SIEMENS

Enhanced thermal Model for Laserdiodes

Introduction

The laser diodes used in Siemens transmitters and the BIDI™ are Fabry Perot GaInAsP lasers designed in MCRW (Metal Clad Ridge Waveguide) and SL MQW (Strained Layer Multi Quantum Well) structure.

If the transmitters have to work in a wide temperature range (–20 °C up to 85 °C) without temperature stabilisation the temperature response of the laser must be considered in detail.

Values in the datasheets

In the datasheets for lasermodules the following parameters are given:

Variation of the laser parameters according to the data sheets				
	Temperature range –40 to 85 °C			
		Minimum	Maximum	
	Ith	2	45	mA
Slope low power		4	80	mW/A
Slope medium power		15	150	mW/A

The variation ranges are the product of the variations of several laser parameters. In order to get a better understanding for the temperature behaviour of the laser the temperature response is calculated here with typical values.

Fundamental temperature response

The fundamental laws for changing the threshold current Ith and the power slope S are given by

$$I_{th}(T) = I_o \exp((T\text{-}25\ °C)/T_o) \qquad (1)$$

$$S(T) = S_o \exp((25\ °C\text{-}T)/T_1) \qquad (2)$$

with

I_o threshold current at 25 °C,

S_o power slope at 25 °C,

T_o characteristic temperature for the behaviour of the threshold current,

T_1 characteristic temperature for the behaviour of the power slope.

Typically values for the SL-MQW laser diode in production now are:

T_o = 83 °K, T_1 = 400 °K, I_o = 14 mA and S_o = 290 mW / A (laser facet).

Calculation of the laser P I characteristic

For current above threshold the P I characteristic can be calculated in the following way:

$$P = S * (I - I_{th}) \qquad (3)$$

Using (1) and (2) in (3) the P I characteristic corresponding to a static measurement can be described.

$$P_{stat} = S_o \exp((25\ °C - T) / T_1) * (I - I_o \exp((T - 25\ °C) / T_o)) \qquad (4)$$

Correction 1

Consideration of the junction temperature T_j versus case temperature T_c

Since for the laser function the actual junction temperature T_j is decisive, this temperature depending on the power dissipation has to be considered. The following parameters are needed for calculating the actual junction temperature T_j in relation to the case temperature T_c:

Forward voltage at low current	U_f [V]
Series resistance	R_s [Ω]
Thermal resistance between junction and case	R_{th} [°C/W]

Using these parameters T in (1), (2) and (4) has to be replaced by

$$T_j = T_c + R_{th} \times I \times (U_f + R_s \times I) \qquad (5)$$

Correction 2

Temperature dependency of T_o and T_1

Unfortunately T_o and T_1 are not constant until high temperature. In order to make the model valid for a high temperature range the temperature dependency of T_o and T_1 has bto be respected. The available results for temperature higher than 25 °C T_o and T_1 have to be corrected in the following way:

$T_o = 83 - (T - 25) \times 0.3$; $T_1 = 400 - (T - 25) \times 3$

These corrections 1 and 2 are included in the Excel spreadsheet and are needed for calculations in the high temperature region. For example with the parameters given above and in the enclosure the following curves P_{dyn} and P_{stat} for 85 °C and 58 mA operating point can be calculated.

