MgB_2 hot-electron bolometer mixers for sub-mm wave astronomy

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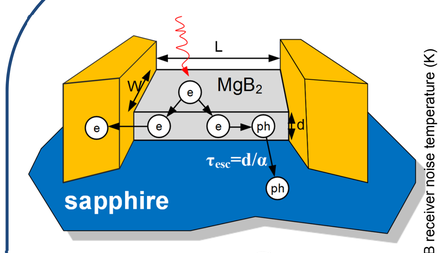
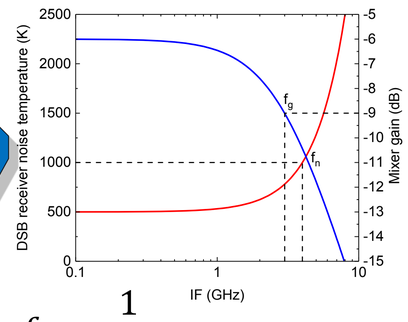
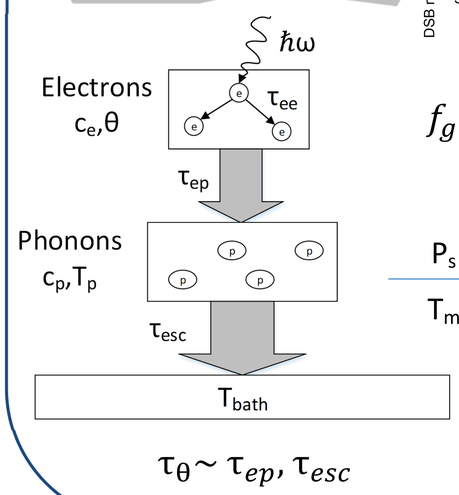
We have managed to improve the bandwidth of HEB mixers without sensitivity sacrificial by using MgB_2 superconducting ultrathin films grown by hybrid physical chemical vapor deposition (HPCVD) technique. Both a high critical temperature (T_c) (short electron-phonon interaction time) and a small thickness (short phonon escape time) are crucial for large bandwidth achievement. Using this deposition method films as thin as 5-10nm with a T_c above 30K were grown. A noise bandwidth (NBW) of 11GHz was measured for HEBs with a T_c of 30K fabricated from an 8nm thick film, and a NBW of 13GHz was measured for HEBs with a T_c of 33K fabricated from a 5nm thick film. The DSB receiver noise temperature of such devices measured at a 5K bath temperature is about 1000K at 0.69THz and 1.69THz local oscillators (LOs).

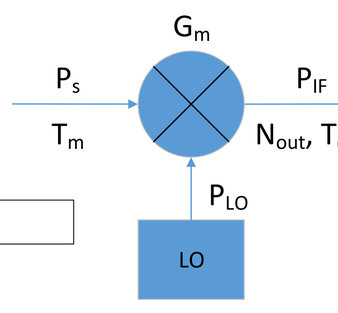
HEB mixers





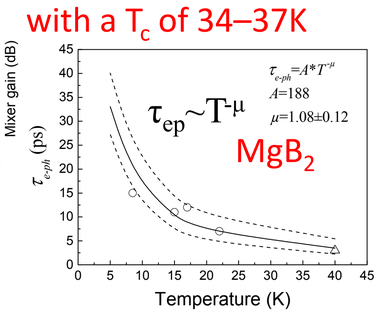
$$f_g = \frac{1}{2\pi\tau} \qquad \tau \sim \tau_\theta$$

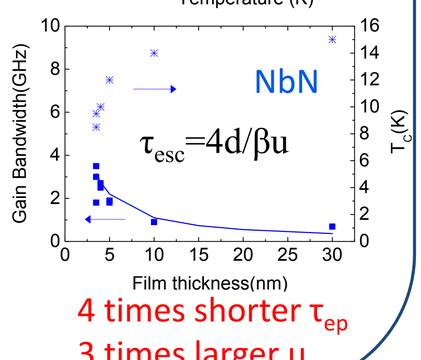




$$\tau_\theta \sim \tau_{ep}, \tau_{esc}$$

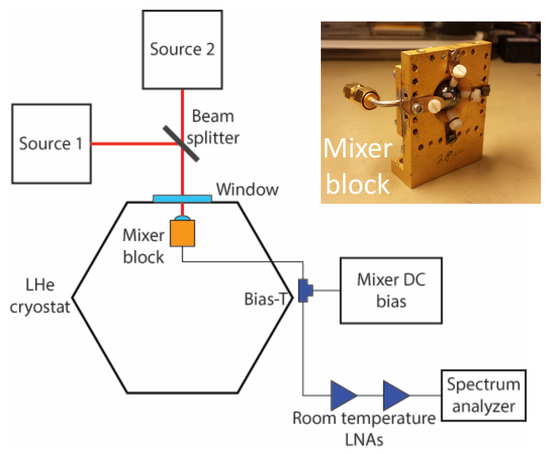
MgB_2 T_c=39K
Ultrathin films (6-10nm) with a T_c of 34–37K



