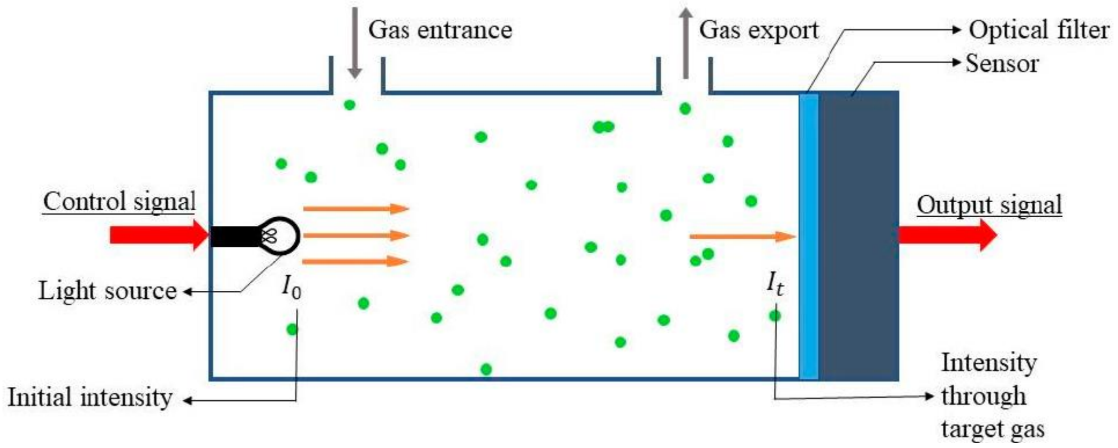
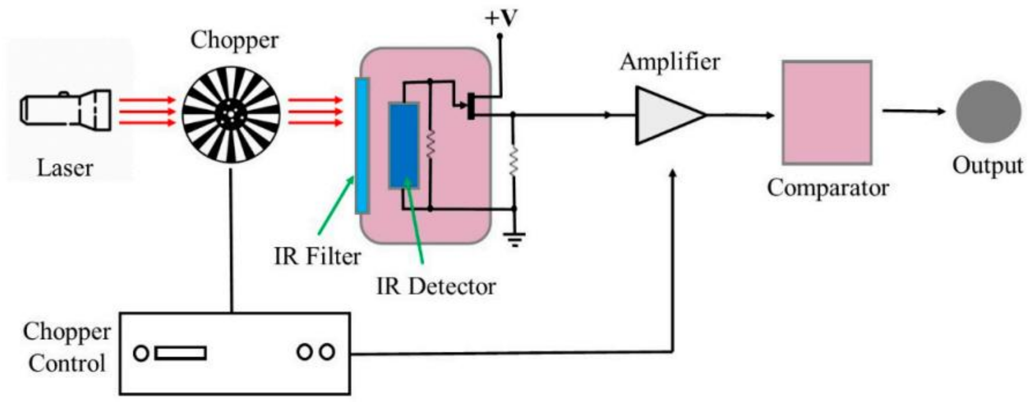
2 | DFB for Gas Sensing

