DP/PS(77)22

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Sun-Earth Observatory and Climatology Satellite

INSTRUMENT DEFINITION

SOLAR FLUX SPECTROMETER

BY

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Bruxelles

Paris, June 1977

S E O C S INSTRUMENT DEFINITION

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I. Scientific aims

The solar spectrometer is proposed to measure the solar irradiation flux between 160 and 3500 nm in order to determine very accurately the spectral distribution of the incoming solar radiation. Such an instrument should also be able to study the temporal variability of the solar irradiation fluxes during the different solar activity cycles. The measurements require a precision better than 1% in the ultraviolet and of the order of 0.1% in the visible. In addition, ozone altitude profiles between 20 and 50 km can be determined measuring the earth backscattered ultraviolet sunlight between 250 and 350 nm.

II. Spacecraft constraints

The proposed instrument has to take into account the spacecraft characteristics which have been defined in the document ref. TF/GD/dr/6033. The three following points should be reminded for the solar spectrometer :

a) the orbit altitude is 1150 km
b) the principal pointing mode is toward the nadir direction, nearly contineously
c) A secondary pointing mode toward the sun is required for direct solar observation and for calibrations, with a frequency of the order of once per week.

the exit slits have the same width defining a triangular slit function with a FWHM of 1 nm for the ultraviolet and the visible spectrometers and of 10 nm for the infrared spectrometer. The wavelength range is scanned by means of 700 step in order to obtained one measurement per nm in the visible part of the solar spectrum.

III.2. Detectors

The detectors for the ultraviolet and the visible spectrometer are photomultipliers tubes with a RbTe and a GaInAs photocathode respectively. Both use a photon counting detection system. The infrared spectrometer detector is a PbS photoconductive cell with a synchroneous detection system. Fig. 3, 4 and 5 show the sensitivity of the detectors in function of wavelength.

III.3. Mechanical mounting

An example of the arrangement of the three spectrometers with the electronics is shown in fig. 6. The three spectrometers can be permuted following the needs but the three entrance slits must stay aligned. The dashed slits show the other possible solutions in the mechanical mounting. The distance between the entrance slits of two different spectrometers could be 50, 100, 150 or 250 mm.

IV. Calculation of the recored signal

IV.1. Sun pointing mode

During the sun pointing mode, a grind is placed at the entrance slit of each spectrometer in order to avoid any measurement errors coming from pointing inaccuracies. Such a grind allows a pointing accuracy of $\pm 2'$ and a pointing stability of $\pm 0.5'$. The field of view of the spectrometer should be a least $6'$. The signal due to the sun is computed by means of the following equation :

TABLE 2.-

UV Spectrometer — Solar Irradiance Measurements

Wavelength nm	Solar flux $h\nu.sec^{-1}.cm^{-2}.nm^{-1}$	Detector Q.E. $el.h\nu^{-1}$	Sun Signal $count.sec^{-1}$
160	1.00×10^{10}	0.08	1.1×10^{3}
250	8.39×10^{12}	0.09	1.1×10^{6}
300	6.71×10^{13}	0.01	9.6×10^{5}
350	1.92×10^{14}	5×10^{-4}	1.4×10^{5}

Slit surface = 3×10^{-3} cm^2 (0.3 mm width)

optics transmission = 5×10^{-2}

grind transmission = 0.5

bandpass = 1 nm

grating solid angle = 6×10^{-2} sr

TABLE 4.-

IR Spectrometer — Solar Irradiance Measurements

Wavelength nm	Solar flux $Watt.cm^{-2}.nm^{-1}$	Responsivity* $volt.watt^{-1}$	Sun Signal µ Volt
900	8.9×10^{-5}	1.1×10^{5}	540
1000	7.5×10^{-5}	4×10^{5}	1650
2000	1.0×10^{-5}	9.3×10^{5}	510
2500	5.5×10^{-6}	1×10^{6}	300
3000	3.1×10^{-6}	2.8×10^{5}	48
3500	1.5×10^{-6}	6×10^{3}	0.5

Slit surface = 3×10^{-2} cm^2 (0.3 mm width)
optics transmission = 5×10^{-2}.
grind transmission = 0.5
bandpass = 10 nm
grating solid angle = 2.3×10^{-2} sr

* for detector surface = 1 mm^2
chopping frequency = 780 Hz
electrical bandwidth = 1Hz
load resistor = 1 M Ω
detector resistor = 1 M Ω

TABLE 5.-

Earth Radiance Measurements

Wavelength nm	Earth radiance $h\nu.sec^{-1}.cm^{-2}.nm^{-1}.sr^{-1}$	Detector Q.E. $el.h\nu^{-1}$	Earth signal $count.sec^{-1}$
250	1.25×10^{9}	0.09	6×10^{3}
280	1.4×10^{10}	0.035	2.6×10^{4}
300	1.5×10^{11}	0.01	7.8×10^{4}
320	1.6×10^{13}	2×10^{-3}	1.7×10^{6}
350	1.8×10^{13}	5×10^{-4}	4.8×10^{5}

Slit surface = 3×10^{-2} cm^2

optics transmission = 3×10^{-2}

bandpass = 1 nm

earth solid angle = 0.035 sr (for a f.o.v. of 12˚).

the telemetry capacity should be of the order of 100 bits/sec or 200 bits/sec if the scanning rate is doubled. Analog output are needed for temperature and high voltage measurements. Two telecommand signals are required for the experiment set-up and for the deployable diffusers.

