VCSEL Measurement Solutions

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Introduction

Vertical Cavity Surface Emitting Lasers (VCSELs) are a type of semiconductor laser diode. Unlike edge emitting laser diodes, VCSELs emit upwards and thus can be easily packaged as emitter arrays containing hundreds of emitters on a single chip.

Other characteristics of VCSELs:

- Wavelength range: 650nm-1080nm, 1550nm.
- Power range: mW to Watts
- High modulation bandwidth

VCSELs were first used in the telecom industry, and today are widely used as light sources in sensing applications. Low power (mW) applications include face and gesture recognition, proximity sensors, and augmented reality displays. High power (Watts) applications include LIDARs for robotics, UAVs and autonomous vehicles. These new applications run on batteries and will need to minimize power consumption. Therefore characterization of VCSEL power, beam profile, noise, etc. is critical.

Often VCSELs are coupled with passive optics or scanning optics to generate very wide beams. Additionally, VCSELs are often used in pulsed mode. These factors make VCSEL test and measurement a challenging task. Our customers have turned to Ophir equipment to get reliable power and beam profile data on their VCSELs.

Power measurement

- Integrating sphere sensors
- Thermopile sensors

An Integrating sphere is used to collect light at high angles. Input port adapters for ±40°, ±60°, and ±85° beam angles are available. A calibrated photodiode detector attached to the sphere is used to measure the optical power. If the laser wavelength is not accurately known, a measurement uncertainty of ±0.2%/nm at 650nm-1000nm, and ±1%/nm at 1000nm-1080nm and 1550nm, is introduced.

Additional ports on the integrating sphere are used for connecting other instruments such as spectrometers and fast photodiode detectors to make multiple types of measurements simultaneously. Integrating sphere power sensors cover power ranges from <1µW up to 30W.

For power levels from 100mW and up, thermopile sensors can also be used. Thermopile sensors are more compact and easier to use than integrating sphere sensors. As they operate on the principle of absorbing laser radiation and transforming it into heat, Ophir sensors with the new LP2 coating have very little sensitivity to incidence angle, making them ideal for measuring the power of divergent laser beams. The black coating is also spectrally flat over hundreds of nanometers. Therefore, measurement error due to wavelength uncertainty is smaller than 0.01%/nm. Thermopile sensors provide the best combination of sensor area and beam angle acceptance. Table 1 shows a comparison between thermopile and integrating sphere power measurement. Figure 2 shows the angle dependence of the LP2 coating.

Figure 1. Power measurement solutions. L40(150)A-LP2 thermopile sensor and IS6-D-IR-170 integrating sphere with 170° input port adapter

Table 1. Power measurement solutions

	Integrating sphere with photodiode sensor	LP2 thermopile
Low power µW-mW	✓	
Medium power 100mW-30W	✓	✓
High power >30W		✓
Wide beam angle	✓	✓
Flat spectral response		✓
Ports for other types of sensors	✓	
Compact size		✓

