60GHz Broadband Up-conversion using Metamorphic HEMT as a Harmonic Optoelectronic Mixer

Chang-Soon Choi[1]*, Hyo-Soon Kang[1], Young-Kwang Seo[1], Jun-hyuk Seo[1], Woo-Young Choi[1]
Kyung-Chul Jang[2], Dae-Hyun Kim[2] and Kwang-Seok Seo[2]

[1] Department of Electrical and Electronic Engineering, Yonsei University
[2] School of Electrical Engineering, Seoul National University
E-mail: cschoi@yonsei.ac.kr

Abstract: *This paper presents the results of experimental investigation for 60GHz up-conversion using the metamorphic HEMT as a harmonic optoelectronic mixer. By applying 10GHz or 30GHz local oscillator signal to the gate of the HEMT, the 60GHz up-conversion from optically transmitted signal was achieved. The experimental results also show that optoelectronic mixing efficiency is strongly dependent on the bias conditions of the HEMT.*

I. Introduction

As wireless communication technologies using 60GHz millimeter-wave (MMW) emerge for utilizing inherent spectral characteristics including the unlicensed band and the high atmosphere absorption, millimeter-wave photonics technologies have received significant attentions because of low loss, large bandwidth and high flexibility of the optical fiber [1-2].

There are two concepts for the construction of millimeter-wave photonics systems: 1) optical generation and transmission of MMW and photodetection at antenna station, and 2) optical modulation and transmission of data or intermediate frequency and remote up-conversion after photodetection at antenna station. The concept 1) is more advantageous than 2) because it moves away structural complexities from antenna stations to the single control station. However, optical generation of MMW signals still remains as a challenging problem because the technology for the required optical component is not mature yet. In addition, chromatic dispersion and phase noise degradation at MMW severely limit the transmission distance.

On the other hand, the remote up-conversion concept 2) mitigates the complexities as mentioned above, and it avoids expensive high-speed photodetector at the antenna station. However, it is difficult not only to realize the mixer and the phase-locked oscillator operating MMW for the up-conversion but also to integrate these photonic and RF components.

In this work, we experimentally demonstrate 60GHz up-conversion using an InAlAs/InGaAs/GaAs metamorphic HEMT harmonic optoelectronic mixer, which can detect 1.55μm modulated light signal, generate harmonics of 10GHz or 30GHz electrical local oscillator signal, up-convert the detected data to 60GHz and have the potential for integration with the other local oscillator and amplifiers on a single GaAs substrate.

II. Experimental Setup

The metamorphic HEMT for the harmonic optoelectronic mixer has the gate length of 0.25μm and the $In_{0.53}Ga_{0.47}As/In_{0.35}Ga_{0.65}As$ composite channel which greatly enhances photoresponsivity to 1.55μm lightwave and breakdown characteristics [3]. The f_T and f_{MAX} of the used HEMT are approximately 95GHz and 170GHz under V_{GS}=0.4V and V_{DS}=1.0V bias, respectively. The experimental setup for the 60GHz up-conversion is described in Fig.1.

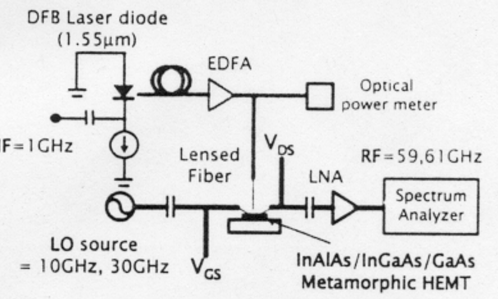

Fig.1. Experimental setup for 60GHz up-conversion.

The DFB laser diode was directly modulated with 15dBm IF frequency of 1GHz. The modulated light was illuminated on the active area (gate finger) of the HEMT by using single-mode lensed fiber. Since the T-shaped gate metal and the passivation material allow only partial coupling of the incident light, the EDFA was used to compensate the optical insertion losses.

The gate was connected to 15dBm RF source having 10GHz or 30GHz frequency for the harmonic optoelectronic mixing to 60GHz band. The two LNAs (gain=14dB) was used for compensating the cable loss (6dB) and RF probe loss (3dB). It should be noted that connectors, cables and the probe were guaranteed for use below 50GHz, and a significant amount of RF losses exists. The amplitude of up-converted signal can be further increased if the higher frequency components are used.

