InAs/GaAs Quantum Dot Lasers with InGaP Cladding Layer Grown by Solid-Source Molecular Beam Epitaxy

N.-T. Yeh, W.-S. Liu, S.-H. Chen and J.-I. Chyi
Department of Electrical Engineering, National Central University
Chung-Li, Taiwan 32054, R.O.C.
chyi@mbox.ee.ncu.edu.tw

Significant progress on the performance of quantum dot (QD) lasers has been made in the past few years. However, emission wavelength from the self-assembled In(Ga)As QDs on GaAs is typically around 1.0 μm. In order to be applied to optical fiber communications, the extension of its optical emission wavelength to 1.3 μm and further is necessary. To avoid the blue shift of lasing wavelength caused by high temperature growth of the upper AlGaAs cladding layer, low substrate temperature of about 600 ^{o}C is usually used. However, high optical quality AlGaAs cladding is hardly obtained at such a low growth temperature. In the present work, we study the room temperature lasing characteristics of InAs/GaAs QD lasers with InGaP cladding layer grown by solid-source molecular beam epitaxy.

The lasers studied in this work are separate confinement heterostructure lasers. The active region consists of 3 stacks of 2.4-monolayer InAs QDs covered with $In_{0.16}Ga_{0.64}As$ strain reducing layer (SRL) separated by 30 nm GaAs spacers. The quantum dot active region is sandwiched by two 100 nm-thick undoped GaAs guiding layers. Both the n- and p-type cladding layers are 1500 nm-thick InGaP grown at 490 ^{o}C. After the growth, the wafers were processed into broad-area lasers using standard photolithography and wet chemical etching. Lasers without SRL in the active layer or with low-temperature grown AlGaAs claddings are also fabricated for comparison.

Room temperature photoluminescence (PL) spectrum shows that a 3-stack InAs QD active layer exhibits the ground state emission wavelength at 1214 nm with a full width at half maximum (FWHM) of 37 meV. After inserting an InGaAs SRL on the InAs QDs, the ground state emission peak can be extended to 1300 nm and its FWHM can be reduced to 24 meV. The red shift of ground state peak wavelength can be attributed to the reduction of the hydrostatic strain in InAs QDs. For the as-cleaved laser diodes with a cavity length of 2500 μm, lasing wavelengths are 1070 nm (second excited state of PL spectrum) and 1190 nm (first excited state of PL spectrum) for the QD lasers without and with InGaAs SRL, respectively. This can be attributed to higher optical gain at first excited state for QD lasers with SRL. No lasing is observed on the QD lasers with InGaAs SRL and AlGaAs claddings unless high reflection coating is applied to both facets. This implies that higher optical loss is present in the low-temperature grown AlGaAs claddings.

The lowest threshold current density among these lasers is measured to be 322 A/cm^2 for the as-cleaved QD lasers with InGaAs SRL and InGaP claddings. Compared to the threshold current density of 703 A/cm^2 for the as-cleaved QD lasers without InGaAs SRL, the reduction of threshold current density can be attributed to the larger dot density and better dots uniformity as shown in our previous report. For a 1000 μm-long device, the lasing wavelength of the as-cleaved QD lasers with SRL increases to 1107 nm (second excited state) and its threshold current density increases to 656 A/cm^2 due to the gain saturation of the first excited state. The results obtained in this work are encouraging for the development of 1.3 μm GaAs based QD lasers.

p-GaAs contact layer
p-InGaP cladding layer
undoped GaAs spacer 100nm
Active region : 3-stack InAs QD with SRL separated by 30 nm spacer
undoped GaAs spacer 100nm
n-InGaP cladding layer
n-GaAs buffer
n-GaAs substrate

Fig.1 Schematic of separate confinement heterostructure QD laser with InGaAs SRL and InGaP cladding layers.

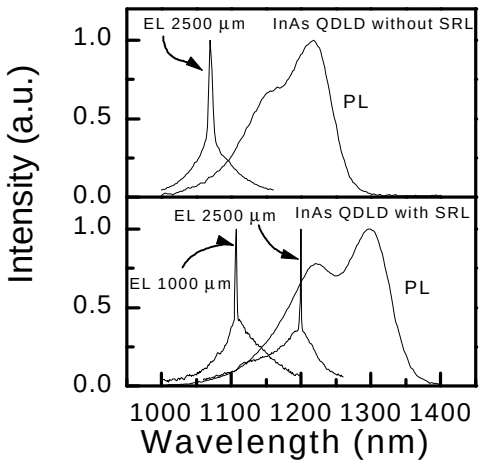

Fig.2 Photoluminescence and electro-luminescence spectra of InAs QD lasers with and without strain reducing layer.

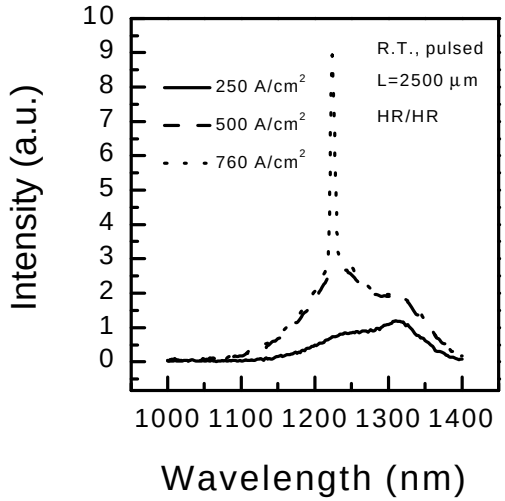

Fig.3 Electroluminescence spectra of InAs QD lasers with strain reducing layer and low-temperature grown AlGaAs cladding layers.

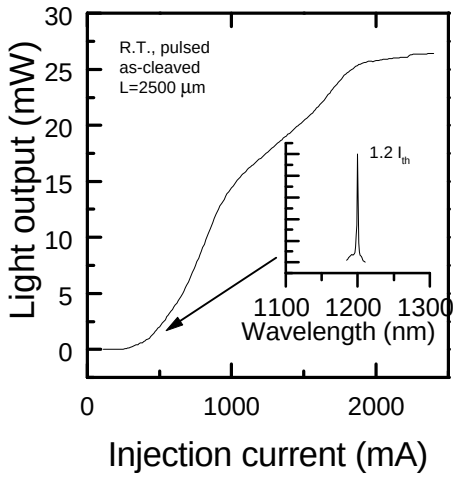

Fig.4 Light output versus injection current characteristics of InAs QD laser with strain reducing layer and InGaP cladding layers.