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Review on Laser Sources based on Third Fifth Semiconductor Hetrostructures

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***Abstract*—In this paper we are working on a brief literature review of AlGaAs/GaAs single quantum well laser for optical communication systems. Under modeling and mathematical simulation, we have describe anti-guiding factor, gain compression, differential gain, peak material gain as a function of carrier density, and convolution optical gain of AlGaAs/GaAs SQW laser as function of wavelength and photonic energy of different authors. The results obtained ensure the usefulness of the AlGaAs/GaAs SQW SCH laser in communication systems based on optical fiber.**

***Keywords*— InGaAs, InGaAsP, AlGaAs, GaAs, SLD.**

1. Introduction:

For optoelectronic device applications and optical fiber based communication systems, heterojunction structures [1-3] play important roles. It is therefore natural to design light sources such as light emitting diodes and laser diodes, semiconductor modulators, and photodetectors operating at the desired wavelengths useful for optical communication systems. Experimental work on low threshold current quantum well lasers [4-6] has been reported for different material systems, such as GaAs/AlGaAs, InGaAsP/InP, and InGaAs/InGaAsP. Advantages of the quantum well lasers, such as higher temperature stability and improved linewidth enhancement factor and wavelength tunability, have also been demonstrated. These devices are based on the energy band structure engineering concept using, for example, a separate confinement- heterostructure (SCH) quantum well structure to enhance the carrier and the optical confinements.

Superluminescent diodes ~SLDs! are important light sources for applications in areas such as optical gyroscopes and sensors, multichannel optical amplifiers, mode-locking semiconductor lasers, and wide-range tunable external-cavity semiconductor lasers. Small spectral modulation and large spectral width are important features for SLDs. Reduction of spectral modulation has been attempted by many efforts, including antireflection coating the facet, tilting the stripe, polishing, or dry etching4 the facet at an angle to the pumping stripe, and bending the mesa stripe.5 On the other hand, relatively fewer works were devoted to broadening the spectral width. We recently reported that, by choosing 40 and 75 Å for the two quantum wells, a bell-shaped emission spectrum with a spectral width 2 to 3 times that of the conventional SLDs is achieved.6 In this letter, we report that the spectral width of the ~SLA! could be engineered to be even broader with a proper design of the quantum-well structure. Using four quantum wells with widths of 20, 33, 56, and 125 Å, respectively, for the four quantum wells, the spectrum could be significantly broadened. At the low injection current, wells with widths of 56 and 125 Å contribute to the emission. At the large injection current, all four wells contribute to the emission. The measured spectra show that, at 350 mA pumping current, the full-width at half-maximum ~FWHM! spectral width could be as large as 915 Å. To our knowledge, this is the broadest spectrum measured from AlGaAs/GaAs superluminescent diodes.

The idea for broadening the spectrum of SLD is very simple. From quantum mechanics, the first quantized energy level of a quantum well is elevated from the bottom of the well potential. As a result, the emitted photon energy of the semiconductor quantum well is a function of the well width. By stacking quantum wells of different widths, the emitted photon energy should cover a wide range of spectrum. Because the gain bandwidth of the GaAs material for each quantized level corresponds to about 50 meV, we expect that the overlapped energy spectrum is maximized without a dip if the energy level for each well is separated from one another by 50 meV. Using Al0.2Ga0.8As as the well barrier and GaAs as the well material and choosing 20, 33, 56, and 125 Å as the well widths, the corresponding transition energies could separate for 50 meV. As a matter of fact, the transition

energies for those wells are about 25, 75, 125, and 175 meV larger than the energy of the well bottom, respectively. Therefore, the overall gain spectrumof the material with four such wells stacked together will be four times wider than that of the single-width quantum well.

2. Related Work:

Reflectivity of a cleaved facet forming a laser cavity in a double heterostructure injection laser is analyzed by **Testsuhiko Ikegami** in **1972 [1],** on the basis of a dielectric waveguide model and the reflectivity of modes was numerically provided for a GaAs-AIGaAs double-

heterostructue injection laser. The modes that distinguish field distributions perpendicular to a junction plane are considered up to the sixth order with TE and TM modes. The dependence of threshold conditions on the mode, the relations between the lowest threshold mode and the structures of the injection laser were studied by them. Provided mode reflectivity is solely responsible for modal selection, the single-mode operation is theoretically shown to be possible by choosing a suitable length of the cavity even though the thickness of the active layer is large.
The reflectivity of the cleaved facet in DH injection lasers was analyzed on the basis of the dielectric waveguide model and the dependence of the reflectivity on the mode is numerically provided for the case of GaAs-AlGaAs DH injection lasers as a function of parameters of the structures. It was found that the reflectivity of the TE wave at the facets is lower than that of the TM wave in the same mode number and the reflectivity of the higher order mode is lower than that of the lower order mode with the same polarization except for the region near the cutoff.

