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Specification, certification and recalibration

Specification

All of Renishaw's experience in metrology and laser interferometry is to be found in each and every measurement system that it produces. Our aim is to deliver the specified accuracy, with full traceability and the confidence that the system will deliver that accuracy day-after-day where it counts, in the workplace.

An important element in this is that all lasers, ballbars, compensators and rotary calibrators have been calibrated at the Renishaw factory. All reference artefacts are traceable to National Standards and our systems are delivered with a comprehensive calibration certificate.

As an example, the frequency accuracy and stability of all new XL-80 lasers, and the sensing and compensation accuracy of XC-80 compensators are guaranteed to meet published specifications and ensure the overall system accuracy (± 0.5 ppm for linear measurement accuracy) on shipment from Renishaw.

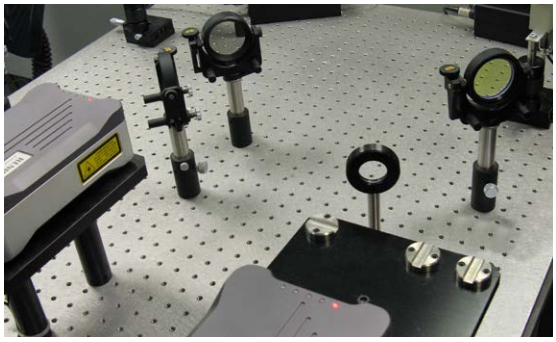
XL-80 laser system

The stated accuracy (as per Renishaw sales and marketing documentation and user manuals) is derived from;

- A production-test-limit value
- An allowance for our uncertainty of calibration due to uncertainty in our test equipment and errors introduced in the calibration process
- An allowance for drift in service

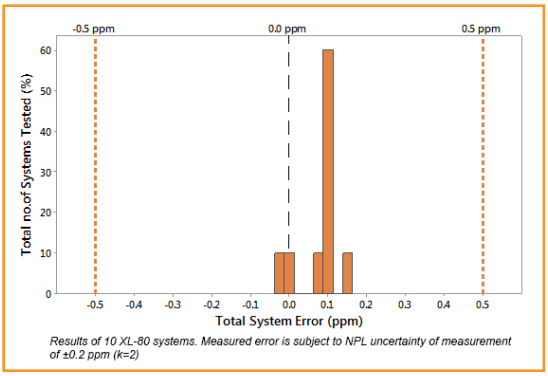
The total accuracy budget for the XL-80 system and its components (XL-80, XC-80 and sensors) is arrived at in accordance with recognised procedures such as EA-4/02 (Expression of Uncertainty and Confidence in Measurement, published by the European co-operation for accreditation) and calculated to a K=2 (95%) confidence level.

These procedures dictate not only that you identify and quantify all the factors that effect the system performance but also the uncertainty in measuring these. In addition it gives guidelines for the methodology that should be used to calculate each factor's contribution to overall system error, both individually and in combination with the other error sources.



Laser calibration test rig

The performance specification of the Renishaw XL-80 system (XL-80 laser, interferometer optics and and XC-80 environmental compensation unit) has been independently validated by calibrations of customer equipment carried out by the National Physical Laboratory (NPL).



Results of 10 XL-80 systems. Measured error is subject to NPL uncertainty of measurement of ±0.2 ppm (k=2)

The graph above shows the results of 10 XL-80 systems calibrated by NPL. It clearly shows that the total system error for each system is well within Renishaw's published specification (± 0.5ppm).

This demonstrates that Renishaw's internal build, test and calibration process assures system performance to specification.

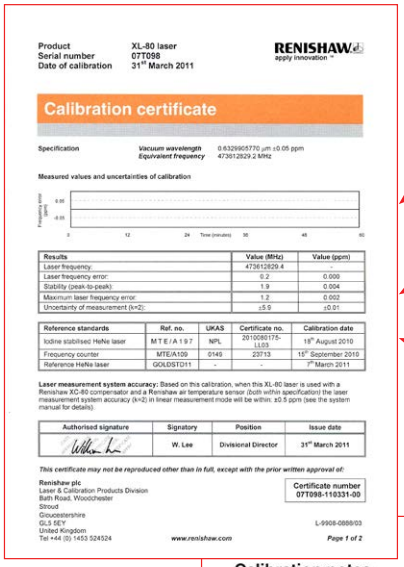
Application note

Certification

Renishaw is proud of its transparency in discussions regarding system accuracy and traceability and welcomes enquiries from customers who wish to discuss this in more detail.

Renishaw recognises that these certificates are a key document for customers QA compliance. Renishaw's standard calibration certificate provides the following key information:

- A graphical representation of test results and specification limits
- Note that if adjustment and repair is required, then a seperate 'as received' certificate will be issued
- Specific test results
- Statement of overall system accuracy (where relevant)
- Traceability data (calibration details, see section below)
- On the reverse side are comprehensive notes detailing test methodology, conditions, traceability, etc.



