GAIN SATURATION AND FEATURES IN THE THRESHOLD BEHAVIOR OF A\text{III}_{\text{B}}^{\text{V}}
HETEROSTRUCTURE LASERS

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ABSTRACT

Properties of semiconductor diode lasers have been improved drastically due to the development of A\text{III}_{\text{B}}^{\text{V}} double heterostructures (DH) with very thin quantum well (QW) active regions. The research in this field now is in progress. Recently\textsuperscript{(1,2)} it has been established that in distinction to conventional DH lasers the threshold current densities ($I_{\text{th}}$) of QW DH lasers with active region thicknesses $d_a$ smaller than 200Å start to increase sharply with decrease of their cavity lengths ($L$) in the region $L < L_0$, where $L_0 < (2-5) \times 10^{-2}$ cm.

Our investigations\textsuperscript{(3)} of InGaAsP/GaAs QW DH lasers show that the whole value of $I_{\text{th}}$ in short cavity lasers is determined only by the rate of radiative recombination in the active region as it is in lasers with longer cavities, i.e. increase of $I_{\text{th}}$ in this case cannot be attributed to the rise of carrier leakage or the rate of nonradiative recombination.

In order to explain this and some other features of the threshold behavior of QW DH lasers the calculations of the dependences of gain and radiative lifetimes on current densities have been performed for devices with different $d_a$. The calculations predict that the dependence of gain on current density has to become sublinear at the level of output losses typical for lasers with cavity length $L < L_0$. It should be noted that the influence of the complex structure of the A\text{III}_{\text{B}}^{\text{V}} valence band and longitudinal hole masses modifications has been taken into account in a version of these calculations.

INTRODUCTION

This talk deals with the influence of gain saturation on the threshold behavior of single quantum well (SQW) separate-confinement (SC) heterostructure lasers.

Most of the studies of SC SQW laser threshold characteristics have
been carried out so far on AlGaAs/GaAs samples grown by MBE or MOCVD techniques.

The lowest values of threshold current densities \( J_{th} \) for MBE and MOCVD grown AlGaAs/GaAs SC SQW lasers were obtained by Tsang\(^1\) and Baldy et al.\(^2\). The dependences of \( J_{th} \) on the reciprocal cavity length studied in Refs. \((1,2)\) were interpreted by the authors as linear just as for the conventional DH lasers with thick active region.

When investigating SC InGaAsP/InP (\( \lambda = 1.3 \mu m \)) lasers prepared by a modified variant of liquid phase epitaxy (LPE)\(^3\) we observed a sharp superlinear rise of thresholds with cavity length decrease\(^4,6\). It was assumed then that the rise of \( J_{th} \) could be attributed to the enhancement of Auger-recombination. However, we later found the same effect for AlGaAs/GaAs SC SQW lasers grown by a similar LPE technique\(^7\).

In 1986 Zory et al.\(^8\) reported data especially devoted to this problem. The superlinear increase of \( J_{th} \) with decrease of \( L \) was declared by those authors to be a typical feature of threshold behavior of AlGaAs/GaAs SC SQW lasers. Nevertheless, we believe that Zory’s results, as well as the data of our previous work\(^7\), cannot be considered as reflecting an intrinsic property of SC SQW lasers because the values of \( J_{th} \) obtained there, even for the lasers with the longest cavities, are three times higher than those reported by Tsang and Baldy.

It is evident that there should not be any nonradiative current.

*It should be noted that after being replotted to a larger scale, the dependence of \( J_{th} = f(1/L) \) for the Baldy low threshold lasers (Fig. 24b from Ref. 2) reveals a considerable deviation from linearity.