LASER SURVEILLANCE SYSTEM (LASSY)*

H. Böck, J. Hammer

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Storage facilities
Motion detectors

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Abstract: The development progress during the reporting period 1988 of the laser surveillance system of spent fuel pools is summarized. The present engineered system comes close to a final version for field application as all technical questions have been solved in 1988.

REMARKS:

During the reporting period the Laser Surveillance System (LASSY) was further developed by the IAEA in cooperation with the JRC Ispra,EURATOM,Italy. The responsible scientific counterpart for the development is Dr.Knud Thomsen in the JRC Ispra. The autors of this progress report have been in constant contact with Mr.Thomsen and have met several times in 1988 at various locations for scientific consultancy, information exchange and technical support.

The present engineered LASSY prototype system comes close to a final version for field application. As the technical questions for the prototype version have been practically solved the future field test in 1989 will mainly depend on solving safeguards policy problems.

C O N T E N T S

I) INTRODUCTION

The Laser Surveillance System (LASSY) is a safeguards device primarily designed for use at spent fuel storage pools. Two beams of laser light scan a plane above the water or underwater. When an assembly or tool penetrates this plane of light the changes in reflectivity and distance at the corresponding angle positions are detected and the system computer evaluates and stores the disturbance in the area under surveillance (see figure 1).

Each of the two optical emitter-detector assemblies "eyes" turns on its own axis and takes measurements at up to 2048 points or angle positions. These readings are compared to a continuously updated background. If deviations meeting a number of criteria occur the corresponding X/Y coordinates of the disturbance are calculated, as well as a rough measure for its size and shape. These shape-figures are used to interpret an obstacle as a certain type assembly or tool. Scans with assembly-like objects leaving the area under surveillance and their interpretation are stored and documented for later retrieval by an inspector.

In 1986 a first full-scale prototype LASSY has been successfully tested under field conditions in a two-week period in a fuel storage pool of the Paks Nuclear Power Plant, Hungary. During these tests LASSY was exposed to a variety of events and environment conditions. The large amount of collected data built the basis for the design of a new prototype system, an engineered version coming close to a final product.

In the framework of an agreement between the IAEA and JRC Ispra, EURATOM, in Italy the construction of such an engineered LASSY is currently undertaken.

II) OPTICAL EMITTER / DETECTOR ASSEMBLY (EYE)

The optical emitter/detector assembly (eye) of the Laser Surveillance System is a device for scanning back and forth 90 degrees in about 5 seconds while emitting and collecting infrared (or green) laser light. Thus a sheet of light above the area under surveillance is established.

For the engineered prototype system a new design was elaborated which offers a number of advantages over previous versions. With the new LASSY eye it is very easy to exchange different parts of the optics. This is especially important for quick adaption of LASSY to the foreseen working media: air / water.

The main body of the eye consists of a stainless steel T-tube, which is closed with three flanges. All of the caps are prepared for fitting with O-rings.

The motors and the angle encoder inside the eye are connected to their respective power supplies and to the system controller (PC AT) by means of electrical cables. Light from the laser diodes (LD) is carried down to the emitting part of the eye in a 100 μm core diameter optical fiber, the collected light is focussed into another fiber (600 or 1000 μm core diameter) in which it is delivered to a silicon avalanche photo diode (APD). These fibers were taken as the starting point when deciding on the design of the optics because there is only one firm on the market which offers suitable light guides also in a radiation resistant version, which is needed for underwater operation. All of these cables run inside a tube or hose from the eyes to the electronics equipment.

The complete eye is turned around its axis by means of two DC motors with gears. Absolute angle position is encoded with a Litton MGC absolute encoder mounted directly on the supporting pipe.

Behind a window in the center of the optical tube of the eye there is the transmitter/receiver system mounted on supporting plates. This assembly consists of two identical adjustment mechanisms for manipulation or the optical fibers. The principal layout of a LASSY eye is shown in figure 2, a more detailed schematic is presented in figure 3.

The emitted light is collimated into a beam of about 3 mrad divergence by a single plano convex lens of focal length f=40 mm or by a two lens system (f1=63.5 mm, f2=100 mm); this means the beam which has a diameter of about 7 mm when leaving the emitter optics spreads out to about 9 cm diameter in 30 meters distance.

The up to 35 mm diameter of the emitting lens and the zoom-system were provisioned to fit the rated numerical aperture of 0.4 of the light delivering fiber. Actual spread out of the fiber was found to be much less resulting in the 7 mm emitted beam diameter. As the (blocking) outer diameter of the emitting optics greatly influences the sensitivity of the eye over distance - shape of g(z) - it would be possible to adjust LASSY to very short range operation by exchanging the central assembly with one employing smaller lenses.

Light reflected back from a target is focussed by a 100 mm diameter collecting mirror (f=170 mm parabolical or f=100 mm spherical) at the rear of the tubus onto the detection part of the transmitter/receiver system. With these two different focal lenghts it is possible to vary the performance of the detection part and to test an optimized versus an economy version of the optics.
Emitter lenses and the collecting mirror are in mounts with threads for translation in one dimension.

Tests of the optics, especially the alignment mechanisms showed a major improvement compared to previous designs. Adjustments on LASSY's optical characteristics can now be accomplished easily and quickly and yield reproducible results.

Figures 5 and 6 give the sensitivity of the eye over the measuring distance, g(z), calculated and measured, respectively.

III) MEASUREMENT ELECTRONICS

For LASSY operation it was found to be necessary to determine the amplitude as well as the phase of the detected light. In conjunction with the triangulation algorithm for the allocation of detected deviations of the measured signal from a background, phase measurement increases redundancy and allows the recovery of events also in case of bad environment conditions. As the phase shift corresponds to the time of flight for the light between LASSY eye and the target, it is possible to gain almost complete information already from one eye.

To achieve this a continuous wave laser diode (LD, up to 4 mW of optical power) or a light emitting diode (LED, 200 µW) is modulated in its amplitude at 1.2 MHz. Reflected light is sampled frequency- and phase-sensitively.

A 33.6 MHz quartz is used as the only reference source. All needed frequencies are derived from this standard by means of a fast digital synchronous divider.

The output of the emitting diode is controlled by a feed back loop to avoid unnecessary high output levels under good environment conditions.

The input is made up of a avalanche photo diode (APD) and a commercial preamplifier. After a band-pass filter centered at 1.2 MHz the signal can be processed alternatively / in parallel in different ways:

A - The preamplified and filtered signal is directly applied to the input of the two demodulator chips AD 630 for synchronous demodulation at 1.2 MHz (lock-in technique). The reference input of the two devices are driven by two different 1.2 MHz signals with a relative phase shift of 90 degrees. This yields a projection of the in-phase signal (at 1.2 MHz) onto two orthogonal axis (x', y') from which absolute amplitude and relative phase can be easily derived. At the output of the demodulators low-pass filters condition the signal for conversion (via a PC analog-input card Analog Devices RTI 815)

B - As 1.2 MHz are close to the operational limits of the demodulator chips frequency conversion to 80 kHz interim-frequency was proposed. This will be inevitable when higher chopping frequencies for higher distance resolution are needed. The mixing frequency of 1.12 MHz is again delivered by the divider. The (filtered) 80 kHz output of the mixer is then processed by the demodulators, this time provided with reference signals of 80 kHz.

Tests, performed on the breadboard, showed that although operation of the demodulator chips at 1.2 MHz might be satifactory, frequency conversion seems to be preferable. Additional tests of the electronics built on a printed circuit confirmed this finding and it was decided to operate the card in the frequency conversion mode (B).

C - Under both operating conditions (A or B) path C can be enabled. With a sufficient signal/noise ratio the filtered 80 kHz output of the mixer can be used for intensity measurement and setting the output level of the laser diode, as well as for a direct time of flight measurement. A time to digital converter is comprised of a constant fraction detector which sets the gate for a counter. During the time of flight clock pulses are counted. To achieve better accuracy and an appropriate conversion rate 64 cycles are summed up. The 16 bit output is stored in a latch register and can be read by a PC digital-input card (Analog Devices RTI 817).

Tests on the breadboard device were hampered by the fact that the circuit had been assembled in wire wrap technique.

The new electronics built on a printed circuit exhibit satisfactory performance of the time to digital converter and distance readings determined this way directly are in good agreement with values calculated from the analog projections x' and y'. As the resolution of the analog to digital converter (RTI 815) perfectly fits the needs and distances derived from x',y' are less subject to noise only these values are currently being used. This also allows for scanning without explicite handshake between computer and the card at each reading.

Figure 4 shows the principal layout of the newly developed LASSY measurement electronics.

IV) PERFORMANCE OF EYE + ELECTRONICS

With the optical part of one eye completely assembled and the mesurement electronics on a printed circuit available various tests on the features of these two LASSY constituents joint together were performed.
From figures 6 to 14 it can be easily seen that the new sensor system (eye + elctronics) works satisfactorily over distances of up to 30 meters and beyond in air, giving true additional information compared to intensitiy measurements only as employed in previous designs.

The actual sensitivity function of the eye - g(z) - resembles very much the ideal calculated one. Even in the blocking range, the first meters in front of the eye, there is light detected to allow for a intensity measurement to about 10 percent accuracy. As soon as there is enough signal dete ted (from about 5 meters onward) phase measurement gives a reliable indication of the distance to a target. Due to the experimental setup only the range up to 30 meters has been thouroughly explored but from the shape of g(z) in the quadratic decay range and some measurements at 70 meters it can be concluded that LASSY eye/electronics work well over the full range of possible dimensions of LASSY installation sites (see figures 6 and 14).

The two projections onto reference signals 90 degrees apart in their phase with the used chopping frequency of 1.2 MHz should allow for a maximum range of absolute distance measurement of about 130 meters in air when using x′ and y′ (65m with the time to digital converter). To minimize a possible error in distance measurement due to excessive relative noise when one projection is close to zero, this point for x′ can be adjusted to lie exactly at the maximum of g(z) and the maximum of y′(z) to minimize overall erro. (see figure 7).

Changing the distance to the target in steps gives a clearer idea of the performance in the various ranges. Wheras intensity readings mirror the instabilities of the reflector when switching distances, measured absolute distance values indicate z-dimension only.
Detected signal was compared to pure noise input which can be seen to yield a signal which stays below about 10 percent even for blocking range values. This corresponds well to derived difference readings given in the lower plots (see figure 8 and table 1).