VII. Calibrations

The absolute accuracy of the solar irradiance measurements depends on the radiometric standards available for laboratory calibrations. The present status for the currently available irradiance standards gives an accuracy of 5% in the ultraviolet, 1% in the visible and 1 to 2% in the infrared. The relative accuracy depends mainly on the the instrument definition. For instance, 0.1% of relative accuracy in the visible part of the solar spectrum requires 10^6 counts per step. This means that the integration time for each measuring step should be of the order of 1 sec. One complete duty cycle will take therefore 700 sec.

One of the most important problem in orbit with such an instrument would probably be the aging effects on the diffuser reflectivity, the grating efficiency and the filter transmission for instance. These degradation problems could be overcome by means of an in-flight calibration, using the spectropyranometer filters and the pyrheliometer during the sun pointing mode. In addition, as a similar instrument is actually developped for the first spacelab payload, cross-calibration by means of a spacelab-borne instrument could also solve any aging effects in the global sensitivity of the instrument. The Spacelab experiment n° 1ES 016 is shortly described in the annex A of this report.

VIII. Interface parameters

The interface parameters are given in the annex B.

ANNEX A

Solar spectrum from 190 to 4000 nm

First Spacelab Payload - Experiment n° 1ES016

by

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Abstract

The purpose of the proposed experiment is the measurement of the spectral irradiance of the sun between 190 and 4000 nm in order to determine with accuracy the solar constant, its possible variation with the solar cycle and the wavelength range responsible of the observed variations.

Three different spectrometers will be constructed; one to measure the solar irradiance between 190 and 350 nm with 1 nm band-pass; the second to measure the solar irradiance between 300 nm and 1100 nm with 1 nm band-pass; the third to measure the solar irradiance between 1000 and 4000 nm with 10 nm band-pass.

An in-flight calibration is foressen.

This objective requires measurements over very long time period (10 years) involving flights of the same instrument on further Spacelab mission. Time of measurements for each flight can be short (4 to 12 hours).

The final accuracy of the instrument depends upon the absolute accuracy of the available standards like transfer sources and/or detectors. The precision of measurement only depends upon the design of the instrument for which each sub-system is designed to have an accuracy better than 0.1%.

The proposed instrument is able to have a final accuracy better than the one of the standards available at the present time. But, this instrument is potentially able to follow any improvement of calibration standards as expected.

Only few spectral solar irradiation measurements from the near UV to the near IR have been performed. The most extensive works are those of Labs and Neckel (1970), Arvesen et al. (1969) and Thekaekara (1970). These measurements were obtained by means of spectrometer on board of aircraft or from high altitude observatories. In all, corrections for atmospheric absorption have been applied to deduce the solar constant. Comparison of these data shows discrepancies mainly in the UV part of the solar spectrum. Measurement outside the atmosphere over the extended period of time should improve the accuracy and the precision of such measurements, eliminating absorption correction for ground based and plane experiments and its possible variability related with atmospheric phenomena. The Space Shuttle seems quite adequate for such new measurements mainly because it allows pre and post-flight calibration of the experiment and also in-flight calibrations.

II. Description of the instrument

The instrument consists of three different parts :

- dispersive elements
- in-flight calibration device
- detectors and counting

2.1. Dispersive elements

The wavelength range 190 - 4000 nm of the solar spectrum is studied by mean of three spectrometers.

	Range	Bandpass	grooves/mm
UV	190 - 350 nm	1 nm	3600
Visible	300 - 1100 nm	1 nm	1800
IR	1000 - 4000 nm	10 nm	400

In Fig. 1, the basic instrument is represented. It is a double monochromator using a grating as a dispersive element (halographic from Jobin Yvon). The two gratings are mounted on the same mechanical axis in order to provide an high accuracy of the bandpass. The input window is constituated by a grind which reduces the effect of an angular variation ($\pm$ 2.5°) between the optical axis and the sun. Colored glasses are used to erase order 2. For the three spectrometers, the rotation angle of the two gratings in cascade is 31°. Therefore, the three sets of gratings rotate on the same axis. The total rotation is made by 750 steps. Each step is defined with 2" accuracy which is made by an analog command of a DC torque motor (Aeroflex). To avoid

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ANNEX B

Interface Parameters for the Solar Spectrometer

Mass : 20 kg

Dimensions : 50 x 25 cm, 30 cm depth

Field of View : 180° complete cone

Mounting location requirements : pointing the earth

Power (continuous) : 6 watts

Telemetry (b/s) - sampling pattern : 200 b/s

Telecommand : 2 powers, 2 serial words

Attitude control requirements (earth and sun) :

