RENISHAW
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High-precision laser interferometer feedback systems

Product scope

In today's semiconductor and electronics marketplace, many manufacturing equipment suppliers are having to adopt 'more for less' strategies to retain a competitive edge. This has resulted from the continual drive to accommodate smaller feature sizes, increase throughput and reliability whilst simultaneously decreasing equipment footprints and costs. These requirements impact on every component integrated into the final system.

For providers of position encoders this means ongoing OEM demand for higher system resolution, velocity and accuracy specifications, coupled with rapid installation times, low initial purchase price and low cost of ownership.

Renishaw offers motion system equipment vendors a range of complementary solutions that can be effectively applied to address these issues, over a broad range of applications, within many industrial sectors.

This document provides details on the range of laser interferometer based encoders and related systems available from Renishaw. It also provides an overview of linear and rotary encoder products, and the laser interferometer calibration system. A summary of each of these product ranges follows.

Laser interferometer based feedback systems

- Provides interferometer performance (sub-nanometre resolution) with the ease of use normally associated with traditional, scale based encoders.

Linear and rotary encoders

- A diverse selection of high speed linear encoders, high precision angle encoders, magnetic rotary encoders and interpolators.

Laser interferometer calibration system

- Providing ±0.5 ppm linear measurement accuracy. Optical accessories available allow the determination of a machine's linear, angular, straightness, squareness and rotary accuracy.

System development

ML10 calibration laser

HS10 laser scale

Dual axis RLE system

XL-80 calibration system

Experts in interferometry

Renishaw began manufacturing the world leading ML10 interferometer based calibration system in the late-1980s, and has recently introduced the next generation solution, the XL-80.

The success of the ML10, combined with Renishaw's unsurpassed reputation in the field of metrology, led the machine tool and aerospace industries to request a Renishaw laser system suitable for positional feedback applications. Consequently, during 1994, utilising the field proven technology of the ML10, the HS10 laser scale was released. This robust unit consistently confirmed its reliability, operating in inhospitable machine environments worldwide on axis lengths to 60 m.

In 2001, the RLE10 opened up the world of interferometry to applications which were previously unable to use laser interferometer based encoders: traditional integration barriers associated with conventional interferometer systems were entirely eliminated with the release of Renishaw's new fibre optic based system.

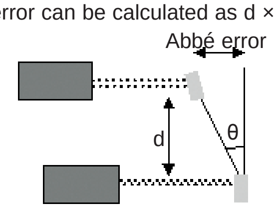
The RLE range now includes a range of complementary components allowing configuration of the ideal solution on an application-by-application basis.

Why interferometry?

Laser interferometers provide the highest positioning accuracy for your motion system:

- **Interferometers have an intrinsically high resolution** - The measurement reference of the RLE interferometer is the internationally recognised wavelength of Helium Neon (HeNe) laser light. At 633 nm, this is much finer than the pitch of typical scale gratings used in many optical encoder systems. This enables the RLE to easily achieve high resolutions, free from the sub-divisional (interpolation) errors experienced when using conventional encoders.
- **Interferometers have the ability to eliminate Abbé errors** - Mechanical constraints often necessitate that conventional encoders are mounted around the periphery of the working zone. The resulting offset, between the measurement axis and the work surface, leaves system accuracy extremely sensitive to any pitch or yaw errors within the motion system. In contrast, the absence of the mechanical scale and the ability to measure off a plane mirror target optic, allows the laser interferometer to take measurements directly in line with the work-piece, thereby avoiding Abbé offset and the sensitivity to axis pitch and yaw.

  Abbé error can be calculated as d × Sine θ

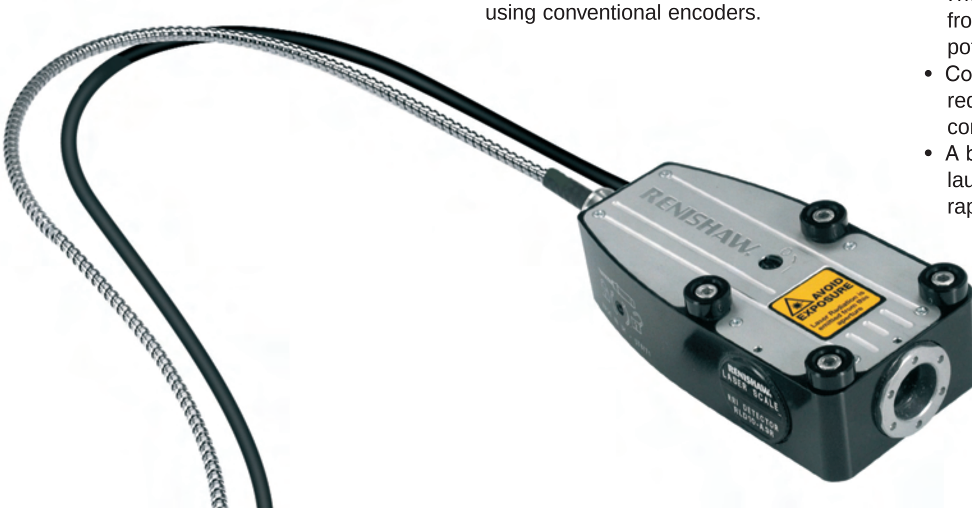


Overcoming traditional barriers

Conventional laser interferometer schemes use separate laser heads, interferometers, reflectors and detector units. The laser beam is routed between these isolated components by a complicated network of beam splitters and benders, resulting in a bulky, complex, system which is time consuming and difficult to set-up, align and maintain.

The RLE uses optical fibres to deliver the laser beam directly to remote launch units which also contain the interferometer optics and detector. This method gives the RLE a number of crucial advantages that minimise integration time and hence cost.

- System footprint is dramatically reduced - only the reflector and miniature launch unit are mounted on the motion system.
- The laser head can be mounted remotely from the measurement axis, eliminating a potential heat source.
- Complicated beam routing optics become redundant, reducing alignment to just two components.
- A beam steerer, incorporated into each launch unit, provides beam adjustment for rapid alignment to the axis of motion.



Introduction to the RLE

The RLE system is a unique, advanced homodyne laser interferometer system specifically designed for position feedback applications.

Each RLE system consists of an RLU laser unit and one or two RLD10 detector heads, the model of which is dependent upon the requirements of the specific application.

The system provides the user with sub-nanometre resolution capability at velocities of up to 2 m/sec (80 inch/sec) for axis lengths of up to 4 m (160 inches).

To maximise application flexibility, all RLE system components are compatible, enabling the best solution for individual applications to be selected at component level. The range of user selectable components within the RLE system includes two laser units and six RLD10 detector heads.

RLU laser units

The laser unit is the heart of the RLE system, containing the HeNe laser tube, the fibre optic launch and the majority of the system electronics.

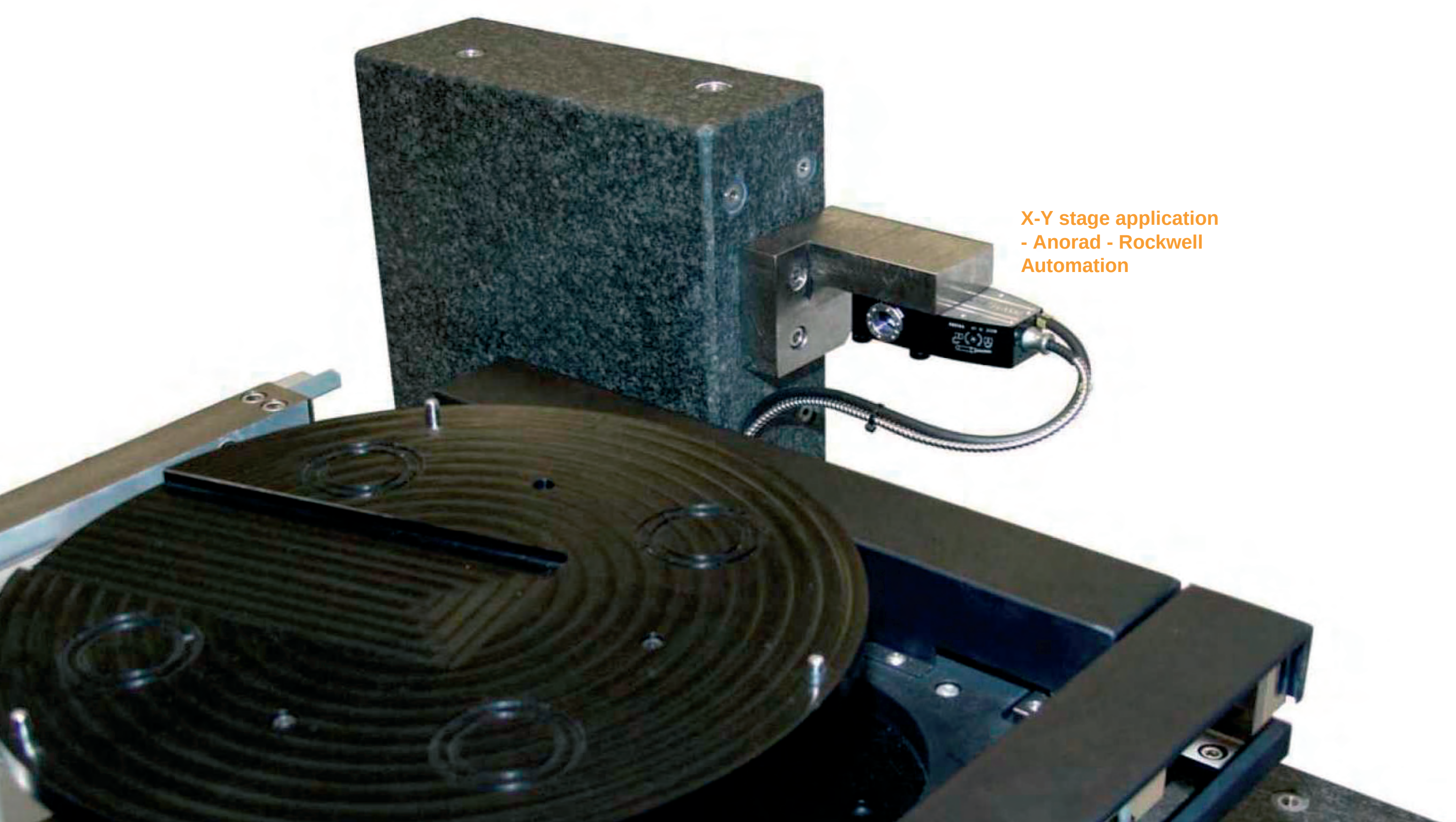
Due to its fibre optic launch method, the RLU laser unit can be mounted remotely from the precision motion stage thereby eliminating a potential heat source without any increased demands on alignment stability. This ensures reliable operation.

