Thermal Performance of an LDM-4616 Laser Diode Mount

TECH NOTE

This technical note presents the results of thermal power (heat) dissipation measurements on a typical LDM-4616 16-Channel Laser Diode Mount, and explains how ILX Lightwave calculated the thermal resistance of the mount.

BACKGROUND

When operating laser diode modules, heat is generated within the laser diode. A thermoelectric cooler (TEC) is commonly used to cool the laser diode by transferring heat from the laser diode to the module case. In addition, the TEC itself produces joule heating from the power applied to it. Heat must be dissipated into the environment to keep the module case temperature within operating range. A good laser diode mount will absorb heat from the module case and dissipate heat into the environment efficiently.

One common way to quantify how well a system (such as a mount) transfers thermal energy from the heat source into the environment is to calculate the system's thermal resistance. Thermal resistance, denoted as θ in °C/Watt, is defined as the ratio between the temperature difference across the system and the amount of heat being transferred. For example, if your heat source is generating 50 W of heat, the ambient air is 23°C, and the hot side of the system at the heat source is 33°C in steady state, the thermal resistance of the system is as follows:

θ = ΔT/Power = (23°C -33°C)/50W = 0.2°C/Watt (example only)

Under the same conditions, if your heat source generates 100 W of heat, the hot side of the system in steady state would be approximately:

T = 23°C + (0.2°C/W x 100W) = 43°C (example only)

This calculation is approximate because natural convection heat sink efficiency improves somewhat with increasing sink-to-ambient temperature.

Many things can affect the thermal resistance of a mount. Properties of the mount such as material, area of the heat sink, and thermal contact between laser module and heat sink will affect the value. Other environmental effects include airflow across the heat sink, and temperature difference from the heat sink to the air. The purpose of this technical note is to give you an idea of how much thermal energy the LDM-4616 Mount will dissipate from your lasers, and approximately how hot your laser module cases will get for a given power dissipation.

THERMAL POWER ESTIMATE

First, an estimate was made as to how much thermal energy the mount would have to dissipate under operating conditions. A data sheet for a common high power 1480nm pump laser diode module was referenced. The thermal power generated by the laser diode is the operating current multiplied by the forward voltage, minus the optical power output:

(600mA x 2.5V) – 140mW = 1.36 W laser thermal power

The MAXIMUM thermal power generated by the TEC is the maximum TEC current multiplied by the maximum TEC voltage:

1.4A x 3.8V = 5.32 W maximum TEC thermal power

Combining the laser and TEC thermal power, the maximum total heat generated for this laser becomes:

1.36W + 5.32W = 6.68 W maximum total thermal power

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An ILX Lightwave LDC-3916 Laser Diode Controller was used to control the TEC to a setpoint of 30°C, which is the maximum submount (TEC) operating temperature specified on the data sheet for this laser. In steady state, the TEC current was –0.28 Amps, which is well below the maximum current of –1.5 Amps specified for this laser. This laser module operated properly in the LDC-4616 Mount at an ambient temperature of –1°C, and appeared to have plenty of margin to operate at colder temperatures.

To check operation at a high temperature with high heat generation, the thermal chamber was set to 40°C, and the remaining 15 resistors in the LDM-4616 were driven to approximately 8 W each. The laser was driven with its maximum operating current of 210mA by the LDC-3916 Controller, and the TEC was set at the minimum laser submount (TEC) operating temperature of 20°C. The results are plotted in Figure 3. The steady state TEC current was 0.6 Amps, which is well below the maximum specified of 1.5 Amps. This laser module had plenty of operating margin under these conditions.

