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SUPERCONDUCTOR SEMICONDUCTOR RESEARCH FOR NASA'S SUBMILLIMETER WAVELENGTH MISSIONS

p6

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DEPARTMENT OF ELECTRICAL ENGINEERING

I. Introduction

Wideband, coherent submillimeter wavelength detectors of the highest sensitivity are essential for the success of NASA's future radio astronomical and atmospheric space missions. The critical receiver components which need to be developed are ultra-wideband mixers and suitable local oscillator sources. This research is focused on two topics, i) the development of reliable varactor diodes that will generate the required output power for NASA missions in the frequency range from 300 GHz through 2.5 THz, and ii) the development of wideband superconductive mixer elements for the same frequency range.

II. Progress to Date

Varactor Diode Research:

For frequencies less than 1 THz, planar GaAs chips with multiple integrated diodes promise increased power handling ability and greater efficiency than presently available multipliers. In the first months of this grant we completed fabrication of a new batch of planar varactor diodes for a 40GHz to 80 GHz doubler which was developed by a student working on a NASA fellowship (D.W. Porterfield). This prototype balanced doubler has been designed for broad band operation without mechanical tuners and is much easier to fabricate than previous versions. It is also readily scaleable to higher frequencies. An SEM photo of one of the new diode chips is shown in Fig. 1. The chips have six anodes for increased power handling. The multiplier has been tested and the initial results show power output of over 100 mW and efficiency of up to 50% [1]. Also, the electronically tuned bandwidth was 17%. These are record values for this frequency range.

For the varactor research we have hired and begun training two graduate students. Willie E. Bowen has begun to learn the planar diode fabrication process and Christopher St. Jean is beginning work on whisker contacted diodes with refractory anodes for increased power handling and reliability.

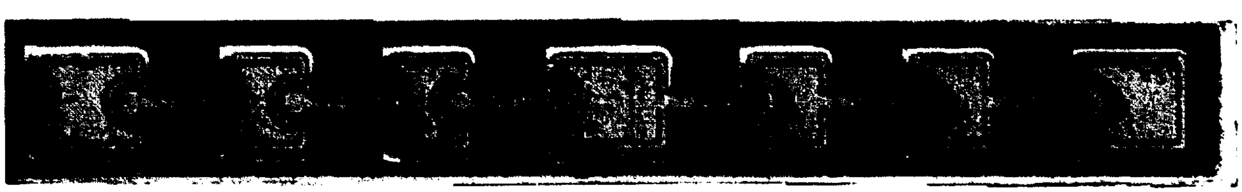

Fig. 1: An SEM photo of the new planar multiplier chip, SB13T1

Superconductive Mixer Element Research:
Our superconductive device research has been undertaken in three separate investigations: hot electron bolometers (HEBs), focused ion beam trilayer junctions, and Nb/Al edge junction distributed mixers (this work is also partially supported from an NSF grant). Two graduate students, Aaron Datesman and Robert Bass, have been chosen for this research. The following initial research has been undertaken in these three investigations:

HEB Mixer Elements: A prototype Nb based HEB fabrication process has been designed. Initial experiments have been undertaken using an existing heterodyne mixer mask in order to develop a better understanding of the processing challenges. The majority of our efforts have been spent learning the capabilities of the new Ga^+ based focused ion beam system which will be used to physically carve the actual 100nm sized microbridge (see Figure 1.). Having accomplished the initial prototype work, we are presently designing 1-2 THz HEB mixers for the first mask set. We have also started a collaboration with Chris Walker at the University of Arizona. Initial research will be on a micromachined 1x4 integrated HEB array for the South Pole observatory (we are also seeking separate funding from NSF for this work).

FIB Trilayer Junctions: This project was not described in our initial NASA proposal; however, the concept evolved naturally from our initial prototype HEB investigations. In this new process, the junction definition and insulation steps are decoupled by using the FIB tool to define a registrated submicron insulation via to the top of the Nb junction counter electrode in what is essentially a machine aligned insulation process. With the precise alignment and ultra small beam features of the FIB tool, we anticipate an eventual process capable of insulating junctions as small as 0.2 um^2. This process may also be applicable to the fabrication of ultra small Schottky barrier diodes. We are presently investigating our initial prototype design.

Nb/Al Edge Junction Distributed Mixer Elements: In this work we have fabricated initial mixer designs for 230 GHz . We have found that the developed edge junction fabrication process does not give repeatable edge angles and hence junction areas. We are investigating both the edge angle milling step and subsequent processing steps and their influence on the resulting edge angle. We are also analyzing the potential use of the FIB tool to trim the finished Nb wiring layer contact to the distributed mixer in order to remove any nonsymmetric portions of the contact (which are predicted to degrade mixer performance).

