lowest NEP calculated for $T_0 = 1.5$ K is 4.8×10^{-14} W/Hz$^{1/2}$ which is about 3.7 times greater than the value obtained for Si.

CONCLUSIONS

The calculations reported in this paper show that the performance of a bolometer is very sensitive to the level of background radiation absorbed by the bolometer element, and that this dependence is due to the resistivity and thermal capacitance of the element being strong functions of temperature. These results also emphasize the need to state explicitly the optical detection system parameters, the background flux, and the thermal time constant when reporting on the NEP performance of a bolometer detector.

The present investigation shows that a high performance bolometer should be obtained from compensated Si with $N_D = 1.3 \times 10^{18}$/cm^3 and $K_n = 0.4$. Similarly, specimens with $N_D = 2 \times 10^{18}$/cm^3 and $K_n = 0.1$ and having a superior value for A_t, should yield good detectors, although the higher resistance at large values of λ_{on} may cause difficulty in obtaining a low-noise figure with available preamplifiers. The effects of the f number of the optical detection system, the size of the element, and the value for λ_{off} on detector performance are presently being investigated both for these two samples and other samples that were characterized in this study. This work together with a more detailed account of the calculations presented here will be the subject of a future publication.

In conclusion, the practical ultimate performance of a bolometer will be reduced by preamplifier noise and possibly by excess noise, such as current or contact noise generated in the element itself by the bias current. Preamplifier noise is expected to be small, because very good preamplifiers are commercially available for the range of detector resistances reported. The magnitude and source of any excess noise in Si bolometers is unknown at present, but the advanced state of Si device technology should be an advantage in enabling detector fabrication without excess noise [8].

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Submillimeter Heterodyne Detection and Harmonic Mixing Using Schottky Diodes

H. R. FETTERMAN, B. J. CLIFTON, MEMBER, IEEE, P. E. TANNENWALD, C. D. PARKER, AND HAYS PENFIELD, MEMBER, IEEE

***Abstract*—Schottky diodes have been used for submillimeter heterodyne detection and harmonic mixing. Using a carcinotron local oscillator at 890 μm, sensitive detectors of optically pumped lasers have been demonstrated up to fifth harmonic mixing at 1757.5 GHz. The measured noise equivalent power (NEP) in fundamenta mixing is approximately 10^{-16} W/Hz.**

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H. R. Fetterman, B. J. Clifton, P. E. Tannenwald, and C. D. Parker are with Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass. 02173.

H. Penfield is with Harvard College Observatory, Cambridge, Mass. 02138.

IN A recent publication [1], we have demonstrated that new low-capacitance small-contact-area GaAs Schottky diodes could provide high-order harmonic mixers at submillimeter wavelengths. Here we report the first application of these Schottky diodes as heterodyne detectors and low-order harmonic mixers of submillimeter radiation. As heterodyne detectors of coherent radiation, they offer exceptional response time and noise equivalent powers (NEP's). In addition, the basic packaging and construction of these diodes make them extremely rugged, free from critical adjustments, and easily mounted into receivers.

Our previous measurements used a quasi-optical mounting configuration with power from the local oscillator fed directly from the end of a closely coupled 4-mm guide. The submillimeter laser radiation was coupled into the diode via a short focal length mirror. This arrangement, while not as efficient as that used in our current studies, permitted higher order harmonic mixing and the use of wavelengths as short as 118 μm. In this case, a 2522.8-GHz CH_3OH laser beam was mixed directly with the thirty-fourth harmonic of a V-band klystron. No evidence was found of roll-off at these frequencies, although the very high-order harmonic reduced the signal-to-noise (S/N) considerably. These measurements indicate that use of these diodes as sensitive heterodyne detectors at extremely high frequencies is feasible.

In our current experiments, we have chosen frequencies corresponding to longer submillimeter wavelengths. This enabled us to optimize our detector geometry and to cover frequencies which, because of the relatively low atmospheric absorption, have astronomical interest. The diodes were mounted in a cross-guide configuration of circular guide having a 0.060-in diameter and are shown in Fig. 1. A 1-mm CSF carcinotron was mixed with various optically pumped lasers in our heterodyne measurements. The carcinotron, serving as a local oscillator, produced about 50 mW of power at 340 GHz.

Our heterodyne system generally used either a low noise parametric IF amplifier at 2.3 GHz or a transistor preamplifier at 40 MHz, followed by a spectrum analyzer with a bandwidth of 300 kHz. Laser power was determined using calibrated power meters and was typically about 400 μW. In fundamental mixing at 890.0 μm using an optically pumped $C_2H_2F_2$ laser as shown in Fig. 2, the S/N of the heterodyne signal was approximately 10^6. Extrapolating to unity bandwidth, our results indicate that heterodyne noise equivalent powers better than 10^{-15} W/Hz (of coherent radiation) are readily obtainable. This is consistent with our previous video measurements with the 337-μm HCN laser.

Third-order harmonic mixing using the carcinotron as the local oscillator for a signal at 292.2 μm (CH_3OH) produced a S/N ratio only 15 dB down from fundamental mixing. Fifth order harmonic mixing as well as further low-order harmonic mixing between submillimeter lasers and powerful (200-mW) high frequency Varian klystrons also yielded high detectivities. Measured NEP's are plotted in Fig. 3, showing the decrease as a function of frequency. Some of the conversion losses at the highest frequencies result from the reduced efficiencies of the mount itself, while others are from the poor diode impedance match. Interestingly, although in our previous V-band work the diodes were optimally biased by the microwave fields themselves, at frequencies above 100 GHz we find a dc bias is required regardless of applied microwave power.