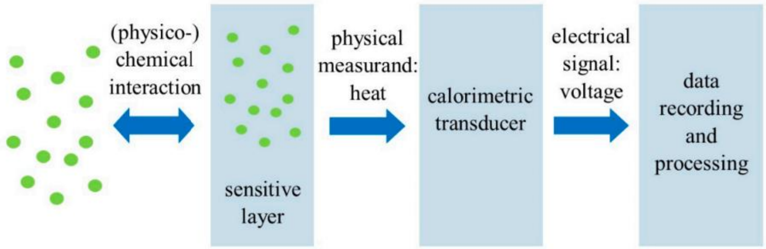
Methane Gas Sensing Technologies



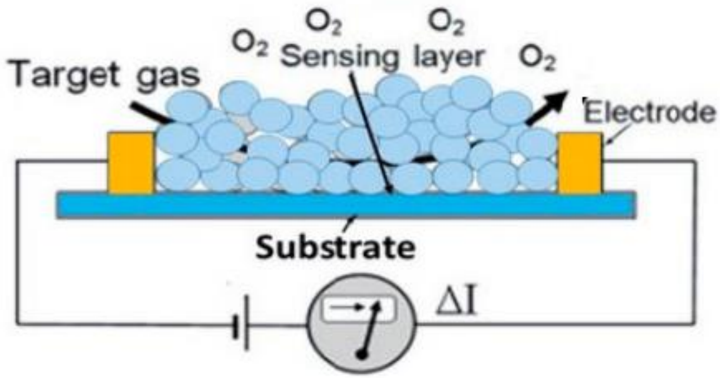
Optical gas sensor by infrared absorption spectroscopy



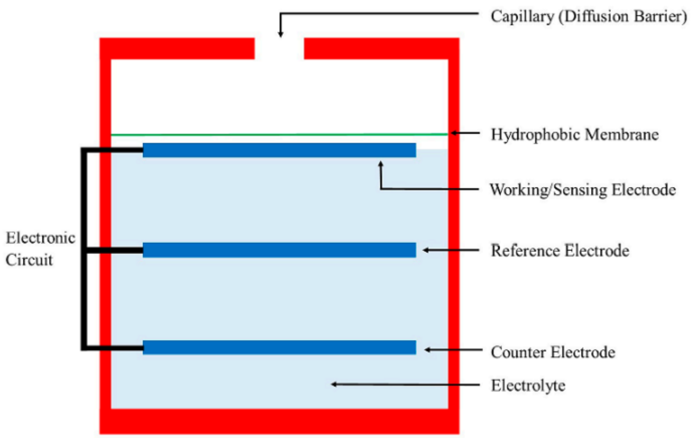
Pyroelectric sensor based on infrared heating



