

## Lab-8, Optoelectronics

Physics U371/372, Electronics for Scientists, Fall 2007  
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Optoelectronics offers a number of benefits for IT (information technology), including: immunity to electromagnetic interference (photons have no electrical charge); multichannel capability (wavelength multiplexing); high speed (femtosecond laser pulses); and ease of coupling between light and electronics. Specific photonic device applications include: TV remote; memory (optical CD-ROM or DVD); fiber optic communications; laser printers; and laser-guided weapons. All of these rely on semiconductor components – silicon for light detectors, III-V compounds such as GaAsP for red/green LEDs (light emitting diodes), InGaAs lasers/detectors for communications, and more recently InGaN for blue lasers in high density DVDs and white room lighting.

In this lab you will investigate the two most important optoelectronic elements: Si photodetector (PD), and light emitter (red LED).

Items needed:

- variable DC voltage supply (0-15V)
- function generator (FG)
- variety of resistors
- Si photodiode (PD) EG&G VTB8441BH
- red/green LED, SSL-LX30591
- neutral-density optical filters (Roscolux #397)
- monochromator

**I. LED** – Here you will measure the electric and optical properties of an LED.

1. **IV curve** – Connect a red LED and current limiting resistor ( $R=V_{\max}/I$ ,  $I\sim 10\text{-}20\text{mA}$ ) in series across a variable voltage DC supply. Vary the supply voltage up to  $V_{\max}$  while measuring the voltage across the LED and the voltage across R. **Record data in a table and make a rough plot as you take data.**

Plot  $I(V)$  for the LED.

Extrapolate the high current points to zero current ( $I=0$ ) to get the voltage onset.

Q: Why is the voltage onset different than the onset of a silicon diode?

2. **Wavelength** – Operate the LED at the prescribed current (10-20 mA). View the LED light through the hand-held monochromator.

Record the center wavelength and end points of the light emission.

Compute the center photon energy (in eV) and energy width of the LED emission?

Q: What does the energy of the LED emission correspond to? Explain.

**II. Silicon Photodiode** – Photodiodes (PD) made from *pn* junctions deliver **current** (I) in proportion to the light **power** (P). However, there is a limit to the amount of current they can produce and the response becomes nonlinear at high current. Here you will determine the linear response region of a silicon photodiode.

Connect a resistor in parallel with the PD, in order to change the output current into a voltage. Configure the PD so that it faces up to collect light from overhead. Try different resistors to find an output where the voltage is between 100 and 150 mV. Then replace the resistor with one that has 3 to 5 times higher resistance. This should produce a voltage of 200-300 mV. Next, measure the voltage as you place small squares of the neutral-density (ND) filters to cover the PD. Record voltage versus the number of ND filters until you reach a voltage below 10 mV. Now, make plots of the voltage versus the number, N, of ND filters.

1. From a plot of  $V_{PD}(N)$  with  $V_{PD}$  on a linear scale, determine the maximum voltage where the response is linear,  $V_{PD}^{\max}$ .
2. From a plot of  $V_{PD}(N)$  with  $V_{PD}$  on a log scale, what is the percent transmission of one ND filter.

**NOTE: from now on, always keep the PD voltage below  $V_{PD}^{\max}$ .**

3. While in the linear response regime, connect the PD to the scope.  
Q: What frequencies are observed on the scope below 1 kHz for the fluorescent lights? Explain.

**III. Frequency Response** – LEDs have a response time on the order of a nanosecond and are thus capable of GHz frequency response. On the other hand, PDs usually have a much slower response time due to the RC time constant of the PD and circuit. You will measure the total capacitance (circuit capacitance plus internal capacitance of the PD) by modulating the LED at a frequency  $f$ .