- accuracy : $\pm$ 2°
- stability : $\pm$ 0.5°
- attitude reconstitution accuracy : $\pm$ 0.25°

Orbit requirements (altitude, circular or not, inclination) : NA

Orbit knowledge : as for pyranometer for ozone measurement, not critical for solar irradiation measurement

Thermal control : 15° $\pm$ 5°C

Stability : 1°/12 min

Chemical sensitivity : TBD

Chemical emission : TBD

Sensitivity to radiations (detectors) : TBD

Potential hazards (pyrotechnics) : TBD

Deployable devices : diffusers

Mechanisms : filters, gratings, depolariser, grind, slits, shutter

Operation : duty cycle 700 sec

FIGURE CAPTIONS

Fig. 1.- Optical schema of the basic spectrometer
S_1, S_2, S_3 = entrance, intermediate and exit slits
M_1, M_2 = plane mirrors
G_1, G_2 = gratings
The dimensions are in mm.

Fig. 2.- Optical schema of the basic spectrometer
S_1, S_2, S_3 = entrance, intermediate and exit slits
M_1, M_2 = plane mirrors
G_1, G_2 = gratings
The dimensions are in mm.

Fig. 3.- Quantum efficiency in function of wavelength for a PMT with a RbTe photocathode.

Fig. 4.- Quantum efficiency in function of wavelength for a PMT with a GaInAs photocathode.

Fig. 5.- Detectivity in function of wavelength for a PbS photoconductive cell.

Fig. 6.- Schema of the solar flux spectrometer without the deployable diffuser. The dimensions are in mm.

Fig. 7.- Schema of the solar flux spectrometer including the deployable diffuser. The dimensions are in mm.

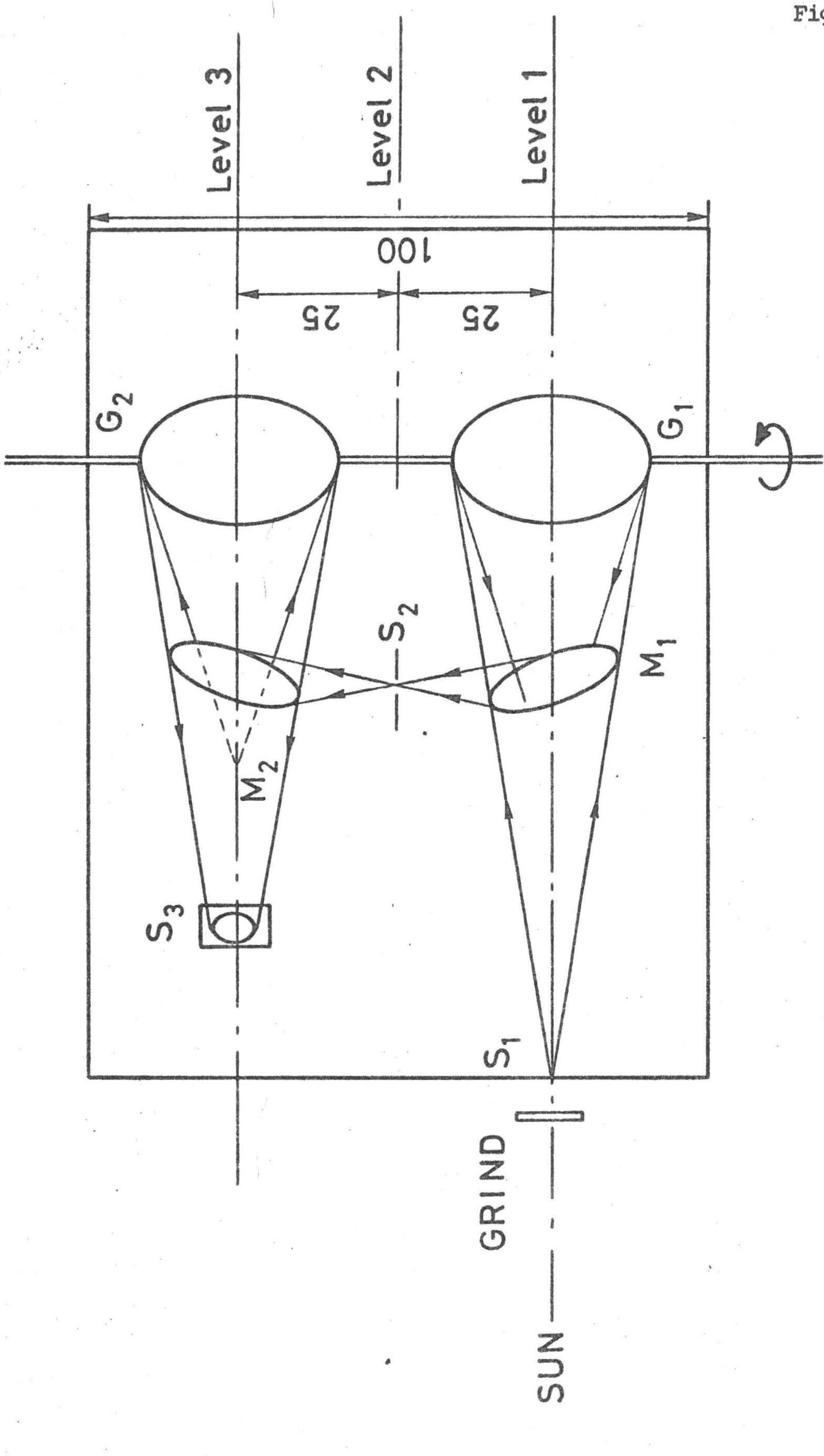

Figure 1.

