Gigabit data transmission in fiber-optic/60GHz-band links using InP Heterojunction phototransistors

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Abstract: We present the device characteristics of InP heterojunction phototransistors (InP HPTs) with the emphasis of photodetection and optoelectronic mixing functions. The fabricated HPT exhibits 44A/W responsivity and photonic 3dB bandwidth of 1.4GHz, which can detect the optically transmitted 1.25Gbps data signals. By endowing it with optoelectronic mixing function, 1.25Gbps data transmission in 60GHz-band is successfully demonstrated.

I. Introduction

Gigabit data transmissions in wireline access networks have made a great progress in last decade with the help of fiber-optic technologies. In parallel, the markets for wireless access networks is also rapidly growing, which gives rise to much attention in wireless gigabit data transmission. In most cases, since subscribers may desire to access either wireline or wireless links according to their network environments, it is important to merge these two wireline and wireless access networks together.

Remote up-conversion systems based on phototransistors are attractive for these broadband convergence networks [1-2]. Fig. 1 illustrates the remote up-conversion fiber-optic/millimeter-wave data transmission systems based on phototransistors to provide broadband data services by wireline and wireless, simultaneously. In this scheme, baseband data signals are optically transmitted through optical fibers. If subscribers wish to receive these data by wireless access, it is only required that LO signals are applied to the input port of a phototransistor, making optoelectronic mixer. If not, phototransistor just recovers the optically transmitted data into corresponding electrical data with amplification. Therefore, these dual-functionalities of phototransistors are expected to facilitate the incorporation of fiber-optic networks with wireless networks. Particularly, InP heterojunction phototransistors (HPTs) have been shown to have high optical responsivity and wide photonic bandwidth compared with HEMT-based phototransistors [3].

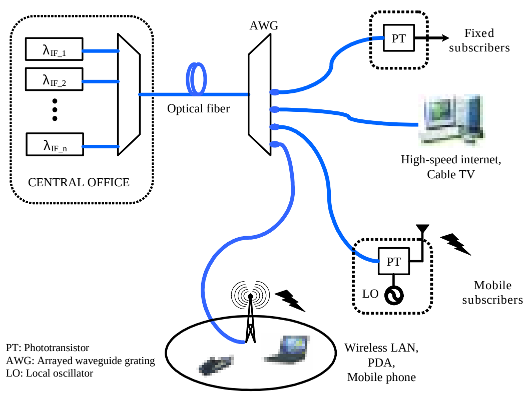

Fig. 1. Merging broadband fiber-optic wireline links and millimeter-wave wireless links using phototransistors

In this work, we investigate the characteristics of InP HPTs for these broadband convergence networks. After presenting their photodetection characteristics, fiber-optic data transmission is first demonstrated. Utilizing them as optoelectronic mixers, 1.25Gbps data transmission in 60GHz link is presented.

II. InP Heterojunction Phototransistor

Fig. 2 schematically illustrates the InP/InGaAs HPT used in this work. The epitaxial layers consist of, from top to bottom, 100nm n+ $In_{0.53}Ga_{0.47}As$ emitter capping layer, 50nm n+ InP emitter grading layer, 150nm n-type InP emitter layer, 5nm undoped $In_{0.53}Ga_{0.47}As$ spacer layer, 50nm p+ $In_{0.53}Ga_{0.47}As$ base layer, 450nm $In_{0.53}Ga_{0.47}As$ collector layer and 500nm n+ subcollector layer. The fabricated InP HPT has the emitter size of $2\times10\mu m^2$. The optical window with 2.5μm diameter is located on the top of base-layer. Under optical illumination, the photoabsorption takes place in $In_{0.53}Ga_{0.47}As$ base-collector junction. In common-emitter configuration, output collector currents are the product of transistor intrinsic gain and photocurrent at base region.

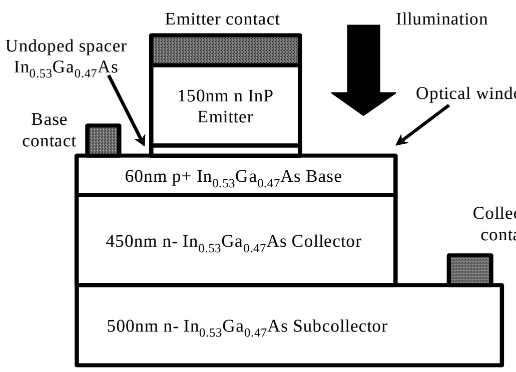

Fig. 2. Schematic diagram of the fabricated InP/InGaAs HPT

Fig. 3 shows the collector current (I_C) as a function of collector-emitter voltage (V_{CE}) with base current (I_B) variation from 0μA to 150μA under dark and -12dBm optical illumination. The high optical responsivity of 44A/W was obtained at V_{CE} of 1V and I_B of 100μA.