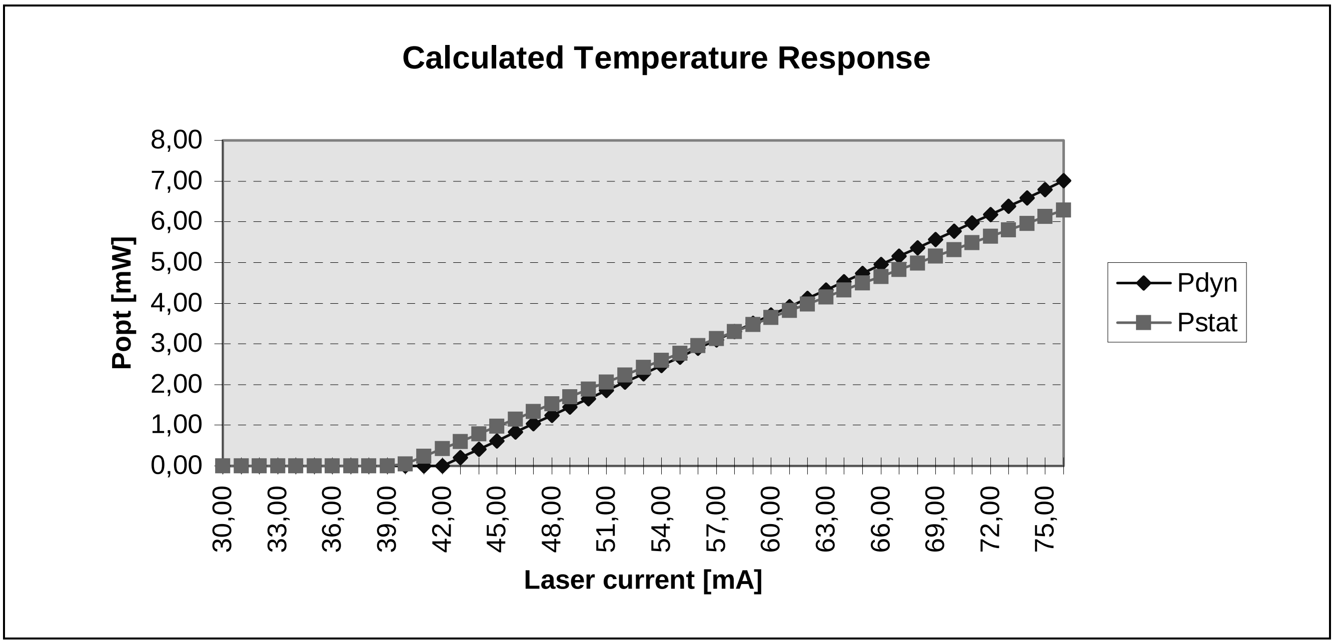

Figure 1
Calculated temperature response of SL MQW laser at 85 °C

How to use the spreadsheet

The fields with double-frames are input fields for the parameters and corrections described above P_{stat} and P_{dyn} versus case temperature including correction 1 and 2 are calculated in following way corresponding to the fields in the spreadsheet in the enclosure:

P_{dyn} = (\$D\$7 $\times$ EXP((\$F\$4 – \$C\$11 – \$G\$11 $\times$ (\$G\$12 + \$G\$13 $\times$ \$C\$14 / 1000) $\times$ \$C\$14 / 1000) / \$D\$17)) $\times$ (A20 – \$D\$4 $\times$ EXP ((\$C\$11 + \$G\$11 $\times$ (\$G\$12 + \$G\$13 $\times$ \$C\$14 / 1000) $\times$ \$C\$14 / 1000 – \$F\$4) / \$D\$16))

P_{stat} = (\$D\$7 $\times$ EXP((\$F\$4 – \$C\$11 – \$G\$11 $\times$ (\$G\$12 + \$G\$13 $\times$ A20 / 1000) $\times$ A20 / 1000) / I20)) $\times$ (A20 – \$D\$4 $\times$ EXP((\$C\$11 + \$G\$11 $\times$ (\$G\$12 + \$G\$13 $\times$ A20 / 1000) $\times$ A20 / 1000 – \$F\$4) / H20))

In row E and F are the values of row B and C with suppressed negative values in order to simulate the threshold.

Row H and I contains actual values for T_o and T_1 using correction 2.

Figure 2 shows another example for the same laser. In order to see the parameters over the normal operating range the step width (C13 in the spreadsheet) is changed from 1 to 4 mA. The P_{stat} curve shows a thermal saturation (roll over) as can be observed in the real measurement.

