Agiltron Inc.

1. ESD handling and precautions

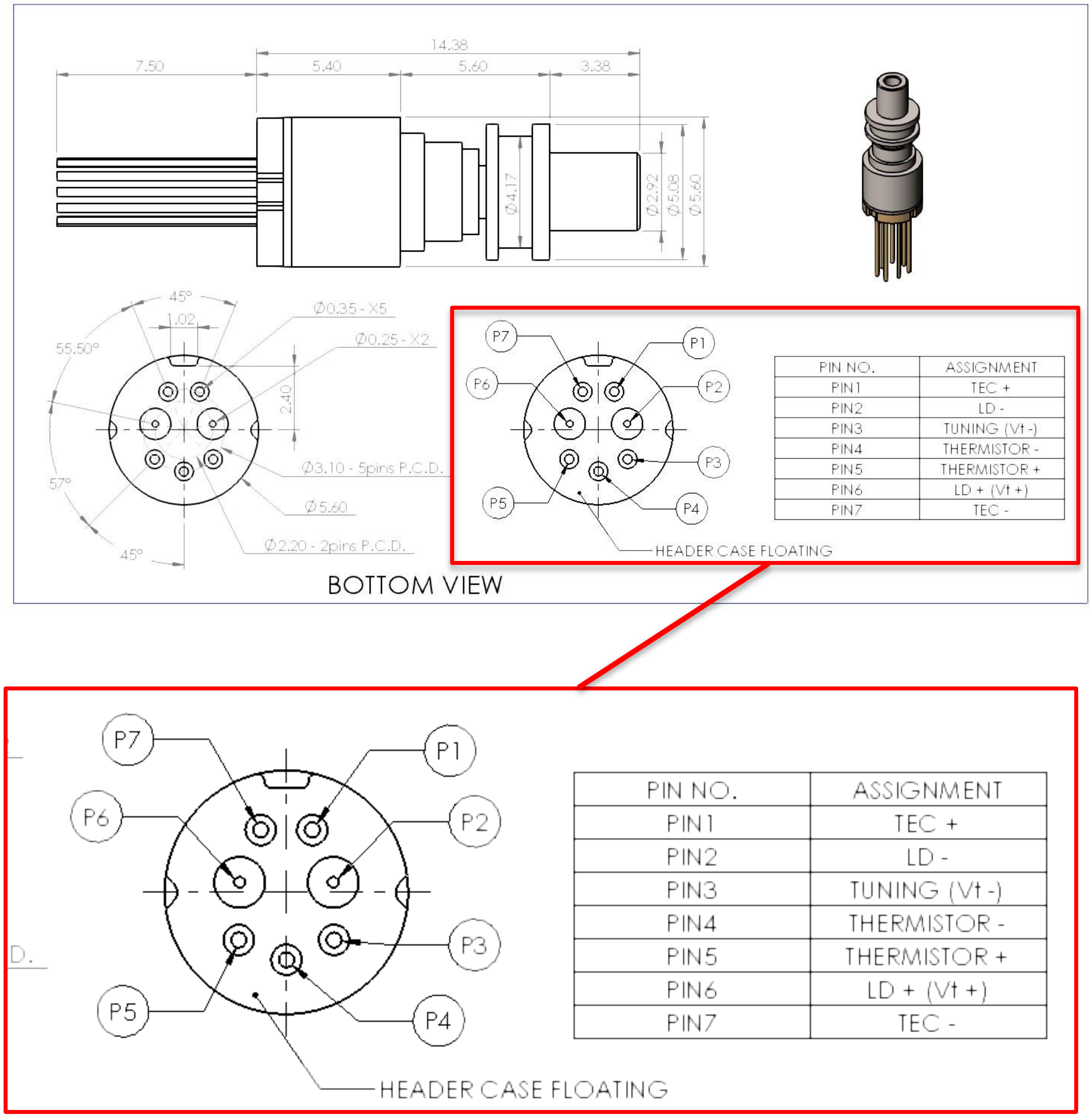
Electrostatic discharge (ESD) can damage the devices permanently and the device does not any ESD protection circuits. Therefore, it is very important to ensure proper ESD protection. Place the packed device on an ESD protected workstation i.e. before removing the ESD protection bag. You must wear a wrist strap and appropriate smocks made from dissipative material. Note that the smocks must be closed to ensure proper ESD protection. A good side for further ESD information is https://www.esda.org/about-esd/

CAUTION: Device is very sensitive to electrostatic discharge.

2. Electrical Pin Out

The electrical pin out for the 1550 devices is given below. The pinout is the same for the pigtailed Tosa and the TO.

Figure 1



PIN NO.	ASSIGNMENT
PIN1	TEC +
PIN2	LD -
PIN3	TUNING (Vt -)
PIN4	THERMISTOR -
PIN5	THERMISTOR +
PIN6	LD + (Vt +)
PIN7	TEC -

Bottom View and Pin Assignments

3. Low Speed Testing Setup and Electrical Diagram

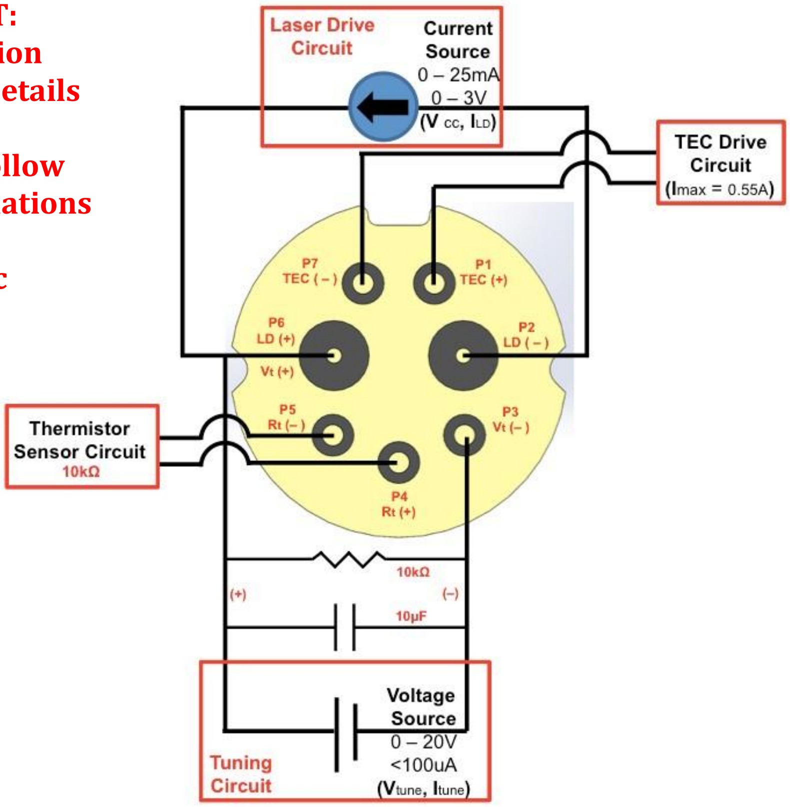
Please ensure the first-time power on sequence in section 3.5 when you power up the device.

3.1. Best Performance Recommendations and quick start guide:

- We recommend using Agiltron's fixture BW10-420B or BW420C . Please note the different pinout of BW10-420C.
- If using a TOSA clamp the TOSA down for best thermal contact. You can clamp down the pigtailed TOSA by lifting carefully the fiber boot.
- If the device is used on a customer PCB, we recommend using Agiltron's socket (model number BW10-SOCK) with additional heat sink or good thermal connection to the housing.
- Connect all cables to the fixture as illustrated in figure 2 and turn on the equipment but disable the outputs before inserting the TO or Tosa. Always disable the output and remove the TO or Tosa before you disconnect any cables.
- Follow the power on and power off procedure given below:
    - Once all cables are connected and the equipment is on, insert the DUT and enable the output of the TEC first and wait until the temperature is stabilized.
    - As a second step increase the laser current and confirm the operation by measuring for example the optical power.
    - Finally ramp the tuning voltage, you can see that the wavelength is decreasing.
    - Turn off the outputs in reverse order before you remove the DUT from the fixture.

