INSTRUCTION MANUAL

NUMBER B-3664A

EG&G

MODEL 560B LITE-MIKE®

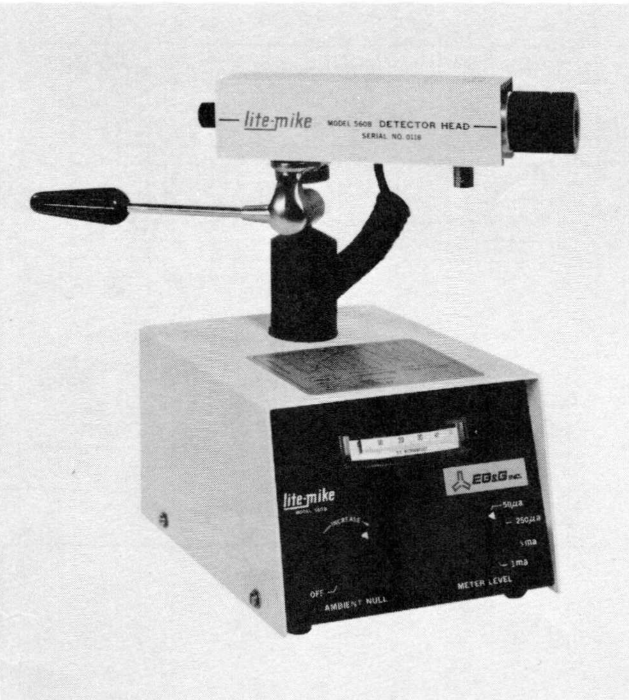
ELECTRONIC PRODUCTS DIVISION
EG&G, INC., 160 BROOKLINE AVE., BOSTON, MASSACHUSETTS 02215

EG&G
ELECTRONIC PRODUCTS DIVISION

lite-mike*
MODEL 560B

TECHNICAL DATA

FOR QUANTITATIVE MEASUREMENTS OF CW AND PULSED LIGHT SIGNALS



FEATURES:

- WIDE SPECTRAL RANGE
- FAST RESPONSE TIME
- HIGH SENSITIVITY
- SIMPLICITY OF OPERATION
- ABSOLUTE CALIBRATION

The Model 560B Lite-Mike is a versatile instrument designed for absolute and relative measurements of continuous and pulsed light sources. Meter readout is provided for average power measurements of continuous light signals. The lite-mike also has provision for oscilloscope display of pulsed light signals so that integrated energy and pulse shape measurements can be made; i. e., peak power, pulse duration, rise and fall times.

The lite-mike base assembly contains a power supply which is operational from a standard 110 volt line. The meter on the front panel encompasses a three-decade range of possible readings with four selectable full scale meter levels. An ambient compensation control allows the nulling of ambient light effects, thereby eliminating the need for a dark room environment.

The lite-mike detector head contains an EG&G SGD-100 Silicon Photodiode which generates a photo current directly proportional to the irradient power level. The performance characteristics of the diode, i. e., high quantum efficiency, fast speed response, wide spectral range, and low noise, are all preserved and available in the operation of the lite-mike. The detector head contains provision for scope output with three internal, selectable load resistors: 50, 500, and 5000 ohms. An "Open" position is also available wherein the current signal can be terminated across any value of external resistance desired. Two sensitivity positions are provided to permit integrated energy measurements of light pulses when working into an oscilloscope.

*EG&G Trade Mark

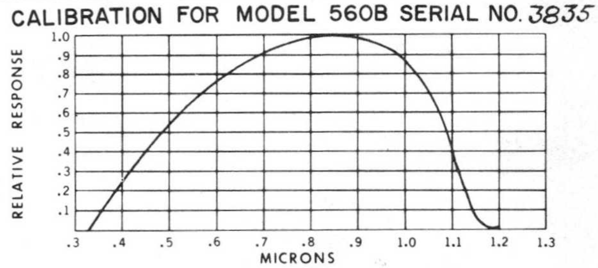
For ease of alignment with a light source to be measured, the detector head is swivel mounted on a universal tripod head. The detector head is detachable and can be mounted on an optical bench, a laboratory bench, or a tripod.

The Model 560B Lite-Mike now includes a detachable lens assembly, which is primarily designed for increasing the sensitivity of the system for relative measurements. Although absolute measurements are obtainable with the lens attachment, the additional focal distance required may negate the optical gain of the lens.

Each lite-mike is individually calibrated as to its sensitivity vs wavelength. A calibration curve is permanently affixed to each instrument for easy reference. A typical calibration chart is shown below.

When used in accordance with the recommended procedures outlined in the detailed instruction manual, this instrument will provide long, reliable, trouble-free service.

CALIBRATION FOR MODEL 560B SERIAL NO. 3835



PULSE OUTPUT	AVERAGE OUTPUT	INTEG. OUTPUT
$K_1 = 24 \frac{MV}{MW}$	$K_2 = 48 \times 10^{-2} \frac{\mu A}{\mu W}$	$K_3 = 146 \times 10^5 \frac{VOLTS}{JOULES}$

AREA = 0.0728 CM²

$G_L = 15.5$

CALIBRATED AT .92 MICRONS
CALIBRATED BY D.Z.
DATE CALIBRATED 8-6-67

CAUTION:
DO NOT ALLOW METER TO GO OFF SCALE

SPECIFICATIONS

Spectral Response (10% points) – 0.35 to 1.13 microns
Sensitivity (at 0.9 microns) – 0.5 μ A/μ W (typical) – no lens
Rise Time (typical) – 5 nanoseconds
Fall Time (typical) – 20 nanoseconds
Linearity – within 5% over a seven-decade range
Detector Head Range Selector Switch (six positions)
- For pulsed light measurement X 1, X 10, X 100, open
- For integrated energy measurements X 1, X 10

Meter Range Selector Switch (full scale)
- 1 mA, 0.5 mA, 250 μ A, 50 μ A

Gain of Lens (G_L) – 16 (typical)
Power Requirements – 105-125 V, 50-60 Hz, 0.3 W
Size
- Base Assembly – 6 in. x 5-1/4 in. x 4 in.
- Detector Head – 5-1/4 in. x 1-1/2 in. x 1-1/2 in. (does not include lens attachment)

Overall Height (including swivel and detector head) – 9-1/2 in.
Total Weight – 3-1/2 lb.

