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Status of Direct Detector and Array Development

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Programs are now underway to develop and demonstrate the detector/array technology needed for the Space Infrared Telescope Facility (SIRTF) [1], LDR, and other future NASA missions. The development goal is to achieve focal plane sensitivities, at extended integration times over the 2-700 μm range, limited only by the low astrophysical backgrounds encountered in cryogenic telescopes such as SIRTF. In a coordinated and cooperative manner, developments are now being carried out by the SIRTF instrument definition teams, with funding from the Office of Space Science and Applications (OSSA), and with advanced technology funding through the Office of Aeronautics and Space Technology (OAST). The former program is coordinated between the three SIRTF conceptual instrument teams, and the efforts are focused toward the requirements and scientific goals of the proposed instruments. The OAST IR astrophysical detector program aims to provide a general base from which a number of instrument and system technologies can be drawn. The OAST projects take a longer view, and represent more speculative approaches for potential future applications. In some cases the projects are co-sponsored by OAST and OSSA, to support baseline SIRTF instrument technologies. (In addition to work on basic detector materials and their associated cryogenic preamplifiers and multiplexing readouts, the SIRTF program also supports development of beamsplitters, specialized cryogenic mechanisms, and adiabatic demagnetization refrigerators.) The NASA programs fund selected technology developments, and in addition support a number of groups in the scientific community to carry out the detailed laboratory characterizations necessary before optimized devices and well-conceived instruments can be achieved for SIRTF. By striving to meet SIRTF goals, these programs are accumulating important experience which will be of substantial benefit when LDR instruments are designed. The SIRTF detector development program has been nicely summarized [2]; the following remarks on the OSSA work draw heavily on this description.

As is indicated in the TABLE 1, the OSSA-sponsored SIRTF Technology Program involves work on a range of intrinsic and extrinsic IR detectors and arrays, and for >200 μm, small arrays of bolometers. The <30 μm arrays utilize switched-MOSFET multiplexers, and have in general been shown to have very good low-background performance: read noise at or below the 100 e^- level, good responsivity, and dark currents at and below the 100 e^-/s level. Complementary work on optimized detector materials [Si:x and Ge:x, in both bulk photoconductive and impurity band conduction (IBC) forms] and JFET integrators for smaller, higher-sensitivity arrays has been similarly successful. The work in the range of direct LDR interest, $\lambda > 30$ μm, includes further characterization of extrinsic Ge materials, and development of suitable schemes to apply stress to Ge:Ga and package relatively small Ge:Be and Ge:Ga arrays, and a Ge:Ga IBC project at Rockwell

TABLE 1. SIRTF Detector Technology Program [2]

Wavelength	SIRTF Instrument		
	IRAC	IRS	MIPS
2 - 7 μm	InSb,Si:In 58x62 UR	InSb 58x62 UR	Si:In UA
4 - 30 μm	Si:Ga 58x62 GSFC	Si:As BIB 10x50 CU	Si:Ga Si:Sb Si:B UA
	Si:Sb 58x62 ARC[1]	Si:Sb 58x62 ARC[2]	Si:As RIBIT UCB[1]
28 - 120 μm	---	Ge:Be 2x25 CIT	Ge:Ga 1x16 UA
		Ge:Ga 2x50	Ge:Ga MATERIALS Ge:Be TEST UCB[2]
		Ge:Ga BIB CIT	Ge:Ga BIB JPL
114 - 200 μm	---	STRESSED Ge:Ga 1x20 CIT	STRESSED Ge:Ga UCB[2]
200 - 700 μm	---	---	Ge Bolometers UCB[2]

Notes:

1. ARC (1.McCreight, 2.Roellig) CIT (Watson) CU (Herter)
   GSFC (Gezari) JPL (Beichman) UA (Young)
   UCB (1.Arens, 2.Richards) UR (Forrest)

2. See page vii and following for explanation of unfamiliar acronyms and abbreviations.

and Caltech. This latter effort has been making substantial progress lately (viz. detection at 200 μm and promising quantum efficiency with a non-optimum device). The IBC technology has the potential of eliminating the stressed detectors and significantly improving sensitivity, both for SIRTF and LDR.

The OAST program [3] provides support for a number of the items mentioned above. In addition, work on the development and characterization of the Rockwell Si:As solid-state photomultiplier, various IBC arrays in Si:As (Rockwell 10 x 50 and 1 x 10, Hughes 20 x 64, Aerojet 16 x 32) and Si:Ga (Hughes 58 x 62), and SBRC 58 x 62 InSb arrays are, or shortly will be, underway. A 1 x 8 test Ge:Ga array has been built at Aerojet, and is now under test in the Ames lab. A prototype GaAs JFET was recently found to have good noise characteristics at 4.2 K. Within the next few months development projects on improved low-noise multiplexers and improved $\geq 30\ \mu m$ arrays should be initiated.

While these programs have produced devices and low-background data which approach (and in some cases already meet) SIRTF goals, significant additional work, particularly in the areas of imaging properties and the effects of energetic particles, is needed.

To summarize, dramatic progress has been made in the last two to three years in integrated array and detector systems for low-background astronomical applications. With the broadly based developments and laboratory characterizations now underway for SIRTF and similar space applications, coupled with the rapidly expanding art and science of ground-based astronomical imagery with arrays [4], the potential for effective utilization of arrays on LDR appears to be very good, provided that support is available to (a) adapt and optimize directly relevant technologies from SIRTF, and (b) pursue new developments for specific LDR needs (e.g., larger Ge:x arrays designed for higher background operation).

References:

1. M.W. Werner, J.P. Murphy, F.C. Witteborn, C.B. Wiltsee, Proc. Soc. Photo-Opt. Instrum. Engineers, 589, 210 (1986).

2. J.R. Houck, "Infrared Detectors for Space Applications," Proc. Workshop on Ground-Based Astronomical Observations with Infrared Array Detectors (C.G. Wynn-Williams and E.E. Becklin, eds.), 108 (1987).

3. C.R. McCreight, M.E. McKelvey, J.H. Goebel, G.M. Anderson, J.H. Lee, Proc. Soc. Photo-Opt. Instrum. Engineers, 686, 66 (1986).

4. C.G. Wynn-Williams and E.E. Becklin, eds., Proc. Workshop on Ground-Based Astronomical Observations with Infrared Array Detectors (1987).