The position output from the RLU is directly available in differential digital RS422 format and/or 1 Vpp analogue sine/cosine formats. From the digital output, resolutions to 10 nm are available. The signal period for the analogue output is 158 nm when using a double pass plane mirror or differential interferometer, and 316 nm for a single pass retroreflector based system. Optionally, the RPI20 parallel interface can be used in combination with the analogue output to provide resolutions to 38.6 picometres.

Two RLU models, referred to as RLU10 and RLU20, are available with frequency specifications of ±50 ppb and ±2 ppb over one hour respectively. Accordingly, the system is referred to as either RLE10 or RLE20. (RLE10 systems incorporate an RLU10, RLE20 systems an RLU20.)

RLE10 laser system

RLU10 laser unit



X-Y stage application - Anorad - Rockwell Automation

Introduction to the RLE

RLD detector units

Most RLD10 detector units contain the fringe detection scheme, interferometer optic and integrated laser beam steerer(s). Six different RLD detector heads are available based on four variants.

- **Single pass interferometer** - Uses an external retroreflector target optic for linear applications with axis lengths to 4 m. Available with 0º or 90º beam launch orientation. Directly produces a sinusoidal output with a signal period of 316 nm that enables digital quadrature resolutions to 20 nm to be provided. Optionally, the RPI20 parallel interface can be used to extend resolution (LSB) to 77.2 picometres.
- **Double pass interferometer** - Requires an external plane mirror target optic for X-Y applications with axis lengths to 1 m. Available with 0º or 90º beam launch orientation. Directly produces a sinusoidal output with a signal period of 158 nm that enables digital quadrature resolutions to 10 nm to be provided. Optionally, the RPI20 parallel interface may be used to extend resolution (LSB) to 38.6 picometres. Low power dissipation models (0.14 W) are also available.
- **No internal interferometer** - The absence of interferometer optics within this head enables the RLE system to be utilised with external optics to perform linear, angle and straightness measurements. Only available with 0º beam launch orientation.
- **Double pass differential interferometer (column reference)** - Requires external plane mirror targets for both reference and measurement interferometer arms for X-Y applications with axis lengths to 1 m. The reference arm should be a fixed distance of up to 0.5 m. Produces a sinusoidal output with a signal period of 158 nm, enabling digital quadrature resolutions to 10 nm. Use of the RPI20 parallel interface will extend resolution (LSB) to 38.6 picometres.

  As the measurement and reference beam paths have an element of commonality, this detector head offers a number of benefits.

- Measures stage versus column or workpiece versus tool for a true differential measurement.
- Removal of errors due to thermal translation of the interferometer mounting position.
- Minimisation of the effects of laser frequency instability as the differential path length (between measurement and reference paths) is reduced.
- Common mode environmental effects enable the detector head to be mounted outside the process chamber with minimal affect on positioning accuracy.

RLE system benefits

The unique fibre optic launch based architecture allows the RLE to provide interferometer system performance with the ease of use normally associated with glass or tape scale based encoder systems.

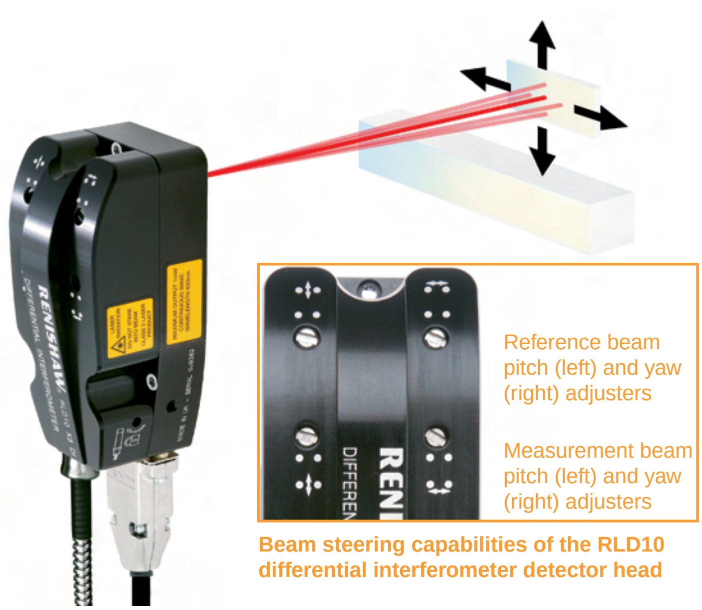
Architectural advantages are achieved through a combination of the following features:

- **Fibre optic laser launch** - Enables the laser light to be taken directly to where the axis position needs to be measured, eliminating the requirement for remote beam benders, splitters and associated mounts. Installation time and alignment complexity are significantly reduced whilst the reduction in space required around the motion system for laser beam paths can provide an opportunity for substantial footprint reduction.
- **Integrated laser beam steerers** - Incorporated in all RLD10 detector heads to further reduce alignment complexity.
- **Integrated interferometer optics** - Most RLD detector heads include pre-aligned interferometer optics and fringe detection system, making installation a case of simply aligning the RLD10 head with the target optic fitted to the moving element. This is an operation not dissimilar to aligning a readhead and scale on a linear encoder system.
- **Removal of potential thermal error source** - The fibre optic launch enables the RLU laser head to be mounted in a location that is insensitive to the heat dissipated, without affecting laser alignment complexity or alignment stability requirements.

RLD10 single pass interferometer

RLD10 double pass interferometer

RLD10 differential interferometer



Beam steering capabilities of the RLD10 differential interferometer detector head

21st century homodyne interferometry

Unique fringe detection system

Every RLE interferometer system comprises a combination of RLU laser unit and RLD detector head(s). The RLD detector head contains the interferometer (single pass, double pass or differential), laser beam steerer and fringe detection scheme. Figure 1 shows a schematic of a double pass interferometer RLD detector head.

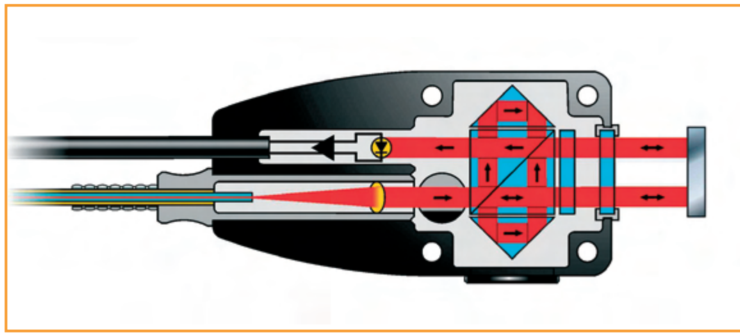


Figure 1: RLD detector head

The unique fringe detection scheme includes a multi-channel integrated photodetector. This advanced approach to homodyne fringe detection is fundamental to the superior performance provided by RLE systems.

The multi-channel photodetector (see figure 2) enables simultaneous real-time production of sine, /sine, cosine and /cosine. In addition, this approach minimises alignment sensitivity (see figure 2, page 7) and reduces interferometer system footprint.

Within the detection system, the individual, orthogonally polarised, reference and measurement beams are recombined and overlaid by an optical wedge. Here the coherency of the two beams causes the wavefronts to interfere (as shown in figure 5). Bright interference fringes appear where intersecting wavefronts are in phase with each other. Dark fringes are generated when the wave fronts are in anti phase. Adjacent bright and dark fringes are separated in phase by 180º.

The sinusoidal interference pattern produces four simultaneous real-time outputs of sine, /sine, cosine and /cosine from the integrated photodetector, shown as A, B, C and D (in figures 4 and 5), representing a sampling of the interference pattern at four points across the 360º fringe separations.

Following fringe detection, the signals are processed by a combination of pre-amplifiers and differential amplifiers. The differential stages amplify the difference voltage between the two inputs of sine, /sine, cosine and /cosine. This removes any DC offsets, generating sine and cosine signals equal to the phase difference alone and independent of any common signal noise.

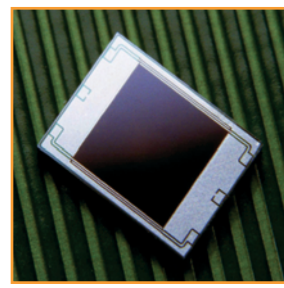


Figure 2: multi-channel photodetector

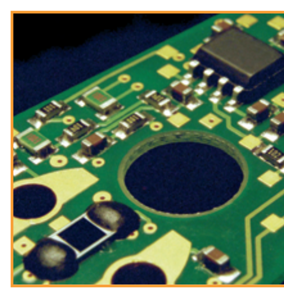


Figure 3: photodetector PCB from detector head

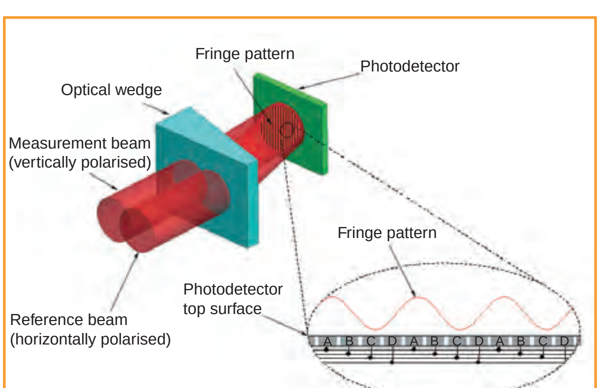


Figure 4: optical wedge and interference patterns

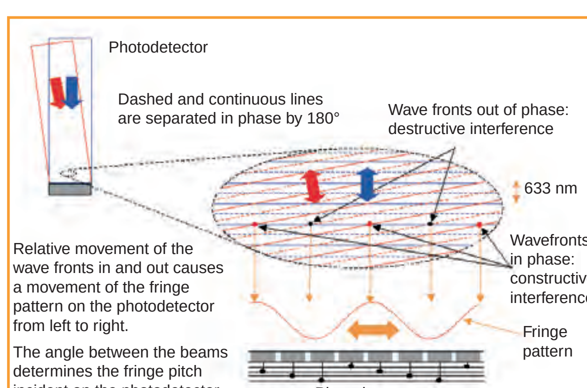


Figure 5: constructive and destructive interference

21st century homodyne interferometry

RLE performance summary

The technology applied within the RLE system provides a versatile, easy to use interferometer system for position feedback applications with axis lengths to 4 m.

As previously shown, a distinct advantage of the homodyne technique is the fact that the fringe detection system produces ‘industry standard’ analogue sine and cosine signals in real-time. These low noise analogue signals are made directly available to the user and may be interpolated within the motion control system or using the Renishaw RPI20 (see page 9) to produce sub-nanometre resolutions.

For applications where sub-nanometre resolution is not required, the RLE includes in-built interpolation providing digital quadrature (AQuadB) resolutions to 10 nm at 200 mm/sec.

