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OPHIR

LASER POWER/ENERGY MONITOR
MODEL DGX

INSTRUCTION MANUAL

OPHIR OPTRONICS JERUSALEM LTD.

SCIENCE BASED INDUSTRY PARK P.O.B. 18076, JERUSALEM 91180, ISRAEL
PHONE 02-819816, TELEX: 26152 OPHIR IL, FAX: 972-2-822366

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DGXUSER: 113/4: 10/90)

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Model	PD2A	10A	30A	150A, 30(150)A F150A	L150A FL150A	300W	L300W	LL300W	1000W	1500W	3000W 3000W-HP
Recommended use	Low powers,[s] photodiode	General[a] use	General[a] use	General[a] use	Large aperture[a]	General[a] use	Large aperture[a]	Very large aperture	CO_2 Nd:YAG	CO_2 Nd:YAG	CO_2 Nd:YAG
Head Specifications	**SURFACE ABSORBERS**										
Spectral range	0.35-1.1 µm[u]	0.19-20 µm[u]	0.19-20 µm[u]	0.19-20 µm[u]	0.19-20 µm[u]	0.19-20 µm[u]	0.19-20 µm[u]	0.19-20 µm[u]	10.6 µm 1.06 µm	10.6 µm 1.06 µm	10.6 µm 1.06 µm (HP)
Max power (continuous)	2W	10W	30W	100W/30W/150W[f]	100W/150W[f]	300W	300W	300W	1000W[n]	1500W[n]	3000W[n]
Max average power density	10W/cm²	200W/cm²[a]	200W/cm²[a]	200W/cm²[a]	200W/cm²[a]	200W/cm²[a]	200W/cm²[a]	200W/cm²[a]	2kW/cm²[g]	2kW/cm²[g]	2kW/cm²[g]
Pulse peak power density[b] (20ns)	10W/cm²	2MW/cm²	2MW/cm²	25MW/cm²[f]	2MW/cm²	25MW/cm²[f]	2MW/cm²	2MW/cm²	25MW/cm²[f]	25MW/cm²	5MW/cm²
Pulse energy density[b] (20ns)	–	0.05J/cm²	0.05J/cm²	0.5J/cm²[f]	0.05J/cm²	0.5J/cm²[f]	0.05J/cm²	0.05J/cm²	0.5J/cm²	0.5J/cm²	0.5J/cm²
Head response time 1/e	0.2 sec	1 sec	1 sec	1.2 sec	6 sec	1.5 sec	5 sec	35 sec	4 sec	5 sec	10 sec
Response with readout 0-95%[q]	0.2 sec	0.8 sec	0.8 sec	0.8 sec	2.2 sec	1 sec	1.7 sec	10 sec	1.5 sec	2 sec	3 sec
Linearity with power	±1%	±1%	±1%	±1%	±1%	±1%	±1%	±1%	±2%	±2%	±3%
Accuracy for power measurements[j]	±5%[p]	±3%	±3%	±3%	±3%	±3%	±3%	±3%	±5%	±5%	±5%
Accuracy for power with -CAL option[r]	–	±1%	±1%	±1%	±1%	±1%	±1%	–	±1%	±2%	±2%
Beam size/position dependence	±2%	±2%	±2%	±2%	±2%	±2%	±2%	±2%	±2%	±2%	±3%
Entrance cone aperture	–	24mm	24mm	25mm	50mm	25mm	65mm	100mm	45mm	45mm	65mm
Absorber diameter	10mm[r]	16mm	18mm	18mm	40mm	18mm	50mm	90mm	35mm	35mm	45mm
Active area	0.75 cm²	2.0 cm²	2.5 cm²	2.5 cm²	12.5 cm²	2.5 cm²	19.6 cm²	63 cm²	9.6 cm²	9.6 cm²	16 cm²
Head sensitivity (approx.)	100-400mA/W	1.0 mV/W	1.0 mV/W	0.35 mV/W	0.15 mV/W	0.15 mV/W	0.13 mV/W	0.08 mV/W	0.05 mV/W	0.03 mV/W	0.025 mV/W
Head dimensions in mm. (diameter x depth)	36x29	60x30	85x45	152x108, 85x45 F-83x83x112	A-152x103 F-83x83x112	90x36	115x45	100x45	100x45	100x45	115x60
Display Specifications											
Meter ranges (full scale)											
Analog display AN	–	3mW to 10W	10mW to 30W	50mW to 150W	50mW to 150W	0.1W to 300W	0.1W to 300W	1W to 300W	0.3W to 1000W	15W to 1500W	100W to 3kW
Analog hand-held ANHH		30 mW to 10W	100 mW to 30W	0.5 W to 150W	0.5 W to 150W				--	–	–
Digital display DGX	–	1W,10W;0.2J,2J	3W,30W,3J,30J	20W,150W;3J,30J	20W,150W;3J,30J	30W,300W,3J,30J	30W,300W,20J,100J	30W,300W	200W,1000W;20J,200J	200W,1500W,20J,200J	300,3000W (no energy)
DGX continued											
Digital hand-held DGHH	2 µW to 2W	2W,20W;0.2J,2J	2W,20W;2J,20J	20W,200W,2J,20J	20W,200W;2J,20J			–	–	–	–
Noise level, pk-pk[k]	1nW	0.3mW	0.3mW	1mW	2mW	2mW	5mW	5mW	5mW	10mW	2W
Energy threshold, DGX (approx.)[l]	–	6mJ	6mJ	20mJ	100mJ	50mJ	200mJ	–	100mJ	175mJ	–
Zero drift[c]	1nW/°C	0.2mW/°C	0.2mW/°C	0.5mW/°C	0.5mW/°C	1mW/°C	2.5mW/°C	0.2mW/°C	2.5mW/°C	5mW/°C	100mW/°C
Readout dimensions (mm)			DGX: 230Wx43Hx180D		AN-: 220Wx130Hx100D		DGHH-: 80Wx175Hx28D	ANHH: 210Wx100Hx40D			
Recorder output						1V Full scale					

FOOTNOTES

a. For use with high power density YAG, CO_2 or visible lasers, can be ordered as -HP version. Power density ratings are then 1kW / cm² (500W / cm² for 10A and 30A versions). Calibration accuracy of HP-CAL version is ±2%.

b. Rating for pulses of the order of 20 nsec. For other pulse widths, see graph. The CW rating is reached for pulses of the order of 1 sec.

c. After initial warm-up.

d. For N type, rating given is for up to 10WCW. For N and -EX, rating falls with increasing power to 2kW / cm² at 30W, and 500W / cm² at 100W or more.

e. EX calibrated at 248 nm. For other wavelengths see graph.

f. For continuous use above 100W, F-150 A should be used. For up to 30W continuous and 150W intermittent, 30(150)A-HP version is available with 150 type disc in 30A head.

g. Rating given at half power. At full power, rating falls to 1 kW / cm².

h. Power and energy density derated 50% between 260nm and 350 nm, and 90% below 260 nm.

i. At full power, derate power density to 50%. Optional beam diffuser available for use at full power with high power density to 500 watt / cm².

j. Power accuracy of HP-CAL version is ±2%. Energy accuracy is ±3% at mid energy range. At 3 times threshold it decreases to about ±10%.

k. Values are given for AN. For ANHH and digital displays noise is 3 times higher.

l. Cut-off threshold, below which DGX unit will not measure, factory-set to discriminate against environmental noise. For small pulse energies, a pulse train, exceeding the threshold, should be fired. For DGHH, threshold is about 4 times higher.

m. Threshold is 0.2mJ from 0.19 to 1.1µm. For 1.1 to 6µm, threshold is 1mJ using self trig function.

n. For use with constant on / off cycles at full power derate 25%.

o. With filter in at powers above 2mW, spectral range is 0.4-1.1 µm. Available with germanium photodiode, spectral range 0.8-1.8 µm.

p. Without filter, for range 350-950 nm. Add 5% to error for spectral range 950-1100 nm and another 5% for "filter in" mode.

q. Add 0.5 sec to response time for CAL option (due to increased mass).

r. Large aperture ø19 mm option available.

