Laser measurement system - system architecture

The Renishaw laser measurement system is an ideal solution for the complete calibration of machines, enabling the measurement of a wide range of geometric and dynamic characteristics. It employs a flexible, modular system architecture ensuring that it can best fit your specific measuring requirements, and grow as they grow.

ML10 Gold Standard laser

page 12

EC10 Gold Standard compensation unit

page 13

DX10 Interface (USB)

page 34

LX10 interface unit

page 34

DX10 Interface (USB)

page 34

RS232/IEEE

Desktop PC

Notebook PC

– HP5528 Laser system
– 3rd party electronic levels and digital indicators*

page 34

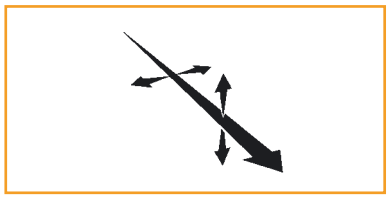
* As an alternative to optics for some measurements and for additional roll measurement.

Measurement options

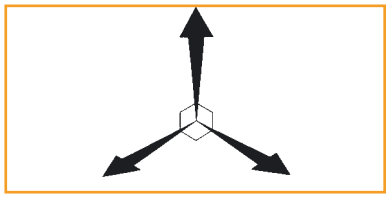
Linear positioning accuracy and repeatability of an axis (page 18)

Angular pitch and yaw of an axis (page 20)

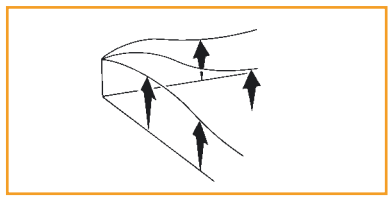
Straightness of an axis (page 22)



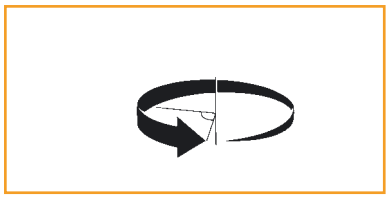
Squareness between axes (page 24)

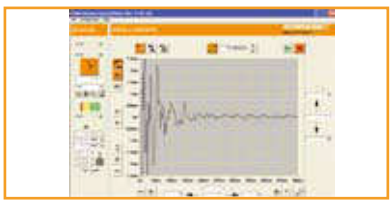


Flatness of a surface (page 26)

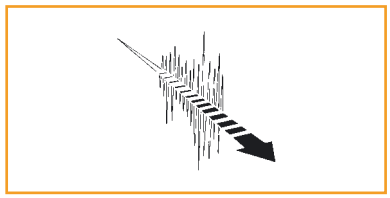


Rotary axis/table angular positioning (page 28)





Dynamic characteristics of a machine (page 17 & 30)



Laser measurement system - the laser and environmental compensation

The ML10 Gold Standard laser measurement system

The ML10 Gold Standard laser represents the ultimate in portable precision laser measurement. With ± 0.7 ppm linear measurement accuracy (not just the frequency accuracy quoted by some suppliers), it combines full traceability with performance that other systems just cannot match. The single frequency laser provides true nanometre resolution measurements at feedrates up to 1 m/s (40 in/s) and can be used for calibrating axes up to 40 m (1600 in) in length (the ML10X can measure axes up to 80 m (3200 in)).

When you purchase a laser system from Renishaw, you are buying the most accurate and flexible system available. You are also buying into a worldwide support network that understands machine metrology, machine service and the demands of maintaining accuracy in a production environment.

Real accuracy . . . where it counts

We believe that you should understand the background to our performance claims, to give you the confidence that the ML10 Gold Standard delivers real accuracy where it counts, in day to day use. The laser wavelength is traceable to internationally recognised length standards. Traceability of every laser is ensured via Renishaw's in-house iodine stabilised reference laser, which is referenced to the UK's National Physical Laboratory (NPL) iodine stabilised reference laser. This provides a recognised association to the network of national standards organisations such as:

- LNE or CTA (France)
- PTB (Germany)
- NIM (China)
- NRLM (Japan)
- IMGC (Italy)
- NPL (India)
- NIST (US)

- **Interferometry is traceable –** all Renishaw's laser measurements, including straightness and angular, are interferometric, and therefore utilise the traceable international standard wavelength of laser light. Other systems which use electronic targets, to measure pitch, yaw and straightness errors, while superficially attractive, often compromise measurement accuracy and stability.

- **Separate interferometer –** Renishaw uses a remote interferometer rather than one mounted on or inside the laser head, to avoid thermal drift.

- **Laser frequency stabilisation –** ± 0.05 ppm over 1 year, ± 0.02 ppm over 1 hr is achieved by thermal control of the laser tubes length to within nanometres.

- **Environmental compensation –** The greatest uncertainty in most laser measurements arises from variations in environmental conditions (air temperature, air pressure, humidity) from nominal values. Under typical conditions these variations can introduce ± 20 ppm uncertainty to a measurement. Renishaw uses very accurate environmental sensors with the EC10 environmental compensation unit. Without accurate sensors and compensation you won't get accuracy, except under controlled laboratory conditions.

- **Operating range –** Great effort has been taken to ensure Renishaw's environmental compensation system and sensors are accurate across the entire operating range of the system, giving uniform ± 0.7 ppm linear measurement accuracy from 0 – 40 °C (32 – 104 °F). This sensor performance is crucial to system accuracy (see graph comparisons with competitor opposite).

The world's leading laser measurement system

- **Performance specifications. -** Renishaw's accuracy specification is derived in accordance with recognised procedures for the calculation of measurement uncertainty (EA - 4/02) for laser stability, sensor output, and all key parameters and calculations affecting the final measurement.

  Overall system accuracy is quoted to the internationally recognised 95% confidence level (k=2) and includes allowance for drift in service.

  Fully documented calculations of the error budget for ML10 and EC10 are available for review.

  Calculations are also available to support the specification of individual measuremant accuracies (eg. angular and straightness).

- **Field performance -** With an installed base of thousands of units worldwide operating over 18 years, our track record shows that Renishaw's laser systems continue to meet specifications day-in day-out, under a wide variety of conditions. This level of performance has been repeatedly verified by third party testing (including national laboratories).

- **Accuracy for all measurements -** Laser linear measurement accuracy is only part of the metrology solution. You can also capture and analyse linear, angular, straightness, squareness, flatness and rotary axis motion with your ML10 Gold Standard system, all using traceable linear measurement as a basis.

The EC10 Gold Standard compensation unit

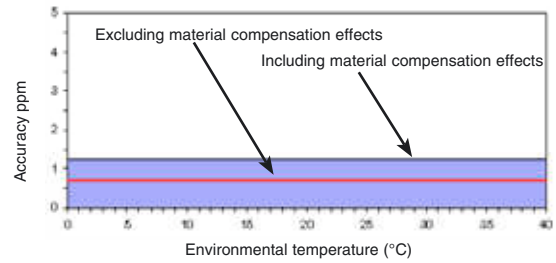
The accuracy of a laser distance measurement system is primarily dependant on how well the system can compensate for the effects of air refraction changes on the wavelength of the laser. Without this compensation, accuracy of any system is significantly compromised. Recognising this fact, Renishaw has designed its environmental compensation unit (EC10) to be extremely accurate.