All Data and Specifications Subject to Change Without Notice

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MODEL 560B LITE-MIKE®

Revised September 1970

ELECTRONIC PRODUCTS DIVISION
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560B LITE-MIKE

1.1 GENERAL INFORMATION

The EG&G LITE-MIKE (see Fig. 1 and the schematic diagram, Fig. 5) provides for the measurement of steady and pulsed light in the visible and near-infrared range. The instrument is fully calibrated, sensitive and reliable. The instructions in the manual should be followed closely so that all of the measurement capabilities afforded by the instrument can be utilized and inadvertent damage can be avoided.

The LITE-MIKE measures for pulsed-light sources: wave shape, rise time, fall time, duration, instantaneous peak light power (in watts), average light power of repetitive pulses (in watts), and integrated light energy (in joules). *The LITE-MIKE also measures steady light sources, and average light power (in watts).

1.2 SPECIFICATIONS

PHOTODETECTOR:
EG&G SGD-100A Silicon Photodiode.

SPECTRAL RESPONSE:
0.35 to 1.13 u, 10% points.

SENSITIVITY:
At 0.9 microns - 0.50 A per W typical.

RISE TIME:
5×10^{-9}s typical.

FALL TIME:
20×10^{-9}s typical.

MAXIMUM POWER LIMIT:
CW 2 mW or 40 mW/cm^2
Pulse 240 mW or 4.8 W/cm^2

ACTIVE AREA OF PHOTODETECTOR:
0.008 in.^{2} (5.1 mm^2) typical.
With lens 1.058 cm^2.

FIELD OF VIEW (HALF-POWER POINTS):
With no attachments, 70°. With two retaining rings and lens shade, 52°. With lens, 8°.

DETECTOR HEAD SENSITIVITY SWITCH (6 positions):
For light power measurements:

open	white
X1	white
X10	white
X100	white

For light energy measurements:

X1	red
X10	red

METER RANGE SELECTOR SWITCH:
1 mA, 0.5 mA, 250 μA, 50 μA.

POWER REQUIREMENT:
115V, 50/60 cycles, 0.3 W.

DIMENSIONS:
LITE-MIKE (excluding swivel and Detector Head):

6 in. deep x 5-1/4 in. wide x 4 in. high.

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*When used in conjunction with an appropriate cathode-ray oscilloscope (CRO).

DIMENSIONS: (Cont)

Detector Head:
5-1/4 in. long x 1-1/1 in. wide x 1-1/2 in. high (without lens).

Overall Height (including swivel and Detector Head):
9-1/2 in.

WEIGHT:

LITE-MIKE
2 lb, 10-1/2 oz.

Detector Head:
11 oz. (without lens)

Total Weight:
3 lb, 5-1/2 oz.

2.1 MODEL 560B LITE-MIKE BASE

The Model 560B LITE-MIKE contains the power supply, swivel, average current meter with illuminated face, meter range selecttor switch and the ambient light balancing circuit and control.

2.2 MODEL 560B DETECTOR HEAD

The Model 560B Detector Head houses an EG&G SGD-100A Photodiode, a lens, and the six-position sensitivity switch, four white positions with different sensitivities for light power measurements, and two red positions with different sensitivities for integrated light measurements. A BNC output terminal is also provided for connection to a CRO. The SGD-100A Photodiode acts as a current generator where current depends linearly on the intensity of the received light. This detector exhibits response times in the nanosecond range, and its linearity has been confirmed over a 10^7 range of light input. The OPEN position takes advantage of the fact that the diode is a current generator and allows termination into any load impedance within the current limitations of the diode (Appendix B).

For ease of alignment with the light source to be measured, the Model 560B Detector Head is mounted on a swivel. The Detector Head is readily detachable and can be mounted on an optical bench, a laboratory bench, or a tripod.

2.3 CALIBRATION CHART

A calibration chart for the LITE-MIKE is permanently affixed to the instrument. The K_1 calibration factor is used for measurement of instantaneous peak light power. It is valid whenever the CRO impedance is at least 100 times greater than the appropriate internal load resistance of the LITE-MIKE as indicated in the following table, or when the OPEN position is used, to terminate in an external load resistor.

The K_2 calibration factor is used to calibrate the meter of the LITE-MIKE for average light power measurements.

The K_3 calibration factor is used for measurements of light energy. It is valid providing the pulse width and repetition rate fall within the limits indicated in Fig. 2.

The G_L calibration factor is used with the lens. This is the lens gain and its use is described in paragraph 4. 3. 4. 4.

2.4 RETAINING RING

A retaining ring is furnished with each Detector Head. This series C adapter can accommodate standard photographic accessories.

Sensitivity Switch Position		LITE-MIKE Internal Load Resistance	Minimum CRO Input Impedance
OPEN	(white)	None	Current Limited
X1	(white)	50 ohms	5,000 ohms
X10	(white)	500 ohms	50,000 ohms
X100	(white)	5000 ohms	500,000 ohms

FACTOR	SENSITIVITY SWITCH POSITION	CRO IMPEDANCE			
		0.1 MEG	1.0 MEG	5.0 MEG	10 MEG
MAXIMUM PULSE DURATION IN MILLISECONDS	RED X1	0.3	3.0	10	15
	RED X10	0.03	0.3	1.0	1.5
MAXIMUM PULSE REPETITION RATE IN PULSE PER SEC.	RED X1	220	22	7.5	4.4
	RED X10	2200	220	75	44

Fig. 2. Pulse Width and Repetition Rate Calibration Factor Limits

2.5 COAXIAL CABLE

Any coaxial cable with a BNC connector can attach to the standard BNC connector on the Detector Head.