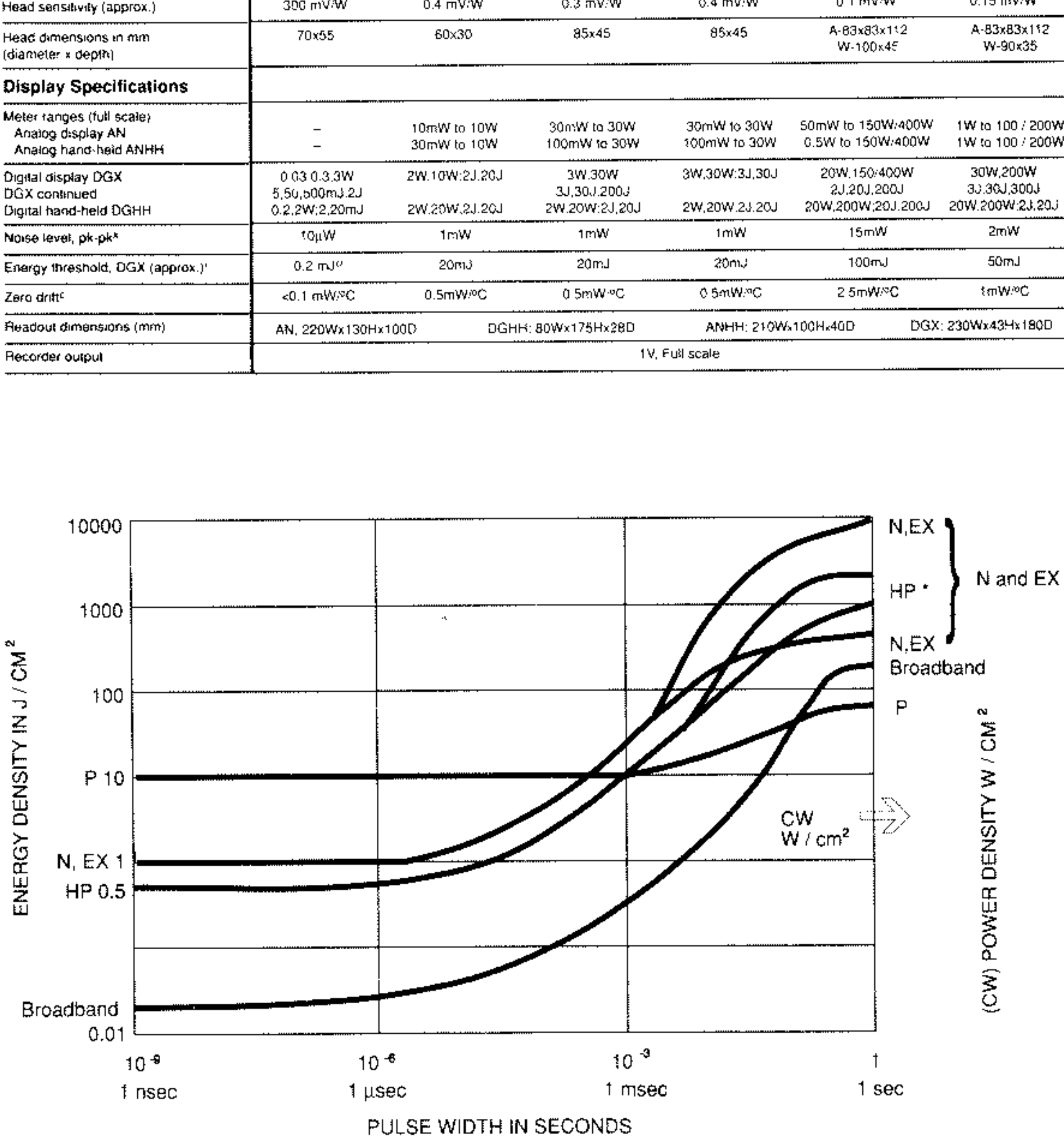
s. Available with fiberoptic adaptor.

t. For HP version.

u. Broadband coating has a dip in absorptivity between 1.6 and 10µm as shown in graph.

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Model	3A-P	10A-P	30A-N 30A-EX	30A-P 30A-P-dif[f]	FL150A-EX L400W-EX	F100A-N 200W-N
Recommended use	Low energies-low powers[5]	Scientific pulsed	High power density YAG excimer, long pulse	High pulse energy	Excimer lasers long pulse lasers	Industrial pulsed YAG lasers
Head Specifications	**VOLUME ABSORBERS**					
Spectral range	0.19-6 µm[m]	0.19-6 µm[h]	N: 1.06 µm EX: 0.19-10.6 µm[e]	0.19-6 µm[h]	0.19-10.6 µm[e]	1.06 µm
Max power (continuous)	3W	10W	30W	30W	150/400W	100/200W
Max average power density	75W/cm²[j]	75W/cm²[j]	10kW/cm²[d]	75W/cm²[j]	2kW/cm²[d]	10kW/cm²[d]
Pulse peak power density[b] (20ns)	0.5GW/cm²	0.5GW/cm²	50MW/cm²	0.5GW/cm²	50MW/cm²	50MW/cm²
Pulse energy density[b] (20ns)	10J/cm²	10J/cm²	1J/cm²	10J/cm²	1J/cm²	1J/cm²
Head response time 1/e	5 sec	3 sec	6 sec	6 sec	12 sec	3 sec
Response with readout 0-95%[g]	2 sec	2.5 sec	2 sec	2.5 sec	4 sec	2 sec
Linearity with power	±2%	±1%	±1%	±1%	±1%	±1%
Accuracy for power measurements[i]	–	±3%	±3%	±3%	±3%	±3%
Accuracy for power with -CAL option[v]	±1%	±1%	±2%	±1%	±2%	±2%
Beam size/position dependence	±3%	±2%	±2%	±2%	±2%	±2%
Entrance cone aperture	16mm	24mm	24mm	24mm	50mm	25mm
Absorber diameter	12mm	16mm	18mm	18mm	40mm	18mm
Active area	1.1 cm²	2.0 cm²	2.5 cm²	2.5 cm²	19.5 cm²	2.5 cm²
Head sensitivity (approx.)	300 mV/W	0.4 mV/W	0.3 mV/W	0.4 mV/W	0.1 mV/W	0.15 mV/W
Head dimensions in mm (diameter x depth)	70x55	60x30	85x45	85x45	A-83x83x112 W-100x45	A-83x83x112 W-90x35
Display Specifications						
Meter ranges (full scale) Analog display AN Analog hand-held ANHH	– –	10mW to 10W 30mW to 10W	30mW to 30W 100mW to 30W	30mW to 30W 100mW to 30W	50mW to 150W/400W 0.5W to 150W/400W	1W to 100 / 200W 1W to 100 / 200W
Digital display DGX DGX continued Digital hand-held DGHH	0.03 0.3.3W 5,50,500mJ.2J 0.2,2W;2,20mJ	2W.10W:2J.20J 2W.20W.2J.20J	3W.30W 3J,30J.200J 2W.20W:2J,20J	3W,30W:3J,30J 2W,20W.2J.20J	20W.150/400W 2J,20J,200J 20W,200W;20J.200J	30W,200W 3J.30J,300J 20W.200W:2J.20J
Noise level, pk-pk[k]	10µW	1mW	1mW	1mW	15mW	2mW
Energy threshold, DGX (approx.)[l]	0.2 mJ[o]	20mJ	20mJ	20mJ	100mJ	50mJ
Zero drift[c]	<0.1 mW/°C	0.5mW/°C	0.5mW/°C	0.5mW/°C	2.5mW/°C	1mW/°C
Readout dimensions (mm)	AN, 220Wx130Hx100D	DGHH: 80Wx175Hx28D	ANHH: 210Wx100Hx40D	DGX: 230Wx43Hx180D		
Recorder output	1V, Full scale					



* Depending on total power

Pulse Energy Rating for Ophir Absorber Options.

Ratings given in the graph are approximate values for single pulse conditions. Pulse rating for a continuous repetitive pulse train are somewhat reduced, and are usually limited by the average power density of the beam, and the total power dissipation.

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SPECIFICATIONS

Head Specifications: see page 2 and 3.

Display Specifications:

Input gains:	Stage 1 – 3, 30
	Stage 2 – 1, 2, 4, 8, 16, 32, 64, 128, 256

Analog to Digital Sampling Rate:	15Hz
A to D resolution:	16 bit + sign
Input noise level:	400 nanovolt, typical
Noise level with head:	see page 3 and 4
Energy thresholds:	see page 3 and 4

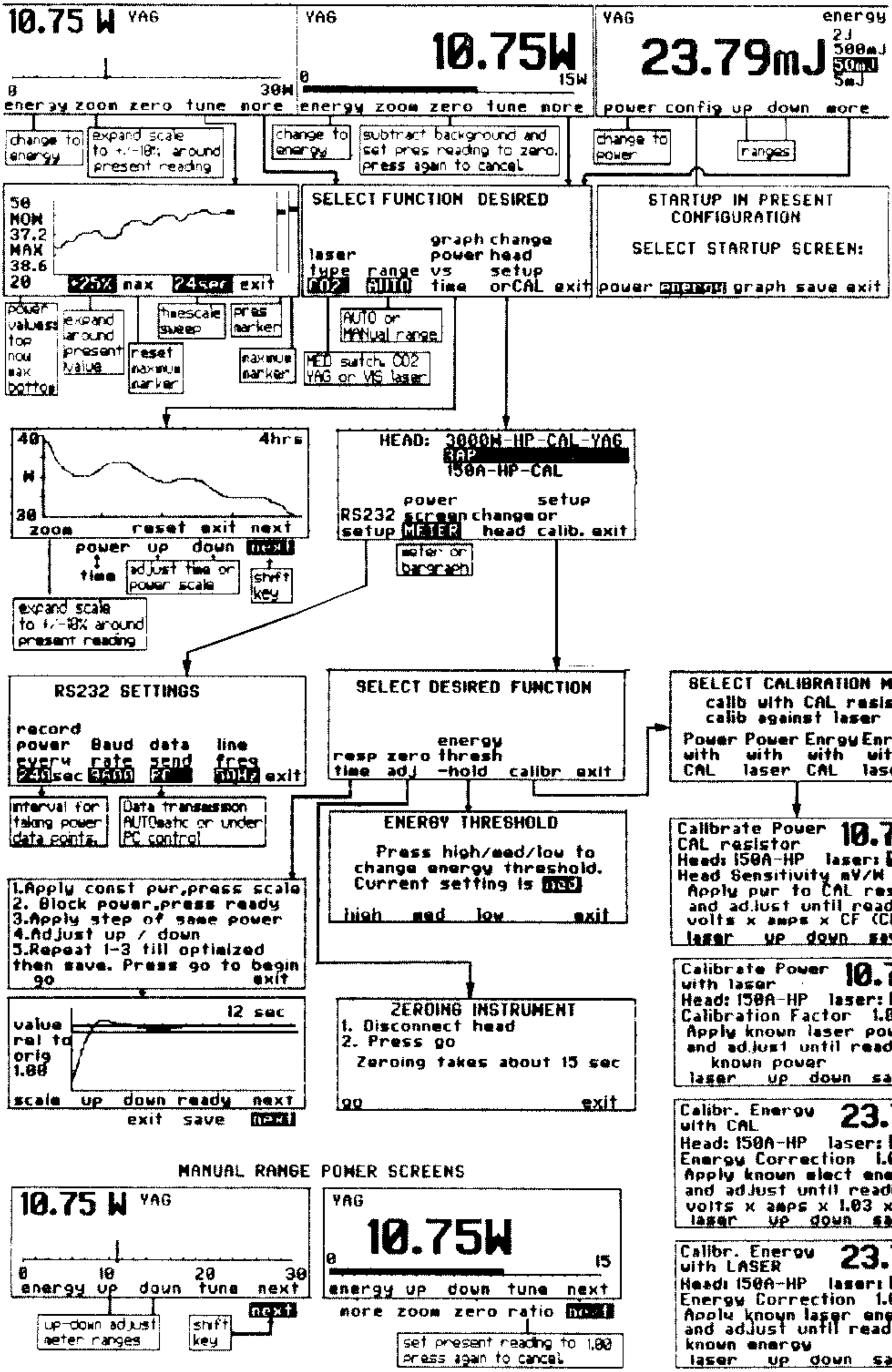
Power requirements

Charger current:	220 mA
Operating current:	90 mA
Battery type:	5 x 1/2D
Battery operation per charge:	24 Hours
Battery charging time:	18 Hours
Charger Specifications:	DC: 12.4–17.2VDC, 500 mA
	AC: 10.7–13.5VAC, 500 mA

Backlight:	Electroluminescent type
Current:	200 mA nom
Lifetime:	10,000 hours.