The EC10 compensation unit continually monitors the surrounding environment by collecting data from highly accurate sensors which measure the ambient air temperature, pressure and humidity. From this data, the unit calculates the true laser wavelength using Edlen's equation.

This compensated wavelength is combined with the fringe count from the ML10 laser to give compensated distance measurements with guaranteed accuracy.

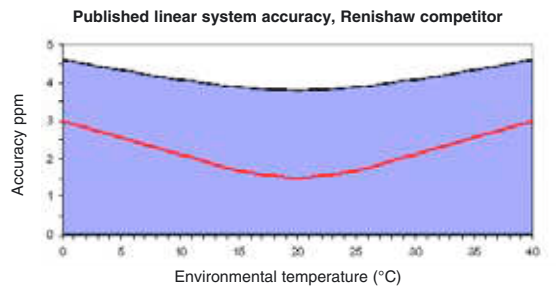
To compensate for a machine's thermal expansion, the EC10 unit can also receive data from up to three material temperature sensors which can be placed in strategic positions on the machine under test. This normalises all readings to a reference temperature of 20 °C (68 °F). Thermal compensation is particularly important when performing linear measurements, especially on large machines or machines made of high expansion materials.

Renishaw linear measurement accuracy*



Laser wavelength accuracy Air	± 0.05 ppm
refraction compensation accuracy	± 0.7 ppm
Renishaw's system accuracy	± 0.7 ppm
Renishaw's material expansion normalisation accuracy @10 ppm/°C	± 1.0 ppm*

Competitor's linear measurement accuracy**



Typical competitor system accuracy	up to ± 3.0 ppm
Typical competitor's material expansion normalisation accuracy @10 ppm/°C	± 3.5 ppm*

* Environmentally compensated linear measurement accuracy.
**Data as of March 2007

Specifications and accuracy to be proud of

ML10 Gold Standard

Specification	
Laser source	Helium Neon (HeNe) laser tube (CLASS II) IEC 60825-1 (2002)
Laser power	<1 mW
Vacuum wavelength	632.990577 nm
Long term frequency accuracy	± 0.05 ppm (parts per million)
Outputs	5 pin 'Datalink'. Optional quadrature output
Power supply	Auto sensing:100-240 VAC (nominal) 50-60 Hz
Operating temperature	0 – 40 °C (32 – 104 °F)
Operating humidity	0 – 95 % non condensing
Weight	Max weight 4.5 kg (9.7 lb)
Dimensions	335 x 176 x 75 mm (13.2 x 6.9 x 2.95 in)

Environmental compensation (EC10)

Specification	Metric	Imperial
Air temperature range	0 – 40 °C	32 – 104 °F
Air temperature accuracy	± 0.2 °C	± 0.36 °F
Air pressure range	750 – 1150 mbar	22.43 – 34.40 in Hg
Air pressure accuracy	± 1.0 mbar	± 0.03 in Hg
Relative humidity range	0 – 95 % (non condensing)	
Relative humidity accuracy	± 15% RH	
Wavelength compensation accuracy	± 0.7 ppm (parts per million)	
Material temperature range	0 – 40 °C	32 – 104 °F
Material temperature accuracy	± 0.1 °C	± 0.18 °F
Power supply	Switchable dual mode 100-120 VAC, 200-240 VAC (nominal)	
Weight	4.0 kg	8.8 lb
Dimensions	335 x 176 x 75 mm	13.2 x 6.9 x 2.95 in

More applications using the ML10 laser system

No matter what the application or industry the ML10 laser measurement system fulfills all of your calibration needs. Although ML10 is the preferred solution for thousands of customers for machine tool and CMM calibration, it has also found applications in a wide range of other markets and industries*.

Wire bonding machine calibration

Problem:

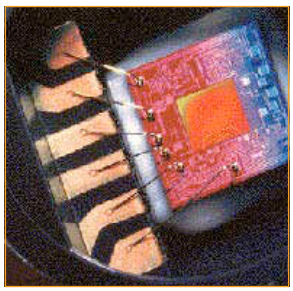
- Wire bonding machines are used to connect electrical wires to silicon chips
- Bond pads are typically < 100 µm square
- Wire bonding machines must operate at high speed (up to 10 bonds/second) and to a positional accuracy of a few micrometres
- 24 hour operation at high speed causes wear and play in bearings and drives

Solution:

- The Renishaw ML10 laser interferometer can be used to check the linear, angular, straightness and squareness motion of the wire bonder's X-Y stage motion

Benefit:

- Higher machine accuracy can be achieved and maintained
- Product integrity and reliability



Wire bonding machine calibration

Printing industry

Problem:

- The printing industry uses drum and flat-bed scanners to digitise high quality original artwork and photographs
- Output is then produced either by direct dye/ink printing onto paper or by UV, thermal or laser writing using plate-setters
- Tiny errors in scanner or writer/print head motion or position will produce banded or poorly registered output

Solution:

- The Renishaw ML10 laser interferometer can identify linear, angular and straightness errors in scanner and writer head motion
- Errors can then be fixed by mechanical adjustment or electronic compensation

Benefit:

- Optimised scanner and laser writer design
- Product validation prior to shipment
- Improved plate quality resulting in improved final print quality

Print industry

LVDT sensor calibration

Problem:

- LVDT sensors and gauges have a non-linear output versus displacement response
- Product requires calibration for traceability and improved accuracy
- Traditional calibration methods used manual "barrel micrometers" which were slow and expensive to maintain

Solution:

- The Renishaw ML10 laser interferometer can be used for automated sensor calibration
- It provides high resolution (1 nm), high accuracy (<1 ppm) linear measurements
- Traceable to national standards

Benefit:

- High accuracy traceable calibration
- Simplifies electronic sensor linearisation
- Reduces costs through faster calibration and elimination of barrel micrometer maintenance charges

LVDT sensor calibration

*More details are available at www.renishaw.com

Laser measurement software -

Laser10 software

Minimum computer requirements

- Windows® XP operating system*
- 1 Ghz processor and 256 MB RAM,
- Minimum screen resolution 1024 x 768 pixels,
- CD-ROM drive for software installation,
- DX10 interface kit (USB) required for data communications with notebooks or desktop PCs.
- An RS232 port or USB-serial adapter will be required if using accessories such as error compensation software, RX10 rotary axis calibrator or the digital indicator interface (ask for details).
- Laser measurement software is supplied on CD-ROM in the following languages:- English, German, French, Italian, Spanish, Japanese, Chinese, Taiwanese, Russian and Korean

Note: *PCM20 available for notebooks using older Windows operating systems.

Software designed with the user in mind

The user interface to the ML10 laser uses dedicated Windows compatible software exclusively developed by Renishaw.

The Laser10 software provides the capability for static and dynamic measurement of a machine's linear, angular, straightness, squareness and rotary accuracy. It is supplied with dynamic, dual axis, digital indicator, electronic level, universal error compensation and on-line help capability as standard.

Flexibility of data collection

To meet the requirements of different applications, the laser software employs an array of automatic and manual data capture methods:

Manual:
Keyboard, remote hand switch.
Automatic:
Time and position based, dynamic, encoder triggered (via the TB10 trigger box).

Simultaneous dual measurement

Data can be collected from two axes simultaneously and then analysed independently.

