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High Performances of 650 nm Resonant Cavity Light Emitting Diodes for Plastic Optical Fiber Applications

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1. Introduction

The low-cost and short-distance networks optical devices based on plastic optical fiber (POF) were widely used for data communication and industrial sensor. In this article, the visible red 650 nm with high performances resonant cavity light emitting diodes (RCLEDs) has been fabricated. The structure of resonant cavity light emitting diodes consists of an active layer for light emitting and placed in a Fabry-Perot (F-P) resonant. The F-P mirrors are typically quarter-wavelength (λ/4) thickness dielectric distributed Bragg reflectors (DBR's). These high reflector mirrors provides the spontaneous emission of optical mode from active layer. The thickness of F-P resonant cavity is designed to be $t_c = m\lambda_{FP} / 2n$, where the λ_{FP} is F-P resonant wavelength, n is refractive index of the cavity material, m is an integer and it usually smaller than four in normal case. The RCLEDs structure was different form conventional LEDs and its properties appeared directionality optical profiles [1], narrower spectral bandwidth [2], and high quantum efficiency [3] and more suitable for optical communication light sources, etc… In addition to these, the RCLEDs devices have less temperature sensitively than VCSELs. It's caused from materials limited and the temperature effect can modify by cavity detuning. The detuning means that different wavelength between F-P resonant and quantum well, $\lambda_{detuning} = \lambda_{FP} - \lambda_{QW}$. The optimize detuning of structure can improve output power, extraction efficiency and decreasing temperature effect. In this study will report high power and high speed RCLEDs properties for POF application.

2. Experiment

The devices were grown by metal-organic vapor phase epitaxy (MOVPE) on 3-inch substrate tilted by 6° toward <111> for the growth of RCLED structures. The TMGa, TMAl, TMIn, phosphone (PH_3) and arsine (AsH_3) were used as the source materials of Ga, Al, In, P and As, respectively. The Si_2H_6 and CCl_4 were used as the n-type and p-type doping sources, respectively and the temperature of substrate about 750℃ for epitaxial growth of RCLEDs structure. This structure consists of an n-DBR of 35 pairs of $Al_{0.5}Ga_{0.5}As/Al_{0.92}Ga_{0.08}As$ Si-doped and doping concentration is 3×10^{-18} cm^{-3} and p-DBR is $Al_{0.5}Ga_{0.5}As$ / $Al_{0.92}Ga_{0.08}As$ C-doped with 1×10^{-5} ohm-cm^2 contact resistance. The p^+-GaAs contact layer of highly-doped was grown on p -DBR for devices ohmic contact. The active layer is three +1% strain un-doping $Ga_{0.5}In_{0.5}P$ quantum wells of 1-λ cavity thickness and $(Al_{0.5}Ga_{0.5})_{0.5}In_{0.5}P$ barrier layer were between the two DBRs [4]. Photo- Luminescence (PL) at room temperature is 650±2 nm and full width at half-maximum (FWHM) about 6 nm. In wafer processing, deposited Ti/Pt on p^+-GaAs cap for p-ohmic contact first. Then grow SiN_x on wafer by PECVD for hard mask of mesa dry etching and ICP dry etching with Cl_2, BCl_3, Ar, N_2 to define mesa. Later, aperture size 84, 60, 40 μm of current confinement was formed by wet thermal furnace oxidation processes. The devices sidewall passivation coated with polyimide and deposited SiN_x except bonding pad. Finally p-electrode pad for bonding was deposited Ti/Pt/Au and wet etching backside until 120 μm and deposited with Au/AuGe. Then, the wafer thermal annealed in 380℃ furnace. After wafer was diced, the chips were bonded on TO-46 by conductive silver-filled glue.

3. Result

Firstly, the typical light-current-voltage (L-I-V) characteristic for different emission window was shown in Fig. 1. From this curve, the 84, 60 and 40μm output power of 20 mA forward current driving and without epoxy is 3, 2 and 1.6 mW, respectively. Furthermore, the series resistance of these devices is 8.4, 14.67 and 27 ohm and caused by contact area.

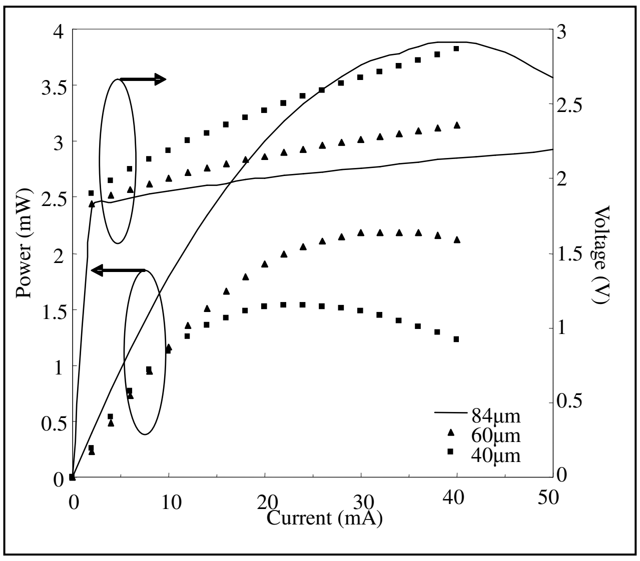

Fig. 1 The L-I-V curves for different emission windows 84, 60 and 40μm.

The wall plug efficiency of 84μm device is high as 12% and the output power achieved 3.5mW at 20 mA with epoxy encapsulated. In order to the band structure optimize and properly detuning the wavelength between cavity and quantum well by 15 nm. In this designed structure, the output power variation with temperature (-40ºC ~ 85ºC) for 84 μm RCLEDs at operation current of 10 mA is shown in Fig. 2. From this figure, the power drop from 20 ºC to 85ºC is less than -2 dB and about -0.5 % ºC^{-1}.