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Fig 1



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Table 1

24 Sec

Set timescale of tune screen for 12 sec, 24 sec, 1 min, 2 min or 4 min depending on setting.

±25%

Expand power scale to ±10%, ±25%, ±50% around present value depending on setting.

Baud rate

set data transmission rate to match your computer or printer. The factory setting is 9600, which is standard for most case.

Calibr

Recalibrate power or energy from built in CAL resistor or from known source of laser power or energy.

Change

change head or some system parameter or recalibrate according to subsequent options.

Change head

switch cyclically betwween heads. This only operates if the customer has purchased multiple heads with this DGX. When the unit has multiple heads, the one currengly used is displayed on the main screen.

Config

save present configuration. DGX will start in configuration saved when switched on.

Data control

When this is set to "PC" then the data link in under PC computer control. the instrument will do various options some of which are supplied on a diskette which can be ordered from Ophir along with explanatory material.

The other mode is "AUTO" in which the DGX automatically transmits each energy reading or the power reading at intervals requested. It can transmit to PC, serial printer or the DGX screen. The data is transmitted in E format.

Down

Change to next lowest range. In calibration mode sets reading to lower value.

Energy thresh-hold

Reset minimum value of energy which will trigger DGX. The best setting is the lowest threshold at with which the instrument will not trigger by itself from noise.

Energy

Change to energy measurement.

Exit

Return to last main power or energy screen used.

Graph power

Starts plotting graph of power vs. time according to setting in that mode.

High

high threshold for energy. Will not easily trigger from noise but less sensitive and less accurate for small energies.

Laser type

Set MED switch to correct calibration for type of laser being used. Pressing button cycles between YAG CO_2 and VIS where VIS is calibrated for visible lasers.

Line freq

Set power line frequency to 50/60 Hz according to country of use.

Low

Low threshold for energy. instrument most sensitive and accurate for small energies but instrument may trigger on noise.

Lowbat

appears when battery voltage falls below preset value. Time to recharge.

Max

Reset maximum marker on right hand side to present value. Marker will subsequently stay at highest value ocurring.

Med

medium energy threshold setting. This is the factoruy setting.

More

Press to access further functions.

Next

Selects additional key functions on this screen. Highlighted when operational. Press again to return to original keys.

Power

Change to power measurement.

Power screen

Select between bargraph and meter type power display.

Power/time

Switch between power and time so user can adjust power scale and time scale he wants. Power scales available are those on the main meter display and time scales are: 1/6, 1/2, 1, 2, 4, 10, 24, 72, 240, hours.

Range

switch between auto and manual ranging.

Ratio

Set present reading to 1.00. Subsequent readings show reading relative to this one. Highlighted when operational. Press again to cancel.

Ready

DGX ready to record power step so as to adjust response time.

Record power

RS232 output will send the power reading at intervals set by this key. The values will be transmitted only if the data control setting is in "AUTO".

Reset

Start new power graph from when reset button is pressed.

Resp time

Readjust response time of DGX with current head.

RS232 stngs

Setup parameters for sending data to computer, serial printer or screen.

Save

Save new calibration or configuration value in DGX memory at end of calibration.

Scale

Adjust power axis of graph so value recorded is on top.

Tune

Select tune screen used for "tweaking" laser power to maximum. This exclusive feature makes laser tuning very convenient.

Up

Change to next highest range. In calibration mode sets reading to higher value.

Zero

Subtract present unwanted backqround reading from this and subsequent readings. Caption highlighted when operational.

Zero adj

Reset DGX so it will read exactly zero with no signal.

Zoom

Expand power scale to +/- 10% around present reading. Caption highlighted when operational. Press again to cancel.

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1. GENERAL DESCRIPTION

The DGX Display Unit

The model DGX laser power/energy meter represents a new level of sophistication, sensitivity and accuracy, and at the same time ease of operation. It operates with all types of Ophir measuring heads, thermopile, photodiode and pyroelectrics. It can operate with as many as 4 different heads, measure power and energy with a high degree of accuracy and do many other tasks as well. It can graph power vs. time and send the data to computer, it can store energy points, process the data and send it to a computer or printer. It can display power in both digital and analog form at the same time. It will also autorange, so you do not have to set scales or manual range if you wish. It will remember what mode you were using before you turned it off and will automatically return to that mode when turned on. You can zoom in on present reading, subtract background and scale. You can recalibrate, adjust risetime and zero at the touch of a button. The main instructions are clearly shown on the screen so you will not have to refer to this manual very often. Above all the DGX has superior circuitry and digital signal processing for excellent sensitivity, signal to noise ratio, accuracy and response time.

1.1 Thermopile Absorber Heads

When a radiant heat source, such as laser, is directed at the absorber head aperture, a temperature gradient is created across the thermopile of the enclosed detector disc, and this generates a voltage proportional to the incident power. The display unit amplifies the signal and indicates the power level received by the head. At the same time, special software causes the display unit to respond faster than the thermal rise time of the detector disc, thus reducing the response time. Energy of a single pulse is measured on the DGX by digitally integrating the pulse power over time.

1.2 Photodiode Heads

The DGX is also equipped to operate with the PD2A photodiode measuring head for measuring very low powers. Unlike thermal heads, the photodiode response changes with wavelength. The DGX provides for automatic wavelength correction with those heads. For operation with the PD2A option see Appendix B.

1.3 Pyroelectric Heads

The DGX is also equipped to operate with Ophir pyroelectric heads to measure very small or rapidly repeating pulses. See Appendix C for operation with pyroelectric heads.

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2. OPERATION

Sections 2–4 describe in detail the operation of the DGX. For quick and easy reference we have assembled in fig. 1 and table 1 the main functions. For most purposes it is sufficient to refer to these two pages.

2.1 Turn On and Shut Down

To turn on the DGX switch the leftmost switch on the rear panel. The unit will switch on and the display will appear.

To switch off the DGX, switch the switch the other way. If you wish to save the configuration the DGX is in, use the "config" function before switching off. (See section 2.6).

2.2 Legends of Keys (see fig. 1)

The DGX has "soft keys". This means that the functions of the keys change as indicated by the legend above each key. The legend usually indicates what will happen when pressing the key; e.g., if "energy" appears that means that pressing the key will change the DGX into energy mode. Some functions operate when the key is pressed and are cancelled when the key is pressed again. These keys show reverse highlighting when operational. Pressing the same key again cancels the operation and highlighting.

2.3 Backlight

The backlight illuminates the panel in dim light and is operated by a switch on the back panel. The backlight consumes considerable power, and, to save the battery, is operable only when the charger is plugged in. The electroluminescent backlight does have a finite lifetime (about 10,000 hours) and therefore should only be operated when necessary.

2.4 Tilting Display

The DGX is equipped with a unique tilt mount for easy viewing of the LCD display. It is designed to tilt up to the best viewing angle (up to 60^0) and fold down flat when not in use.

When the DGX is folded flat, the thickness is only 42 mm, making it easily portable using the optional carrying case or your briefcase.

2.5 Charging

The DGX can be operated both by battery and from an AC source with the charger plugged in all the time.

The DGX will charge the batteries much more rapidly when it is switched off and the backlight is not lit. Therefore it is recommended to leave the charger plugged in when the unit is not in use. The DGX charges fully in about 18 hours and the unit will operate about 24 hours from one battery charge. When the battery is low, "BAT" is displayed on the screen. When this happens, the charger should be plugged in. In order to charge the batteries again, the charger should be left plugged in with the unit

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switched off overnight. Even with "BAT" displayed the unit will operate properly for about 1 hour. After that, accuracy will be impaired.

2.6 Changing Configuration

Most users will want to use the DGX repeatedly to do similar types of measurements. So that you do not have to set up the DGX to do this each time, the configuration you wish to use can be saved and then the DGX will automatically go into this configuration each time.

The functions saved by the "config" operation are: energy/power, range, laser type, power screen, head type, auto/manual range, tune screen and RS232 settings. Other calibration and setup parameters are saved without the "config" function.

To use this function, set the DGX to the functions you wish to use, enter energy mode and press "config". Select power, energy or graph to be the first screen which appears when turning on the DGX, press save and exit.

Note: In order to protect the EEROM permanent memory, the unit is shipped with the small DIP switch #2, which is the write protect switch, in the up position. In order to change cofiguration, you must switch the #2 switch down, save the configuration, then switch it back up again. If you try to save when the EEROM is write protected, an error message will appear. If you forget to return the switch to the protected position, another error message will appear when the DGX is switched on.

2.7 Multihead Capability

The DGX can operate with up to 4 different standard Ophir heads, if configured to do so when purchased. When equipped for multiple heads, the DGX will indicate which head is set up at present. Each head has individual values of sensitivity, response time, power and energy scales and so on. Thus if the DGX is set for one head and a different head is connected, the readings will be completely erroneous. When the multihead option is operational, the main power and energy screens will display the type of head presently selected so the user will not make a mistake.

