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# Characterization and comparison of a potential new (SUS) local sensor

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# 1 OVERVIEW

This document describes investigations of potential replacements of the light-emitting-diode (LED) and photodiode (PD) currently used in the SUS local sensor-actuator heads (OSEM). The search for replacement devices is driven primarily by the need for a sensor which is much less sensitive (by at least one order of magnitude) to the ambient 1064 nm light than the current sensors. A secondary driver is the desire to use devices that are more vacuum compatible (little or no plastic or epoxy packaging).

This document contains measurement results on a LED-PD pair that provides both greater immunity to 1064 nm radiation and greater vacuum combatibility than the current devices. In addition, a possible mounting/packaging approach for retrofitting the existing OSEM heads with these devices is presented.

# 2 DEVICE PROPERTIES

The current LED and PD are Toshiba part; the LED is part number TLN 107A, and the PD is TPS 703; complete datasheets may be found at www.semicon.toshiba.co.jp/noseek/us/td/td2frame.htm. The center wavelength of the LED is 940 nm. The leads of both parts are slightly magnetic.

The new proposed LED and PD are both Honeywell parts; the LED is part number SME2470, and the PD is SMD2420. Complete datasheets may be found at *www.honeywell/sensors/prodinfo/infrared/*. The packages for the two devices are identical in form and material. They are surface mount ceramic chip packages, with glass lenses bonded to the chip, and gold contacts; thus the only materials exposed to the vacuum are ceramic, glass, and gold (it is unknown how the lens is bonded to the ceramic). This is to be compared to the current Toshiba devices, which present a couple of $cm^2$ of plastic and epoxy to the vacuum. The center wavelength of the SME2470 is 880 nm; this shorter wavelength allows a short-pass dichroic filter, which blocks 1064 nm but passes the LED light, to be used in front of the PD. In addition, the Honeywell PD includes a lens, which makes it less sensitive to (1064 nm) radiation coming in from large angles of incidence. These devices are also slightly magnetic (they seem to be somewhat more magnetic than the Toshiba devices, perhap from Kovar used for the lens bonding).

The tables below compare significant specifications of the Honeywell LED & PD with the Toshiba models. Device lifetime is another important parameter. The SME2470 uses Honeywell's SEC555 AlGaAs:Si diode chip, for which fairly extensive long-term operating life studies have been performed (though in different packages than the SME, which is a new product) – a summary document can be downloaded from the above Honeywell web page. A summary statement is that at operating conditions of 125 C case temperature and 100 ma forward current, the chip had zero failures (defined as a 50% drop in power output) in 1.5 million device hours. A conservative estimate of the case temperature in our application can be made using the thermal impedance value for the hermetic TO-46 package of 370° C/W with no heat sink; that would put the case temperature at about 50° C for this application. In comparison, a GaAs:Si chip (emits at 940 nm, so presumably the same semiconductor makeup as the Toshiba LED) had 10 failures in the same conditions. However, no specific lifetime data for the Toshiba LED is available to our knowledge.

| Parameter | Honeywell SME2470 | Toshiba TLN 107A |
|---|---|---|
| Spectral bandwidth, 10% relative intensity pts | 800–960 nm | 900–1000 nm |
| Radiation cone 20% half-angle | 18 deg. | 23 deg |
| Maximum storage temperature | 150° C | 100° C |
| Max. continuous forward current | 75 ma | 50 ma |
| Power dissipation at operating current | 75 mW @50ma | 12 mW @10ma |
| Output power | 1.15 mW @50ma | (unknown) |

**Table 1: LED parameters**

| Parameter | Honeywell SMD2420 | Toshiba TPS 703 |
|---|---|---|
| Response at 1064 nm, relative to PD peak | 20% | 60% |
| Relative response at 30 deg incidence | 5% | 90% |
| Maximum storage temperature | 150° C | 90° C |