Measurements reported sofar were performed using a large sheet o. paper for a target; this is not an especially good refletor for infrared. In the comparison of the reflectivity at various angles of incidence white paper yields about the same values as a blue painted surface or shining structured aluminum. The latter target only gives rise to higher signals a angles close to 90 degrees due to more direct reflections. Despite changes in the detected intensity of a factor of 7 from one target to the other only minor impact on distance readings is noticed (see figure 9).

In a simulated scan a target (rod of 22 mm diameter) was moved across the laser beam which was pointed at the 30 meter distant wall. Already from this setup the clear superiority of combined signal/distance measurement it evident. Several events are clearly detected in one modality only, for all instances the combination of the two modalities reveals additional information (see figure 10).

For medium range applications of LASSY in air it might be preferable to avoid the use of a laser altogether. If a light emitting diode (LED) can be used as a light source this reduces the component price and also further increases system reliability as LEDs have virtually unlimited lifetime. Another advantage would be the resulting change in the classification of the device. Having a LED emitting 200 µW of optical power gives a "class 1" instrument, "no risk laser device" - even direct viewing of the emitted beam for unlimited time as the worst case does no harm to the observer's eye.

When using a laser diode as the source of light LASSY eyes fall in "class 3B" which essentially means that it is not wise to stare forever into the emitted beam. In any case it is safe to view a disconnected or broken fiber from a distance of 30 cm and to look into the outcomming beam for unlimited time at a distance of 15 meters. Even when upgrading the system for long distances by use of a 20 mW LD it would be safe to look directly into to beam for 10 seconds in worst case conditions. There is no danger whatsoever from diffuse reflections of the beam, LASSY detecting levels well below 1 nW.

The feasability of a "LASSY" without any laser is documented in figures 11, 12 and 13. Performance in air up to 30 meters can be considered almost as good as when employing the LD. Using such low intensities of the emitted beam result also in a different operation regime of the preamplifier, which is close to saturation already from the noise of the input. This fact can be exploited to even out g(z). Comparing figures 6 and 11 it is easily seen that although optical alignment is the same weak signal is enhanced when using the LED (the high peak values are not fully transfered). This operating mode has the advantage of allowing satisfactory distance measurements in a range starting already below 3 meters. An inherent drawback of this setup is a sensibility to changes in background light, which in turn can be taken care of by the evaluation software.

Stability of the detected signal over long periodes proves to be high also when using the LED. During a 40 hour run variations in the detected intensity were observed due to intensive sun irradiation of the unmantled light guide carrying the reflected signal, in the correspondent distance values only minor changes occurred (see figure 12).

To avoid unnecessary high output levels under changing environment conditions a feedback loop is foreseen to control the emitted laser power. Also for the LED this feature proved to be valuable for automatical adjustment of signal levels. Output power is regulated slowly as an inverse function of the mean detected signal. This does not interfere with LASSY response to any fast event, the different timescales can be thought of as completely independent (see figure 13).

The distance of 30 meters in conjunction with delimiters of the surveillance area of medium reflectivity marks the end of the applicability of a LED for a LASSY light source.

Again using the LD a scan over a wall with varying reflectivity in 70 meters distance was simulated. Although some improvements in the detected signal could be expected from aligning the eye for this distance it seems to be close to the maximum range which can be covered by the present setup and when not using any reflective material to constrain the angle of backscattering from the wall (see figure 14).

V) GENERAL FEATURES

The present engineered LASSY prototype system comes close to a final version for use in field. The modular and compact design of the optical and electronical constituents of the system mark a clear improvement over previous approaches. The inclusion of phase shift measurements for a direct determination of distance proved to yield a considerable enhancement of LASSY detection capabilities.

Depending on the use of a light emitting diode (LED) or a laser diode (LD) LASSY eyes fall in class 1 or class 3B, respectively. In any case it is completely safe to view diffuse reflections of the beam, with the LD version it should be avoided to look directly into the beam for longer than 10 seconds. As the eyes are continously moving there will be hardly any chance to do so.

As a result of this preliminary test report the most suitable place for a first field test of the current system seems to be a facility where LASSY would:

- scan in air
- cover a distance of about 25 meters.

Space needed for the main part of the system (computer, electronics) can be specified as one rack. Power needed will be less than 1 kW from standard 220 V mains.

LASSY's two eyes ought to be mounted in adjacent corners of the area to be scanned. For air operation it is sufficient to just put the eyes in their supporting structures at the designated locations to scan 20 cm above ground.

VI) FIGURES

1) Basic installation and operation mode of the Laser Surveillance System LASSY. Two scanning laser beams build up a sheet of light above nuclear fuel under surveillance

2) Principal layout of LASSY emitter-detector assembly "eye"

3) more detailed schematic of present eye

4) Block diagram of new LASSY measurement electronics

5) Calculated shape of eye responsivity over distance "g(z)"

6) Upper half shows measured g(z) (shifted in comparison to calculation because of finite beam diameter) and deviation between successive points; lower half shows the measured distance and its derivative at the corresponding points

7) Absolute values of the projections of the detected signal onto the reference frequency (80 kHz) with zero and 90 degrees fix phase offset

8) "step version" of g(z) to give a better idea of its stability: signal between 29 and 30 is due to generic noise background of open Avalanche Photo Diode (APD)

9) Up: reflectivity of various materials at 830 nm and about 30 meter distance

   a) and first half of j): white paper, α = 85 degrees

   b) white paper, 45°

   c) white paper, 30°

   d) structured aluminum, 85°; instability due to experimental setup

   e) structured aluminum, 45°

   f) structured aluminum, 30°

g) blue painted surface, 85°

h) blue painted surface, 45°

i) blue painted surface, 30°

j) (second half) open APD

table 1: Some statistics on measured values of intensities and distances; all values clearly distinct from open diode (down right)

figures

10) Simulated scan over rod of 22 mm diameter; events at 6, 10, 13, 17 would have gone unnoticed by intensity measurement only, whereas the event at 25 (partly shading of "sensitive volume" without touching the outgoing beam) can only be seen in the amplitude; notice that events at 15 and 20 give different responses in the intensity due to different positioning of the tool but are clearly located at about the same distance; event 25 was very close to the eye

11) g(z) and measured distance using a LED as light source (same wavelenght 830 nm, 200 µW emitted power); due to saturation of a preamplifier weak signal is enhanced compared to figure 6

12) Stability of signal and distance readings over 40 hours; owing to the regime of operation of the stage before the first filter amplitude decreases with increasing background irradiation, which has however only little impact on distance values

13) Performance of automatic gain control, long term changes in output power are not effected by and do not deteriorate LASSY short term behavior; virtually unchanged distance readings during power adjustment

14) Simulated scan over a wall with varying reflectivity at a distance of 70 meters close to the limit of present LASSY (eye + electronics) capabilities

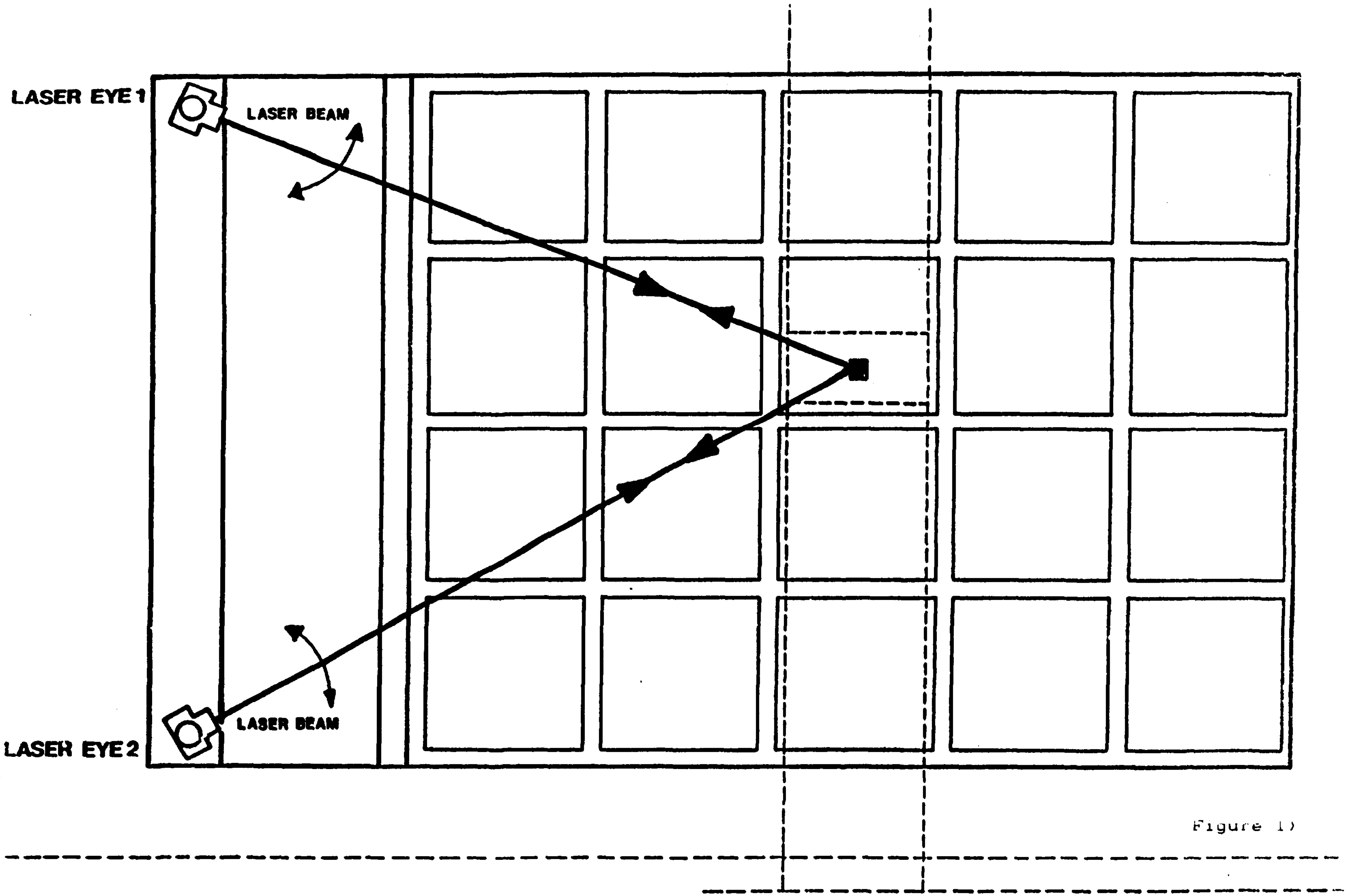


Figure 1)

