COHERENT.

White Paper

Understanding ISO 17025 for Laser Power and Energy Measurement

Coherent is accredited to ISO/IEC 17025:2005, the industry recognized standard that defines management and technical requirements for a calibration laboratory.

Introduction

ISO/IEC 17025 accreditation assures customers that laser manufacturers are producing calibrations to the highest standards. Updated specifications and enhanced calibration certificates provide additional clarity to uncertainty specifications, helping customers better understand the accuracy and repeatability that products can deliver.

Most manufacturers of laser power and energy measurement instruments calibrate their product against third party reference standards, such as those from NIST. However, only with independent accreditation can end-users have strong confidence in their measurements.

This document covers the calibration process, the requirements of ISO/IEC 17025, and the benefits of accreditation.

The Calibration Process

A laser power or energy sensor converts incident light into an electrical signal which is then processed by meter electronics into a reading in the desired units (e.g. Watts or Joules). Each component of a laser measurement system has its own manufacturing tolerances. For example, there are unit-to-unit variations in the coatings applied to detectors, in the bulk material of the detectors themselves, and in the electronic characteristics of components used to construct the meter. As a result, two different measuring systems, as originally built, may not produce identical readings when exposed to exactly the same light input.

Manufacturers minimize this unit-to-unit variation through a process of calibration. Specifically, calibration refers to an unbroken and traceable series of comparisons to a widely agreed upon reference standard that is typically maintained by a national laboratory or international standards body.

Traceability of Sensors. For optical laser power and energy measurements, the calibration process starts when an instrument builder sends a dedicated "golden" sensor to a standards organization, which then exposes the sensor to a series of known power and/or energy inputs (depending upon the sensor type), recording the output for each case. In this way, the sensor has its performance confirmed in the form of Volts of electrical output per Watt or Joule of optical input. This ratio of output to input is known as the responsivity of the sensor, and is typically labeled as R_v. This sensor then becomes a "golden standard sensor" against which all other sensors can be measured.

Once the "golden standard sensor" is returned to the manufacturer and other sensors are measured against it, accurate and traceable responsivity measurements can be put into place. These results can be recorded or stored for use in calculating the power or energy when the sensor is delivered to a customer and used in a measurement system. In practice, a standards body, such as NIST, can only certify a small number of sensors for a given manufacturer each year. So, companies such as Coherent, that produce laser measurement systems in high volume, normally maintain a number of "working standards" within their organizations, each calibrated against the " golden standard." Production units are then, in turn, calibrated against the working standards and enough working standards are maintained to meet all production testing needs.

Traceability of Meters. Coherent energy or power meter electronics are traceable to a national standard by calibrating them against NIST-traceable current or voltage standards. Internal electronics in the meter can be adjusted to ensure that it is sensing voltage correctly. That is, if it is given a 1V input, that it "sees" this as 1V, and then correctly converts this voltage into laser power or energy.

Calibration Process Summary. This type of arrangement provides a clear path of traceability from production units to the national standard; production units are calibrated to working standards, working standards are calibrated to golden standards, and golden standards are calibrated to national standards.

While every major supplier engages in a traceable calibration process, there are significant differences in the details of how this is accomplished. In particular, there are variations in the statistical methods used to define uncertainty, and in the exact protocols that each manufacturer maintains with respect to establishing and maintaining laboratory methods. To understand the reliance that can be placed on a reading from a laser measurement system, it is necessary - and appropriate - to ask instrument manufacturers about their precise calibration methods, the meaning of their specifications and, in some circumstances, it may be even necessary to audit a supplier's facility and processes.

Understanding Calibration Uncertainty

The primary parameter used to specify calibration capability is uncertainty. Calibration uncertainty defines how far away readings from a given instrument should be to the actual, true value of the parameter being measured. This uncertainty takes into account the combined uncertainties from all stages of the calibration process, from variations in the golden standard itself, all the way through to the unit under test.

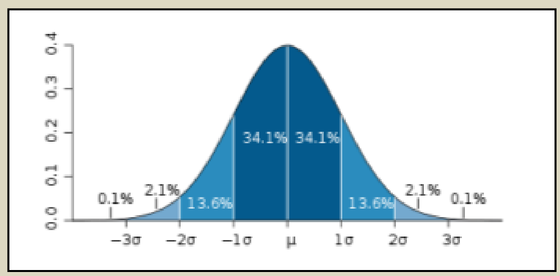
Components of Uncertainty. If a large number of identical measurements are made with a single instrument, the values obtained will have a distribution representing the instrument's repeatability. If these same measurements are made with several instruments, then these measurements will also vary slightly from instrument to instrument reflecting slight variations in the calibration process. Even the calibration of the "golden standard sensor" will also have some uncertainty associated with it. All of these contributions are combined to produce an overall calibration uncertainty of the final instrument. Repeated measurements made with multiple instruments will typically adhere to a normal (Gaussian) distribution.