A new circuit model of a stripe-geometry double-heterojunction injection laser below threshold is presented by **Rodney S. Tucker 1981** [2]. The model was derived from the physics of the semiconductor heterojunction, and takes into account the effects of active-layer carrier degeneracy, high-level injection, and non radiative recombination along the stripe edge. Turn-on delay characteristics and small-signal input resistance characteristics of a laser are computed using the circuit model.
The circuit model presented by him includes phenomena which have not been considered in previous laser-diode circuit models. It has been shown that, although the number of ionised acceptor atoms depends on the carrier density, the variation in ionised acceptor concentration with carrier density above equilibrium has little effect on the overall I/V characteristics. It has been shown that the calculated characteristics agree with previous experimental and theoretical data. The model uses familiar circuit elements and is readily implemented using circuit-analysis computer programs. It should find application in the computer-aided design of laser switching and modulation circuits.

Three-dimensional thermal analysis of catastrophic mirror damage in stripe-geometry diode lasers was carried out in the work done by **Wlodzimierz Nakwaski 1989 [3]**. The spatial extent of the heat source at and near to the mirror surface as well as the temperature dependences of both the thermal conductivity and the thermal diffusivity are taken into account in the model. The heat conduction equation is solved by means of the Green function method.
First results of the three-dimensional time-dependent thermal analysis of the catastrophic mirror damage in stripe-geometry double-heterostructure GaAs/(AlGa)As diode lasers have been presented in the work.

Ching-Fuh Lin, Bor-Lin Lee, and Po-Chien Lin, (1996) [4], worked on road-band AlGaAs-GaAs superluminescent diodes that were fabricated using asymmetric dual quantum wells. With a proper design of the quantum-well structure, the spectral width of the superluminescent diodes could be engineered. By choosing 40 and 75 A, respectively, for the two quantum wells, the spectrum remains bell-shaped and is broadened to 2~3times that of the conventional superluminescent diodes. The measured spectra show that there is no obvious preference on the transition in either well at any pumping current.
Broad-band SLD's were fabricated using asymmetric dual quantum wells. The spectral width of the SLD's could be engineered by the proper design of the quantum-well structure. With the widths 40 A, and 75 A, respectively, for the two GaAs quantum wells bounded by the the $Al_{0,l8}Ga_{0.82}$ As barrier, the spectral width is increased 2~3 times that of the conventional SLD’s. The broadened spectral width is observed for both the tilted-stripe and the bent-waveguide SLD’s. In addition, the occurrence of n = 2 transition in the wider quantum well at a large pumping current could further increase the spectral width. An even wider spectral width should be expected as additional quantum wells of different widths were added.

Ching-Fuh Lina and Bor-Lin Lee 1997 [5], Extremely broadband AlGaAs/GaAs superluminescent diodes are fabricated on substrate with four quantum wells of different widths. By choosing 20, 33, 56, and 125 Å, respectively, for the four quantum wells, the spectrum could be broadened to several times that of the conventional superluminescent diodes. The measured spectra of the fabricated devices with such quantum-well structure show that the full-width at half-maximum spectral width could be as large as 915 Å.
In conclusion, extremely broadband SLDs are fabricated on AlGaAs/GaAs substrate with a proper design of the quantum-well structure. By choosing 20, 33, 56, and 125 Å, respectively, for four quantum wells, the spectrum could be broadened to several times that of the conventional SLDs. The spectral width increases with the injection current. At low injection current, the spectrum at the long-wavelength side dominates, but still larger than the gain bandwidth of the material with a single well. With increased injection current, the spectrum is broadened due to the transitions occurring at the narrower wells. At pumping current of 350 mA, the measured spectrum has a FWHM as large as 915 Å.
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With the incorporation of multiple quantum dot layers as highly effective three-dimensional dislocation filters, self-organized quantum dot lasers monolithically grown on Si exhibit, for the first time, relatively low threshold current (J_{th} = 900 A/cm2) and very high temperature stability (T_0 = 244 K). III-V semiconductor nanowire light emitting diodes on Si, with emission wavelengths from UV to near-infrared, have also been demonstrated by **Z. Mi and Y.-L. Chang (2008) [6]**.