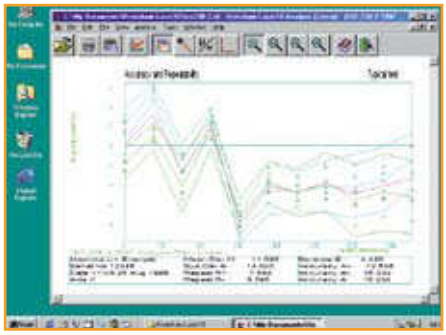
Linking to other instruments

The software is extremely flexible, enabling the capture, storage and presentation of data from supported electronic levels and digital indicators. The captured data can then be analysed in accordance with national and international standards.

Data analysis to international standards

Laser data is analysed to the following standards: ISO 230-2, ANSI B5.54, ANSI B89, VDI 3441, VDI 2617, JIS-B6330 and GB-10931-89.

Operating within the Windows environment, data can be exported into other applications in raw format. Alternatively, analysed data can be cut and pasted into other applications, thus enabling professional presentation of test results.



ISO linear analysis

Integrated help

The full system manual can be integrated with the software, with comprehensive search and index facilities. Making extensive use of graphics it brings full details of system hardware, software and operational use directly to the system operator. The manual is supplied on CD ROM and can also be used on a "stand alone" basis.

*Note that some language versions have a system manual with the key sections translated, all other sections in English.

Laser measurement software -

QuickView™ software

QuickView™ is a simple to use, intuitive software package to capture, review and save dynamic data acquired via the ML10 laser measurement system.

NEW

In conjunction with the DX10 interface kit - a new laser to PC interface - QuickView™ enables users to determine dynamic characteristics of machine tools, CMMs and other motion systems and structures and provides users with the following functionality:

- Live data display in an oscilloscope style format
- Data capture rate of 5 kHz
- Supports measurement with linear, angular or straightness measurement optics
- Three modes of data capture: free running, single shot trigger and multi-shot trigger
- Distance, velocity and acceleration display modes
- User selectable filters of 0, 1, 2, 5, 10, 20, 50 and 100 ms response
- Cursors for measurement of amplitude, time and frequency
- Manual scale, pan and zoom functions allowing 'close up' analysis of selected data
- Auto scale option

Captured data can easily be loaded into supporting applications such as MathCAD, Mathmatica and Excel for further analysis using CSV file format. It can also be loaded into Renishaw's Laser10 software allowing FFT analysis.

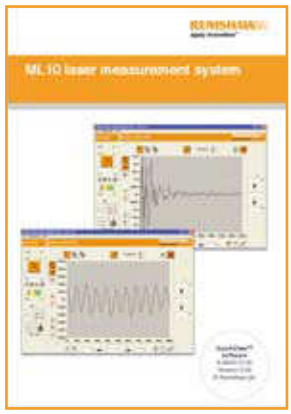
Laser measurement systems have become common place, not just for equipment calibration but also for use as an investigative and analytical tool during development and build processes. Increasingly stringent quality assurance programmes, continued development of higher speed machining processes and the demand for increased reliability and repeatability have all influenced this.

Technological developments within industries such as microelectronics, semiconductor, biomedical and digital imaging have identified a new level of positional and dynamic requirements on a diverse range of machines such as PCB drillers, wafer dicers, pick and place and XY motion stages.

Knowledge of a position sensitive machine's dynamic characteristics - acceleration, velocity, vibration, settle time, resonance and damping - is critical in many applications. These characteristics will influence operational capabilities such as positional accuracy, repeatability, surface finish, throughput and wear.

Recognising the need to identify the dynamic behaviour of machines in a wide range of industries, Renishaw's new QuickView™ software will instantly be recognised as an important and valuable diagnostic tool.

Wafer dicing machine calibration (photograph courtesy of Manufacturing Technology Inc)



Minimum computer requirements

- Windows® XP
- 1 GHz processor and 256 MB RAM
- Minimum Screen resolution 1024 x 768 pixels,
- CD-ROM drive for software installation,
- 1 free USB port
- DX10 interface kit (USB) required for data communications for both notebooks and desktop PC.
- QuickView™ software is supplied on CD-ROM in the following languages:- English, German, French, Italian, Spanish, Japanese, Chinese, Taiwanese, Russian and Korean.

DX10 interface (USB)

Laser measurement system - linear measurement

This is the most common form of measurement performed on machines. The system measures linear positioning accuracy and repeatability by comparing the position displayed on a machine's readout with the true position measured by the laser. These values can then be viewed, printed and statistically analysed by the system's software to national and international standards. On many of today's machine tools, it is also possible to take this process one step further and automatically download the measured data to a compensation table in the machine's controller. In this way, a machine's positioning accuracy can be verified and significantly improved, quickly and easily.

Set-up

The components used in this measurement comprise:

- Linear beam-splitter
- Retro-reflectors
- Targets (for easy optical alignment)

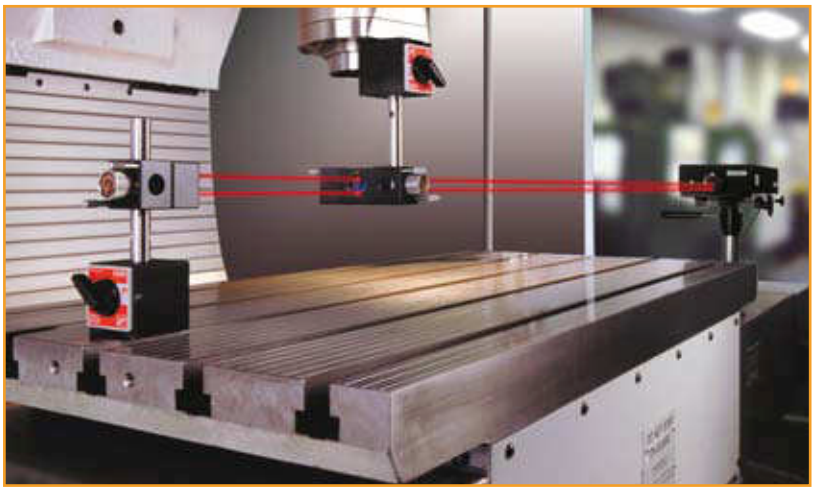
In linear measurement, one retro-reflector is secured to the beam-splitter, to form the fixed length reference arm of the interferometer. The other retro-reflector moves relative to the beam-splitter and forms the variable length measurement arm. The laser system tracks any change in the separation between the measurement arm retro-reflector and beam-splitter.

To mount the optics on a machine, a range of accessories and fixtures is available. There are additional accessories which can be supplied to help measurement set-up and data capture. These are described on the system accessories section on page 32.

When measuring axes of lengths above 40 metres, the long range version of the laser head, ML10X, and patented long range linear optics are required.

Linear optics

Long range retro-reflector and periscope



X axis linear positioning measurement on a VMC

For measurement of dual or tandem drive machines, connect two laser systems together with the DUAL AXIS SOFTWARE. Refer to page 34.

For easier alignment set up use the LS350 beam steerer. Refer to page 32

Before

After

The unique design of linear, angular and straightness optics enables easy interchange for different measurements without having to re-align the laser.

For users with PCB drilling and routing machines.
Sieb & Meyer's error compensation software (V8.66J or later) can accept data output files directly from Laser10's generic error compensation facility.

The power of automatic linear error compensation
With the addition of a linear error compensation package, the data obtained from a calibration cycle is used to calculate compensation values, which can then be fed into a machine's controller. Once the compensation has been completed, a final laser check ensures that a machine's positioning accuracy has been significantly improved. The software is used in combination with the Laser10 calibration software and now includes a "wizard" to make axis compensation even easier.

