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Room Temperature Operation of Quantum Confined Field Effect Light Emitters

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We have proposed a quantum confined field-effect light emitting device[1)2)] to break through the limitation on the switching speed in the conventional light emitting diodes. So far, the field control of luminescent characteristic was demonstrated with the three-terminal field-effect light emitting devices[3)4)]. A high speed switching of emission intensity free from life time limitation was confirmed at low temperature, ~150K. However, from the practical viewpoints of the device application, it must be cleared to realize the device operation at room temperature. In this paper, we report, for the first time, the room temperature operation of the proposed device, demonstrating a life time free switching of emission intensity.

Figure 1 shows the schematic structure of the device used in the experiments. In order to improve the luminescence efficiency of the GaAs quantum well (QW) active layer, we used the superlattice buffer layers (SLBLs)[5)6)]. The electric field applied to the QW region was controlled by changing the bias voltage between collector and base electrodes (V_{CB}). The barrier height between the QW and collector region was designed high enough to prevent the sweeping out of the injected holes. This is one of the key point to design the device structure in marked contrast to the conventional heterobipolar transistors. The light intensity modulation in the device does not rely on the change in carrier density, but makes use of the fast switching of the radiative recombination rate in QW structure caused by the field effect[1)-4)].

In our previous works[3)4)], a carrier leakage was the bottleneck for realizing the room temperature operation of the device. Figure 2 shows the emission spectra at room temperature for various V_{CB}. The emission intensity was drastically improved in the sample by use of the SLBLs (about 100-times that of the sample without SLBLs). As the V_{CB} decreases, the emission spectra is significantly shifted toward the lower energy side. The result is consistent with well known spectral red-shift due to the quantum confined Stark effect. This convinces us that the electric field across the QW can be controlled by V_{CB} in the device. On the other hand, it is worthwhile to note that the reduction of the emission intensity, integrated over the wave-lengths, at V_{CB} of -4.0V (internal field >100kV/cm) was as small as 10% of the emission intensity at V_{CB} of 2.0V (near the flat band condition). This indicates that radiative processes, which can be controlled by the electric field, completely dominates over the nonradiative processes under a constant generation rate of carriers[7)].

Figure 3 shows the transient response of the emission intensity for a short pulsed voltage, applied to the collector-base junction. The electric field was switched from high to low and low to high with a voltage pulse shown in a broken line. The response time of the light intensity as short as 0.8nsec is much shorter than the life time of carriers ~8nsec which was able to be determined from the decay rate of emission intensity[7)8)]. This is the first demonstration of the life time free switching of the light intensity in the proposed device at room temperature. The observed response time is limitted by a C•R time constant (C~20pF).

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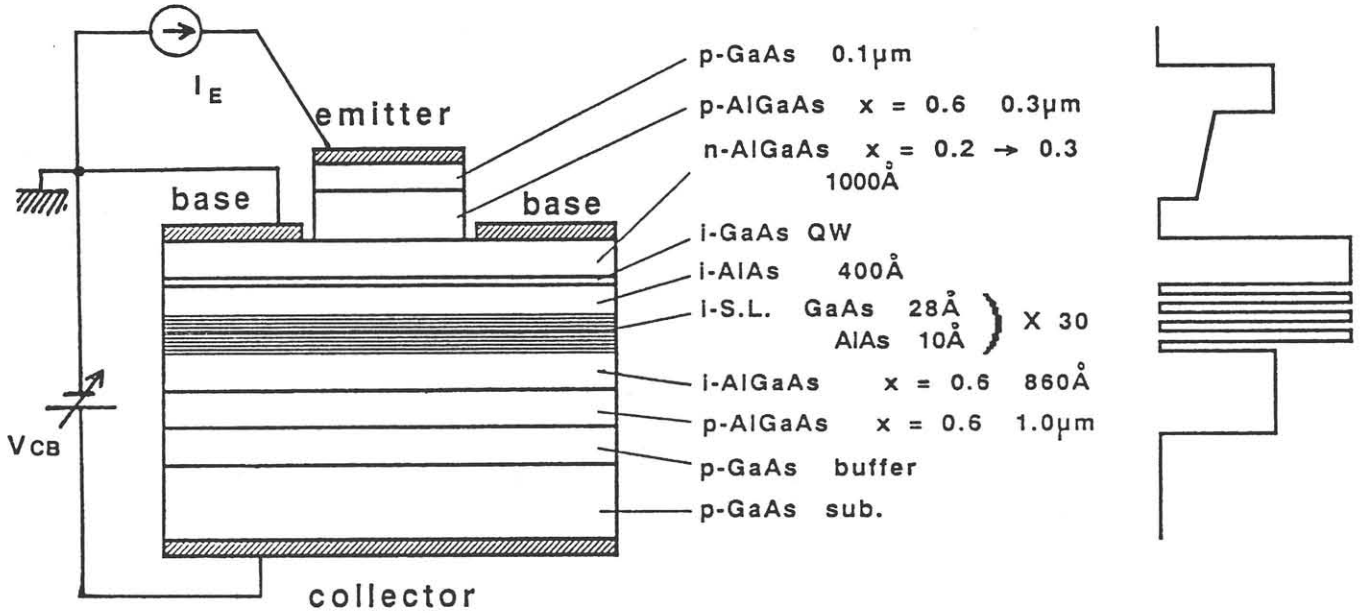