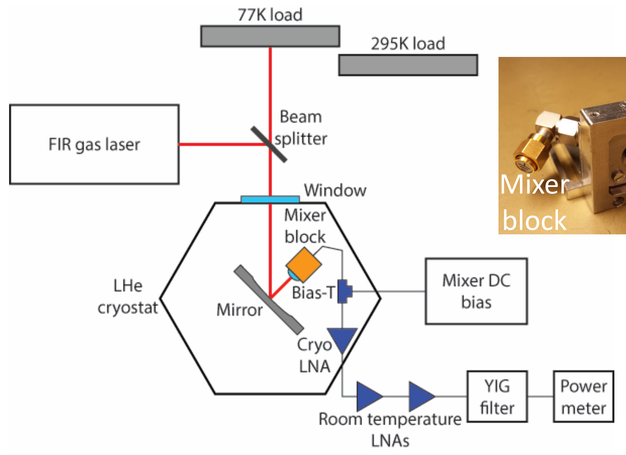


4 times shorter τ_{ep}
3 times larger u

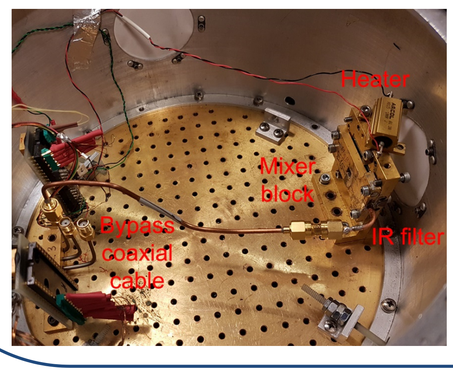
Device characterization techniques

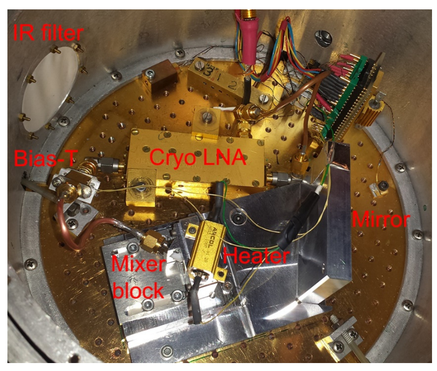


GBW measurement setup

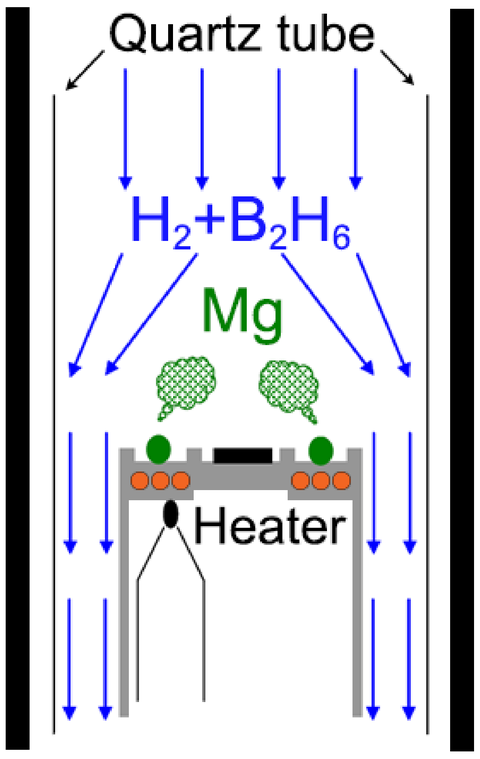


Noise temperature measurement setup

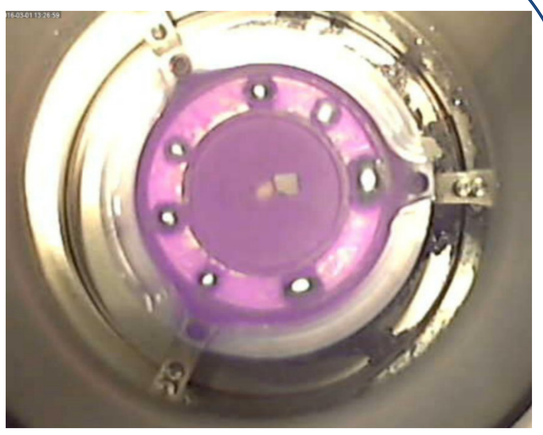




HPCVD grown MgB_2 films on SiC

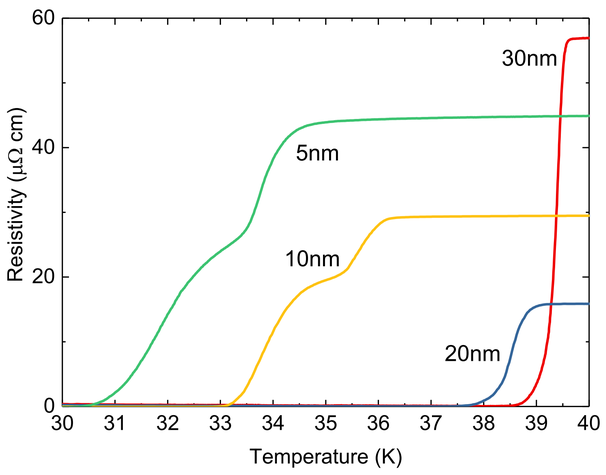


Deposition chamber

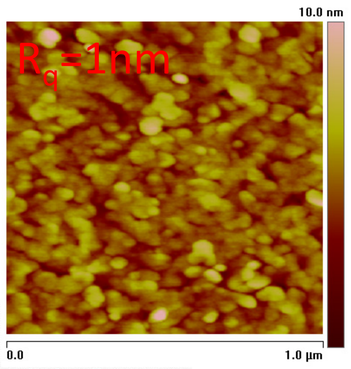


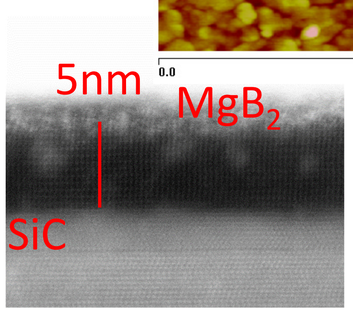
Chamber view during deposition