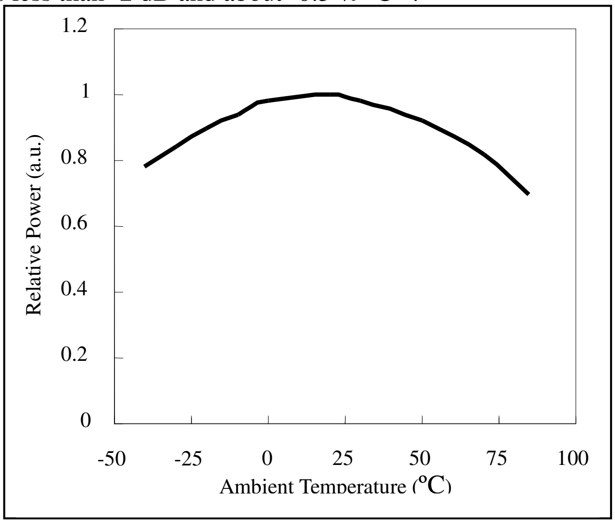

Fig. 2. The output power variation with different temperature for 84 μm RCLEDs at operation current of 10 mA.

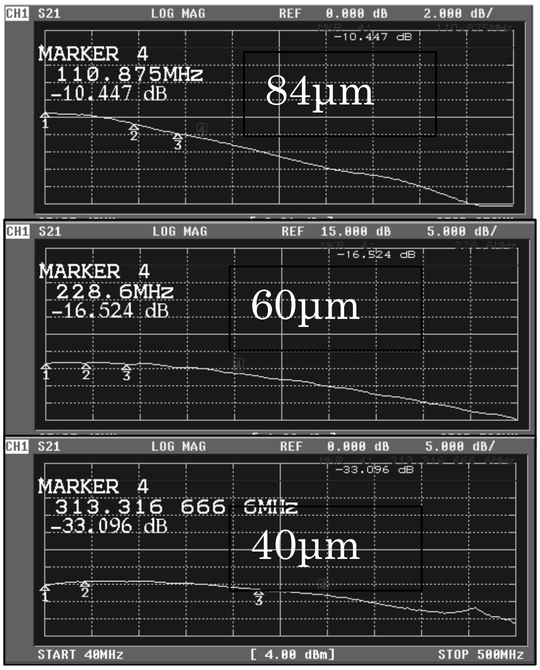

Fig. 3 Three type different emission window of cut-off frequency at 20 mA.

The three different emission window of cut-off frequency -3dB (f_{-3dB}) at 20 mA were illustrated in Fig. 3. The f_{-3dB} of diameter 84, 60 and 40 μm was achieved to 110.8, 228.6 and 313.3 MHz, respectively. These records were based on 3 QWs structure and still keeping higher output power over 1.5 mW. For standard POF-based communications, the diameter 84 μm RCLEDs emission window of f_{-3dB} is obtained over 110 MHz with $P_{out} \approx$ 3.2 mW and 20 mA forward drives current, which is suitable for 1394b s200 standard. Future, the device rise and fall time is 2.86 ns and 1.08 ns, receptivity. Lastly, a group of ten transceivers with 84 μm RCLEDs held at 85°C oven and 40 mA driving current were test for investigating reliability and the properties were shown in Fig. 4.

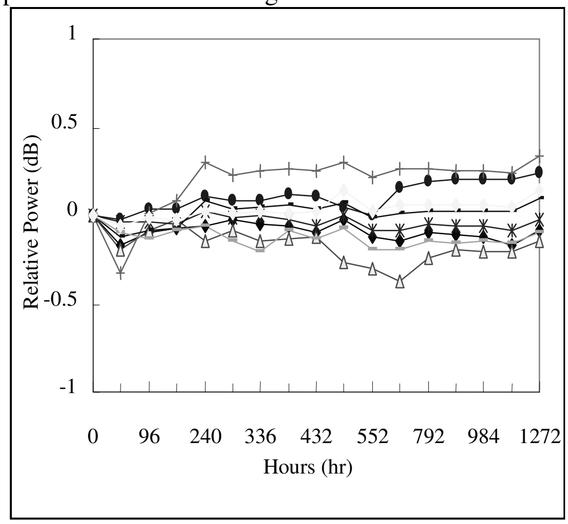

Fig. 4. A group of ten transceivers with 84 μm RCLEDs held at 85°C and 40 mA driving current were test for reliability.

4. Conclusions

In this study, the visible 650 nm RCLEDs with high power and high speed performances have successfully fabricated by excellent epitaxy and innovative, stable processing. The 84 μm RCLEDs with 3 QWs devices were achieved high power (3.7 mW) and high wall-plug efficiency (12%) for POF type RCLEDs. The transceiver with RCLEDs has good performance in transmission speed and high temperature ambient (< -3dB). In addition to fabricate small size RCLEDs (40μm) with high speed (314 MHz) for 1394b s400 standard with adequate power level (1.5 mW).

Acknowledgements

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References

[1] E. F. Schubert, Y. -H. Wang, A. Y. Cho, L. -W. Tu, and G. J. Zydzik, *Appl. Phys. Lett.* **60** (1992) 921.

[2] E. F .Schubert, N. E. J. Hunt, R. J. Malik, M. Micovic and D.L. Miller, *J. Lightwave Technol*. **14** (1996) 1721.

[3] H. De Neve, J. Blondelle, P. Van Daele, P. Demeester, R. Baets, G. Borghs, *Appl. Phys. Lett*. **70** (1997) 799.

[4] M. M. Dumitrescu, M. J. Saarinen, M. D. Guina, and M. V. Pessa, *IEEE select. Quantum Electron.* **8** (2002) 219.