THz performance of MgB_2 HEB mixer with non-uniform thickness profile

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Abstract—MgB_2 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 MgB_2 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, MgB_2 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 MgB_2 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) MgB_2 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 MgB_2 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.