Compensation packages are available to interface with many of today's machine controllers* including:

- Fanuc OM and OT
- Fanuc 10 - 12, 15, 16, 18, 20 & 21
- NUM 750, 760, 1060.
- Mazak M2, M32, M PLUS
- Siemens 810, 810D, 820, 840, 840C, 840D, 850, 880
- Acramatic 2100
- Cincinnati A850, A850SX, A950
- Combination package (includes all the above)

*Note that error compensation software may not work with "customised" controller specifications.

System advantages

- **Highly durable optics –** the aluminium optics housings, including threads, are all hard-anodised, corrosion proofed and shock resistant.
- **Improved dynamic response –** with less than half the weight of steel optics housings, machine loading is reduced.
- **Quick thermal acclimatisation –** aluminium optics acclimatise 10 times quicker than steel optics.
- **No thermal drift problems –** the interferometer is remote from the heat of the laser head, with the laser heat source remaining outside the machine.
- **Easier set-up –** the remote interferometer can be fitted to specific areas of interest on a machine, without loss of axis travel. This also allows for multiple axis measurements to be made from one position, without the need to re-align the laser.
- **External laser alignment –** tripod mounted laser makes for easy alignment outside the machine.
- **Easier long-range alignment –** the larger retro-reflector gives an easy target to hit and returns more laser light, even in turbulent air.

Specification		Metric	Imperial
Linear measurement	(standard range)	0 – 40 m	0 – 1600 in
	(long range)	0 – 80 m	0 – 3200 in
Accuracy (with EC10 compensator)		± 0.7 ppm (parts per million)	
Resolution		0.001 µm	0.1 µin

Laser measurement system - angular measurement

Pitch and yaw angular errors are among the largest contributory factors to positioning inaccuracy in machine tools and measurement accuracy errors on CMMs.

Set-up

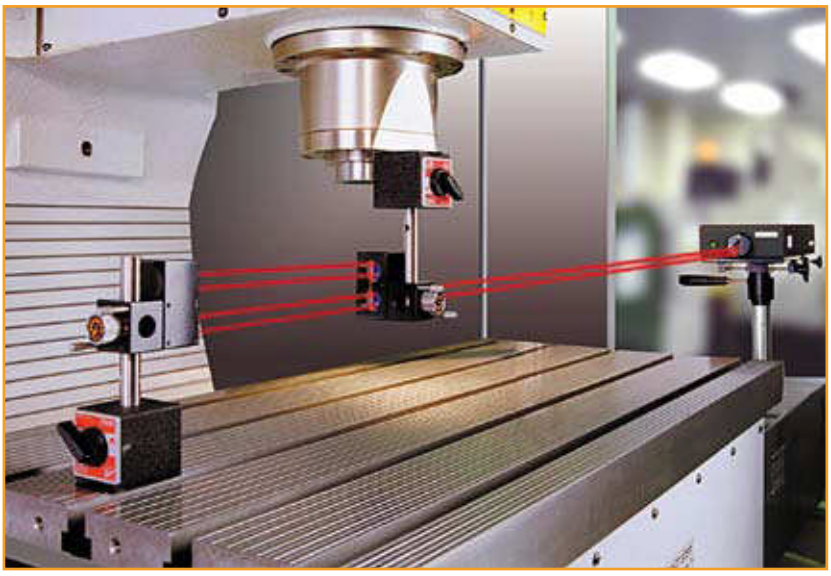
The components used in this measurement comprise:

- Angular beam-splitter
- Angular retro-reflector
- Targets (for easy optical alignment)

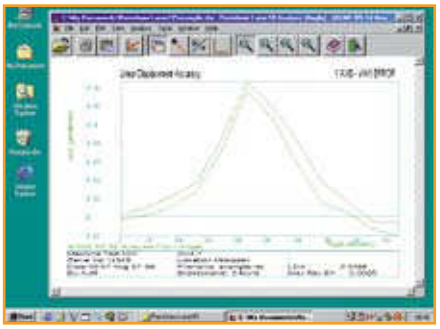
For measurement set-up, the angular beam-splitter optic is best mounted in a fixed position on a machine, for example, the spindle on a moving bed machine tool or granite table on a CMM. The retro-reflector optic is then mounted to the moving part of the machine, for example, the moving bed of a machine tool or probe-head of a CMM. The measurements are made by monitoring the change in relative angle between the beam-splitter optic and the reflector optic.

Angular optics

For single set-up of both linear and angular measurements, contact us to find out more about our special optics combination kits.



X axis pitch measurement on a moving bed VMC



A typical plot captured when performing an angular measurement.

For easier angular alignment set-up use the LS350 beamsteerer.
Refer to page 32

Angular optics can also be used to measure the flatness of CMM table and surface plates.
Refer to page 26.

Rotary axes can also be calibrated using angular optics in combination with the RX10 rotary indexer. Refer to page 28

System advantages

All the advantages of linear measurement plus . . .

- **Traceability –** interferometry directly benefits from the traceability of the laser wavelength. PSD/CCD/Quad cell based systems do not.
- **Accuracy –** interferometry offers more accuracy and linearity with less sensitivity to air turbulence noise, compared to PSD/CCD/Quad cell based systems.
- **Easier set-up –** the remote interferometer can be fitted to specific areas of interest on a machine, without loss of axis travel. This also allows for multiple axis measurements to be made from one position, without the need to re-align the laser.

Specification	Metric	Imperial
Axial range	0 – 15 m	0 – 590 in
Angular measurement range	± 175 mm/m	± 10°
Angular accuracy	± 0.6%* ± 0.5 ± 0.1 M µm/m	± 0.6%* ± 0.1 ± 0.007 F arc sec
Resolution	0.1 µm/m	0.01 arc sec

Where M = measurement distance in metres; F = measurement distance in feet
% = percentage of calculated angle
* Higher accuracy angular optics of ± 0.2% can be supplied for a small surcharge

Laser measurement system - straightness measurement

Straightness measurements highlight any bending component or overall misalignment in the guideways of a machine. This could be the result of wear in these guideways, an accident which may have damaged them in some way, or poor machine foundations that are causing a bowing effect on the whole machine. Straightness error will have a direct effect on the positioning and contouring accuracy of a machine.

Set-up

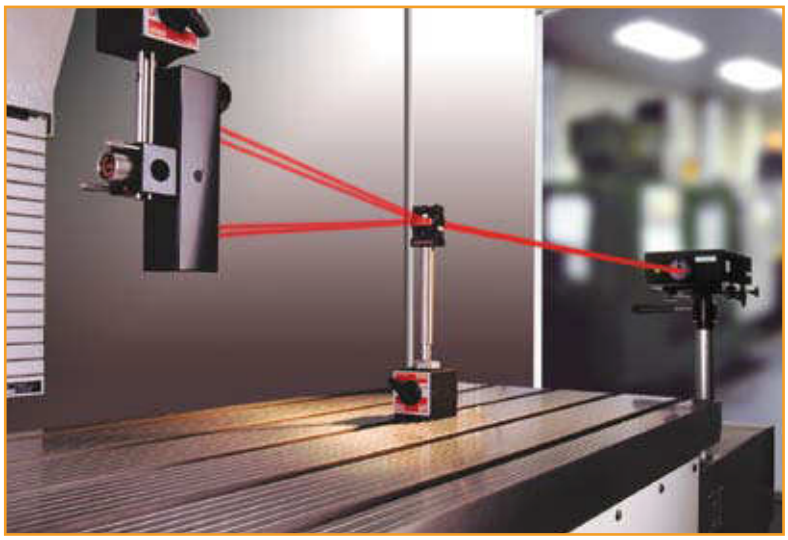
The components used in this measurement comprise:

- Straightness beam-splitter
- Straightness reflector

For measurement set-up, the straightness reflector is mounted to a fixed position on the table even if it moves. The straightness beam-splitter should then be mounted in the spindle. There are two kits available for measuring both shorter axes (0.1 – 4.0 m) and longer axes (1 – 30 m).