Figure 2

**IMPORTANT:
Review section 3.3-3.4 for details on sources.
Failure to follow recommendations may lead to catastrophic damage!**



3.2. The TEC driver

- The leads of TEC+/- and Thermistor +/- can connect to a standard TEC controller. Please verify that the controller's connection assignments match with the TOSA pinout.
- Limit the maximum TEC current to Imax to 0.55A
- The thermistor is a 10 kΩ sensor, details are given at the end of this document.
- The following TEC controllers were tested with our devices:
  - Arroyo Instruments (Separate application note with PID values available on request)
  - Newport / ILX lightwave LDC-3724B and LDT-5910B (important: limit the max current and set the gain to 1, use the Steinhart constants: C1=1.123, C2= 2.349, C3= 0.853)
  - Newport / ILX lightwave LDT 5412: Set the gain on the backside to minimum gain to reduce temperature oscillations, i.e. use a small blade screwdriver and turn the control fully counter clockwise.

3.3. The laser driver

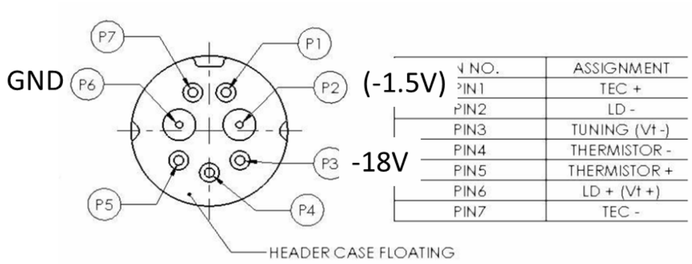
- The laser should be driven by an anode grounded or a floating laser and tuning circuit. We recommend the use of floating sources. Cathode grounded circuits can be used but are not recommended since the required tuning voltage will vary with the laser drive voltage. This relationship for a tuning voltage of 18V is illustrated in figure 3. Additionally, cathode grounded circuits are more at risk for catastrophic MEMS damage.

Some commercial laser driver current sources do not work well with VCSELs. They are typically designed for Edge Emitters and the VCSEL differential resistance often trips the driver's protection circuitry.

- The following laser drivers were tested with the 1550 nm devices:
  - Newport / ILX lightwave LDC 3724B (floating)
  - Newport / ILX lightwave LDX3412 (floating)
  - Keithley 2400/2401/2602 source meters (floating)
  - Arroyo Instruments Laser sources (floating)
  - Thorlabs benchtop laser drivers of the LDC family (anode grounded configuration)
  - Koheron DRV100 (anode grounded)
- Typical current-voltage response is shown in section 6.1.

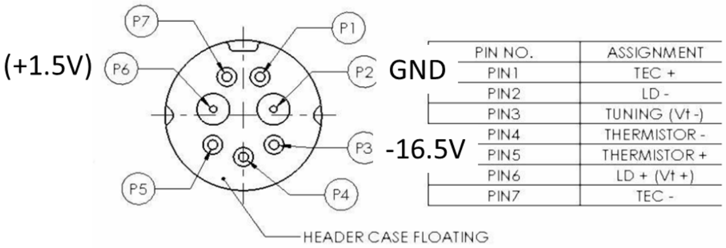
Figure 3

Assuming a laser driver with anode (LD+) grounded:



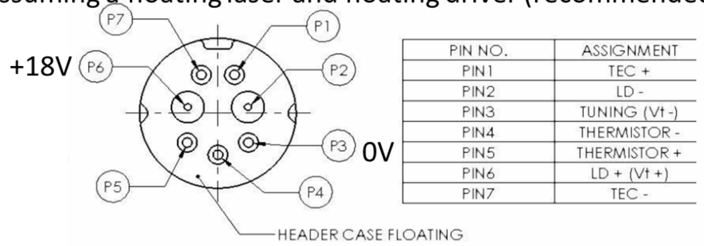
N NO.	ASSIGNMENT
IN1	TEC +
PIN2	LD -
PIN3	TUNING (Vt -)
PIN4	THERMISTOR -
PIN5	THERMISTOR +
PIN6	LD + (Vt +)
PIN7	TEC -

Assuming a laser driver with cathode (LD-) grounded:



PIN NO.	ASSIGNMENT
PIN1	TEC +
PIN2	LD -
PIN3	TUNING (Vt -)
PIN4	THERMISTOR -
PIN5	THERMISTOR +
PIN6	LD + (Vt +)
PIN7	TEC -

Assuming a floating laser and floating driver (recommended):



PIN NO.	ASSIGNMENT
PIN1	TEC +
PIN2	LD -
PIN3	TUNING (Vt -)
PIN4	THERMISTOR -
PIN5	THERMISTOR +
PIN6	LD + (Vt +)
PIN7	TEC -

3.4. Voltage source for the MEMS for tuning the laser

- The polarity of the tuning voltage depends on the used laser driver. For anode and cathode grounded configurations the required tuning voltage needs to be negative with respect to pin 6. On our test sheets we always give the voltage without polarity. **The Vt+ pin must have a higher potential than the Vt-pin.** For floating laser and voltage sources apply a voltage of e.g. +10V between pin 3 and pin 6. For anode grounded devices pin 6 is pulled to GND by the laser driver, hence pin 3 needs to have a lower potential i.e. apply a negative voltage. For cathode grounded laser drivers pin 6 has a laser voltage of approximately 1.5V, hence the voltage on pin 2 needs to be lower than 1.5V and the acceptable range is between approximately 1.5V and 1.5V–test sheet value.
- The voltage source should not exceed the voltage given in the test sheet (Typically 16V to 18V)
- The compliance current should not exceed 100 µA
- For reducing noise and guard against any transients we recommend a 10 µF capacitor and 10 kΩ resistor in parallel with the tuning voltage if the laser is used at a fixed wavelength. For sweeping the laser, the capacitor of the low-pass filter should be removed or significantly reduced so it bypasses the sweeping signal.
- The wavelength tuning is approximately quadratic with voltage.
- Typical wavelength over voltage response is shown in section 6.2
- For sweeping the laser we recommend the Tektronix function generator AFG3011C operated in high Z mode. Note that the BNC shield of most function generators are grounded, so most will need to be used in an anode grounded configuration.

3.5. Detailed Setup and Turn-on Sequence

1. Following steps in order, “Do Not” proceed to a next step without completing a previous step
2. Hook up all testing equipment, laser power source, tuning source, and the TEC controller
   Lots of supplies have transient pulse from the supply when first turn-on. We recommend shorting the laser driver and voltage outputs.
3. Power up the equipment. Ensure that all outputs are disabled.
4. Connect all cables to the Tosa fixture
5. Insert the Tosa in the fixture and clamp it down for best thermal connection. Wear an ESD wrist strap when handling the devices. The MEMS section of the laser is very ESD sensitive.
6. If properly connected, the TEC controller should have a readout of the TEC’s current temperature, which should be at the room temperature.
7. If TEC’s required parameters are properly set and the controller is showing a room temperature readout, then set the controller to 20°C and turn it on.
8. Plug in the fiber to the TOSA’s LC connector or connect the pigtail to a power meter or an OSA or both using a fiber splitter.
9. Once the TEC Controller shows the TOSA is stable at 20°C, it is ok to remove the laser source short and apply a 15mA bias current to the laser. At which time, the TEC controller will show a jump in the TOSA temperature. This is normal and allow the TEC to stabilize back to the 20C set point.
10. Check the Laser source meter readouts to verify that,
    a. the voltage is within the expected range as noted on the data sheet
    b. the output power is at the expected power level for 15mA @20°C
    c. if there is a spectrometer connected, turn it on to see the wavelength of the TOSA matches the values given in the test sheet.
11. Double check the TEC controller is still holding the temperature at the set point.
12. Finally, turn on the tuning circuit source meter, starting at 0V, then slowly increase the voltage to +10V (floating driver) or -10V (anode / cathode grounded driver) to verify the device is properly connected and tuning.
13. Double check the TEC controller is still holding the temperature at the setpoint. Now, apply various tuning voltages, not to exceed the limits found on the data sheet, to test out the changes in wavelength to get a good understanding of what the TOSA will tune to.
14. Always turn off the outputs in reverse order before you remove the DUT from the fixture.
15. If one or more of these steps fail and several attempts to start over from the beginning continue to result in failure of a working and tunable laser or controlled temperature, then notify you BW10 contact for further support.