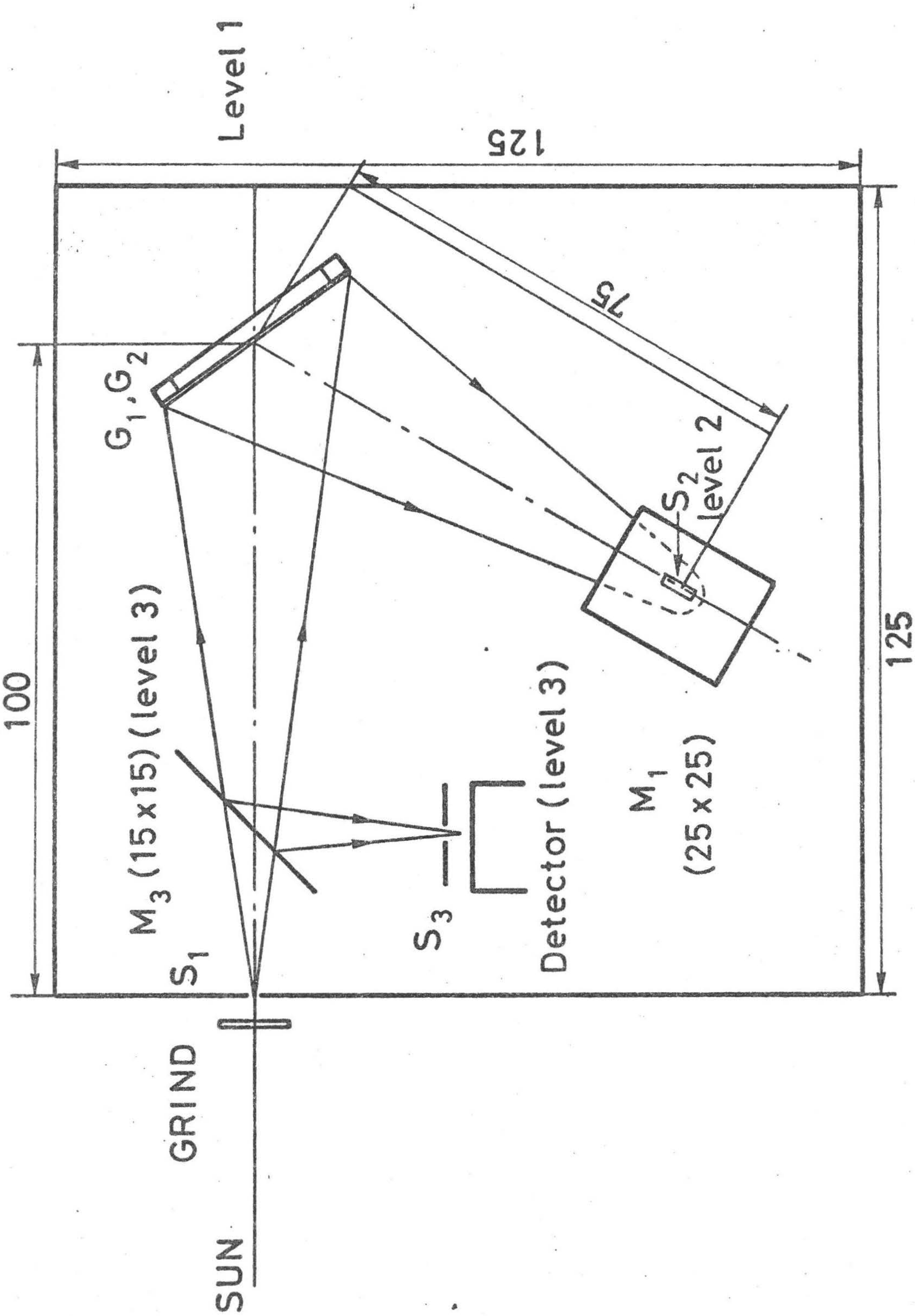
Level 1
125
75
G_1, G_2
S_2
level 2
100
M_3 (15 x 15) (level 3)
Detector (level 3)
M_1
(25 x 25)
S_3
S_1
GRIND
SUN
125

Figure 2.

