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DESIGN AND STATUS OF THE DETECTOR BLOCK FOR THE ISO-SWS

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Introduction

The SWS is one of the two spectrometers for the Infrared Space Observatory ISO. It consists of a pair of grating spectrometers and a Fabry-Pérot interferometer. Together, the grating spectrometers cover the wavelength range 2.4-45 μm, at a resolution between 1000 and 2000. The Fabry-Pérot interferometer, in series with one of the grating spectrometers, provides a resolution of about 20,000 at the wavelengths between 15 and 35 μm [1]. The SWS is being built by the Space Research Organization of the Netherlands and the Max Planck Institute for Extraterrestrial Physics in Garching, Germany.

The spectrometer has 52 discrete detectors, most of which are bulk detectors. In the design of the spectrometer, the main emphasis is on the sensitivity of the individual channels, rather than on the number of detectors. This was one of the main reasons to select non-destructive read-out circuits, with a separate heated-JFET pre-amplifier for each individual detector. The signals are amplified and filtered in parallel.

At the time of writing of this paper, the engineering tests on the SWS detector block have not yet been completed. This paper describes the design of the detector block and indicates the present problem areas.

Detector configuration and detector block design

The spectrometer consists of two sections, each with its own output. One section is a grating spectrometer for the wavelengths below 13 μm, with 12-element InSb and Si:Ga arrays at its output; the second section is a grating spectrometer for the wavelengths above 12 μm, with 12-element Si:P and Ge:Be arrays. A pair of Fabry-Pérot interferometers at the output of the long-wavelength sections has pairs of Si:P and Ge:Be detectors. The detector configuration is described in Table I.

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Type	Range	Dimensions	Spacing	FOV/det
12 x InSb	2.4 - 4 μm	120 x 120 μm	50 μm	7.5" x 20"
12 x Si:Ga	4 - 13 μm	120 x 120 μm	50 μm	7.5" x 20"
12 x Si:P	12 - 28 μm	370 x 280 μm	50 μm	10" x 20"
12 x Ge:Be	28 - 45 μm	450 x 450 μm	100 μm	12" x 32"
2 x Si:P	14 - 26 μm	200 x 700 μm	100 μm	11.4" x 40"
2 x Ge:Be	22 - 38 μm	300 x 700 μm	100 μm	17.2" x 40"