Analogue sine/cosine interpolation is carried out by digitising the analogue signals. The top bits of this digitised signal determine the current Lissajous quadrant. Additionally, all bits of both digitised sine and cosine results are combined to form an address for pre-programmed ‘look up table’ memories (see figure 1). These memories continuously provide both the fractional Lissajous position and the signal strength.

The accuracy of any laser interferometer system, homodyne or heterodyne, is related to the environment within which it is used, with optimum performance being achieved in vacuum conditions. For non-vacuum applications that do not offer substrate based fudicial marks (that can be used as an ‘artefact reference’ for the position feedback) Renishaw offers the RCU10 real-time compensation system (detailed on pages 11 and 12).

In a vacuum environment, positioning errors (not including effects such as cosine error) are reduced to the frequency instability of the laser system, thermal drift, non-linearity and electrical noise error. The RLE system offers the following performance:

- Frequency stability: <±1 ppb (1 min) <±2 ppb (1 hr)
- Thermal drift coefficient: <50 nm/ºC
- Non-linearity error: <±1 nm
- Electrical noise: <0.2 nm RMS

(Figures based on RLE20 plane mirror system with differential interferometer detector head.)

Additionally, the integrated multi-channel photodetector reduces signal level variation sensitivity with typically <0.5 nm position change introduced as the signal strength changes between 100% and 20% (see figure 2).

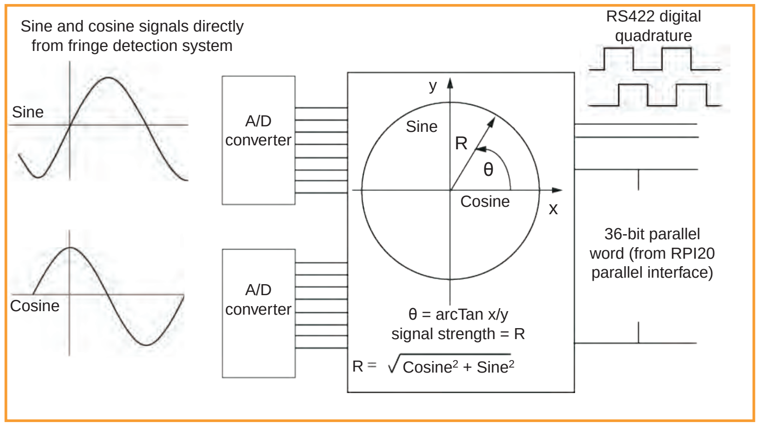


Figure 1: interpolation of sine and cosine signals

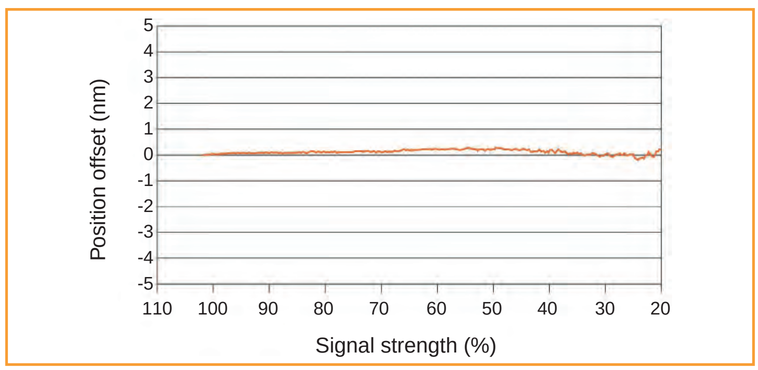


Figure 2: typical misalignment insensitivity of RLD10 detector heads

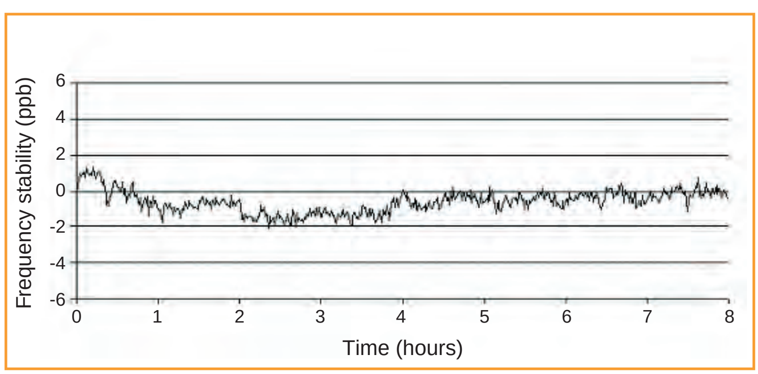


Figure 3: typical frequency stability of Renishaw RLE20 system

RLE system accessories

Accessories

To complete an RLE interferometer system requires only one additional, external target optical component fitted to the motion system. (When using the differential interferometer, optics are required on the motion system and a fixed reference point e.g. column/tool.)

In applications where a single pass interferometer is used, a housed retroreflector is supplied with the RLE system kit.

For applications that use standard double pass or differential interferometer configurations, Renishaw can supply plane mirrors and adjustable mirror mounts, if required.

Plane mirrors

Plane mirrors are manufactured on a Zerodur® (or similar) substrate and have a hard oxide dielectric coating. A summary mirror specification is shown below. Please contact Renishaw for a detailed specification of specific mirror lengths.

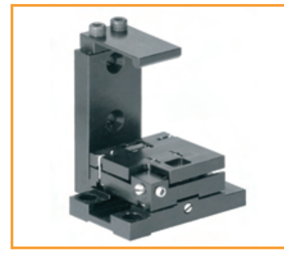
- Local flatness <λ/10 over area 12 mm wide x 7 mm high
- Total flatness λ/10
- Mirror coating Hard oxide dielectric
- Reflectivity >97%
- Operating temperature 0 ºC to 40 ºC
- Cross section 25 mm x 25 mm

Mirrors mounts

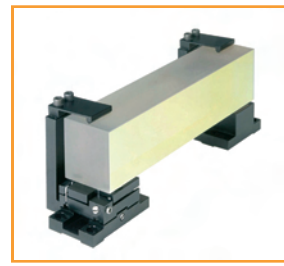
To enable mirrors to be mounted and aligned on the motion system, Renishaw can also provide adjustable mounts for use with mirrors up to 350 mm in length with 25 mm x 25 mm cross section.

These mounts enable adjustment of both mirror pitch and yaw, with screw adjusters positioned to allow easy access from the front and sides of the mirror respectively.

The mirror mounts provide up to ±2.5º of yaw adjustment (actual adjustment range is dependent on the length of the mirror) and ±1º of pitch adjustment.

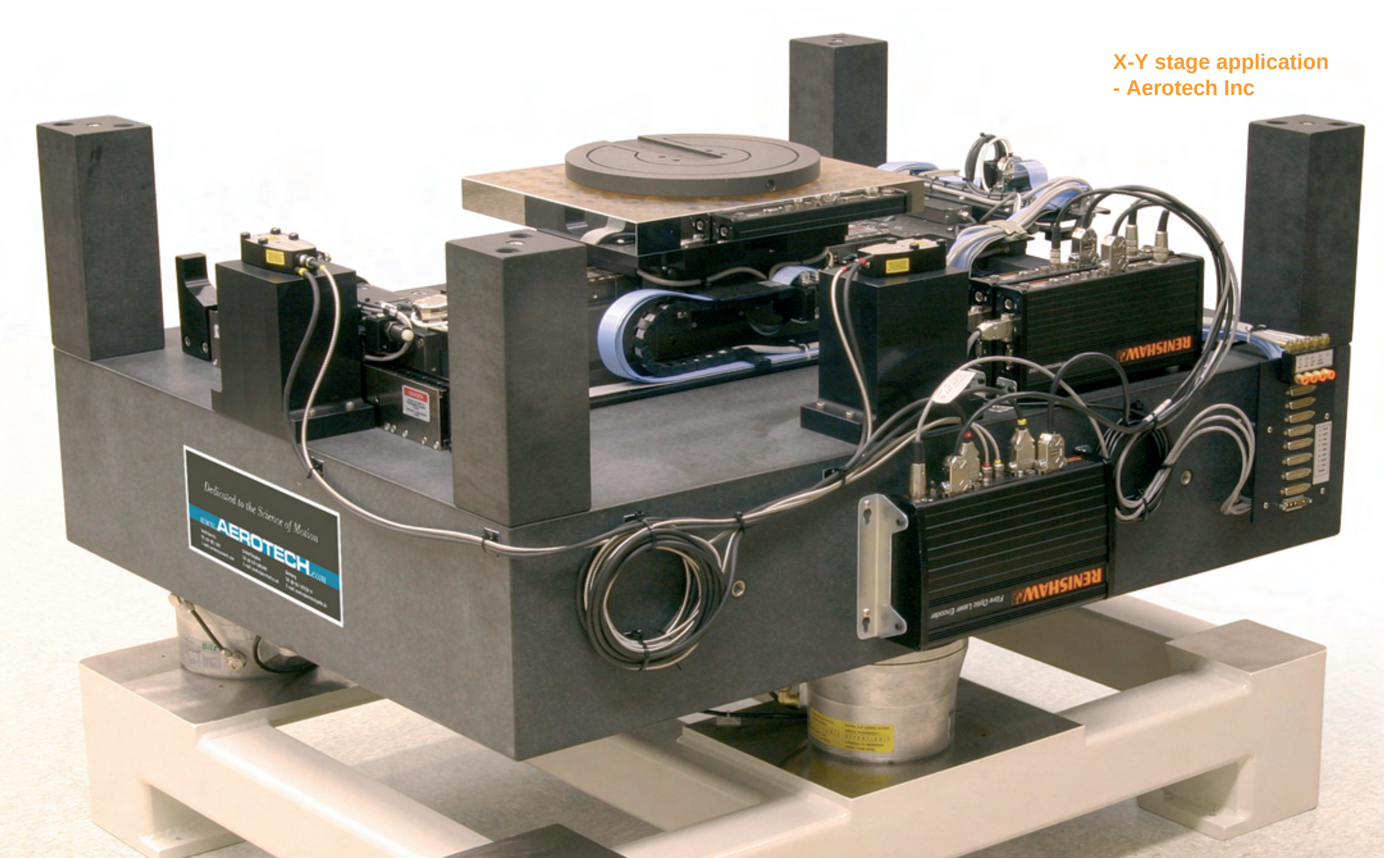


Mirror mounting block



Mounted mirror

X-Y stage application - Aerotech Inc



RPI20 parallel interface

Renishaw's RLE laser interferometer systems directly produce 1 Vpp sine/cosine signals with periods of 316 nm and 158 nm from single and double pass interferometers respectively. These sinusoidal signals can be interpolated to provide ultra-high resolution positional feedback.