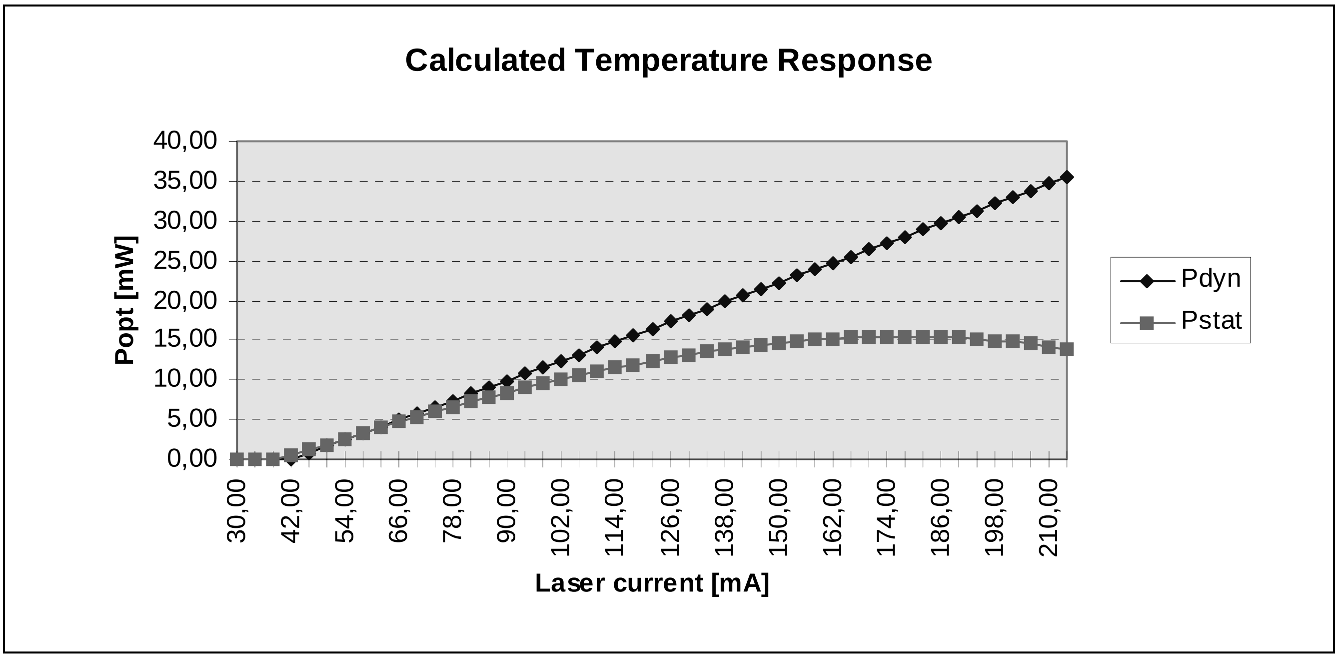

Figure 2
Calculated temperature response of SL MQW laser at 85 °C with 4 mA step width

Simulation of the burst mode modulation

Working with burst mode modulation for the first bit of the burst T_j is equal T_c and the output power has to be calculated according to P_{dyn} without any internal heating. After some µs due to heating up the junction, P_{stat} has to be used for describing the output power. Depending on the thermal capacity of the chip and case, the average outpower of the laser driven with a constant current is decreasing after being switched on shown in **Figure 3**.