Table I: SWS detector configuration

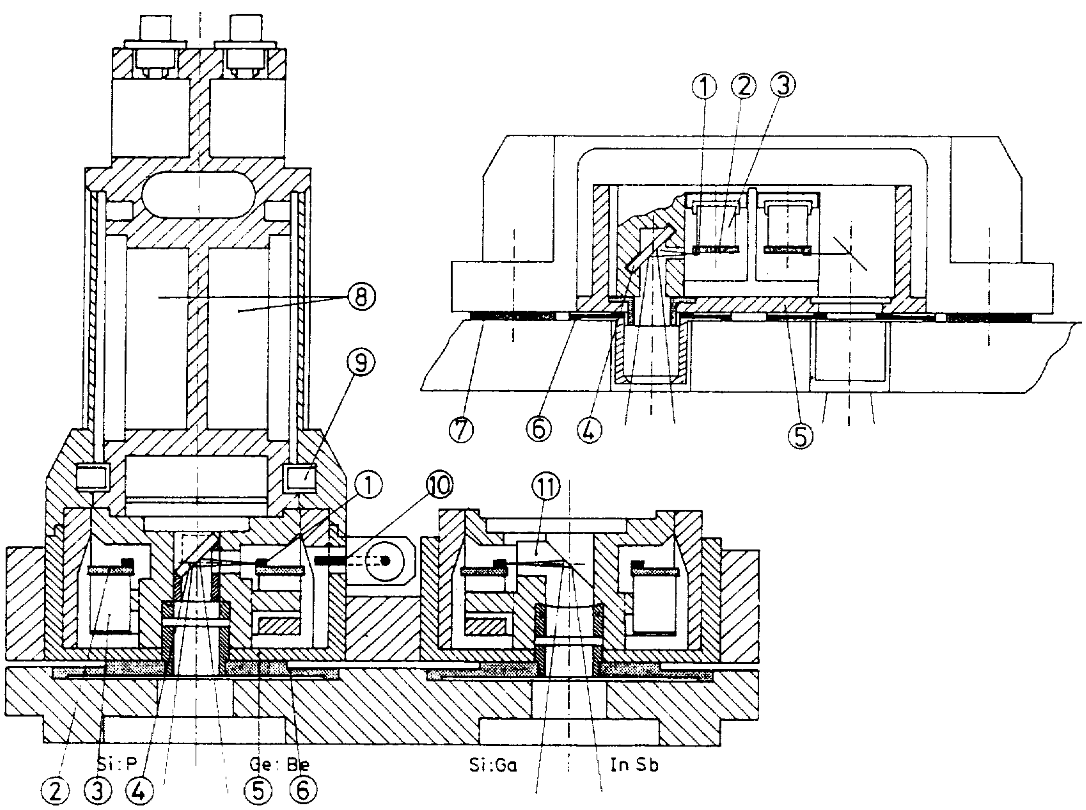

Figure I. Cross sections of the grating detector block and the Fabry-Pérot detector block (upper right). The dispersion is perpendicular to the plane of the drawing.

1 detectors, 2 detector substrate with heater and temperature sensor, 3 stainless-steel leaf springs for thermal insulation, 4 reflection filter, 5 high-Z shield, 6 light baffle, 7 electrically insulating mounting pads, 8 heated-JFET compartment, 9 light barrier, 10 helium tank strap, 11 ZnSe lens with total reflection.

The detector block consists of two different parts. One part stradles the two grating sections and contains all four 12-element arrays. The second part contains the two detector pairs for the Fabry-Pérot exits. Schematic drawings of these different parts of the detector block are given in Fig. 1.

The detector block will be mounted on a structure with a temperature of about 3.5 K. A strap to a 1.8-K heat sink is available for those detectors that need a lower operating temperature, in this case the Ge:Be detectors.

For each array independently the temperature is controlled by means of heaters on the substrates, counteracting the heat flow towards the telescope structure or through the 1.8-K strap (Fig. 1a, item 10, ≈ 30 μW/K at 4 K, with sufficient optical stability). The heaters can also be used to give a thermal pulse to anneal detectors after a satellite passage through a radiation zone.

For EMC reasons, the detector block is insulated electrically from the spectrometer and from the telescope structure.

Around the detectors, a shield of 2 mm high-Z material and 1 mm aluminium in all directions minimizes the effect of ionizing particle radiation (mainly trapped high-energy electrons).

A light baffle between the detector and amplifier compartments prevents leakage of IR radiation to the detectors. In the engineering model, the light-tightness of other baffles turned out to be insufficient, so that the baffle design is being improved.

Detector read-out

The arrays are read out with 12-channel units, the Fabry-Pérots with single pre-amplifiers, all procured from Infrared Laboratories in Tucson, Arizona. Some properties are listed in Table II.

	IA-12	JF4
Gain	≈ 0.8	0.8 - 0.9
Input capacitance	3.5 - 4 pF	7.5 - 8 pF
Output impedance	100 - 200 kΩ	80 kΩ
Read noise (1-10sec)	30 - 50 e^-	20 e^-
DC levels	< 40 mV	-
Channels per unit	12	1

Table II. Properties of the heated-JFET pre-amplifiers

The units passed vibration tests at room temperature and at liquid-nitrogen temperature, at the vibration levels specified for the spectrometer.

Modelling, confirmed by testing, indicates that the high output impedances of the pre-amplifiers do not present a problem with the EMC specifications set for ISO.

The on-board signal processing is shown schematically in Fig. 2. An AC amplifier with a cut-on frequency of 0.1 Hz is employed to handle the DC offsets of the pre-amplifiers. The gain of 50 in the first amplifier stage is consistent with the expected magnitude of the offsets. To minimize these offsets, the individual pre-amplifiers used with the Fabry-Pérots have trimming capacitors. The transfer characteristic is consistent with the expected spike rates of one per 10 or 100 sec.

