Notes from the 1997 THz Symposium & Visits to SAO and J&E Tool

SIS Mixers

No stunning new results on SIS receiver performance.

SIS junctions made at JPL on a new material, NbTiN, have a gap frequency ~1.2 THz (*cf.*~700 GHz for Nb). The high specific capacitance of NbTiN junctions (~140 fF/μm^2 compared with ~60 for Nb) makes mixer design more difficult, as does the larger London penetration depth (~185 nm -- *cf.* ~75 for Nb).

Shitov *et al.* use a current-carrying control line above the junctions in a mixer to suppress the critical current.

The IRAM multi-beam 230-GHz SIS receiver has $T_{Rx} \leq 50$ K DSB *measured without optics*.

Work is continuing on developing a practical theory of operation of the distributed SIS mixer.

Debate continues on the usefulness of the "intersecting line technique" for measuring the input noise contribution of SIS receivers. Honingh *et al.* find the method unsatisfactory (which has been our experience at NRAO).

Hot Electron Bolometer Mixers

IF bandwidths are still limited to ~2 GHz by the thermal time constants. It seems that T(Rx) ≈ 1 K/GHz for the best HEB mixers.

Submillimeter Array (SMA) Receivers

The SMA receiver modules drop in from the top (*cf.*, our "rockets"). A cover-plate on the dewar bottom allows the IF cable and 4 K heat-straps to be connected and removed. Contact to the 70 K radiation shield is by spring-finger stock around the edge of a hole in a 70 K cold plate. To reduce the effect on the optics of bowing of the dewar top-plate under atmospheric pressure, the receiver modules are bolted to a jig plate above the dewar top plate. O-rings on the modules contact the sides of holes in the top plate of the vacuum vessel.

All SMA receivers have a (quite thick) lens at 70 K, which typically increases Tr(DSB) by 20 K -- quite serious.

The SMA receiver dewars each have a turbo-pump permanently attached. (They are only run when needed.)

Large polarizing grids of elliptical shape with about 10" major axis are made by QMC Instruments in London (Richard Wylde). These have invar frames supporting gold plated tungsten (?) wires.

IR filters in the SMA receivers consist of 1-3 floating sheets of 7.5-25 mil thick Zitex, about 2.5" dia. in largest case. Zitex is similar to Goretex RA7957.

I have a lot of photographs of SMA receivers, components, and other things of interest in their Cambridge lab.

Other SAO notes

SAO is building a portable 850 GHz atmospheric monitor for our Chile site using a FTS made by QMC Instruments in London.

The SMA telescopes are having serious trouble with their CFRP backup structure falling apart. Poor CFRP quality control, and polished gluing surfaces are problems, but baking at high temperature after painting seriously weakened the epoxy joints.

Quasi-Optical SIS Mixers

The two-slot quasi-optical mixer design used by Zmuidzinas (originally demonstrated by Kerr & Siegel) can have a pointing problem if there is any asymmetry in the RF circuit -- this includes not only mechanical asymmetries, but circuit asymmetries such as differences in Rn or Jc in the two junctions typically used in these mixers. (This difficulty cannot arise in waveguide mixers with feed-horns.)

mm Sources

Neal Erickson reported wideband fixed-tuned multipliers for 240-325 GHz (~100 μW), 575-735 GHz (20-100 μW). These bands correspond to frequency ratios of 1.35:1 and 1.28:1.

Elliott Brown's group at Lincoln Lab reported photomixers using LTG GaAs photoconductors. State-of-their-art: (driving the detectors close to burnout) 10 μW at 200 GHz, 1 μW at 1 THz. Next step: traveling-wave photomixer, still using LTG GaAs photoconductors.

JPL (Siegel, *et al.*) using e-beam lithography to make GaAs quad doubler (4 diodes) got 1.4 mW at 640 GHz with 100 mW input from a 320 GHz carcinotron.