Short range straightness optics

Long range straightness optics



X axis straightness measurement on a moving bed VMC

Straightness accessory kit

When measuring vertical straightness in a horizontal axis, or straightness in a vertical axis of a machine, a straightness accessory kit is required for set-up.

This is a typical plot captured when performing a straightness measurement.

If straightness measurements are taken on two axes, it is possible to assess parallelism. It is also possible to measure squareness errors between these axes.
Refer to page 24.

System advantages

- **Easier set-up –** geometry of the patented straightness retro-reflector gives non-overlapping output and return laser beams, making alignment far easier than with other systems.
- **Best long-range performance –** PSD/CCD/Quad cell based systems can suffer from noise and accuracy problems, particularly on long range measurement.
- **Convenience –** moving optics have no cables to drag or snag, for best accuracy and convenience.
- **Flexibility –** the software also supports straightness measurements using digital indicators and straight edges.

Specification	Metric	Imperial
Axial range (short range)	0.1 – 4.0 m	4 – 160 in
(long range)	1 – 30 m	40 – 1200 in
Straightness measurement range	± 2.5 mm	± 0.1 in
Accuracy (short range)	± 0.5% ± 0.5 ± 0.15 M^2 µm	± 0.5% ± 20 ± 0.5 F^2 µin
(long range)*	± 2.5% ± 5 ± 0.015 M^2 µm	± 2.5% ± 200 ± 0.05 F^2 µin
Resolution (short range)	0.01 µm	1 µin
(long range)	0.1 µm	10 µin
Where M = measurement distance in metres; F = measurement distance in feet % = percentage of displayed value; * subject to environmental conditions		

Laser measurement system - squareness measurement

Squareness measurement determines the out-of-squareness of two nominally orthogonal axes, by comparing their straightness values. Squareness errors could be the result of wear in machine guideways, an accident which may have caused damage, poor machine foundations or misaligned home position sensors on gantry machines. Squareness error will have a direct effect on the positioning accuracy and contouring ability of a machine.

Set-up

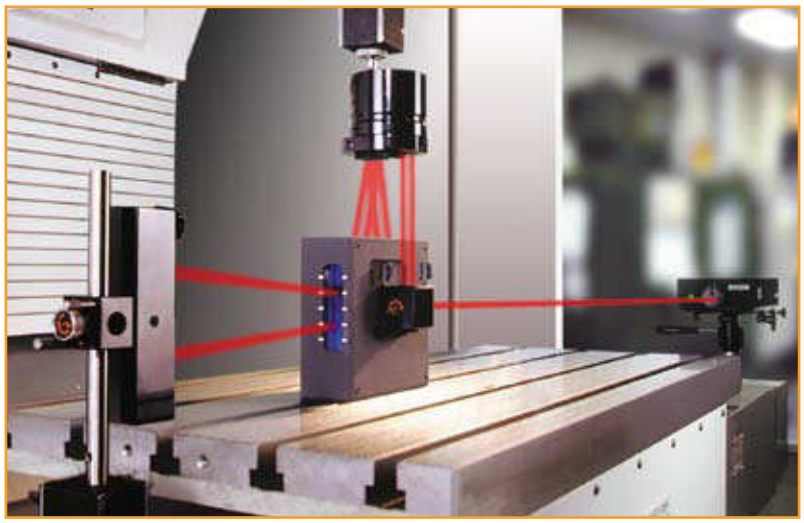
The specific component required for this measurement is:

- Optical square and bracket.

In addition to the optical square, straightness optics and a straightness accessory kit are also required for set-up (see opposite). Other set-up accessories may also be required, depending on what axes are being measured and the configuration of the machine.

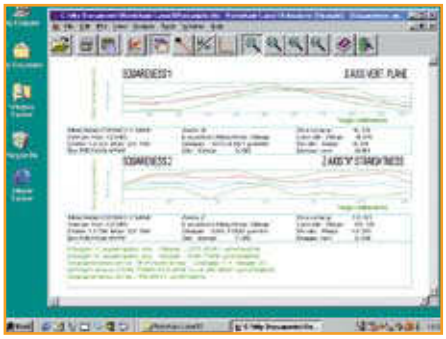
As a quick alternative for measuring squareness on machine tools, why not use the QC10 ballbar?
Refer to page 36.
Or on a CMM use the MCG;
refer to page 42.

Optical square



X-Z axis squareness measurement on a VMC

On smaller machines, the limited working volume can make laser squareness measurement inconvenient. Instead, why not use a granite square and connect a digital indicator to the Renishaw squareness measurement software?
Refer to page 35.



This is a typical plot captured when performing a squareness measurement.

Straightness optics

Straightness accessory kit

System advantages

- **Easier set-up –** geometry of the patented straightness retro-reflector gives non-overlapping output and return laser beams, making alignment far easier than with other systems.
- **Best accuracy –** the optical square provides better accuracy than other systems due to the premium grade optics used(± 0.5 arc sec).
- **Flexibility –** the software also supports squareness measurements using digital indicators and square.

Specification	Metric	Imperial
Range	± 3/M mm/m	± 2000/F arc sec
Accuracy (short range) (long range)	± 0.5% ± 2.5 ± 0.8 M µm/m ± 2.5% ± 2.5 ± 0.08 M µm/m	± 0.5% ± 0.5 ± 0.05 F arc sec ± 2.5% ± 0.5 ± 0.005 F arc sec
Resolution	0.01 µm/m	0.01 arc sec
Where M = measurement distance in metres of the longest axis; F = measurement distance in feet % = percentage of displayed value		

Laser measurement system - flatness measurement

This measurement is performed to check the accuracy of CMM tables and all types of surface plate. It determines whether any significant errors in form exist and, in turn, quantifies them. If these errors are significant to the application of the flat surface, then remedial work, such as further lapping, may be required.

Angular measurement optics are also required to attach to the top of the flatness bases. These are available separately and are shown in the angular measurement section. Refer to page 20.

The angular retro-reflector is mounted on one of three lengths of flatness foot-spacing base. The size of base used depends on the size of surface to be tested and the required number of points to be taken. The angular beam-splitter is mounted on the flatness mirror base.

