IN-ORBIT PERFORMANCE OF THE LWS DETECTORS

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ABSTRACT

The Long-Wavelength Spectrometer (LWS) onboard the Infrared Space Observatory (ISO) covers the 43-197μm region with ten doped-Germanium photoconductors that are read out with integrating JF-4 amplifiers. The behaviour of these detector/readout units during some 500 days of operations in space is described. There are no systematic variations of the sensitivity and of the dark current in observations of photometric standard sources in the sky or in measurements with internal illuminators. The effects of ionising radiation do not vary on long timescales, either. It is shown that the impact of the slow response times of the detectors on the accuracy of line scans is small.

1. INTRODUCTION

LWS is one of the four experiments on the European Space Agency's ISO satellite [Ref. 1]. Its focal plane unit consists of three subsystems: The optical subsystem, the Fabry-Perot subsystem and the detector subsystem, which is equipped with photoconductive detectors made of Ge:Be to cover the 43-50μm region, Ge:Ga to cover the 50-104μm region and stressed Ge:Ga for the region up to 197μm [Ref. 2].
The six unstressed detectors are operated at 3K, the temperature of the focal plane, whereas the four stressed detectors are cooled to 1.8K via direct coupling to the helium tank. Their photocurrents are integrated at the input nodes of Infrared Laboratories JF-4 amplifiers. A standard integration lasts half a second; during this time the output voltage is sampled 44 times. For very bright sources the charge accumulated at the input nodes can significantly reduce the detector bias during the integration. This leads to a non-linear response, especially for the stressed detectors, which must be calibrated out [Ref. 3]. Inside the instrument five illuminators are mounted vis-a-vis the detectors. These are used to check their responsivity with a well known and reproducible signal. The illuminators are essentially nichrome resistors that heat a small disk of diamond which behaves in the wavelength range of the LWS like a grey body with an emittance of 0.7.

2. LONG TERM STABILITY OF THE LWS DETECTORS IN FLIGHT

2.1 Responsivity

Checking the repeatability of measurements and the long term stability of the instrument behaviour is the main task of the routine phase calibration of the LWS. Four hours are reserved once per week for these obser-

Detector	$\overline{x}$	$\sigma_m/\overline{x}$
	A	
SW1	5.32×10^{-14}	0.02
SW2	3.24×10^{-14}	0.05
SW3	3.86×10^{-14}	0.04
SW4	2.24×10^{-14}	0.03
SW5	1.58×10^{-14}	0.05
LW1	4.27×10^{-14}	0.01
LW2	9.25×10^{-14}	0.02
LW3	1.70×10^{-13}	0.04
LW4	8.32×10^{-14}	0.06
LW5	8.38×10^{-15}	0.05

Table 1: Mean output signal and its standard deviation for seven observations between revolutions 126 and 314 on the bright HII region S106

vations. Most of them are repeated always in the same way on standard sources like Uranus, S106 or NGC6543 whenever those are visible with ISO. It was found that the overall flux varies among end-to-end grating scans by about ten percent (see table 1).

Very useful data are also obtained from illuminator flashes before and after the bias boost during handover between ground stations in the middle of a revolution, as these measurements are always done at the same position in the orbit. Their repeatability is in good agreement with that of the observations on celestial standards thus proving that also the illuminators have not changed during the mission (see figure 1). The responsivity of one stressed Ge:Ga detector (LW2), however, was reduced by 22 percent after a period of 64 days during which no standard observations were performed with the LWS.

Illuminator flashes are performed as part of every observation, too, in order to monitor the gradual increase of responsivity caused by hits of highly-energetic particles (see chapter 2.3). These responsivity changes are of similar size in all revolutions: They amount to several ten percent, depending on detector, within eight hours, the time between the curing procedures (see figure 2).

2.2 Dark Current

The dark current is measured by observing at grating rest position with a misaligned Fabry-Perot interferometer in the beam. This measurement gives strictly speaking only the sum of dark current and photocurrent produced by the straylight that was not blocked, but unless there is a strong source in the field of view it can be assumed that the contribution of external stray-

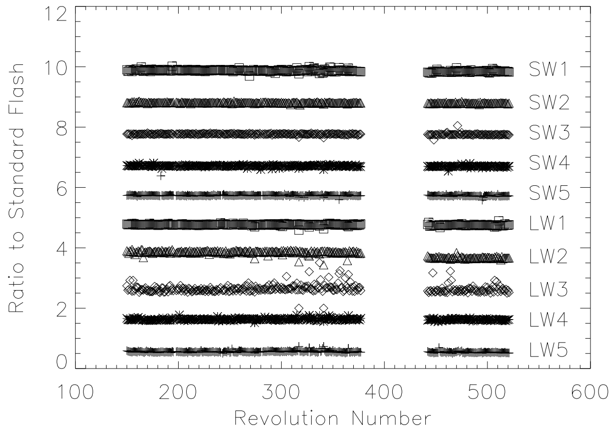

Figure 1: Normalized signals from standard illuminator flash sequences during handover as a function of revolution number (points shifted in vertical direction by integers to separate signals of different detectors)

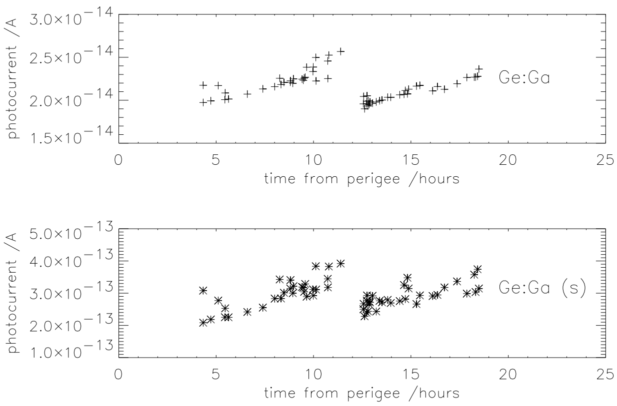

Figure 2: Output signal from standard illuminator flash sequences in calibration observations between revolutions 442 and 503 as a function of position in the orbit