4. High Speed Setup

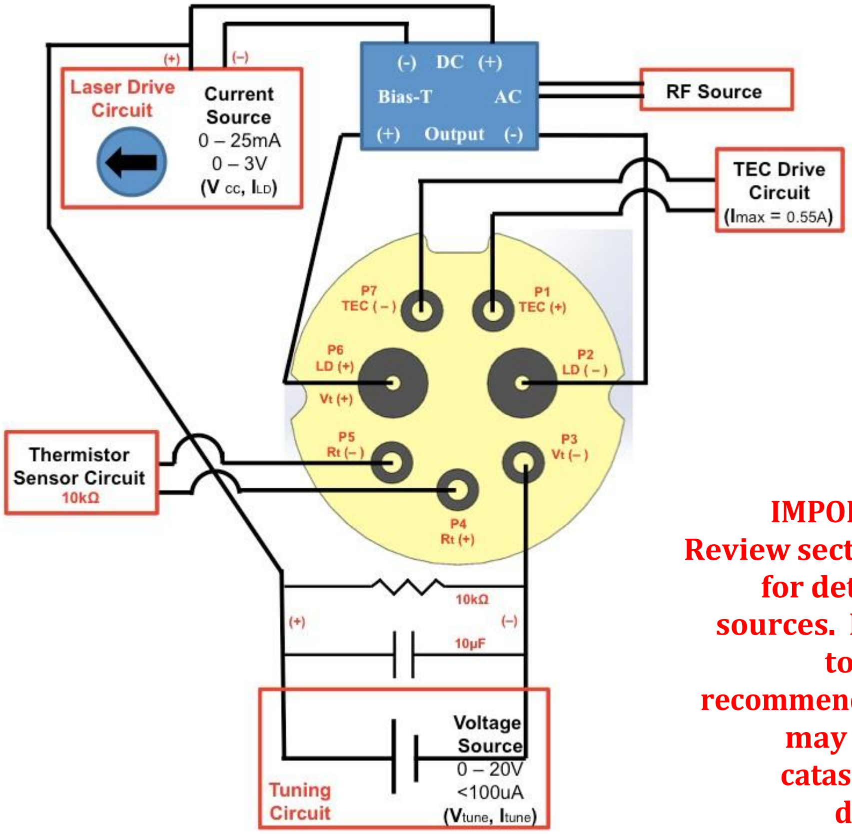
4.1. Requirements for High Speed Modulation:

- The TOSA must be connected to a high-speed modulation board, either directly soldered or via a high-speed flex board. For high speed modulation two broadband bias-tees are required.

4.2. High Speed Electrical Diagram Explained

- Diagram below is laid out for high speed testing of the TOSA
- There is a RF source required
- The TEC controller, Tuning source, and the laser DC power source are all the same as described in the low Speed Setup, (All sequential setup steps should be followed for the high speed setup as well to ensure proper testing of the TOSA)
- As in diagram 1, there is a 10µF capacitor and 10kΩ resistor, parallel to the tuning circuit.

Figure 4



IMPORTANT: Review section 3.3 for details on sources. Failure to follow recommendations may lead to catastrophic damage!

5. Beam characteristics

5.1. 1550 nm VCSEL chip

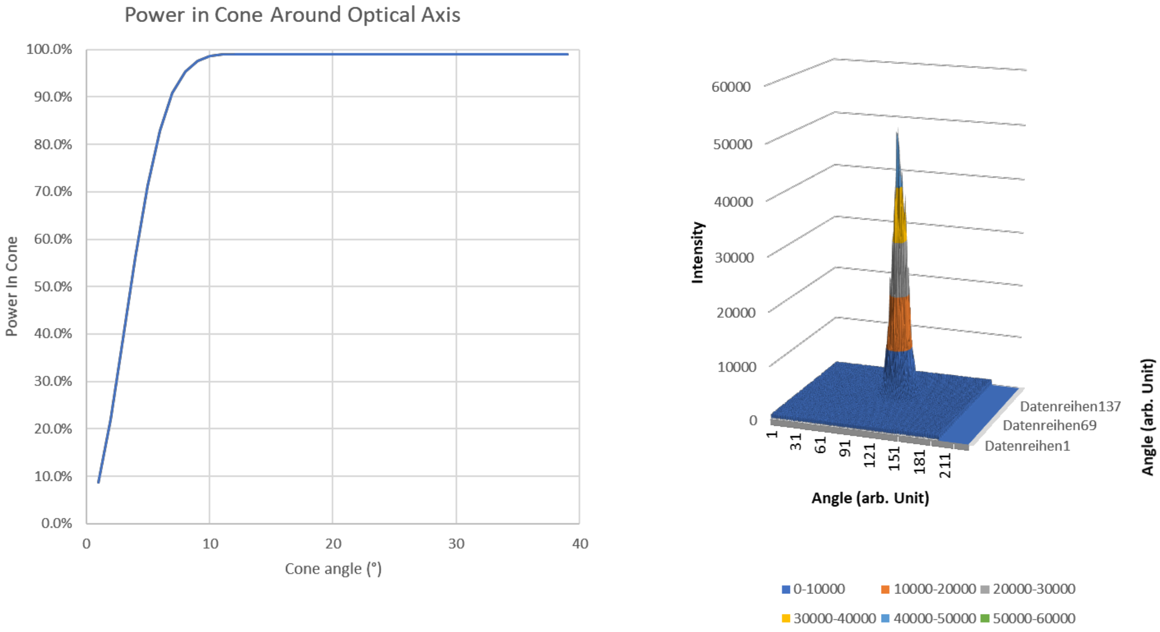
The VCSEL chip inside the TO / TOSA has the following optical parameters:

The 1/e^2 Gaussian beam waist on the major axis is approximately 12°. On the minor axis it is ~8°-10°. The aperture is approximately 10 µm (FWHM).

5.2. BW10-1550-TO beam characteristics

The TO with aspherical lens far field divergence (full angle) is 4° at 50% power, and 8° at 95% power.

