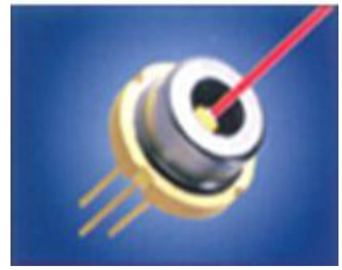
LIGHT READING - VCSEL TESTING

Using the SemiProbe Probe System for Life (PS4L), vertical cavity surface emitting lasers (VCSELs) can be tested in a variety of formats including full wafer, diced die on stretch frame, singulated die in waffle pack or as bars similar to EELDs (Edge Emitting laser diodes). Each solution requires test components specific to testing each type of laser. However, with the modularity of the Probe System for Life, several different test scenarios can be incorporated on a single PS4L system.



VCSEL OVERVIEW

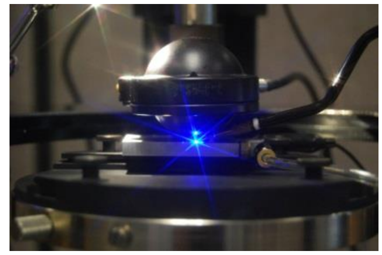
VCSEL testing on a full wafer can be done employing a manual, semiautomatic or fully automatic test system. Typically, selection of the test system's capabilities is dependent upon the speed and volume of the testing required versus the costs associated with desired features and functionality. Most of our customers prefer our semiautomatic system due to its precision, accuracy, repeatability and conformity.

We recommend using an integrating sphere because of its depolarization effect, its insensitivity to beam alignment and divergence, and ability to eliminate reflections which can damage the sensitive die being tested. Using this sphere, total flux measurements may be accurately accomplished. The sphere is constructed using a high-speed silicon detector, a high speed L-I-V test system and a Spectroradiometer. Typically, forward current, forward voltage, optical power, peak wavelength, and Full width/half max (FWHM) measurements are made on the DUT (device under test). The system is capable of measuring:

- Radiant Flux (optical power)
- Power
- L-I-V Curves
- Spectral Properties
- Peak Wavelength
- Full-Width/Half max
- Kink Current
- Kink Voltage
- Threshold Power
- Threshold Current
- Threshold Voltage
- Wall Plug Efficiency
- Slope Efficiency
- External Quantum Efficiency

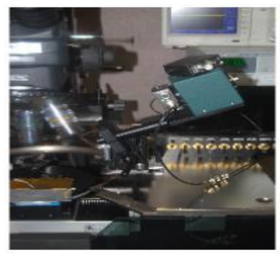
CONFIGURATIONS

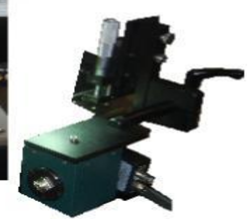
Integrating Spheres are made by several different manufacturers and all have their own particular characteristics. While the inside of the sphere is round, different manufacturers package their product in either round or square designs. The square configuration is easier to mount as the sphere itself has a single mounting hole. Spherical designs usually include a fixture for holding the sphere.



For all sphere configurations, the sphere must be held securely in place a short distance from the emitter. The integrating sphere must be held just above the device under test (DUT) leaving just enough room for contacting probes.

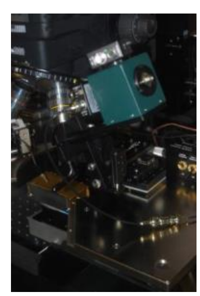
There are 3 choices available for customers when deciding upon a configuration. The first choice is to mount the integrating sphere into one of the objective mounts on the turret of a compound microscope. This is a very easy solution as the optics are aligned to the DUT and the turret is then rotated from the viewing objective to the integrating sphere. The sphere is then aligned and the system is ready for test. While easy to use, this configuration requires the use of a high powered compound microscope, which is relatively more expensive.



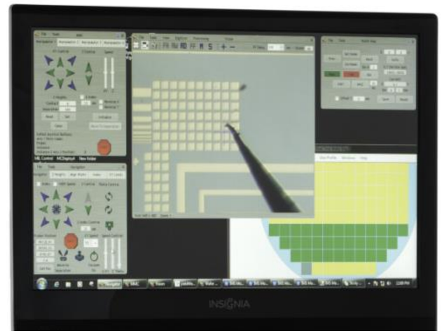


Another method of aligning the integrating sphere utilizes an articulating mount in conjunction with StereoZoom optics. The sphere mounts on the post between the microscope and the DUT. To align this system, the integrating sphere is removed from the holder while an alignment target is mounted and aligned to the DUT. Once aligned, the target is replaced with the integrating sphere. The sphere can be slid behind the optics for a clear view of the DUT to align probes or check probe alignment. When ready for test, the sphere is slid forward into the designated position defined during setup.