Note: Do not use with 2 heads plugged in at the same time.

2.7.1 Changing Heads

Changing Heads on the DGX is very simple:

a) Connect proper head to DGX

b) press more → change head setup or cal → change head

The various heads will be highlighted in cyclical fashion as "change head" is pressed. The head which is highlighted is the one presently operational.

2.7.2 Reprogramming the DGX for additional or different Heads

Please contact your local agent for the latest status of how to change or enlarge the capability or your DGX for additional heads.

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2.7.3 Line Frequency

The DGX is factory set for 50 or 60 Hz according to the destination country. If you wish to reset the line frequency, turn on the DGX, press more → change → RS232. Mains freq. 50 or 60 will appear as the button is pressed.

3. POWER MEASUREMENT

3.1 Head Setup

Connect the head to the rea d-out unit using the coaxial lead provided . If the head is a water-cooled type, ensure that the cooling water is flowing at an adequate rate; see table.

Minimum Flow Rates For Water-Cooled Heads

Head Type	Liters/Minute	U.S. Gallons/Minute
3000W	5	1.3
1500W	2.5	0.6
1000W	1.5	0.4
300W	1	0.25

3.2 Basic Operation

Switch on the DGX by means of the leftmost switch on the rear panel. The DGX will enter the mode of operation last saved with the "save config" operation. Thus for basic operation, just set up the parameters for the type of measurement you wish (section 2.6, 3.3) and then the DGX will be ready to measure each time it is switched on.
If the DGX is in energy mode, pressing power will cause it to enter the power mode.

3.3 Power Options

In the following section, we describe a number of useful functions the DGX offers in the power mode in addition to the basic power measurement mode described in 3.2. For your convenience, fig. 1 shows all the main DGX functions as well as a short form description of keys. For most purposes, reference to fig. 1 will be all that is necessary for operation.

3.3.1 Automatic/Manual Range:

Autorange: The DGX allows you to choose autorange or manual ranging. In autorange mode, you do not have to change scales. When the reading of the meter or bar is more than 110% of full scale, the range goes to the next higher one. The ranges are arranged in factors of 1, 3, 10, 30 etc. When the reading falls below 27% of full scale, the range changes to one lower after a few seconds delay. Thus there is a certain hysteresis (overlap) so the meter doesn't keep flipping back and forth when reading close to the end of the scale.

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Manual Range: There are certain disadvantages to autorange since autorange changes scale even if you don't want to do so. If you want to measure the same range all the time then it is better to use manual range. To select manual range press more — RANGE and see that the screen says "MAN".
In manual range, press up to go to the next higher range and down to the next lower range. Full scale is indicated by the number on the right hand side of the meter.
Note that in manual range the 5 buttons are not enough for all the functions. To access zero, ratio, zoom and more press "next" and this accesses those functions. To return to original functions energy, zoom, up, down press "next" again.
If you wish the DGX to be in manual mode when switched on, save this configuration before switching off (see section 2.6).

3.3.2 Bargraph/meter

The user can choose two types of power display, large numbers with a bargraph type display or smaller numbers with a meter type display. The bargraph or meter display updates at 15 times per second. The bar or meter thus reacts quickly like a real analog meter and can easily be used to tune power. To select the type you prefer, press more —→ change head —→ power screen: The legend on the screen for power screen: will alternate between METER and BAR. After deciding which display you prefer, save this configuration with "config" (section 2.6).

3.3.3 Zoom

This function causes the scale to expand around your present reading ±10%. Thus if the full scale of the bargraph is 20 watts and you are now reading 15 watts, when pressing ZOOM the bargraph scale will be between 13.5 and 16.5 watts approximately. The variations in power are more easily seen in this mode. When ZOOM is engaged, the legend is highlighted. To cancel this function press ZOOM again. The ZOOM function, as well as the tune function described in 3.3.5 is useful for laser power tuning and peaking.

3.3.4 Zero

This function subtracts background signal. If you have a thermal background and the DGX reads nonzero power even with no laser, you can subtract off this signal using the ZERO function. For example: if while blocking the laser the display reads 0.1 watt and with laser power applied it reads 20.5 watts then your true power is really 20.5 – 0.1 = 20.4 watts. To subtract this background, press ZERO while the laser is blocked. The reading will now be zero and this means that 0.1 watt will be subtracted from all subsequent readings. Thus you now will read 20.4 watts for the laser power. When ZERO is engaged the

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display is highlighted. To cancel press ZERO again. If the ZERO is engaged and you wish to subtract a new value of background, press ZERO twice, first cancelling the first value, then engaging the new value.
If the DGX shows a nonzero reading even when the head is not connected then the instrument zero should be reset. This is described in section 7.1 on calibration and alignment.

3.3.5 Tune

This exclusive Ophir function makes adjusting your laser to maximum power easier than ever before. Unlike a bargraph or mechanical meter, the display shows graphically what went before as well as the trend so you can se at a glance if maximum power has been reached.
The screen is completely autoranging.
As soon as the cursor goes over the top or under the bottom edge, the display rescales and the cursor jump back to the middle of the screen. Thus the user can devote all attention to tuning the laser and does not have to touch the DGX settings.

Operation:

1) Set the power expansion scale to ±10%, ±25%, ±50% or ±100% as desired (if the laser power will change a lot, use a large value, if a little, use a small value).
2) Set the horizontal sweep time to 12 sec, 24 sec, 1 min or 4 min as desired. (Both the expansion and time settings can be saved for future use using the "config" setting described in section 2.6).
3) Measure the power of the laser and "tweak" laser power until you see that it has reached a maximum.
4) To facilitate seeing when maximum has been reached, note that there are two cursors on the right of the screen. The rightmost cursor shows the highest value that has been reached till now. The one next to it shows the present value. Where the two are equal, the laser power is maximum. The right cursor can be reset to the present value at any time by pressing "max".

3.3.6 Ratio

This function (which is available only from the manual range mode 3.3.1), is used to compare two power values, e.g.: your laser power with or without a filter installed. When RATIO is pressed, the present reading is set to 1.000 and all subsequent readings are proportional. Thus if your present reading is 20 watts and you press RATIO, the DGX will read 1.000. Applying 15 watts it will now read 15/20 = .750
To access RATIO, use manual range mode and press "next" → "ratio".

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When RATIO is engaged, the legend is highlighted. To cancel, press RATIO again. To set a new baseline power to 1.00 press RATIO twice, first cancelling old value then engaging new one. If you are measuring very low power values then the RATIO function cannot operate properly and an error message will appear.

3.4 DATA TRANSMISSION

3.4.1 RS232

The RS232 data interface allows readings of power and energy to be sent to a remote computer or printer. There are two basic ways to use the interface:

1) Automatic mode:
   The DGX instrument periodically sends the power reading, or, in energy mode, it sends the energy of each pulse.
2) PC Mode:
   A remote computer (an IBM PC or compatible) sends commands to the DGX, and the DGX responds immediately with the requested data or action.

The RS232 settings menu is reached by using the key sequence: MORE → CHANGE → RS232.

This menu allows you to choose which of the two modes you wish to use, and also allows you to change the baud rate and the rate at which power data are sent in automatic mode.

The data are sent in ASCII format using standard scientific notation. For example, if the reading is 123.4 Watts, the data will be sent as 1.234E+2, followed by a carriage return character.

The real power of the data interface becomes available in PC mode. The PC mode allows the remote computer to control all of the DGX functions as well as to log data under PC control.

The DGX RS232 Utility Package, available from your Ophir sales agent, contains full details of the PC mode instruction set, and guidelines for programmers wishing to develop their own application software. The package also contains a general purpose program for IBM PCs and an RS232 cable.

The program is menu driven and provides:

* Logging of power or energy data to printer or disk file
* Graphical display of power
* Statistical functions of pulse energies
* Real-time histogram display of pulse energies
* Remote control of the DGX instrument.

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3.4.1.1 Baud Rate

This sets the data transmission rate to be compatible with your printer or computer. The standard setting is 9600. Consult the manual of your computer or printer to determine the compatible baud rate in your case.

3.4.1.2 Record Power Every – Sec

This sets the intervals at which the DGX will send power readings in the "AUTO" data control mode. The readings are transmitted via the RS232 link.

3.4.2 Anolog/Recorder Output

The recorder output is via a 2.5 mm pin jack on the rear panel. It provides 1 volt full scale with an output impedance of 1K ohm, and 10–bit (0.1%) resolution. The output tracks the bargraph display so that if you press "ZOOM", the output is expanded 5–fold about the present power level. The lower and upper domain of the output voltage can then be read from the annotation of the bargraph.

3.5 POWER vs. TIME GRAPH

The DGX has the option of graphing your laser power vs. time, storing the data and sending it to computer, printer or screen.

3.5.1 Setup

a) Set up the RS232 settings if you have not done so yet (section 3.4).
b) Press more — graph power to enter power graph mode.
c) Press next and then power/time. The display will alternate between power and time. Set to power.
d) Adjust up/down to proper power scale. Scales available are the same as the main power screen.
e) Press power to switch to time. Now adjust time scale to full scale desired. Time scales available are 1/6, 1/2, 1, 2, 4, 10, 24, 72 and 240 hours.
f) If you plan to make many similar graphs, save the configuration with "config" (section 2.6).

3.5.2 Functions

Zoom: Just like in the main power screen, this expands the scale $\pm$10% around the present reading. In this fashion, the resolution of the graph is increased.

Reset: When the reset button is pressed, a new power graph starts from the beginning of the time scale.

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4. ENERGY MEASUREMENT

4.1 Setup

Switch the DGX on as in 3.2.2. If it is in power mode press "energy" and it will enter energy mode.