Set-up

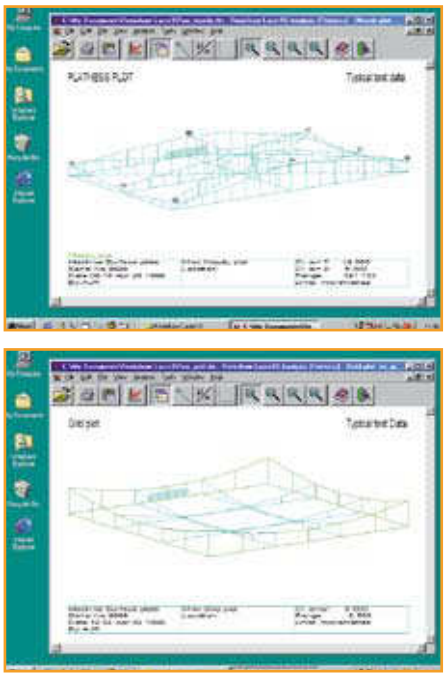
The specific components used in this measurement comprise:

- Base (50 mm)
- Base (100 mm)
- Base (150 mm)
- Flatness mirrors

Flatness mirrors and bases

Angular optics

If you currently use Mahr-Federal Product's electronic levels for flatness measurement, why not connect them to the Renishaw flatness measurement software? Refer to page 35.



These are the typical plots obtained from a flatness measurement. The top graph shows a Moody plot type whilst the bottom shows a typical Grid plot type.

Before making any measurements, a 'map' of the measurement lines should be marked out on the surface. The length of each line should be an integer multiple of the foot-spacing base selected. There are two standard methods of conducting flatness measurements:

a) Moody method – in which measurement is restricted to eight prescribed lines.

b) Grid method – in which any number of lines may be taken in two orthogonal directions across the surface.

System advantages

- **Reduced thermal drift –** the interferometer is remote from the warmth of the laser head.
- **Traceability –** interferometry directly benefits from the accuracy and traceability of the laser wavelength. PSD/CCD/Quad cell based systems do not.
- **Easier set-up –** the flatness mirrors are non-slip and fully adjustable for both pitch and yaw for simple, quick alignment.
- **Flexibility –** the software supports flatness measurement using electronic levels. It can also support both Grid and Moody plot techniques.
- **Single laser positioning –** all measurement lines can be achieved from a single laser position.

Specification	Metric	Imperial
Axial range	0 – 15 m	0 – 590 in
Flatness measurement range	± 1.5 mm	± 0.06 in
Accuracy	± 0.6%* ± 0.02 M^2 µm	± 0.6%* ± 0.08 F^2 µin
Resolution	0.01 µm	1 µin
Where M = length of the diagonal in metres; F = length of the diagonal in feet % = percentage of calculated flatness * Higher accuracy angular optics of ± 0.2% and better can be supplied to special order		

Laser measurement system - rotary measurement

On many machines, the accuracy of a rotary axis is important to overall machine accuracy. This could be the rotary axes on 4 and 5 axis machine tools or the rotary table on a CMM. In line with the fundamental importance of rotary axis accuracy, recent national and international standards have made strong provision for their measurement. It is for this reason that Renishaw developed a specific rotary axis calibration system, the RX10, to be used in conjunction with its laser system.

The RX10 system has revolutionised measurement of rotary axes. Automated testing now enables rotary axes to be checked in just 25 minutes and at any angular position. This represents a massive time saving of more than 5 hours over traditional methods such as auto-collimators and optical polygons.

For automatic calibration of rotary tables or axes that lift before rotating, ask about our lifting table accessory kit.

Set-up

The components used in this measurement comprise:

- RX10 rotary indexer
- RX10 controller/power supply

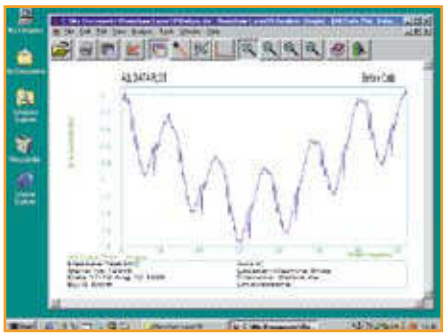
Angular measurement optics are also required to attach to the top of the indexer. These are available separately and are shown in the angular measurement section. Refer to page 20.

The RX10 features an extremely accurate Hirth coupling design that guarantees quality and reliability of the indexer along with the accuracy of the laser. With its built-in calibration routine, centring and other set-up inaccuracies are easily eliminated. The system will operate horizontally, vertically or even upside-down for easy calibration of different orientations of rotary axis.

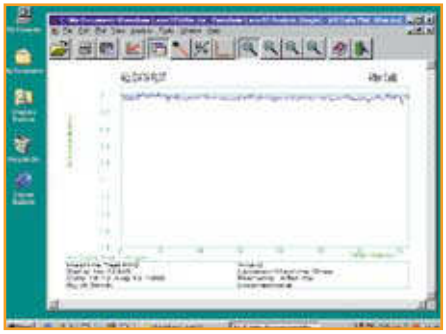
RX10 rotary indexer

Controller / power supply

Hirth coupling



Before



After

The two graphs show errors in a rotary axis both before calibration and after repair work has been carried out.

A rotary axis can be calibrated in five easy steps:

1 Attach a standard angular retro-reflector to the RX10 rotary indexer.

2 Attach the RX10 rotary indexer to the axis under test by clamping the mounting plate to the table.

3 Attach the angular beam-splitter optic to a stable independent mounting.

4 The rotary axis is calibrated by rotating it sequentially through a number of angular targets as pre-selected in Renishaw's calibration software. Laser readings are taken at each position.

5 As the axis rotates, the RX10 rotary indexer is counter-rotated automatically to ensure that the laser beam is returned back to the laser.

Recent international standards state that a rotary axis should be calibrated in a number of ways, which include:

- 0.1^{o} increments through 5^{o}.
- 3^{o} intervals through 360^{o}.
- At 0^{o}, 90^{o}, 180^{o} and 270^{o} positions and nine further random angular positions through 360^{o}.

It is extremely difficult, if not impossible, to complete these measurements using auto collimators and optical polygons.

System advantages

- **Easier set-up –** the indexer performs an automated calibration routine to eliminate set-up errors, therefore there is no need to accurately centre the system.
- **Quick, automated calibration –** the indexer is motorised for lock, unlock and rotate movements to enable automatic alignment and tracking without any operator or machine intervention (ideal for CMMs).
- **Flexibility –** can calibrate any angle with accuracy, even multiple revolutions.

Specification	Metric	Imperial
Angular range	unlimited	
Indexing accuracy (Standard)	± 5 µm/m	± 1 arc sec
Repeatability	1 µm/m	0.2 arc sec
Mounting	Top or bottom faces for spindle or table location	
Operation	Vertical or horizontal	
Control	Automatic via RS232 to PC	
Operating temperature	0 – 40 °C	32 – 104 °F
Max velocity of indexer table	30 rpm when the measurement step size is less than 10 degrees 2 rpm when measurement step size is more than 10 degrees	

Laser measurement system
Dynamic measurement

The dynamic measurement capability of Renishaw's laser system adds a new dimension of flexibility and power. In addition to the traditional static tests it enables dynamic measurement of the motion characteristics of machines and motion systems to be made. Only specialised equipment can normally pinpoint such characteristics. This greatly extends the capability of the laser system and makes it an essential tool in machine condition monitoring programmes.

