achieved in 1970 by Hayashi et *al.*[1] because of the successful achievement of crystal growth methods to prepare double heterostructures.

"We had received some of this new double heterostructure material and initially tried oxide-insulated stripe metallic contacts. Unfortunately, these early lasers had quite high threshold currents (usually greater than 400 mA). We concluded that our high thresholds resulted from excessive sideways spreading of the current as it flowed from the stripe toward the active layer. In order to provide more precise current confinement, we decided to try a new technique based on proton-bombardment. We were particularly attracted to a paper published by Foyt *et. al.*[2] at MIT's Lincoln Laboratory. These authors had used proton implantation to isolate p-n junction diodes and to form Schottky barrier guard-ring diodes. Our plan was to implant protons outside of the narrow stripe region; this would create high resistivity material which should prevent sideways current spreading. In order to form the stripe regions, we used either Au-plated stripes or an array of parallel tungsten wires placed in contact with the wafer. The latter method was preferred because the stripe regions were precisely defined with smooth edges. Our initial problems of making the small frames holding the wires were solved by some clever people in our machine shop and we soon found that the proton-bombardment technique did give dramatic improvements in the laser performance. Much lower threshold currents and consequently much higher CW operating temperatures (up to 110°C) were soon realized. The latter figure was the highest obtained at that time.

"In order to achieve this success, several departments became involved in the project. B.I. Miller was the crystal grower who prepared the state-of-the-art crystals; J.C. North provided the facilities for the proton-bombardment; L.A. D'Asaro was the manager of our group who pointed out the MIT work to us; J.E. Ripper and I planned and implemented the various aspects of how to ,form the tungsten wire bombardment masks and how to hold the wafers in the desired orientation with the wires. I was in charge of laser processing and initial device characterization so I was the first to see the fruits of our labor.

"I believe this paper has been cited often because it was the first to describe the proton-implantation technique which has been widely accepted in many laboratories and production facilities around the world. It is gratifying that Bell Laboratories and Western Electric are still using this same basic principle today more than ten years later."

1. **Hayashi I, Panish M B, Foy P W & Sumski S.** Junction lasers which operate continuously at room temperature. *Appl. Phys. Lett.* **17**:109-11, 1970.
2. **Foyt A G, Lindley W T, Wolfe C M & Donnelly J P.** Isolation of junction devices in GaAs using proton bombardment. *Solid State Electron.* **12**:209-14, 1969.