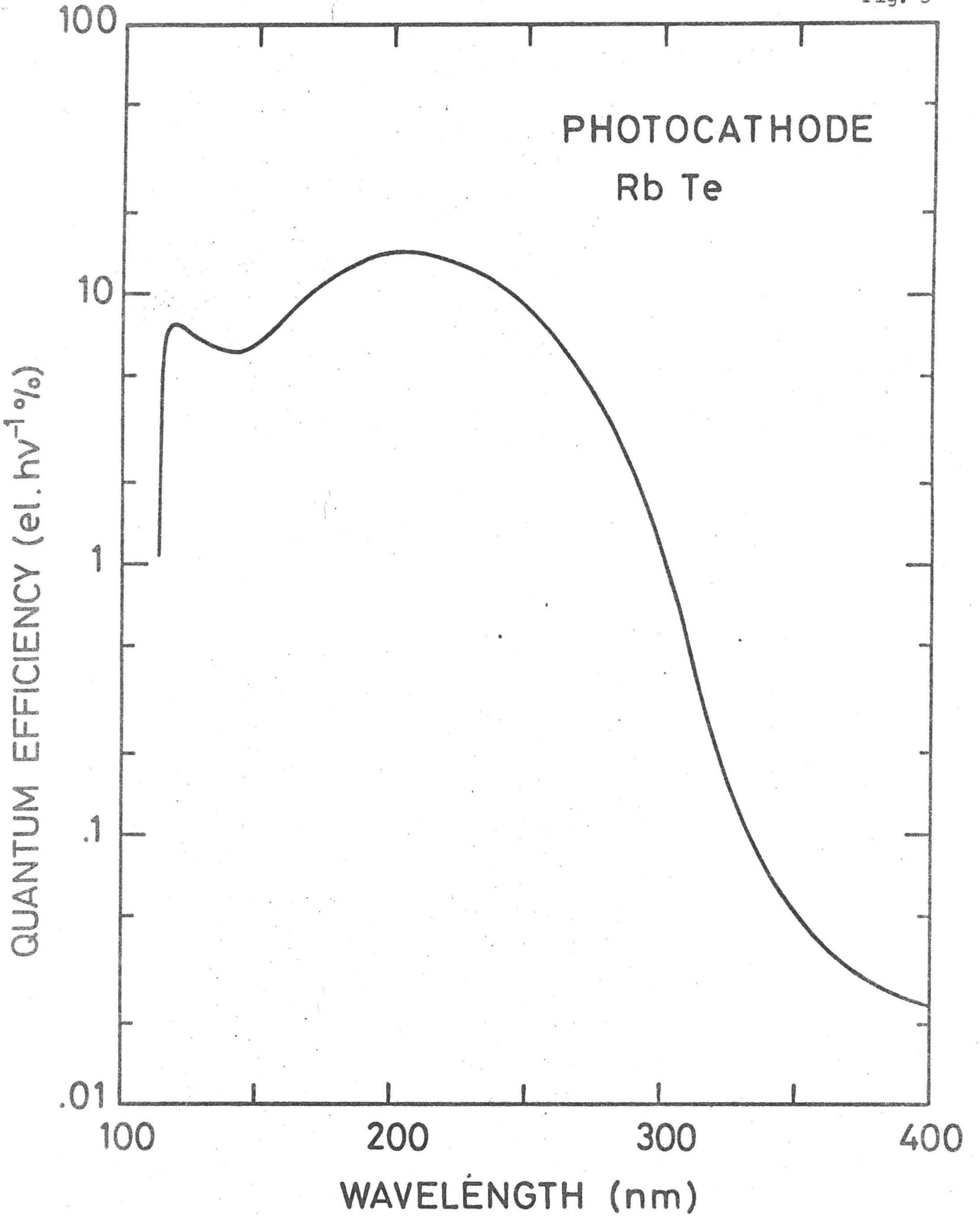
PHOTOCATHODE
Rb Te
100
10
1
.1
.01
QUANTUM EFFICIENCY (el.hv⁻¹%)
100
200
300
400
WAVELENGTH (nm)

Figure 3.