The third option for holding and positioning the integrating sphere on these systems utilizes a unique manipulator mount. This manipulator mount also enables the user to quickly configure for either EELD or VCSEL applications. In addition, this unit is designed to swing up out of the way for loading and then return to the precise spot where it was originally aligned. Most VCSEL test applications only require a less expensive StereoZoom microscope to consistently obtain precise, meaningful data.



PILOT CONTROL SOFTWARE



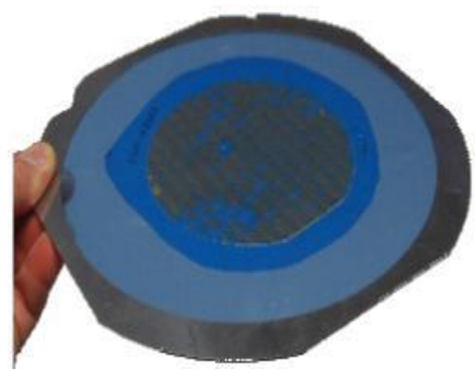
PILOT software suite main screen display with Navigator and Wafer Map Modules, microscope and manipulator controls and integrated video display

Configuration and management of the system is controlled through the SemiProbe PILOT control software suite. Our software is designed similar to our hardware. Several different types of modules are available and customers only purchase what they require. New modules and capabilities are easily added in the field as required.

With its intuitive graphical user interface, PILOT is easy to set up, learn and use. All probing operations may be programmed and controlled through PILOT. The wafer map module quickly creates a specific wafer map for a wafer type and then saves and stores all test data and configuration data to the test wafer file. The data is easily transferred to other downstream equipment or available off-line for complete life cycle device monitoring.

KNOWN GOOD DIE (KGD)

These lasers are often mounted into expensive Multi-Chip Modules (MCMs) which include reference detectors and Peltier thermoelectric cooling chips to control device temperature. Due to this, KGD is usually required and advisable to improve final yields and lower overall product costs.



SemiProbe has a unique system capable of testing VCSELS after singulation on stretch frame or in waffle packs. Because of the small size of these die, diced die on stretch frame is the most common approach. To accomplish this, the system scans the entire wafer at high speed. Once scanned, the system internally identifies the X, Y and theta locations of each die on the frame. The prober moves to each specific location and completes the test. Speed comparable to standard production wafer probers testing whole wafers are achieved with accurate results for every die. Bad die can be inked or just referenced to the wafer map which can be exported to downstream pick and place equipment.

SUMMARY

SemiProbe also offers full turnkey solutions with custom test software to meet your specific test requirements. Our modular Probe System for Life enables you to create complex test configurations requiring multiple sources of stimulation to meet your most challenging test and measurement configurations at cost effective prices.

Kink Current and kink voltage in the I-V curve is the current or the voltage due to increases in current when the energy of a photon emitted during indirect tunneling exactly equals the applied energy across the diode. The Kink Current can be measured using an LI curve and its derivative. The kink voltage is the voltage level measured at the kink current

FWHM (full width at half maximum) is the wavelength difference between the center and the point at which the power is 50% of the maximum.

The threshold current is the current level at which the VCSEL begins lasing

The threshold voltage is the voltage level measured when the threshold current is applied.
The threshold power is the measured or calculated power when the threshold current is reached.

Wall plug efficiency is the ability of a VCSEL to convert electrical energy into optical energy.

External quantum efficiency (EQE) is the ration between the number of generated photons escaped from a substance or a device and the number of electrons flowing through it.

Slope efficiency is the incremental increase in power for an incremental increase in current. The rate of increase in optical power with the increase of the current applied.

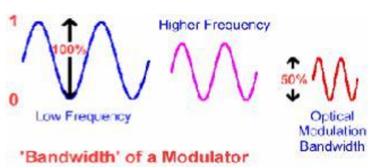
Peak wavelength is the wavelength at which the VCSEL lases the most.

