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The Current Status and Future Plan of mm/sub-mm Mixers in ASIAA

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Extended Abstract

The Nb-based superconductor-insulator-superconductor (SIS) mixers demonstrate excellent performance on the detection in mm/sub-mm wavelength due to their extremely high nonlinearity in current-voltage relation, low gap voltage, and low RF loss. The receivers with SIS mixers can achieve few times of quantum limit noise temperature, which enhance the sensitivity of telescope significantly. However, SIS mixers have several well-known constraints. The loss of superconductor increases dramatically as the incident photon energy is higher than pairing energy of superconducting electrons. In addition, the conversion gain of the SIS mixer decreases significantly in high frequency regime. For Nb-based SIS mixers, the upper working frequency is around 500 μm, but can be extended to 250 μm if an Al/SiO2/NbTiN transmission line is adapted. Fortunately, this limitation on upper working frequency is good enough for the ground-based astronomical observations which are constrained more seriously by the absorption of atmosphere. The large parasitic capacitance of junction will reduce the RF (radio frequency) and also IF (intermediate frequency) bandwidths. People manage this problem by circuit design and fabrication technology. The Nb-based SIS mixers have been developed for decades. The fabrication technology is quite mature for regular astronomical applications. Most of ground-based mm/sub-mm telescopes have SIS mixers in their receivers.

Developing new technology is important for future receivers and mixer is definitely one of key components. There are several possible schemes for future mixer applications, such wide IF bandwidth receivers, wide RF bandwidth receivers, large focal plane receivers, and multi-pixel interferometer. The first two schemes enhance the performance of receiver, which require novel design and fabrication technology in device level. The last two can speed up the observation of telescope, but have to manage issues in system level. In past couple decades, ASIAA (Institute of Astronomy and Astrophysics, Academia Sinica) has involved the receiver development both in device and system levels for several telescopes, such as SMA (sub-millimeter array), ALMA, GLT (Greenland Telescope), and JCMT (James Clerk Maxwell Telescope). For fulfilling the needs of different receivers, we have developed a reliable fabricating process for Nb-based SIS mixers and we are also developing new technologies for future receivers. In my presentation, I will include our activities on wide IF bandwidth SIS mixer for SMA, the mixers in THz regime, and finally wide RF bandwidth receiver for future application.

On the wide IF bandwidth mixer, in collaborating with SAO (Smithsonian Astronomical Observatory), the IF bandwidth of SMA receivers have been extended from 2 GHz to 8 GHz. The new generation SMA receiver will have an IF bandwidth up to 16 GHz in three years. The details of new receivers will be presented. On the mixers in THz regime, we have developed new technology for fabricating high quality NbN films with a thickness of few monolayers. Using these films, the IF bandwidth of HEB (hot-electron bolometer) mixers could be extended to several GHz. We are constructing a multi-pixel ALMA-type cartridge receiver working at 1.5 THz which can be potentially deployed on ALMA, GLT, or other telescopes. The progress and future plan will be included. The wide RF receiver, traditionally, needs a mixer having a very low Q-factor circuit which requests an SIS junction with extremely high critical current density. This kind receiver can operate in a wide RF regime, while the mapping speed is the same as the regular mixer and some issues need to be solved, such as wide bandwidth LO (local oscillator) source and harmonic coupling. An alternative configuration of wide RF receiver combines superconducting band-pass filters and wide IF bandwidth mixers. The superconducting band-pass filters divide the whole RF band into several sub-bands with sharp band edge which can minimize the loss of RF window between two RF sub-bands, and the wide IF bandwidth mixer can significantly reduce the number of sub-band. Ideally, whole in-band RF signal can be received simultaneously, which can increase the mapping speed and also the sensitivity. Challenges and progress to achieve such ultimate receivers will be discussed.