Calorimetric gas sensor



Semiconducting metal oxides



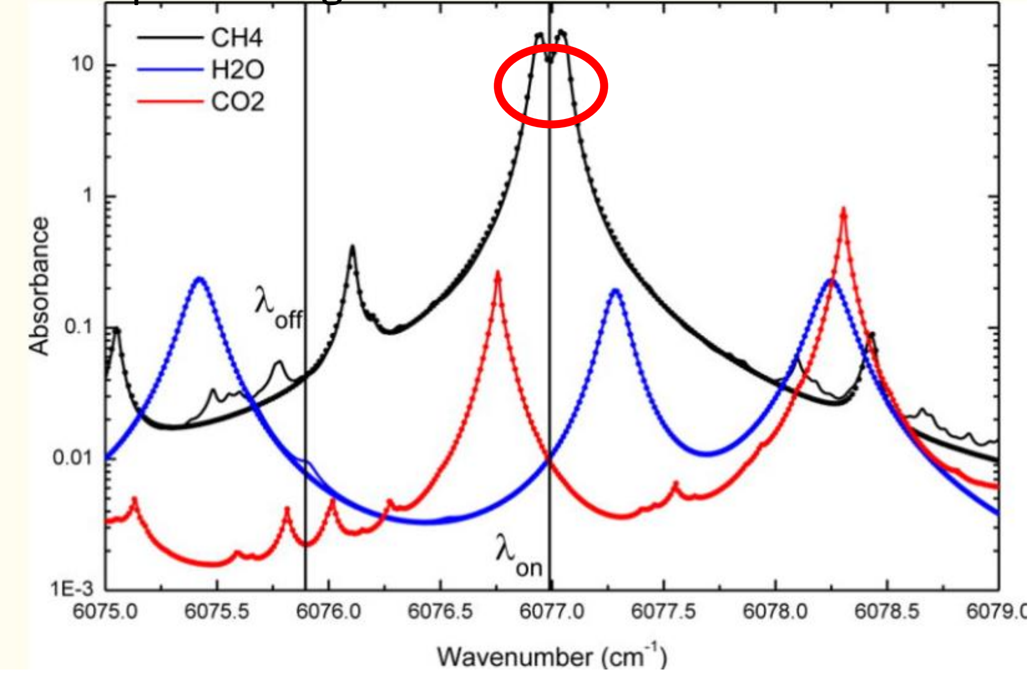
Schematic of an electrochemical sensor

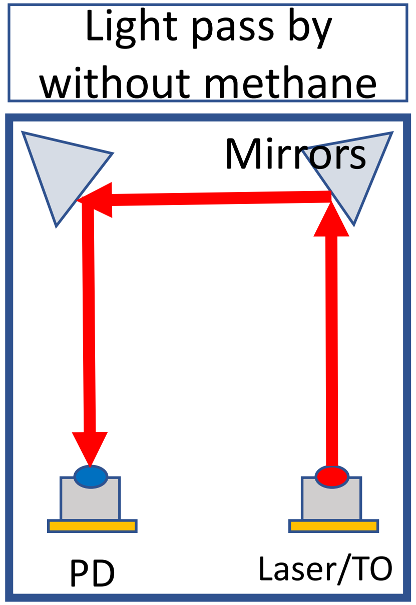
Source: A Review of Methane Gas Detection Sensors: Recent Developments and Future Perspectives, Inventions 2020, 5, 28

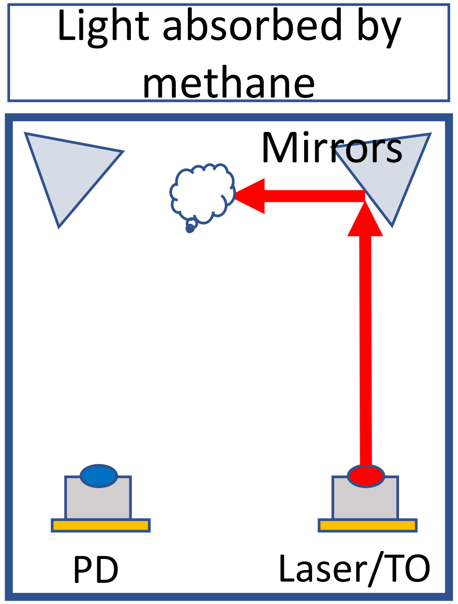
DFB for Methane Gas Optical Sensing: Principle

This means for a setup that maintains a wavelength of 1653.7nm, most of the power will be absorbed.
Reflected power will be lost, hence the detection capability