Configure the LED so that it shines directly on the PD. Connect the function generator (FG) in series to a current limiting resistor and LED. Connect the two scope channels (DC coupling) to the function generator and PD to measure  $V_{FG}$  and  $V_{PD}$ . Adjust the **sawtooth** wave amplitude and add a DC offset on the FG to achieve a nice sawtooth wave at the PD. Make sure the PD voltage is in the linear response region either by adjusting the PD resistor or adding ND filters. Increase the frequency from  $f=100$  Hz to  $\sim 1$  MHz in steps of 10x and record the FG and PD voltages. Then fill in data points where  $V_{PD}$  is decreasing. **Record data in a table and make a rough plot as you take data.**

**Plot**  $G \equiv V_{PD}/V_{FG}$  as a function of  $f$  (using  $f$  on a log scale).

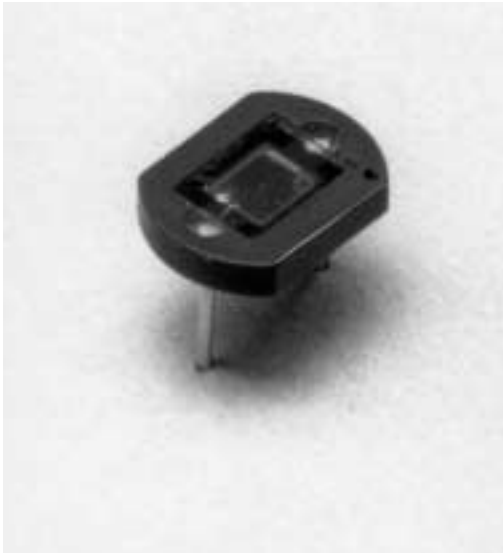
Q: What is the frequency  $f_0$ , where  $G$  has decreased to the 3-dB point?

Q: Compute the effective capacitance of the PD and circuit?

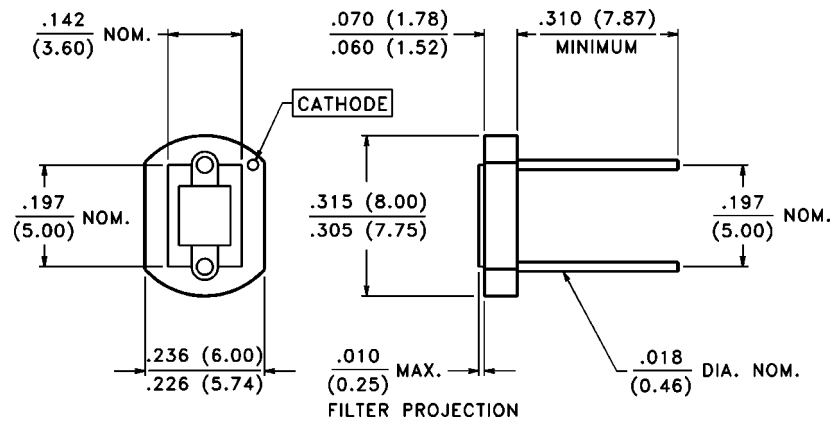
(Hint: use  $\omega_0 \tau = 1$ , where  $\omega_0 = 2\pi f_0$  and  $\tau = RC$ .)

Q: Compare this capacitance to the junction capacitance from the specifications.

Q: What is sacrificed when the maximum frequency is increased by decreasing R?



## PACKAGE DIMENSIONS inch (mm)



CASE 21F 8 mm CERAMIC  
CHIP ACTIVE AREA: .008 in<sup>2</sup> (5.16 mm<sup>2</sup>)

## PRODUCT DESCRIPTION

Planar silicon photodiode in recessed ceramic package. The package incorporates an infrared rejection filter. These diodes have very high shunt resistance and have good blue response.