Product XL-80 laser
Serial number 07T098
Date of calibration 31st March 2011

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Calibration certificate

Specification
Vacuum wavelength 0.632990577 0 µm ±0.05 ppm
Equivalent frequency 473612929.2 MHz

Measured values and uncertainties of calibration

Results	Value (MHz)	Value (ppm)
Laser frequency:	473612929.4	
Laser frequency error:	0.2	0.000
Stability (peak-to-peak):	1.9	0.004
Maximum laser frequency error:	1.2	0.002
Uncertainty of measurement (k=2):	±5.9	±0.01

Reference standards	Ref. no.	UKAS	Certificate no.	Calibration date
Iodine stabilised HeNe laser	M T E / A 1 9 7	NPL	2010080175-L03	18th August 2010
Frequency counter	MTE/A109	0149	23713	15th September 2010
Reference HeNe laser	GOLDSTD11	-	-	7th March 2011

Laser measurement system accuracy: Based on this calibration, when this XL-80 laser is used with a Renishaw XC-80 compensator and a Renishaw air temperature sensor (both within specification) the laser measurement system accuracy (k=2) in linear measurement mode will be within: ±0.5 ppm (see the system manual for details).

Authorised signature	Signatory	Position	Issue date
	W. Lee	Divisional Director	31st March 2011

This certificate may not be reproduced other than in full, except with the prior written approval of:

Renishaw plc
Laser & Calibration Products Division
Bath Road, Woodchester
Stroud
Gloucestershire
GL5 5EY
United Kingdom
Tel +44 (0) 1453 524524

Certificate number 071098-110331-00

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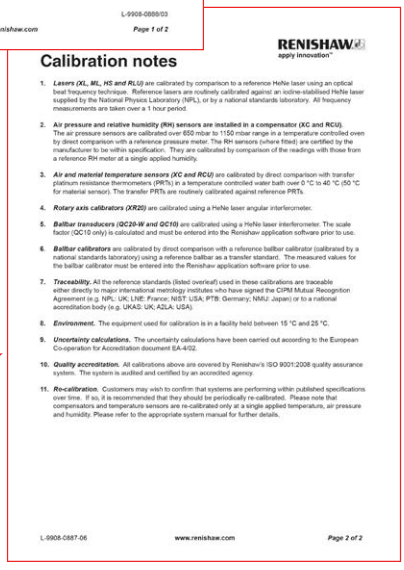
www.renishaw.com Page 1 of 2

Graphical representation of test results (after adjustment and repair if required) and specification limits

Specific test results

Traceability data



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Calibration notes

1. ***Lasers (XL, ML, HS and RLU)*** are calibrated by comparison to a reference HeNe laser using an optical beat frequency technique. Reference lasers are routinely calibrated against an iodine-stabilised HeNe laser supplied by the National Physical Laboratory (NPL), or by a national standards laboratory. All frequency measurements are taken over a 1 hour period.
2. ***Air pressure and relative humidity (RH) sensors are installed in a compensator (XC and RCU).*** The air pressure sensors are calibrated over 650 mbar to 1150 mbar range in a temperature controlled oven by direct comparison with a reference pressure meter. The RH sensors (where fitted) are certified by the manufacturer to be within specification. They are calibrated by comparison of the readings with those from a reference RH meter at a single applied humidity.
3. ***Air and material temperature sensors (XC and RCU)*** are calibrated by direct comparison with transfer platinum resistance thermometers (PRTs) in a temperature controlled water bath over 0 °C to 40 °C (50 °C for material sensor). The transfer PRTs are routinely calibrated against reference PRTs.
4. ***Rotary axis calibrators (XR20)*** are calibrated using a HeNe laser angular interferometer.
5. ***Ballbar transducers (QC20-W and QC10)*** are calibrated using a HeNe laser interferometer. The scale factor (QC10 only) is calculated and must be entered into the Renishaw application software prior to use.
6. ***Ballbar calibrators*** are calibrated by direct comparison with a reference ballbar calibrator (calibrated by a national standards laboratory) using a reference ballbar as a transfer standard. The measured values for the ballbar calibrator must be entered into the Renishaw application software prior to use.
7. ***Traceability.*** All the reference standards (listed overleaf) used in these calibrations are traceable either directly to major international metrology institutes who have signed the CIPM Mutual Recognition Agreement (e.g. NPL; UK, LNE; France, NIST; USA, PTB; Germany, NMIJ; Japan) or to a national accreditation body (e.g. UKAS; UK, A2LA; USA).
8. ***Environment.*** The equipment used for calibration is in a facility held between 15 °C and 25 °C.
9. ***Uncertainty calculations.*** The uncertainty calculations have been carried out according to the European Co-operation for Accreditation document EA-4/02.
10. ***Quality accreditation.*** All calibrations above are covered by Renishaw's ISO 9001:2008 quality assurance system. The system is audited and certified by an accredited agency.
11. ***Re-calibration.*** Customers may wish to confirm that systems are performing within published specifications over time. If so, it is recommended that they should be periodically re-calibrated. Please note that compensators and temperature sensors are re-calibrated only at a single applied temperature, air pressure and humidity. Please refer to the appropriate system manual for further details.