3.1 INSTALLATION

The LITE-MIKE System is ready to use with any CRO by using a simple BNC cable.

3.2 WARM-UP AND AMBIENT NULL

No warm-up period is required. However, before taking any meter readings, the meter should be adjusted to zero with the AMBIENT NULL control. This adjustment balances out the dark current of the SGD-100A Photodiode (1 μa typical) and the current resulting from ambient light up to 8 μa. (Normal room lighting is typically in the 2 to 3 μa range.)

3.3 METER RANGE

The meter range selector switch has steps for full-scale deflections of 50 μa, 250 μa, 0.5 ma and 1.0 ma. On the 50 μa scale, the smallest division is 1 μa.

3.4 OPERATIONAL LIMITS

Operational limits exist for maximum average and peak light flux density that can be applied to the photodiode. The maximum limit for average light power received is a reading of 1.0 ma on the meter. (Conveniently, this is full scale on the highest scale.) For operation with the sensitivity switch on the white X1 position, the maximum limit for peak light power received is a peak voltage of 5 volts as measured at the output from the Detector Head. For operation at any of the other five positions (white or red) of the sensitivity switch, the peak output voltage must not exceed 40 volts for the position used. In the OPEN position, the current should not exceed 1 ma for steady light source and 120 ma for pulsed light sources. If the light beam is focused to an area smaller than the active area of the SGD-100 Photodiode, the light flux density must not exceed an amount producing a peak current density of 2.3 a per square centimeter of the active area used (for pulses in the range of a few microseconds duration) and a steady current of 20 ma per square centimeter of the active area used.

3.5 ALIGNMENT OF THE DETECTOR HEAD

The Model 560B Detector Head is detachable and can be mounted on an optical bench, laboratory bench or tripod. When mounted on the 560B LITE-MIKE base, the swivel allows a three-plane attitude (spherical coverage). Normally, the head can be visually aligned with the source to be measured, and when extreme accuracy is required, final alignment can be made by maximizing the output as indicated by either the CRO or the meter. This maximizing of the output is the best method when using the lens.

3.6 SENSITIVITY SWITCH

The sensitivity switch located on the Detector Head has six positions: four white positions (OPEN, X1, X10, and X100), and two red positions (X1 and X10). The switch should be in one of the white positions for all instantaneous and average light power readings, and in one of the red positions for all integrated light (energy) readings. The four white positions provide for the selection of four different compromises between speed of response and sensitivity. On the X1 position, the LITE-MIKE exhibits the fastest speed of response (5 ns rise time capability), on the X100 position, the LITE-MIKE exhibits its highest sensitivity. The OPEN position allows selection of load resistance thus controlling both response and sensitivity. The two red positions provide for the selection of alternate compromises among sensitivity, pulse width and pulse repetition rate. On the X1 position, the LITE-MIKE can accommodate light pulses of greater energy, on the X10 position, it can accommodate higher pulse repetition rates and exhibits higher sensitivity.

NOTE

When using the meter of the the LITE-MIKE, the sensitivity switch must be on one of the three white positions (X1, X10 or X100).

3.7 SELECTION OF A CATHODE RAY OSCILLOSCOPE

3.7.1 The CRO selected for use with the LITE-MIKE System must be compatible with the measurement requirements of the end application. When measuring the rise time of fast light pulses, it is particularly important that the CRO does not introduce limitations into the overall measurement system. In this respect, the pertinent characteristics of the CRO which must be considered are its bandwidth and input capacitance.

3.7.2 The graph in Fig. 3 shows the interrelationship among the rise time of the pulse to be measured between the 10 and 90% points (Tr), and CRO bandwidth at the upper half-power frequency (f_{3db}), and the total circuit capacitance. The total circuit capacitance includes the LITE-MIKE output capacitance and the CRO input capacitance. On any position in which the cable does not match the LITE-MIKE load impedance, cable capacitance must also be included in the calculation of the total circuit capacitance.

3.7.3 To determine the Tr measurement capability of a CRO-LITE-MIKE combination, first calculate the total circuit capacitance. The LITE-MIKE output capacitance may be taken as 15 $\mu\mu$f. The CRO input capacitance depends on the type of CRO used, and typically will be in the range of 20 to 50 $\mu\mu$f. The cable capacity must be added in unmatched conditions (for RG 58 A/U, this value is 29 $\mu\mu$f per foot of length). Then, using the total circuit capacitance thus determined and the bandwidth of the CRO, locate this point on Fig. 3. From this point, drop a vertical line to the horizontal Tr scale. All values of Tr equal to or greater than the indicated Tr may be accurately measured with the given CRO-LITE-MIKE combination. The curves of Fig. 3 are based on less than 5% lengthening of Tr. By using properly terminated transmission line techniques, Tr measurements down to 5 ns may be made to 5% accuracy without correction.

3.7.4 In addition to the CRO bandwidth and input capacitance, the CRO input impedance must also be considered in the selection of the CRO. The CRO input impedance must exceed the minimum values presented in Section 2.3 for the stated K_1 calibration factor to be valid. The exception is the case of the OPEN position in which the K_2 calibration factor is used with the load resistance (R_L) value.