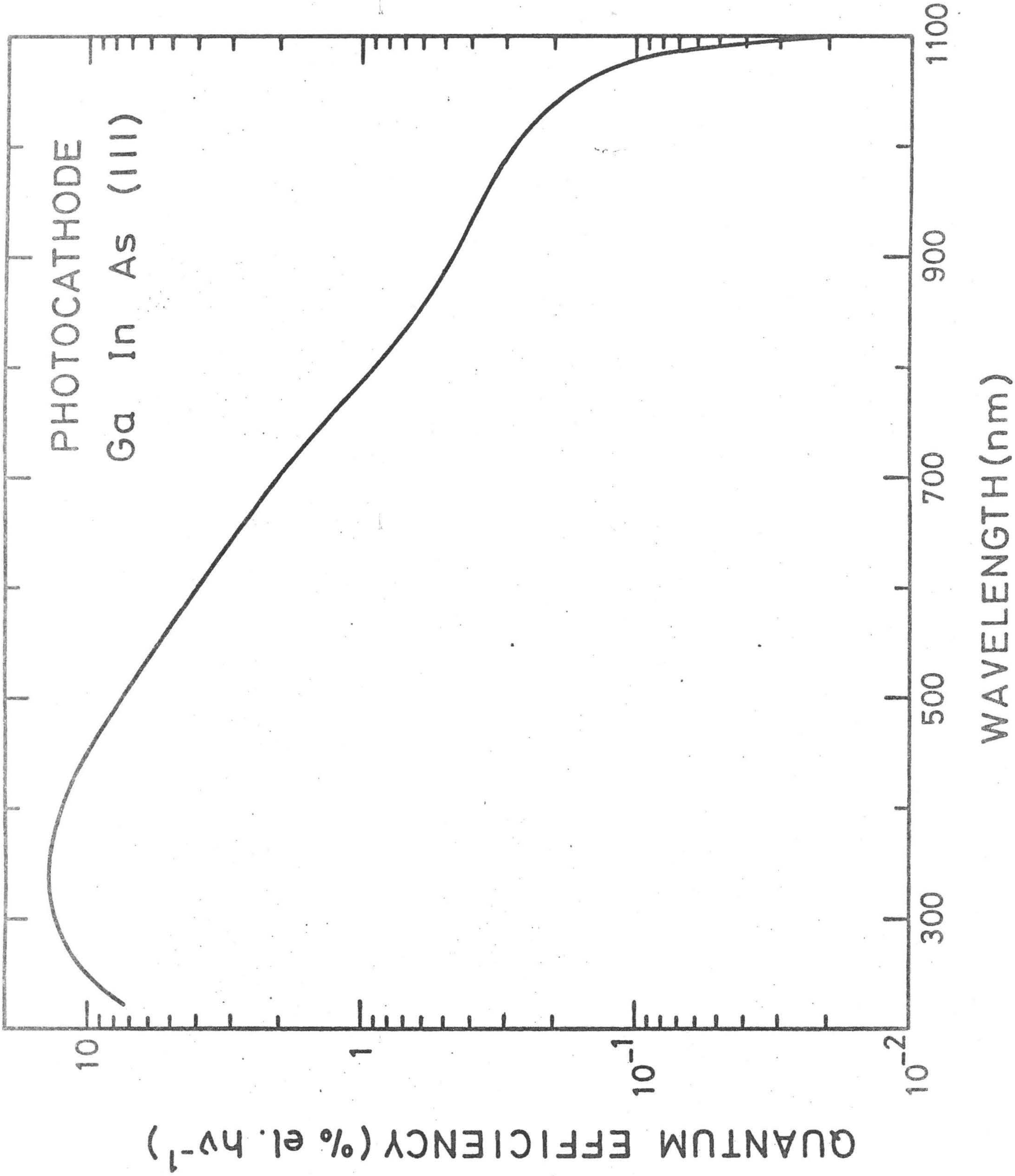
PHOTOCATHODE
Ga In As (III)
WAVELENGTH (nm)
300
500
700
900
1100
10
1
10^{-1}
10^{-2}
QUANTUM EFFICIENCY (% el. $h\nu^{-1}$)

Figure 4.

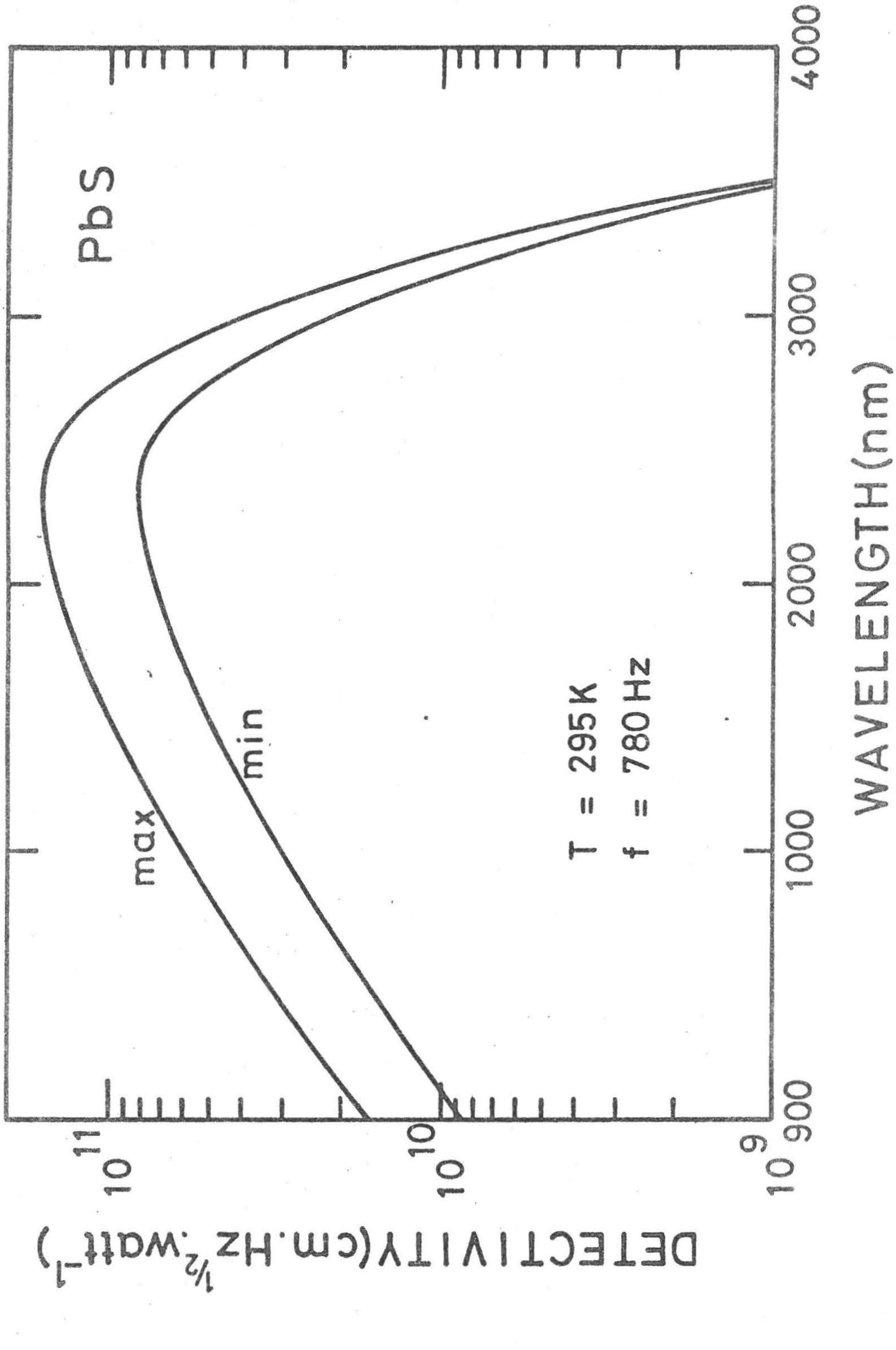
PbS
max
min
T = 295 K
f = 780 Hz
WAVELENGTH (nm)
900
1000
2000
3000
4000
DETECTIVITY (cm.Hz½.watt⁻¹)
10¹¹
10¹⁰
10⁹