EYE

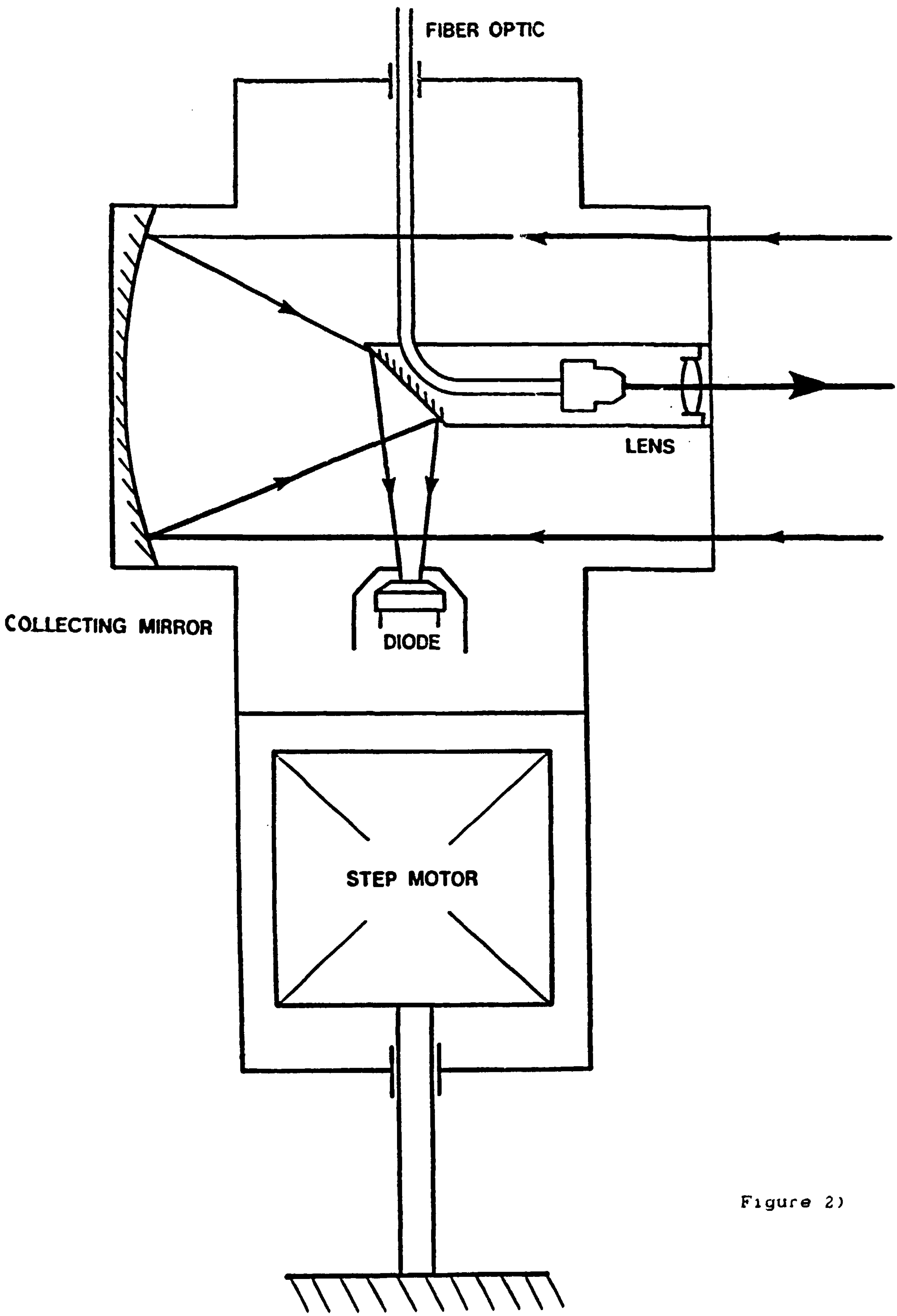


Figure 2)

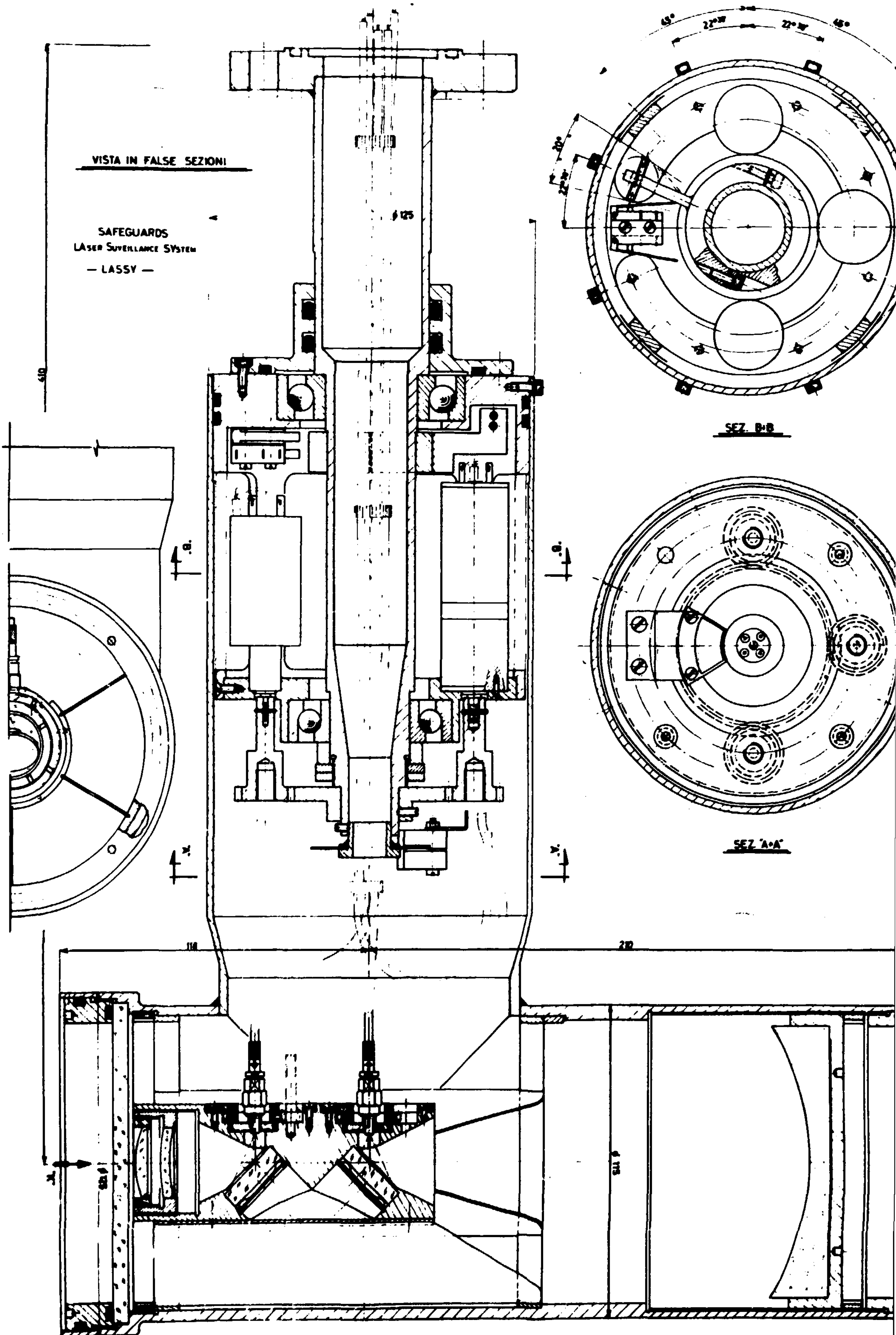

VISTA IN FALSE SEZIONI
SAFEGUARDS
LAser Suveillance SYstem
— LASSY —
SEZ. B-B
SEZ. A-A

Figure 3)

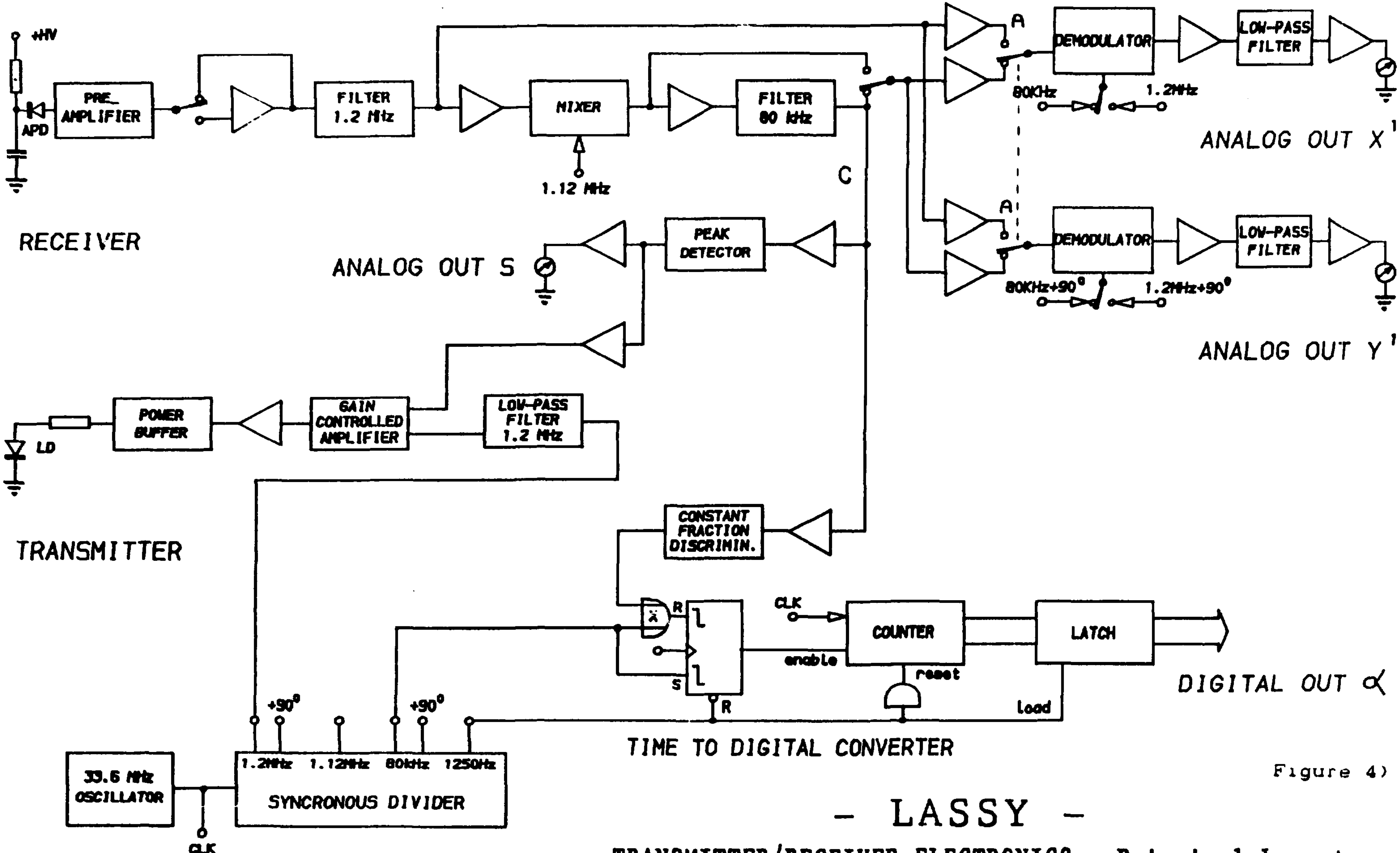


Figure 4)