Although sine/cosine interpolation is available within a number of proprietary control systems, the analogue bandwidth of these systems is often designed for tape and glass scale based encoders. These scale systems produce relatively coarse signal periods and the sinusoidal frequencies for any given velocity are considerably lower than those produced by an interferometer. This bandwidth limitation means that laser interferometer feedback systems can only be used in low velocity motion applications.

The Renishaw RPI20 parallel interface has been specifically designed to overcome this limitation by providing ultra-high resolution parallel format output at high-speed. The RPI20 interpolates by 4096, produces resolutions to 38.6 picometres and has an analogue input bandwith of <6.5 MHz, enabling the interferometer system to be used in applications that have velocity requirements of up to 1 m/s.

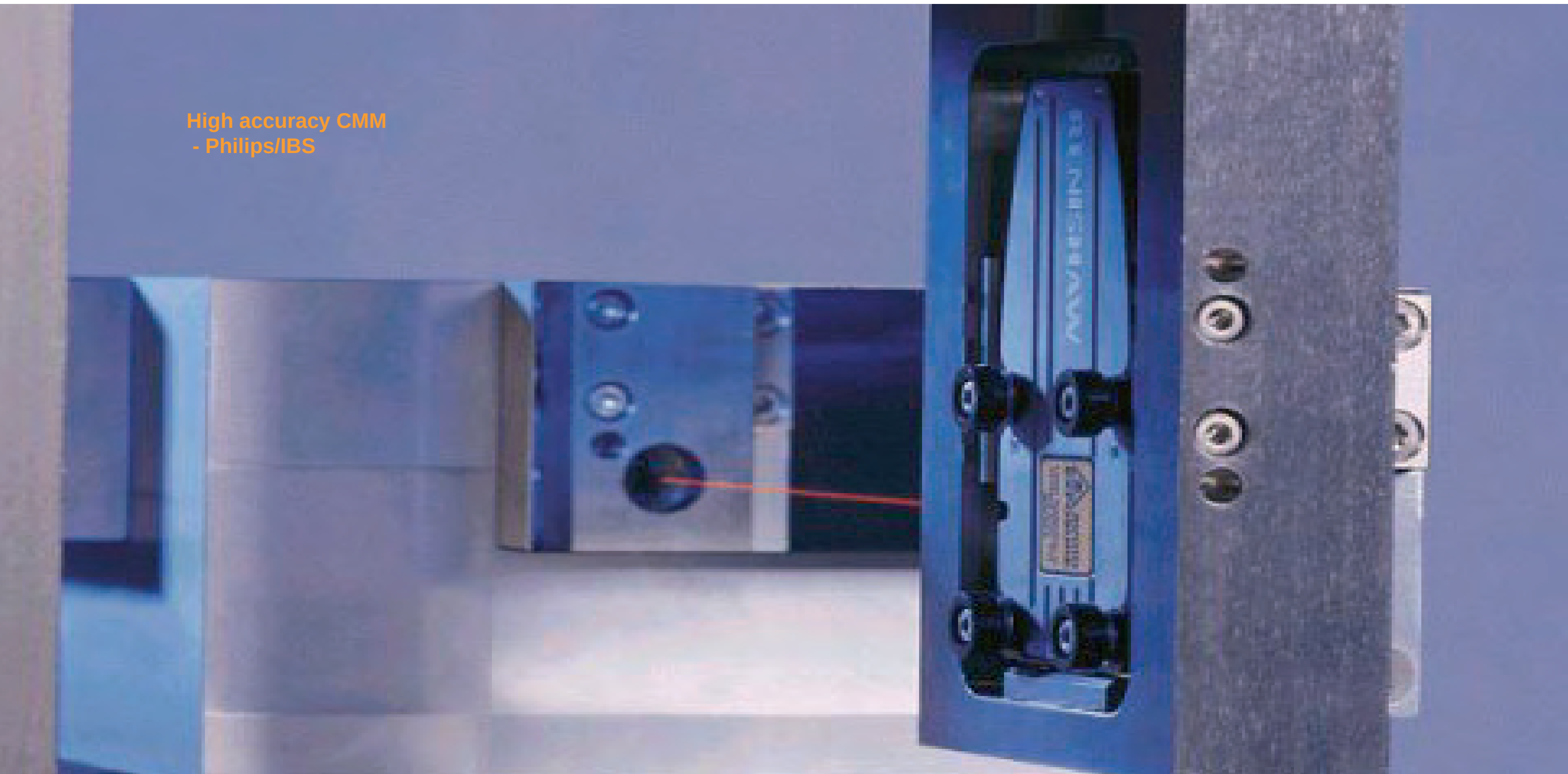
The RPI20 parallel interface accepts differential analogue 1 Vpp sine/cosine signals and provides an output in parallel format with up to 36-bits of position data being available.

Features of the RPI20 include:

- 4096x interpolation
- Analogue input bandwidth of <6.5 MHz
- 36-bit parallel format output
- Up to seven axis capability on one bus
- Switch selectable output resolution (least significant bit weighting)
- Addressable registers providing:
  - Position data
  - Card status including Lissajous co-ordinates, laser signal strength and system status
- Compact 110 mm x 72 mm board size
- Optional dual axis VME host to enable the RPI20 to be used in VME system architectures

RPI20 parallel interface

Dual axis VME configuration



High accuracy CMM
- Philips/IBS

REE series interpolators

The REE range of interpolators produce high-resolution digital quadrature signals from analogue 1 Vpp sine and cosine signals supplied by the position encoder. The resolution of the digital output quadrature is a function of the distance represented by one 360º cycle of the input analogue signals, and the interpolation factor.

When REE interpolators are used with the RLE laser interferometer, the following resolutions can be obtained:

Interferometer type	Double pass (plane mirror target optic)
Sinusoidal input resolution	158 nm
Available output resolutions	0.39, 0.79, 1.58 nm*
Interferometer type	Single pass (retroreflector target optic)
Sinusoidal input resolution	316 nm
Available output resolution	0.79, 1.58, 3.16 nm*

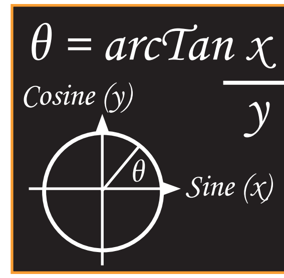
Each interpolator module includes reference mark circuitry, analogue input amplitude detection and interpolation integrity monitor.

Analogue input amplitude is communicated to the user through an integral multi-colour LED, error output signal, and tri-stating of the output quadrature when inoperable amplitude levels are reached.

Additionally, the error line is asserted if the motion system velocity exceeds the specified maximum indicating an overspeed condition.

REE interpolators are available with interpolation factors of 100, 200 AND 400** with each interpolator recommended for use with laser interferometers having output an update rate of 20 MHz.

An REE used with a plane mirror interferometer that has an analogue signal period of 158 nm would directly produce edge to edge separations of 39.5 nm. With x400 interpolation, this resolution is increased to 0.395 nm.



Interpolation technique

REE 200 interpolator

Performance summary table

Interpolator type	Part number	Plane mirror system		Retroreflector system	
		Resolution (nm)	Maximum velocity (mm/s)	Resolution (nm)	Maximum velocity (mm/s)
REE 100	REE0100A20B	1.582	17.7	3.164	35.4
REE 200	REE0200A20B	0.791	8.8	1.582	17.7
REE 400	REE0400A20B	0.395	4.4	0.791	8.8

* Note that maximum system velocity reduces as output resolution becomes finer. For part numbering and velocity limitation information, please refer to the table above.

** For information on the compatibility of other interpolators with the RLE system, please contact your local Renishaw representative.

Linear air bearing stage - Danaher Motion

RCU10 compensation system

The Renishaw RCU10 quadrature compensation system provides significant improvements in process accuracy and repeatability by addressing environmental error sources associated with the feedback system, the workpiece and the machine structure; all in real time.

To achieve this, the RCU10 compensator is located directly within the position feedback loop. Taking readings from the encoder and environmental sensors, the position feedback is then modified to remove associated errors before the signals are supplied to the motion control.

The system can be used with any linear encoder that produces differential digital quadrature and can implement user selectable combinations of the following algorithms:

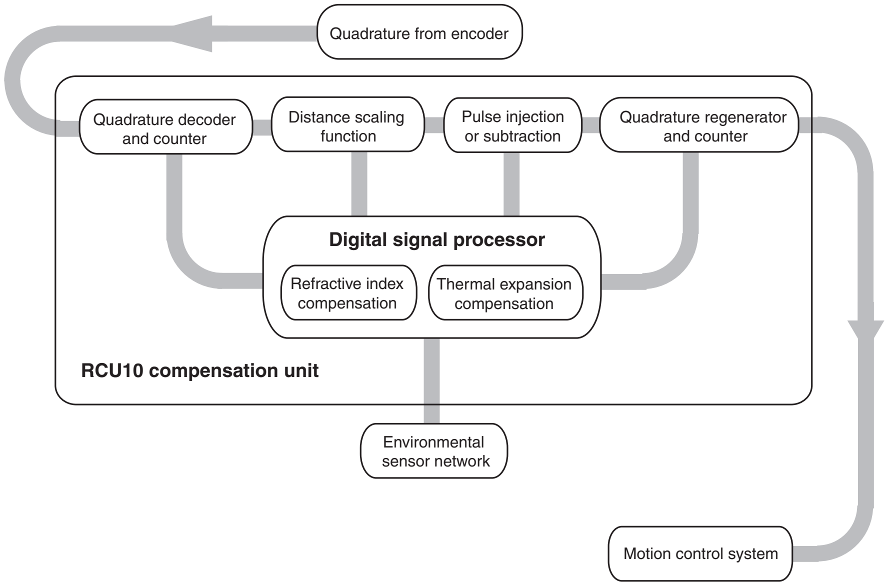
- Refractive index compensation (for laser interferometer based encoder systems)
- Scale compensation (for tape or glass based encoder systems)
- Workpiece compensation
- Machine structure compensation

The RCU10 system accepts a wide range of discrete digital quadrature resolutions and the user can select to receive the compensated output in either differential digital or differential analogue 1 Vpp sine/cosine formats.

To perform compensation, the RCU10 unit converts the quadrature input supplied by the encoder into 'unit of resolution' count pulses and an associated direction (up/down line). This is followed by a digital scaling circuit which allows the effective resolution to be changed, enabling the conversion of laser wavelength related units into more standard engineering units. (For example, in machine tool applications 633 nm is often converted to 1 µm.) After the scaling circuit, an injector arrangement allows 'unit of resolution' pulses to be added or subtracted into the count pulse stream. It is through a combination of scaling and injection of 'unit of resolution' pulses that the compensation is implemented. After these corrections have been applied to the feedback, it is then converted to digital quadrature or analogue sine/cosine and dispatched to the control system. This whole process incurs a delay of less than 2 µs.