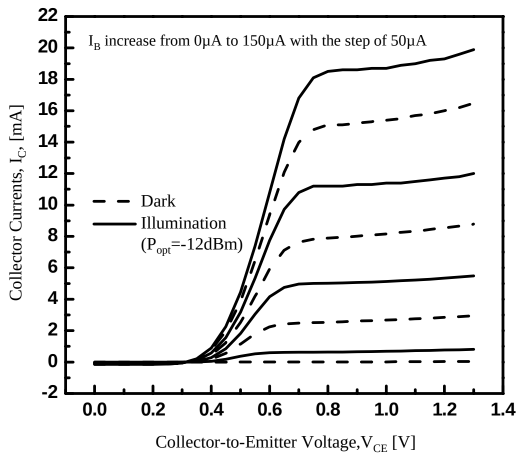

Fig. 3. Common emitter I_C-V_{CE} characteristics under dark and optical illumination conditions

The optical modulation responses of InP HPT are shown in Fig. 4. Under the PD-mode where V_{BE} is 0V, HPT operates as a photodiode without providing internal gain. The Tr-mode indicates that HPT is actively biased, I_B>0, which provides phototransistor internal gain by transistor operation. The phototransistor internal gain (G_{int}) is the photoresponse difference between Tr-mode and PD-mode. The fabricated InP HPT has the 23.6dB phototransistor internal gain at 100MHz optical modulation frequency. Since HPT should be operated at Tr-mode for the applications of phototransistors and optoelectronic mixers, the optical modulation response determines the photodetection bandwidth of optically transmitted data signals. It can be seen from the figure that the photonic 3dB bandwidth is about 1.4GHz with high internal gain, which is sufficient for receiving 1.25Gbps optical data signals in our investigation.

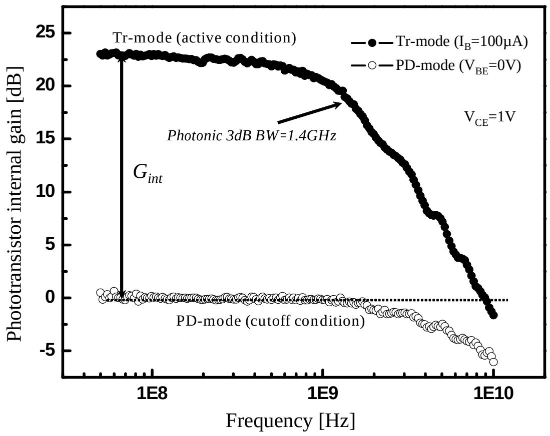

Fig. 4. The measured optical modulation responses of InP HBT under I_B of 100uA (active condition) and V_{BE} of 0V (cut-off condition) at fixed V_{CE} of 1V. G_{int} represent phototransistor internal gain

III. *Gigabit data transmission in fiber-optic and 60GHz links.*

Fiber-optic transmission of 1.25Gbps NRZ data signals is first demonstrated in order to verify that the HPT can detect optically transmitted 1.25Gbps data signals. The results are shown in Fig. 5. Clear eye opening for photodetected 1.25Gbps signals can be observed. The link performance was evaluated by measuring bit-error rate (BER) characteristics. From these results, we conclude that the fabricated InP HPT has no problem to detect optically transmitted 1.25Gbps data signals.

The InP HPT can be used as an optoelectronic mixer, which can eliminate a frequency mixer in antenna base station of fiber-optic/millimeter-wave data transmission systems [1-2]. Fig. 6 shows the 63GHz band output spectrum of InP HPT optoelectronic mixer under applying 63GHz LO signal to base port and illuminating optical 100MHz IF signal.

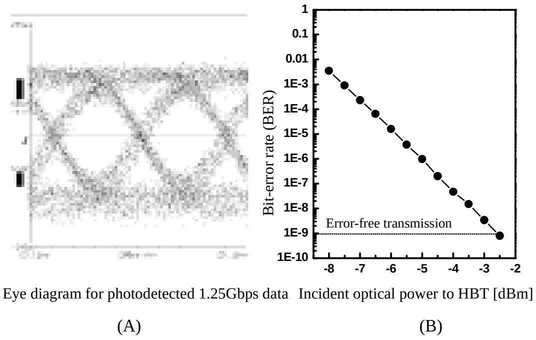

Fig. 5. Eye diagram for photodetected 1.25Gbps data signals (B) BER characteristics as a function of incident optical powers to HPT

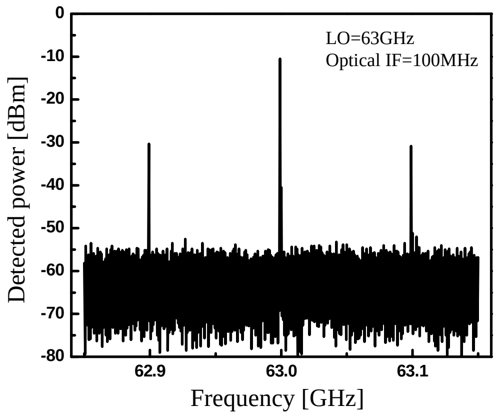

Fig. 6. 63GHz band spectrum of frequency up-converted 100MHz optical IF signal by InP HPT optoelectronic mixer

