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Analysis of Large Kink Mechanism in I-L Characteristics of Tunnel Injection Lasers

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Abstract

Large kink in I-L and lasing prohibition are interesting characteristics of tunneling-injection lasers. We suggested these characteristics are due to change of the carrier accumulation in the tunneling-well and ballistic injection to p-cladding layer, respectively.

1 Introduction

Semiconductor lasers with high-speed direct modulation capability and good temperature characteristics are strongly required for local- and metro-area networks. The modulation speed of conventional quantum well (QW) lasers is limited by a carrier capture time.1) A novel tunnel injection structure was proposed to overcome this limit.2), 3) It is possible to inject carriers directly into emission energy level of the QWs by a resonant tunneling structure. A high speed direct modulation is expected by high speed direct carrier injection.4) Good temperature characteristics and high quantum efficiency are also expected because hot carriers with an excess energy can be eliminated by the tunnel barriers.

Lasing characteristics of large kink in I-L and prohibition of lasing are also reported by lasers with tunneling structures.5) However, these novel lasing mechanisms has been not understood. Clarifying of these mechanisms is important for improvement of the lasing performance of tunneling injection lasers.

In this report, we discussed carrier dynamics of tunnel injection lasers to clarify the lasing mechanism of large kink in I-L and prohibition of lasing by theoretical analysis of the tunneling current in comparison with the measured characteristics.

2 Analysis and measurement

Figure 1 shows a schematic band diagram of MBE-grown tunneling injection lasers. The emission layer is $Ga_{0.8}In_{0.2}As$ single QW with the thickness of 80 Å. Tunneling barrier layers are $Al_{0.8}Ga_{0.2}As$ with the thickness of L_b and the tunneling well layer is $Ga_{0.8}In_{0.2}As$ with the thickness of L_w. Stripe laser structures with no-facet coating and the cavity length of approximately 700μm were measured under room temperature pulsed condition.

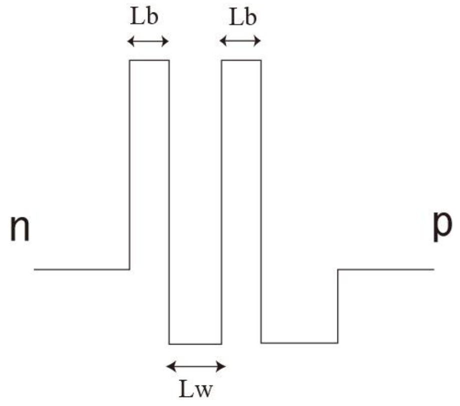

Fig. 1 Schematic band diagram of grown and model tunneling injection lasers

Figure 3a) is experimentally measured I-L, I-V characteristics for L_b of 30, 20, 10 Å and L_w of 40 Å. Figure 3b) is theoretically calculated J-V characteristics. Detail of the fabrication and measurement of tunneling injection lasers are shown in reference 5). The theoretical analysis was carried out by calculation of the tunneling current from n-side SCH-layer to p-side one. The tunneling probability was calculated by the transfer matrix method for the biased potential structures. The dotted line of Fig. 3b) shows a voltage at which the

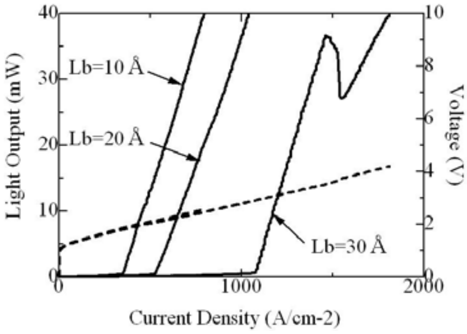

Fig. 3a) Measured I-L,I-V characteristics for L_b of 30 , 20 ,10 Å and L_w of 40Å.

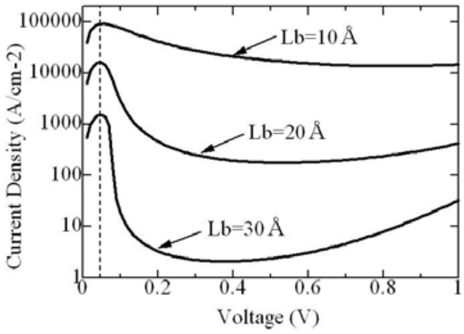

Fig. 3b) Theoretical J-V characteristics for L_b of 30, 20, 10 Å and L_w of 40Å.

quantized energy level in the tunneling well becomes above the band edge of the p-SCH layer.

In Fig. 3a), there is kink in I-L characteristics for L_b of 30 Å. It is thought that only a sample with L_b=30 Å reached to a voltage at which the quantized level in the tunneling well reaches the band edge of the p-SCH layer in the measured current density range. The quantized level of the injection well of the fabricated laser is located below the band edge of the n-SCH layer, and thus the carrier may accumulated in the injection well. The accumulated carrier flowed out to the p-SCH layer when the bias condition reached the kink. This may cause the potential structure change and the gain characteristics in the emission well are also modified, resulting in the kink in I-L characteristics.

Figure 4a) shows measured I-L, I-V characteristics for L_b of 20Å and L_w of 20Å. Figure 4b) is theoretical J-V characteristics. This structure has a considerably higher quantized level in the tunneling well than the band edge of the SCH layer, The dotted line in the Fig. 4b) shows the case that the quantized level reaches to the band edge of the p-cladding layer. Thus, the lasing was not obtained as shown in Fig. 4a), though sufficient current was obtained under a high bias for the analysis.

In conclusion, we discussed about lasing mechanism of tunneling injection lasers by comparing measured result with analyzed one. The tunnel injection laser shows various characteristics by tunneling structures. A large kink may be caused by the carrier accumulation in the tunneling well and prohibition of laser is due to carrier leakage to the p-cladding.

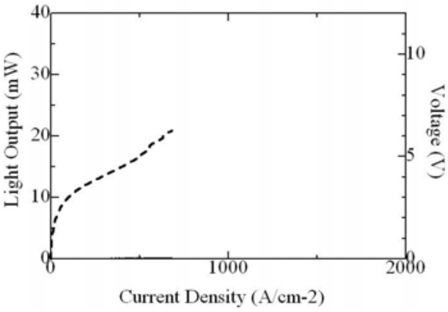

Fig. 4a) Measured I-L,I-V characteristics for L_b of 20Å and L_w of 20Å.

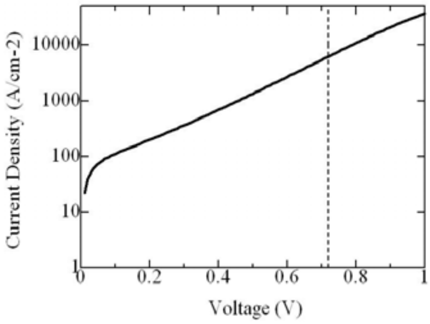

Fig. 4b) Theoretical J-V characteristics for L_b of 20Å and L_w of 20Å.

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