RCU10 compensation system

Internal view of RCU10



RCU10 compensation system

When using any laser interferometer system in non-vacuum conditions and where it is not possible to reference the encoder system output against a known distance (for example the distance between fuducial marks on a wafer), some form of refractive index compensation is required to maintain accuracy under changing environmental conditions.

This is because the fundamental fringe spacing (unit of count) is a function of the wavelength of the laser light which varies very slightly depending on the refractive index of the air through which it travels. This depends primarily on its temperature, pressure and humidity.

The following changes in environmental conditions will result in a 1 ppm variance in laser wavelength*:

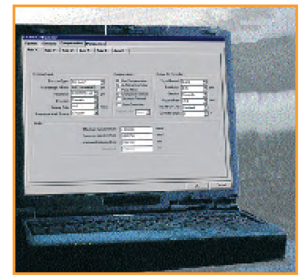
- ~1 ºC variance in air temperature
- ~3.3 millibar variance in air pressure
- ~50% variance in % RH

* These sensitivities are based on changes from a nominal atmospheric environment of 20 ºC, 1013.25 millibars, 50% RH

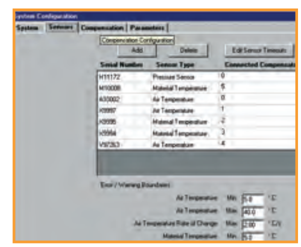
Correction for refractive index variation is calculated within the RCU10 using Edlen's equation, with the environment being sampled at intervals of fractions of a second via the unit's pressure and humidity sensors.

The RCU10 system offers the following features/benefits:

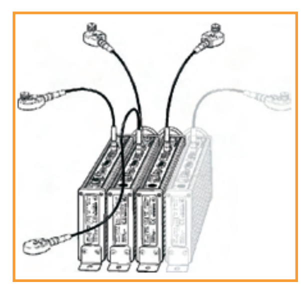
- ±1 ppm positioning (with refractive index compensation only) over a broad range of environmental conditions.
- Simultaneous implementation of multiple error correction algorithms.
- Use of individual air temperature sensors for each axis allows the environment in close proximity to the laser beams to be sensed, rather than inferring that the environment is consistent throughout the machine.
- Application flexibility through the RCU10-CS configuration software enables the RCU10 system to be configured to match the requirements of the application. Following configuration, the PC is disconnected and the RCU10 operates as a standalone system.
- One to six axis capability. Although each RCU10 unit is a single axis compensator, multi-axis systems can formed using a number of individual RCU10 compensators connected via a high-speed serial communications link to facilitate data sharing.
- Extended diagnostic and error reporting system enables integrity of the compensated signal to be assured.



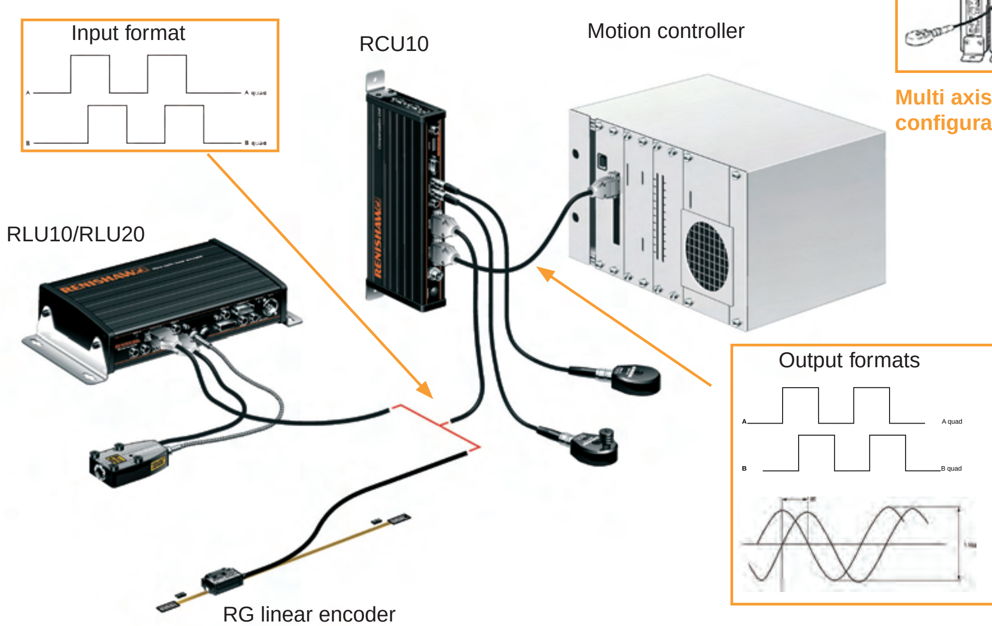
System configuration screen



Sensor configuration screen

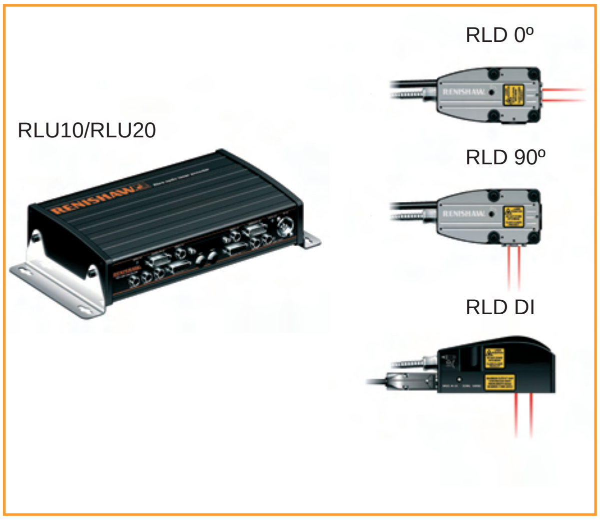


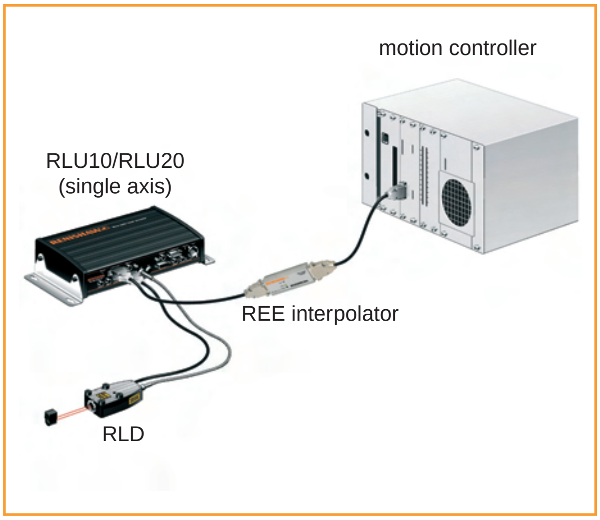
Multi axis RCU10 system configuration



The RCU10 can be used to compensate digital position feedback signals from a variety of sources and can produce compensated output in analogue or digital format.

Typical system configurations

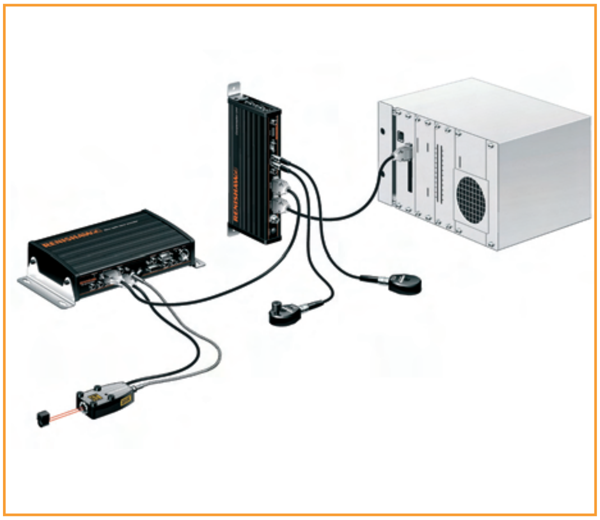


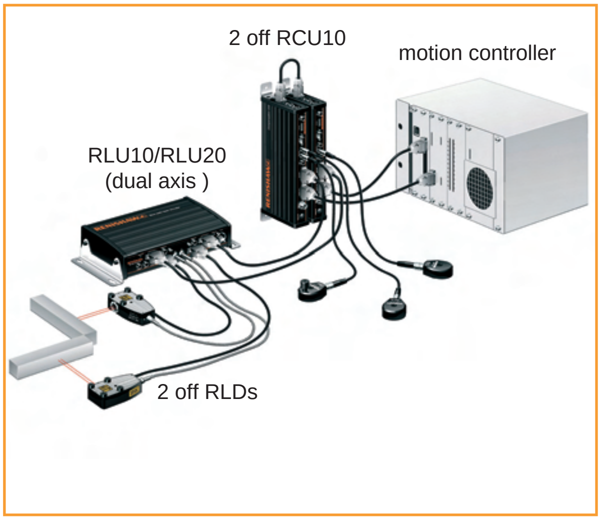


RLU10 and RLU20 laser units are fully compatible with the complete range of detector heads: RLD10 0º output and 90º output (available configured for either retroreflector (single pass) or plane mirror (double pass) applications), and the RLD10 DI differential interferometer.

RLU10 and RLU20 laser units are available in single or dual axis variants supplied with one or two RLDs as appropriate.

RLE interferometer system with REE interpolator used to convert analogue sinusoidal output (from RLE) to high-resolution differential digital quadrature signals. Suitable for retroreflector (single pass), plane mirror (double pass) and differential configurations.