$$B_2H_6\ (g) \rightarrow 2BH_3\ (g)$$
$$Mg\ (s) \rightarrow Mg\ (g)$$
$$BH_3\ (g) \rightarrow BH_3\ (abs)$$
$$Mg\ (g) + 2BH_3\ (ads) \rightarrow MgB_2 + 3H_2$$

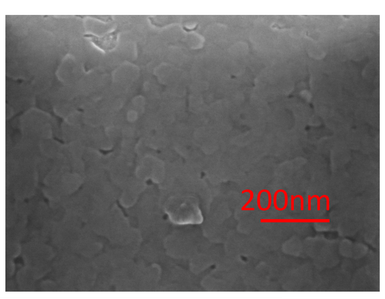


AFM



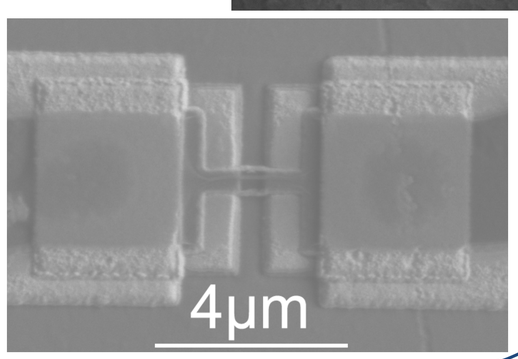


TEM

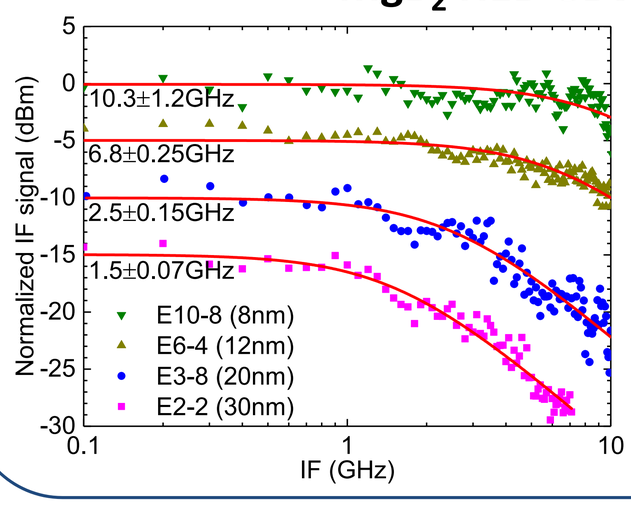


- Deposition rate 0.8-0.9Å/s
- Thickness (d) 5-30nm
- Critical temperature (T_c) 35-41K
- Sheet resistance (R_s) 2-50 Ω/sq
- Residual resistance ratio (RRR) 2-6

Several batches of sub-micrometer size HEBs were fabricated using e-beam lithography, metal evaporation and ion-beam milling