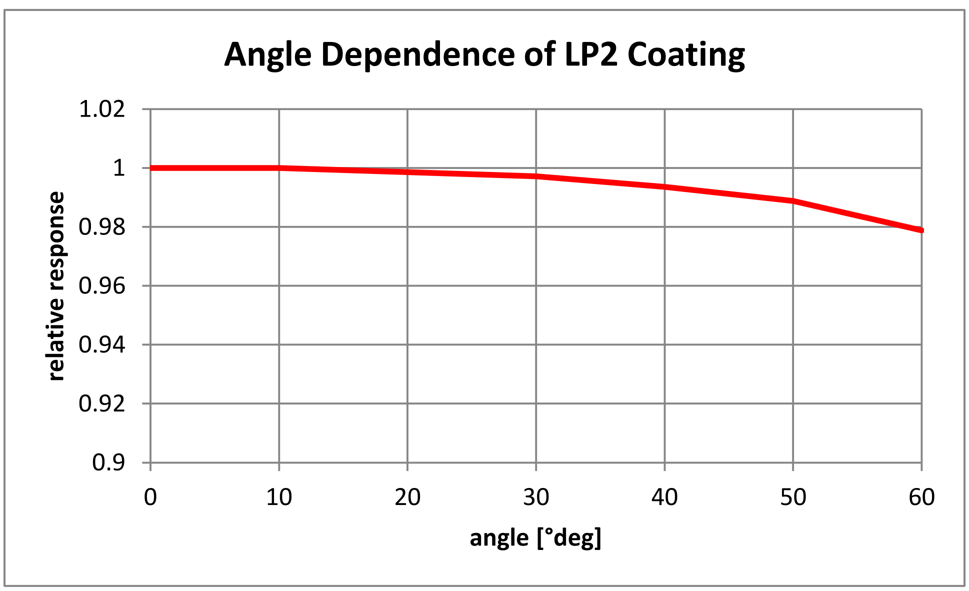

Figure 2. Sensitivity to angle of LP2 thermopile sensor coatings

Port adapters for correct measurement of widely diverging sources

When measuring a wide beam VCSELs with an integrating sphere, the thickness of the sphere's side wall and port adapter usually restricts the acceptable angle. Furthermore, bringing the VCSEL close to the sphere also brings the PCB it is mounted on into the field of view of the sphere. The PCB now reflects light back into the sphere, light that would otherwise exit it. This effect changes the sphere's calibration, and one can measure different values depending on the PCB's color and reflectivity.

Ophir's new IS6 integrating sphere offer several solutions to these challenges:

1. 1 inch/120° Low profile port adapter. This port adapter has a 120° acceptance angle for the center 5mm. magnets are embedded in the port adapter to allow easy attachment and removal of apertures.

Figure 3.low profile port adapter

2. Removable apertures for the 120° port adapter

5mm, 7mm and 10mm black apertures are magnetically attached to the 1 inch port adapter. Shown in the foreground of Figure 13, the apertures limit the filed of view of the sphere to the laser only and eliminate unwanted reflection from the PCB or laser carrier as shown in Figure 4. The apertures are coated with a low reflectivity black paint which means they do not affect the calibration of the sphere.

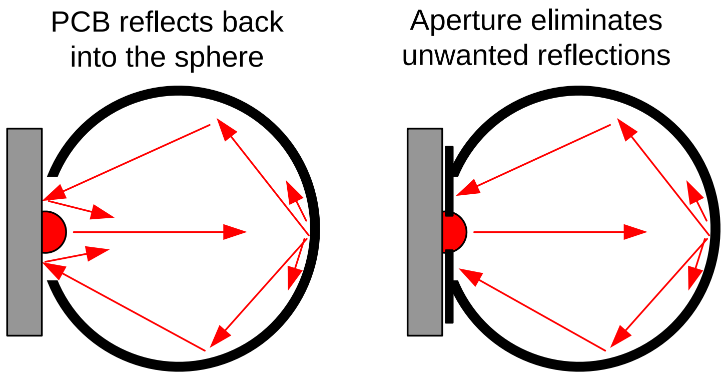

Figure 4. Unwanted reflections from the PCB (Left) are eliminated by the aperture (Right)

3. IS6-D-IR-170 Integrating sphere with 8mm, 170° port adapter

This integrating sphere has a special port adapter which uses a gold coated cone to collect light at an angle of 170°. The cone acts as a collimator, reducing the beam angle that enters the sphere. Figure 5 shows the inside of this adapter. The opening facing up fits into the sphere, and the opening at the bottom (not seen in the image) is the entrance for light collection.

Figure 5. Gold coated 170 degree port adapter

Pulse energy measurement

When operated in pulsed mode, it may be needed to measure the energy per pulse of the laser. Ophir's line of pyroelectric and photodiode energy sensors can measure at pulse rates of up to 25KHz and at pulse energies as low as 10pJ at 900nm and 30pJ at 1550nm.