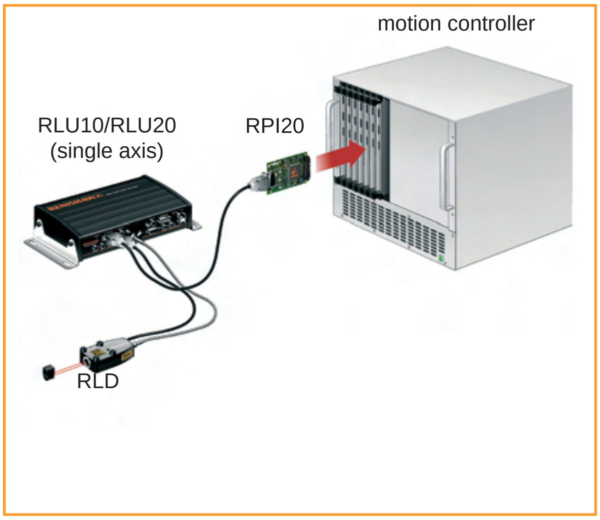




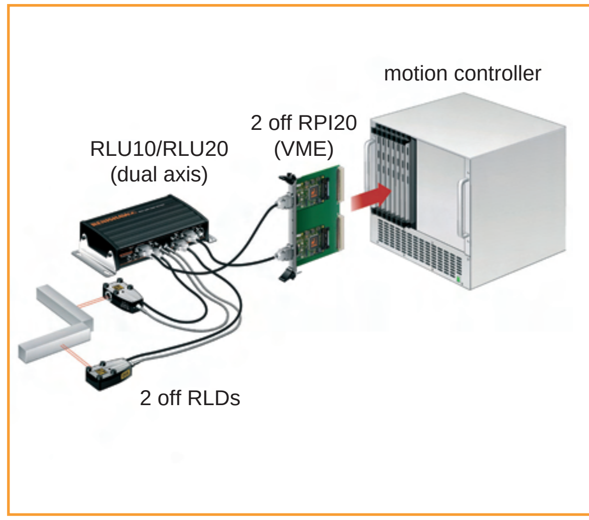
Retroreflector (single pass) RLE interferometer system for linear applications with axis lengths of up to 4 m. Optionally, the RCU10 compensation system can be used to correct for refractive index variation.

Plane mirror (double pass) RLE interferometer system for X-Y applications with axis lengths of up to 1 m. Optionally, the RCU10 compensation system can be used to correct for refractive index variation.

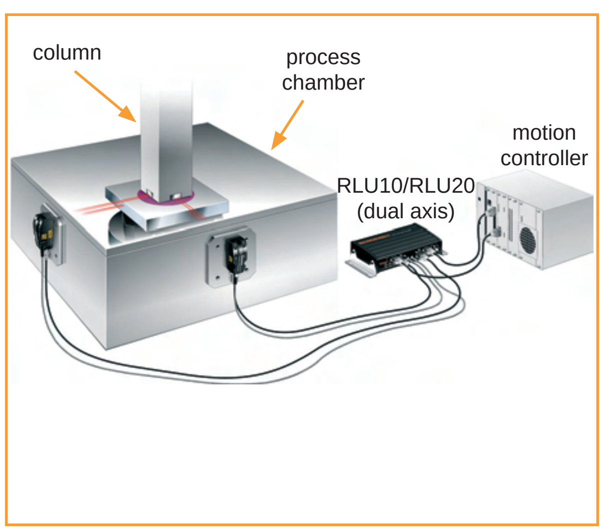
Typical system configurations



RLE interferometer system with RPI20 36-bit parallel interface for ultra high-resolution applications.



RLE interferometer system with dual axis VME configuration (2 off RPI20 36-bit parallel interface modules) for ultra-high resolution applications.



RLE interferometer system with differential interferometer (RLD10 DI) detector heads.

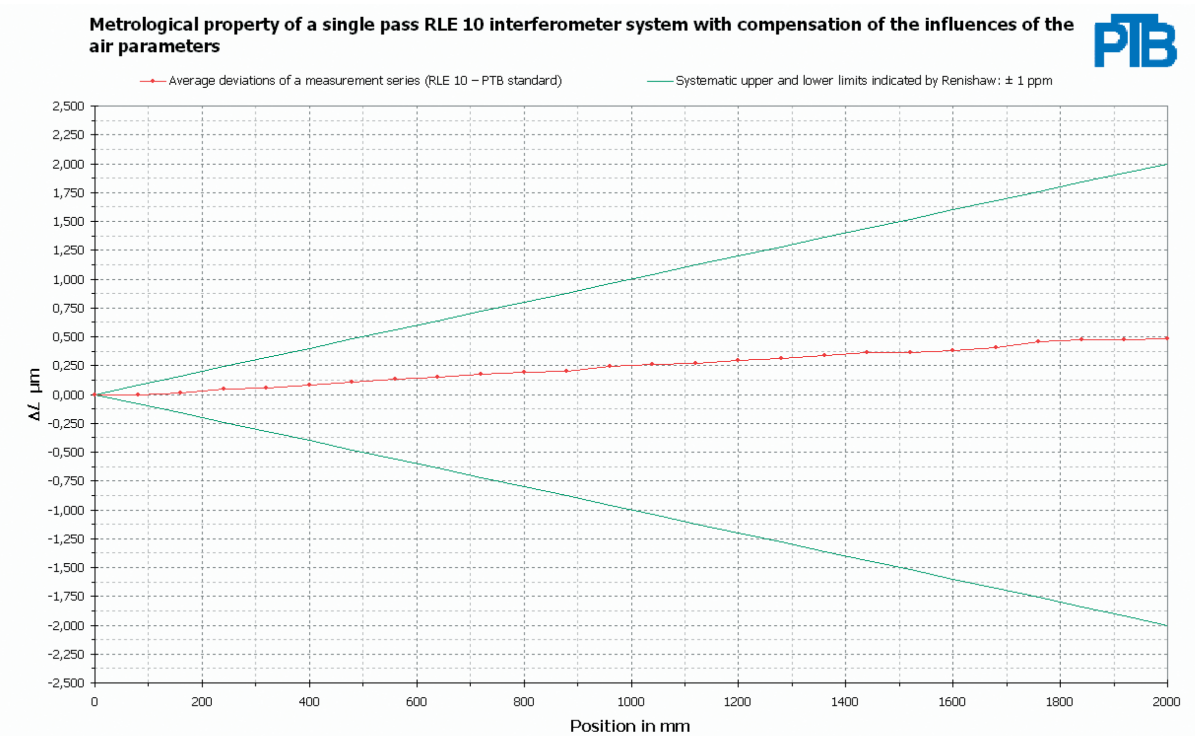
Typical system performance

The graph below has been compiled from results of independent system testing performed by Physikalisch-Technische Bundesanstalt (PTB), Germany.

The graph shows the measurement difference between the PTB reference laser system and a Renishaw RLE10 laser interferometer system measured over a range of 0 m to 2 m. Compensation for refractive index variation was applied to the outputs of both lasers. Corrections to the PTB laser were calculated using sensors and an algorithm supplied by PTB. The Renishaw laser output was compensated by a Renishaw RCU10 quadrature compensation system.

The Renishaw RLE10 system tested comprised an RLU10, with a single pass (retroreflector) interferometer RLD10 detector head. The RCU10 was configured to perform refractive index compensation only: no material compensation was applied to either the PTB or Renishaw laser.

The specification for an RLE10 interferometer system compensated for refractive index effects by an RCU10 is ±1 ppm, as indicated by the upper and lower limit lines on the graph. Actual results achieved in this test show the accuracy of the tested system to be approximately 0.24 ppm, equivalent to 0.24 µm/m.



System accuracy is quoted to the internationally recognised 95% confidence level (k=2).

PTB is the German national metrology laboratory based in Braunschweig, and is a signatory to the ‘Mutual Recognition Agreement for national measurement standards and for calibration and measurement certificates issued by National Metrology Institutes’, signed in October 1999. This agreement means that results obtained by PTB are recognised by a significant number of national laboratories including those in The People’s Republic of China, Israel, Japan, The Netherlands, Sweden, United Kingdom and United States of America.

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Kalibrierschein
Calibration Certificate
Translation, original in German

Gegenstand:	Laser interferometer for length measurements
Hersteller:	Renishaw
Typ:	RLE 10
Kennnummer:	see point 1
Auftraggeber:	RENISHAW plc New Mills, Wotton-under-Edge Gloucestershire GL12 8JR GL12 8JR UNITED KINGDOM
Anzahl der Seiten:	8
Geschäftszeichen:	5.44-4017370
Kalibrierzeichen:	5665-PTB-05
Datum der Kalibrierung:	2005-01-19 until 2005-02-04
Im Auftrag	Braunschweig, 2005-05-19 — Bearbeiter
	Siegel
Dipl.-Ing. G. Sperrer	T. Mayer

Warranty, service and support

Warranty

All Renishaw laser encoder products are covered by a 24-month warranty as standard.

Service and support policy

Renishaw has served the metrology requirements of the manufacturing sector for over thirty years, allowing the development of unparalleled, first hand knowledge of service requirements and expectations.

Building on this knowledge, Renishaw has established a first class, global service and support network, backed by specialised application engineers who can provide detailed recommendations regarding individual proposed applications.

The support function provided by these engineers is further enhanced by our service staff. Service technicians are ready to provide prompt and efficient service and repair assistance.

A range of service levels are available to suit individual customer needs.

Service options

- **Advance RBE** (repair by exchange)
  Through this service we ship you 'as new' replacement product. This simple to use option is designed to minimise downtime caused by in-service failures. To take advantage of this option, simply call your local Renishaw office, tell us the serial number of your system, and we'll ship you a replacement.

- **Post inspection RBE**
  This quick response option provides you with factory standard, replacement product, after we have inspected your returned system. Send us your faulty system, our technicians will inspect it, diagnose any faults and either fix it or provide you with a replacement system, built to 'as new' standard.

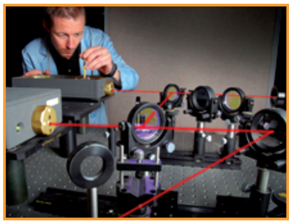
  These RBE service options enable existing customers to replace faulty product, with minimal expenditure and downtime, without compromising process integrity.

  To take advantage of the RBE policy and pricing structure, original product must be returned to your local Renishaw office.

- **Repair**
  Skilled technicians at our UK service centre will test your returned system and repair identified faults.

  Repair charges will always be advised, and authorisation received, prior to any repair work being undertaken.

