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1970

Success in continuous-wave (CW) operation of a semiconductor laser diode (LD) at room temperature (BTL); Practical application of optical fiber (Corning Incorporated)

~ Discrete Semiconductor/Others ~

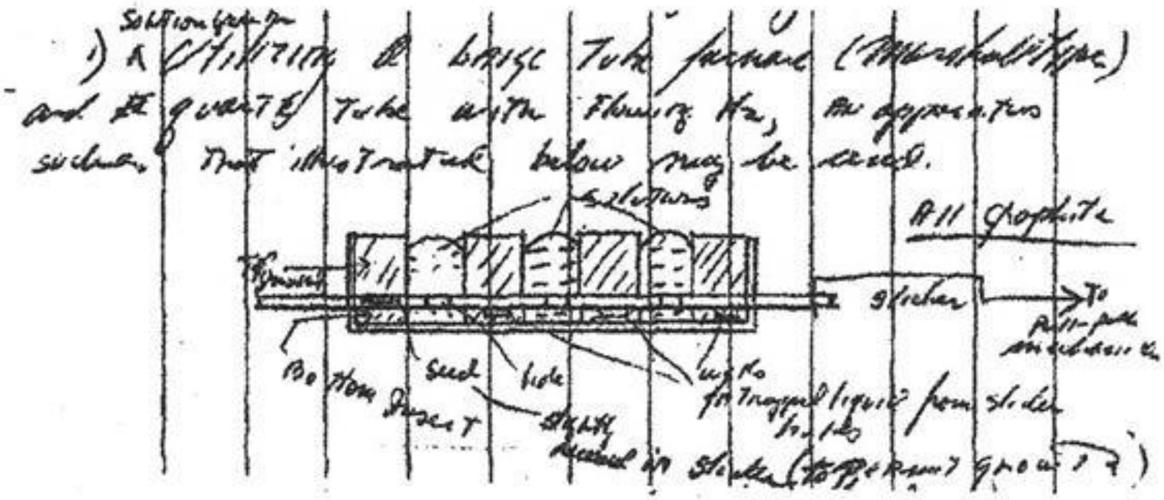
Electron injection laser oscillation in the GaAs p-n junction was confirmed in several groups since about 1962 and was expected as a light source of optical communication. However, since the oscillation threshold current value was as high as 100kA/cm^2, and the operation was limited to the pulse operation at the liquid temperature (77K), it was a big issue to lower the threshold current and to achieve the room temperature CW operation.

It came to be understood that it was important to confine injected electrons in the active region to lower the threshold. In 1963 Kroemer discovered that using a heterojunction rather than a p-n junction would have better electron confinement effect and proposed a double heterostructure (DH) laser.

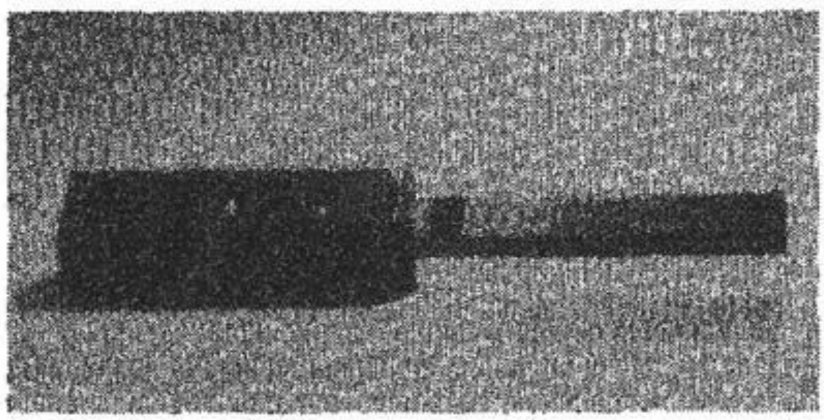
Hayashi of BTL (Bell Telephone Laboratory) worked on realizing this DH laser, but at that time only liquid phase method (LPE: Liquid Phase Epitaxial) was possible for GaAs epitaxial, and it was difficult to form a sandwich structure of p-type AlGaAs and n-type AlGaAs on the both sides of GaAs active layer of 1μm thick. Panish of BTL devised a sliding boat method and succeeded in making a DH laser prototype. The threshold current dropped to 2.5 kA/cm^2, achieving room temperature CW operation for the first time in the world.

Full-scale research on optical fibers began in the early 1960s, but at that time attenuation was large and it did not reach practical use. Various improvements were made by many people, such as reducing the core diameter of the fiber to perform single mode transmission or continuously changing the refractive index in the radial direction of the fiber, but a substantial solution to decrease the attenuation of light could not be attained.

