INSTRUMENTING DWDM LASER DIODE PRODUCTION TESTS

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Smart Testing and the Right System Design Reduce Costs

Dense Wavelength-Division Multiplexing (DWDM) fiber optic communications is the current, if not the ultimate, solution to our voracious bandwidth appetite in the Internet Age. The resulting pressures to accelerate development and production of optoelectronic devices, such as laser diodes, requires a similar expansion in product testing "bandwidth". However, a convenient first approach to production testing often is a duplication of laboratory methods on the production line. While this is expedient, it is far less than optimal in terms of throughput, measurement integrity and overall test efficiency.

The better solution is an automated test system with tightly integrated instruments designed specifically for laser diode measurements. Some of the immediate benefits are higher throughput, fewer instrument lock-ups, less operator interaction and reduced measurement transposition errors. Properly designed, such a test system can be used early in production processes to avoid wasted assembly and testing with bad components.

Sort and Separate

Laser diode production tests are used to sort lasers according to performance characteristics, or weed out bad devices to minimize processing costs. Vertical cavity surface emitting lasers (VCSELs) can be tested while still on the wafer, because their light is emitted perpendicular to the wafer surface. Edge emitting laser diodes must be cleaved from the wafer, but can be left in a strip (also called a bar) that contains a single row of several devices. The front and back edges of this diode array are coated to form optically reflective interfaces. The back facet coating is mostly reflective to provide efficient optical feedback while passing only a small portion of the light outside the laser. In the final module assembly, the light feeds the back facet monitor diode. The front facet is coated with a less reflective coating to provide enough optical feedback to ensure lasing while allowing high optical output power. Once coated, the individual diodes on the bar are tested.

After laser diodes have passed wafer or bar stage tests, they are diced into chips and mounted on carriers. These submounts facilitate handling of laser chips during subsequent assembly operations. Additional testing may take place after carrier mounting to ensure that device characteristics have not changed. Because of high added value, testing typically is done at each major step in a higher level assembly, such as a Laser Diode Module (LDM) used in a DWDM communications system.

Typical Measurements

Basic laser diode measurements include optical power and its derivatives, along with electrical characteristics that are used to derive more complex parameters. To achieve high throughput in a production test environment, optical power usually is measured with a photodiode detector. (Optical power is proportional to the square of light intensity, which requires appropriate calibration of the photo detector output current.)

The most common laser diode tests use Light-Current-Voltage (L-I-V) sweeps to measure drive current, forward voltage drop, and light output. Some of these tests may be run at multiple operating temperatures. At the chip-on-carrier step, laser diode light is directed into an open integrating sphere where a photo detector converts it to an electrical signal. For assembled LDMs, laser output is coupled though an optical fiber to the integrating sphere. (See Figure 1.) The photo detector output current is measured and correlated to the laser's optical output power.

Collected data are used to determine the laser diode's lasing threshold current, L-I efficiency, and L-I linearity. In LDM assemblies that utilize edge emitting lasers, measurements also include the current generated in a back facet monitor diode (BFMD). Other measurements might include laser diode leakage and photodiode dark current. Testing of the BFMD usually is limited to verification of forward and reverse I-V characteristics.