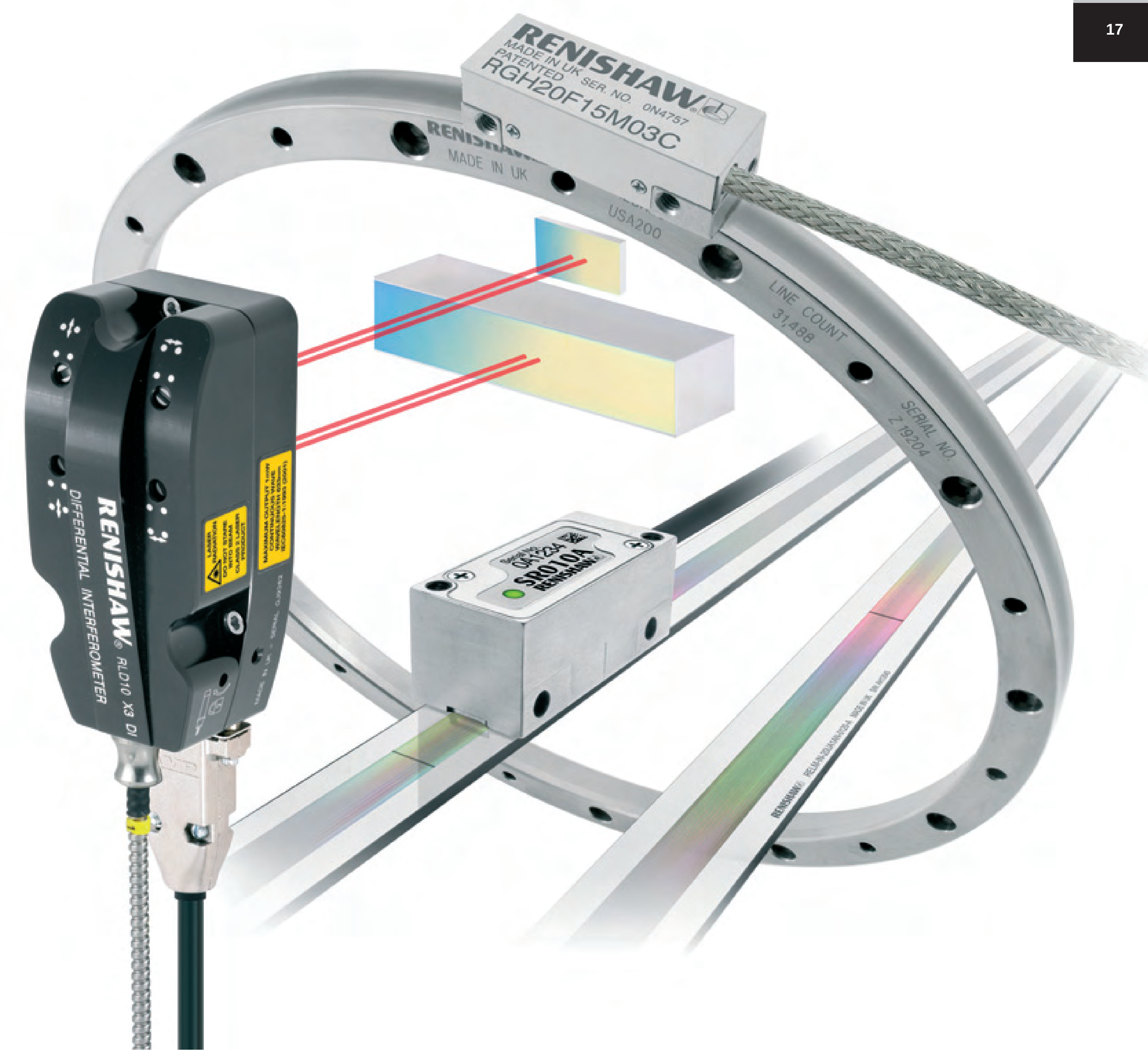
Specialised applications engineers are available for immediate telephone support



Frequency stability test facility; Renishaw plc

Global sales and support network

Complementary solutions and product offerings



Complementary solutions: optical encoder products

Optical linear encoders

Renishaw also offer a wide range of compact optical and magnetic encoder systems to suit the requirements of the diverse industry sectors served.

Renishaw's innovative non-contact optical scheme provides excellent metrology and high resolution with zero mechanical hysteresis, yet can withstand a variety of contaminants such as dust, light oils and scratches without compromising signal integrity.

The flexible gold plated scale can be cut to suit any axis length and the special formula self-adhesive backing removes the need for drilling and tapping: saving time and money.

RG2 20 µm

The RG2 is an open, non-contact optical system, eliminating friction and wear, whilst permitting reliable high-speed, high-resolution operation. Unique filtering optics ensure excellent signal stability even in workshop environments.

All readhead types come with industry standard analogue or square wave outputs, with 20 µm analogue signal period and digital resolutions from 5 µm to 5 nm. All systems incorporate a unique, integral set-up LED, which lights green when optimum installation has been achieved.

RGH22

- Compact and robust housing
- Integral interpolation and set-up LED
- Resolutions available: 5 µm, 1 µm, 0.5 µm, 0.1 µm and 50 nm
- Reference mark and single or dual limit switch sensors
- 16.0 mm x 44.0 mm x 27.0 mm (H x L x W)
- Mitsubishi Melservo serial comms compatible version also available

RGH24

- Super-compact and robust housing
- Integral interpolation and set-up LED
- Resolutions available: 5 µm, 1 µm, 0.5 µm, 0.2 µm, 0.1 µm, 50 nm, 20 nm and 10 nm
- Reference mark or single limit switch sensor
- 14.8 mm x 36.0 mm x 13.5 mm (H x L x W)

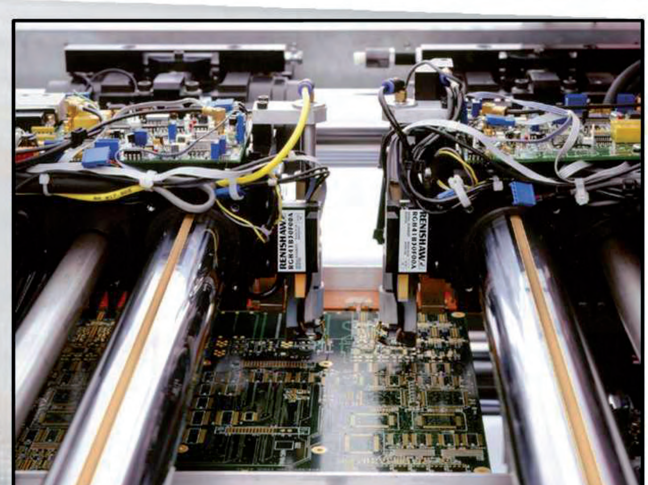
RGH25F

- Ultra-high resolution
- Ultra-compact and robust housing
- Resolutions available: 5 µm, 1 µm, 0.5 µm, 0.2 µm, 0.1 µm, 50 nm, 20 nm, 10 nm and 5 nm
- Self-tuning adaptive electronics give low SDE
- Ultra-high vacuum version available
- 10.5 mm x 36.0 mm x 13.5 mm (H x L x W)
- Reference mark or single limit switch
- External interpolation with set-up LED

RGH22

RGH24

RGH25F



Automated circuit board tester - Probetest

RENISHAW
apply innovation™

Complementary solutions: optical angle encoders

SIGNUM™ RESM angle encoder

Renishaw's SIGNUM™ encoder range offers high-speed, reliable, non-contact performance combined with advanced features including the ***IN-TRAC™*** auto-phase optical reference mark. The RESM angle encoder comprises the RESM ring, the SR readhead and Si interface.

The RESM is a one-piece stainless steel ring with 20 µm scale marked directly on the periphery. It features the ***IN-TRAC™*** optical reference mark, which repeats, regardless of direction, at operational speeds over 4,500 rev/min (ø52 mm) and up to 85 ºC. The SR readhead is sealed to IP64, enabling a quick recovery from coolant splashes and immersions.

In addition, the RESM angle encoder uses SIGNUM™ intelligent signal processing to ensure excellent reliability and low cyclic error, whilst comprehensive software enables optimum set-up and real-time system diagnostics via a PC's USB port.

For applications that require the highest angular accuracy the REXM angle encoder offers new levels of performance - better than ±1 arc second total installed accuracy, zero coupling losses and exceptional repeatability.

REXM features a thicker cross-section to minimise all installation errors except eccentricity, which is easily corrected using Renishaw's new DSi (Dual SIGNUM™ interface).

Features of the SIGNUM™ range include:

- Non-contact open optical system
- ***IN-TRAC™*** bi-directional reference mark and dual limit outputs
- Graduation accuracy to ±0.5 arc second
- System resolution to 0.0038 arc second
- Patented taper mount simplifies integration and minimises installation errors
- Large internal diameter for ease of integration
- ø30 mm to ø550 mm with line counts from 4,720 to 86,400
- Operating temperatures up to 85 ºC
- Speeds over 4,500 rev/min
- Dynamic signal control ensures a cyclic error typically better than ±30 nm
- Integral LEDs for optimum set-up and system diagnostics
- Comprehensive SIGNUM™ software for ease of installation and real-time diagnostics via USB
- Filtering optics providing excellent dirt immunity

Available in a wide range of diameters

SIGNUM™ software

Complementary solutions: UHV encoder products

Ultra-high vacuum compatible readhead systems

Renishaw's vacuum range has been specially constructed from clean UHV compatible materials and adhesives to give low outgassing rates and a clean RGA. The readheads also consume less current to minimise heat dissipation. The RGH20F UHV is designed for use with Renishaw's 20 µm RESR angle encoder to provide precision feedback for rotary motion in UHV environments.

The RGH20F UHV and RGH25F UHV readheads are used with the REF interface which incorporates automatic gain control and unique self-tuning adaptive electronics. Combined with filtering optics, these ensure excellent signal strength integrity and low cyclic error.

Key features of the range include:

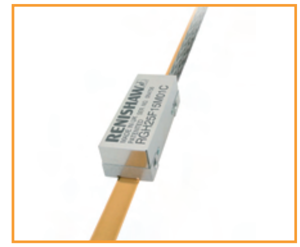
- Clean RGA
- Bake out temperature of 120 ºC
- Low outgassing rates
- Low power consumption readheads (50 mA)
- Resolution to 5 nm
- Low cyclic error (<±50 nm)
- Self-tuning adaptive electronics give high accuracy and long-term reliability

Linear vacuum - REF

- Resolutions available: 0.2 µm, 0.1 µm, 50 nm, 20 nm, 10 nm and 5 nm
- System comprises:
  - RGH25F UHV readhead
  - REF interface
  - RGS20-S scale