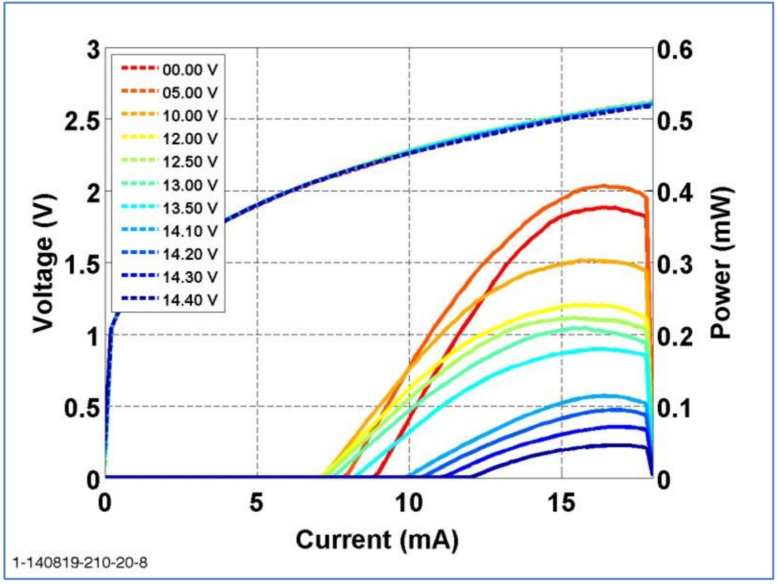
Figure 5



6. Laser Electrical and Optical Characteristics

6.1. Light-Current Voltage Response at 20ºC

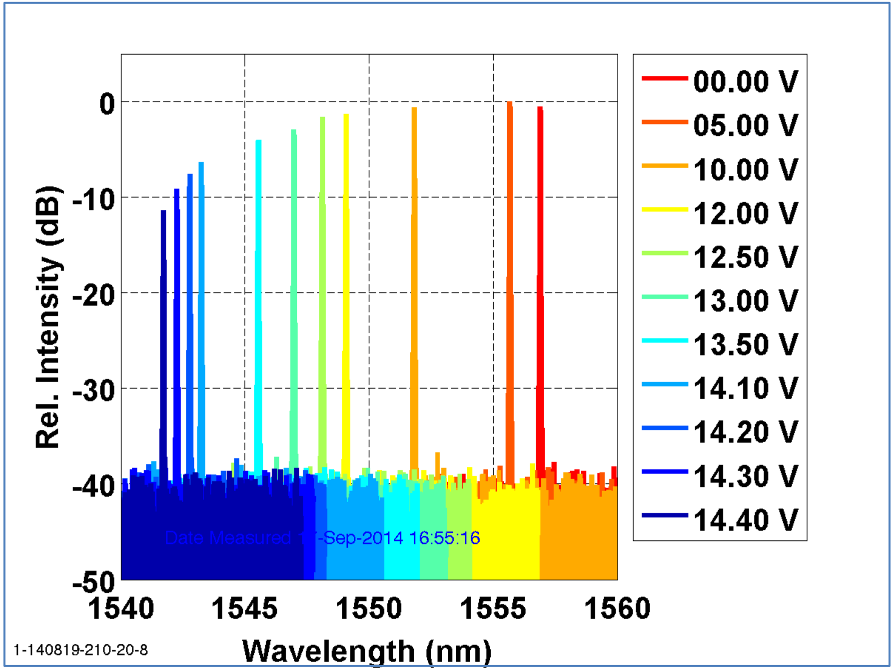
Figure 6



6.2. Optical Spectrum at 15mA at 20ºC

(As a function of Tuning Voltage)

Figure 7



Typical Device shows:

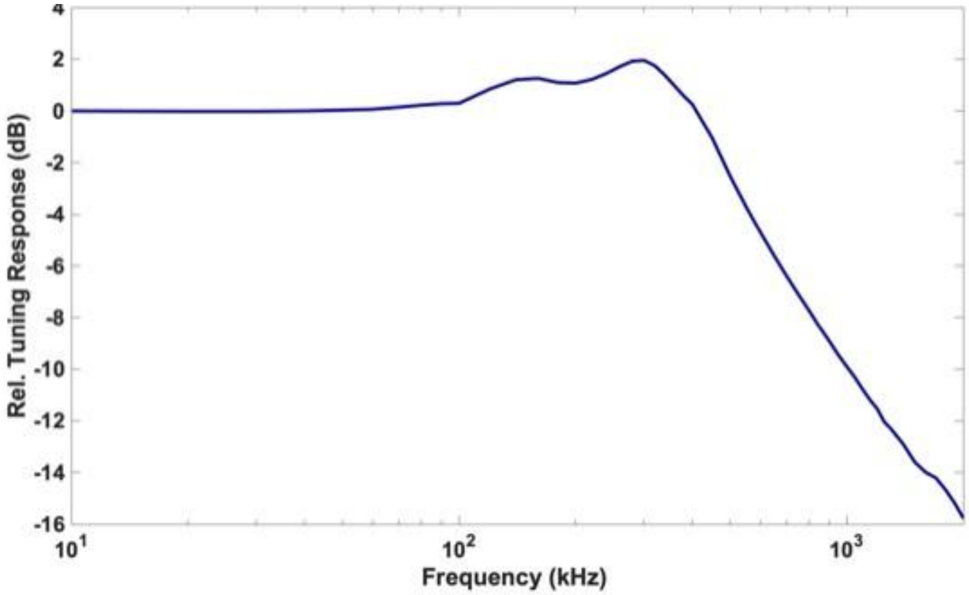
- Typical Tuning Curve (Note that start and stop wavelengths may differ)
- It is >10 nm, continuous, mode-hop-free tuning range
- Δλ is ~ quadratic with respect to tuning voltage

- Maximum output power is relatively constant across the range
- ~5-13V (maximum power decreases beyond that voltage)
- Tuning voltage is the voltage between the laser drive pin (LD+) and tuning pin (Vt -), (The LD+ pin being the positive side)

6.3. Mechanical Wavelength Tuning Response

Typical devices show mechanical tuning responses to input frequencies up to ~1 MHz on the tuning contact with a -3dB point of ~400 kHz.

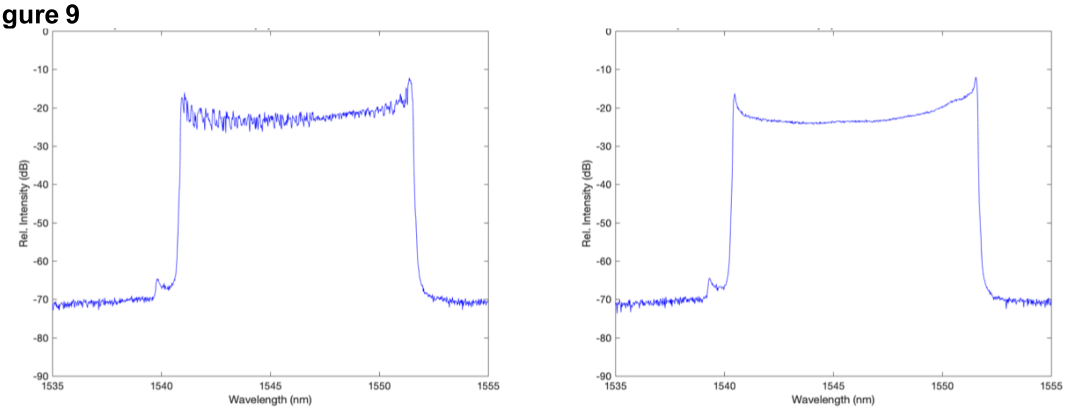
Figure 8



7. Swept source operation

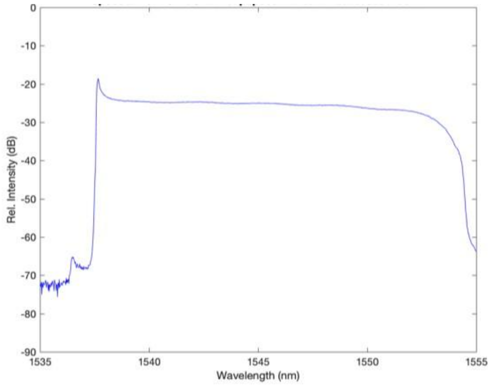
The device can be used as a swept source. As a function generator we recommend using Tektronix AFG3011C. The response of a typical device is shown for 10kHz, 80kHz and 300 kHz in Fig. 7. For the 300kHz response the MEMS is exceeding the laser’s tuning range on the right side of the spectrum due to reaching a MEMS resonance at 300 kHz. The laser was biased at 20 mA drive current with a tuning voltage of 12 V DC and 16 Vpp AC (i.e. 12 V DC ±8V AC). The AC signal is a sine wave. Special precautions should be taken selecting the correct waveform generator. We noticed that several generators on the market have the BNC shield connected to GND and do not turn off the output when the output is disabled by software, i.e. in most cased only the buffer amplifier is disabled.

