THz performance of MgB2 HEB mixer with non-uniform thickness profile

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Abstract—MgB₂ based HEB mixers have been under development for the past several years with the goal to achieve an adequate broadband heterodyne detector for high-resolution spectroscopy above 3 THz. Here, certain molecular lines in our galaxy may have radial velocity spread reaching several hundred km/s. This will require an intermediate frequency (IF) bandwidth up to 8 GHz at around 5 THz. Such a large bandwidth has been currently demonstrated, however other characteristics of the MgB₂ HEB mixer need further investigation and improvement.

The principal technique for make thin MgB₂ films as thin as 5 nm with high critical temperature > 30 K is Hybrid Chemical-Physical Vapor Deposition. As a result, MgB₂ HEB devices of the small size similar to that of NbN HEB mixers have become feasible. However, the local oscillator (LO) power required for pumping such devices is substantially larger (~ 10 µW) than that needed for pumping the NbN HEB (~ 100 nW). This is quite expected given the large IF bandwidth and high electron temperature (electron heat capacity) in MgB₂ devices. Reduction of the required LO power is very desirable for enabling large heterodyne arrays. This can, in principle, be achieved by decreasing the device area to ≈ 100 nm × 100 nm since the film normal sheet resistance is several tens of Ohm (compared to ~ 1000 Ohm in NbN film).

This presentation will describe the operation of small (submicron size) MgB₂ HEB where the device area reduction was achieved in an unconventional way, using a postfabrication milling of the device with Ar-ion beam. The original devices made from a 40-nm thick film and integrated with planar log-spiral antennas are milled down to achieve smaller thickness and higher sheet resistance. However, the milling process of the MgB₂ film patch confined between tall gold walls (contacts to integrated antenna) is non-uniform and leads to the arched thickness profile. In the experiment, the thinnest central part of the device behaves as a very small HEB which is possible to pump with an LO power of 70-100 nW. These non-uniform devices still demonstrate very robust noise performance with a double-side band (DSB) noise temperature ~ 2,000 K in the 0.6-4.3 THz range using both molecular gas laser and quantum cascade laser LOs. Longer ion mill time results in creation of a weak-link Josephson junction with good sensitivity up to 2 THz.

Despite the difficulties in reproduction of such devices, this method deserves attention given the important benefits associated with small LO power requirement. The latter is critical for achieving large scale (~ 100 pixels) heterodyne cameras. An alternative approach may include the Focused Ion Beam technique in order to define better the geometry of the small thickness sub-HEB.