## ABSOLUTE MAXIMUM RATINGS

Storage Temperature:

-20°C to 75°C

Operating Temperature:

-20°C to 75°C

**RoHS Compliant**



## ELECTRO-OPTICAL CHARACTERISTICS @ 25°C (See also VTB curves, pages 21-22)

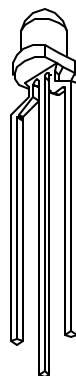
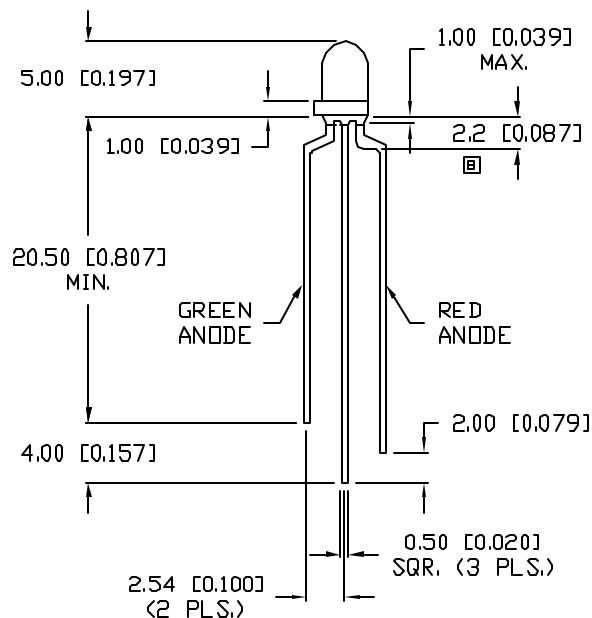
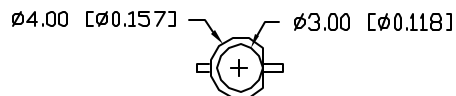
| SYMBOL             | CHARACTERISTIC                          | TEST CONDITIONS    | VTB8440BH                      |      |      | VTB8441BH                      |      |      | UNITS   |
|--------------------|---|--------------------|--------------------------------|------|------|--------------------------------|------|------|---------|
|                    |   |                    | Min.                           | Typ. | Max. | Min.                           | Typ. | Max. |         |
| I <sub>SC</sub>    | Short Circuit Current                   | H = 100 fc, 2850 K | 4                              | 5    |      | 4                              | 5    |      | μA      |
| TC I <sub>SC</sub> | I <sub>SC</sub> Temperature Coefficient | 2850 K             |                                | .02  | .08  |                                | .02  | .08  | %/°C    |
| V <sub>OC</sub>    | Open Circuit Voltage                    | H = 100 fc, 2850 K |                                | 420  |      |                                | 420  |      | mV      |
| TC V <sub>OC</sub> | V <sub>OC</sub> Temperature Coefficient | 2850 K             |                                | -2.0 |      |                                | -2.0 |      | mV/°C   |
| I <sub>D</sub>     | Dark Current                            | H = 0, VR = 2.0 V  |                                |      | 2000 |                                |      | 100  | pA      |
| R <sub>SH</sub>    | Shunt Resistance                        | H = 0, V = 10 mV   |                                | .07  |      |                                | 1.4  |      | GΩ      |
| TC R <sub>SH</sub> | R <sub>SH</sub> Temperature Coefficient | H = 0, V = 10 mV   |                                | -8.0 |      |                                | -8.0 |      | %/°C    |
| C <sub>J</sub>     | Junction Capacitance                    | H = 0, V = 0       |                                | 1.0  |      |                                | 1.0  |      | nF      |
| λ <sub>range</sub> | Spectral Application Range              |                    | 330                            |      | 720  | 330                            |      | 720  | nm      |
| λ <sub>p</sub>     | Spectral Response - Peak                |                    |                                | 580  |      |                                | 580  |      | nm      |
| V <sub>BR</sub>    | Breakdown Voltage                       |                    | 2                              | 40   |      | 2                              | 40   |      | V       |
| θ <sub>1/2</sub>   | Angular Resp. - 50% Resp. Pt.           |                    |                                | ±50  |      |                                | ±50  |      | Degrees |
| NEP                | Noise Equivalent Power                  |                    | 1.1 x 10 <sup>-13</sup> (Typ.) |      |      | 2.4 x 10 <sup>-14</sup> (Typ.) |      |      | W/√Hz   |
| D*                 | Specific Detectivity                    |                    | 2.2 x 10 <sup>12</sup> (Typ.)  |      |      | 9.7 x 10 <sup>12</sup> (Typ.)  |      |      | cm√Hz/W |