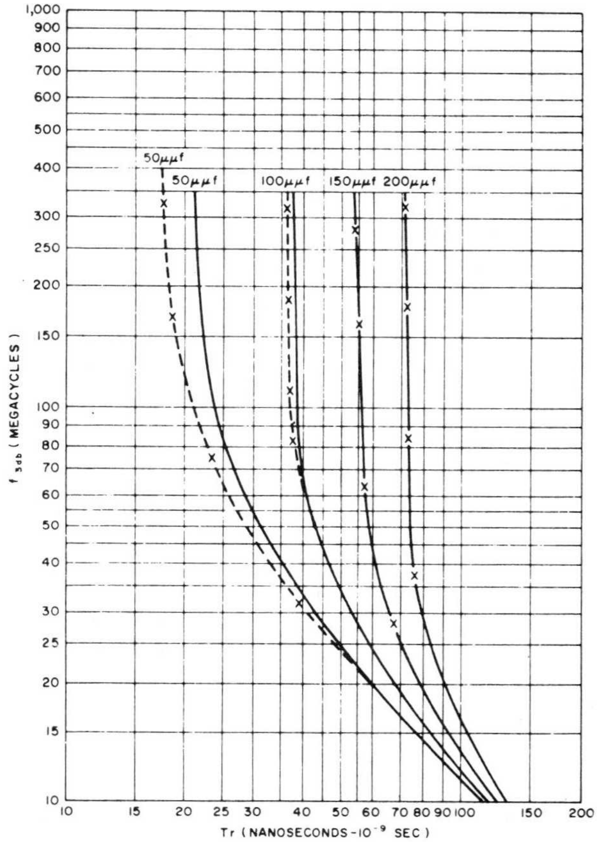
$$K_1 \text{ (OPEN)} = K_2 R_L$$

Legend	Sensitivity Switch Position	Scale Multipliers f3dB	Tr
--	X1 (white)	1.0	1.0
	X10 (white)	0.1	10
X--X	X100 (white)	0.01	100

f3dB CRO bandwidth at upper half-power frequency.

Tr Rise time of pulse to be measured between 10 & 90% points.

Capacitance is total circuit capacitance which includes LITE-MIKE output capacitance and CRO input capacitance when applicable.



NOTE
CURVES ARE BASED ON LESS THAN 5% LENGTHENING OF Tr.

Fig 3. Pulse rise time, CRO Bandwidth and circuit capacitance interrelationships

4.1 GENERAL

4.1.1 In addition to the time measurements of pulse rise time, duration and fall time which are read directly from the CRO display, the types of measurements accomplished with the LITE-MIKE include the following.

a. Measurement of instantaneous peak light power.

b. Measurement of average light power.

c. Measurement of light energy.

4.1.2 Before selecting the method to be used in making each or any of these measurements, the conditions associated with the measurement must be examined by answering the following questions.

a. Is the light source monochromatic or chromatic?

b. Is the diameter of the light beam less than or greater than the diameter of the active area of the photodiode? If using the lens, is the light source diameter greater than the lens diameter?

c. If the light beam or area of radiation is greater than the active area of the photodiode, or the lens, is the radiation uniform or nonuniform?

d. If using the lens in absolute measurements, is the source size to distance away ratio greater than 100 (see paragraph 4.3.4.4).

4.1.3 From the standpoint of ease of measurement, the simplest condition is when the light source is monochromatic and the light is confined to a beam whose diameter is less than the active area of the photodiode or the lens. The most complex condition is when the light source is chromatic and the radiation is nonuniform. The various methods of measurement are described in the subsequent sections.

4.1.4 In paragraph 4.2.1 the basic procedure associated with the measurement of instantaneous peak light power is presented for the simple condition in which the diameter of a monochromatic light beam is less than the diameter of the active area of the photodiode or the lens. In paragraph 4.2.2, the basic procedure associated with the measurement of average light power is presented for the simple condition in which the diameter of a monochromatic light beam is less than the diameter of the active area of the photodiode. In paragraph 4.2.3, the basic procedure associated with the measurement of light energy is presented for the simple condition in which the diameter of a monochromatic light beam is less than the diameter of the active area of the photodiode.

4.1.5 The additional procedures associated with the case of uniform radiation are presented in paragraph 4.3.1. In paragraph 4.3.2, the additional procedures associated with the case of nonuniform radiation are presented. In paragraph 4.3.3, the additional procedures associated with the case of chromatic sources are presented.

4.1.6 Thus, for a given type of measurement under given conditions, the total required procedure will consist of the procedures in several of the following sections. For example, to measure average light power from a nonuniform, chromatic light source, the procedures in paragraphs 4.2.2, 4.3.2, and 4.3.3 must be followed.

4.2 LIGHT MEASUREMENT

4.2.1 Measuring Instantaneous Peak Light Power.

4.2.1.1 To determine instantaneous peak light power for a monochromatic source whose beam diameter is less than the diameter of the active area of the photodiode, set the Detector Head sensitivity switch on that white position (OPEN, X1, X10, or X100) which renders the desired sensitivity. With the Detector Head aligned with the light source to be measured, read the peak amplitude of the waveform displayed on the CRO in millivolts. Calculate instantaneous peak light power from the following equation:

$$\hat{P} = \frac{V_1}{K_1} \text{ or } \hat{P} = \frac{V_1}{K_2 R_L} \text{ (OPEN)} \quad (1)$$

where:

$\hat{P}$ = Instantaneous peak light power in milliwatts.

V_1 = Peak voltage as measured on CRO in millivolts with sensitivity switch on a white position. (On X10 position, divide CRO reading by 10; on X100 position, divide CRO reading by 100.)

K_1 = Calibration factor shown on LITE-MIKE in millivolts/milliwatts.

K_2 = Calibration factor shown on LITE-MIKE in microamps/microwatts.

R_L = CRO input impedance or load resistor.

4.2.1.2 Utilizing the LITE-MIKE's K_1 calibration factor in this equation, the calculated instantaneous peak light power, $\hat{P}$, is the peak power of the unknown source if it were at the same wavelength at which the K_1 factor was measured. To correct for the actual wavelength of the source, refer to the calibration curve of relative response versus wavelength (located on the LITE-MIKE) and multiply $\hat{P}$ by the ratio of the relative response at the wavelength at which the K_1 factor was measured to the realtive response at the wavelength of the source. The product is the corrected instantaneous peak power of the unknown source. This same method of correction applies to the K_2 factor. Multiply by the same ratio.