**Table 2: Photodiode parameters**

# 3 Sensor Properties

This section presents the properties of the sensor combinations of LED-PD. The Toshiba sensor was measured in an OSEM head, by a UFlorida grad student. The Honeywell characterisations were measured in a lab-bench setup, at a LED-PD separation of 0.25 inch, approximately the separation existing in the current OSEMs. A significant difference between the two sensors is that the Honeywell PD includes a lens which, at our operating separation, is smaller than the LED beam; the PD thus detects a relatively small fraction of the LED light output. This is a disadvantage in terms of the sensitivity along the sensing axis (or in terms of the LED current required to reach a given sensitivity), but it is an advantage in terms of lower sensitivity to non-sensing axis motions of the magnet (since the magnet is wider than the PD lens).

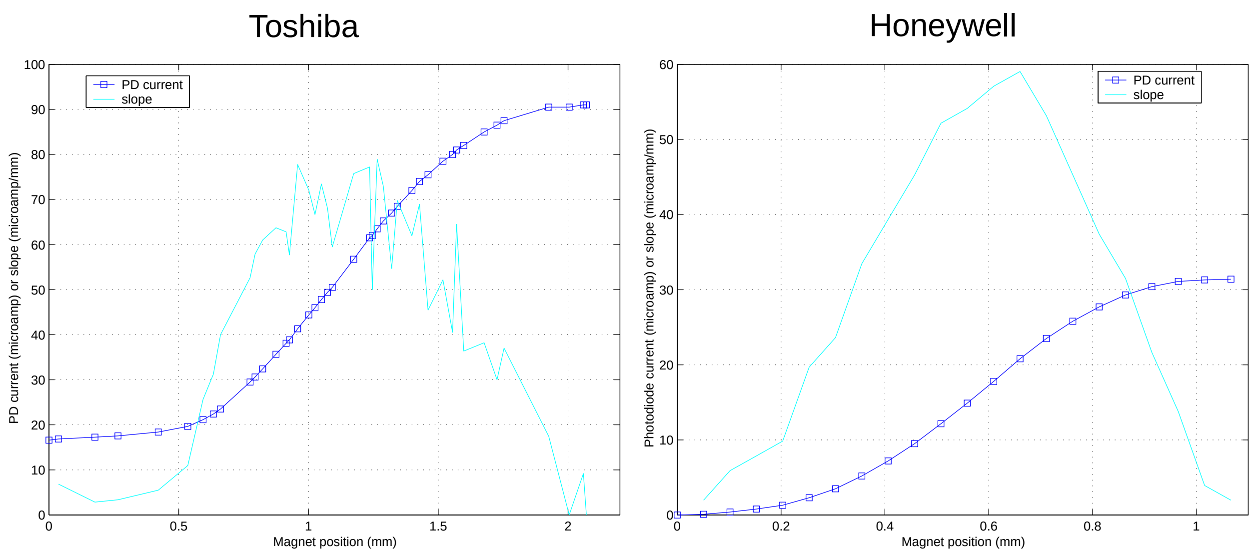


**Figure 1: Sensor response along the sensing axis. The Honeywell LED-PD lens-lens separation is 0.25 inch; the Toshiba sensor data is measured with a OSEM. Also shown is the slope vs magnet position.**