Kao of Corning payed attention not only to the physical phenomenon of optical fiber but also to the material, and he clarified in 1966 that the cause of the attenuation of light was absorption and scattering by a very small amount of impurities such as iron contained in the material, and he predicted that the attenuation would be improved if they were removed. In addition, together with his fellow researchers, he measured the attenuation with various glass materials, and showed that fused quartz was the most suitable material. Four years later in 1970, Corning commercialized a fused quartz optical fiber made by CVD method. Improvement and practical applications of optical fiber rapidly progressed with this, and the total optical fiber installed around the globe has reached more than 25 thousand times of the circumference of the earth.



(a)



(b)

Fig. 5. (a) A new "moving seed" multiple layer solution growth apparatus (Dec. 25, 1969). With this apparatus three DH epitaxial layers can be grown in succession from three solutions. A slider will be moved (push–pull) from outside. All parts are graphite. (b) A photograph of an early sliding boat. The top and the bottom part inserts were tied by platinum wires.

Fig. 1: Photos of notes and a boat of Sliding Boat Method devised by Panish(1)

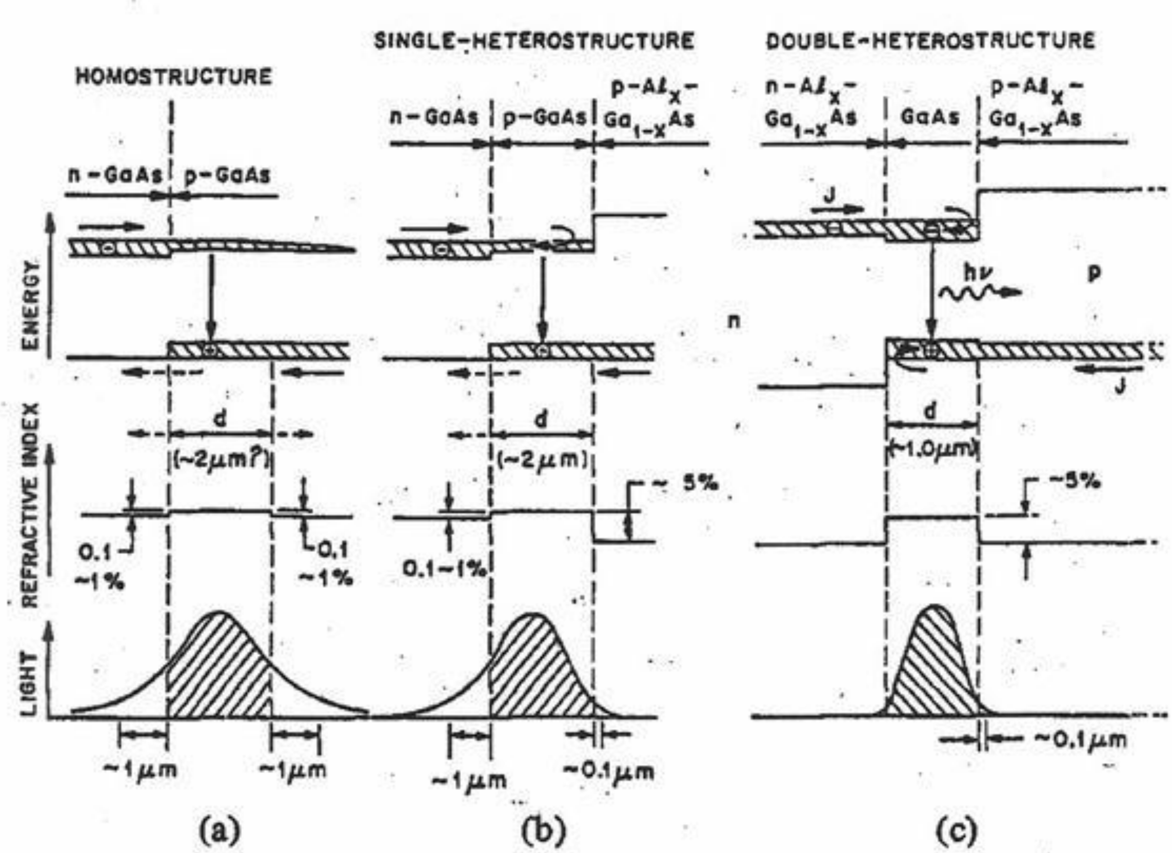


Fig. 9. A schematic comparison of homostructure, SH, and DH lasers under forward bias. [Fig. 2 in 33]. Distribution of:
Carriers in the energy band
Refractive indices
Optical fields
in three structures are indicated. Difference in the carrier and the optical-wave confinements are clearly shown in the figure.

Fig. 2: Figure which Hayashi used to explain the effectiveness of DH structure. (1)

Reference:

(1) I. Hayashi, “Heterostructure lasers”, IEEE Trans. on Electron Devices, Vol. ED-31, pp. 1630- 1642, (Nov. 1984)

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