4.2.1.3 In the foregoing procedure, as well as in the procedures presented in paragraphs 4.2.2 and 4.2.3 the sensitivity of the SGD-100 is assumed constant over an active area. This assumption is valid to an accuracy of ± 4% for spot sizes of 1/2 mm diameter or larger.

4.2.2 Measuring Average Light Power.

4.2.2.1 To determine average light power for a monochromatic source whose beam diameter is less than the diameter of the active area of the photodiode, or of the lens (paragraph 4.3.4.4), set the Detector Head sensitivity switch on any white position. With the Detector Head aligned with the light source to be measured, read the current on the LITE-MIKE meter. Calculate the average light power from the following equation:

$$P = \frac{I_L}{K_2} \qquad (2)$$

where:

P = Average light power in microwatts.

I_L = Current as read from LITE-MIKE meter in microamperes.

K_2 = Calibration factor shown on LITE-MIKE in microamperes/microwatts.

4.2.2.2 Utilizing the LITE-MIKE K_2 calibration factor in this equation, the average power calculated (P) is the power of the unknown source if it were at the same wavelength at which the K_2 factor was measured. To correct for the actual wavelength of the source, refer to the calibration curve of relative response versus wavelength (located on LITE-MIKE) and multiply P by the ratio of the relative response at the wavelength at which K_2 was measured to the relative response at the wavelength of the source. The product is the corrected average light power of the unknown source. In the event that the average power of the light pulses is too small to be read accurately on the LITE-MIKE meter, refer to paragraph 4.3.4.2 for a method of measuring weak light sources.

4.2.3 Measuring Light Energy

4.2.3.1 To measure light energy for a monochromatic source whose beam diameter is less than the diameter of the active area of the photodiode, or lens, set the Detector Head sensitivity switch on that red position which renders the desired sensitivity (X1 or X10). With the Detector Head aligned directly with the light source to be measured, read the peak amplitude of the waveform displayed on the CRO in volts. Calculate the light energy from the following equation:

$$U = \frac{V_3}{K_3}, \qquad (3)$$

where:

U = Light energy in joules

V_3 = Peak voltage as measured on CRO in volts with sensitivity switch on a red position. (On X10 position, divide CRO reading by 10)

K_3 = Calibration factor shown on LITE-MIKE in volts/joules

4.2.3.2 Utilizing the LITE-MIKE's K_3 calibration factor in this equation, the light energy calculated (U) is the light energy of the unknown source if it were at the same wavelength at which the K_3 factor was measured. To correct for the actual wavelength of the source, refer to the calibration curve of relative response versus wavelength (located on the LITE-MIKE) and multiply the calculated light energy by the ratio of the relative response at the wavelength at which K_3 was measured to the relative response at the wavelength of the source. The product is the corrected light energy of the unknown source.

NOTE

For measurements associated with the two red positions, the pulse duration and repetition rate must conform to the conditions specified in Fig. 2 to assure meaningful measurements.

In the event that the pulse width or repetition rate exceed the limits specified in Fig. 2, the energy per pulse can still be obtained by reading the average power on the meter (following the procedure described in paragraph 4.2.2) and dividing the final result by the repetition rate.

4.3 ASSOCIATED CONDITIONS

4.3.1 Uniform Radiation

4.3.1.1 When the light to be measured covers an area greater than the active area of the SGD-100 Photodiode or the lens and the radiation is uniform in all directions (i.e., the case of a uniformly radiating point source) the LITE-MIKE can be used to sample the light. By multiplying this sample by the ratio of the area of the total surface associated with the measurement to the area of the sample, the total light power and energy radiated by the source can be calculated.

4.3.2.1 The following equations apply to a point light source with uniform radiation in all directions (spherical).

Total instantaneous peak light power radiated by source,

$$\hat{P} = \frac{4\pi S^2 V_1}{0.051\ K_1} = 246.5\ \frac{S^2 V_1}{K_1}\ \text{(in mW)} \qquad (4)$$

Total average light power radiated by source,

$$P = \frac{4\pi S^2 I_L}{0.051\ K_2} = 246.5\ \frac{S^2 I_L}{K_2}\ \text{(in } \mu\text{W)} \qquad (5)$$

Total light energy radiated by source,

$$U = \frac{4\pi S^2 V_3}{0.051\ K_3} = 246.5\ \frac{S^2 V_3}{K_3}\ \text{(in J)} \qquad (6)$$

where:

S = Distance between light source and photodiode in cm.

K_1 = Calibration factor shown on LITE-MIKE in mv/mw.

K_2 = Calibration factor shown on LITE-MIKE in μa/μw.

K_3 = Calibration factor shown on LITE-MIKE in v/j.

V_1 = Peak voltage as measured on CRO in mv with sensitivity switch on a white position. (On X10 position, divide CRO reading by 10; on X100 position, divide CRO reading by 100.)

I_L = Current as read from LITE-MIKE meter in μa.

V_3 = Peak voltage as measured on CRO in volts with sensitivity switch on a red position. (On X10 position, divide CRO reading by 10.)

0.051 = Active area of SGD-100 Photodiode in cm^2.

4.3.2 Nonuniform Sources

4.3.2.1 When the light beam to be measured covers an active area greater than the active area of the SGD-100 Photodiode and the radiation is not uniform over the area of the beam, the spacial distribution of light power or energy must be analyzed to determine the total power or energy radiated by the source.