The fiber-optic/60GHz-band gigabit data transmission system based on InP HPT optoelectronic mixer was constructed and depicted in Fig. 7. At central office, 1.25Gbps NRZ data with the amplitude of 2Vpp was directly modulated to DFB laser diode. The optically transmitted data signals over 10Km single mode fiber were frequency up-converted to 63GHz band in InP HPT optoelectronic mixer with optimum bias conditions of I_B=250μA and V_{CE}=0.7V. For this frequency up-conversion, 63GHz oscillator in conjunction with RF attenuator was applied to the base port. The frequency up-converted signals would be

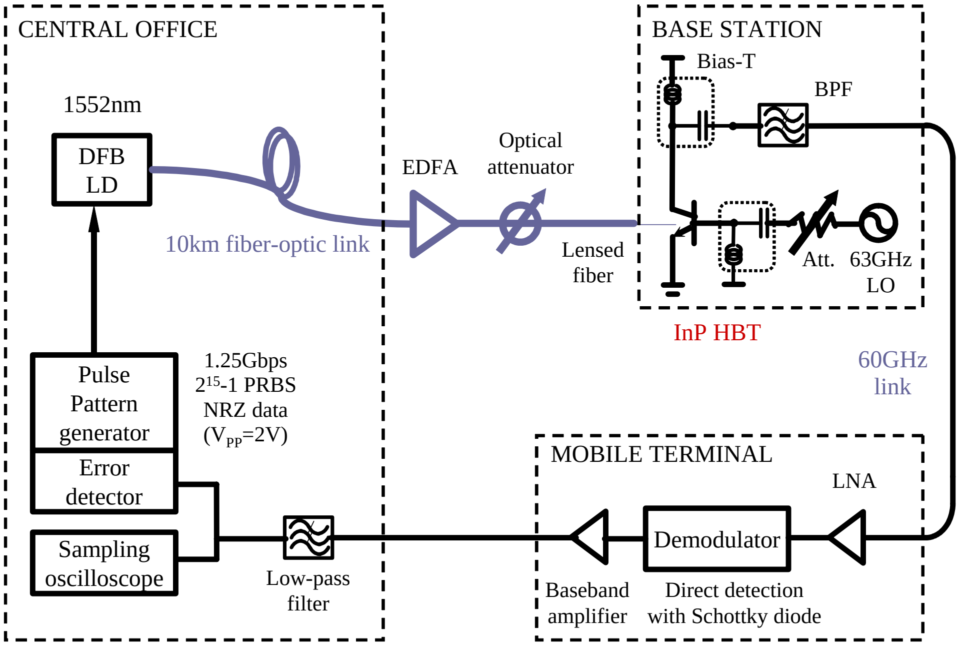

Fig. 7. Fiber-optic/60GHz gigabit data transmission system utilizing InP HPT as an optoelectronic mixer

actually radiated into free-space through an antenna, it was skipped in this experiment. After bandpass filtering, the output signals at 60GHz band were amplified by LNA and demodulated using direct detection technique with a Schottky diode. The recovered signals were low-pass filtered and connected to a sampling oscilloscope and an error detector. Fig. 8-(A) shows the eye-diagram for recovered 1.25Gbps data having the pattern length of 2^{15}-1. There are inconsiderable errors which are further evaluated by BER measurements shown in Fig. 8-(B).

IV. Conclusion

This work presents the device characteristics of InP HPT and how to implement them into gigabit data transmission in wireline and wireless networks. The HPT has high optical responsivity of 44A/W and wide photonic bandwidth of 1.4GHz, which make it possible to detect optically transmitted gigabit data signals. By utilizing it as an optoelectronic mixer, 1.25Gbps in 60GHz link was successfully demonstrated.

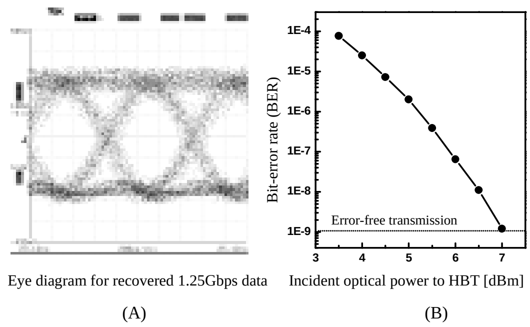

Fig. 8. Eye diagram for recovered 1.25Gbps data signals after transmission (B) BER characteristics as a function of incident optical power to HPT

Reference

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[2] C.-S. Choi et al., will be presented in IMS 2005
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