The energy mode is manual ranging: press up/down until the proper range is indicated. The correct range is the lowest one which is larger than the pulse energy measured. If you plan to use the same setting often, press "config" (section 2.6) before switching off the first time. When the DGX is switched on again it will automatically go into the same mode until a different configuration is saved. Thus for simple measurements of the same type, the DGX needs no setting up each time.

4.2 Measurement

To measure energy of a single pulse, set up as above and fire the laser. The display will blank while the energy is being integrated and after 2–4 seconds the correct energy will be displayed. The next pulse, will automatically blank the screen and display the new value. When the DGX is ready to measure a new pulse, "ready" will appear on the screen. If you fire another pulse before "ready" appears, the reading may be inaccurate.

4.3 Minimum Energy Threshold

If the instrument is used in a noisy environment, or in a location with a high level of background thermal radiation, the instrument may trigger spuriously on the noise or background radiation, and then fail to measure the intended pulse.

Since there is always some degree of noise or background radiation, the instrument is designed not to respond to pulses below some preset minimum size. This "Minimum Energy Threshold" is typically set to 0.3% of full scale of the selected range.

If this level is found to be too sensitive for the user's particular environment, it may be altered by the user; see calibration instructions, section 6.3. The threshold should not, however, be raised higher than necessary, since there is a degradation in the accuracy of energy measurements of pulses up to about 4 times the threshold level.

The factory setting of energy threshold is "med" = medium. If the unit triggers on noise, set to "high". If you are measuring small energies and it doesn't trigger, set to "low".

4.4 Measuring Pulses of Very Low Energy

When it is necessary to measure pulses of very low energy, i.e. less than 0.5% of the maximum range of the instrument, the following two alternative methods enable greater accuracy to be obtained.

a) A continuous train of pulses may be fired and the average power measured using POWER mode. Then the energy per pulse can be calculated:

Energy per pulse = Average power / Pulse Repetition Rate

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b) A train of a known number of pulses may be fired, and the total energy measured in ENERGY mode. This train should not exceed 5 seconds duration.
In both of the above methods the pulse repetition rate must exceed 3Hz and higher rates will generally give improved accuracy, but care should be taken not to exceed maximum power ratings.

4.5 Measuring Energy of Rapidly Repeating Pulses

The standard DGX will only measure individual pulses every 5 seconds or so. You can also calculate the average energy of rapidly repeating pulses by measuring average power on the power setting and using the formula:

Average Energy per Pulse = Average Power / Pulses per Second

There is a special version of the DGX which will measure both average power and exact individual pulse energy of rapidly repeating pulses. It will record pulse energy at up to 1000 pulses per second and and send the data to a computer or printer by RS232 link. This version is called the DGX-RP. For more information, contact your Ophir dealer.

5. CIRCUIT DESCRIPTION

The DGX has no user adjustable hardware inside. All adjustments are made by software. In any event a general circuit description is provided for the user.
A block diagram of the circuitry is provided in fig 2. and a diagram of the signal flow in fig 3. Component layout diagrams are provided in figures 4 and 5.

Preamplifier and Programmable-gain amplifier

The preamplifier is based on a high performance op-amp in inverting mode, with gain of either –3 or –30. The signal is then amplified by a programmable gain amplifier with gain variable between –1 and –256 as set by microprocessor control. The offset nulling and gain trimming for these sections is done digitally by the microprocessor, by storing the necessary corrections in non volatile memory (EEROM).

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Analog to digital converter

The A/D converter is a dual slope integrating type whose timing is controlled by the microprocessor. It runs at 15 samples per second with full 16 bit (0.002%) accuracy, and provides very good line-frequency rejection.

Microprocessor section

The microprocessor section is based on an Intel 80196 running at 8MHz with an 8–bit bus. The bus connects the microprocessor to RAM, EEROM, EPROM, display and the programmable-gain amplifier. The microprocessor also controls the RS232 driver, the analog output and the keypad.

Analog output

The analog output, useful for driving chart recorders and the like, provides an analog voltage proportional to the laser power.

Signal Flow

The DGX signal flow is depicted in fig. 3.

The input is first amplified by the preamplifier, then further amplified by the programmable amplifier (PGA). The signal is digitized in the A/D stage and fed to the nanovoltmeter. This stage compensates for nonlinearities and offsets.

The amplified and compensated signal is now processed through a sophisticated digital filter which speeds up head response (as much as 200 times in some cases) and rejects noise. In power mode, this signal is sent to the display. In energy mode, the data is integrated over the signal period and then sent to the display module.

6. CALIBRATION AND ALIGNMENT

The DGX has no internal hardware adjustments. All adjustments are made by means of software via the keyboard. Therefore there is no need to open the instrument under normal conditions. If your measuring head is equipped with the exclusive Ophir CAL resistor then calibration is done following the instructions in section 6.1 and 6.2. If not, then you can recalibrate from a known source of power or energy following the instructions in section 6.3.

6.1 Instructions for – CAL Versions

Mounted on the rear center of the sensor disc is the exclusive Ophir calibration heater. By applying electrical power to the terminals at the rear of the sensor head, the disc is heated by electrical power instead of radiation. By accurately measuring the voltage and current applied, the calibration can be checked and readjusted if necessary, taking into account the calibration factor necessary, as explained in Appendix A.

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a) Do not exceed the maximum electrical power stated in the table below.

Table 1

Model	Power
10A Series	10 Watts
30A Series	30 Watts
150A Series	100 Watts
300W Series	125 Watts
1000W Series	200 Watts
1500W Series	200 Watts

b) Use the resistor for calibration only, and turn off the power as soon as calibration is done.

c) Do not operate the calibration resistor when the sensor disc is under radiation; the excessive heat may burn out the calibration resistor.

6.2 Recalibration of Power/Energy using the Built in CAL Resistor

If your instrument has the Ophir CAL resistor then you have a traceable absolute calibration source available just by measuring the voltage and current into the CAL resistor and multiplying by the calibration factor provided by Ophir.
(See Appendix A for a detailed description of calibration with the CAL resistor).
Calibration instructions:

a) Make sure the DGX is in power/energy mode on correct range and is set to correct head if you have a multihead unit.

b) Press more → change → setup → calibr.

c) Press "Power/Energy with CAL".

d) To set for power or energy calibration press the appropriate choice.

Power Calibration

Using a D.C. power supply, apply power to the CAL resistor (black and red terminals at the back of the head). For highest accuracy use the same power as you intend to measure, but do not exceed values in table 1 (section 6.1).
Maximum voltage applied should not exceed:

$$\sqrt{\left[\begin{array}{l}\text{Max power}\\ \text{shown in}\\ \text{table 1 X}\end{array}\right] \quad X \quad \left[\begin{array}{l}\text{Resistance}\\ \text{of CAL}\\ \text{resistor}\end{array}\right]}$$

The voltage should be measured at the input to the head and current in series with the current loop.
Adjust up/down until READING reads the same value as the (voltage in volts) x(current in amps)x(current calibration factor for your model and laser from Appendix A or as shown on DGX).

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Note 1: For MED/HP units which have different calibration factors for **CO_2 YAG or VISIBLE** lasers press "laser" to select correct type of laser before calibration. When recalibrating using the CAL resistor, the other two settings will be changed proportionately. If you wish to charge the calibration of only 1 laser type, then use the function "Power with laser"

Note 2: The unit retains for your information the current sensitivity of the head in mV/W. The original value is retained at the factory. You should record the original setting so you can return to it if you wish.

Energy Calibration

To calibrate energy using the CAL resistor you must apply a pulse of electrical power of known voltage, current and duration to the CAL resistor. For all models except the 3A-P, a long pulse of about 5 seconds is recommended in order to eliminate edge effects. For the 3A-P a pulse of 1/10 – 1/2 seconds is recommended. It is always advisable to use fairly large energies for calibration to minimize zero errors.

The voltage applied should not exceed:

$$\sqrt{\left[\begin{array}{l}\text{Max power}\\ \text{shown in X}\\ \text{table 1}\end{array}\right] \times \left[\begin{array}{l}\text{Resistance}\\ \text{of CAL}\\ \text{resistor}\end{array}\right]}$$

Adjust up/down until READING reads the same value as:
(the pulse voltage in volts) x (current in amps) x (duration is seconds) x (current calibration factor for your model and laser from Appendix A) (see note 1 above).

If it is difficult to measure current, an alternate formula is:

$$\text{Energy} = \frac{(\text{pulse voltage})^2 \text{x} (\text{calibration factor})}{(\text{resistance of CAL resistor})}$$

e) Press next to access save button and press save to save new value. If save is not pressed then the old calibration will remain.

Note 3: The energy calibration is independant of power calibration.

Note 4: The DGX shows a number ("Energy Correction") proportional to the current calibration. Please record this value so you can return to it later if you wish.

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6.3 Recalibration from a Known Source of Laser Power / Energy

a) Make sure the DGX is in power/energy mode on correct range and is set to the correct head if you have a multihead unit.

b) Press more → change → setup → calibr.

c) Press "Power/Energy with laser".

d) Apply known laser power/energy.

e) Adjust up/down until READING reads the same value as the known laser power/energy.

Note: For MED/HP units which have different calibration factors for **CO_2 YAG or VISible** lasers press "laser" to select correct type of laser before calibration. The other two settings will not be affected when adjusting power and must be recalibrated separately, if needed. When adjusting energy the other two values will also change proportionately.

g) Press next to access the save button and press save to save the new value. If save is not pressed, old calibration will remain.

h) Press exit to return to main screen.

Note: The unit retains for your information the current sensitivity of the head in mV/W. The original value is retained at the factory. You should record the original setting so you can return to it if you wish.