- LASSY -

TRANSMITTER/RECEIVER ELECTRONICS Principal Layout

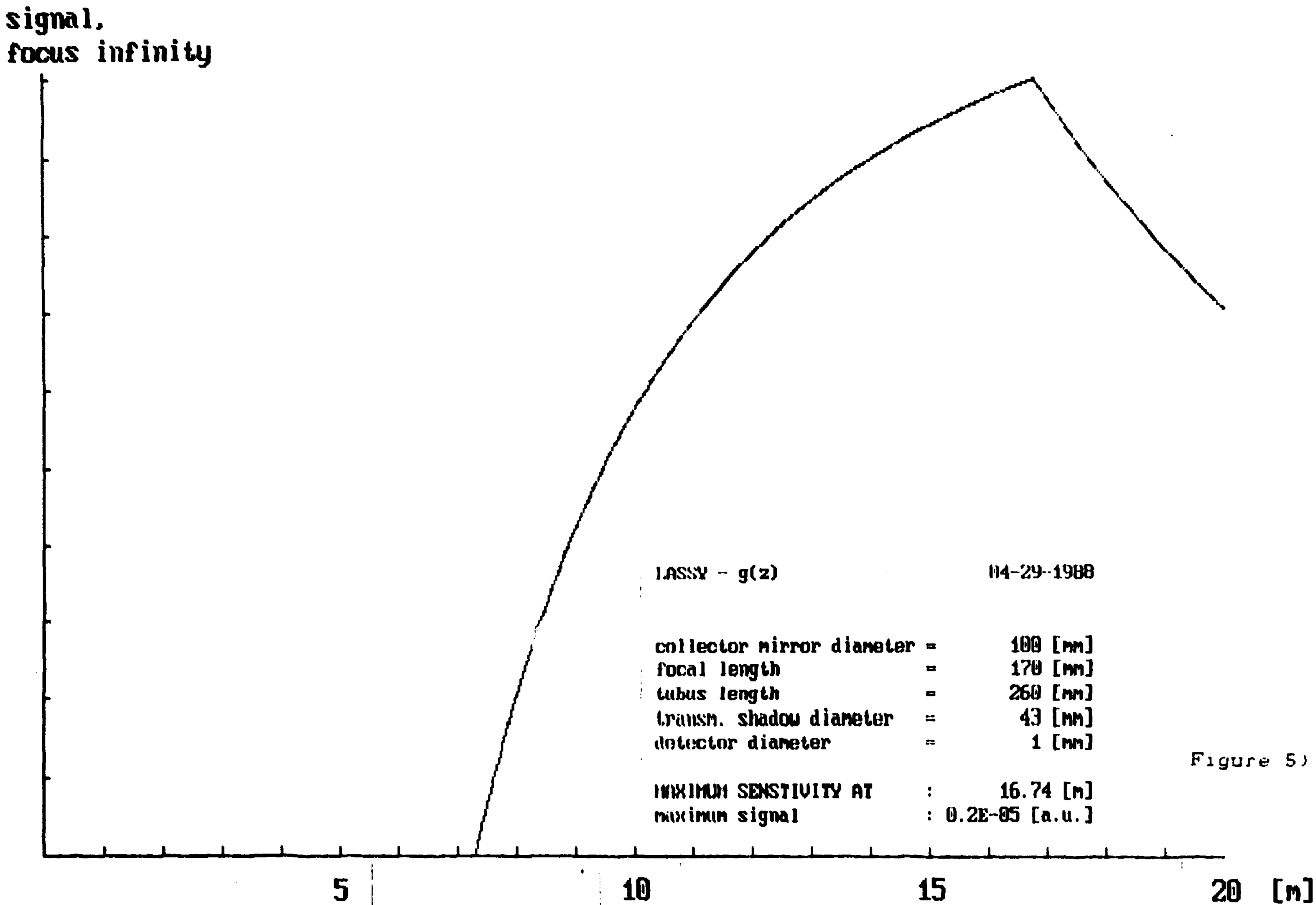
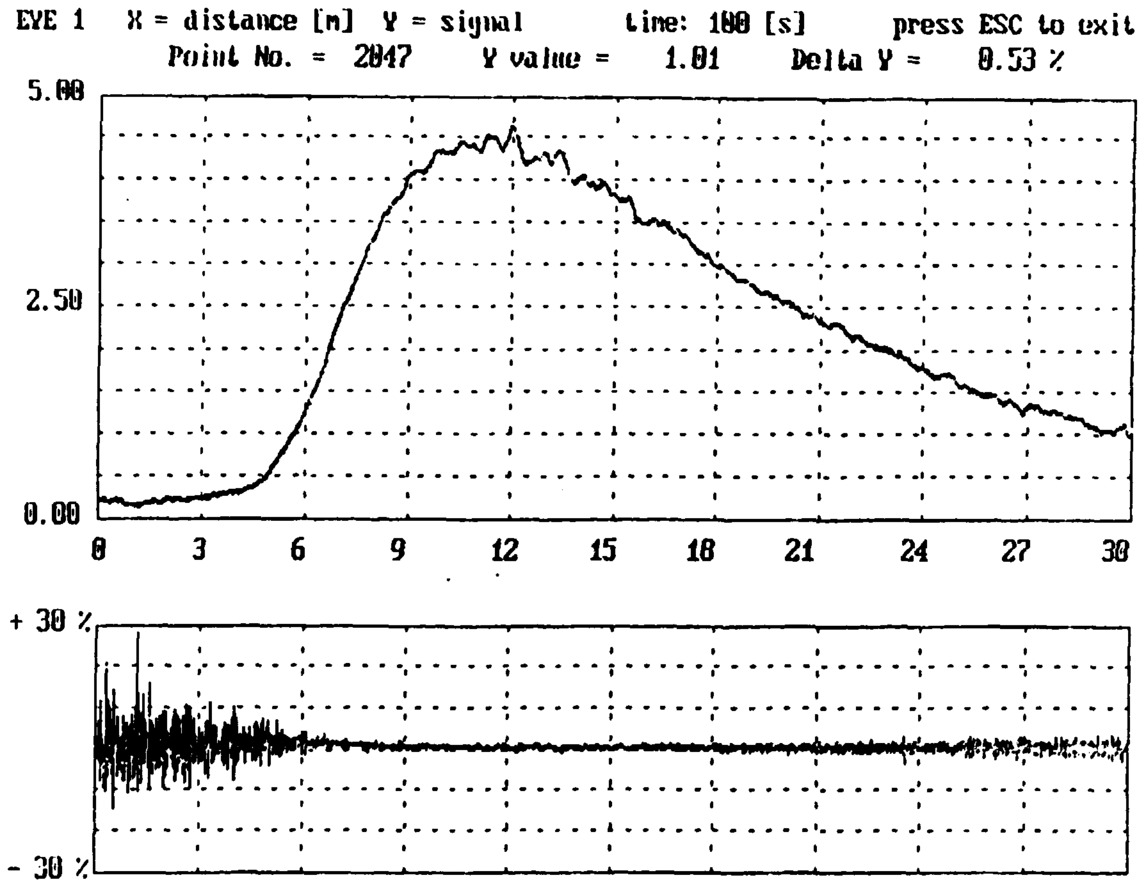

signal,
focus infinity
LASSY – g(z)
04-29-1988
collector mirror diameter = 100 [mm]
focal length = 170 [mm]
tubus length = 260 [mm]
transm. shadow diameter = 43 [mm]
detector diameter = 1 [mm]
MAXIMUM SENSTIVITY AT : 16.74 [m]
maximum signal : 0.2E-05 [a.u.]
5
10
15
20 [m]

Figure 5)


EYE 1 X = distance [m] Y = signal time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 1.01 Delta Y = 0.53 %
5.00
2.50
0.00
0
3
6
9
12
15
18
21
24
27
30
+ 30 %
- 30 %