Absorption is highest at 1650.9nm and 1653.7nm

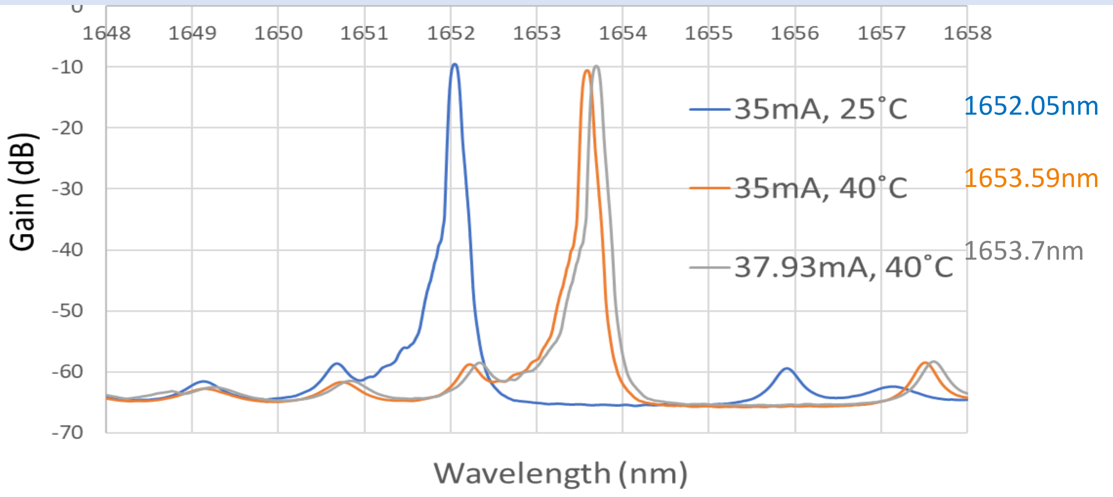




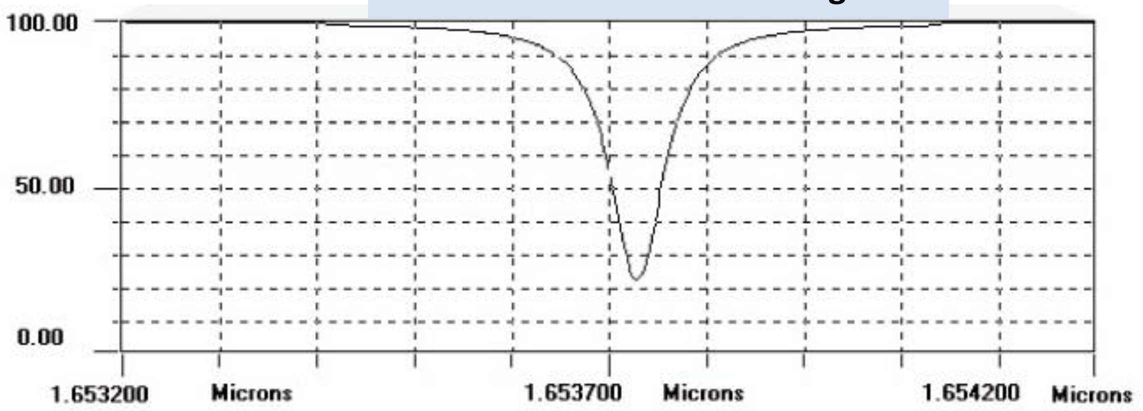


DFB for Methane Gas Sensing: Detection Scheme

Precise tuning of central wavelength to 1653.7 nm via TEC and current

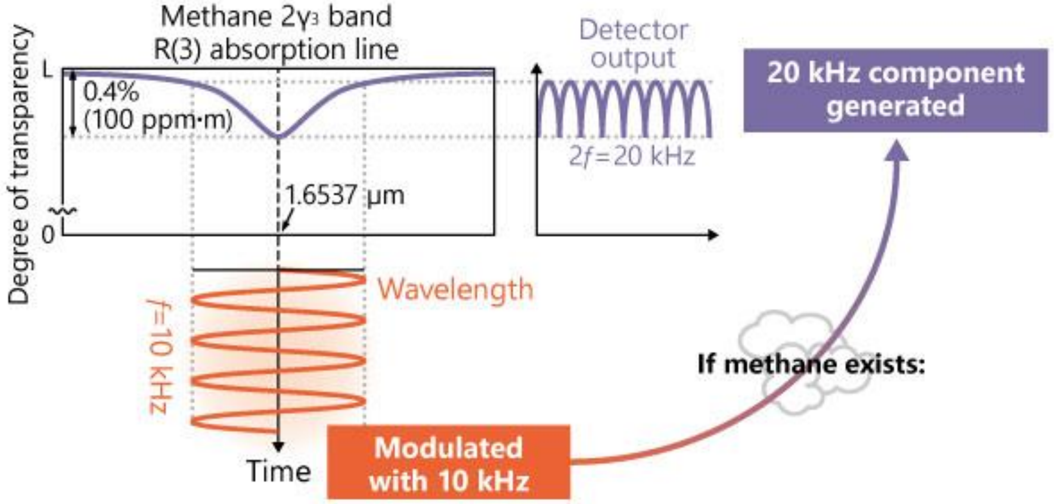


Transmission vs. wavelength



- The central wavelength at TEC temperature of 25˚C with bias current of 35mA is 1652.05 nm
- It is tuned to 1653.59 nm by tuning the TEC temperature to 40˚C alone.
- A fine tuning to achieve 1653.7 nm is then completed by increasing the bias current to 37.93mA.
- Wavelength is tuned by modulating bias current. The gas detector detects the 1f and 2f components, and determines the gas concentration.