7. REALIGNMENT

7.1 Zero Adjustment

In the DGX, all adjustments including zeroing internal circuits are done from the software. This ensures simple and accurate realignment. It is recommended to rezero the DGX every 2 months for best performance. The simple zeroing procedure is as follows:

a) The DGX should be on for at least 30 seconds before zeroing.

b) Disconnect the head. For best results, short the BNC input.

c) Press more → change → setup → zero adj to access this function.

d) Press "go". The DGX will follow an automatic zeroing routine. It will indicate when zeroing is completed and will return to the main screen when exit is pressed.

7.2 Response Time

The response times for the particular head or heads which were sold with the DGX were set in the factory, However, the user may wish to readjust the response time if he has to change a disc or feels that the response time can be improved. Please note, though, that major changes in the response time can also affect the calibration of energy measurement.

Procedure:

a) Press more → change → setup → resp time to acess this function.

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b) Apply a constant laser power to head. Press "scale". This scales the gain of the DGX so the graph of power is near the top of the screen.

c) Now block the laser power and wait until the graph goes to zero. Press "ready" to prepare the DGX for a measurement.

d) Uncover laser power quickly, thus applying a step of power to the DGX. The response on the graph will show if the response time is properly adjusted.

e) If the response looks sluggish, press "up" and repeat steps c) and d) again. If response overshoots (a slight overshoot is okay), then press "down" and try c) and d) again. The reading on the right side "value rel to original" lets you know how much you are changing the response above or below the original value.

f) After you are satisfied with the response time, press next → save to save the new value of response time.

g) Press exit to return to the main screen.

7.3 Energy Threshold

As explained in section 4.3, there may be a necessity to change the energy threshold if the factory set value is not the optimum for your use (in most cases the factory value is optimum and there is no need to change the value). In the following cases try a new threshold (the original factory value is always "med").

Procedure:

Press more → change → setup → energy threshold to access this function. If your instrument often triggers on noise, set threshold to "high". This will make DGX less sensitive to small pulses but also less accurate for low energies. If the instrument does not trigger on small pulses, set the threshold to "low".

8. ERROR MESSAGES

The DGX displays various error messages when operated outside of its normal range:

8.1 Overrange

When the power or energy being measured exceeds the range of the measurement scale being used, the overrange message is displayed, but the reading still appears on the display. If the power or energy exceeds the maximum by more than 10%, the reading on the display is blanked.

8.2 Low Battery

When the battery is almost discharged, the message "BAT" appears. When the low battery message appears, the DGX should be connected to the charger. It will operate normally and charge slowly while connected to the charger. When connected to the charger while turned off, the DGX will charge faster, in about 18 hours.

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Input too small

The ratio button was pressed when the input power was less than 5% of full scale. Press ratio again.

EEROM Not Write Protected.

The #2 DIP switch on the back panel has been set to the down position. in order to change some configuration parameter. Set switch to up position so as to protect EEROM from becoming corrupted.

EEROM Write protected

You have entered a menu which generally results in permanent changes being made, but the write-protect switch is on. Switch off write protect switch (see back panel diagram and then after saving switch back up again).

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9. MAINTENANCE

9.1 Troubleshooting

Instrument will not operate after having been completely discharged and plugged into charger	Check that all 4 DIP switches on the back panel are in the up position. Check that charger provides 200mA at 12VDC. Open back and check fuse.
Instrument shows zero reading in both power and energy modes	Check connections between the head and the instrument; see under signal tracing (sec. 9.2). Check that the sensor disc is operative. Resistance at head BNC output should be about 1.8k Ω. If the sensor is bad, there will be an open or short circuit. See sec. 8.3.
Instrument responds while head is cold but suddenly fails as it heats up	Replace sensor disc. See section 9.3.
Instrument does not return completely to zero on power measurement	If head is very hot, allow it to cool. Disconnect the head from the instrument. If readout unit does not zero, adjust zero with head disconnected. (sec. 7.1).
Coaxial lead alone causes a reading	Lead has probably corroded and is generating an electrochemical voltage. Replace lead.

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Tilt display is loose	Remove plastic back by unscrewing 6 phillips screws. Tighten 2 phillips screws on either side of hinge to proper tension. Reclose back.

ENERGY MEASUREMENT FAULTS

Instrument triggers on background noise or sometimes fails to catch large pulse	Increase threshold level; see section 7.3.
Instrument cannot be reset for a long while after a reading is made	Increase threshold level; see section 7.3.
Non-reproduceable results when measuring very small energy pulses or no response to pulses at low energy	Decrease threshold level; see section 7.3.
Instrument operates with charger but not battery	Battery is dead. Recharge overnight with DGX turned off for 14–18 hours. If DGX still doesn't work with battery then the NiCd battery is dead. See sec. 9.4 for replacing battery.

9.2 Signal Tracing from Head

With the instrument open, apply an approximately known amount of power to the head, either with a laser or using an electrical power supply and the calibration resistor. Estimate the approximate signal voltage that should be developed by the head by multiplying the input power by the head-sensitivity shown in the specification table.

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Unplug the coaxial lead from the head, and check that this voltage appears between the center pin and outer ring of the BNC socket on the head. Connect the cable to the head and see that the same voltage appears at the other end of the cable.

9.3 Disc Replacement

If the absorber disc becomes inoperative, it can easily be exchanged with another, available from the distributor.

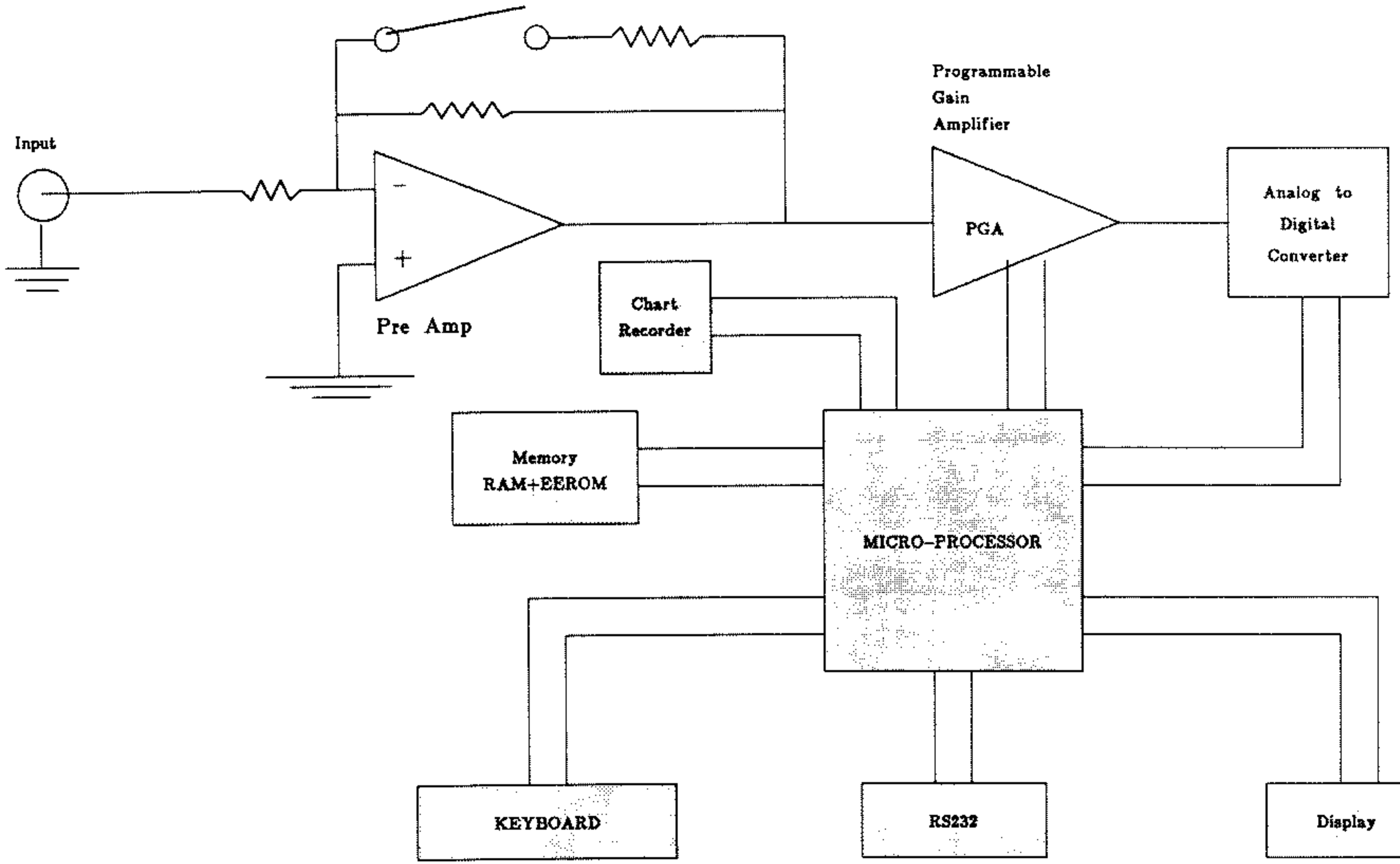
a) Remove the screws from front and rear flanges of the absorber head.
b) Remove the front flange and slightly raise the rear flange, taking great care not to tear the wires attached to the connectors.
c) Unsolder the wires from the faulty absorber disc from the BNC connector in the head, remembering which wire is connected to each terminal.
d) Pry the absorber disc free from its seat by using a screwdriver in the hole provided at the edge of the seat.
e) Smear the new absorber disc seat in the head evenly with heat-sink compound.
f) Feed the wires through the hole and install the new disc. It is best to turn the disc back and forth a few times while pressing on it to insure good contact between the disc, grease and head.
g) Reassemble the front flange, making sure the screws are tight.
h) Resolder the two wires to their proper locations on the rear flange and reassemble the rear flange.
i) The instrument should be recalibrated according to the instructions in section 6.

For water-cooled heads, steps d, e, and f are omitted. Instead, the water-sealing O-rings should be carefully cleaned and lightly greased with silicone grease befor installing a new disc.