III. Results and Discussion

Fig.2 shows the up-converted spectrum at 61GHz (upper sideband) when the 30GHz LO was applied to the gate bias with V_{GS}=-0.3V and V_{DS}=2.3V. We clearly observe the stabilized up-converted signal ($f_{RF}=f_{IF}+f_{LO}$) having the power of -34dBm. The photodetected power at 1GHz was - 25.8dBm and the second harmonic of 30GHz LO was 6.5dBm at 60GHz. When 10GHz LO was applied to the gate under the same bias condition, the peak power of up-converted signal was -42dBm at 61GHz and the harmonic of 10GHz LO was 1dBm at 60GHz. During the experiment, we found that the power of lower sideband was 7dB larger than that of the upper sideband. It may be due to the loss difference of cables and RF probes which were guaranteed within only 50GHz. However, the origin of this difference is presently under investigation.

Fig. 3 shows measured photodetected IF power and up-converted RF power at lower sideband (59GHz) with 10GHz or 30GHz LO applied to the gate as a function of V_{DS} (V_{GS}=-0.3V). The results indicate that the photodetected and up-converted powers strongly depend on drain-bias conditions, thus the bias should be optimized for high optoelectronic mixing efficiency. The trend for photodetected power is approximately consistent with the I_D-V_D characteristic of HEMT. However, the dependence of up-converted RF power on the drain bias is slightly different from that of photodetected IF power.

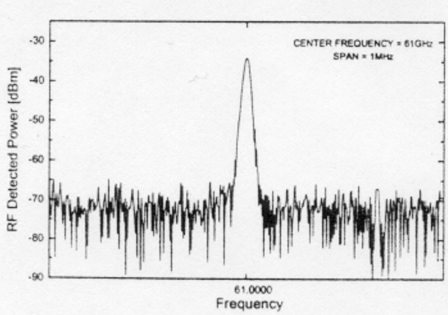

Fig.2. Spectrum analyzer trace of up-converted 61GHz.

Although the origins of these results are questions under debate [2], we believe that square law characteristics which enhance mixing efficiency are lost when the kink effects are prevalent [3].

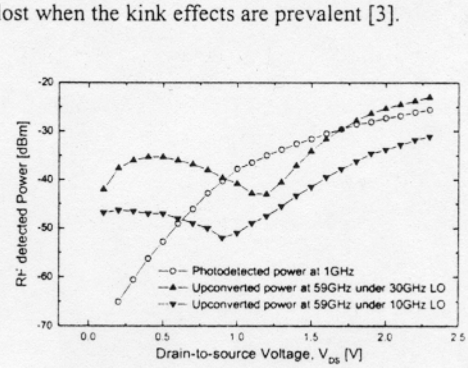

Fig.3. RF detected power as a function of V_{DS}.

Fig.4 indicates the dependence of photodetected IF and up-converted RF powers on the gate-bias conditions (V_{DS}=2.3V). From the measurements, we find that the gate-bias condition does not significantly affect the RF detected power.

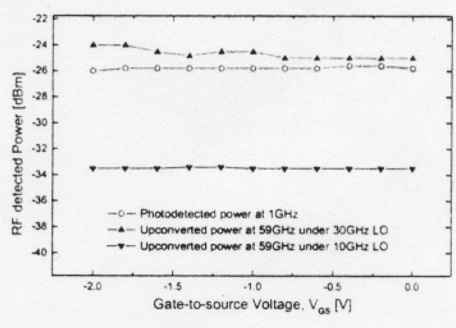

Fig.4. RF detected power as a function of V_{GS}.

IV. Conclusion

We demonstrated 60GHz up-conversion using the metamorphic HEMT harmonic optoelectronic mixer by applying electrical 10GHz or 30GHz LO source. The dependence of photodetected and up-converted RF powers on the bias conditions was investigated. We anticipate that low cost LO and metamorphic HEMT make it possible to realize cost-effective antenna stations and to integrate other RF active components on a single GaAs substrate.

References

[1] H. Ogawa et al., IEEE MTT, pp.2285, 1992
[2] C. Rauscher et al., IEEE MTT, pp.2027, 1994
[3] C.-S. Choi et al., submitted in photonics 2002