Gas detector scheme



Comparison of Different Methane Sensors (1)

Sensor Types	Working Mechanisms	Advantages	Disadvantages
Optical sensors	Detect changes in light waves that result from an interaction of the analyte with the receptor part.	• Non-destructive method; • Immune to electromagnetic interference; • Operate without oxygen; • Fast response time.	• Need to achieve low cost
Calorimetric sensors	Measure the heat produced from a reaction and correlate the value to the reactant concentration.	• Low cost; • Simplistic design; • Portable; • Easy to manufacture; • Good selectivity for methane; • Can operate in harsh environmental conditions.	• Low detection accuracy; • Susceptible to cracking, catalyst poisoning and oversaturation; • High power consumption; • Short lifespan; • Require high temperature
Pyroelectric sensors	Convert thermal energy into electrical energy based on the phenomenon of pyroelectricity.	• Non-destructive; • Operate without oxygen; • Good sensitivity and responsivity; • Wide measuring range; • Operate at room temperature.	• High cost; • High power consumption; • Immobile; • Difficult to manufacture.

Comparison of Different Methane Sensors (2)

Sensor Types	Working Mechanisms	Advantages	Disadvantages
Semiconducting metal oxide sensors	Absorption of gas on the surface of a metal oxide changes its conductivity, which is then quantified to obtain the gas concentration.	• Low cost; • Lightweight and robust; • Long lifespan; • Resistant to poisoning.	• Poor selectivity; • Small and high operational temperature range; • Slow recovery rate; • Significant additive dependency; • Affected by temperature; • Susceptible to degradation; • Sensitive to changes in humidity

Electrochemical sensors	Measure the target gas concentration by oxidizing or reducing the gas at an electrode and measuring the resulting current.	• AE-based:
		  • Low cost
		• IL-based:
		  • Non-hazardous materials;
		  • High boiling points and low volatility;
		  • Good selectivity for methane;
		  • Can detect small leaks.
		• SE-based:
		  • No leakage;
		  • Safe; Robust;
		  • Good selectivity for methane;
		  • Can detect small leaks.
			• AE-based:
			  • Susceptible to leakage and evaporation;
			  • Hazardous materials;
			  • Slow response time.
			• IL-based:
			  • Susceptible to leakage;
			  • Slow response time.
			• SE-based:
			  • Require high temperature;
			  • Unable to detect low gas concentrations;
			  • Susceptible to degradation or loss of electrolyte.

- DFB for Methane Gas Sensing is a non-destructive optical sensor method, which is immune to electromagnetic interference, operate without oxygen, and achieve fast response time.

DFB Product for Gas Sensing Introduction

Accuracy and real-time detection of methane gas is very important, which is used in many scenarios, including natural gas pipeline leakage monitoring, household safety and coal mining safety production monitoring.

DenseLight 1653.7 nm DFB laser is widely used in applications where accurate measurement of methane is required. By adjusting the temperature and driver current of the DFB laser device, methane concentration can be detected in real time and on line, providing the advantages of extra full concentration detection range, high accuracy and good selectivity.

Our 1653.7nm DFB laser assembly allows easy integration into commercially available methane gas sensors platform for our customers

Product Wavelength (nm)	Product Code	Package
1653nm DFB	DL-DFB65310A	14pin BTF
	DL-DFB65404T-C-S	TO-60
	DL-DFB65407D	Die

Application

- OTDR
- Gas Sensing
- Biomedical Sensing
- Telecommunications

TO DFB Product for Methane Gas Sensing

- The DL-DFB65404T-C-Sx is an InGaAsP based and cooled distributed feedback laser in a low cost TO60 package, with a collimated output, optimized for methane sensing applications.
- Denselight's advanced technology enables mode-hop free tunability, high power, excellent SMSR, and high accuracy of the lasing wavelength.