Figure 5.

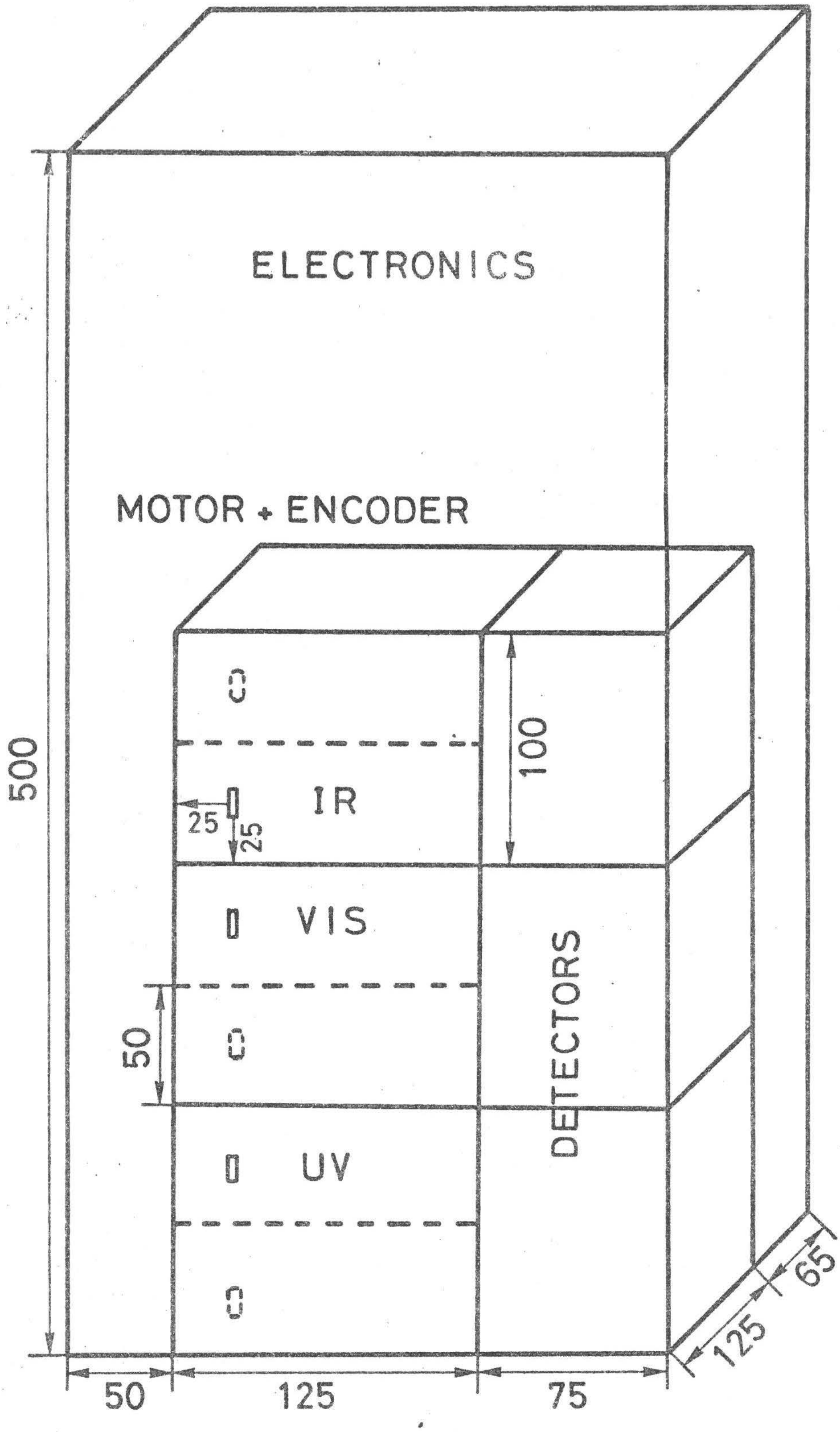
ELECTRONICS
MOTOR + ENCODER
IR
VIS
UV
DETECTORS
500
100
50
25
25
50
125
75
125
65