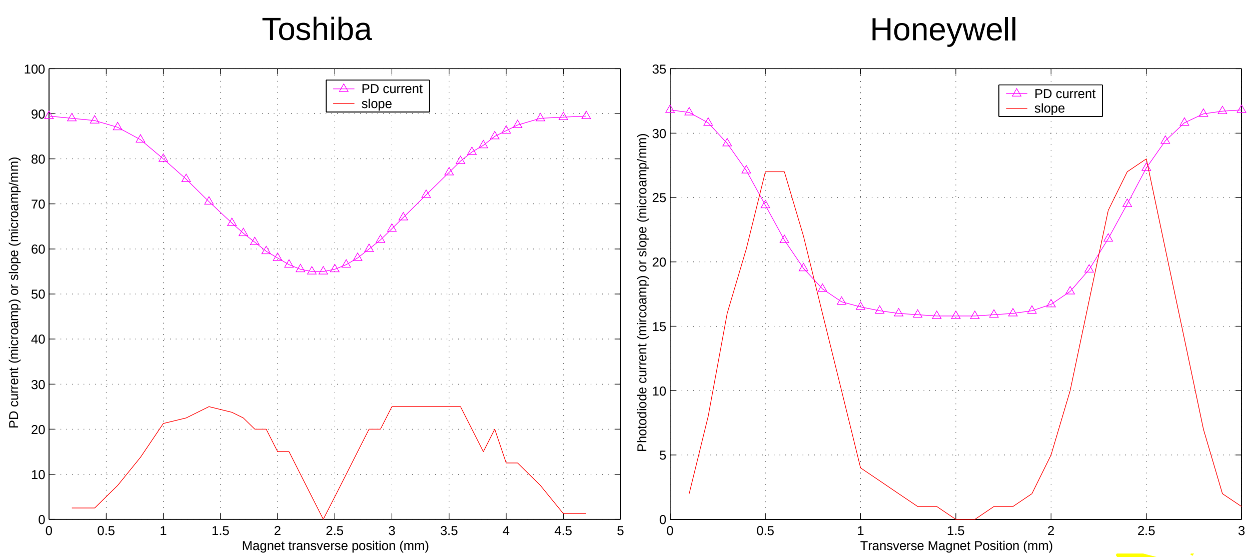


**Figure 2: Sensor response along the direction transverse to the sensing axis (and transverse to the LED beam direction). In each case the magnet is in the center of the range of the sensing direction.**

| Parameter | Honeywell | Toshiba |
|---|---|---|
| Sensing range: 10-90% of $I_{max} - I_{min}$ | 0.5 mm | 1.0 mm |
| Transverse tolerance[a] | $\pm$ 0.6 mm | $\pm$ 0.25 mm |

**Table 3: Performance parameters of the combined LED-PD sensors.**

a. defined as the magnet transverse offset at which the transverse sensitivity (slope) is 20% of the sensing axis sensitivity

Noise measurements were made of the Honeywell sensor in the following manner. The LED was operated at 42 ma of forward current, using a bank of 9V batteries to achieve low current noise. The PD (reverse biased at 5V) was operated in a transimpedance amplifier configuration, using an OP27 with a transimpedance of 100 kohm. At a LED-PD separation of 0.25 inch, with no magnet-shadow; the PD current was 25 microamp (this is somewhat larger than the 15 microamp of photocurrent that would exist with 50 ma of LED current, and the magnet in the center of the range). Two boxes (box around a box) were put over the setup to improve low frequency performance. The spectrum of the PD amplifier output is shown in Figure 3. The requirement is a sensitivity of $10^{-10}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$ or better at $f > 40$ Hz; this sensor reaches this level starting at 10 Hz.

Comparison with the current Toshiba sensor comes from T950072-00-R, *"Evaluation of proposed changes to the suspension sensor electronics"*, and from the UFl measurements. From the latter, the shot noise sensitivity should be about $6\times10^{-11}\mathrm{m}/\sqrt{\mathrm{Hz}}$. This is not entirely consistent with the former (T950072), which claims that the sensitivity is $10^{-10}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$ at $f > 50$ Hz. That document goes on to say that "Below 50 Hz, the spectrum rises approximately as $1/\sqrt{f}$, while below 1 Hz the spectrum seems to approach $1/f$." An estimate of the Toshiba sensing noise is also shown in Figure 3, using the more optimistic level for the noise floor, but the slopes from T950072.