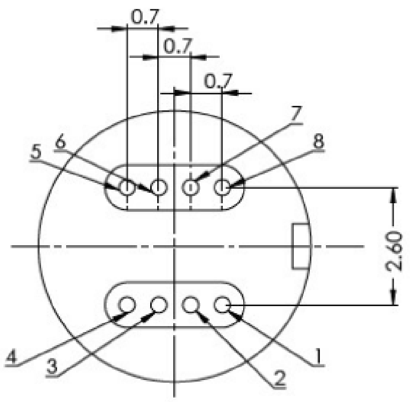
Features

- Optical output power : > 3.5mW
- Peak wavelength : 1653.7 ±1nm
- Typical SMSR of 40dB

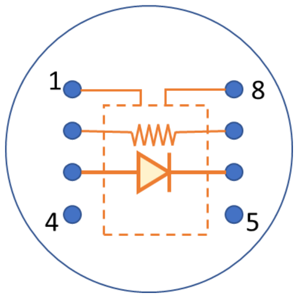
Pin out

PIN	S1 Type	S2 Type
1	TEC-	TEC-
2	Thermistor+	Thermistor+
3	LD+	LD+
4	NC	NC
5	NC	NC
6	LD-	LD-/ Thermistor-
7	Thermistor-	LD-/ Thermistor-
8	TEC+	TEC+

