Installation and user's guide
M-8003-3192-05-A

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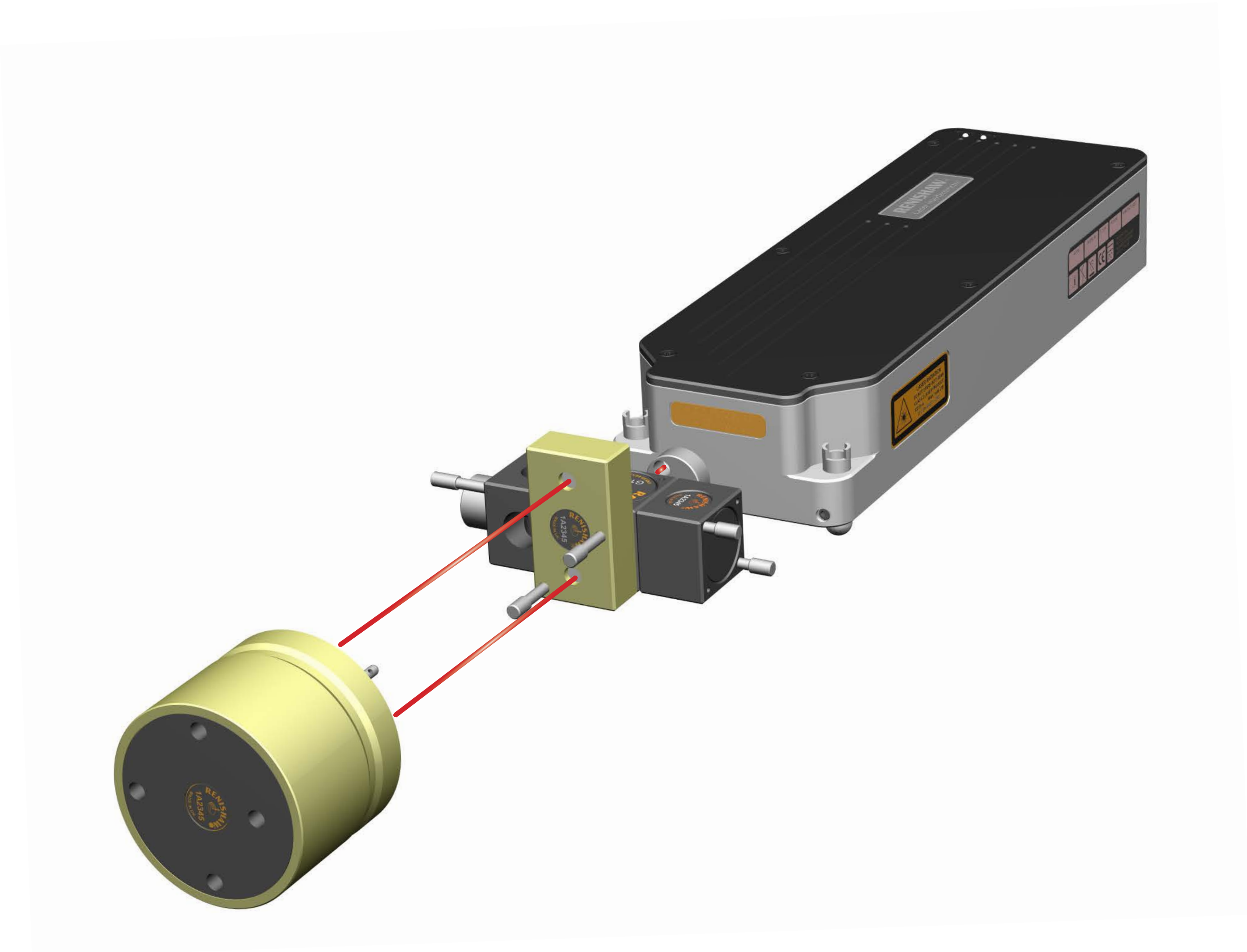
HS20 installation guide



Document Information

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Care of equipment

Renishaw HS20 laser encoder and associated products are precision components and must therefore be treated with care. For further information refer to Appendix B.

Changes to Renishaw products

Renishaw plc reserves the right to improve, change or modify its products and documentation without incurring any obligation to make changes to Renishaw equipment previously sold or distributed.

Disclaimer

Trademarks

Safety

The Renishaw HS20 laser is designed for integration into the primary position feedback loop of a motion system. It is essential that the system is installed in accordance with the instructions in this installation guide and it is the responsibility of the system integrator to ensure that, in the event of a failure of any part of the Renishaw system, the motion system remains safe.