Confidence Interval and Coverage Factor. The calibration uncertainty for laser power and energy measurement instruments is commonly in the range of 1% to 5%. The assumption could be made that every reading taken with an instrument will be within that accuracy range. For example, if a laser power meter product that has a 1% calibration uncertainty takes numerous measurements of a continuous wave laser beam having a true power of exactly 1 Watt, then one might think that all the readings will be between 0.99 Watts and 1.01 Watts. However, this is not the case.

The way that calibration uncertainty is defined by manufacturers is not intended to include all values within this distribution. Rather, it includes values that occur within a set number of standard deviations from the mean. Unless this number of standard deviations, representing the "confidence interval," is explicitly stated, the value for calibration uncertainty cannot be interpreted and becomes essentially meaningless. Coherent uncertainty specifications are based upon a confidence interval of 95%, equal to two standard deviations, otherwise known as a "k=2" coverage factor.

In Depth: Uncertainty Coverage Factor

For a normal distribution, approximately 68% of the readings will have a value that is within one standard deviation ($\pm 1\sigma$) of the mean value. Going out to two standard deviations ($\pm 2\sigma$) encompasses 95% of all readings.



For example, when using a power meter with a calibration uncertainty of ±1%, and a confidence interval of 1 (usually denoted k=1), nearly one third (about 32 of 100) of the readings would be expected to be greater than 1% different from the true value. In contrast, a power meter with a calibration uncertainty of ±1% and k=2 would deliver readings that have an absolute accuracy of better than 1% in 95 out of 100 measurements.

Obviously, there is a big difference between these two situations, despite the fact that each one can reasonably be said to represent a system displaying a calibration uncertainty of ±1%. Unfortunately, confidence interval is often not stated explicitly, and it is up to the buyer to question potential suppliers as to the precise meaning of their published specifications for calibration uncertainty.

ISO/IEC 17025 Fundamentals
ISO 17025 accreditation requires adherence to guidelines for a variety of policies and processes, not just covering a calibration organization's metrology methods and procedures, but also its management system. It represents a substantially more exacting series of requirements than those necessary in the more general ISO 9001 standard.

Accreditation. Accreditation can only be accomplished by having a compliant Management System as well as demonstrating competency and proficiency to a third party auditor. Coherent has selected ACLASS, one of three brands of the ANSI-ASQ National Accreditation Board, as its third party ISO 17025 auditor.

ACLASS is a signatory to the International Laboratory Accreditation Cooperation (ILAC), the international body which helps standardize and recognize accreditation systems worldwide and publishes guidance documents to support these efforts. Accreditation bodies around the world typically pursue ILAC recognition through one of the acknowledged regional cooperations of ILAC. Recognizing the value of regional information-sharing among members of the accreditation community, ACLASS has signed the MRAs of both the Asia-Pacific Accreditation Cooperation (APLAC) and the Inter-American Accreditation Cooperation (IAAC).

Scope of Accreditation
The scope of accreditation is a document listing a laboratory's specific test or calibration capability as verified by the accreditation body. For a calibration laboratory, the scope includes the type of test or calibration, range or detection limits, reference standards, procedures used, and the calibration and measurement capabilities. The scope refers to a certificate of accreditation.

The scope table for a calibration laboratory contains the following elements:

- Measuring instrument
- Specific calibrations performed
- Specific ranges of measurement
- Calibration capability expressed as an uncertainty with the appropriate confidence levels
- Reference standards and key accessories used to perform the calibrations

In Depth: Accreditation Versus "Compliance"
Many companies may claim to be "compliant" with ISO 17025, so it's important to distinguish between compliance and accreditation. Non- accredited "compliance" with ISO 17025 can really mean whatever a particular company wants it to mean, so again, it is necessary to question manufacturers as to the specifics of their methods. For example, a company may state that their calibration certificates are compliant with ISO 17025, but this may just mean that test parameters are listed on the calibration certificate in a format that is consistent with ISO 17025 requirements. However, it doesn't necessarily mean that the procedures and instrumentation used to obtain these numbers are ISO 17025 compliant. In fact, accomplishing that level of compliance requires a third party audit and accreditation.

The scope of accreditation document is published on an accreditation body website listing the witnessed and approved calibrations and/or tests compliant to ISO/IEC 17025. Coherent's Scope of Accreditation can be found on the ACLASS website here.