L-9908-0887-06 www.renishaw.com Page 2 of 2

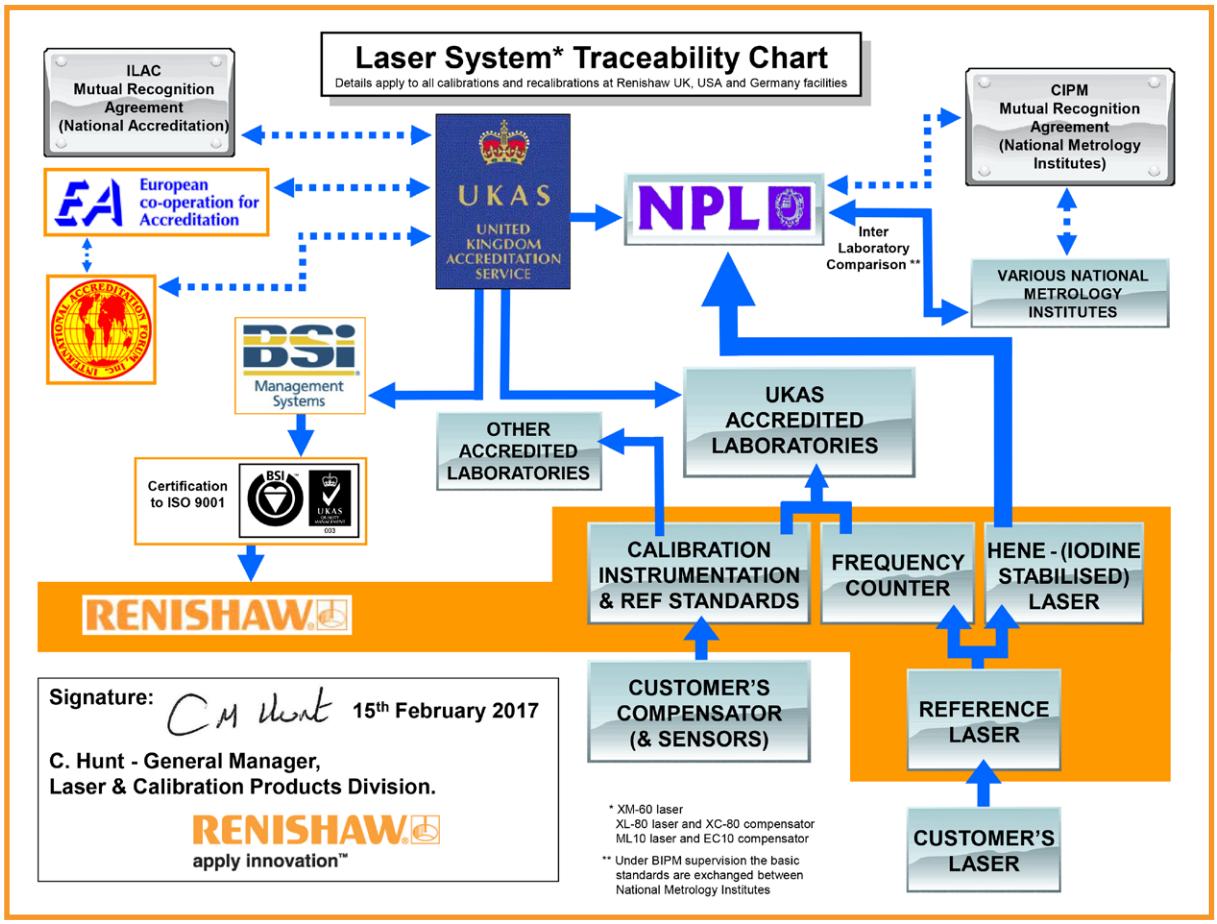
Explanation of test procedure and traceability

Traceability

A measurement is said to be "traceable" if it can be related back to other identified reference standards, (usually national or international standards) through an unbroken chain of comparisons, with each step in the chain having stated uncertainties.

