THz Heterodyne Sensors Based on MgB_2

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Terahertz range is rich with molecular lines important for understanding the chemistry associated with evolution of star-forming molecular clouds. Current state-of-the-art receivers use mixer devices made from NbN films with critical temperature ~ 9-11 K. Despite its good sensitivity and well-established fabrication process, the NbN HEB mixer suffers from the narrow intermediate frequency (IF) bandwidth ~ 2-3 GHz and is limited to operation at liquid Helium temperature. As an interest in high-resolution spectroscopy of high frequency lines above 2 THz is growing, the need in larger IF bandwidth becomes more pressing.

A possibility to increase both the operating temperature and the IF bandwidth of HEB mixers lies with the use of superconducting $MgB_2$with critical temperature of 39 K. Realization of a receiver operating at 20 K would allow a relatively low-cost mechanical cryocooling in space. This would be a big impact on the cost reduction and lifetime increase of an associated space mission.

Recently, thin films of this superconductor have become available that opened the door for development of various detectors. Our current work focuses on the development of practical HEB mixers and Josephson Junction (JJ) mixers using ultrathin (5-15 nm) MgB_2 films prepared with the Hybrid Physical-Chemical Vapor Deposition (HPCVD) process in combination with ion mill on THz-transparent 6H SiC substrates. Recent measurements of HEB devices yielded a double-sideband (DSB) noise temperature of 1,000-2,000 K (bath temperature independent between 4 and 15 K) in the 0.6-4.3 THz range which is close to the state-of-the-art performance.

The new direction of our work is to pursue HEB mixer devices on Si membranes. This is critical for embedding mixers into waveguides. Waveguide architecture allows for dense packaging of heterodyne pixels that paves a way to a 100-pixel array camera driven by a single local oscillator source. Unprotected Si cannot withstand MgB_2deposition by HPCVD because the high temperature required for evaporating Mg (≈ 700 C) promotes a chemical reaction of Mg with Si. By putting a boron buffer on Si, we have achieved good quality thin MgB_2 films with $T_C > 30$ K.

Another heterodyne detector being developed by us is the THz planar JJ mixer in which a large product $I_C R_N = 5.3$ mV has been achieved. This mixer has demonstrated a low noise temperature (≈ 2,000 K @ 2 THz) and can be driven by extremely small local oscillator power. Given the very small LO power requirement, this mixer can be a good approach to a 100-pixel camera for mapping of [CI] @ 1.89 THz line and for determination of the D/H ratio in comet tails from space telescope.

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