4.3.2.2 For the general case, divide the surface of the beam to be analyzed into either unit crosssectional areas or unit solid angles or fractions thereof. The number of sections required is determined by the accuracy required. Measure each of these sections with the LITE-MIKE. Use the per unit equations which follow, equations (7) to (12), to calculate the instantaneous peak light power, average light power, and/or light on a per unit basis. Sum the per unit measurements to obtain the desired result.

Instantaneous peak light power per unit solid angle ($\hat{P}\omega$)

$$\hat{P}\omega = \frac{S^2 V_1}{0.051\ K_1} = 19.6\ \frac{S^2 V_1}{K_1}\ \text{(in MW}/\omega) \tag{7}$$

Average light power per unit solid angle ($P\omega$)

$$P\omega = \frac{S^2 I_L}{0.051\ K_2} = 19.6\ \frac{S^2 I_L}{K_2}\ (\text{in } \mu\text{W}/\omega) \tag{8}$$

Light energy per unit solid angle ($U\omega$)

$$U\omega = \frac{S^2 V_3}{0.051\ K_3} = 19.6\ \frac{S^2 V_3}{K_3}\ (\text{in J}/\omega) \tag{9}$$

Instantaneous peak light power per unit area ($\hat{P}_A$)

$$\hat{P}_A = \frac{V_1}{0.051\ K_1} = 19.6\ \frac{V_1}{K_1}\ (\text{in MW/cm}^2) \tag{10}$$

Average light power per unit area (P_A)

$$P_A = \frac{I_L}{0.051\ K_2} = 19.6\ \frac{I_L}{K_2}\ (\text{in } \mu\text{W/cm}^2) \tag{11}$$

Light energy per unit area (U_A)

$$U_A = \frac{V_3}{0.051\ K_3} = 19.6\ \frac{V_3}{K_3}\ (\text{in J/cm}^2) \tag{12}$$

where,

S, K_1, K_2, K_3, V_1, I_L, and V_3

are the terms as defined in paragraph 4. 3. 1.

4. 3. 3 Chromatic Sources

4. 3. 3. 1 The relative light power or energy of chromatic sources having the same spectral distribution may be directly compared by

readings from the LITE-MIKE. However, to obtain quantitative values of the light power or energy for chromatic sources, the spectral distribution curve of the source must be known.

4.3.3.2 The following procedure is presented for measurement of average light power. By changing only the units of the vertical scales, however, the same procedure can be applied to the measurement of instantaneous peak light power or light energy.

a. Plot the curve of spectral output of the specific chromatic source to be measured. The maximum peak amplitude of the curve should have a value of 1.0 on the vertical scale for convenience in the subsequent calculations. The units of the vertical scale are microwatts per incremental wavelength ($\mu W / \Delta\lambda$). Define the unknown coefficient of the vertical scale as "C" as indicated in Fig. 4.

b. Using the same horizontal scale (wavelength) as used in step 1, plot the spectral response curve of the LITE-MIKE. (This curve is included in the calibration chart located on the instrument.) Again the maximum peak amplitude of this curve will have a value of 1.0 on

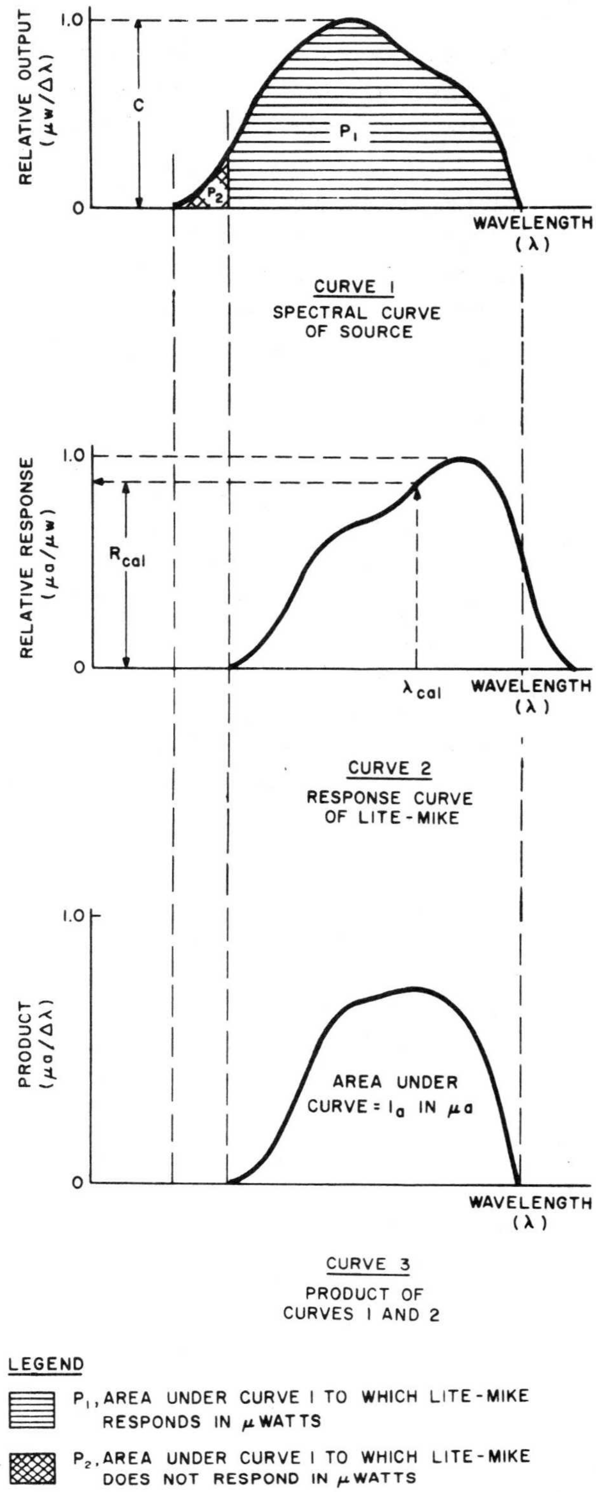


Fig. 4. Methods of measuring average chromatic source light power

its vertical scale. The units of this vertical scale are microamperes per microwatt. On the horizontal scale, locate the wavelength at which the LITE-MIKE was calibrated and define the relative response of the LITE-MIKE at this wavelength as R_{cal}.

