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Optical Gain of Polarized Emission in InAs Quantum Dots with $In_xGa_{1-x}As$ Capping Layer

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1. Introduction

Recent development of well-controlled high-quality self-assembled quantum dots (QDs) improves optical performance in semiconductor lasers, and contributes to the development of new optical devices such as QD semiconductor optical amplifiers (SOAs) which can provide many signal processing functions for high-bit-rate multiple wavelength signals. In the case of the traveling-waveguide SOA, control of the polarization properties becomes extremely important for practical applications. Some techniques have been proposed to control the polarization of optical transitions in QDs based on the result of photoluminescence experiments.[1,2] However, before these techniques are used in real devices, it is important to know the properties of the polarized emission of QDs in the optical gain region. This paper reports first determination of the polarization-discriminated gain in InAs-based quantum dots including the effect of In composition of capping layers.

2. Experiments

In our measurement, we evaluated the optical gain of QDs using variable stripe length (VSL) method with a configuration as sketched in Fig. 1.[3] The samples are MBE-grown InAs QDs with 1.9ML InAs deposition. The QDs were covered with 8 nm thick GaAs (sample A) and $In_{0.13}Ga_{0.87}As$ (sample B) capping layers, respectively. The QD active layer was sandwiched by a pair of GaAs/AlGaAs waveguiding layers. In VSL measurements, the sample was excited by a Ti-sapphire laser tuned to 750 nm at room temperature. The CW laser power monitored before a cylindrical lens was 200 mW. A movable slit was introduced in the proximity of sample surface (d<500 μm) for excitation length control and a ×50 microscope objective lens was used for collection of the edge-emitted light.

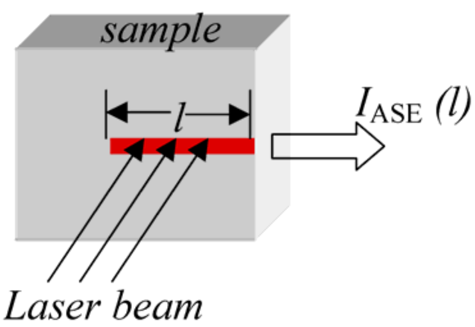

Fig. 1 Model of variable stripe length method.

3. Results and Discussion

Figure 2 shows examples of measured edge-emitted light PL spectra. Figure 3 shows plots of the amplified spontaneous emission (ASE) intensity I_{ASE} against the excited stripe length l for TE and TM polarizations. This plot can be described by an expression $I_{ASE} \propto (I_{sp}/g)\cdot[\exp(gl)-1]$, where I_{sp} is spontaneous emission per unit length and g is net optical gain (= total gain–loss). Fitting data with this equation (lines in Fig. 3) yields a 100 ± 10 cm^{-1} as the mean value of g for TE&TM in sample A. The optical gain shows appreciably smaller value, 8 ± 2 cm^{-1}, for sample B. This ASE intensity data has shown TE-dominant polarization in GaAs capping layer and TM-dominant polarization in InGaAs capping layer. The possibility of controlling the polarization through varying the capping layer In composition has confirmed under the optical gain condition. On the other hand, the optical gain has been found to reduce for InGaAs capping layer much more significantly (by a factor 12) than in PL intensity (by a factor of approximately 3). Although an explanation of this gain reduction is subject to further study, a relationship among the gain, stripe length and polarization has been obtained through our polarization-discriminated gain measurement, and this provides data prerequisite for device design. Further discussion for the polarization related optical gain would be present in the conference.

4. Conclusion

We have investigated the optical gain of InAs quantum dots with InGaAs capping layer. The gain factors differ largely with respect to the indium composition in capping layer. However, in our investigations, the polarization dominance of QD emission remains the same either for the PL intensity or the ASE intensity.

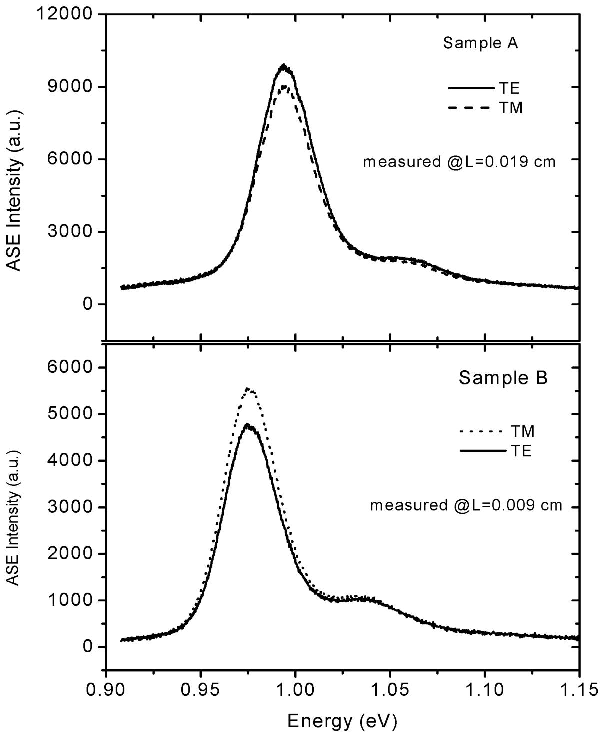

Fig. 2 Example of the amplified spontaneous emission signal measured at room temperature.

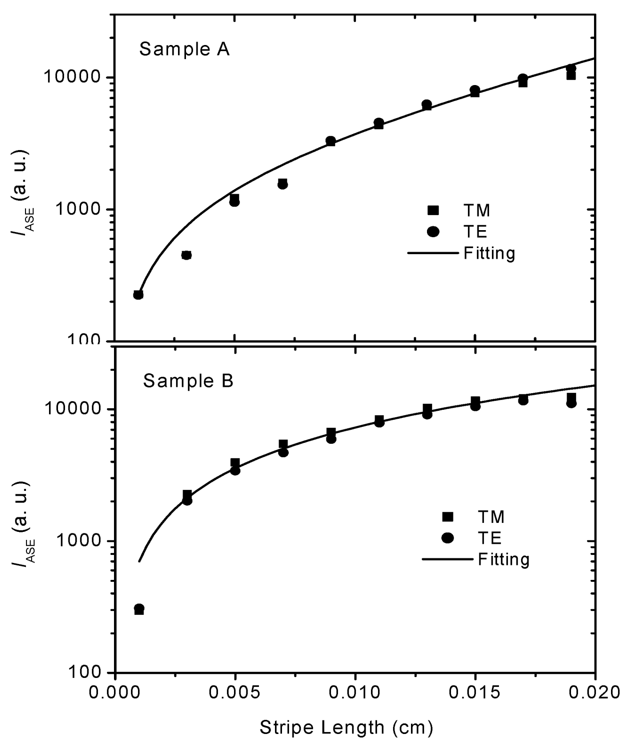

Fig. 3 VSL data for polarized emission of QDs at room temperature for samples A and B.

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