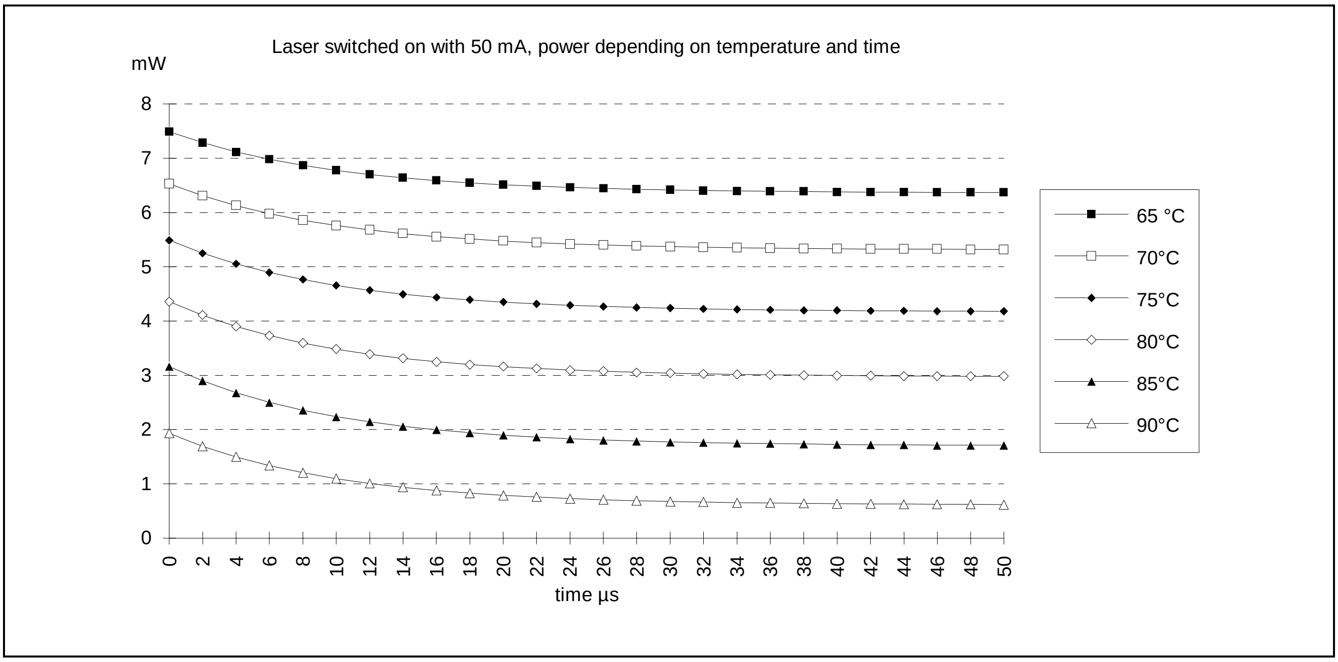

Figure 3 Power decrease due to thermal effects

Without suitable power control this may cause a penalty in the power budget of systems working with databursts.

Enclosure: Excel Calculation

	A	B	C	D	E	F	G	H	I	J
1	**Calculation of the laser characteristic**					Including temperature dependend To and T1				
2										
3	**From protocol**			value	unit	Note		Toc=To-(F5-25)*f (if T>25°C)		
4	**Threshold measured**			14,3	mA	25	°C	To	83	
5	Threshold 2 calculated			36,56	mA	85	°C	f	0,3	
6										
7	**Slope measured**			0,29	W/A	25	°C	T1c=T1-(F5-25)*f (if T>25°C)		
8	Slope 2 calculated			0,21	W/A	85	°C	T1	400	
9								f	3	
10	**Calculation of the laser characteristic**					For calculation junction temperature				
11	Temperature		85	°C		Rth	100	K/W		
12	Starting current		30	mA		U forward.	1,12	V		
13	Step width		1	mA		Resist.	3,2	Ohm		
14	Operating point		58	mA						
15	Operating point		Tj	92,57						
16	Operating point		Toc	62,73						
17	Operating point		T1c	197,2826						
18										