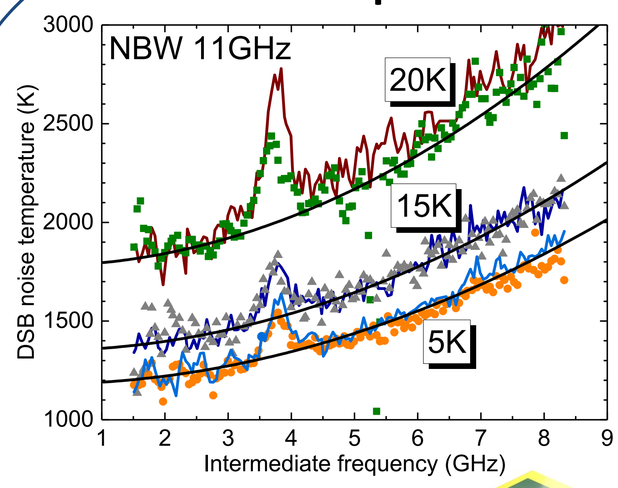


MgB_2 HEB GBW measurements

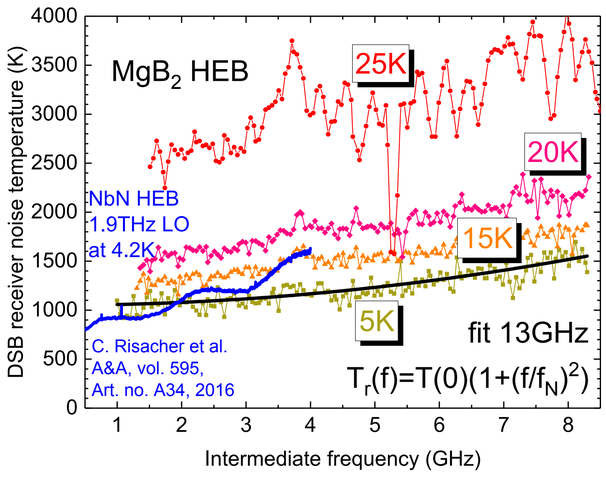


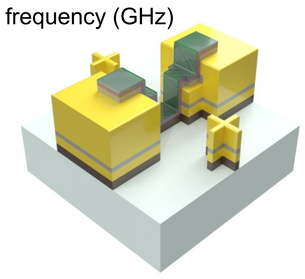
d (nm)	GBW (GHz)	$\tau_{e\text{-}ph}$ (ps)	τ_{esc} (ps)
30	1.5	3.5	22
20	2.5	4	20
12	6.8	5	5
8	10.3	6	3

Noise performance of MgB_2 HEB mixers

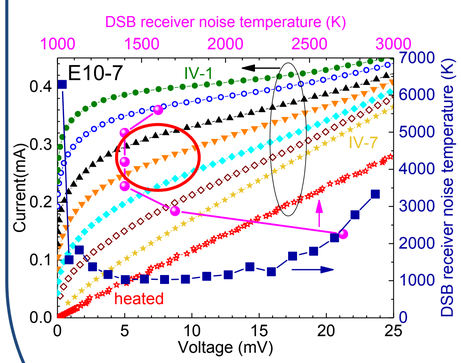


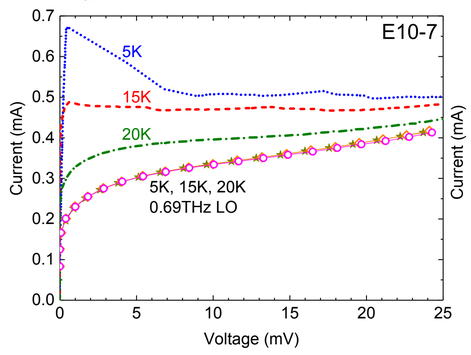
MgB_2 HEB mixer
1x1um²
d = 5nm
T_c = 33K

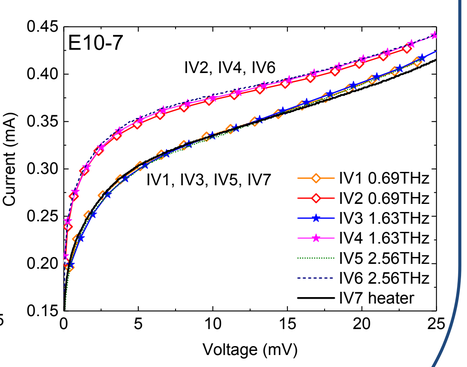




MgB_2 HEB mixer
1x1um²
d = 8nm
T_c = 30K







The minimum T_{rec} in a wide bias point range. The effect of the THz waves on the mixer is totally thermal, due to absorption in the π conduction band of MgB_2

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