High Speed Velocity-Matched Distributed Photodetectors

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In the last few years, remarkable progress has been made in ultrafast, and high-speed, high power photodetectors, as reviewed in [1,2]. In terms of applications, the high-speed photodetectors can be divided into four general different categories: (1) high-speed digital communication systems, (2) RF photonic systems, (3) ultrafast optoelectronic sampling, and (4) optoelectronic generation of millimeter-waves and sub-millimeter-waves. The requirements are different for different applications. For high-speed digital communications, bandwidth and efficiency are most important [2]. For analog and RF photonic systems, in addition to bandwidth and efficiency, maximum linear photocurrent is important to achieve desired RF performance [1,2]. Several approaches have been proposed to increase the maximum linear photocurrent, including waveguide photodetectors with reduced confinement factor [3], traveling-wave photodetectors [4,5], velocity-matched distributed photodetectors [1,6], and distributed absorption waveguide photodetector with non-exponential photon distribution inside the photodetector [7]. Uni-traveling-carrier photodetector (UTC-PD) has also been demonstrated to increase the saturation photocurrent density limited by the space charge effect in the intrinsic region [2,8]. The frequency of interest for RF photonic systems ranges from 1 to 100 GHz. For optoelectronic sampling or ultrashort electric pulse generation, short impulse response and flat frequency response with high 3-dB bandwidth are needed. Short-lifetime materials such as low-temperature (LT) GaAs are often used to eliminate the long tails of the impulse response, at the expense of reduced efficiency. Photodetectors with bandwidth over 500 GHz have been demonstrated using surface-illuminated metal-semiconductor-metal (MSM) [9,10] and p-i-n traveling wave photodetectors [11] with LT-GaAs absorption layer. For millimeter-wave and THz generation by optical heterodyning, the photodiodes are often referred to as photomixers. The frequencies of interest for photomixers ranges from 100 GHz to several THz. The most important parameter for photomixers is the amount of power that can be generated without damaging the photomixer. LT-GaAs photomixers with 1 μW of power at 600 GHz and somewhat lower power at 1 THz have been reported [12,13].

For distribution of local oscillator signals for radio astronomy antenna array, photomixers operating at long wavelength (1.55 μm) are preferred due to low fiber loss, availability of high power Erbium-doped fiber amplifiers (EDFA) and tunable lasers, and other fiber components, thanks to the rapid advances of optical fiber communications community. To date, there has been very few reports on millimeter-wave photomixers at 1.55 μm. A power of –24 dBm at 60 GHz was reported using traveling wave photodetectors [4].

In the past few years, we have been working on long-wavelength (1.55 μm) velocity-matched distributed photodetectors (VMDP) for RF photonic systems and millimeter-wave photomixers. Figure 1 shows the schematic of the VMDP. It consists of an array of photodiodes connected by an optical waveguide. The output is collected in phase by the velocity-matched 50Ω microwave transmission line. The VMDP offers many advantages for high frequency photodetectors with high saturation power. The distributed absorption is also desirable for increasing the damage threshold due to thermal runaway. Recently, we have experimentally demonstrated millimeter-wave generation at 95 GHz using a 1.55-μm VMDP. Millimeter-wave signals of –23 dBm has been measured at 95 GHz. Full W-band, 75GHz-

0-7803-5634-9/99/$10.00©1999 IEEE

110GHz, and higher power measurement are in progress. In this paper, we will review the state of the art of high-speed photodetectors, and present the recent progress in VMDP for millimeter-wave generations.

This project is supported by ONR MURI on RF Photonics, and NRAO. The authors would like to thank R. Muller and P. Maker at JPL for help with E-beam writing.

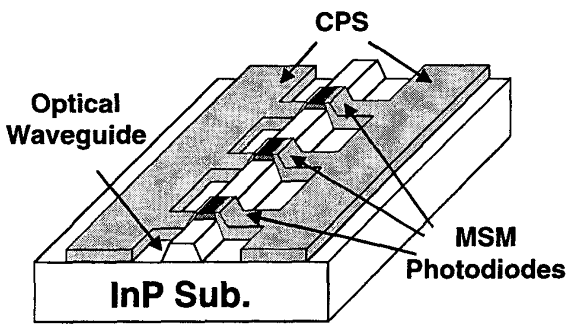

Figure 1. Schematic of VMDP

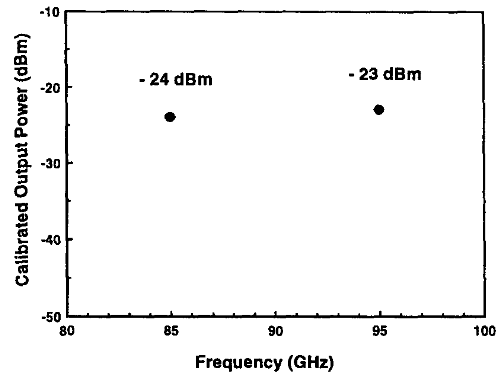

Figure 2. Millimeter-wave signal at 85 and 95GHz

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