THzSensors Based on Superconducting MgB_2

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Terahertz range is rich with molecular lines important for understanding of the chemistry associated with evolution of star-forming molecular clouds. High-resolution spectroscopy of such clouds greatly relies on hot-electron superconducting bolometric (HEB) mixers. Current state-of-the-art receivers use mixer devices made from ultrathin (~ 3-5 nm) films of NbN with critical temperature ~ 9-11 K. Such mixers have been deployed on a number of ground based and suborbital (SOFIA, STO, TELIS) platforms, and have been used in HIFI instrument on the Hershel Space Observatory. Despite its good sensitivity and well-established fabrication process, the NbN HEB mixer suffers from the narrow intermediate frequency (IF) bandwidth ~ 2-4 GHz and is limited to operation at liquid Helium temperature. As an interest in high-resolution spectroscopy of high THz frequency lines (e.g., [HD] 2.68 THz, [OIII] 3.39 & 5.79 THz, [OI] 4.75 THz, [NIII] 5.23 THz, etc.) 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 for the use of 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 achievable, which opened a door for development of various detectors. Our current work focuses on the development of practical HEB mixers using ultrathin (8-20 nm) MgB_2 films. We prepare films using the Hybrid Physical-Chemical Vapor Deposition (HPCVD) process in combination with ion mill yielding high-quality ultrathin films with critical temperature ~ 37-39 K on THz-transparent SiC substrates.The combination of small film thickness, large sound velocity, high acoustic phonon transparency at the interface with the substrate, and short electron-phonon relaxation time results in an IF bandwidth ≈ 9 GHz, which has been measured in 15 -nm thick HEB devices. Even larger IF bandwidth is expected in thinner (5-10 nm) films, which have been already achieved. Micron- and submicron-sized spiral-antenna coupled HEB mixers have been fabricated in order to minimize the local oscillator (LO) power requirements. Preliminary measurements yielded a double-sideband noise temperature of ≈ 2,500 K weakly dependent on temperature between 4 and 20 K. This indicates that, indeed, mixer operation may be possible using a cryogen-free cooling system. An on-going material development work focuses on achieving disordered films (but still with high critical temperature) where the intrinsic quantum efficiency is expected to be high. An additional benefit of the high resistivity will be better rf and IF impedance match of HEB devices.

We will report on experimental results to date as well as on the progress in development of a cryocooler based 4.7 THz HEB receiver using a Quantum Cascade Laser (QCL) as an LO source. We will also discuss other potential applications of MgB_2 films to THz sensors. Promising devices include tunnel-junction mixers, kinetic inductance detectors and parametric amplifiers, and flux-flow oscillators.