Traceability is characterised by six essential elements:

1. An **unbroken chain** of comparisons originating at national or international standards of measurement and ending with the comparison of the local working reference standard and the unit under test.
2. The **measurement uncertainty** for each step in the traceability chain must be calculated according to defined methods and must be stated at each step of the chain so that an overall uncertainty for the whole chain can be calculated.
3. Each step in the chain must be performed according to **documented** procedures and the results must be published in a calibration or test report.
4. The laboratories or bodies performing one or more steps in the chain must supply evidence of technical **competence**, e.g., by demonstrating that they are accredited by a recognised accreditation body.
5. Where possible, the primary national or international standards must use **SI units**.
6. **Calibrations** must be repeated at appropriate intervals in such a manner that traceability of the standard is preserved.



Example of traceability chart XL-80, XC-80 and XM-60

All instruments and artefacts used in the factory calibration of Renishaw XL-80 laser systems are fully traceable to UKAS accredited laboratories and thus to national standards, e.g. NPL. Traceability data (artefacts used and calibration details) are included on each certificate and flow charts illustrating the traceability process are also available for customer information.

NPL is a signatory to the CIPM Mutual Recognition Agreement (MRA) then other National Metrology Institutes who have signed the agreement (e.g L.N.E., France; NIST, USA; PTB, Germany) recognise the validity of NPL's standards as well as their calibration and measurement certificates.

Recalibration

Why recalibrate?

Your Renishaw measurement system is a precision instrument. Even with perfect care of the system, changes in performance over time can effect the accuracy of measurement and potentially result in values outside of the specified accuracy.

As with any calibration reference it is recommended that the Renishaw system components are periodically recalibrated to give confidence that the system is capable of delivering the specified accuracy of measurement. It is for this reason that recalibration of test equipment is normally a mandatory requirement of most quality assurance systems.

The inspections Renishaw carries out when recalibrating can also show up accidental damage that you might have not been aware of, avoiding future problems. With ballbar systems, we also replace the balls and magnetic cups, that are liable to wear, as part of our service policy.

Compared to the investment in the measurement system, the staff and the procedures that it is operated with, recalibration is a modest additional cost and could prevent far more expensive and bigger problems arising later.

Recalibration periods

Recalibration periods are a recommendation based on average use of the equipment and is considered to be “after the equipment has been put into use”. Generally this should ensure that your system is still performing within specification at the end of the stated period. However, there are several factors that may generate the need for more or less frequent recalibrations including:

- Environmental conditions
- Frequency and duration of use
- Harsh treatment of the laser system, during storage, transportation or use
- Level of accuracy required by the user
- The requirements of company QA procedures and/or national/local regulations

Ultimately it is for the user to determine the appropriate calibration period after taking into account the operational environment and performance requirements.

The recommended recalibration period for Renishaw products is:

XM-60 multi-axis calibrator	2 years
XL-80 laser	3 years
XR20-W rotary axis calibrator	3 years
XC-80 compensator and sensors	12 months
QC20-W ballbar	12 months

The recommended periods are based on actual performance data.

Recalibration facilities

Laser and ballbar recalibration is available through your local Renishaw contact at facilities in the UK, USA and Germany (with NPL traceability), and Shanghai, PRC (with NIM traceability). Laser calibrations only are available in Japan in association with a third party Japanese accredited laboratory.

The USA facility is A2LA accredited to ISO17025.

All lasers and ballbars returned to Renishaw for recalibration or repair (where recalibration is carried out after the repair), are recalibrated using the same equipment and procedures as used for the original factory calibrations.

Environmental compensators and sensors are calibrated via a direct measurement comparison to a reference system at a single ambient temperature and pressure (compared to multi-point characterisation for the original build). This is an approach used by several NMI and also accepted during the A2LA audit of the USA facility.

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About Renishaw

Renishaw is an established world leader in engineering technologies, with a strong history of innovation in product development and manufacturing. Since its formation in 1973, the company has supplied leading-edge products that increase process productivity, improve product quality and deliver cost-effective automation solutions.

A worldwide network of subsidiary companies and distributors provides exceptional service and support for its customers.

Products include:

- Additive manufacturing, vacuum casting, and injection moulding technologies for design, prototyping, and production applications
- Advanced material technologies with a variety of applications in multiple fields
- Dental CAD/CAM scanning and milling systems and supply of dental structures
- Encoder systems for high accuracy linear, angle and rotary position feedback
- Fixturing for CMMs (co-ordinate measuring machines) and gauging systems
- Gauging systems for comparative measurement of machined parts
- High speed laser measurement and surveying systems for use in extreme environments
- Laser and ballbar systems for performance measurement and calibration of machines
- Medical devices for neurosurgical applications
- Probe systems and software for job set-up, tool setting and inspection on CNC machine tools
- Raman spectroscopy systems for non-destructive material analysis
- Sensor systems and software for measurement on CMMs
- Styli for CMM and machine tool probe applications

For worldwide contact details, please visit our main website at www.renishaw.com/contact

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