Figure 9



10 kHz

80 kHz

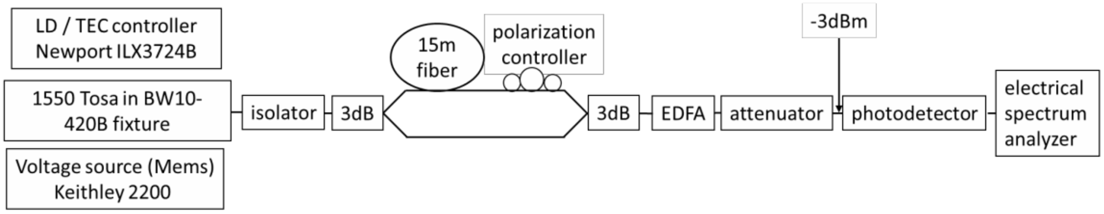


300 kHz

8. Laser linewidth / Coherence length

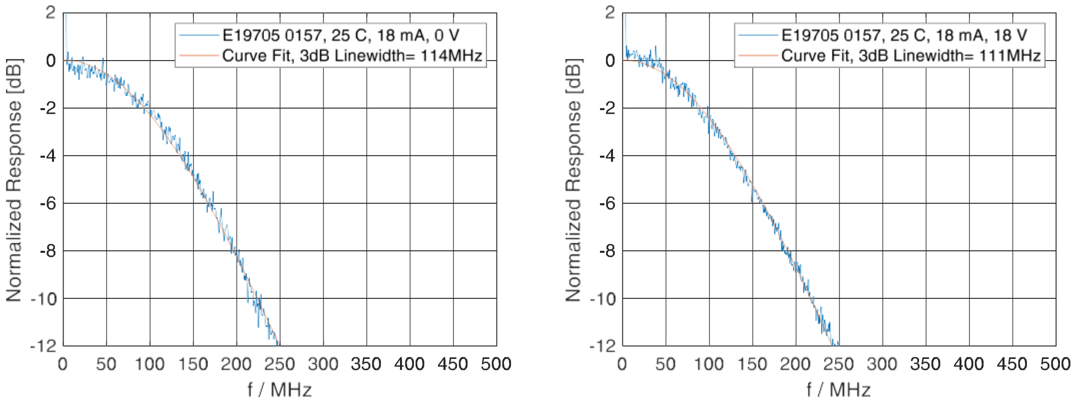
The laser linewidth of the TOSAs was characterized using a self-homodyne measurement setup with a standard photodetector and an electrical spectrum analyzer. The fiber delay length in one arm of the Mach Zehnder interferometer set-up was 15 m which corresponds to a linewidth measurement resolution of approximately 6 MHz. An additional isolator was placed behind the device under test to reduce the impact from reflections from the Mach Zehnder interferometer. In the electrical spectrum analyzer video averaging was enabled, i.e. the measurement time was rather long and this method the very small instantaneous linewidth cannot be measured.

Figure 10



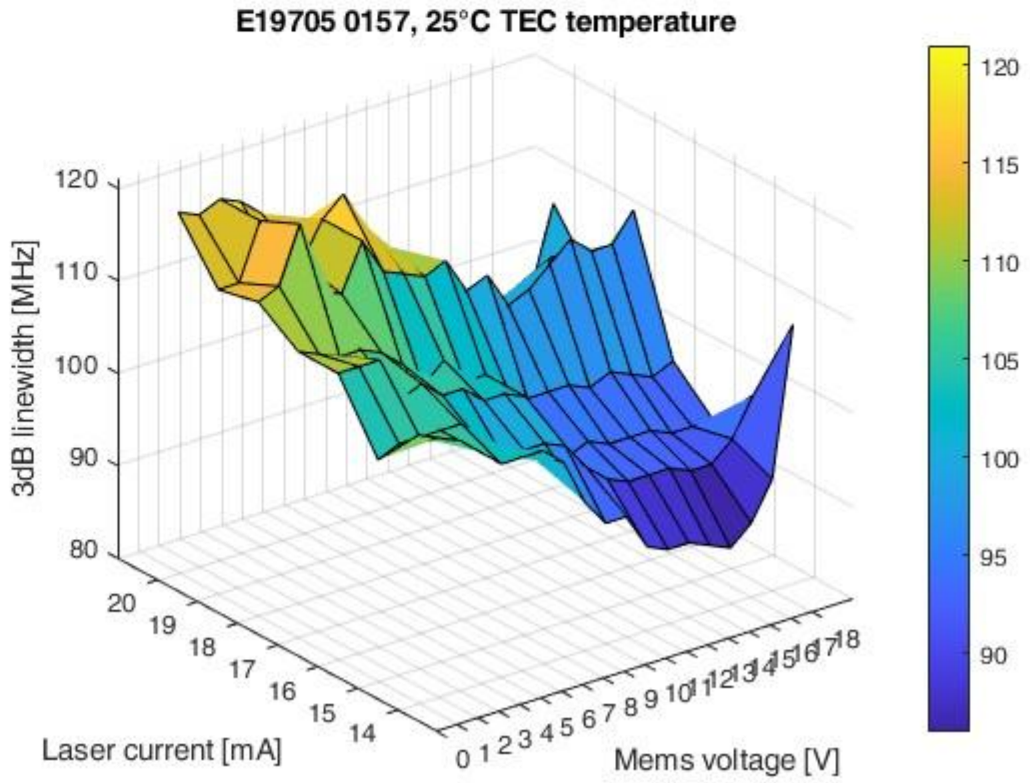
The measured response of a typical Tosa for a certain current, voltage and temperature combination is shown below. The repose is a convolution of the Lorentzian portion of the laser convoluted with the dominating Gaussian portion of the Brownian noise originating from the micro electrical mirror (Mems) on top of the laser.

Figure 11



A typical plot of the linewidth vs. tuning voltage and drive current at a fixed TEC temperature of 25°C is shown below. Lowest linewidth can be obtained with a driving current set to the optimum current value I_{OPT} given in the test report (typically around 18mA). It is noticeable that the linewidth is slightly reduced with increasing tuning voltage which is resulting in a stiffer grating which results in lower Brownian noise and smaller laser linewidth.

Figure 12

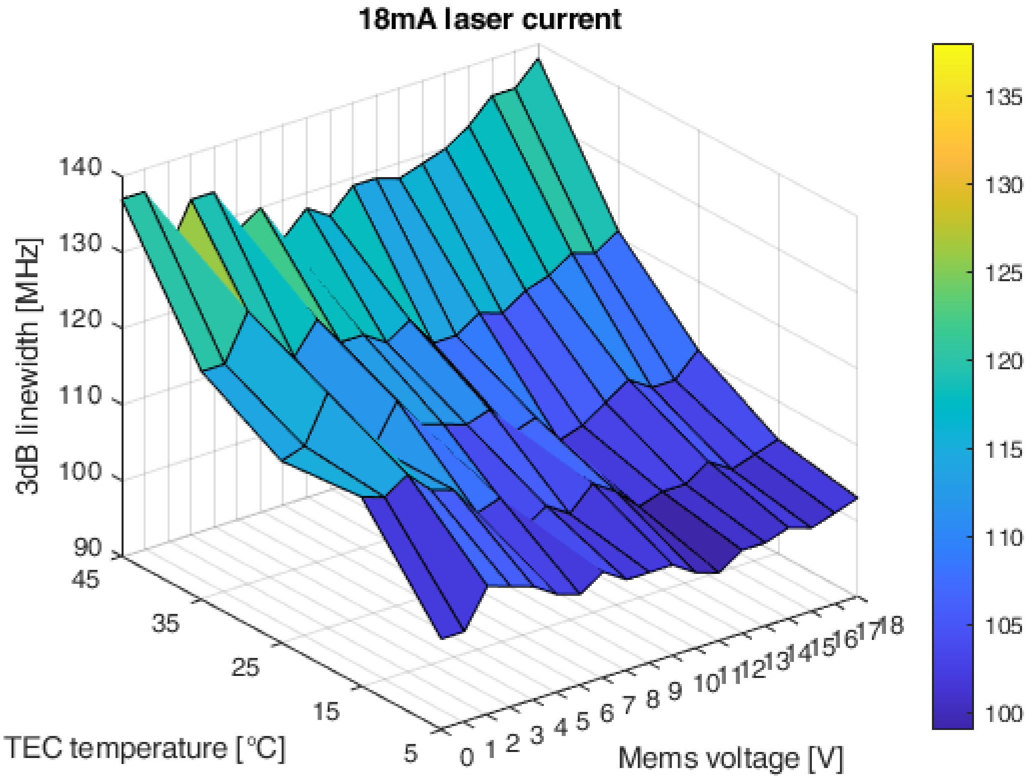


Laser current [mA] vs. Mems voltage[V]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
14	109	108	107	105	103	103	103	101	96	93	93	89	88	88	87	86	88	92	108
15	104	105	105	105	105	102	100	100	100	99	96	94	93	93	93	92	92	94	98
16	111	111	111	106	107	105	105	103	103	102	97	94	95	94	94	94	93	93	93
17	111	110	109	109	108	106	103	105	102	102	100	98	98	98	97	98	97	96	97
18	114	115	121	113	112	117	113	112	111	112	108	109	105	106	108	110	108	108	111
19	113	113	119	113	113	117	119	115	112	107	103	100	100	98	98	100	105	100	101
20	119	118	119	118	116	113	112	108	106	103	103	102	100	98	98	98	99	99	107

3dB laser linewidth in MHz at a fixed temperature for different laser currents and tuning voltages.

