Optically Pumped Mixing at 100 GHz with Travelling-Wave Uni-Travelling Carrier Photodiodes

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Abstract: Frequency down-conversion Optically Pumped Mixing was performed at 100 GHz with a Travelling-Wave Uni-Travelling Carrier Photodiode. A conversion loss of 40 dB and 54 dB was obtained for fundamental and sub-harmonically pumped mixing respectively.

OCIS codes: (040.5160) Photodetectors; (040.2235) Far infrared or terahertz.

1. Introduction

Optically Pumped Mixing (OPM) has been used extensively for frequency up-conversion in Radio-over-Fibre links, where the Local Oscillator (LO) can be distributed optically [1]. Uni-Travelling Carrier Photodiodes (UTC-PDs) have successfully demonstrated low up-conversion loss for electrical pumping [2]. In this paper we demonstrate the capability of a photodiode with an improved response at THz frequencies, the Travelling-Wave Uni-Travelling Carrier Photodiode (TW-UTC-PD) [3], to be used for down-conversion of THz signals in the electronic domain. Generation and detection of THz waves with ultrafast photodetectors can lead to high data rate mm-wave communication systems and portable, low-cost CW THz spectroscopic systems [4].

2. Experimental Arrangement

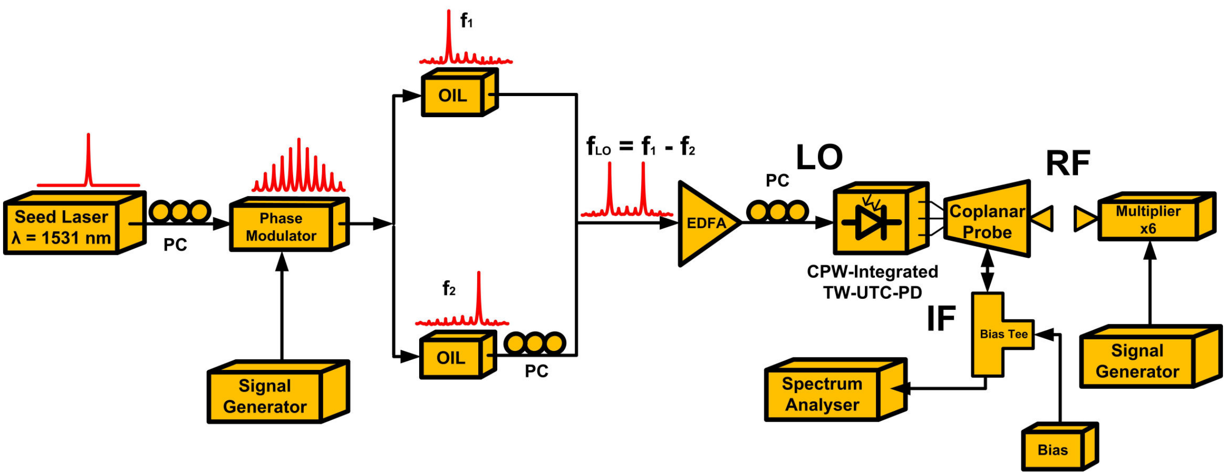

Fig. 1: Experimental Arrangement used for OEM experiments at a frequency of 100 GHz.

Figure 1 illustrates the experimental arrangement for OPM at 100 GHz with a TW-UTC-PD. An optical Local Oscillator (LO) was generated by two Optically Injection Locked (OIL) slave lasers which were locked to a comb generated by a phase modulator. The seed laser wavelength was 1531 nm and the phase modulator was driven with a 20 GHz signal for fundamental and 10 GHz for subharmonic mixing experiments and this allowed for the two slave lasers to be locked at a spacing of 100 GHz and 50 GHz respectively. A W-Band (75-110 GHz) frequency multiplier was used as the Radio Frequency (RF) source driven by a signal generator. A W-Band coplanar probe was used to probe the device. The RF signal was fed into the photodiode through a free space path employing two 20 dBi gain horn antennas. The f_{RF} was chosen to be at f_{LO}-f_{IF} and $2f_{LO}$-f_{IF} for fundamental and sub-harmonically pumped mixing respectively. The Intermediate Frequency (IF) signal was extracted from the DC port of the internal bias-tee of the probe. A second bias-tee was used to split the DC bias from the IF signal which was then displayed on a spectrum analyser. The final results were calibrated to the measured losses of the IF (5 dB) and RF (2.7 dB) signals.