UNCONTROLLED DOCUMENT

PART NUMBER  
SSL-LX3059IGW

REV.  
B

| REV. | E.C.N. NUMBER AND REVISION COMMENTS | DATE   |
|------|-------------------------------------|--------|
| A    | E.C.N. #10BRDR. & REDRAWN.          | 1.9.98 |
| B    | E.C.N. #10700.                      | 1.9.01 |



ELECTRO-OPTICAL CHARACTERISTICS  $T_A=25^\circ\text{C}$   $I_f=20\text{mA}$

| PARAMETER             | MIN         | TYP         | MAX     | UNITS    | TEST COND            |
|-----------------------|-------------|-------------|---------|----------|----------------------|
| PEAK WAVELENGTH       |             | 635 (RED)   |         | nm       |                      |
|                       |             | 565 (GREEN) |         | nm       |                      |
| FORWARD VOLTAGE (R/G) |             | 2.0/2.2     | 2.5/2.6 | $V_f$    |                      |
| REVERSE VOLTAGE       | 5.0         |             |         | $V_r$    | $I_f=100\mu\text{A}$ |
| AXIAL INTENSITY (R/G) |             | 30          |         | mcd      | $I_f=20\text{mA}$    |
| VIEWING ANGLE         |             | 60          |         | 2x theta |                      |
| EMITTED COLOR:        | RED/GREEN   |             |         |          |                      |
| EPOXY LENS FINISH:    | MILKY WHITE |             |         |          |                      |

LIMITS OF SAFE OPERATION AT  $25^\circ\text{C}$

| PARAMETER                      | COLORS | MAX        | UNITS                |
|--------------------------------|--------|------------|----------------------|
| PEAK FORWARD CURRENT*          |        | 150        | mA                   |
| STEADY CURRENT                 | (R/G)  | 30/25      | mA                   |
| POWER DISSIPATION              |        | 105        | mW                   |
| DERATE FROM $25^\circ\text{C}$ |        | -1.6       | mW/ $^\circ\text{C}$ |
| OPERATING, STORAGE TEMP.       |        | -40 TO +85 | $^\circ\text{C}$     |
| SOLDERING TEMP.                |        | +260       | $^\circ\text{C}$     |
| 2.0mm FROM BODY                |        |            | 3 SEC. MAX           |

\*  $t < 10\mu\text{s}$

\*UNLESS OTHERWISE SPECIFIED TOLERANCES PER DECIMAL PRECISION ARE: X= $\pm 1$  ( $\pm 0.039$ ), X.X= $\pm 0.5$  ( $\pm 0.020$ ), X.XX= $\pm 0.25$  ( $\pm 0.010$ ), X.XXX= $\pm 0.127$  ( $\pm 0.005$ ), LEAD SIZE= $\pm 0.05$  ( $\pm 0.002$ ), LEAD LENGTH= $\pm 0.75$  ( $\pm 0.030$ ), MIN=<sup>+DECIMAL PRECISION</sup><sub>-0.00</sub>, MAX.=<sup>+0.00</sup><sub>-DECIMAL PRECISION</sub>

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REV.  
B

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T3x5mm TRI-LEADED LED, BICOLOR RED/GREEN,  
COMMON CATHODE, MILKY WHITE DIFFUSED LENS.

RELIABILITY NOTE  
OUR MANY YEARS OF EXPERIENCE DATA ACCUMULATION INDICATE THAT SOLDER HEAT IS A MAJOR CAUSE OF EARLY AND FUTURE FAILURE. PLEASE PAY ATTENTION TO YOUR SOLDERING PROCESS.

|                 |             |              |               |
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| DRAWN BY:<br>BC | CHECKED BY: | APPROVED BY: | DATE: 8.30.94 |
|                 |             |              | PAGE: 1 OF 1  |
|                 |             |              | SCALE: N/A    |