c. Using the same horizontal scale (wavelength) as used in steps a and b, plot the product of these two curves. The units of the vertical scale for this curve are microamperes per $\Delta\lambda$.

d. Determine the area under the curve developed in step c. Call the area under this curve "I_a" microamperes.

e. Following the procedure for measuring average light power in paragraph 4.2.2 take a LITE-MIKE reading. Call the LITE-MIKE reading "I_L" microamperes.

f. By using the following equation, calculate C, the coefficient of the vertical scale of curve 1;

$$C = \frac{I_L}{I_a} \cdot \frac{I_L}{R_{cal} \times K_2}, \qquad (13)$$

where,

I_L, I_a, and R_{cal}, are as defined above.

g. Define the area under curve 1 to which the LITE-MIKE can respond as "P_1". Define the area under curve 1 to which the LITE-MIKE cannot respond as "P_2".

h. Incorporating C as calculated in step f on the vertical scale of curve 1, determine the area under curve 1 in the P_1 region and the area under curve 1 in the P_2 region. Call these areas "P_1" μW and "P_2" μW respectively.

i. Add P_1 and P_2 to determine the total average power associated with this chromatic source in μW

$$P = P_1 + P_2.$$

4.3.3.3 After P is calculated once with the above procedure, subsequent average light power measurements of the same source, (P_{new}), or any source with the same spectral distribution, can be readily determined from a single LITE-MIKE reading (I_{Lnew}) and use of the sample relationship,

$$\frac{P_{new}}{P} = \frac{I_{Lnew}}{I_L}. \qquad (14)$$

4.3.4 Special Application Considerations

4.3.4.1 Use of Filters

The spectral response of the LITE-MIKE can be changed by adding known filters with the use of the retaining rings supplied. Also, a longer lens shade can be used to cut down excessive unwanted light.

4.3.4.2 Weak Light Sources. When working with weak light sources, additional sensitivity may be obtained by using the lens in front of the Detector Head to collect more of the available light signal on the active area of the photodiode. Absolute measurements will then require correction depending upon the size of the beam (paragraph 4.3.4.4). To measure average light power of pulses too weak to be read accurately on the LITE-MIKE meter in paragraph 4.2.2, measure the light energy of the pulse, see paragraph 4.2.3 and multiply that energy reading by the repetition rate to obtain the average light power.

4.3.4.3 Strong Light Sources. When working with intense laser beams, the focused energy could potentially cause damage to the photodiode. To keep the LITE-MIKE within its maximum operational limits (paragraph 3.4) a beam splitter or other form of light sampler or attenuator must be used in front of the Detector Head. For medium power lasers successive neutral density filters of known attenuation can be added to the Detector Head.

4.3.4.4 Use of the Lens. The use of the lens allows a gain of 14 to 20 on relative measurements of weak light sources. The gain factor (G_L) at the peak wavelength point (0.9u) for each lens is recorded on the calibration decal. Since the lens affects the field of view as noted in paragraph 1.2 (8^{o} to half power points) alignment is more critical than without the lens. The lens can be used for absolute measurements but the distance to source diameter ratio has to be 100 minimum. This eliminates the benefit of the lens gain in absolute measurements unless viewing a distant or point source. The same calibration factors apply with the lens but the accuracy is ± 20%.

MAINTENANCE

A periodic recalibration service is offered by EG&G at nominal cost to assure consistent meaningful measurement with the LITE-MIKE System. The SGD-100 Photodiode and its associated circuitry in the Detector Head must not be replaced or serviced in the field.

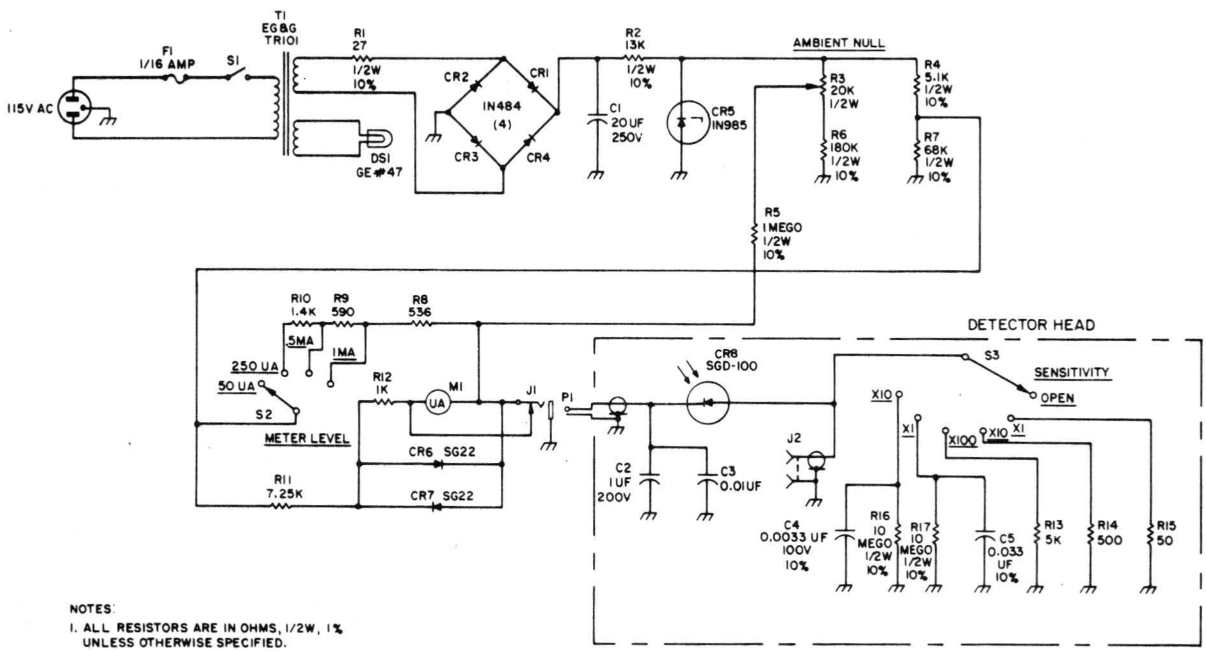


Fig 5. LITE-MIKE schematic diagram

APPENDIX A

CALIBRATION PROCEDURES

The LITE-MIKE is calibrated as follows.