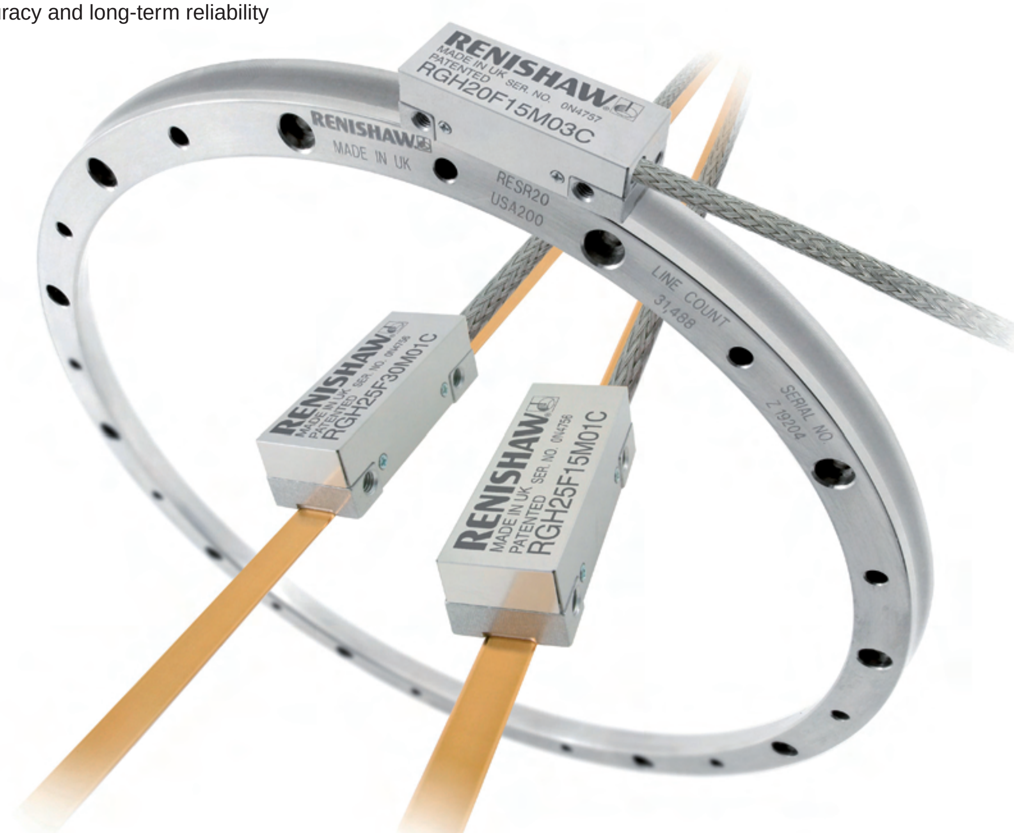
Rotary vacuum - REF

- Resolutions available: 0.2 µm, 0.1 µm, 50 nm, 20 nm, 10 nm and 5 nm
- System comprises:
  - RGH20F UHV readhead
  - REF interface
  - RESR ring



RGH25F UHV

Thermo VG Scientific



For further information on the available range of Renishaw optical encoder products, please contact your local Renishaw office.

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Complementary product offerings: calibration hardware

XL-80 laser measurement system

The Renishaw XL-80 laser measurement system is designed to take motion system calibration to the next level. A compact, lightweight laser head (XL-80) and independent environmental compensator (XC-80) provide linear measurement accuracy of ±0.5 ppm over the complete environmental operating range: 0 °C to 40 °C and 620 mbar to 1150 mbar.

With linear, angular, rotary, flatness, straightness and squareness measurement capability, the single frequency XL-80 laser unit provides nanometre resolutions at feedrates of up to 4 m/s and by selecting the switchable 'long-range' option, axis lengths to 80 m can be calibrated using a single laser.

When you purchase a laser system from Renishaw, you are not only 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.

Interferometry is traceable - All XL-80 measurements are interferometric and therefore utilise the traceable international standard of laser light. Other systems which use electronic targets to measure pitch, yaw and straightness errors often compromise measurement accuracy and stability.

Separate interferometer - The XL-80 system utilises a remote interferometer rather than one mounted on or inside the laser head, thus avoiding thermal drift.

Laser frequency stability - ±0.02 ppm over any one hour and ±0.05 ppm over one year.

Intelligent - System auto-senses/auto-adjusts to the input voltage.

Ease of set-up and adjustment - Tripod mounting removes the laser from the machine under test, helping to reduce thermal effects and the risk of damage during operation, whilst the tripod stage provides angular rotation and translation of laser position. Laser pre-heat is less than six minutes, and the USB connectivity of both XL-80 and XC-80 eliminates the requirement for additional interface units.

Environmental compensation - The greatest uncertainty in most laser measurements arises from variations in environmental conditions (air temperature, air pressure and relative humidity) from NTP values. Typical variations in these conditions can introduce ±20 ppm uncertainty to a measurement. Without accurate sensors and compensation you cannot achieve accuracy except under controlled laboratory conditions e.g. in a vacuum. To compensate for environmental fluctuations during measurements, Renishaw use highly accurate environmental sensors and the XC-80 environmental compensation unit.

Performance specifications - Renishaw's accuracy specification is derived in accordance with recognised procedures for the calculation of measurement uncertainty 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.

Constant visibility - Status LEDs provide constant indication of current system status.

XL-80 calibration laser

The optics 'family'

Complementary product offerings: calibration software

To coincide with the release of the XL-80 laser calibration system, Renishaw have also launched revised and updated versions of its two calibration software packages, LaserXL™ and QuickViewXL™.

These multi-lingual packages are compatible with Windows® XP and Windows Vista™ only.

LaserXL™

LaserXL™ measurement software allows users to perform static and dynamic measurements to determine a machine's linear, angular, flatness, straightness and squareness measurements, with the dynamic measurement mode offering 12 user selectable data capture rates between 10 kHz and 50 kHz

Standard report options conform to a number of international machine performance checking standards, including ISO, ASME, JIS and GB, plus comprehensive Renishaw developed analyses.

QuickViewXL™

QuickViewXL™ is designed specifically to provide real-time information on the dynamic behaviour of your motion system. Whether your application is in machine tool, sensors, printing and imaging equipment, electronic or biotechnology process equipment, QuickView™ is an ideal metrology tool.

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

For years, electronics engineers have used oscilloscopes to study high-speed variations in voltage or current. Renishaw's new QuickViewXL™ software offers similar capability to mechanical engineers, allowing them to study live traces of linear or angular position versus time.

With QuickViewXL™, your XL-80 system becomes a tool not just for equipment calibration, but also an investigative and analytical tool for use during development and build processes. Quality assurance programmes, continued development of higher speed machining processes and the demand for increased reliability, have all highlighted the requirement for such a tool.

An intuitive and easy-to-use software package, QuickViewXL™ provides a real-time, graphical view of the XL-80 laser's measurement data sampled at 50 kHz, with 1 nm linear and 0.01 arc second angular resolution.

Using an icon based interface, with a single screen for set-up and data viewing, the 'oscilloscope' function provides a graphic display of the captured data. Following on-screen review, data can be exported for further analysis into various applications such as MathCAD, Mathmatica and Excel, in addition to FFT analysis within Renishaw's LaserXL™ software.

Capabilities include:

- Live data display of position, velocity or acceleration traces
- Choice of triggering modes (rising edge, falling edge, single shot, multi-shot)

Typical benefits:

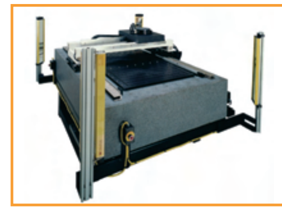
- Streamline your R&D process, bringing new product to market more swiftly
- Diagnose production problems
- Enhance field service capabilities

Support packages

A comprehensive, multi-lingual system manual is supplied on CD-ROM with each laser system when shipped. This manual contains written and illustrated set-up information for each measurement option.

The manual can be installed on your PC and accessed directly via the Help button within your software application, or as a stand-alone option, read directly from the CD.

Additional/replacement CDs are available free of charge from your local Renishaw representative.



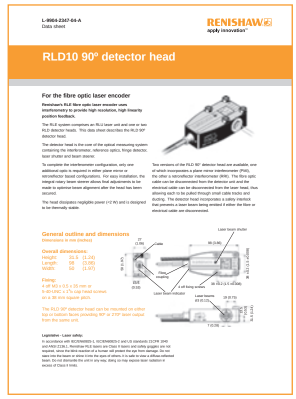
Typical application for dynamic data capture: gantry flat panel inspection stage (photo courtesy of Danaher Precision Inc)

Optional small linear optics kit reduces mass effects on dynamic performance

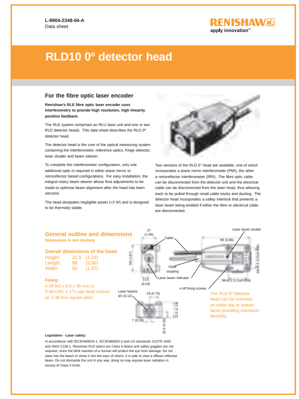
For further information on the available range of Renishaw calibration products, please contact your local Renishaw office.

Available datasheets

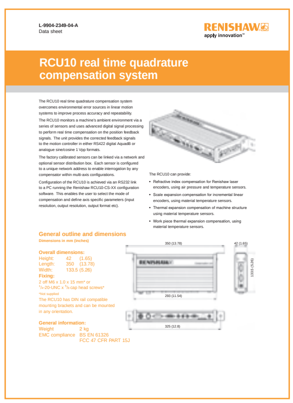
L-9904-2346 (RLU10)



L-9904-2347 (RLD 90°)

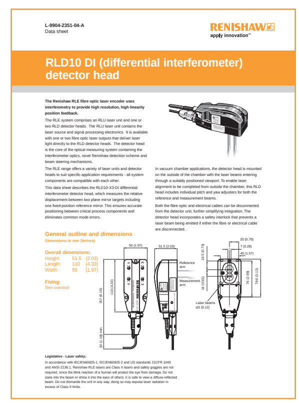


L-9904-2348 (RLD 0°)

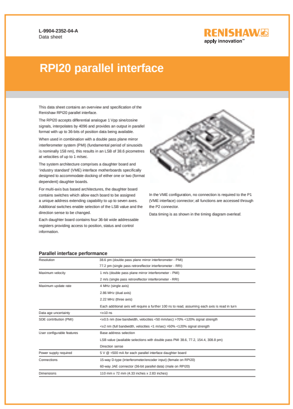


L-9904-2349 (RCU10)

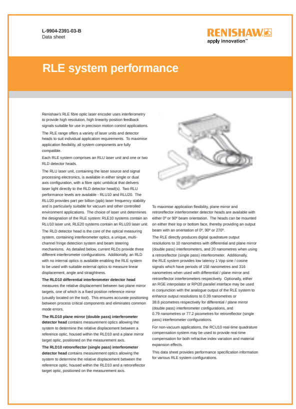
L-9904-2350 (RLU20)



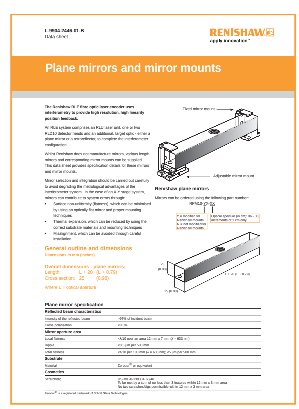
L-9904-2351 (RLD DI)



L-9904-2352 (RPI20)



L-9904-2391 (RLE system performance)



L-9904-2446 (plane mirrors and mirror mounts)

Renishaw reserves the right to change specifications without notice.

All latest version datasheets are available as pdf documents at www.renishaw.com/rle

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RENISHAW apply innovation™

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:

- **Dental CAD/CAM** scanning and milling systems
- **Encoder systems** for high accuracy linear, angle and rotary position feedback
- **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 (co-ordinate measuring machines)
- **Styli** for CMM and machine tool probe applications

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