This software can be used to evaluate acceleration, vibration, velocity and servo control performance. This is extremely useful for assessing the performance of many different types of motion systems used in industry (not just CMMs and machine tools). Examples of other machines that can benefit from dynamic measurement include:

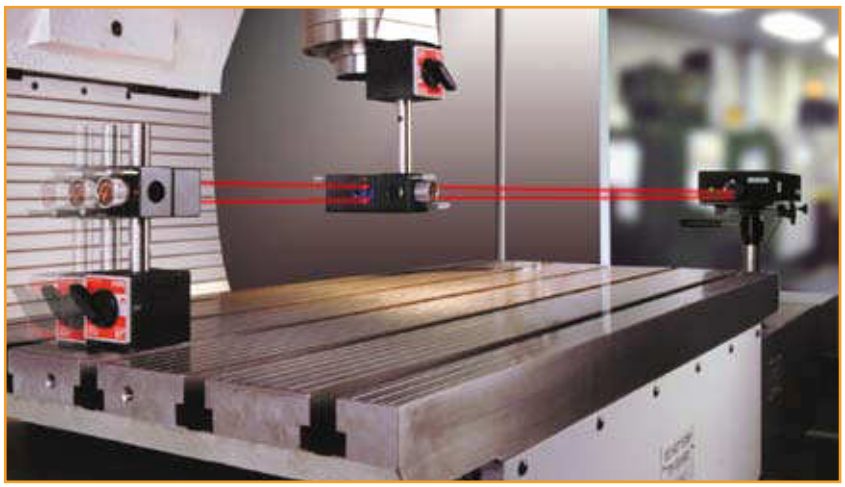
- Robotic pick and place machines
- Surface mount machines
- PCB drilling/routing machines
- PCB printing machines
- Optical stages
- Printing presses
- Hydraulic and pneumatic systems
- Reciprocating and positioning systems

This measurement capability is supplied as part of the standard Laser10 software package and requires no additional hardware other than the optics for the specific measurement being performed.

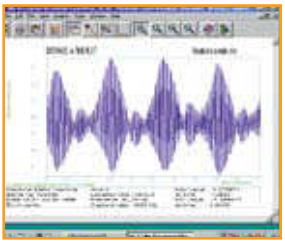
X-Y stage.
(photo courtesy of Danaher Precision Systems)

These dynamic measurements allow certain machine error characteristics to be highlighted and quantified. For example:

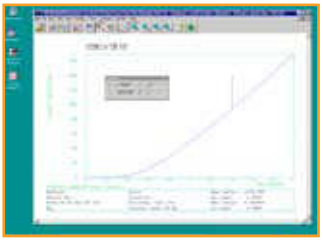
- Pre-load and hysteresis of ballscrew and nut mechanisms
- Positional stability and encoder performance
- Resonance characterisation of drive motors, spindles and other systems
- Feedrate accuracy, stability and interpolation accuracy
- Control-loop optimisation



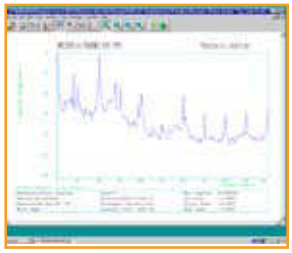
For real-time "oscilloscope style" display of live position velocity or acceleration data refer to QuickView™ software on page 17



Vibration analysis



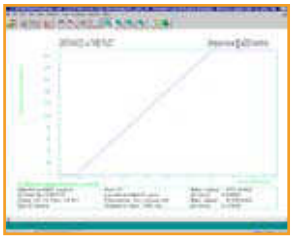
Servo response analysis



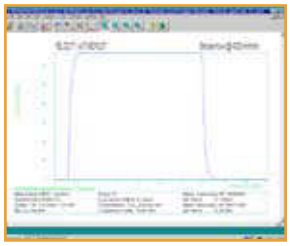
FFT frequency analysis

Using the dynamic measuring capability, the following measurements can be performed:

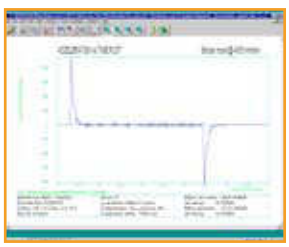
- Displacement against time
- Velocity against time
- Acceleration against time
- Vibration amplitude and frequency



Displacement against time



Velocity against time



Acceleration against time

Used in conjunction with the TB10 trigger box, dynamic software is ideal for inspecting ballscrew assemblies.
Refer to page 33.

System advantages

- **Powerful vibration analysis –** integrated FFT (Fast Fourier Transform) routines give a detailed frequency spectrum enabling identification of vibrations and pinpointing their source.
- **Optics versatility –** the software supports dynamic data capture and analysis using linear, angular or straightness optics.
- **High capability –** using a single frequency laser system provides true nanometre resolution at feedrates up to 1 m/s, with 5000 Hz sample rate and no acceleration limit.
- **Flexibility –** data can be taken in response to internal timebases, or in synchronisation with external triggers at rates up to 4000 Hz.

Specification	Metric	Imperial
Sampling rates	10 – 5000 Hz	
Linear displacement accuracy	± 0.7 ppm (parts per million)	
Linear velocity accuracy	± 0.01%	
Linear acceleration accuracy	± 0.01%	
Linear resolution	0.001 µm	0.04 µin
Maximum velocity	60 m/min (1 m/s)	2400 in/min (40 in/sec)
Time accuracy	± 0.18%	
% = percentage of displayed value		

Laser measurement system - system accessories

Optics accessories

LS350 beam steerer
This unique patented optic provides easy angular adjustment of the laser beam in both horizontal and vertical planes, making laser alignment a simple one step process. The beam steerer speeds up linear, angular and straightness measurements, whether in-line or at 90°. The optic is also compatible with the linear/angular combination kit and swivel/fixed turning mirrors. Clamping screws allow the beam steerer to be easily attached to measurement optics.

Specification	Metric	Imperial
Steering angle range	± 35 mm/m	± 2°
Steering linear range	0 - 10 m	0 - 33 ft

Swivel mirror
This mirror can be used as an alignment aid for ANSI B5.54 diagonal measurements. It is also useful when measuring slant-bed lathes. Clamping screws allow the mirror to be easily attached to measurement optics.

Fixed turning mirror
This mirror reflects the laser beam through 90°. Like the swivel mirror, it can be attached to the measurement optics to aid optical set-up and is used primarily when there is restricted access to the required axis of measurement.

Optics mounting kit
This kit provides the essential elements required to mount the Renishaw optics to a machine. Optics can be easily interchanged without the need to re-align the laser. It comes with hard anodised aluminium mounting blocks, stainless steel pillars and bases for the optimum combination of portability and durability. They also incorporate M8 threads for attachment to standard magnetic bases or Renishaw's CMM probe heads.

Tripod

Compact tripod
This tripod can be supplied with a small carrying case, which is both rugged and lightweight.

Note: the mounting stage for the tripod is stored in the Supercase (see opposite).

Cases

Portability of laser measurement systems is extremely important. This is especially true for mobile calibration companies or organisations based in a number of different geographical locations. Renishaw's laser system has been designed with this in mind and comes with a range of carrying cases to complement the size of system.

Supercase kit
This case is capable of housing the comprehensive range of optics and equipment of the laser system. This includes ML10 laser head, EC10 compensation unit and all optics kits, sensors, cables and the tripod stage. It is extremely durable, with built-in dust and pressure seals, giving the best protection to the system. It comes with an accompanying cart, which attaches directly to the case, and padlock for added security. The compact tripod can also be carried with the case on the cart to provide easy portability of the complete system.

Large carrying case
This case can house an ML10 laser head, EC10 compensation unit and sensors, cables, linear optics, angular optics and flatness kit.

Small carrying case
This case is designed to hold either an ML10 laser head or EC10 compensation unit along with environmental sensors.

Optics carrying case
This carrying case can hold the straightness and squareness optics and their associated accessories.

