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EXTREMELY BROADBAND InGaAsP/InP SUPERLUMINESCENT DIODES

For superluminescent diodes fabricated on the substrate with five 6 *nm* and two 15 *nm* InGaAsP quantum wells, a very broad emission spectrum is obtained. The spectral width is nearly 400 *nm*, covering the range from 1250 *nm* to 1650 *nm*.

Keywords: surfactant, heteroepitaxial growth, thin film, surfactant mediated growth.

1. Introduction. Broadband characteristics are attractive for optical fiber communication. Recent technology has made optical fiber exhibits very broad bandwidths, almost covering the range from 1.2 μm to 1.6 μm with a loss of less than 1 *dB/km*. Superluminescent diodes (SLDs) are good candidates of light sources for optical fiber communication because they are of compact size, can be directly integrated with electronic components. However, to cover the entire usable bandwidth of an optical fiber, many conventional SLDs having different spectral range are required because each conventional SLD usually has a bandwidth of less than 50 *nm*. Therefore, if the bandwidth of SLDs could be broadened, they will be even more attractive.

Multiple quantum well (MQW) is a convenient way that has been widely used to broaden the bandwidth of SLDs [1]. However the design is not straightforward because the carrier distribution within the MQW is not uniform [2]. By considering the uniform carrier distribution within MQWs, we demonstrate that the spectral bandwidth of SLDs can be significantly broadened by using properly designed nonidentical MQWs grown on InP substrate.

2. Experiment. To achieve the broadband characteristics, a sequence of nonidentical MQWs is designed. The layer structure is shown in Fig. 1. The five 60 $\AA$ $In_{0.67}Ga_{0.33}As_{0.72}P_{0.28}$ quantum wells, designed for a transition energy corresponding to 1.3 μm, are grown near the p-cladding layer, while the two 150 $\AA$ $In_{0.53}Ga_{0.47}As$ quantum wells, designed for a transition energy corresponding to 1.3 μm, are grown near the n-cladding layer. $In_{0.86}Ga_{0.14}As_{0.3}P_{0.7}$ barriers of 150 $\AA$ width are used to separate the QWs. The separate confinement heterostructure (SCH) layer is 300 $\AA$ thick for better uniformity of carrier distribution.

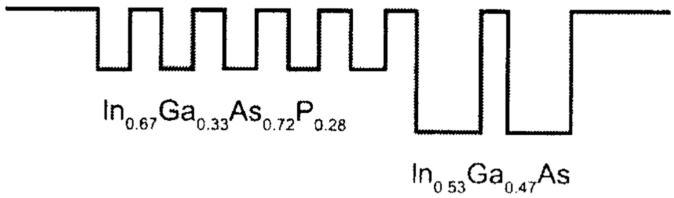
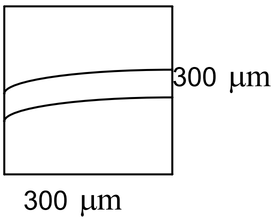


Fig. 1. Quantum-well structure of designed nonidentical MQWs Barrier: 15 *nm*, $In_{0.86}Ga_{0.14}As_{0.3}P_{0.7}$, SCH region: 30 *nm*, $In_{0.86}Ga_{0.14}As_{0.3}P_{0.7}$

The designed nonidentical MQW structure was grown on InP substrate. Typical processing techniques were used to fabricate bent-waveguide SLDs [3]. With the bent-stripe structure, the reflection of light from the cleaved facet is reduced, thus minimizing the influence of Fabry-Perot resonance [3]. We used two kinds of devices, one of which is 300 μm, as shown in Fig. 2 and the other is 500 μm, as shown in Fig. 3. No facet coatings were applied to the devices.



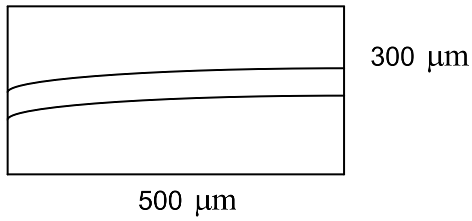


Fig. 2. This is the waveguide structure of the 300 µm long device

Fig. 3. This is the waveguide structure of the 500 µm long device

The emission spectra of the 500 μm fabrication devices at different current levels are measured and they are shown in Fig. 4 and the emission spectra of the 300 μm fabrication devices at different current levels are measured which are shown in Fig. 5.

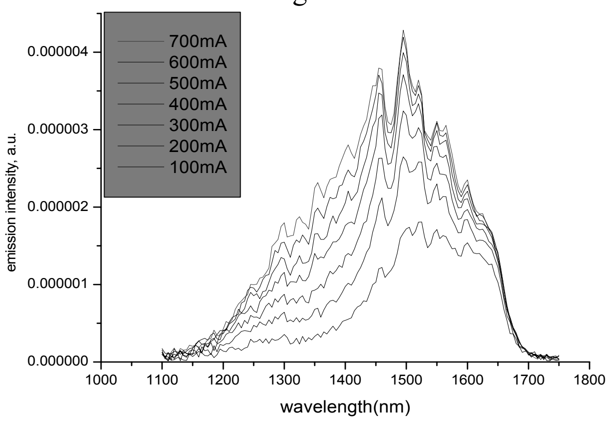


Fig. 4. Emission spectra of SLDs at different injection currents, 500 μm, bending side facet