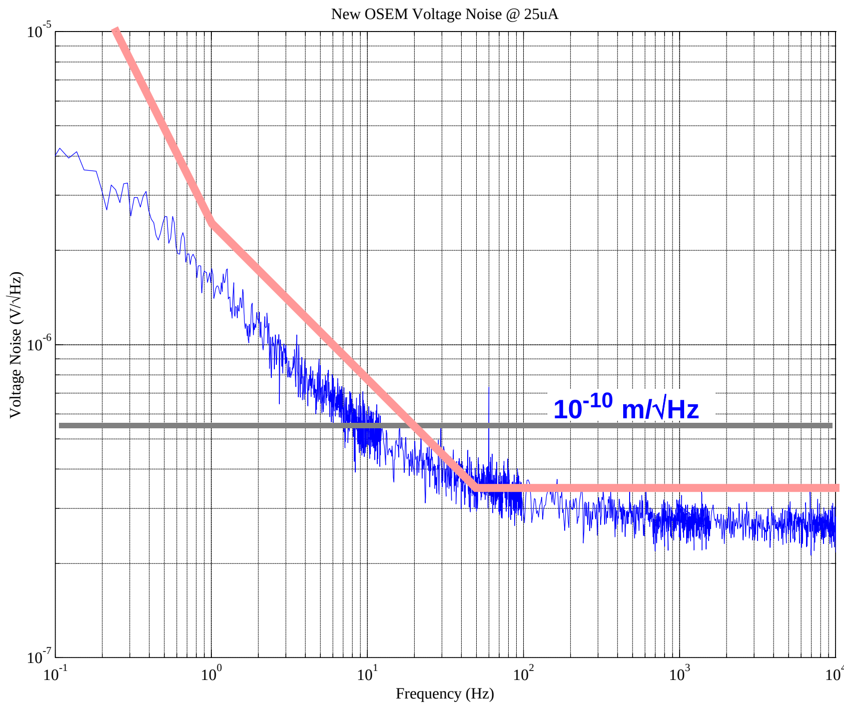


**Figure 3: Noise performance of the Honeywell LED-PD pair (blue, noisy curve). Sensing calibration is 5.5 V/mm. The LED-PD separation is 0.25 inch, and the PD current is 25 microamp. The noise level at 1kHz and above is the shot noise of the photocurrent. The slight change in slope below 0.2 Hz is due to the AC coupling on the signal analyzer. The pink polyline is an estimate of the Toshiba sensor noise performance (see text).**

# 4 Short-pass Filter

The SMD2420 PD itself gives some greater immunity to 1064 nm light, because of its relatively lower response at this wavelength, and because it is less responsive at non-normal angles of incidence. To give further resistance to 1064 nm light, a short-pass filter could be mounted over the PD. The filter should be as thin as possible, so as not to restrict the clearance around the magnet.

The filter design shown in xxxx is designed by Rocky Mountain Instrument, for coating onto a microscope cover glass (~0.2 mm thick).