Management Requirements. ISO/IEC 17025 accreditation is formal recognition that a calibration laboratory is competent to carry out specific tests or calibrations. In particular, it certifies that a company has devoted resources to creating and sustaining all the specified management requirements related to the operation and effectiveness of the quality management system within the laboratory including:

- Management of testing facilities
- Record keeping, data storage, and data handling
- Handling customer complaints
- Instituting corrective action when necessary
- Performing audits and reviews

Technical Requirements. In terms of technical requirements, ISO/IEC 17025 ensures that a company:

- Maintains technically competent calibration staff
- Confirms validity and appropriateness of methods, especially so-called “non-standard” methods, such as those used to calibrate laser measurement equipment, that have not been standardized by an industry group
- Uses appropriate mathematical methods for calculating results and process uncertainties
- Has a traceable path of calibration to independently maintained national or international standards
- Produces compliant calibration certificates, including received and outgoing data, when available
- Performs proficiency testing, a comparison of results between labs, on a routine basis

Full ISO 17025 accreditation provides Coherent’s customers the highest degree of confidence that calibration measurements are trustworthy, and that these results will be reported in an unambiguous and intelligible manner. Accomplishing all this requires that a company commit substantial economic and human resources to the task. This substantial commitment is the reason that Coherent is the first, and currently the only, laser power and energy measurement equipment manufacturer to have achieved full ISO 17025 accreditation.

Conclusion

In conclusion, Coherent has engaged in a demanding and lengthy process to achieve full ISO 17025 accreditation. This accreditation establishes precisely how testing is performed, and provides assurance to customers that calibration processes are maintained to the highest standards. This accreditation is especially valuable to users in government regulated industries (such as medical, military, and aerospace) where system builders must document the traceability and performance accuracy of their own products.

In Depth: “Non-Standard” Methods for Laser Measurement Calibration

There is no internationally agreed upon “standard” procedure for calibrating laser power and energy sensors. As a result, different companies have developed their own particular techniques. ISO 17025 accreditation ensures that Coherent’s internally developed techniques have been validated by third party auditors that specialize in all manners of calibration. Thus, there is a formal accreditation trail that documents all the procedures utilized by Coherent for performing calibration, and which independently ensures that proper methods and processes have been put into place and are being maintained.

Other suppliers may claim that various aspects of their process or reporting are ISO 17025 “compliant,” but this claim really tells the instrument buyer very little about the actual procedures they use internally, or the true uncertainty of measurements made with their products. In contrast, the ACLASS accreditation mark on Coherent calibration certificates ensures that every step in the testing process has been audited and verified by a third party, and that Coherent’s calibration processes used in its scope of accreditation are fully compliant with every aspect of the ISO specification.

Additionally, since Coherent has been independently audited by an ILAC certified accreditor, this will often eliminate the need for customers to perform their own costly, time-consuming supplier audit.

Coherent’s scope of accreditation and certificate of accreditation can be located on the ACLASS website.

Appendix 1: Certificate of Calibration

COHERENT®

27650 SW 95th Ave.
Wilsonville, OR 97070
Phone (800) 343-4912

Certificate of Calibration

Power Sensor

ACLASS logo verifies that Coherent is accredited and certified

Certification Number 120105134519

ACLASS ACCREDITED CALIBRATION

Date: 01/05/2012

Part Number: 1097901

Description: PM10

Serial Number: 0682C11R

Temperature (°C): 22.4

Relative Humidity (%): 32.8

Procedure: QI-19.70 RevGC

Testing returned units on receipt allows Coherent to report "as received" data

Coherent reports uncertainty at the k=2 confidence level

Instrument Condition As Received

Wavelength	Sensor Rv	Uncertainty (k=2)	Laser Power	Sensor Reading	Uncertainty (k=2)*	Status
514 nm	1.560E-3 V/W	±1.0 %	1.043W	1.040W	±1.5 %	In Tolerance

Sensor confirmed to be reading accurately with a meter in terms of Watts

Instrument Condition As Shipped

Wavelength	Sensor Rv	Uncertainty (k=2)	Laser Power	Sensor Reading	Uncertainty (k=2)*	Status
514 nm	1.576E-3 V/W	±1.0 %	1.023W	1.022W	±1.5 %	In Tolerance

Uncertainty values in terms of Watts include a meter, in addition to the sensor, which is why these values are slightly higher than the uncertainty for the sensor responsivity (Rv) alone

*The reported uncertainty includes the uncertainty of the standard instrument (1.1 %, k=2) used to measure power at the test point(s) listed.

Standards	Asset #	Calibration Due
MOLECTRON PM10	0011W00	Aug 2012
Coherent LabMax-TO	1723T11	Oct 2012
HP 3478A	0004T97	Jan 2012

Comments:

Calibrated By:

V PERRY — Test Technician

生产日期
MFD 2012 01 05

Calibration Interval Start Date: ______________________ Due Date: ______________________

The calibration interval begins when the equipment is placed into service. The "Due Date" may be established (by the customer) by adding the calibration interval to the "Start Date". Contact Customer Service for recommended calibration intervals for Coherent products.

Coherent hereby certifies that the above equipment meets or exceeds our published specifications and has been calibrated using standards traceable to NIST within the limitations of the Institute's calibration services, or has been derived from accepted values of natural physical constants, or has been derived by the ratio type of self-calibration techniques. This certificate complies with the requirements of ISO/IEC 17025:2005.

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