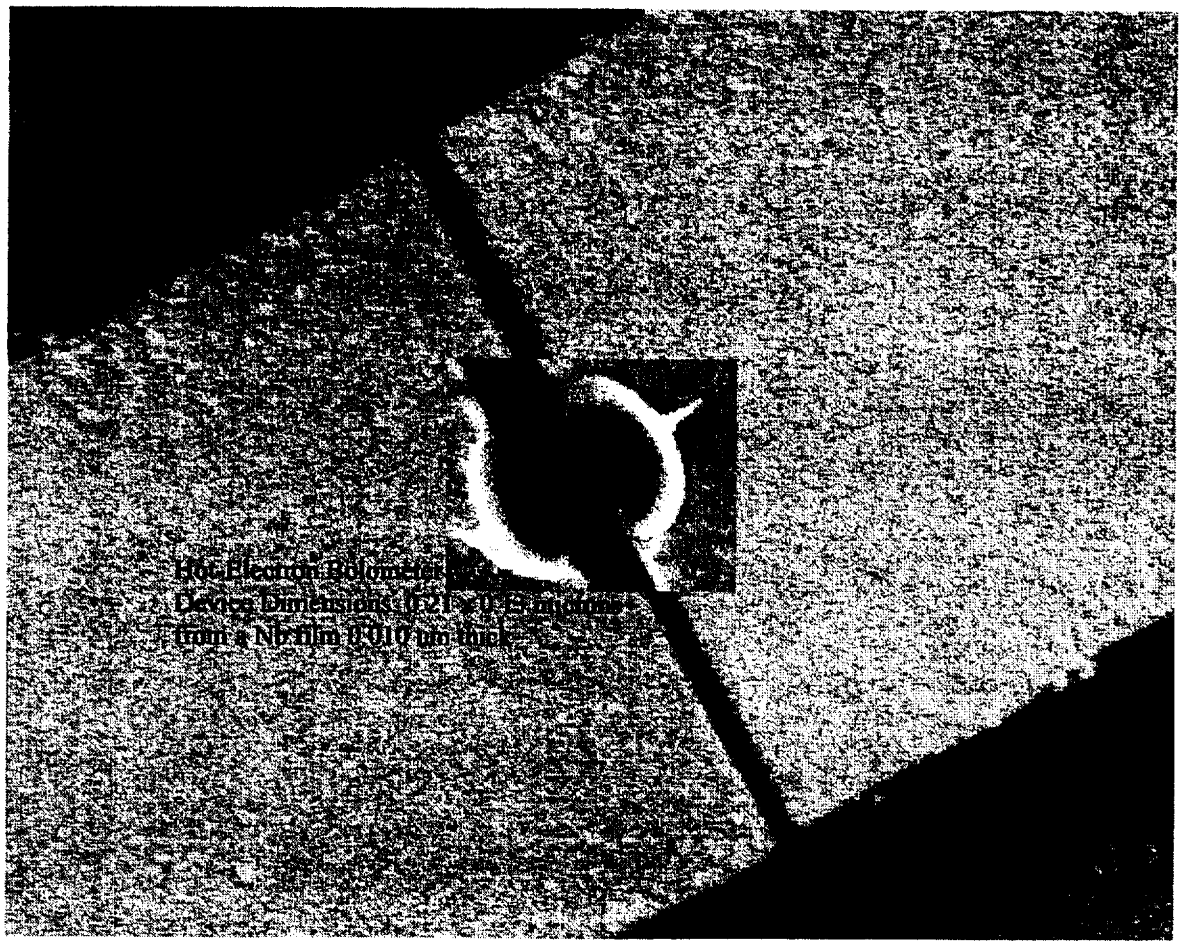

Fig. 2: A micrograph of a prototype hot-electron bolometer fabricated with the focused ion beam (FIB) etching system.

III. Proposed Research for the Second Year

Varactor Diode Research:

Emphasis will be placed on three topics; whiskered diodes for 1 THz and above, planar diodes for 320 GHz through 1 THz, and investigation of diode power handling and reliability issues. The following tasks will be emphasized.

- Investigate whisker-contacted varactor diodes for greater than 1 THz. Consider the diode design tradeoffs, consult with those who will build multipliers to use these devices (Zimmermann and Erickson), design the diode and fabricate a first batch of devices for 1 THz.

- Investigate the best results yet achieved with the 80/160 and 160/320 GHz doublers. Optimize the chip design and process technology and fabricate a new batch of each device for experimental evaluation. Begin design of the fabrication process for the first batch of 320/640 GHz planar balanced doubler chips.

- Begin life testing of the various planar varactor diodes that have already been fabricated. Draw conclusions on the suitability of these diodes for long duration space applications. Develop a plan to improve lifetime. This may include better anode plating, use of refractory metal anodes, better chip heat sinking, or other improvements.

- Implement methods to improve standard varactor lifetime. Continue life test experiments to verify improvements.

Superconductive Mixer Element Research:

- In the coming year this research will focus on the three major tasks begun in the first four months of the grant, i) HEB mixer elements, ii) FIB trilayer junctions, and iii) Nb/Al edge junction distributed mixer elements. Specific tasks to be accomplished include:

- Design a 1-2 THz HEB mixers for the first mask set. Begin process development and HEB fabrication.

- Collaborate with Chris Walker at the University of Arizona on a micromachined 1x4 integrated HEB array for the South Pole observatory.

- Develop an initial prototype of a focused ion beam fabricated trilayer junction. We anticipate an eventual process capable of insulating junctions as small as 0.2 um^2

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