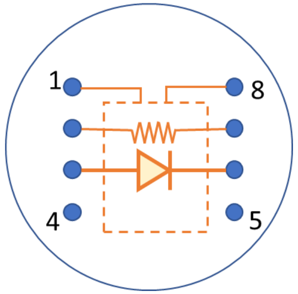
Bottom View



Type S1 Pinout



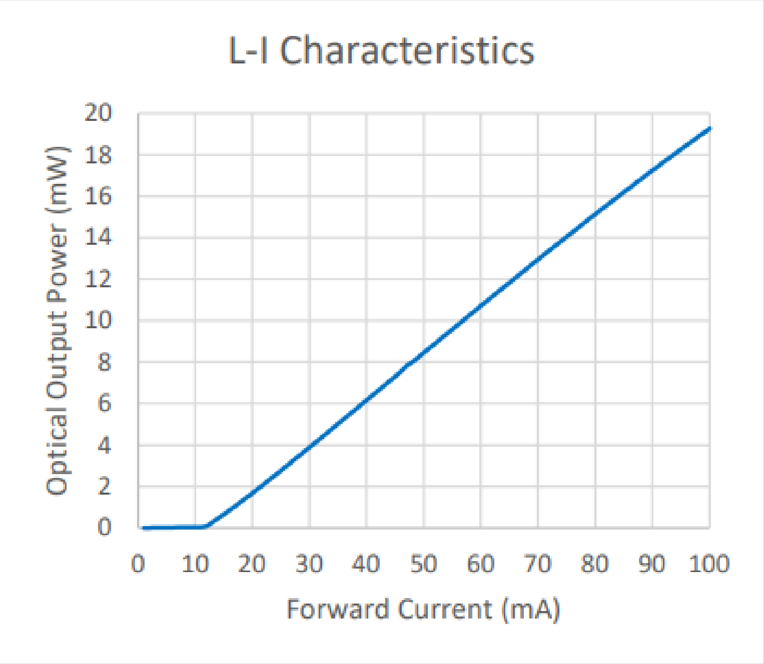
Type S2 Pinout

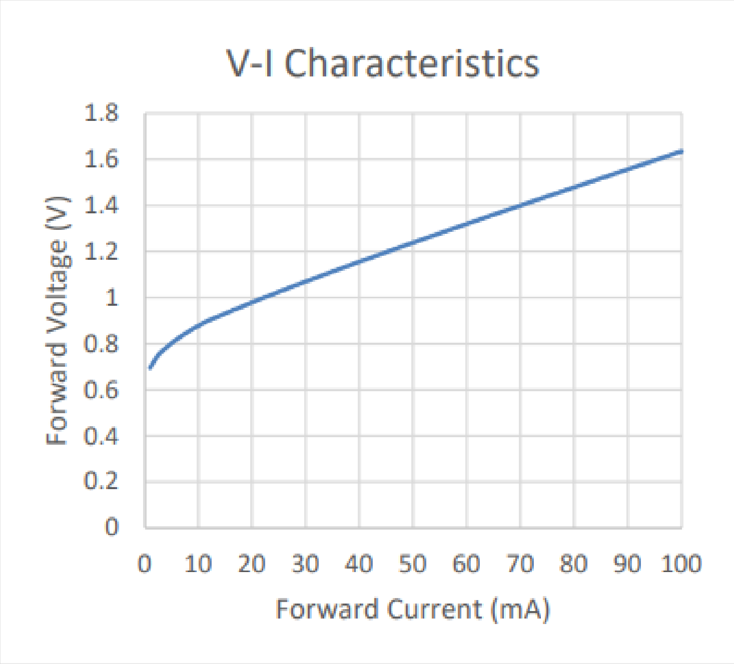


Note
- Type-S1 is standard products
- Type-S1 and Type-S2: Both have the same functional pinout
- Type-S2 has Pins 6,7 shorted, it provides better thermal tracking of LD, hence lower wavelength and current drift during ambient temperature change.

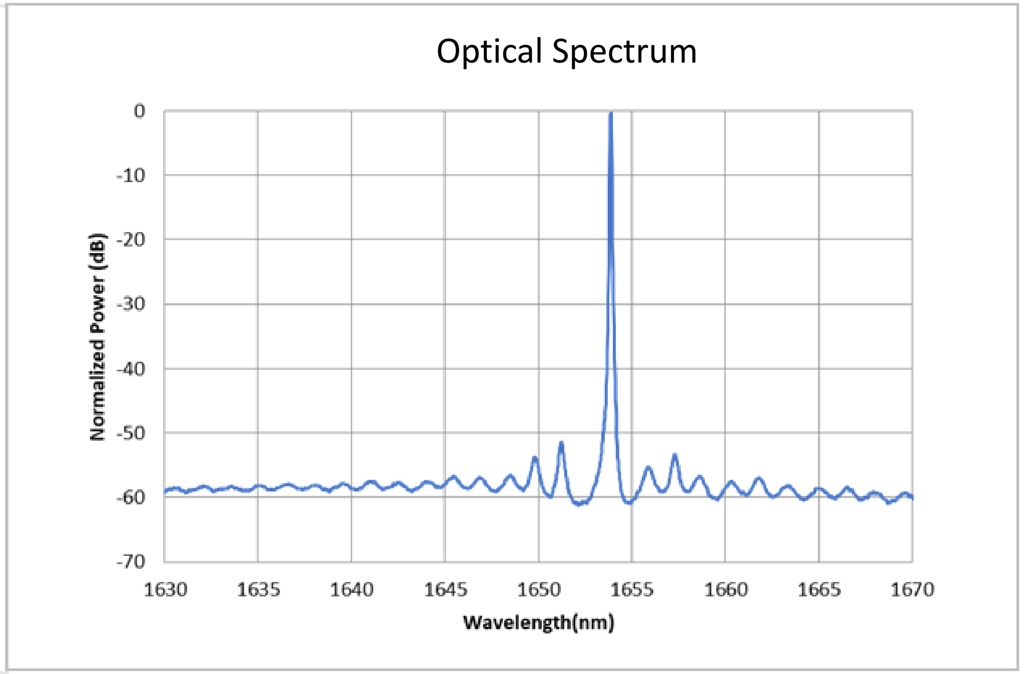
TO DFB Product for Methane Gas Sensing

The L-I and V-I characteristics are evaluated at T_{chip}=25°C and CW





The Optical Spectrum is evaluated at T_{chip}=25°C, I_{op}=45mA and CW



Electrical and Optical Characteristics

实光半导体 DenseLight SEMICONDUCTORS

Product code: DL-DFB65404T-C-S (1653.7nm Cooled TO-can with Collimated Output)