Supercase kit

Case and cart

Data capture accessories

Hand held switch
This enables remote datuming of the laser and manual data capture. It is ideal in applications where the machine's controller is far from the point of test. It has a built-in delay to prevent accidental datuming and comes with 10 metres of cable which may be extended in 5 metre increments, if necessary.

TB10 quadrature trigger box
This device monitors the position feedback signals between a machine's encoders and its controller and feeds trigger signals to the Renishaw laser system. This allows synchronisation of data capture from the ML10 laser head to encoder position or movement.

It is primarily used in applications such as 'on-the-fly data capture' or for monitoring encoder errors, so a machine can be driven along an axis without stopping to collect data for position, angle, straightness etc. This mains-powered unit works with RS422 quadrature or analogue current loop encoders and triggers the laser measurement at regular user-defined intervals.

TB10 quadrature trigger box

Laser measurement system - system interfacing

Laser interfaces

DX10 interface kit (USB)

The DX10 replaces the PCM20 (PCMCIA) card as the standard interface offered for ML10 and EC10 to PC communications. It is equally suitable for laptop and desktop PCs. The DX10 is a compact and reliable high speed USB communications device, transmitting high resolution data at 5 kHz directly to Laser10 and new QuickView™ software.*

The DX10 is compatible with Windows® XP, including SP1 & SP2, but is not compatible with earlier versions of Windows operating system.

The DX10 interface kit (USB) includes;

- DX10 interface (USB)
- 3 metre USB cable
- DX10 driver installation CD-ROM

Dual axis measurement

In some installations, one axis is controlled by two drives and two feedback systems (eg “SPAR MILL” and large dual beam type CMMs). In this instance, a second laser, optics and DX10, coupled with dual axis software, provides the capability to automatically capture data of parallel axes simultaneously.

Dual axis measurement software is included as standard with Laser10 software.

PCM20

For use on notebook PCs where USB and / or Windows® XP is not available the PCM20 is a PCMCIA PC Card (type II) interface, which supports data capture at 5 kHz, at feedrates of 1 m/sec, whilst still maintaining true nanometre resolution.

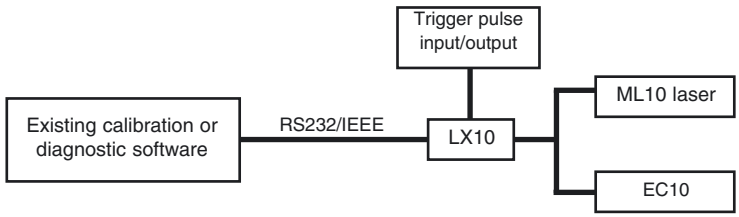
PCM20 Interface

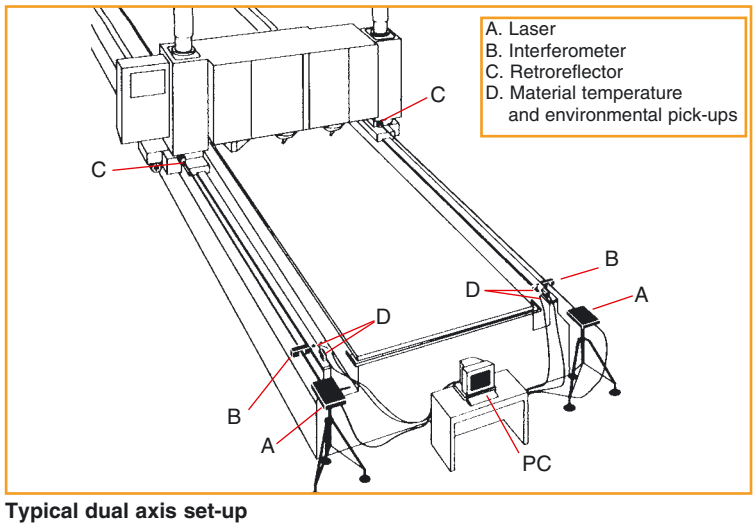
LX10: interfacing with HP5528 software†

The LX10 takes ML10 and EC10 signals and outputs these in HP5528 signal format, with no loss of resolution or accuracy. This allows HP users to upgrade to the benefits of ML10 laser system ownership without having to modify existing custom software written for HP5528 input.

(NB. Dynamic mode not supported via LX10).

LX10





Typical dual axis set-up

* For users who want to interface with 3rd party custom software then a software developer’s kit (SDK) is available for use with DX10. The SDK is COM based and developed for use with VB6, C++ and C#. Please ask for further details. † LX10 for HP5528 emulation.

Instrument interfaces

Instrument interfaces give you the capability of displaying, recording and analysing your data, using Renishaw's calibration software.

- Access Renishaw's powerful suite of software* for angle, straightness and flatness data capture when using electronic levels or digital indicators.
- Analyse data to national and international standards.
- Unified presentation of calibration graphs, whatever the measurement technique.
- Offers a consistent user interface.
- Single location for data storage, retrieval and back-up.
- Increase your choice of measurement instruments, allowing your preferred method to be assigned to each measurement.

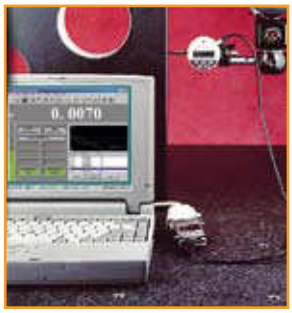
* Excludes dynamic.

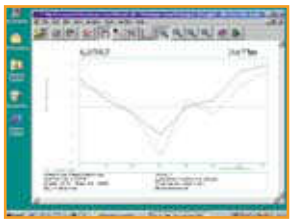
Digital indicator interface

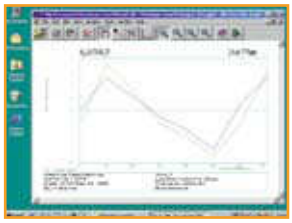
This interface accepts data from both the Mahr-Federal Product's μMAXμM and Mitutoyo's Digimatic digital indicators. Output data from the indicator through a specially developed interface, is automatically converted into a format which can be used by Renishaw's calibration software (included with Laser10). The serial adaptor cable is available as a separate item.

What can you measure?

- Axis straightness – using a digital indicator and straight edge.
- Axes squareness – using a digital indicator and square.
- Axis roll – using two digital indicators, straight edge and dual axis software.
- Linear repeatability, backlash and drift tests – using a digital indicator.





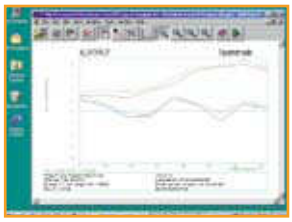


Mahr-Federal products 832 amplifier interface

This interface accepts data from a (Mahr-Federal Product's 832 Series) amplifier and its associated electronic levels and gauges. Output data from the amplifier is transferred directly to Renishaw's calibration software via the serial port of a PC and special translation software (included with Laser10). The serial adaptor cable is available as a separate item.*

What can you measure?

- Axis straightness – using electronic gauge and straight edge.
- Axes squareness – using electronic gauge and square.
- Horizontal axis pitch and roll – using electronic levels.
- Vertical axis pitch and yaw – using electronic levels.
- Vertical axis roll – using twin electronic gauges and straight edge.
- Surface flatness – using electronic levels.



*Note: These interfaces do not include any third-party instruments or Renishaw's calibration software which can be purchased separately.