The development of III-V compound semiconductor nanostructures on Si substrates is briefly reviewed by them. High quality quantum dot and nanowire heterostructures, that are suitable for device applications have been achieved, and high performance quantum dot lasers and nanowire LEDs have also been demonstrated. It is evident that III-V compound semiconductor nanostructures on Si not only provide an enormous amount of opportunity for fundamental materials research, but also may enable the achievement of practical photonic devices, including lasers, photodetectors, and amplifiers on Si substrates, that can be integrated with CMOS electronics for future high speed systems.

Christian Grasse, Simeon Katz, Gerhard Bohm, Augustinas Vizbaras, Ralf Meyer, and Markus-Christian Amann, (2011) [7], they presented a wave length prediction procedure on the basis of X-ray measurements and simulations for In P-based injector less quantum cascade laser (QCL) devices. These lasers show excellent performance in the mid infrared wavelength range, but are very sensitive to growth deviations, which cause strong wavelength shifts and area serious obstacle for applications like gas sensing. However, by XRD-simulations of the active region, which consists of In As, AlAs, GaIn As and Al In As, the thicknesses and compositions can be extracted and are used as input values for band structure calculations, so that a prediction for the resonance energy of the laser transition canbe obtained. With this technique a wavelength evaluation of injector less QCLs with 3% accuracy could be accomplished, which is an essential improvement in applications like gas sensing.

Pyare Lal, M. J. Siddiqui, and P. A . Alvi (2011) [8], their work aim to report various lasing characteristics of AlGaAs/GaAs single quantum well laser for optical communication systems. Under modeling and mathematical simulation, they have calculated anti-guiding factor, gain compression, differential gain, peak material gain as a function of carrier density, and convolution optical gain of AlGaAs/GaAs SQW laser as function of wavelength and photonic energy. On behalf of calculations, they have shown that the modeled SQW laser has maximum optical gain at ~ 0.83 µm.
The numerical simulation has been performed for lasing characteristics of AlGaAs/GaAs SQW laser, for which the maximum optical gain has been achieved at ~0.83µm for lasing action. The results obtained ensure the usefulness of the AlGaAs/GaAs SCH laser in communication systems based on optical fiber.

A. Andronico, I. Favero, S. Ducci, J. M. Gérard, and G. Leo (2013) [9] they report on the modeling of an electrically pumped nonlinear source for spontaneous parametric down-conversion in an AlGaAs single-sided Bragg waveguide. Laser emission from InAs quantum dots embedded in the waveguide core is designed to excite a Bragg pump mode at 950 nm. This mode is phase matched with two cross-polarized total-internal-reflection fundamental signal and idler modes around 1900 nm. Besides numerically evaluating the source efficiency, they discussed the crucial role played by the quantum dots in the practical implementation of the phase-matching condition along with the tuning capabilities of this promising active device.
They have designed an integrated SPDC active source based on a modal phase matching with the laser medium consisting of QDs embedded in the waveguide core. Intracavity contacts and refractive index grading allow us to use low doping levels, which in turn result in low propagation losses and considerable conversion efficiencies. Their study represent a decisive step towards the goal of fabricating an integrated electrically pumped optical parametric oscillator.

Xiaoqing Zhang et. al (2013) [10], they demonstrate that sum frequency generation signals can be acquired from GaAs nanowires when excited by a fem to second laser at 1048 nm and a tunable optical parametric oscillator ranging from 1416 nm to 1770 nm. The SFG intensity is insensitive to the polarization but quite sensitive to the temporal overlap of incident lasers pulses. It is shown that they can work for pulsewidth measurement of fem to second lasers in the near infrared band.
They demonstrate that GaAs NWs can generate SFG signals across a broad spectral range by using a femtosecond laser at 1048 nm and a tunable OPO from 1416 nm to 1770 nm. Their results suggested GaAs NWs to be excellent frequency mixers in nano-optical systems.

3. Conclusion:

This paper presents a literature review of the use of various techniques for AlGaAs/GaAs single quantum well laser for optical communication systems. This literature review is very useful, since it brings a better understanding of the field of study, and this is an important contribution of this paper. From the literature review it can be concluded that this subject attracts a great deal of interest by researchers and a tremendous algorithms are present related to Under modeling and mathematical simulation, we will calculate anti-guiding factor, gain compression, differential gain, peak material gain as a function of carrier density, and convolution optical gain of AlGaAs/GaAs SQW laser as function of wavelength and photonic energy. We will ensure the usefulness of the AlGaAs/GaAs SQW SCH laser in communication systems based on optical fiber.

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