µHeterodyne mixing of acoustic and microwave signals using a beam-lead Schottky diode

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This paper looks at the use of a microwave (W-band) beam-lead Schottky diode for heterodyne detection of acoustic waves with frequencies up to about 100 GHz. Schottky diodes are commonly employed as microwave mixers, and are well known to respond to incident microwave signals. It has also been shown that Schottky diodes can respond to acoustic waves on the picosecond time scale generating a transient current [1].

The mixer element was an e2v beam-lead Schottky diode, shown in part (A) of figure 1. This was mounted in the W-band waveguide circuit shown in part (B). The 94 GHz local oscillator signal was provided by an e2v Gunn diode oscillator and coupled to the Schottky diode via an attenuator and a waveguide. Acoustic waves were generated in the GaAs substrate on the back side of the Schottky diode sample by using a femtosecond pulsed laser [2], shown schematically in part (C). These acoustic waves propagated across the GaAs substrate to the Schottky diode where they caused transient voltage changes across the diode, which were measured on an oscilloscope.

The acoustic wave generated in the sample by a single laser pulse contains a broad spread of acoustic frequencies. To form a quasi-monochromatic acoustic wave packet for the mixing experiments a Fabry-Perot etalon was made from two parallel partially reflective mirrors. A single laser pulse incident on the etalon experienced multiple partial reflections which led to a train of optical pulses at a frequency f_0 set by the cavity spacing. The spacing of the cavity mirrors could be adjusted to tune the cavity frequency f_0. The train of optical pulses incident on the GaAs sample produced an acoustic wave packet strongly modulated at the cavity frequency f_0.

The voltage measured across the Schottky diode in the presence of both the microwave LO signal and the acoustic signal is the intermediate frequency signal. This was Fourier transformed on the oscilloscope to determine the frequency components present in the IF for a range of acoustic frequency f_0. Examples of such results are shown in figure 2, for the case when the second harmonic acoustic signal was mixed with the microwave LO. A clear peak is observed in the IF which changes in frequency as the acoustic frequency is changed. This is the first evidence of heterodyne mixing of acoustic waves with microwaves.