Radiometer Physics (Peter Zimmermann's company in Meckenheim) is working with the Institut für Hochfrequenztechnik in Darmstadt to make "substrateless" Schottky diodes for THz applications.

Using a second-harmonic Gunn oscillator (TEO's), Jones (UVA) and Carlstrom (Chicago) obtained 8 mW at 170 GHz.

BWO's: Mikhail Gershteyn (Insight Product Co.) says BWO's are now easy to Φ-lock and have typical lifetimes of 15,000 hrs (about 2 yrs continuous operation). Their cost is ~$50k -- comparable to the cost of a multiplier chain LO at 300 GHz. Greg Gol'tsman designed a very compact BWO power supply -- available commercially from Insight Products. Their power is in the mW range, but above ~ 150 GHz BWO's usually have messy overmoded waveguide outputs.

Greg Herman (NASA/LaRC) uses undoped GaP for difference frequency generation at THz frequencies. Uses two 0.5 W Nd YAG lasers to produce 100 μW at 2500 GHz. Output power varies as output frequency per Manley-Rowe. Could possibly get useful power at ~300 GHz, but much development is needed. The Schottky photomixer approach looks more promising.

Integrated SIS receiver/autocorrelator

Marc Feldman (Rochester U.) is writing a proposal to build a superconducting autocorrelator integrated with an SIS mixer using Nb single-flux-quantum technology. A SFQ A/D would replace the IF amplifier, the IF from the junction going straight into the A/D converter. This demonstration device would have an IF bandwidth of ~16 GHz and only a few lags, and would thus be well suited to observing far-red-shifter proto-galaxies which have very broad lines.

Refrigerators

Inatani *et al.* reported a refrigeration system for SIS receivers in space. The system uses a two-stage Stirling refrigerator with a JT stage. Cooling capacity is 30 mW at 4.5 K with a power consumption of only 260 W.

LMSA (the Japanese MMA) -- discussions with Inatani

For the LMSA, Inatani wants to use multiple refrigerators per telescope, although this would be more expensive and probably consume more power. Nobeyama uses Sumitomo JT refrigerators (cf: Daikin on the SMA). These have about 3.5 capacity at 4.2 K, use an adjustable JT valve, and use ~9 KW. Inatani wants to try and determine an optimum refrigerator for the array -- Gifford-McMahon using Er3Ni, or JT, and how much cooling power is needed.

Dutch Receiver Work -- discussions with Gao

The Nb facility at RUG is part of a university department and must do research primarily, not production work. They feel that most of the academic research on Nb SIS mixers has now been done, and they are moving into HEB and NbN work.

SRON is neither a national lab nor a university department, but is an autonomous (private) research organization which is funded by the Dutch government. They can't do production work, but want to set up a company under their control to make hardware and Nb circuits. For this, they need funds from FIRST and the MMA. Gao would like to be involved in this.

MMA Receiver Package

I discussed with Woody and Erickson our (Payne/Kerr) idea of a single dewar with a central evacuated tower which would act as a reference surface to which the receivers would be attached, and would allow most IR to pass through. They saw no immediate objections to the idea.

HIA Post Doc

Charles Cunningham's post-doc said he would be willing to test some of our untested SIS373 mixers. We have a whole wafer similar to the one we are now testing, that we can give to Charles.

Machine Shops

SAO has a 1-man shop in their receiver lab. It does only the high precision work for the Submillimeter Array (SMA). There is a rebuilt Moore jig borer (2400 RPM max!!), the old Linley jig borer from GISS, and a new Hardinge lathe. They like Robb-Jack small end-mills.

Beautiful polished Al mirrors are made by a local company using diamond tooling and SiO2 coating -- see my photographs.

Visited J&E Precision Tool Co, Westford, MA. They have a very clean shop with a number of large CNC mills and lathes. They also have a few Bridgeport milling machines, one of which is equipped with computer control. This allows either full computer control of the tool path, or manual operation.

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April 8, 1997