3. Results and Discussion

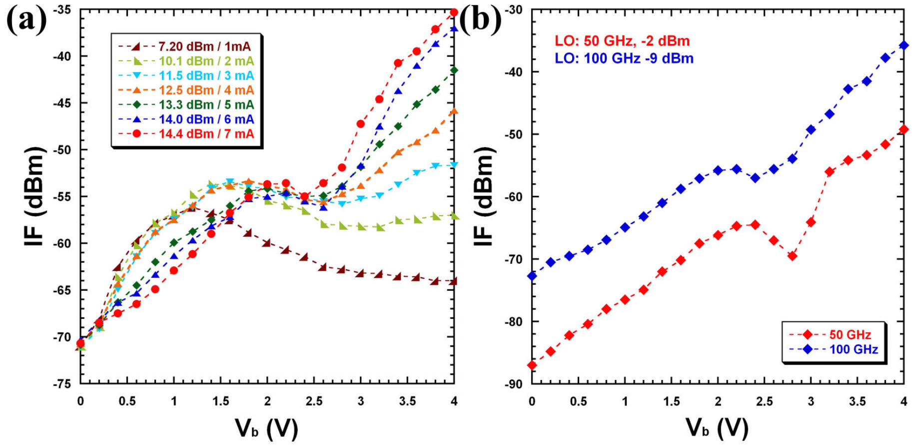

Fig. 2: (a) Calibrated IF power versus applied reverse bias for different levels of optical input power. The incoming calibrated RF power was kept constant at approximately 4 dBm. (b) Calibrated IF power versus applied reverse bias for fundamental (f_{LO} = 100 GHz) and sub-harmonically pumped (f_{LO} = 50 GHz) mixing. The corresponding LO powers measured on a 50 Ω load are given in the inset.

Initially, the OIL generated 100 GHz millimetre-wave signal from the particular 4×25 μm^2 device was measured and a drop of about 8 dB at a frequency of 100 GHz was found. Further details about this type of devices can be found in [3]. The motivation for these experiments originated from the static I-V characteristics of the device. At low levels of photocurrent and above a certain level of reverse bias V_b (typically 1-1.5 V), the photocurrent remains almost constant with increasing V_b. However, at levels of optical power that correspond to high photocurrents, a slope in the I-V curve was confirmed even at high levels of photocurrent. This is a desirable effect since the high LO power that is generated at high levels of V_b is correlated with a weaker but still important nonlinearity in the static I-V curve. OEM down-conversion experiments were carried out at an LO frequency of 100 GHz. Figure 2(a) illustrates the measured IF signal for the same levels of optical input power as a function of the applied V_b. For optical input power levels up to 10.1 dBm, the IF power is maximised at a V_b of about 1-1.5 V and then drops smoothly. But as the optical power increases, the highest IF power is detected at 4V. At a low V_b the device shows a strongly nonlinear response but poor LO power. When V_b increases, the LO generated power increases substantially so even for a weak nonlinearity the generated output is optimised. The mixing mechanism is attributed to the AC term in the applied reverse bias caused by the LO signal. The final set of measurements shows a comparison between fundamental and subharmonic mixing. The RF power was kept at 4 dBm, the optical power at 14.4 dBm that delivered -9 dBm at 100 GHz and -2 dBm at 50 GHz both measured on a 50 Ω load. The results are shown in Fig. 2(b). For subharmonic mixing the behaviour of the mixer is very similar with the obtained curve for the fundamental. At the maximum V_b level, the difference is about 13.5 dB.

4. Conclusion

We anticipate that nonlinearities in TW-UTC-PDs will allow for efficient down-conversion of THz signals. A significantly improved performance is expected from devices that have previously shown a 3dB bandwidth of about 100 GHz together with high saturation currents [3]. Further work on this detection technique is expected to allow for coherent, high-sensitivity CW THz systems.

5. References

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