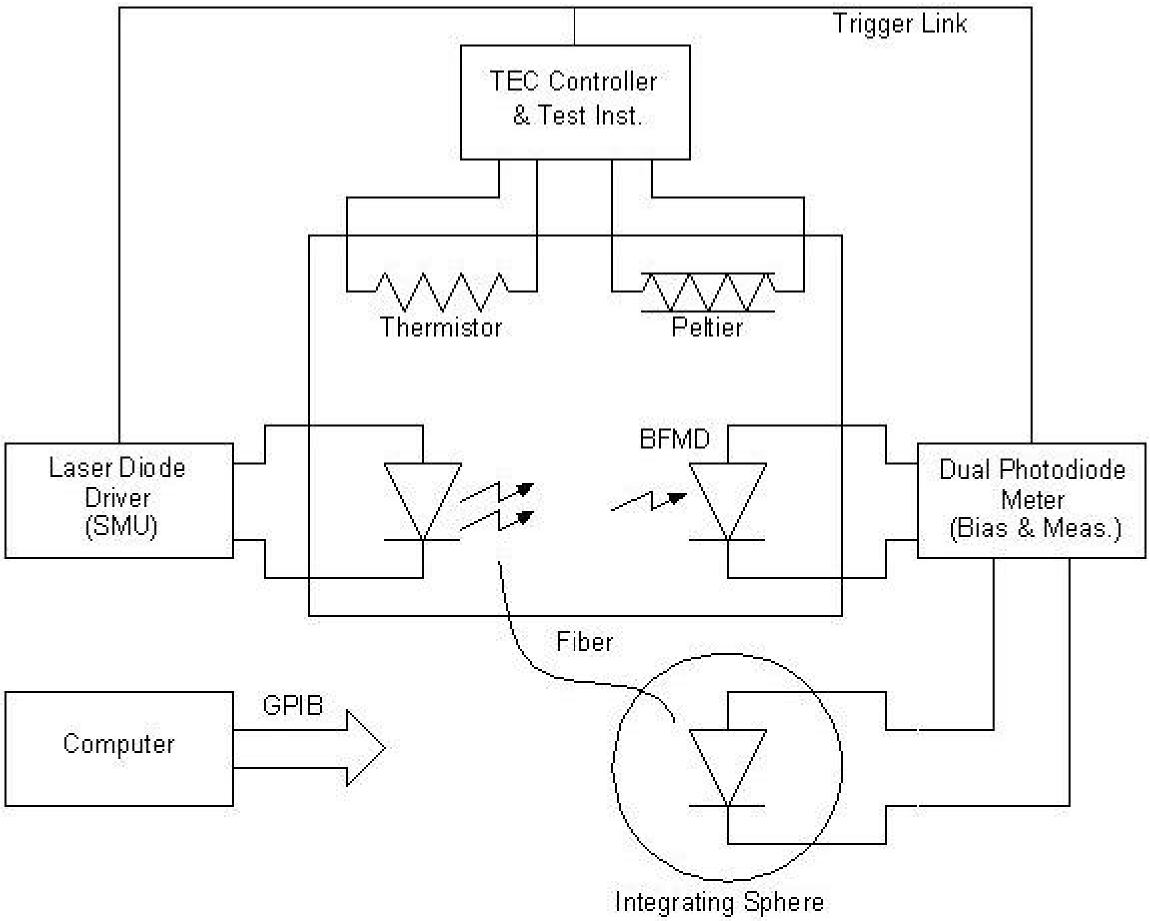

Figure 1 — Simplified LDM test equipment block diagram.

Regardless of physical mounting, a laser diode is designed to emit coherent light over a range of currents. The lower end of the range is defined as the lasing threshold. Above that is a linear operating region. Ideally, this region is characterized by a constant slope in the light power output as a function of input drive current (e.g., the L-I curve). Verification of L-I linearity is a key quality assurance test. This involves the use of a first or second derivative of the L-I curve to look for "kinks", which would be a reason to disqualify the DUT.

Essential Ancillary Equipment

A key test variable is the laser diode's operating temperature, since small variations can shift the output wavelength. In an LDM assembly, the temperature typically is maintained within ±0.005ºC by mounting the laser diode to a Peltier type thermoelectric cooler (TEC). The TEC controller PID coefficients usually are optimized for either minimum overshoot (for DUT protection), or minimum settling time (for fastest time to a stable temperature setpoint, which minimizes test time).

When laser testing is conducted at the wafer or bar stage, cooling is problematical. Cooled wafer chucks are one way to dissipate heat when testing VCSELs on the wafer plane, but localized thermal gradients may still induce mechanical stresses that degrade these devices. To avoid self-heating of an uncooled DUT, short pulse testing may be conducted.

Similarly, light collection from the wafer plane can be a problem. An open integrating sphere suspended above the wafer provides the best measure of total optical radiated power and is relatively immune to polarization dependent losses (PDL). However, even the smallest integrating sphere will collect light from tens of VCSELs on a wafer if they are simultaneously activated. Therefore, only one VCSEL can be tested at a time. Parallel device tests require fiber optic light collection probes. Large areas detectors can also be designed to minimize PDL and provide a high level signal for optical power measurements similar to that of an integrating sphere.