The performance is evaluated at T_{chip} of 25°C and CW, unless stated otherwise

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Peak wavelength	λ_p	I_{op} = 45mA	1652.7	1653.7	1654.7	nm
Optical output power	P_O	I_{op} = 45mA	3.5	8	13	mW
Threshold current	I_{th}	-	–	12	-	mA
Operating current	I_{op}	-	-	45	-	mA
Operating Voltage	V_{op}	I_{op} = 45mA	-	1.2	1.6	V
Side mode suppression ratio	SMSR	I_{op} = 45mA	-	40	–	dB
Wavelength Temperature Tuning Coefficient	$\Delta\lambda/\Delta T$	-	0.07	0.1	0.14	nm/°C
Wavelength Current Tuning Coefficient	$\Delta\lambda/\Delta I$	-	0.008	0.01	0.03	nm/mA
Spot Size	SS	Optical path = 80mm	–	3	5	mm
Optical Linewidth	Δf	I_{op} = 45mA	–	–	2	MHz
Thermistor Resistance	R_{th}	25°C	9.5	10	10.5	kΩ
B constant of R_{th}	B	–	-	3930	-	K
Case Temperature	T_{case}	I_{op} = 45mA	-30	-	60	°C

Note: T_{chip} is monitored by internal thermistor with external pin out

Proven Reliability

Test	Reference	Test Conditions	Sample Size	Pass/Fail Criteria	Test Status
Accelerated Life Test (HTOL)	GR-468 issue 2 Section 3.4.1	70ºC, 80mA, ACC mode, 2000hrs	39	δPo >20% 0/22 fails	pass
Temp Cycling	MIL-STD-883C Method 1004.7	-40ºC to 85ºC, 10ºC/min ramp rate 100 cycles	13	δPo >20% 0/11 fails	pass
Thermal Shock	MIL-STD-883E Method 1011.9	Cond. A 0 and 100ºC Dwell time>5min/temp	11	δPo >20% 0/11 fails	pass
High Temp Storage	GR-468 issue 2 Section 3.3.2.1	85ºC, 2000hrs	15	δPo >20% 0/11 fails	pass
Low Temp Storage	GR-468 issue 2 Section 3.3.2.1	-40ºC, 72hrs	22	δPo >20% 1/22 fails	pass
ESD-HBM	FOTP-129	3 units subjected to positive pulses and 3 to negative pulses up to 500V	6	δPo >20% 0/11 fails	pass
Die Shear	MIL-STD-883E Method 2019.6	Contact tool to load against die edge	11	31g 0/11 fails	pass
Wire Bond	MIL-STD-883E Method 2011.7	Wire-pull (single bond)	11	5gf wire strength 0/11 fails	pass
Vibration	MIL-STD-883E Method 2007.3	Cond A, 20G, 20-2000Hz, 4min/cycle, 4cycles/axis	11	δPo >20% 0/11 fails	pass
Mechanical Shock	MIL-STD-883E Method 2002.4	1500G, 0.5ms, 6 axis, 5 times/axis	11	δPo >20% 0/11 fails	pass

Advantages of DenseLight DFB Products for Methane Gas Sensing

Requirements	Benefits of DenseLight
Low cost	Chip designed and manufactured in DenseLight own fab Low cost TO-60 platform
Low power consumption	Internal design and fab capability allow lower power consumption
High performance	• More than 3mW output power at 45mA operation current • Typical SMSR of 40dB
Reduced form factor	COS, TO and BTF available
Extended temperature	• -30~60C standard product • Larger temperature range is available per request
Long-term stability and high reliability	• Aging to stabilize output power • Telcordia qualified