Radiant flux or **radiant power** is the measure of the total power of electromagnetic radiation (including infrared, ultraviolet and visible light). The power may be the total emitted from a VCSEL.

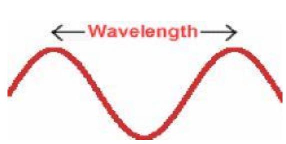
LIV Curve is the plot of the optical power versus the current and voltage.

Spectral Properties of a VCSEL is the frequency response and its behaviors at different wavelengths

Bandwidth of a modulator



Wavelength



Wavelength and Frequency

$$\text{Frequency\_in\_Hz} = \frac{\text{Speed\_of\_light}}{\text{Wavelength\_in\_m}}$$

$$\text{Wavelength\_Separation} = \frac{\text{Frequency\_Separation x Wavelength}^2}{\text{Speed\_of\_light}}$$

		WDM Frequency Spacing	WDM Wavelength Spacing		
		100 GHz	0.8 nm		
		50 GHz	0.4 nm		
		25 GHz	0.2 nm		
WDM Wavelength (nm)	**WDM Frequency (THz)**	**WDM Wavelength (nm)**	**WDM Frequency (THz)**	**WDM Wavelength (nm)**	**WDM Frequency (THz)**
1539.766	194.7	1550.116	193.4	1560.606	192.1
1540.557	194.6	1550.918	193.3	1561.419	192.0
1541.349	194.5	1551.721	193.2	1562.233	191.9
1542.142	194.4	1552.524	193.1	1563.047	191.8
1542.936	194.3	1553.329	193.0	1563.900	191.7
1543.730	194.2	1554.134	192.9	1564.679	191.6
1544.526	194.1	1554.940	192.8	1565.496	191.5
1545.322	194.0	1555.747	192.7	1566.314	191.4
1546.119	193.9	1556.555	192.6	1567.133	191.3
1546.917	193.8	1557.363	192.5	1567.952	191.2
1547.715	193.7	1558.173	192.4	1568.773	191.1
1548.515	193.6	1558.983	192.3	1569.594	191.0
1549.315	193.5	1559.794	192.2	1570.416	190.9

Gain or Loss in dB

$$\text{dB} = 10 \cdot \log\left(\frac{\text{Power\_in}}{\text{Power\_out}}\right)$$

dBm	mW	dBm	mW	dBm	mW
-30	0.0010	-10	0.1000	12	15.8489
-28	0.0016	-8	0.1585	14	25.1189
-26	0.0025	-6	0.3000	16	39.8107
-24	0.0040	-4	0.3981	18	63.0957
-22	0.0063	-2	0.6310	20	100.0000
-20	0.0100	0	1.0000	22	158.4893
-18	0.0158	2	1.5849	24	251.1886
-16	0.0251	4	2.5119	26	398.1072
-14	0.0398	6	3.9811	28	630.9573
-12	0.0631	8	6.3096	30	1000.0000
		10	10.0000		

Multipliers

Multipliers

peta	P	10^{15}	1,000,000,000,000,000	**milli**	m	10^{-3}	0.001
tera	T	10^{12}	1,000,000,000,000	**micro**	µ or u	10^{-6}	0.000 001
giga	G	10^{9}	1,000,000,000	**nano**	n	10^{-9}	0.000 000 001
mega	M	10^{6}	1,000,000	**pico**	p	10^{-12}	0.000 000 000 001
kilo	K	10^{3}	1,000	**femto**	f	10^{-15}	0.000 000 000 000 001

e.g. 193 THz = 193 terahertz = 193 x 10^{12} = 193,000,000,000,000 Hertz
e.g. 2.5 Gbit/s = 2.5 gigabits per second = 2.5 x 10^{9} = 2,500,000,000 bits per second
e.g. 12 ps = 12 picoseconds = 12 x 10^{-12} = 0.000 000 000 012 seconds
e.g. 1550 nm = 1550 nanometers = 1550 x 10^{-9} = 0.000 001 550 meters

n.b. In terms of length you may also hear of the unit "Angstrom" (Å) which is 10^{-10} meters.

Optical Power

$$\text{Power\_in\_dBm} = 10 \cdot \log\left(\frac{\text{Power\_in\_mW}}{1\ \text{mW}}\right)$$

$$\text{Power\_in\_mW} = 10^{\left(\frac{\text{Power\_in\_dBm}}{10}\right)} \cdot 1\ \text{mW}$$

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