With higher TEC temperature i.e. higher laser temperature the Brownian noise increases, which results in a broader laser linewidth as illustrated below:

Figure 13



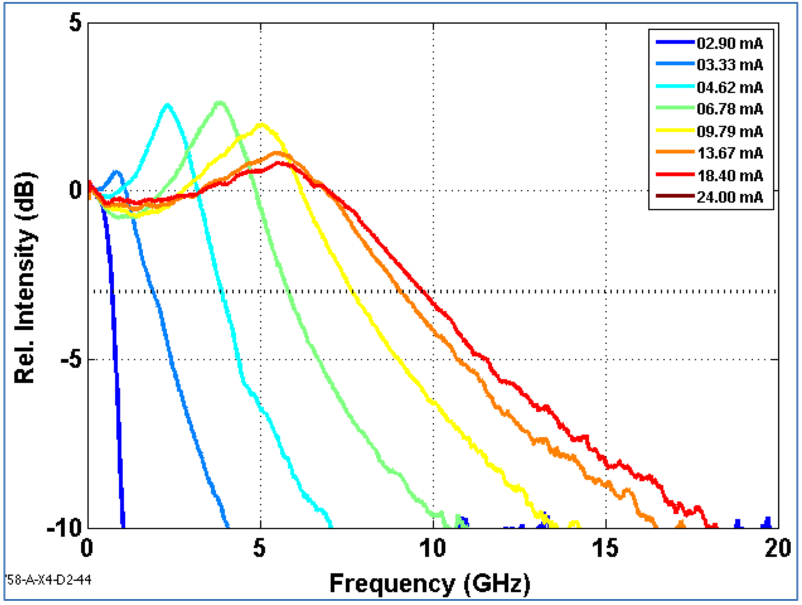
TEC temperature [°C] vs. Mems voltage[V]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
5	102	102	107	106	105	103	102	104	102	102	102	100	99	101	101	102	101	102	103
15	115	114	116	113	112	108	109	104	106	104	107	105	102	103	103	105	103	104	105
25	114	115	121	113	112	117	113	112	111	112	108	109	105	106	108	110	108	108	111
35	120	120	126	119	118	122	118	118	116	118	114	114	116	115	117	118	120	119	121
45	137	137	128	134	134	128	130	125	128	126	129	129	128	129	130	132	135	135	138

3dB laser linewidth in MHz at a fixed laser current for different TEC temperatures and tuning voltages.

9. Direct Modulation Small Signal (S21) Response

Typical TOSAs show direct optical modulation responses due to electrical input responses (S21) up to 8+ GHz.
Typically, the maximum response is achieved near the roll over point of the VCSEL

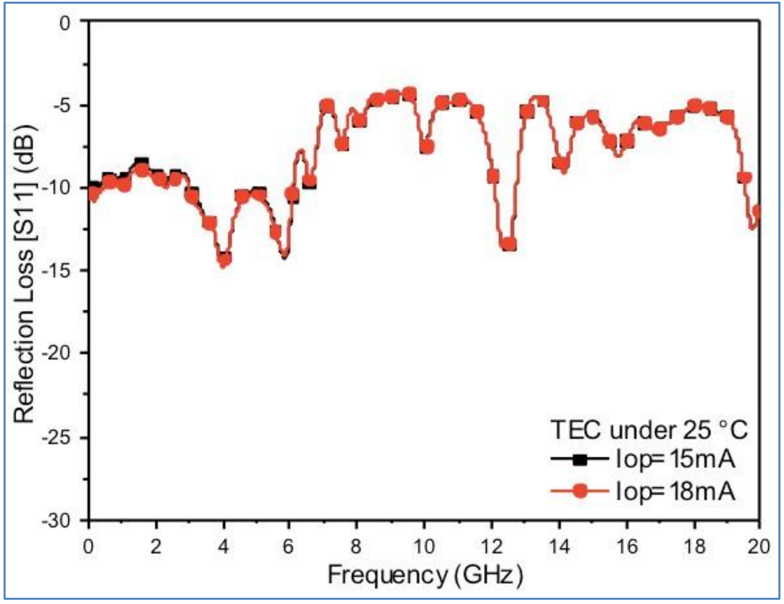
Figure 14



10. S11 Performance

A typical S11 response of a BW10-1550-T-T6B is shown below at 15 and 18 mA bias currents, with the TEC set at 25º C

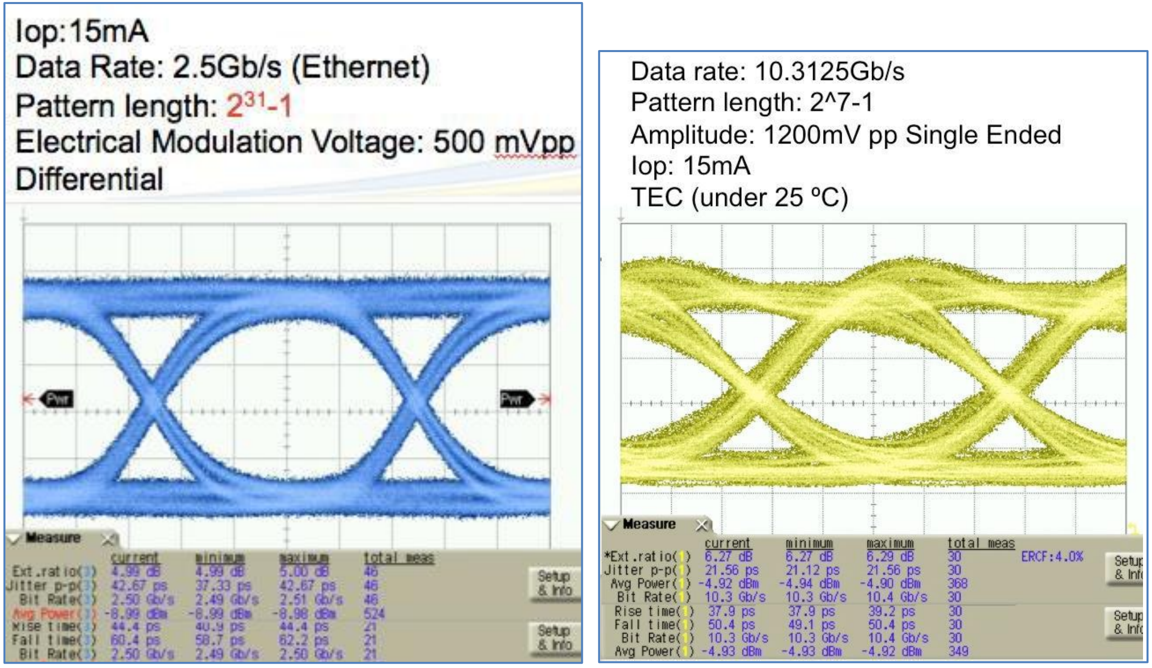
Figure 15



11. Large Signal Performance

Typical eye diagrams at 2.5G and 10G (with drive condition notes above the eye and measured results noted below the eyes), with the TEC set at 25º C are shown below:

Figure 16



Iop:15mA
Data Rate: 2.5Gb/s (Ethernet)
Pattern length: 2^{31}-1
Electrical Modulation Voltage: 500 mVpp Differential

```
Measure
              current      minimum      maximum      total meas
 Ext.ratio(3)  4.99 dB      4.99 dB      5.00 dB      46
Jitter p-p(3)  42.67 ps     37.33 ps     42.67 ps     46
  Bit Rate(3)  2.50 Gb/s    2.49 Gb/s    2.51 Gb/s    46
 Avg Power(3) -8.99 dBm    -8.99 dBm    -8.98 dBm     524
 Rise time(3)  44.4 ps      40.9 ps      44.4 ps      21
 Fall time(3)  60.4 ps      58.7 ps      62.2 ps      21
  Bit Rate(3)  2.50 Gb/s    2.49 Gb/s    2.50 Gb/s    21
```

Data rate: 10.3125Gb/s
Pattern length: 2^7-1
Amplitude: 1200mV pp Single Ended
Iop: 15mA
TEC (under 25 ºC)

```
Measure
              current      minimum      maximum      total meas
*Ext.ratio(1)  6.27 dB      6.27 dB      6.29 dB      30          ERCF:4.0%
Jitter p-p(1)  21.56 ps     21.12 ps     21.56 ps     30
 Avg Power(1) -4.92 dBm    -4.94 dBm    -4.90 dBm     368
  Bit Rate(1)  10.3 Gb/s    10.3 Gb/s    10.4 Gb/s    30
 Rise time(1)  37.9 ps      37.9 ps      39.2 ps      30
 Fall time(1)  50.4 ps      49.1 ps      50.4 ps      30
  Bit Rate(1)  10.3 Gb/s    10.3 Gb/s    10.4 Gb/s    30
 Avg Power(1) -4.93 dBm    -4.93 dBm    -4.92 dBm     349
```

Please note that 500 mV differential drive indicates the laser itself is seeing a full 1 Vpp swing.

12. Heat Sinking

The TO/TOSA PKG generates heat along the header base, (golden colored area) where the pins are extending out of. The pins are isolated from header base and cannot electrically connect to the header base.

For maximal heat sinking we suggest, mounting the Header PKG to a metal heat sink plate/sub-mount, such as Aluminum or Ni Plated Copper, keeping the pins isolated from contacting the heat sink. The contact points are around the edge and the base of the header, like how our 420Test Box is designed. Ideally, a thermal conductive compound, not electrically conductive, can be used at the interface to maximize heat conduction. Whether or not a compound is used, a clamping mechanism is recommended, to hold tightly the TO/TOSA flush against the heat sink, for best heat conduction.

A non-heat sink option is, the usage of a deformable heat conducting material pad, wrapping side of the package, and if possible, the bottom side of the PKG metal areas, to bring heat out. One such pad for example is a TG-A1780 Ultra Soft Thermal Pad from t-global Technology. See an example of how this is implemented in a transceiver in the picture below, where the TOSA is pressed against the thermal pad, which is attached to a metal housing. With such a setup it is possible for the case temperature to exceed 70º C while holding the laser at ~35º C.

13. TEC Parameters and Response

Typical Performance under Controlled Conditions				
	ΔTmax (K)	Qmax (W)	Imax (A)	Umax (V)
@ 27C	0.71	0.30	0.55	1.0
@ 75C	0.89	0.40	0.55	1.3

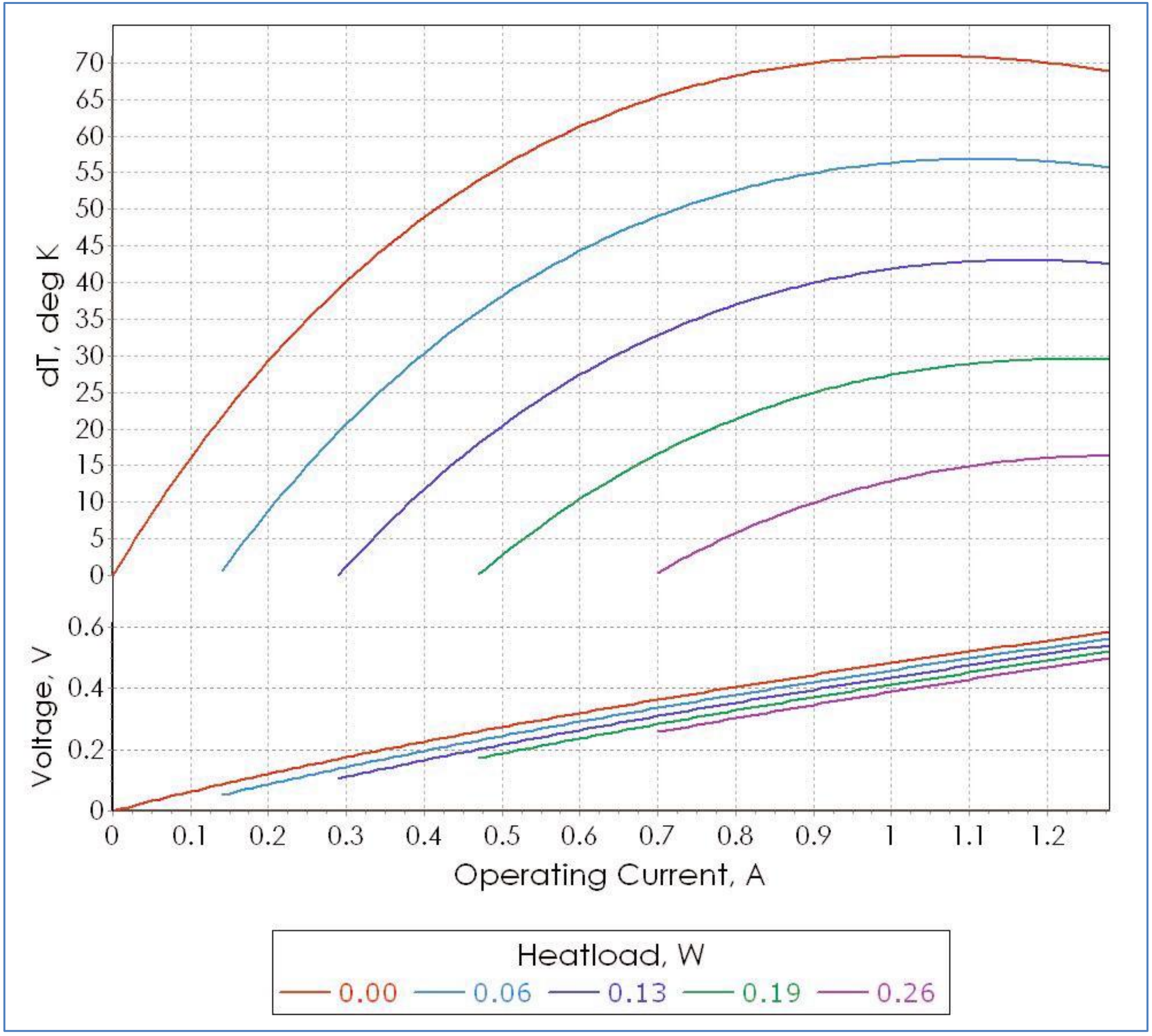
Typical Gain PID Settings

P = 0.005

I = 0.0001

D = 0.01

Figure 18



Typical TEC Performance under Lab Controlled Conditions, 10^-5 TORR Vacuum

14. Thermistor Performance Table

The thermistor is a standard 10kΩ thermistor. A table showing thermistor resistance over thermistor resistance at 25º C is shown below.