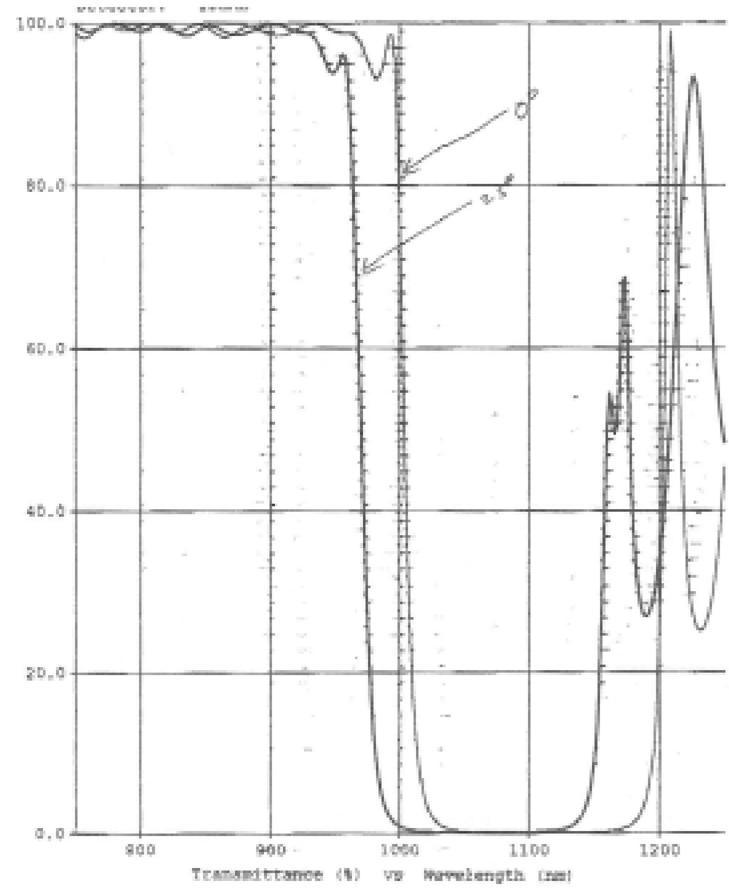


**Figure 4: Specifications for a short-pass dichroic filter from Rocky Mountain Instruments. The coating could be applied to a microscope cover glass. The transmission at 1064 nm is less than 0.5%.**

# 5 IMPLEMENTATION

The current OSEM heads may be retro-fitted with the new sensor, after removing the Toshiba devices. Janeen and Jay came up with a design where each device is mounted on an alumina ‘circuit board’ in an inverted position, with the lens exposed through a hole in the board. The circiut board has conduction traces leading from the device to the rear of the OSEM head, where wires are soldered to the board. The electronics changes required for the new sensor are limited to the satellite module: 5 resistors would need to be changed to increase the LED current to 50 ma; and we would probably want to increase the transimpedance value from 20 kohm to 50-100 kohm.

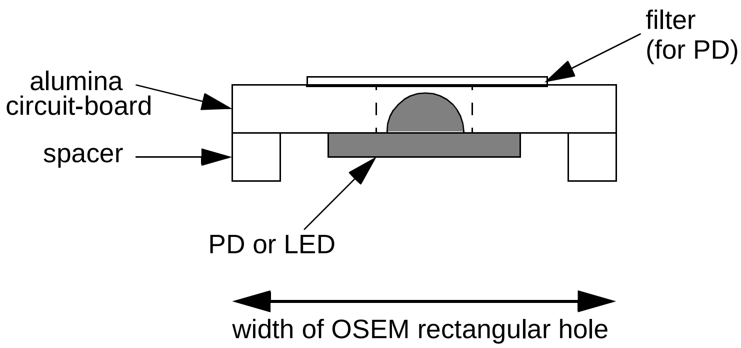


**Figure 5: Cross-sectional view of mounting scheme for retro-fitting the current OSEM heads with the new sensors. The alumina circuit-board and spacers (alumina/macor) are identical for the PD and LED. The device is soldered to solder pads on the board. The spacers are bonded to the board, and the whole assembly is bonded into the OSEM head (using Vacseal or ceramic adhesive). For the PD assembly, a short-pass filter may be bonded to the top of the board. The circuit-board runs the length of the OSEM head, with plated traces to carry the signals to the other end for wire connection.**

# 6 OPTIONS

There are a couple of options to the above approach that are worth considering. The first is to use a larger surface PD, with no lens, in place of the SMD2420. UDT, e.g., sells a bare silicon solderable photodiode chip (5.1 mm x 5.1 mm, eg), that could be mounted in a similar fashion as above with a short-pass filter. The advantage would be a larger sensing range, with less LED current needed to reach the required position sensitivity. The disadvantage would be a greater sensitivity to transverse offset, and in this case a filter would be required.

The second option would be to make new OSEM forms, rather than retro-fitting the current ones. The bore hole in the OSEM form could be circular, which would allow quicker and cheaper delivery than reproducing the current shape. This may be simpler than retro-fitting.