Fig.1 Schematic-cross sectional view of the three-terminal light emitting device used in the experiments.

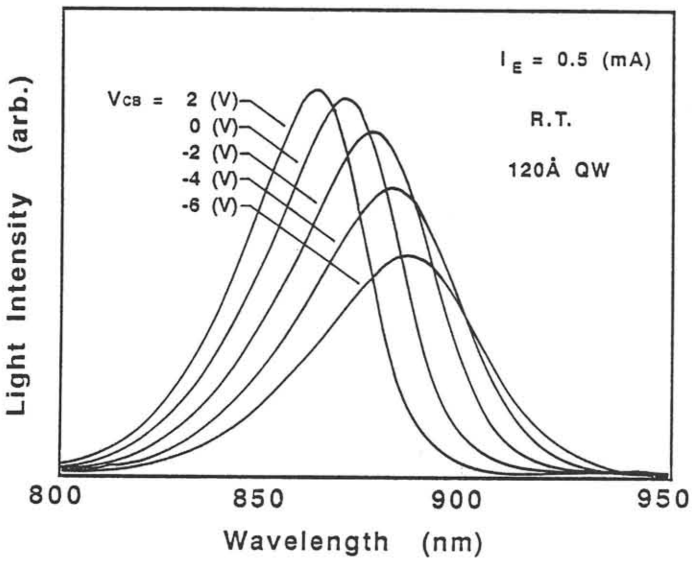

Fig.2 Emission spectra for various collector-base bias voltages at room temperature. The 0.5mA-injection current results in a current density of $4A/cm^2$.

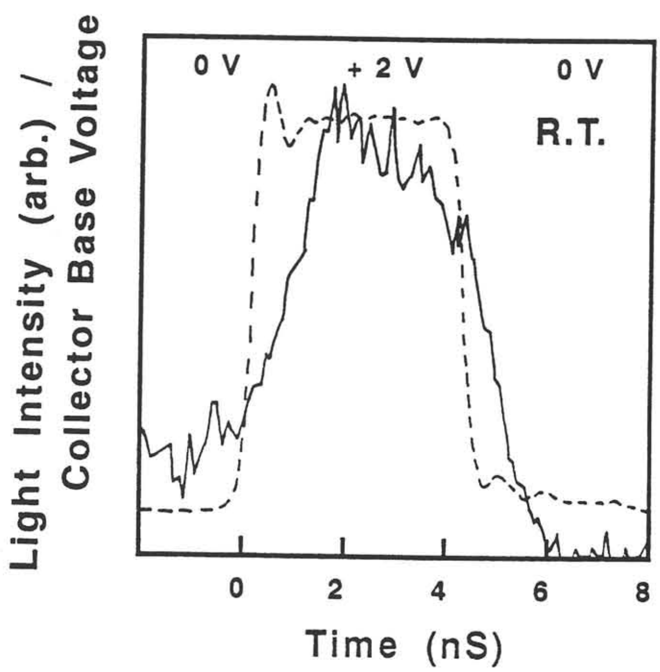

Fig.3 Transient response of the emission intensity for a short pulsed collector-base voltage (dashed line) at room temperature, demonstrating a life time free switching. The response time of the detection system (0.9nsec) is numerically subtracted off from the measured response.