Light is emitted from a known source, a tungsten filament ribbon lamp. The tungsten ribbon lamp is focused 1:1 on the entrance slit of a monochromator with f/3.5 optics. The monochromator also has f/3.5 optics. A thermopile is placed at a known aligned distance from the monochromator exit slit. The radiant energy output of the monochromator is then ascertained over the spectral band of interest. During these measurements, the tungsten lamp is operated at a constant current and the entrance and exit slit of the monochromator are kept 1 mm wide (= 108 Å).

The LITE-MIKE is then placed in the same position as was the thermopile, its output in μA is then determined in the same manner.

The thermopile is calibrated from a National Bureau of Standards carbon filament lamp and is considered to be a perfect black body with a flat spectral response for this calibration.

An identifying description of the elements used in this calibration procedure appear below:

Tungsten Filament Lamp
  GE 18A/T10/1-6V-3R8FIL

Monochromator
  Farrand Optical Company UV-VIS Grating Monochromator 2200 Å to 7000 Å
  Farrand Optical Company I. R. Grating Monochromator 0.7 to 1.3 μ

Thermopile
  Eppley Laboratory, Inc.
  Newport, Rhode Island
  Serial No. 4986

National Bureau of Standards
  No. C-1063 Carbon Filament

Carbon Filament Lamp
  Standard Radiometric Bulb

OPERATIONAL LIMITS OF THE LITE-MIKE

Because of the many questions concerning the operational or upper power limits of the LITE-MIKE, the following technical note is presented.

The EG&G SGD-100 Photodiode is the critical element which imposes operational limits on the LITE-MIKE. Because of the construction of the photodiode, the operational limit is the maximum power that the photodiode can absorb before being destroyed. This power can be expressed in terms of either cell current or incident light power. With steady-state light, the incident light energy must not exceed the amount to cause a steady-state cell current of greater than 1 mA. If the incident light energy is in the form of a transient pulse of less than a few microseconds duration, then damage may occur to the photodiode with a transient cell current of greater than 120 mA. In any case, saturation occurs at this current level, and the photo current is no longer linear with respect to incident illumination.

The operational limits for the SGD-100 may also be expressed in terms of incident light power. Thus, for steady-state monochromatic light at 0.9μ, the light flux density must not be greater than 39 mW per square centimeter, or if the aperture of the cell is taken into account, the steady-state incident light power striking the active area of the cell must not exceed 2.0 mW.

If the incident monochromatic light energy at 0.9μ is in the form of a transient pulse of less than a few μs duration, damage will occur with light flux densities greater than 4.7 W per square centimeter. If the aperture of the cell is taken into account, damage will occur with a transient pulse if the incident light power striking the active area of the diode is greater than 240 mW.

The operational limits given above were calculated for the conditions of peak sensitivity on the spectral response curve. A typical peak sensitivity of 0.5μA/μW occurs at approximately 0.9μ. At other wavelengths in the spectral range, the sensitivity or response of the photodiode falls off and so the LITE-MIKE can safely withstand higher power levels. The steady-state and transient pulse operational power limits for a typical unit are plotted against wavelength in microns in Fig. 6.

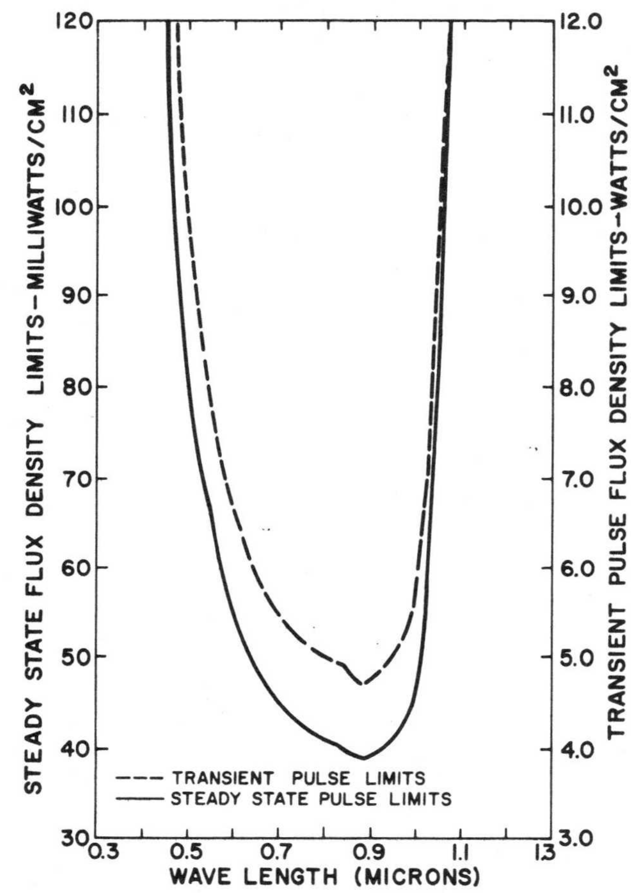


Fig 6 Typical LITE-MIKE steady-state and transient pulse operational power limits