9.4 Replacing Battery

If the battery is dead and does not recharge from the charger then it must be replaced. Remove the bottom of the DGX by unscrewing 6 phillips screws. Unplug the battery connector from the circuit board and loosen the two screws holding the battery holder. Remove the battery and replace it with a new one obtained from your Ophir representative. Tighten the battery holder, plug it into the board and reassemble the bottom.

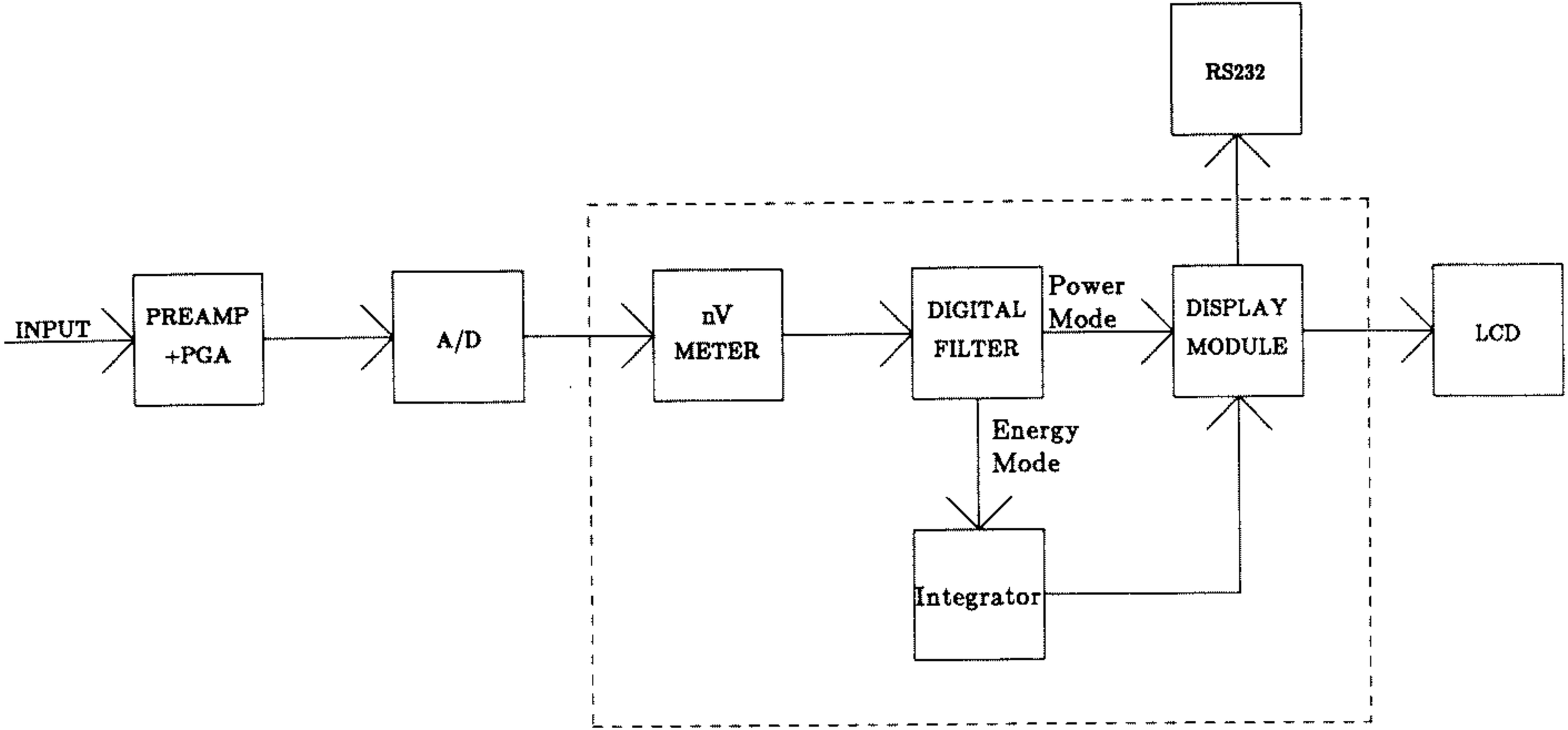
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DGX – BLOCK DIAGREM

fig – 2

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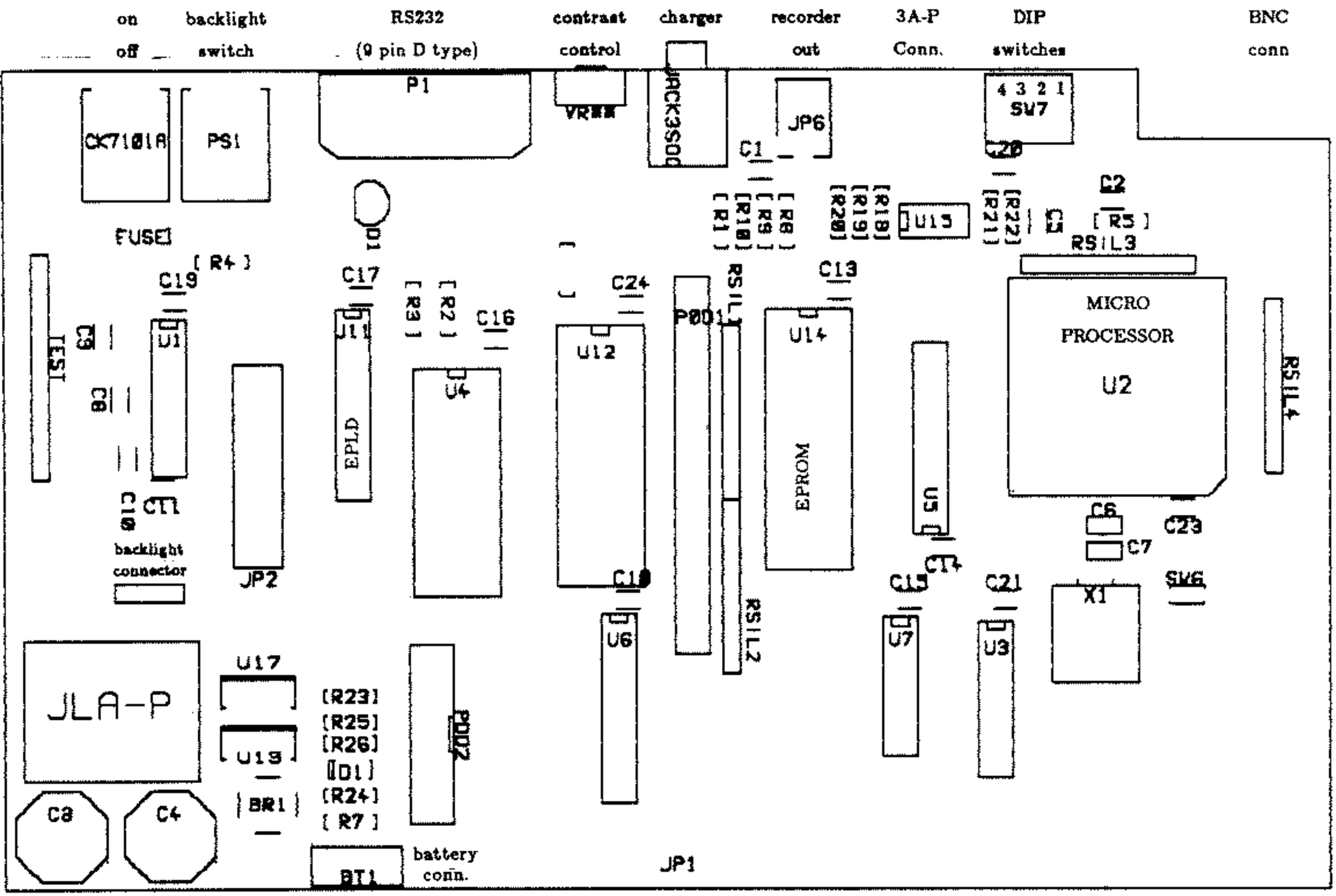


DGX - SIGNAL FLOW

fig - 3

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REAR PANEL



DGX PC board layout

DGXUSER: 113/4: 10/90)

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CALIBRATION AND ACCURACY OF OPHIR POWER MONITORS EQUIPPED WITH CALIBRATION HEATER

The exclusive calibration resistor supplied on Ophir CAL models allows unprecedented accuracy and repeatability of laser power measurements.

On the rear of the CAL version detector disc, directly behind the area under laser radiation, is mounted a special heating element of low thermal mass. The user supplies electrical heating power, which can be measured to high accuracy by measuring voltage and current to the heating resistor. This electrical heating can be directly substituted for the radiative power of the source measured.

There are several sources of inequivalence between the heating of the disc by electrical power and optical radiation which must be taken into account when making measurements to the highest accuracy. These factors are:

1. Electrical heating of other parts of the circuit such as lead wires. This heat is not absorbed by the detector disc.
2. Inequivalence caused by the fact that the laser heats the front surface of the disc. whereas electrical substitution power heats the rear of the disc.
3. Incomplete absorption of the incident radiation on the detector front surface.

Other heat losses, such as convection, thermal conduction through the electrical leads and radiation can be neglected, both because they are very small (less than 0.3% combined at full rated power) and because they are nearly equal for electrical and optical heating of the disc.

Of the three factors mentioned above, the first also turns out to be very small, provided that the voltage is measured close to the head.

The inequivalence between front and rear surface heating has been carefully measured by Ophir engineers by mounting calibration heaters on both the front and rear surface of discs and directly measuring the difference in sensitivity due to front or rear heating. The detector is always more sensitive to rear surface heating than to front surface heating and the magnitude of the correction is dependent on the diameter-to-thickeness ratio of the disc. The measured correction factors are shown in the table below.