Beam profiling

For a laser to perform its function, the beam profile **can be as important as the power**. Mode structure, beam size, beam quality, beam shape and divergence are all determined by analyzing the beam profile. The camera-based beam profiling system consists of a camera and **BeamGage™** analysis software. Often times, this system will need to be used with beam attenuation or beam sizing accessories, depending on your laser application. The advantage to camera-based beam profiling is the real-time viewing and measuring of a laser beam structure. **BeamGage™** software includes an extensive set of ISO quantitative measurements, featuring a rich graphical interface, and its patented UltraCal™ algorithm, providing the industry's highest accuracy measurements

Near-field profiling: This method is used for measuring the mode structure and size at the laser output. A microscope objective is used to image the near field onto the camera. The near field beam profiling system includes:

- Fixture
- Microscope objective
- Attenuator
- Camera beam profiler
- BeamGage software

Figure 6. Photograph of near field beam profiling system

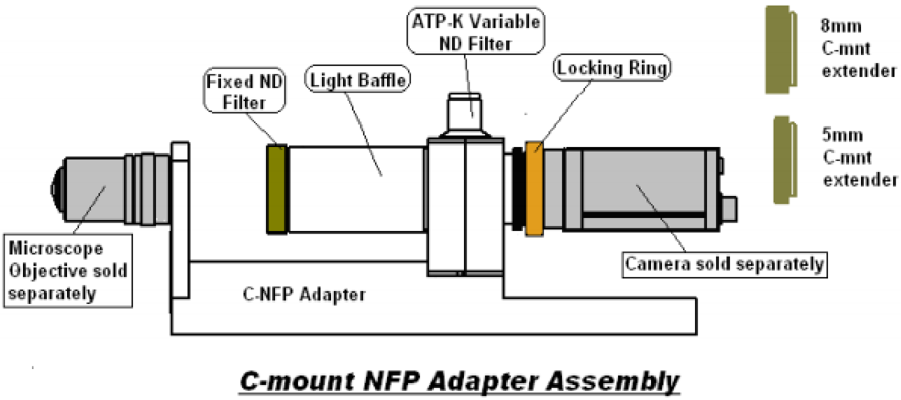

Figure 7. Schematic diagram of near field beam profiling system

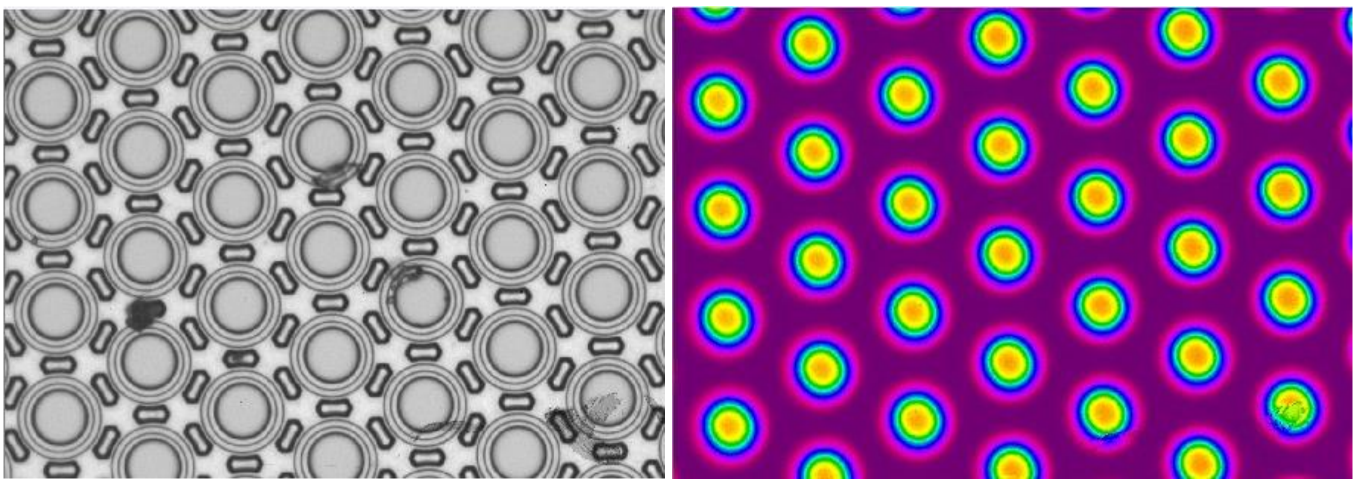

Figure 8. Left: microscope image of VCSEL array. Right: near field image of the VCSEL array operating at 940nm

Far field profiling: This methos is used for measuring the beam profile and divergence angle far from the source. Two methods are available for far field, direct and imaging. The BeamGage software supprts both methods.

Direct method: The laser beam is incident on the CCD camera beam profiler. This method works best for collimated beams.

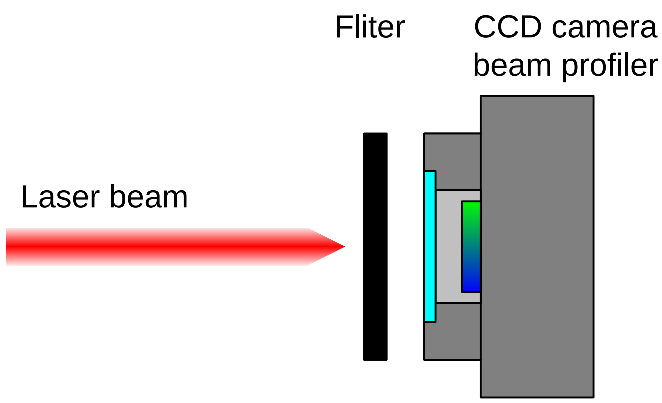

Figure 9. Direct Beam Profiling

Imaging method: If the laser beam is too wide or rapidly diverging to fit the CCD sensor, a CCTV lens is used to image the beam profile incident on a diffuser.

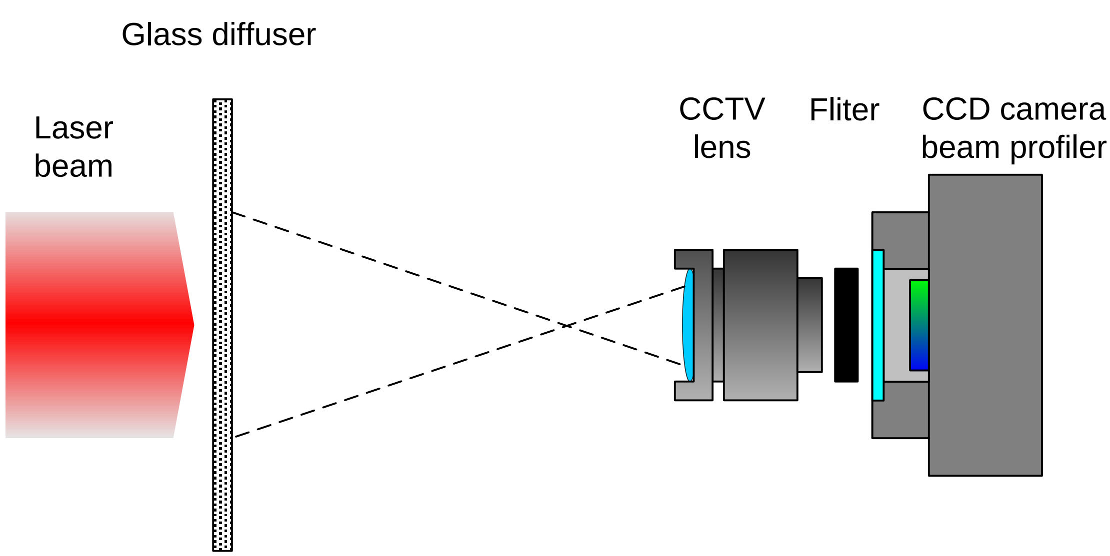

Figure 10. Imaging beam profiling

Figure 11 shows a screenshot of the BeamGage software user interface. Various graphical representations of the beam profile are seen, and beam analysis information is displayed on the left.