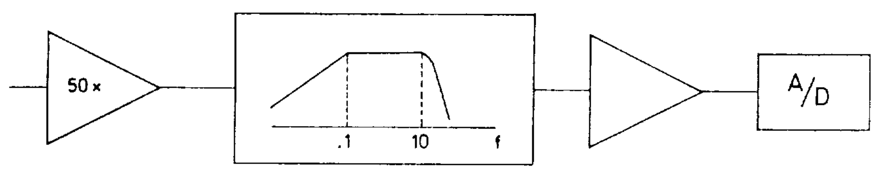

Figure 2. Transfer characteristic of the warm detector-signal amplifiers.

Detector status

A sample of the low-capacitance type InSb detectors from Cincinnati Electronics Corp. showed a responsivity of 1.7 - 2 A/W and a dark current of less than 100 e^-/s. Irradiation with a Co-60 source caused an increase in the dark current, but the responsivity changed only slightly. The capacitance is about 5 pF for the size given in table I. The cross-talk, measured with a trans-impedance amplifier, is about 0.1%.

The other detector types are being supplied by the Battelle Institute in Frankfurt, Germany.

The engineering version of the Si:Ga array has a responsivity of about 3 A/W and a dark current of 100 - 300 e^-/s. Neither of these values depends much on temperature. The observed cross-talk is less than 3%.

The Si:P engineering array has a responsivity of 2 to 3 A/W and a dark current of 10 - 100 e^-/s. Both a thermal pulse and a bias boost resulted in considerable reduction of the dark-current time constant after irradiation with a Co-60 source. In other units spontaneous spiking has been observed, which could be remedied by increasing the operating temperature.

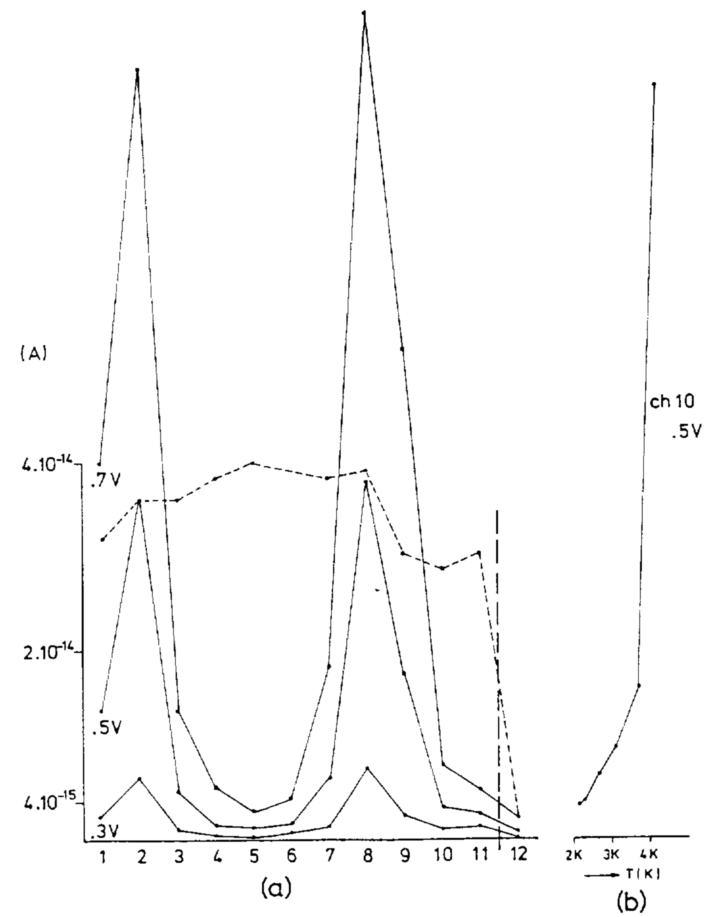

Figure 3. Dark currents in a 12-element Ge:Be array at bias voltages of 0.3, 0.5 and 0.7 V. The dashed line indicates the relative responsivities (channel 12 was not operative). Fig. 3b shows the temperature-dependence of the dark current in one of the detectors.

The main problem comes with the Ge:Be array. A large scatter in dark currents is observed (see Fig. 3). Lowering the temperature to 1.8 K (which would mean a significant thermal re-design) and reducing the bias voltage will help but are not sufficient to solve this problem. Selecting the best parts of the available material, even of manufactured arrays, may solve this problem.

1. De Graauw Th., et al., 1987, Proc. of the Workshop on Groundbased Astronomical Observations with Infrared Array Detectors, p438