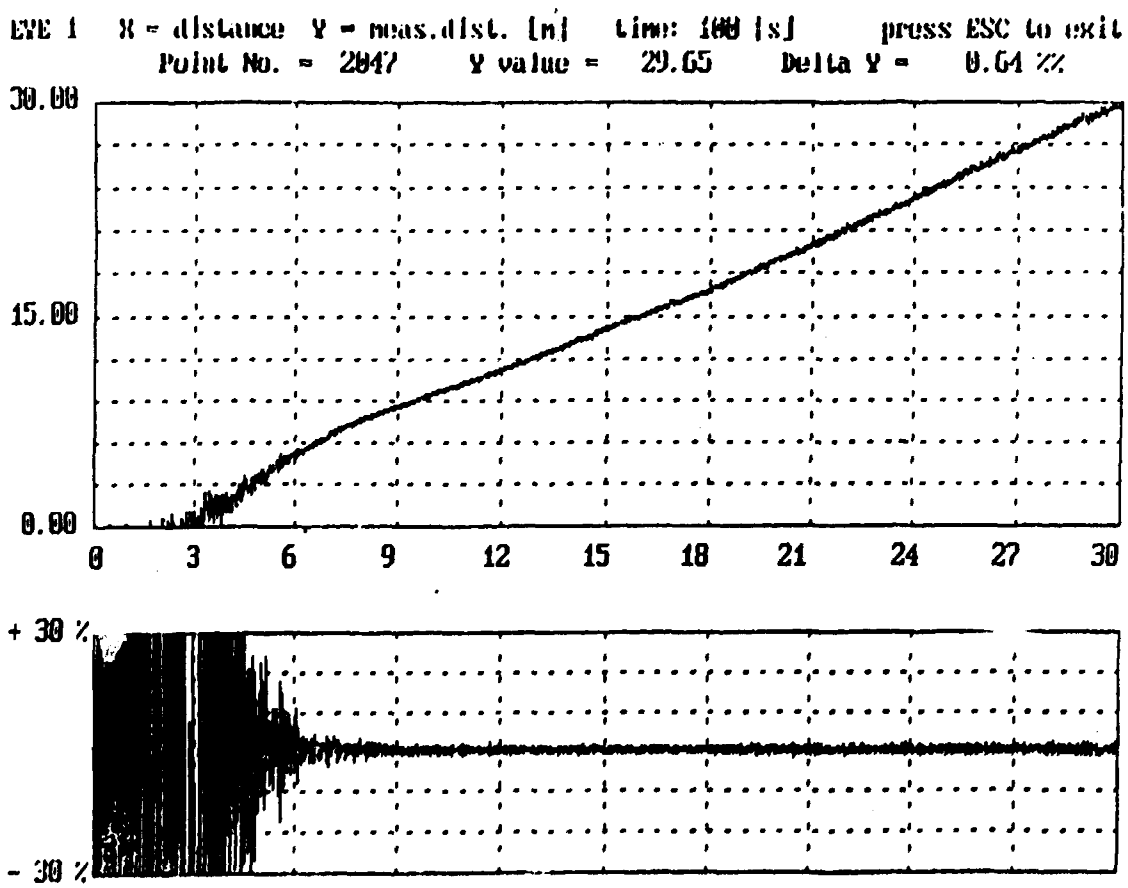
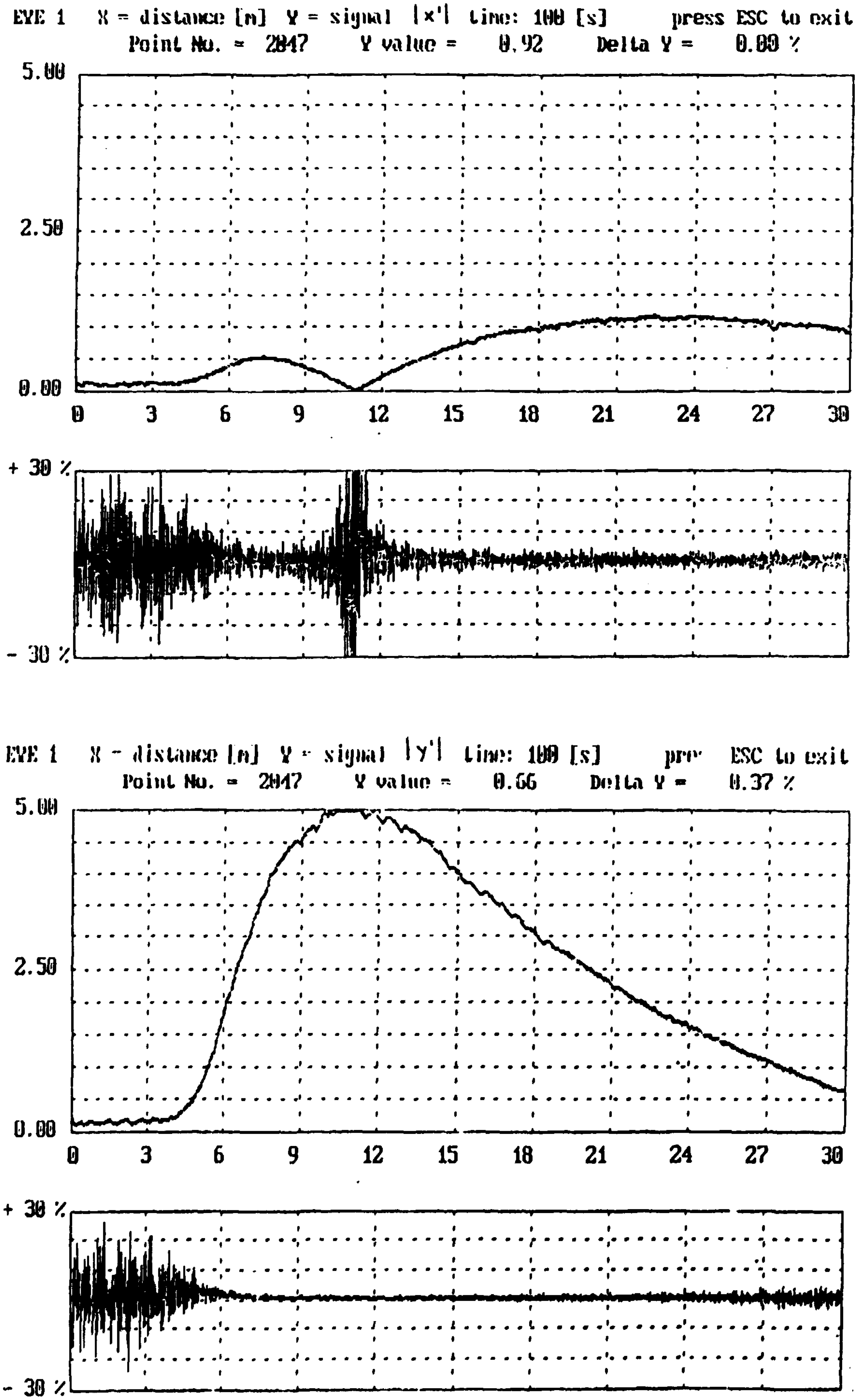

EYE 1 X = distance Y = meas.dist. [m] time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 29.65 Delta Y = 0.64 %%
30.00
15.00
0.00
0
3
6
9
12
15
18
21
24
27
30
+ 30 %
- 30 %

Figure 6)



EYE 1 X = distance [m] Y = signal |x'| time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 0.92 Delta Y = 0.00 %
5.00
2.50
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %
EYE 1 X = distance [m] Y = signal |y'| time: 100 [s] pre ESC to exit
Point No. = 2047 Y value = 0.66 Delta Y = 0.37 %
5.00
2.50
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %

Figure 7)

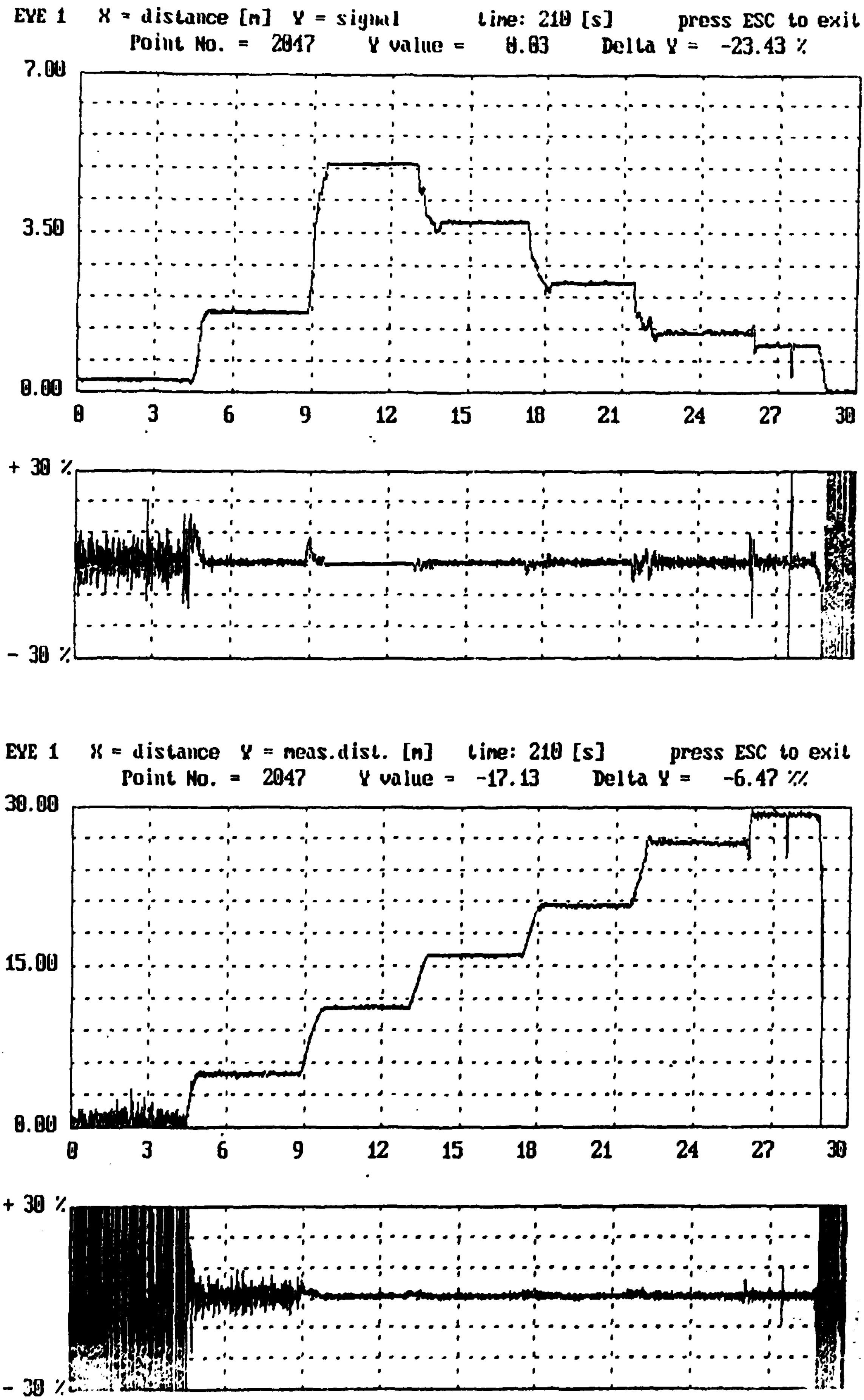

EYE 1 X = distance [m] Y = signal time: 210 [s] press ESC to exit
Point No. = 2047 Y value = 0.03 Delta Y = -23.43 %
7.00
3.50
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %
EYE 1 X = distance Y = meas.dist. [m] time: 210 [s] press ESC to exit
Point No. = 2047 Y value = -17.13 Delta Y = -6.47 %%
30.00
15.00
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %

Figure 8)