Instrument Implications

For the highest test efficiency and throughput, instruments in the L-I-V test system of Figure 1 should include precision source-measure units (SMUs) designed with production testing in mind. Primary considerations are tight control of the source output, protection of the DUT with voltage compliance functions, high resolution readback and Kelvin (4-wire) measurement capabilities. When all the instruments are tied together on a GPIB bus, this can be a highly effective test system that identifies bad DUTs early in their processing, which avoids useless and expensive frequency domain testing.

The laser diode driver must be a programmable low-noise current source that has adequate output capacity for the laser under test. This can require outputs up to 5A for the latest generation of pump lasers. For uncooled DUT testing, a pulsed source with programmable pulse widths down to about 500ns is required. Pulse rise and fall times should each be an order of magnitude less than the minimum pulse width. Hard-wired trigger I/O (Trigger Link in Figure 1) allows precision synchronization between the laser driver and photodiode measurements.

For LDMs, a two-channel photodiode meter is required for laser and BFMD measurements. This instrument must be able to bias both the BFMD and the laser's external photo detector, and measure nanoamp current levels with sub-picoamp resolution. When used with a calibrated integrating sphere, these current measurements can be converted to optical power values.

The integrating sphere and detector are calibrated as a set. For each calibration wavelength, the power-to-current transfer function is measured. These calibration coefficients are read into the test software to provide a true measure of light power output. Also, since most detectors use semiconductor materials with temperature coefficients of about 2 mV/^{o}C, the temperature of the detector must be known or controlled.

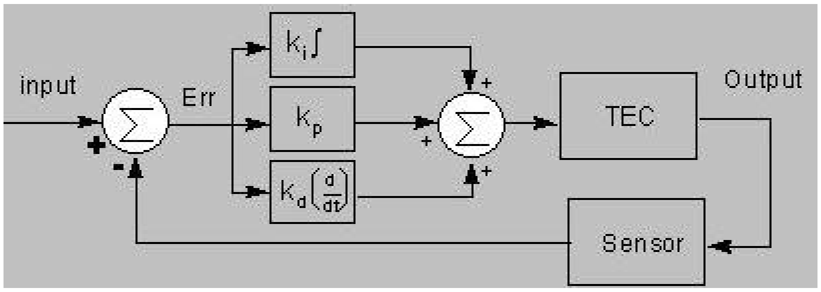

Figure 2. TEC control loop with tunable PID coefficients.

As mentioned earlier, the laser diode also requires tight temperature control. Ideally, the LDM's TEC controller algorithm allows optimization of the PID coefficients. (See Figure 2.) However, manually optimizing these coefficients can take hours. This creates a bottleneck for LDM manufacturers that utilize the same test system for different products. Therefore a controller with an autotuning feature is highly desirable. In addition to supplying and controlling power, another nice feature in a TEC controller is instrumentation for checking the cooler. A quick quality check can be accomplished with an AC ohms measurement on the Peltier device and its thermistor feedback element. To avoid wasted laser testing, these resistance tests are run first.

To prevent the GPIB bus from turning into a bottleneck, all these instruments need features such as Source Memory, Buffer Memory, Digital I/O and external trigger I/O. Furthermore, built-in math and comparator functions can reduce the PC controller's processing load. With appropriate programming, these features reduce much of the data traffic over the GPIB bus during a test. This applies to all types of laser diode tests, whether they are conducted on finished LDM assemblies, or on wafer plane devices. In the latter case, the instruments are integrated with a wafer prober. For high-efficiency testing on multiple DUTs, a switching matrix would also be part of an integrated test system.

If the DUT passes L-I-V testing, it moves on to non-DC tests. Using an Optical Spectrum Analyzer (OSA), wavelength meter, and far field beam profiler, the frequency domain tests include operating wavelength, spectral linewidth, noise, sidemode suppression checks and beam profile. However, the idea of fast DC testing is to avoid the more costly tests when they would be a waste of time. Clearly, the creation of a fast integrated system for laser diode testing involves a lot of details.

An instrument manufacturer that supplies application and integration services can facilitate test system design, help get it up and running quickly, and ultimately reduce the cost of ownership.

About the Author

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