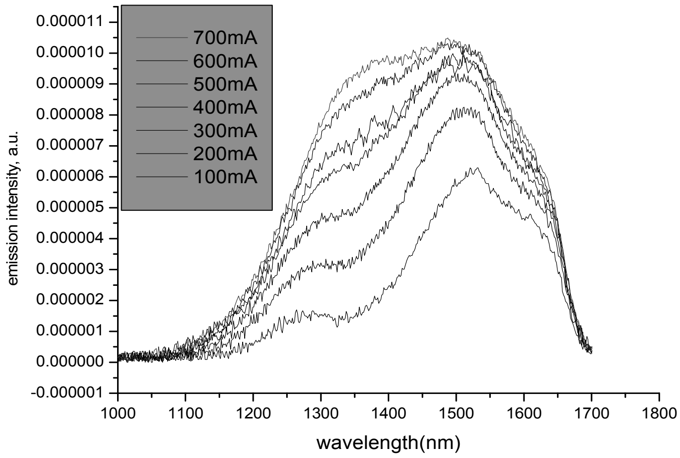


Fig. 5. Emission spectra of SLDs at different injection currents, 300 μm, bending side facet

In Fig. 5 for the spectrum of the 300 μm device at low injection current the wavelength of the emitted light is close to 1.5 μm, which corresponds to the transition between n = 1 conduction band and n = 1 valence band of 150 $\AA$ $In_{0.53}Ga_{0.47}As$ quantum wells. These wells are designed for light emitted at 1.6 μm wavelength. Some part of light is emitted at the wavelength close to 1.3 μm, which corresponds to the transition between n = 1 conduction band and n = 1 valence band of five 60 $\AA$ $In_{0.67}Ga_{0.33}As_{0.72}P_{0.28}$ quantum wells. These quantum wells are of 1.3 μm range. These spectra describe that at low injection current the carriers gathering in the five 60 $\AA$ $In_{0.67}Ga_{0.33}As_{0.72}P_{0.28}$ quantum wells are able to provide the gain. Note that 150 $\AA$ $In_{0.53}Ga_{0.47}As$ QWs are near the n-cladding layer. Thus more carriers accumulate near the n-cladding layer.

When the injection current increases to 200 *mA*, carriers in five 60 $\AA$ $In_{0.67}Ga_{0.33}As_{0.72}P_{0.28}$ QWs have the same contributions as the double 150 $\AA$ $In_{0.53}Ga_{0.47}As$ QWs. However, when the injection current increases to 300 *mA*, carriers in five 60 $\AA$ $In_{0.67}Ga_{0.33}As_{0.72}P_{0.28}$ QWs provide more gain than the double 150 $\AA$ $In_{0.53}Ga_{0.47}As$ QWs. If we increase the current above 500 *mA*, carriers in five 60 $\AA$ $In_{0.67}Ga_{0.33}As_{0.72}P_{0.28}$ QWs cannot provide the gain any more. Therefore, the two kinds of MQWs have almost equal gain at a particular injection level. The spectral width is near 400 *nm*, covering the 1250 … 1650 *nm* range.

When designing a broadband SLD using a nonidentical MQW structure, factors such as QW transition energy, number and sequence of the different QWs, the thickness of the SCH layer, the selection of the dominant carrier, the ability of the QW to trap the 2D carrier, the uniformity of the 2D carrier within the QWs, etc. must be taken into account. Using a properly designed nonidentical MQW structure, the fabrication of even more broadband SLDs should be possible.

3. Conclusion. We have demonstrated extremely broadband SLDs using properly designed two 150 *Å* $In_{0.53}Ga_{0.47}As$ QWs and five 60 *Å* $In_{0.67}Ga_{0.33}As_{0.72}P_{0.28}$ QWs. A spectral width covering the range from 1.25 μm to 1.65 μm has been achieved. The spectral width could be as broad as 400 *nm*.

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SEUA. The material was received 05.11.2005.

Գ.Շ. ՇՄԱՎՈՆՅԱՆ

ԾԱՅՐԱՀԵՂ ԼԱՅՆ InGaAsP/InP ՍՈՒՊԵՐԼՅՈՒՄԻՆԵՍՑԵՆՏԱՅԻՆ ԴԻՈԴՆԵՐ

Սուպերլյումինեսցենտային դիոդները, որոնք պատրաստվել են հինգ 6 *նմ* և երկու 15 *նմ* լայնությամբ InGaAsP քվանտային փոսեր ունեցող հարթակի վրա, ունեն ճառագայթման շատ լայն սպեկտր: Սպեկտրային լայնությունը կազմում է մոտ 400 *նմ*, որն ընդգրկում է 1250 *նմ*-ից 1650 *նմ* տիրույթը:

Առանցքային բառեր. մակերևութային ակտիվ տարր, հետերոէպիտաքսային աճեցում, բարակ թաղանթ, մակերևութային ակտիվ տարրի ձևափոխման աճեցում:

Г.Ш. ШМАВОНЯН

ЭКСТРЕМАЛЬНО-ШИРОКИЕ InGaAsP/InP СУПЕРЛЮМИНЕСЦЕНТНЫЕ ДИОДЫ

Для суперлюминесцентных диодов, изготовленных на подложке с пятью 6-нанометровыми и двумя 15-нанометровыми InGaAsP квантовыми ямами, получен широкий эмиссионный спектр. Спектральная ширина составляет ~ 400 *нм*, которая покрывает область от 1250 *нм* до 1650 *нм*.

Ключевые слова: поверхностно-активный элемент, гетероэпитаксиальный рост, тонкая пленка, поверхностно-активный преобразующий элемент роста.