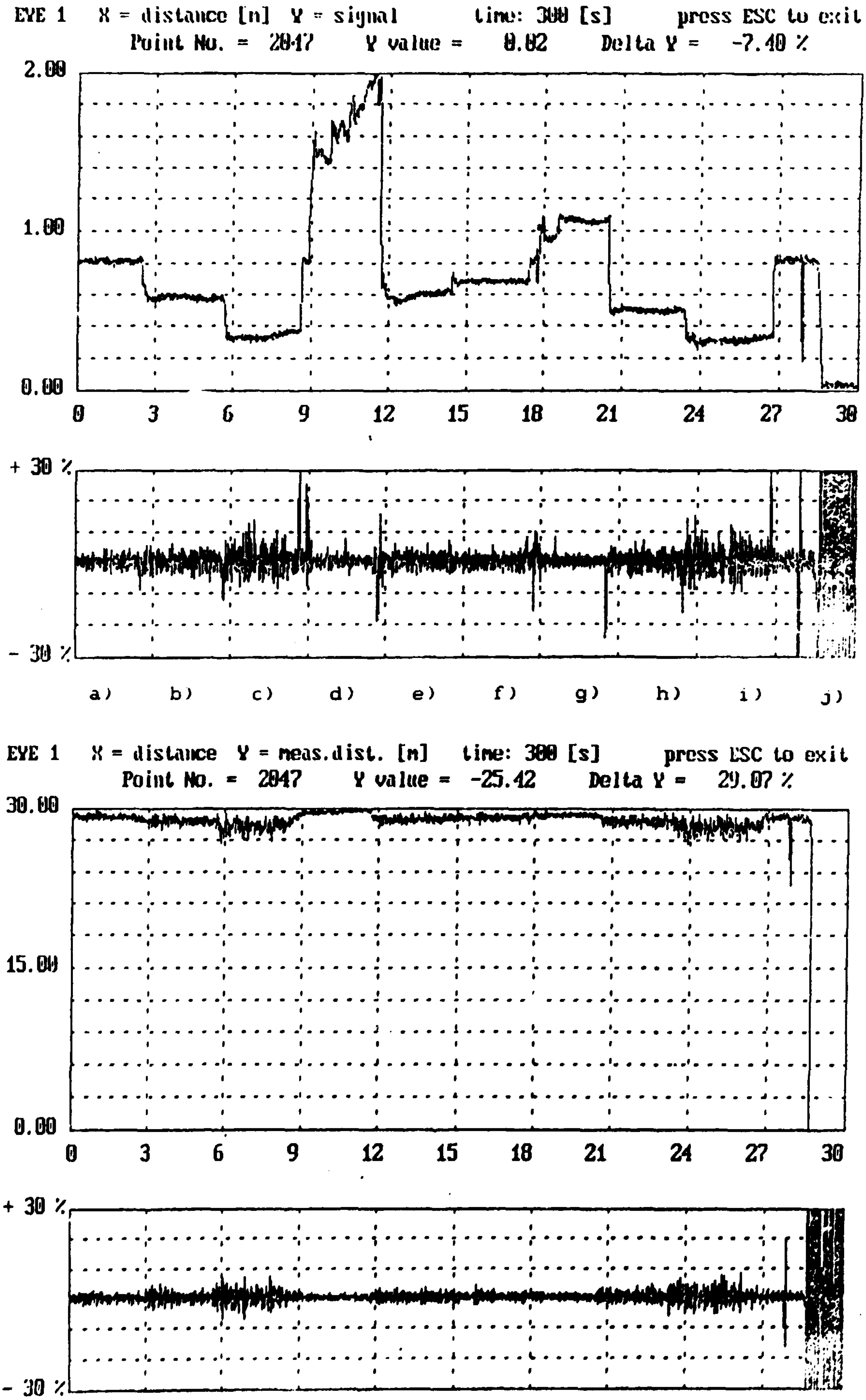
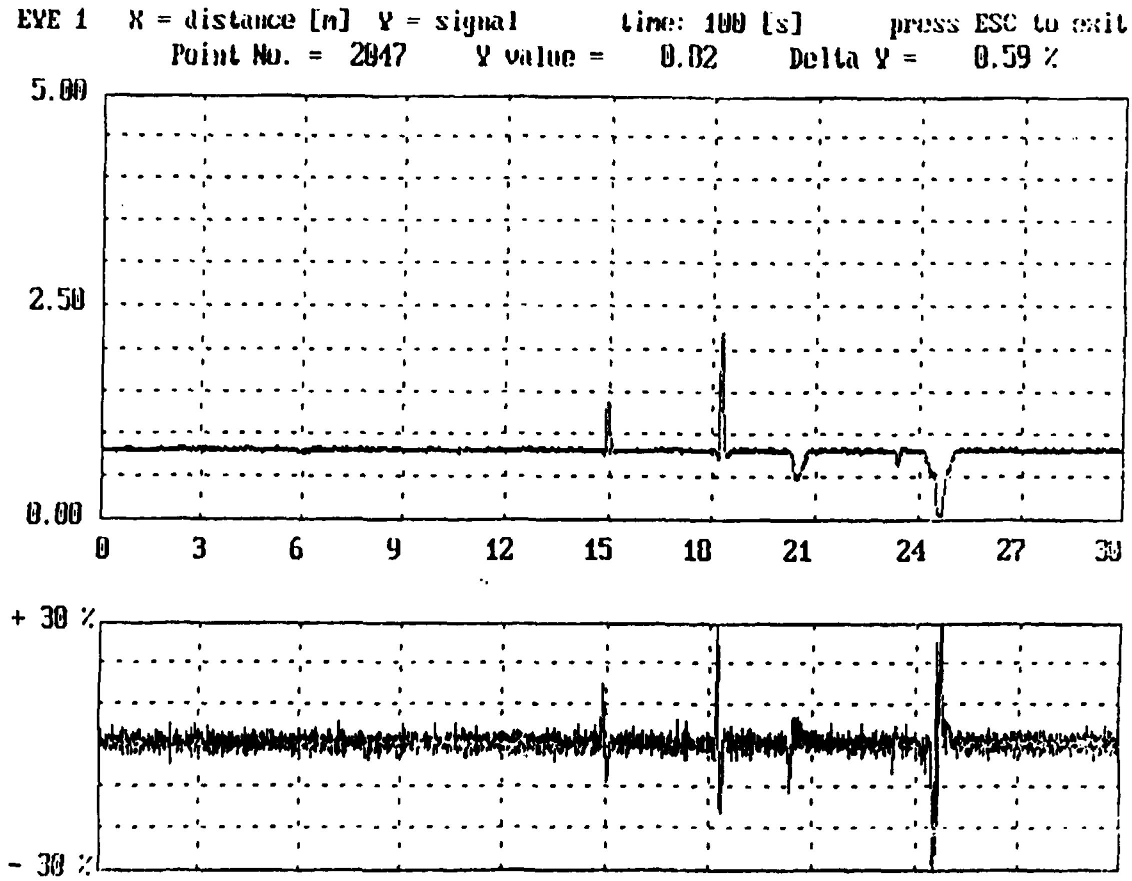

EYE 1 X = distance [m] Y = signal time: 300 [s] press ESC to exit
Point No. = 2047 Y value = 0.82 Delta Y = -7.40 %
2.00
1.00
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %
a) b) c) d) e) f) g) h) i) j)
EYE 1 X = distance Y = meas.dist. [m] time: 300 [s] press ESC to exit
Point No. = 2047 Y value = -25.42 Delta Y = 29.07 %
30.00
15.00
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %

Figure 9)

JRC ISPRA, ELECTRONIC DIVISION   Thu Oct 13 11:31:38 1988

POINT NOISE	EYE 1					
ABSOLUTE POSITION	0.00	3 m	0.00	5 m	0.00	10 m
GAIN	1		1		1	
OUTPUT FILTERING	10		10		10	
	SIGNAL	DISTANCE	SIGNAL	DISTANCE	SIGNAL	DISTANCE
ARITHMETICAL MEAN	0.23	0.18	1.42	4.91	4.93	11.11
MINIMUM VALUE	0.19	-3.45	1.38	4.43	4.88	10.92
MAXIMUM VALUE	0.26	3.40	1.45	5.42	4.98	11.27
NOISE PP	0.07	6.85	0.08	1.00	0.10	0.36
NOISE PP [%]	29.08	3793.52	5.40	20.30	2.05	3.20
NOISE RMS [%]	3.98	466.49	0.69	2.71	0.29	0.34

ABSOLUTE POSITION	0.00	20 m	0.00	30 m	0.00	APD
GAIN	1		1		1	
OUTPUT FILTERING	10		10		10	open
	SIGNAL	DISTANCE	SIGNAL	DISTANCE	SIGNAL	DISTANCE
ARITHMETICAL MEAN	2.04	20.46	0.91	29.19	0.04	-21.71
MINIMUM VALUE	2.00	20.15	0.88	28.51	0.00	-52.73
MAXIMUM VALUE	2.07	20.79	0.94	29.87	0.08	-1.63
NOISE PP	0.07	0.63	0.06	1.36	0.07	51.10
NOISE PP [%]	3.21	3.09	6.83	4.67	193.26	-235.34
NOISE RMS [%]	0.46	0.43	1.00	0.66	24.31	-22.54


EYE 1 X = distance [m] Y = signal time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 0.82 Delta Y = 0.59 %
5.00
2.50
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %

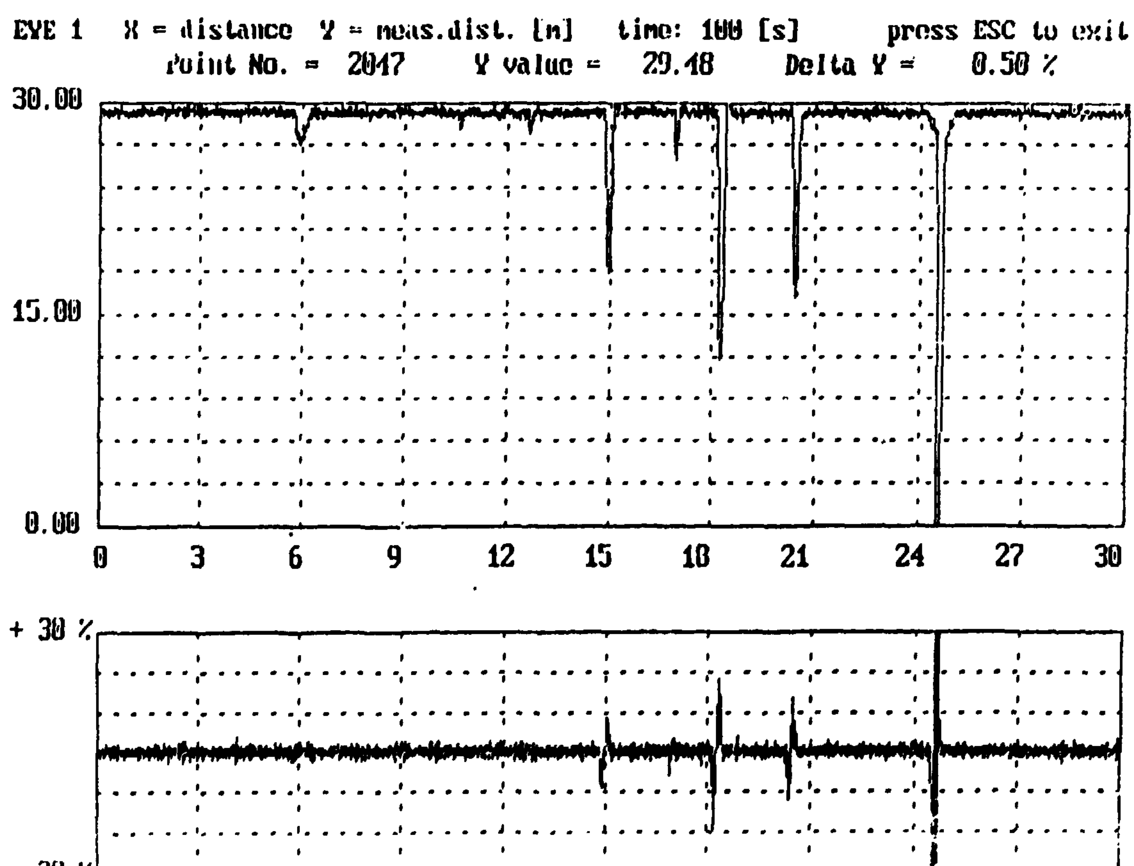

EYE 1 X = distance Y = meas.dist. [m] time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 29.48 Delta Y = 0.50 %
30.00
15.00
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %

Figure 10)

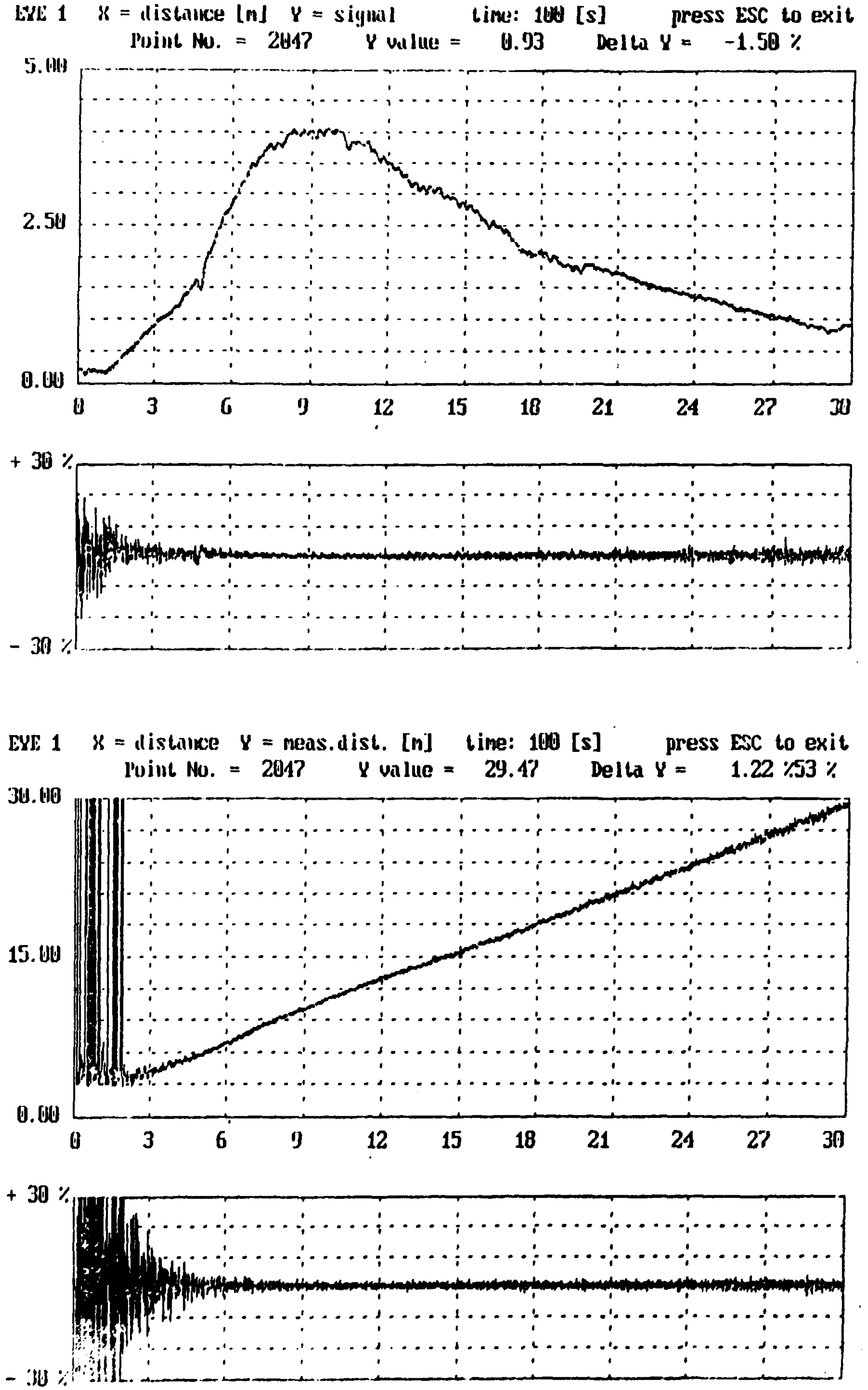

EYE 1 X = distance [m] Y = signal time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 0.93 Delta Y = -1.50 %
5.00
2.50
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %
EYE 1 X = distance Y = meas.dist. [m] time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 29.47 Delta Y = 1.22 %53 %
30.00
15.00
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %

Figure 11)

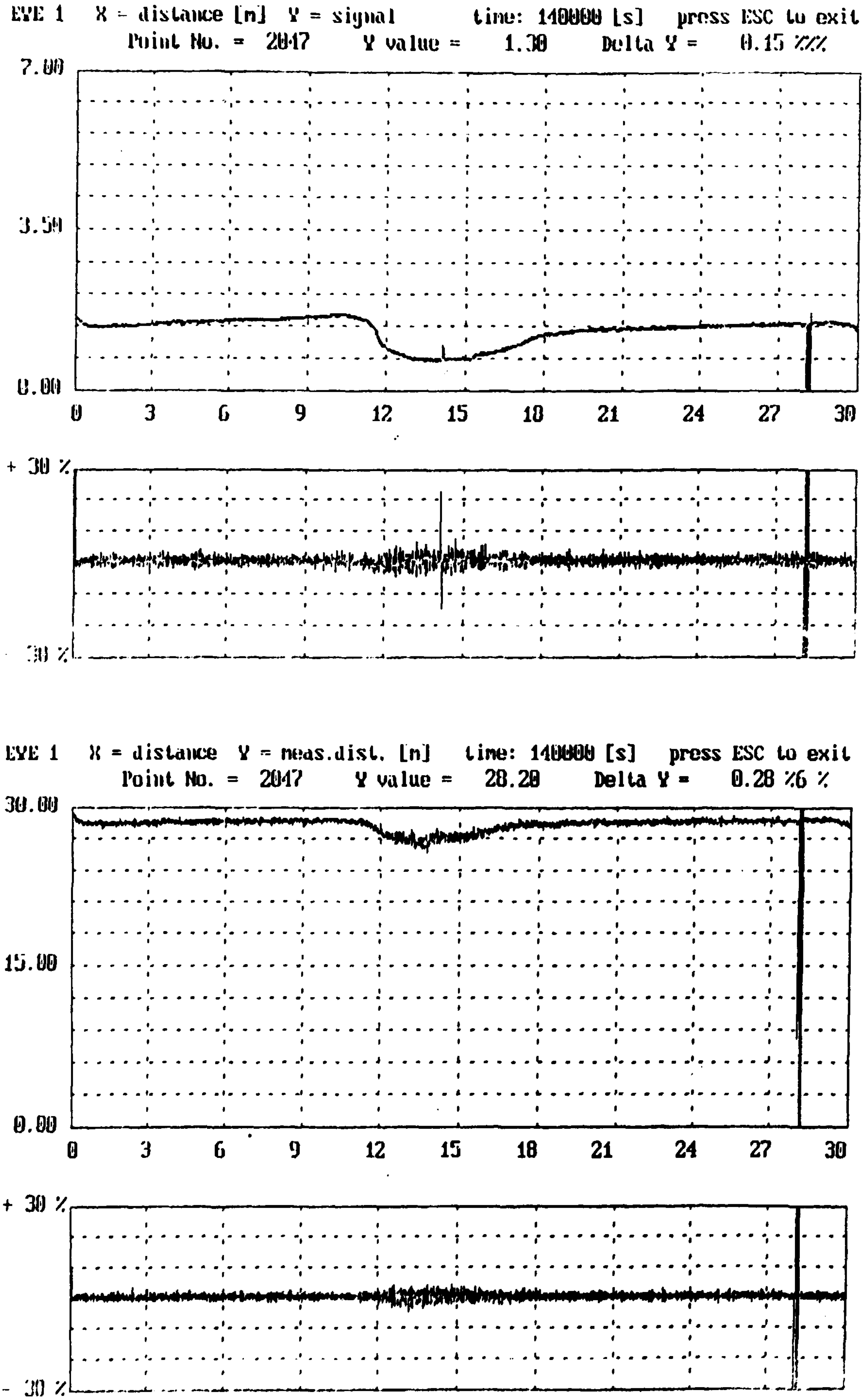

EYE 1 X = distance [m] Y = signal time: 140000 [s] press ESC to exit
Point No. = 2047 Y value = 1.30 Delta Y = 0.15 %%%
7.00
3.50
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %
EYE 1 X = distance Y = meas.dist. [m] time: 140000 [s] press ESC to exit
Point No. = 2047 Y value = 28.20 Delta Y = 0.28 %6 %
30.00
15.00
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %

Figure 12)