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TABLE I

MODEL	Rear/Front Sensitivity Factor (accuracy ± 0.005)
3A-P	1.000
10A/10A-HP	1.005
10A/10A-P	1.030
30A/30A-HP	1.000
30A-P/EX/N	1.025
150A/150A-HP	1.015
150A-N/300W-N	1.030
FL100A-EX	1.100*
L150A/L300W	1.010
300W/300W-HP	1.015
1000W	1.030
1500W	1.035
3000W	1.02

(*) can vary from disk to disk; factory calibrated.

The most important inequivalence between electrical and optical heating results from incomplete absorbtion of radiation by the detector disc (3). For each type of absorber surface, a material has been selected or developed which has the maximum possible absorbtivity, commensurate with the power handling capacity required. Furthermore, for those discs with a ridged surface (types 150, 300, 1000 and 1500), a major fraction of the energy reflected from the first surface is reflected to a nearby surface and reabsorbed. This feature increases the total absorbtion of the detector especially for the –HP absorber in the visible and near IR where the absorbtion is not as good as in the far infra-red.

Five types of absorber surface are used in Ophir instruments:

1. On standard broadband Ophir power monitors, a solar absorber coating is used, to give high absorbtivity from the UV through the IR. A spectrophotometric plot of the coating is shown in the graph, from 300 nm to 25 um, and absorbtivity is seen to be well over 90% for most of this range, and 96.5% in the visible.
2. The models with the – P suffix, for use with visible and near infrared pulsed lasers, have a special absorbing glass surface with an absorbance of 95 ± 0.5% over the operating range. The specular reflectance of this glass is known from the index of refraction in the wavelength range and the affect of the matt surface on absorbtion has been measured using a special absorber glass, half mat and half polished.

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3. The -HP type discs are designed so that incident light makes multiple bounces before escaping. This unique light trapping feature is designed especially for high average power density YAG, CO_2 and visible lasers. It provides for high absorption in the visible, near IR and 10.6µm, as well as the capability to withstand high power densities without changing its absorption.
4. The -EX option is designed for high power excimer lasers as well as other wavelengths. This surface is a special ceramic which is a volume absorber in the spectral range 190nm – 10.6 µm. Its absorption is 85+5% in the range 0.19 – 0.35 µm.
5. The -N option obsorber, used specifically for high power density Q-switched or CW Nd: YAG lasers at 1.06um, absorbs 79±3% of incident energy, with the remainder being diffusely reflected because of the matt nature of the surface.

The absorbtivity of the various absorber surfaces used in Ophir power monitors is shown in Table II below. Since the absorbtion of the HP, EX and N surfaces can vary considerable, They are measured and calibrated individually at the factory.

TABLE II

Type of Surface	Model	Absorbtivity (in %) at Various Wavelengths (in um)						
		0.19	0.35	0.7	1.06	2.5	5	10.6
Broadband, flat	10A 30A	96.5 ± 0.5 see graph						95.0 ± 0.5
Broadband, ridged	150A 300W	96.5 ± 0.5 see graph						95.0 ± 0.5
-HP, flat	10A/30A-HP 300W	93 ± 3*			88 ± 10			97.0 ± 0.5
-HP, ridged	150A-HP 300W-HP 1000W 1500W 3000W-HP	94 ± 4 see graph			92 ± 4			99 ± 0.5
-P	3A-P 10A-P 30A-P/EX	95.0 ± 0.5						
-EX	30A-EX FL100A-EX 1400W-EX	85 ± 5 see graph						99 ± 1 99 ± 1
-N	30A-N 150A-N 300W-N				79 ± 3			

* IF SURFACE NOT BLEACHED.

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The above corections can all be combined to give a calibration factor accurate to within +1% for most specified wavelengths and model types. These results are shown in Table III.

TABLE III
CALIBRATION FACTOR
(using built in calibration resistor)

Model Number	Wavelength Range (um)					Value as set in factory
	0.19	0.35	0.7	1.06	10.6	
03A-P	1.05					1.06
10A/30A	1.04				1.06	1.05
10A-P	1.08					1.08
30A-P	1.08					1.08
30A-EX	1.21(2)					factory set
30A-N				1.27(2)		factory set
10A-HP/30A-HP		1.08(1)(2)		1.14(2)	1.03	switchable
150A	1.05				1.07	1.06
L150A/L300W	1.05				1.06	1.05
150A-HP/300W-HP		1.08(2)		1.08(2)	1.03	switchable
FL150A-EX	1.29(2)					factory set
100A-N/200W-N				1.30(2)		factory set
300W	1.05				1.07	1.06
1000W				1.10(2)	1.04	switchable
1500W				1.10(2)	1.05	switchable
3000W					1.03	
3000W-HP				1.09(2)	1.03	switchable

1. If not bleached by power densities above $1KW/cm^2$.
2. These values are approximate. Exact calibration factor of EX,N and HP is set by direct measurement of absorbtion during factory calibration. The EX surface is calibrated at 300 nm.

To obtain ultimate measurement accuracy at any wavelength, when calibrating the instrument, electrical calibrating power must be multiplied by the appropriate factor. Switchable models must be set to the proper switch setting (CO_2, YAG, visible) before calibration.

EXAMPLE: A Model 150A-HP-CAL is to be used to measure a CO_2 laser. 20 watts of electrical power is applied in order to calibrate the unit. The monitor should be adjusted to read $20 \times 1.03 = 20.6$ watts while switched to the CO_2 setting. The instrument will then read CO_2 power accurately.

Also, to eliminate residual non-linear effects, it is advisable to perform electrical calibration at about the same power level as that to be measured so long as the rating of the heating resistor is not exceeded.

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CALIBRATION ACCURACY OF OPHIR POWER MONITORS NOT EQUIPPED WITH BUILT-IN CALIBRATION HEATER

The power monitor is factory-calibrated at midrange power by an electrical substitution method, to an accuracy of within +1.5%. This factor, together with the linearity of the power monitor given in the specifications, then determines the maximum error throughout the range. The excellent linearity of the power monitor, which has been carefully measured by direct electrical substitution calibration, ensures high accuracy throughout the dynamic range, as stated in the specifications.

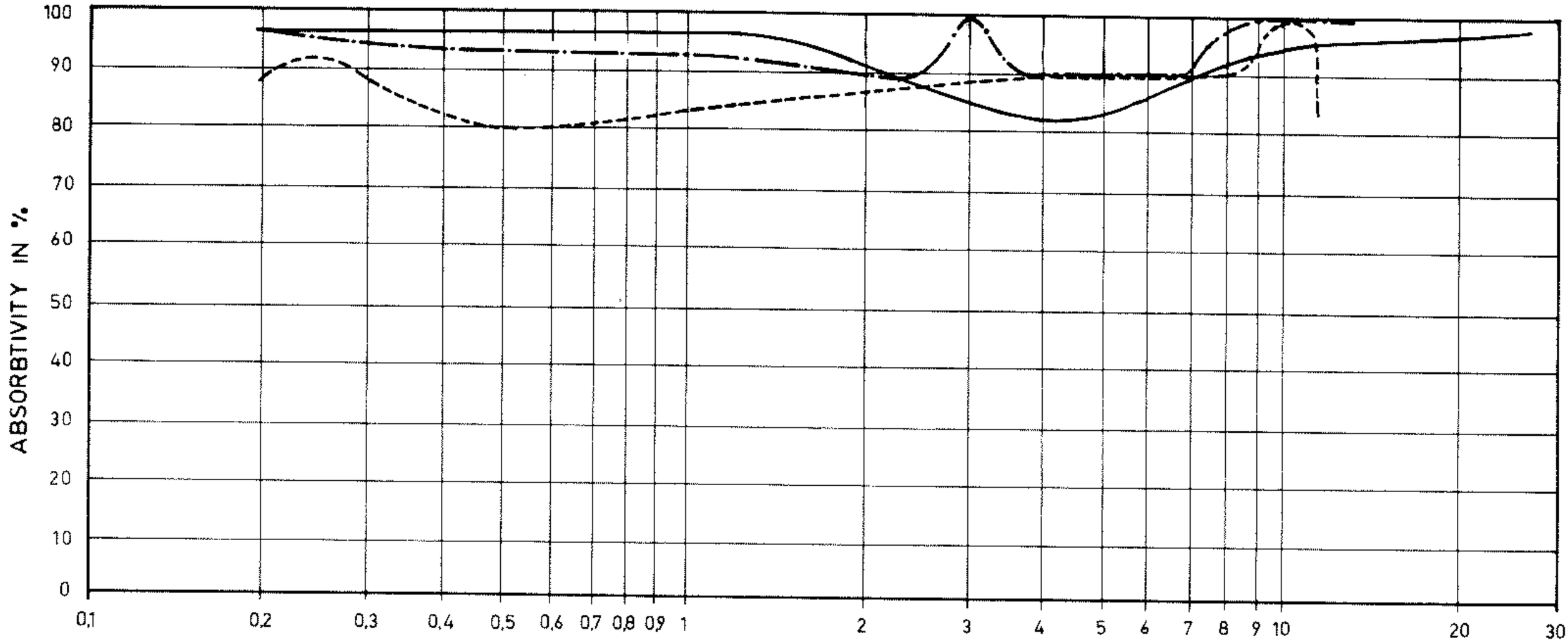
Since the absorption of the detector surface varies with wavelength, the factory calibration factor is set at some average for the most commonly used wavelengths with that particular model. Table IV lists the spectral region for which each type is set.

TABLE IV
PRE SET FACTORY CALIBRATION

Absorber Head Type	**Wavelength**
Broadband	UV-VIS-NIR
–P/EX type	UV-VIS-NIR
–N type	YAG
–HP type, 1000W/1500W/3000W – HP	Switchable, calibrated for both CO_2 and YAG
3000W	CO_2

This average correction ensures a reading to within ±3% of the true power for all models at any wavelength within the specification. Note that on the –HP and 1000W models, where there is a sizable variation in reading at different wavelengths, the instrument is supplied with a built – in switch to retain correct calibration for various types of lasers.

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