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REVISED DRAFT of SIS fabrication proposal from JPL 10-29-98

The purpose of this revised concept paper is to update the cost plan and deliverables to reflect recent, preliminary cofunding commitments from SAO, CSO/OVRO, and FIRST/SOFIA. The combined level of effort and funding is deemed to be the minimum necessary to develop and maintain an optimized, routinely operating process for Nb-based mixers, and reflects a commitment to maintain a Nb capability at JPL. In the event that NRAO participation is not obtained, commitments for Nb-based mixers to the other sponsors will be met with current equipment and personnel on a best effort, time-available basis.

Objectives:

The objectives of this proposed task are to develop device processing for Nb-based SIS mixers based on NRAO-supplied designs for the 230 GHz and 650 GHz bands for the Design & Development (D&D) phase of the Millimeter Array, and to deliver mixers for a prototype 230 GHz receiver.

Technical Approach:

JPL will, on a best effort basis, work closely with the NRAO receiver development personnel, with mixer design and processing to be modified iteratively to meet the needs of the prototype receiver and to attain a sufficient level of confidence that the goals of the follow-on construction phase of the Millimeter Array can be achieved. It is estimated that 2 sets of mixers per year will be delivered to NRAO, each set of mixers to consist of 2 wafer runs from an optical photomask set (design to be supplied by NRAO in consultation with JPL), and DC testing data from each wafer run. JPL will supply all mixer materials, including substrates. Since this is a design & development effort for devices intended to operate together in an array of unprecedented size, and the initially-conceived mixer design requires several SIS junctions per mixer, it is recognized that device yield and uniformity (across a wafer and run-to-run) are issues which should be addressed in the D&D phase. The number of mixer sets and/or wafer runs may therefore be adjusted by mutual consent to allow additional process development or to obtain meaningful device statistics, with an accompanying possible adjustment in estimated costs.

NRAO will deliver to JPL optical photomask sets [wrong—NRAO just supplies the designs, JPL produces the masks]. JPL will utilize these designs and deliver to NRAO the fabricated mixer dies and DC testing data. NRAO will deliver to JPL high frequency test data on the fabricated mixers. JPL will deliver to NRAO quarterly technical progress reports in JPL format.

Mixer fabrication during the D&D phase will preferably utilize optical lithography and Si substrates. Utilization of quartz substrates and development of a low-dose e-beam process may also be pursued by mutual agreement. Alignment tolerances will be at least 0.5 micron for fabrication utilizing the stepper mask aligner, and at least 1.5 micron for fabrication utilizing the contact mask aligner. Wiring lines will have a minimum linewidth of 2 micron. SIS junction widths will be at least 0.8 micron. Junction diameters will be within ±5% of the design value for junctions sizes larger than1.2 micron, but for smaller junctions the size variation is unknown at present. The resistance of the resistors will be within ±10% of the design value. Jc will be within ±20% of the design value assuming that the target Jc is 1-10 kA/cm2. The I-V characteristics will be of good quality, with a gap voltage in excess of 2.8 mV, and a subgap to normal state resistance ratio of at least 8.

Personnel:

When fully staffed, the Nb-based SIS effort is planned for 2.3 workyears (WY) per year. This workforce includes two employees for equipment maintenance and mixer fabrication. One is currently working on the SAO task, which is assumed to continue for an additional 3 years beyond the end of the current contract end date of 11/99 at a level of approximately $200K/year. We also assume additional support of approximately $100K/year from CSO/OVRO to support Nb-based SIS efforts. The other person will be hired near the middle of FY'99. The workforce also includes technical direction by Dr. Henry LeDuc (0.1 WY/yr), task planning and reporting and personnel supervision by Dr. Richard Vasquez (0.1 WY/yr), and secretarial/administrative support (0.1 WY/yr). Finally, this plan assumes that the device designs and performance requirements of NRAO, SAO, and CSO/OVRO are sufficiently similar that the efforts are synergistic so that common device processing is possible. The level of effort
apportioned to each sponsor will be proportional to the funding supplied.

Facilities and Equipment:

The major part of JPL's mixer fabrication takes place in the Microdevices Laboratory (MDL). This facility includes a large (5500 square feet) clean room and general use equipment including optical lithography, electron beam lithography, a dielectric deposition system, a reactive ion etcher (RIE), a stepper mask aligner, acid and organic chemical processing. Diagnostic equipment includes a Zeiss optical microscope and a JEOL scanning electron microscope (SEM).

In addition to the shared equipment, the Superconducting Materials & Devices Group maintains in the MDL clean room an oxygen RIE for polymer etching and a dedicated UHV sputtering system for SIS junction fabrication. This load-locked system can accomodate up to 4-inch diameter wafers and has a base pressure less than 10^(-9) Torr. The system has four 3-inch diameter sputter sources, a gold evaporation source, and an ion mill. Near the beginning of FY'00, this system is expected to be completely converted to fabrication of NbTiN-based mixers. An additional system with equivalent capabilities dedicated to the fabrication of Nb-based mixers is therefore necessary for this task, and the purchase and installation of this new system during FY'99 is planned. As this is a major capital equipment item (~$500K), a loan to spread the cost over 5 years has been sought. The FIRST/SOFIA projects have verbally agreed to provide $100K towards the purchase of this system to meet their future!
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needs,
which are expected to be minor. The cost estimate below includes $80K/yr loan payback for the remaining cost of this system.

MDL also has general use equipment outside the cleanroom, including a second SEM for sample inspection, a dicing saw, and an aluminum wire bonder, as well as group equipment for DC characterization of devices at 4.2 K. The superconductivity group also maintains a lab in another building with UHV sputtering systems, two dielectric deposition systems, an RIE, and a general use contact mask aligner.

Cost Estimate (dollars expressed in thousands):

This is a rough order of magnitude estimate, meant to serve as a basis for discussion until details of the requirements are understood and agreed upon. It is assumed that this task will operate in conjuncttion and closely cooperating with other tasks utilizing Nb-based SIS mixers so that common processing can be utilized. It also assumes that a loan for the cost of a new deposition system can be obtained from the JPL capital equipment fund to spread the cost over 5 years. The period of performance is to be determined, for the purpose of this cost estimate the NRAO portion of the work is assumed to begin near the middle of FY'99 (~3/99) and continue through FY'01 (9/01).

	FY'99	FY'00	FY'01	Total
Workyears	1.7	2.3	2.3	6.3
SAO	$200K	$200K	$200K	$600K
CSO/OVRO	$100K	$100K	$100K	$300K
NRAO	$270K	$385K	$395K	$1050K
Totals	$570K	$685K	$695K	$1950K

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FY99 + FY00 + 1/4 FY01 = NRAO 99 + 00 = calendar 99 + 00

$754K requested

vs. $485K budgeted

shortfall $269K