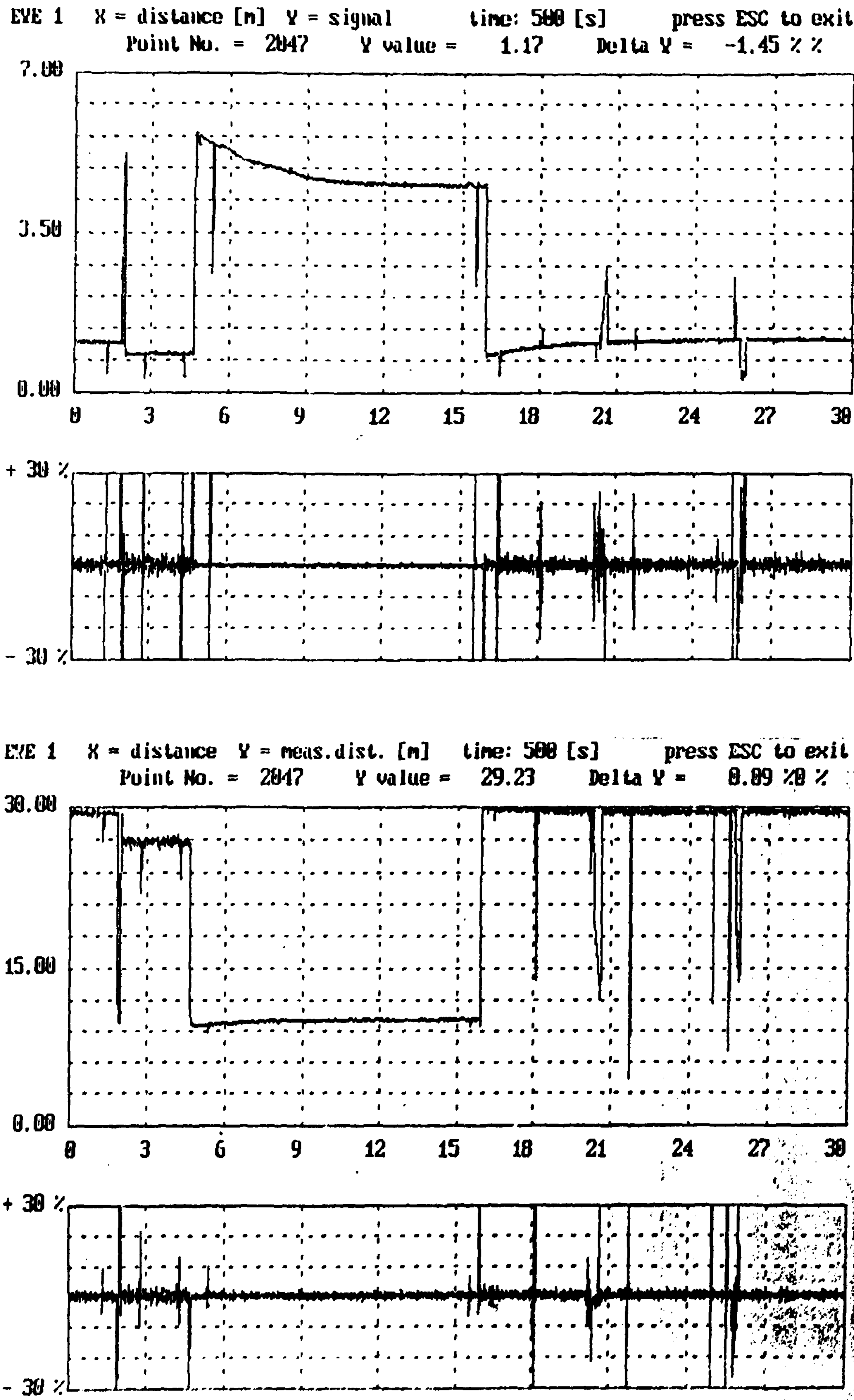
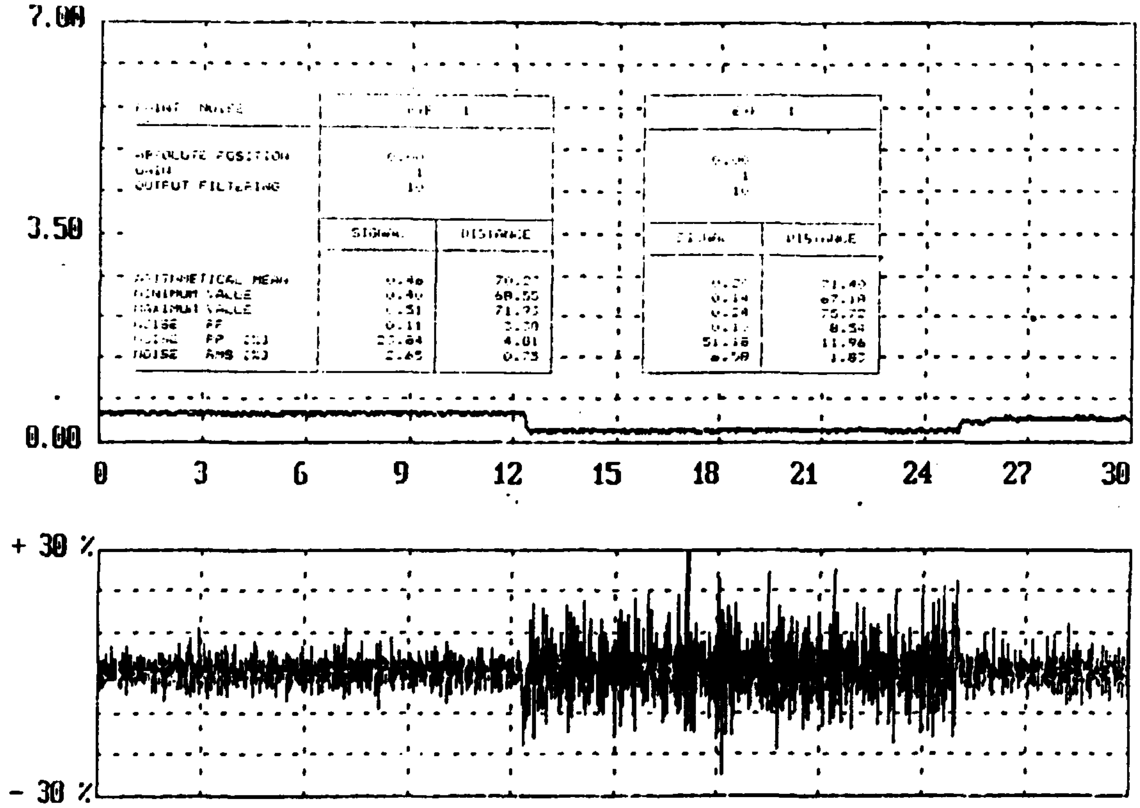

EYE 1 X = distance [m] Y = signal time: 500 [s] press ESC to exit
Point No. = 2047 Y value = 1.17 Delta Y = -1.45 % %
7.00
3.50
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %
EYE 1 X = distance Y = meas.dist. [m] time: 500 [s] press ESC to exit
Point No. = 2047 Y value = 29.23 Delta Y = 0.09 %0 %
30.00
15.00
0.00
0 3 6 9 12 15 18 21 24 27 30
+ 30 %
- 30 %

Figure 13)

EYE 1 X = distance [m] Y = signal time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 0.37 Delta Y = 1.32 %%



EYE 1 X = distance Y = meas.dist. [m] time: 100 [s] press ESC to exit
Point No. = 2047 Y value = 70.80 Delta Y = 1.60 %

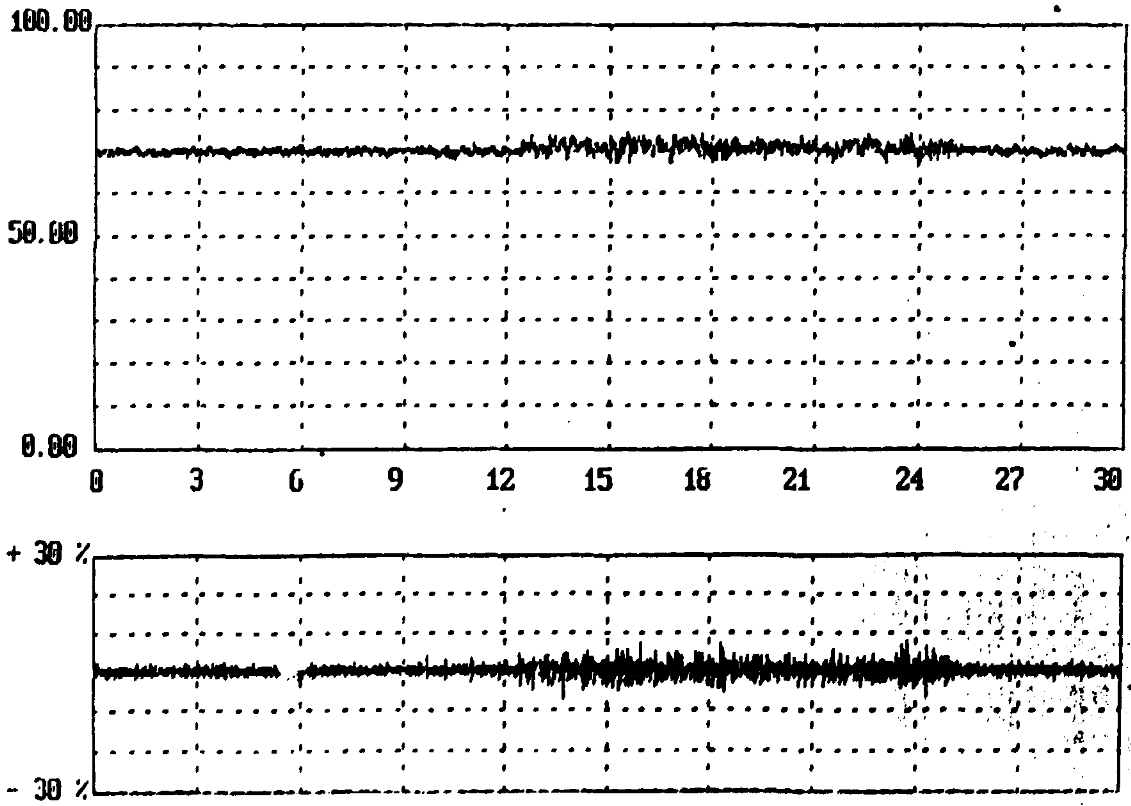


Figure 14)

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Nach dem Pressegesetz verantwortlich: Prof. Dr. G. EDER,
alle Schüttelstraße 115, 1020 Wien, Tel. (0222) 72 51 36