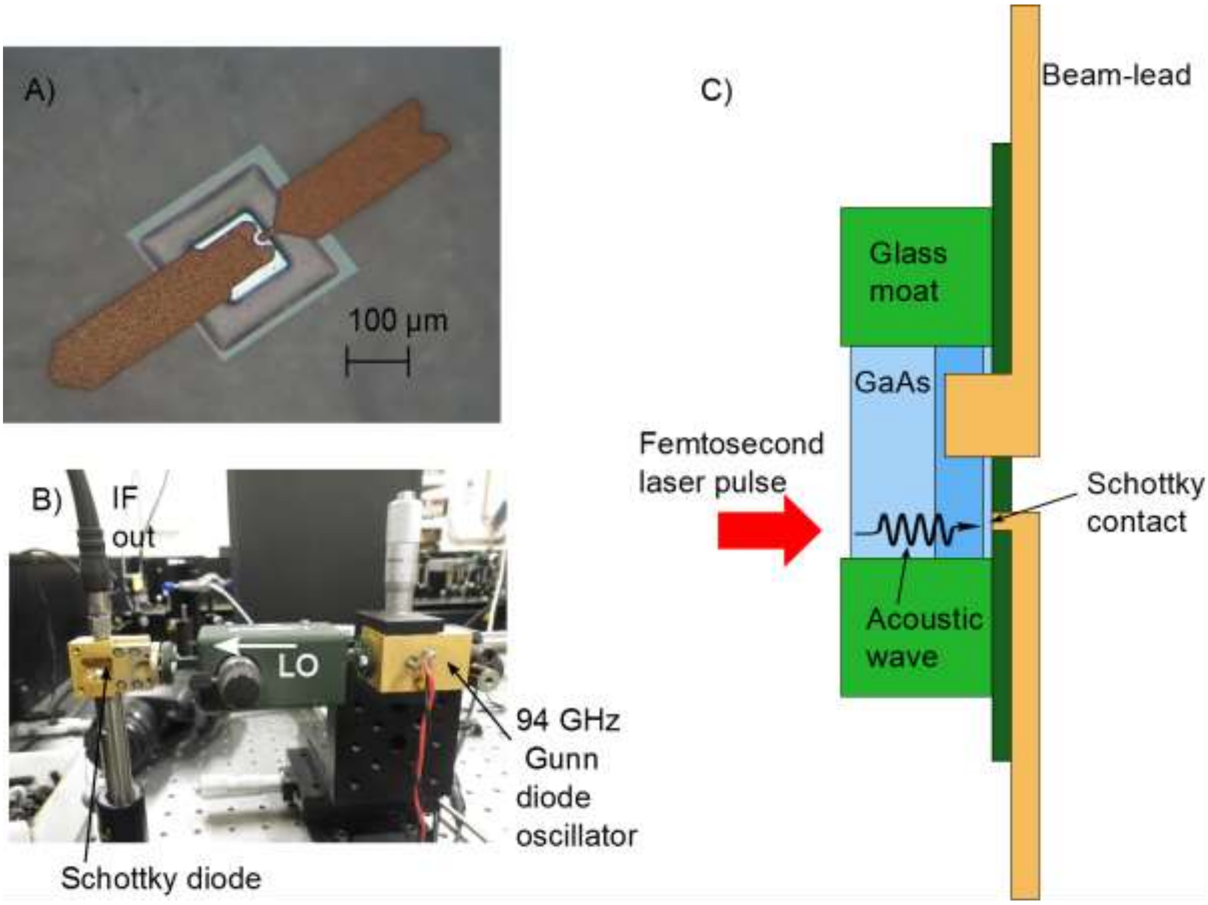

Figure 1: (A) beam lead microwave Schottky diode; (B) Schottky diode mounted in a waveguide circuit with a Gunn diode oscillator LO; (C) schematic diagram of the acoustic wave generated in the beam-lead Schottky diode

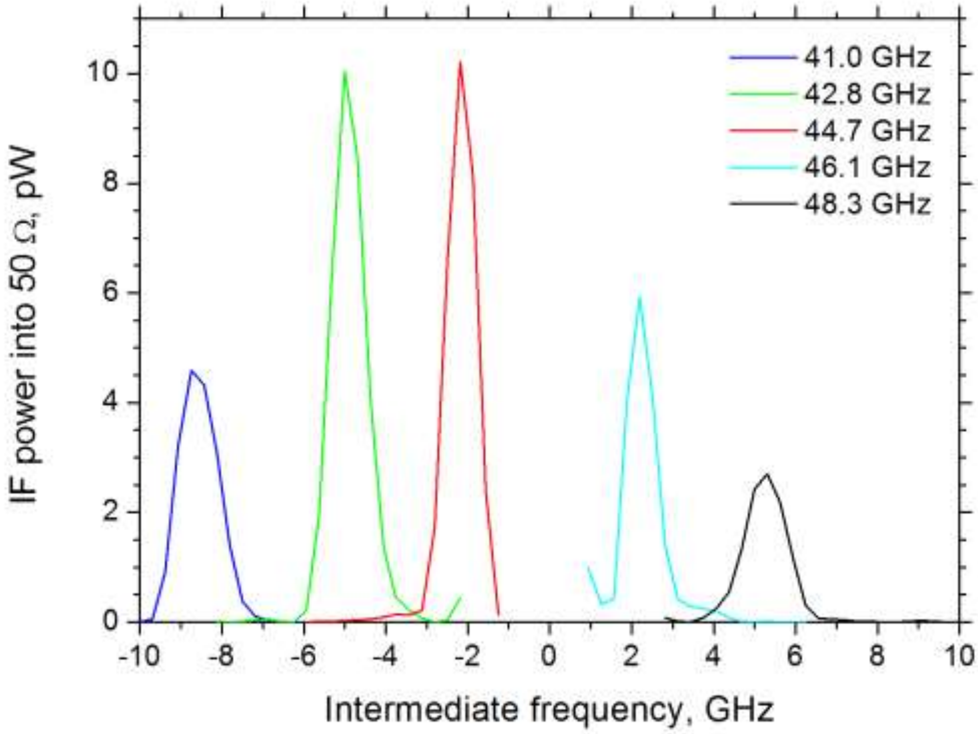

Figure 2: IF power as a function of the difference frequency ($2f_0$ – 94 GHz), the values of f_0 determined by the cavity spacing are shown in the legend. The resoluation bandwidth of the oscilloscope spectrum analyser was 500 MHz, corresponding to a 2 ns duration signal capture window.

The laser and Fabry-Perot etalon used to generate the acoustic wave in the sample were required as a known generation method of acoustic waves for these proof-of-principle experiments. It is proposed that in the future it could be possible to use an acoustic local oscillator on-a-chip type device along with a Schottky diode for the heterodyne detection of microwaves. An acoustic LO could offer a simpler method of achieving the high frequencies required for the local oscillator, while also being stable in time and having very low phase noise.

[1] D M Moss, A V Akimov, B A Glavin, M Henini and A J Kent, Phys. Rev. Lett. 106, 066602 (2011)

[2] C Thomsen, H T Grahn, H J Maris, and J Tauc, Phys. Rev. B. 34, 4129 (1986)