19	current	Pdyn	Pstat	current	Pdyn	Pstat	Tj	Toc	T1c	
20	30	-2,47	-1,86	30,00	0,00	0,00	88,65	63,91	209,06	
21	31	-2,26	-1,67	31,00	0,00	0,00	88,78	63,87	208,66	
22	32	-2,06	-1,48	32,00	0,00	0,00	88,91	63,83	208,26	
23	33	-1,85	-1,28	33,00	0,00	0,00	89,04	63,79	207,87	
24	34	-1,65	-1,09	34,00	0,00	0,00	89,18	63,75	207,47	
25	35	-1,44	-0,90	35,00	0,00	0,00	89,31	63,71	207,06	
26	36	-1,23	-0,71	36,00	0,00	0,00	89,45	63,67	206,66	
27	37	-1,03	-0,52	37,00	0,00	0,00	89,58	63,63	206,25	
28	38	-0,82	-0,33	38,00	0,00	0,00	89,72	63,58	205,85	
29	39	-0,62	-0,14	39,00	0,00	0,00	89,85	63,54	205,44	
30	40	-0,41	0,04	40,00	0,00	0,04	89,99	63,50	205,02	
31	41	-0,20	0,23	41,00	0,00	0,23	90,13	63,46	204,61	
32	42	0,00	0,42	42,00	0,00	0,42	90,27	63,42	204,19	
33	43	0,21	0,60	43,00	0,21	0,60	90,41	63,38	203,78	
34	44	0,41	0,79	44,00	0,41	0,79	90,55	63,34	203,36	
35	45	0,62	0,97	45,00	0,62	0,97	90,69	63,29	202,94	
36	46	0,83	1,15	46,00	0,83	1,15	90,83	63,25	202,51	
37	47	1,03	1,34	47,00	1,03	1,34	90,97	63,21	202,09	
38	48	1,24	1,52	48,00	1,24	1,52	91,11	63,17	201,66	
39	49	1,44	1,70	49,00	1,44	1,70	91,26	63,12	201,23	
40	50	1,65	1,88	50,00	1,65	1,88	91,40	63,08	200,80	
41	51	1,85	2,06	51,00	1,85	2,06	91,54	63,04	200,37	
42	52	2,06	2,24	52,00	2,06	2,24	91,69	62,99	199,93	
43	53	2,27	2,42	53,00	2,27	2,42	91,83	62,95	199,50	
44	54	2,47	2,59	54,00	2,47	2,59	91,98	62,91	199,06	
45	55	2,68	2,77	55,00	2,68	2,77	92,13	62,86	198,62	
46	56	2,88	2,95	56,00	2,88	2,95	92,28	62,82	198,17	
47	57	3,09	3,12	57,00	3,09	3,12	92,42	62,77	197,73	
48	58	3,30	3,30	58,00	3,30	3,30	92,57	62,73	197,28	
49	59	3,50	3,47	59,00	3,50	3,47	92,72	62,68	196,83	
50	60	3,71	3,64	60,00	3,71	3,64	92,87	62,64	196,38	
51	61	3,91	3,81	61,00	3,91	3,81	93,02	62,59	195,93	
52	62	4,12	3,98	62,00	4,12	3,98	93,17	62,55	195,48	
53	63	4,33	4,15	63,00	4,33	4,15	93,33	62,50	195,02	
54	64	4,53	4,32	64,00	4,53	4,32	93,48	62,46	194,56	
55	65	4,74	4,49	65,00	4,74	4,49	93,63	62,41	194,10	
56	66	4,94	4,66	66,00	4,94	4,66	93,79	62,36	193,64	
57	67	5,15	4,82	67,00	5,15	4,82	93,94	62,32	193,18	
58	68	5,35	4,99	68,00	5,35	4,99	94,10	62,27	192,71	
59	69	5,56	5,15	69,00	5,56	5,15	94,25	62,22	192,25	
60	70	5,77	5,32	70,00	5,77	5,32	94,41	62,18	191,78	
61	71	5,97	5,48	71,00	5,97	5,48	94,57	62,13	191,30	
62	72	6,18	5,64	72,00	6,18	5,64	94,72	62,08	190,83	
63	73	6,38	5,80	73,00	6,38	5,80	94,88	62,04	190,36	
64	74	6,59	5,96	74,00	6,59	5,96	95,04	61,99	189,88	
65	75	6,80	6,12	75,00	6,80	6,12	95,20	61,94	189,40	
66	76	7,00	6,28	76,00	7,00	6,28	95,36	61,89	188,92	