Detector	LWS position	Bias	Dark Current
		mV	e^-/s
Ge:Be	SW1	700	3430 ± 750
Ge:Ga	SW2	247	1560 ± 130
Ge:Ga	SW3	197	1361 ± 9
Ge:Ga	SW4	197	719 ± 10
Ge:Ga	SW5	197	890 ± 9
Ge:Ga	LW1	197	1394 ± 11
Ge:Ga(s)	LW2	40	221 ± 16
Ge:Ga(s)	LW3	60.6	351 ± 13
Ge:Ga(s)	LW4	60.6	1068 ± 20
Ge:Ga(s)	LW5	40	727 ± 8

Table 2: Dark background signals of the LWS detectors in flight

light is negligible. The dark background is checked as part of all standard observations and of the activities during handover between ground stations. In addition dedicated measurements of long duration were carried out during the performance verification phase of the satellite. The results are included in table 2; these values have remained constant until present (revolution 500).

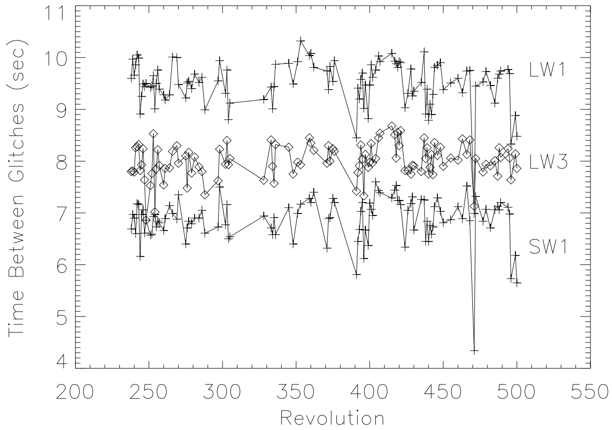

Figure 3: Average time between glitches for three detectors in the LWS: SW1 (Ge:Be), LW1 (Ge:Ga) and LW3 (stressed Ge:Ga); in revolution 471 ISO was exposed to a particularly high electron fluence along its orbit.

2.3 Glitch Rate

In its highly eccentric orbit ISO enters for eight hours the Earth's radiation belts where it gets so often hit by highly energetic particles that its instruments cannot be used for observations. But also outside these belts particles from solar flares and cosmic rays or their products from interaction with the spacecraft hit a given detector of the LWS in the average once in eight seconds. Such an event releases a large number of charge carriers, thus creating a glitch on the output voltage, making the affected integration ramp useless and changing the slope of the next few ramps. Over the timescale of hours the accumulated effect of these hits increases also the responsivity of the detectors [Ref. 4, 5]. Extensive testing of the radiation-induced effects in Germanium photoconductors had been performed before launch, but the stronger impacts of the few most energetic particles which affect the responsivity for a long time could not be simulated in the laboratory. They made a reduction of the bias in some detectors necessary to stabilize their performance. The glitch rate remains constant within the science window of the orbit and no spontaneous spiking is observed during this time (see figure 3).

3. NON-LINEAR TRANSIENT RESPONSE TO A QUICK ILLUMINATION CHANGE

Doped germanium photoconductors exhibit memory effects, i e certain delays in the response of the output signal to changes in the incident flux [Ref. 6]. This can cause changes in the observed line shapes, and therefore all grating scans are done in both directions of grating movement (see figure 4). Measurements of the standard illuminator flash sequence are particularly prone to this form of hysteresis, because big differences in illumination occur in them on short time scales. An improved flash sequence with longer periods between flux changes was devised during the mission which gives the detectors more settling time and produces more accurate values for the monitoring of responsivity and dark current.

4. CONCLUSIONS

By means of changes to the operating modes, stable and reliable operation of the LWS detectors has been achieved in the presence of the effects of ionising radiation. Dark current, responsivity and glitch rate of

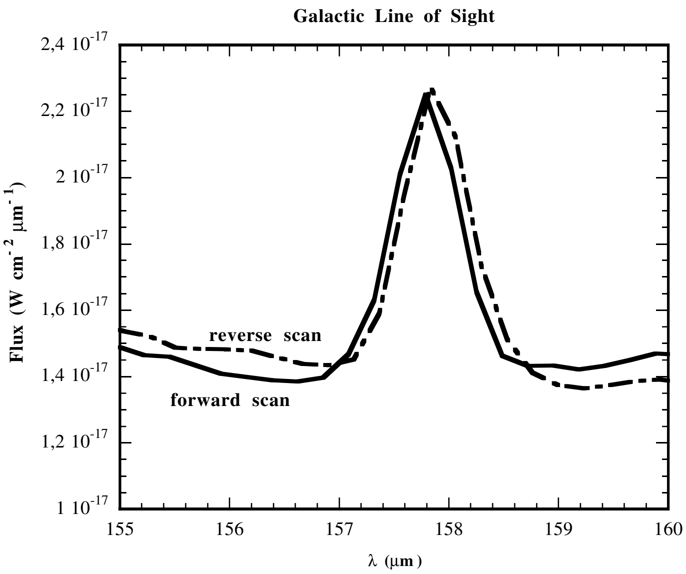

Figure 4: Shapes of the CII-line in the galactic plane at 30 degrees galactic longitude when observed in forward and backward scanning direction with the grating

the detectors have remained constant for several hundred revolutions. The impact of slow response times to changes in illumination has been minimized by the observing strategy.

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