The diodes used here were all typically about 1 μm in diameter and had capacitances of approximately 2×10^{-15} F. Actual details of the construction of these diodes have been described elsewhere [3]. In general, characterizing the particular diode by spot diameter, capacitance, and dc resistance determined their performance. Therefore, consistent results could be obtained from many diodes having similar values for these parameters.

Current efforts include further optimization of coupling the submillimeter to the diodes, introduction of IF filters, and operation at lower temperatures. Cooling these units to nitrogen temperatures (they show no deterioration due to thermal cycling) has already shown increases of four in conversion efficiencies [4]. These diodes are excel-

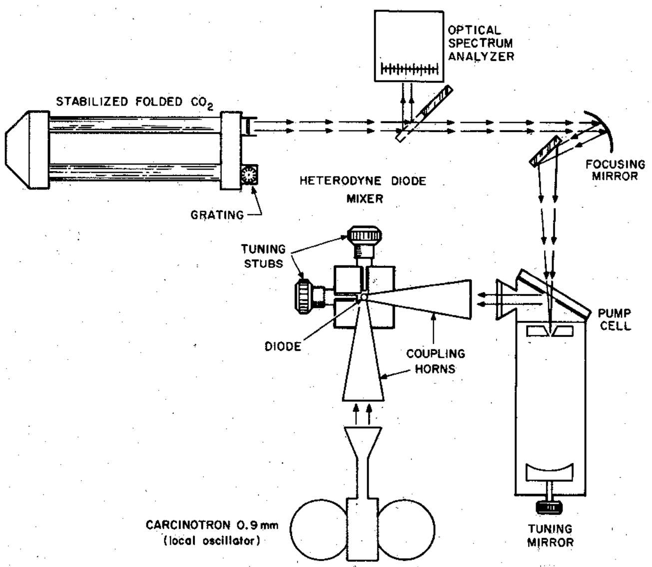

Fig. 1. Heterodyne mixing setup showing schematically the new cross-guide detector mount and CW optically pumped laser and local oscillator.

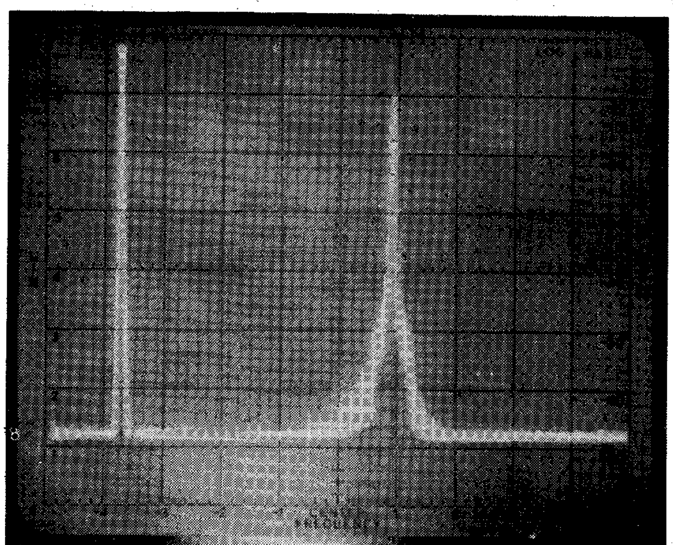

Fig. 2. Spectrum analyzer display showing on a log scale the S/N obtained by heterodyning a carcinotron with a 890-μm optically pumped laser. Scale is 5 MHz/cm.

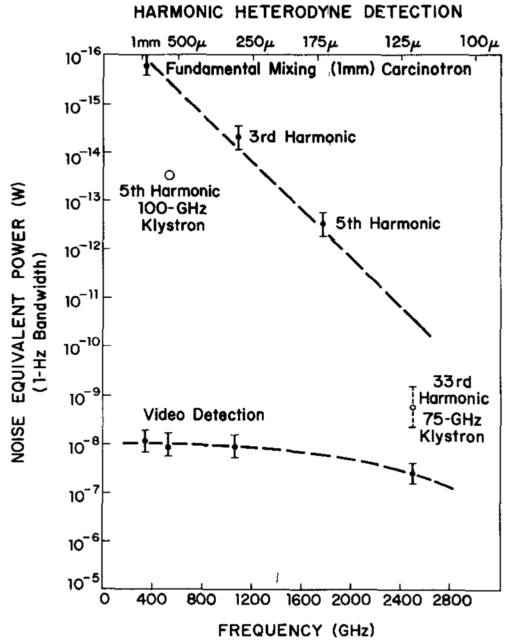

Fig. 3. Decrease of NEP as a function of frequency resulting from higher local oscillator harmonics and from the decrease in coupling efficiency of the cross-guide mount. Almost 20 dB is lost at 500 μm going to fifth harmonic mixing using a 100-GHz source. The point at 118 μm was taken using a quasi-optical mount.

lent wide-band and heterodyne detectors, virtually free from the alignment and adjustment problems common to most detectors in this wavelength range. Other devices, currently available at microwave frequencies, can now be constructed in the submillimeter using this technology.

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