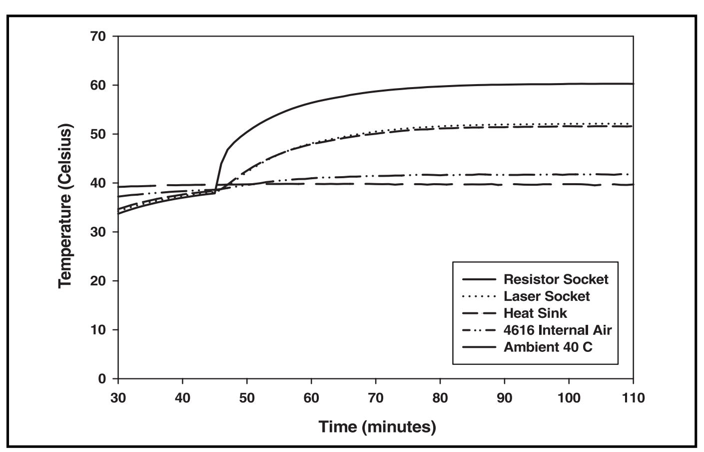

Figure 3. Operating Laser in High Temperature Environment.

As can be seen in Figure 3, the temperature of the laser socket was lower than a resistor socket. The reason is that the laser was only generating about 1.26 W of thermal power. The 8 W per socket used in the tests above is a very conservative (high) value for the butterfly packaged laser diodes that we have seen.

Estimated laser socket temperatures will be calculated assuming there are 16 lasers that each generate the 1.26 W of thermal energy that our test laser was generating. Assuming still air in an open environment, the thermal resistance of the LDM-4616 is 0.413°C/Watt; therefore, the socket temperature can be approximated as follows:

ΔT = 0.413°C/W x 1.26W x 16 = 8.33°C (above ambient)

Assuming air moving similar to that in our thermal chamber, the thermal resistance of the LDM-4616 is 0.171°C/W; therefore, the socket temperature can be approximated as follows:

ΔT = 0.171°C/W x 1.26W x 16 = 3.45°C (above ambient)

As illustrated, the LDM-4616 16-Channel Laser Diode Mount shows excellent thermal performance. The laser socket temperature is only a few degrees hotter than the ambient air in this example. The laser module case temperature will be very close to the socket temperature when clamped to the cold plate.

For lasers with exceptionally high heat output, or laser module cases that need to be kept very near ambient temperature, fan arrays can be rack mounted below the LDM-4616 that will blow air directly on the heat sink. This significantly reduces the effective thermal resistance to cool your lasers even better than shown in this Technical Note.

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Note that in actual operation, the TEC would normally operate at a much lower drive level in steady state. The actual total thermal power is estimated to be 2 to 4 W for this high power pump laser diode module. To simulate a variety of conditions, the test measurements were made with 2W, 8W, and 12W on each of the 16 sockets in the LDM-4616 Laser Diode Mount.

MEASUREMENT SETUP

To simulate the thermal power of laser diodes while maintaining easy control of power levels, 10 Ω resistors were used instead of actual lasers. The 16 resistors were clamped to the cold plates in the 16 sockets using the spring clips on the sockets. Heat sink compound was put under the resistors to facilitate heat transfer into the mount. The resistors were connected to a variable power supply.

Thermistors were used to measure temperatures during the tests. To measure socket temperatures, thermistors were secured with thermal epoxy into holes in three of the cold plates. To monitor the temperature of the finned heat sink, a thermistor was secured with thermal epoxy between fins near the center of the heat sink. Another thermistor was suspended in the tray of the mount to measure air temperature within the mount with the mount cover shut. Ambient air temperature was measured with a thermistor suspended about four inches outside the mount. All the thermistors were connected through a terminal board to an HP®3457A multimeter. The thermistor resistances were monitored via GPIB control by a computer program which converted the resistance values to temperatures. The program recorded the temperatures every 60 seconds.

The LDM-4616 was placed in a thermal chamber on three small wooden blocks to thermally isolate it from the metal rack in the chamber.

RESULTS

To determine the thermal resistance of the LDM-4616 under varied conditions, the mount was tested with moving air at 40°C in a thermal chamber, and again in still air at room temperature. Then, operation of a laser in the mount was tested at cold and hot conditions.

For the first test, the thermal chamber door was shut and the chamber control set to 40°C. Power to the mount was left off to allow the temperatures to settle. At time T1 the power supply was turned on to supply 8 W of power to each of the 16 resistors in the LDM-4616 Mount. At time T2 the power was increased to 12 W per socket. At time T3 the power was decreased to 2 W per socket. As can be seen in Figure 1, the temperatures settled to different values depending on how much power was applied.