Figure 6.

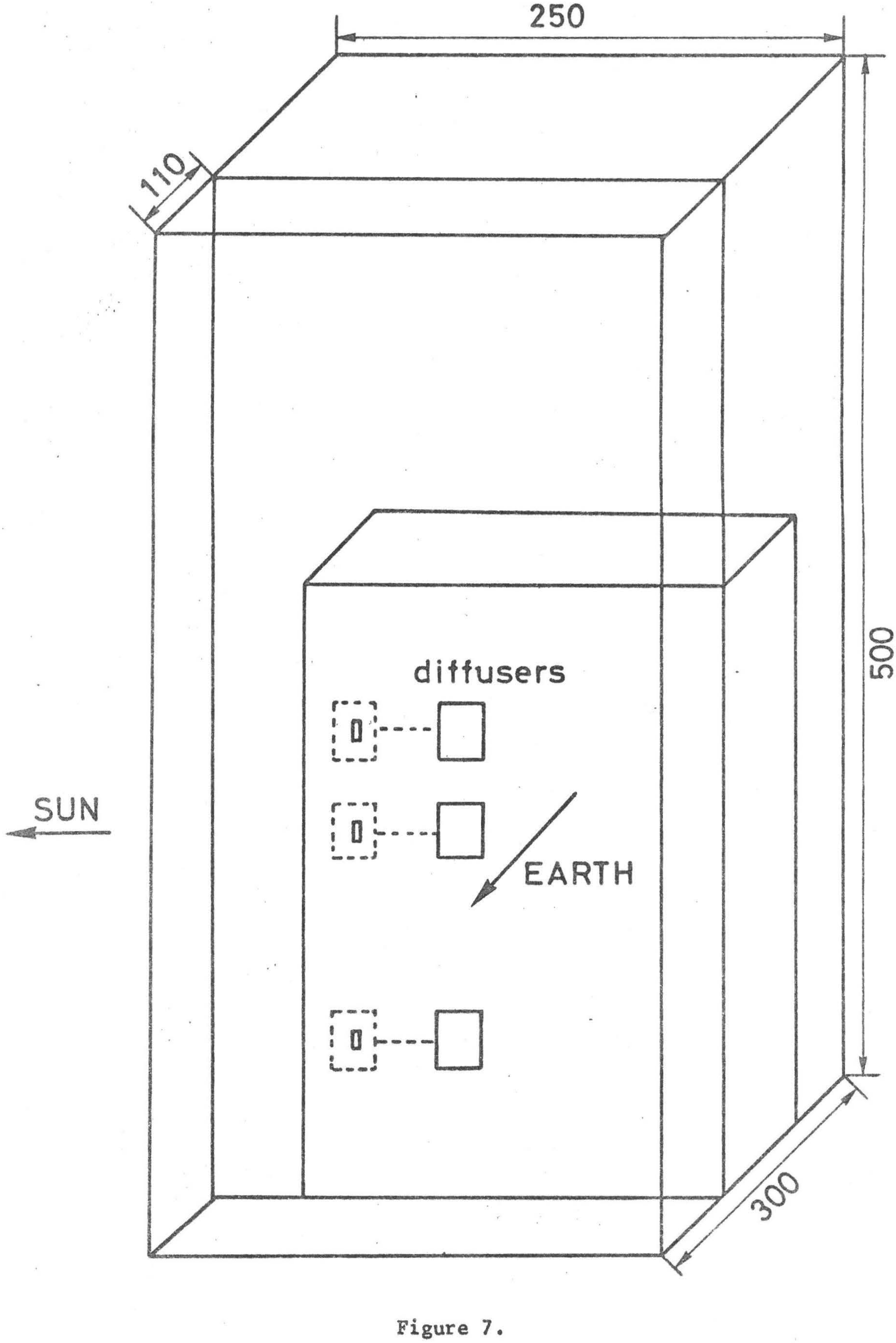

Figure 7.