Figure 19

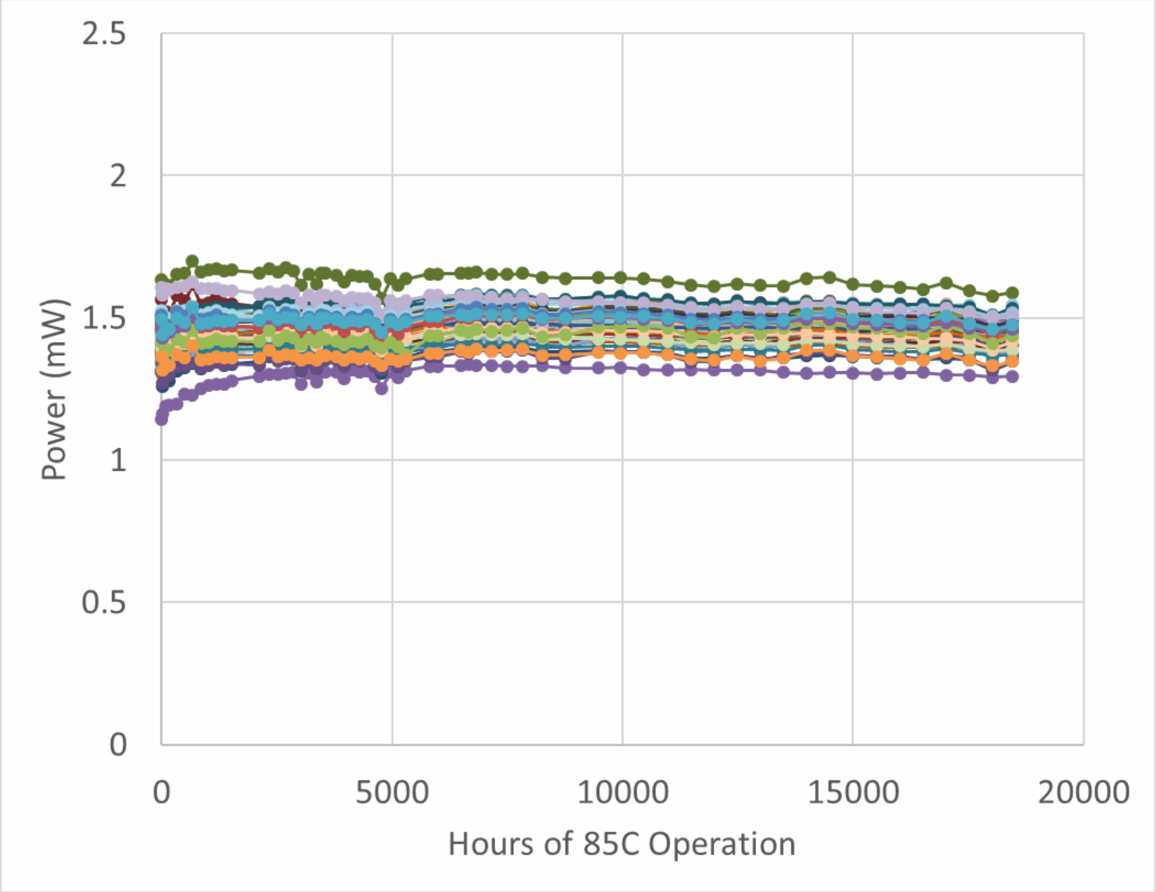
°C	Rt/R25	°C	Rt/R25	°C	Rt/R25	°C	Rt/R25v	°C	Rt/R25
-50	67.0115	-9	5.24025	32	0.74025	73	0.15816	114	0.045755
-49	62.4122	-8	4.96529	33	0.70983	74	0.15295	115	0.044531
-48	58.1579	-7	4.70621	34	0.68082	75	0.14793	116	0.043345
-47	54.2210	-6	4.46231	35	0.65314	76	0.14311	117	0.042196
-46	50.5749	-5	4.23247	36	0.62675	77	0.13846	118	0.041083
-45	47.1985	-4	4.01573	37	0.60157	78	0.13399	119	0.040004
-44	44.0682	-3	3.81144	38	0.57752	79	0.12969	120	0.038958
-43	41.1655	-2	3.61858	39	0.55456	80	0.12554	121	0.037945
-42	38.4725	-1	3.43675	40	0.53266	81	0.12155	122	0.036962
-41	35.9716	0	3.26505	41	0.51172	82	0.11771	123	0.036009
-40	33.6499	1	3.10302	42	0.49172	83	0.11400	124	0.035086
-39	31.4920	2	2.94995	43	0.47262	84	0.11044	125	0.034190
-38	29.4867	3	2.80530	44	0.45435	85	0.10700	126	0.033321
-37	27.6208	4	2.66858	45	0.43689	86	0.10368	127	0.032478
-36	25.8853	5	2.53931	46	0.42019	87	0.100484	128	0.031660
-35	24.2694	6	2.41710	47	0.40422	88	0.097402	129	0.030867
-34	22.7642	7	2.30140	48	0.38893	89	0.094430	130	0.030096
-33	21.3619	8	2.19191	49	0.37431	90	0.091563	131	0.029349
-32	20.0546	9	2.08829	50	0.36031	91	0.088797	132	0.028623
-31	18.8354	10	1.99013	51	0.34687	92	0.086127	133	0.027919
-30	17.6977	11	1.89719	52	0.33401	93	0.083552	134	0.027234
-29	16.6360	12	1.80903	53	0.32168	94	0.081064	135	0.026570
-28	15.6440	13	1.72553	54	0.30988	95	0.078666	136	0.025925
-27	14.7176	14	1.64633	55	0.29857	96	0.076348	137	0.025299
-26	13.8515	15	1.57121	56	0.28773	97	0.074109	138	0.024690
-25	13.0418	16	1.49991	57	0.27735	98	0.071948	139	0.024099
-24	12.2842	17	1.43235	58	0.26739	99	0.069860	140	0.023524
-23	11.5754	18	1.36814	59	0.25784	100	0.067842	141	0.022966
-22	10.9116	19	1.30718	60	0.24869	101	0.065901	142	0.022423
-21	10.2899	20	1.24927	61	0.23990	102	0.064023	143	0.021895
-20	9.70741	21	1.19424	62	0.23147	103	0.062208	144	0.021383
-19	9.16150	22	1.14195	63	0.22338	104	0.060453	145	0.020884
-18	8.64951	23	1.09223	64	0.21562	105	0.058757	146	0.020399
-17	8.16902	24	1.04497	65	0.20816	106	0.057117	147	0.019928
-16	7.71837	25	1.00000	66	0.20101	107	0.055527	148	0.019470
-15	7.29500	26	0.95721	67	0.19413	108	0.053991	149	0.019024
-14	6.89749	27	0.91649	68	0.18753	109	0.052505	150	0.018590
-13	6.52404	28	0.87774	69	0.18118	110	0.051066		
-12	6.17302	29	0.84083	70	0.17508	111	0.049673		
-11	5.84286	30	0.80567	71	0.16922	112	0.048325		
-10	5.53247	31	0.77217	72	0.16358	113	0.047019		

15. HCG-VCSEL reliability

15.1. 1550 nm VCSEL FIT rate

For FIT rate determination 155 parts from 2 lots were operated at 85ºC for approximately 18,500 hours at a typical drive current of 15 mA. All VCSELs were measured at room temperature at intervals. The results are given in the figure below.

Figure 20



After 18454 hours under stress, or for about 29 years at operating conditions, the output power is constant within expected small variations of the room temperature.

For the actual 3.55 million device-hours so far with just one failure, we predict a FIT = 179 with 90% confidence, using Ea=0.35eV for random failures; the FIT = 42 using an activation energy of 0.7eV determined from wear-out studies.

15.1. 1550 nm VCSEL wear out

Less than 25% drop in output power was observed after over 11,000 hours of stress in a wear-out study with 5 groups of 12 parts being biased at various currents.

The range of bias caused the junction temperature of the 5 groups to range from 134°C to 190°C.

Applying the corresponding acceleration factors based on derived activation energy of 0.7eV, this corresponds to < 10% wear-out in 340,000 hours or about 39 years at operating conditions.

Figure 21