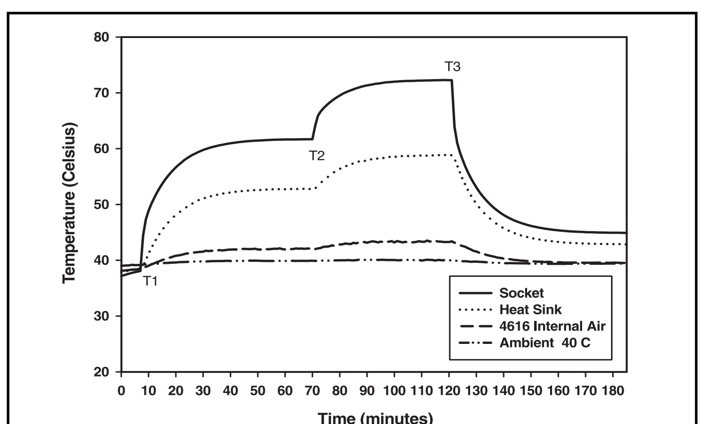

Figure 1. Moving Air at 40°C.

Table 1 summarizes the steady state values at the three power levels in the first test under the columns labeled "Moving Air at 40°C". The results of thermal resistance calculations are shown at the bottom of Table 1, and the 8 W calculation is repeated here:

Thermal Res. $= \theta =$ ***[(socket temp) – (ambient temp)] / (power)***
= [61.7°C – 39.9°C] / 127.5W = 0.171°C/W in chamber

Thermal Resistance Calculations

	Natural Convection 8W	Natural Convection 12W	Moving Air at 40°C 8W	Moving Air at 40°C 12W	Moving Air at 40°C 2W
Load Voltage (V)	35.788	43.94	35.91	44	18.134
Load Current (A)	3.55	4.35	3.55	4.35	1.8
Total Power (W)	127.0	191.1	127.5	191.4	32.6
Temperatures (°C):					
Socket Plate (hottest)	76.6	99.5	61.7	72.3	44.9
Heat Sink	68.8	87.6	52.8	58.8	42.8
Ambient	24.2	25.8	39.9	39.9	39.4
Thermal Res. (°C/W):					
plate-to-sink	0.0614	0.0623	0.0698	0.0705	0.0644
sink-to-ambient	0.3512	0.3233	0.1012	0.0987	0.1043
Total Thermal Resistance (°C/W)	0.4125	0.3857	0.1710	0.1693	0.1687

Table 1. Summary of Thermal Resistance Measurements.

The thermal chamber circulates temperature controlled air to keep the chamber temperature at the setpoint. Since moving air across a heat sink facilitates heat transfer, the effective thermal resistance decreases when the air is moving. Many instrument racks have moving air in them, but air volume and velocity will change the effective thermal resistance.

The second test was done to calculate thermal resistance in still air with natural convection. The thermal chamber was turned off and the door was left open for this test at room temperature. At time T1 the power supply was turned on to supply 8 W of power to each of the 16 resistors in the LDM-4616. At time T2 the power was increased to 12 W per socket. Figure 2 plots the results of this test. Table 1 summarizes the results under the columns labeled "Natural Convection". The thermal resistance calculation for 8 W is repeated here:

Thermal Res. $= \theta =$ ***[(socket temp) – (ambient temp)] / (power)***
= [76.6°C – 24.2°C] / 127.0W = 0.413 °C/Watt in still air

Cold and hot tests were then done with an actual laser in one of the sockets to verify performance. The resistor in socket 11 of the LDM-4616 was removed, and a common 980nm pump laser diode module was mounted in socket 11.