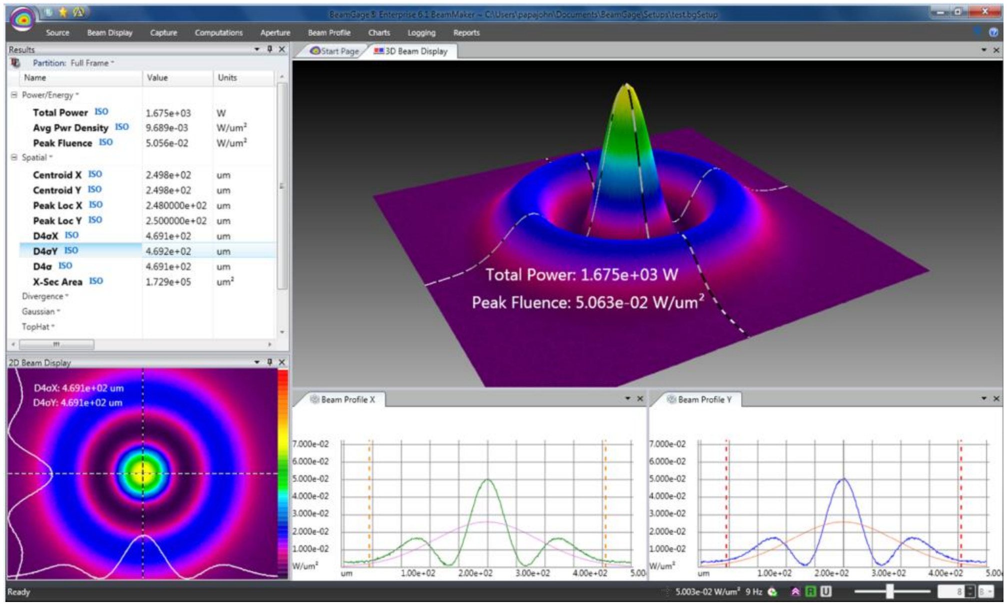

Figure 11. Screenshot of BeamGage software user interface

Pulse shape and noise measurement

Noise and pulse shape characterization is done using a fast photodiode detector and analysis in the time domain (after analog to digital conversion) or frequency domain (using a spectrum analyzer). Ophir's offers silicon and InGaAs high speed detectors with response time down to 25ps. These detectors can be used in free space, and also attached to Ophir's integrating spheres.

Figure 12.Ophir's line of fast photodiode detectors

For calibrated power measurements of fast pulses, the new 'Centauri' laser power meter shown in Figure 13 is capable of measuring at a sample rate of 10kHz.

Wavelength measurement

Ophir offers OEM spectrometers from leading brands. Fiber adapters for the integrating sphere enable system integration. Contact Ophir for more information.

OEMs and integrated solutions

Many laser systems manufacturers need to have a measuring capability built into their systems. With extensive experience accumulated over many years, Ophir offers the largest variety of OEM products and is therefore best able to satisfy customer requirements. An OEM solution is usually needed to monitor laser performance in the system, and possibly to provide fast feedback for system control.

Depending on your application, various configurations can be used, such as:

- Only a sensor, with raw analog output
- A sensor with electronics providing an amplified – or digital – output
- A complete instrument, including numeric display and/or PC interface
- A custom designed solution for special requirements

Figure 13. Integrating sphere with 170° port adapter, calibrated photodiode power sensor, fast photodiode and Centauri display. Integrating sphere accessories appear in the front

Figure 14. A selection of OEM sensors