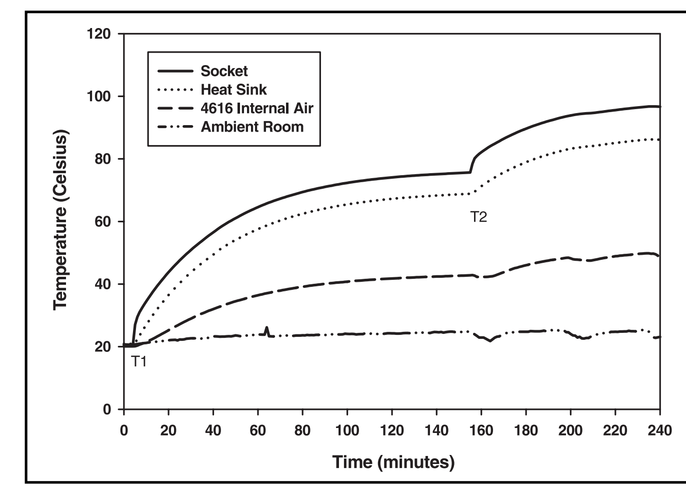

Figure 2. Still Air at Room Temperature.

To check operation at a cold temperature, the thermal chamber with the LDM-4616 inside was set at –1°C. All power was turned off to the resistors and the laser so no heat was generated except by the TEC in the laser module.

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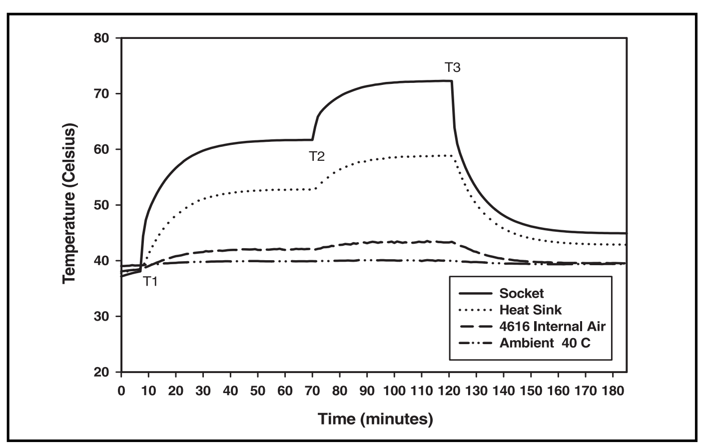

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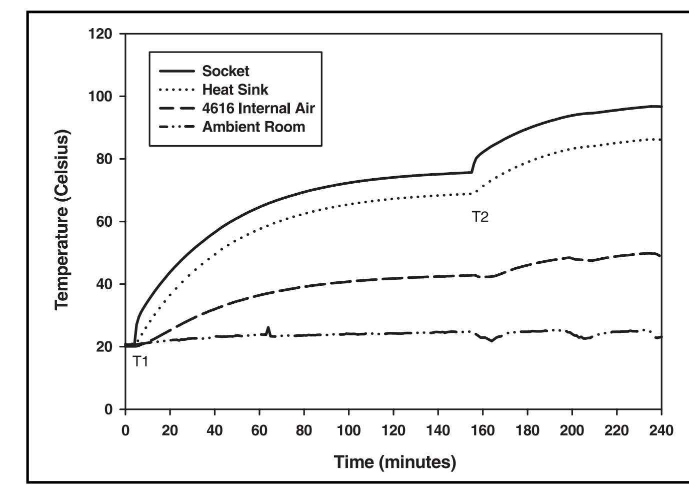

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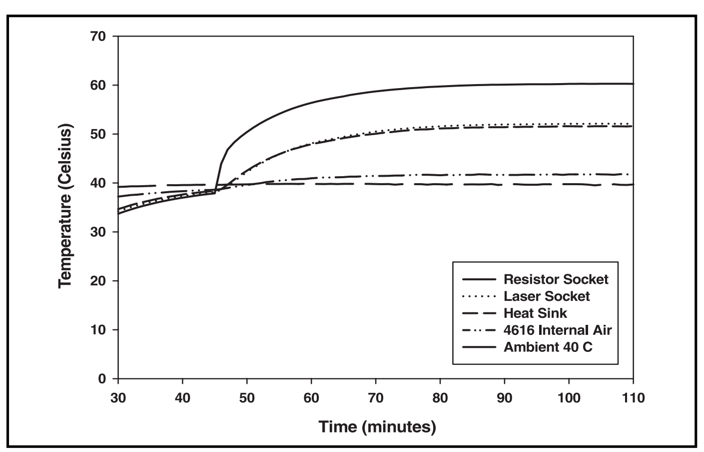

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