In the case of motion systems with powers or speeds capable of causing injury, it is essential that appropriate safety protection measures are included in the machine design. Further guidance on this can be found in EN12100:2010 Safety of Machinery - General principles for design - Risk assesment and risk reduction". It is the responsibility of the application integrator to ensure that the complete machine or equipment complies with appropiate standards. The user is also referred to Appendix D which contains additional safety information.

Laser safety

DO NOT STARE DIRECTLY INTO THE BEAM

In accordance with EN60825-1, EN60825-2 and US standards 21CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice no. 50, dated June 24, 2007. Renishaw HS20 lasers are Class 2 lasers and safety goggles are not required, since the blink reaction of a human will protect the eye from damage. Do not stare into the beam or shine it into the eyes of others. It is safe to view a diffuse-reflected beam. Do not dismantle the unit in any way; doing so may expose laser radiation in excess of Class 2 limits. For further product and motion system safety information refer to Appendix D.

Electrical safety

Do not remove any part of the housing; to do so may expose a danger of high voltage electric shock. Defective products should be returned to Renishaw for service.

Safety information

The following symbol is used in this manual wherever important safety information is present.

Before proceeding with any electrical connection or operation of the laser system, refer to the General safety information in the introduction.

Warranty

Renishaw plc warrants its equipment provided that it is installed exactly as defined in associated Renishaw documentation.

FCC (USA only)

Information to the user (47CFR section 15.105)

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the HS20 installation guide, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Information to user (47CFR section 15.21)

The user is cautioned that any changes or modifications not expressly approved by Renishaw plc or authorised representative could void the user's authority to operate the equipment.

EC compliance

Renishaw plc declares that the HS20 laser encoder complies with the applicable directives, standards and regulations.

HS20 Laser measurement system relevant patents and patent applications

The following patents and patent applications relate to this and other products:

EP 0397289

JP 2,630,345

US 5,026,163

EP 0668483

JP 3,502,178

US 5,638,177

GB 2337339B

DE 19980326 T1

US 6,473,250 B1

JP 3,388,738

US 5,341,702

JP 2001-194184A

US 6,934,641 B2

JP 2005-37,371

WEEE

The use of this symbol on Renishaw products and/or accompanying documentation indicates that the product should not be mixed with general household waste upon disposal. It is the responsibility of the end user to dispose of this product at a designated collection point for waste electrical and electronic equipment (WEEE) to enable reuse or recycling. Correct disposal of this product will help to save valuable resources and prevent potential negative effects on the environment. For more information, please contact your local waste disposal service or Renishaw distributor.

Packaging

Packaging components	Material	94/62/EC code	94/62/EC number
Outer box	Cardboard - 70% recycled material	PAP	20
Inserts	Cardboard	PAP	20
Bags	Low density polyethylene	LDPE	4

REACH

Information required by Article 33(1) of Regulation (EC) No. 1907/2006 (“REACH”) relating to products containing substances of very high concern (SVHCs) is available at:

www.renishaw.com/REACH

RoHS compliance

Compliant with EC directive 2011/65/EU (RoHS)

Contents

Section 1 - Operation overview

Contained in this section

Introduction

The Renishaw HS20 laser head provides linear position feedback for machine tools using laser interferometry. The HS20 laser head has been designed to be rugged and reliable whilst operating 24 hours a day in a machine shop environment. Depending on the application, the HS20 laser head may be connected directly to a motion control system, alternatively it may be connected via the RCU10 quadrature compensation unit. In case of the latter, please also refer to the RCU Manual (M-9904-1122) which provides extensive information on system integration. Always refer to the manual for information on the HS20 laser system.

This manual is separated into chapters to cover the standard installation of the HS20 laser system. The chapters cover mechanical and electrical installation and integration of the system in the machine controller. The appendices give further instruction on alignment diagnosis and system troubleshooting.

WARNING If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

General safety information

The Renishaw HS20 laser encoder and compensator systems are designed for integration into the primary position feedback loop of a motion system. It is essential that the system is installed in accordance with the instructions in the installation manuals and it is the responsibility of the system integrator to ensure that, in the event of a failure of any part of the Renishaw laser system, the motion system remains safe.

In motion systems with powers or speeds capable of causing injury, safety protection measures must be included in the design. It is recommended that satisfactory operation of these protection measures is verified **before** the feedback loop is closed. The following are examples of safety protection measures that can be used. It is the sole responsibility of the system integrator to select appropriate measures for their application.

1. The HS20 quadrature will go into a tristate condition (open circuit) under fault conditions. The equipment receiving this quadrature (RCU or machine controller) must detect the tristated condition and stop the axis moving. All status lines should be connected so that the HS20 condition is monitored and the following actions should be initiated:
   - **/UNSTABLE** - Whilst /UNSTABLE asserted low, the machine motion **must be** disabled.
   - **/BEAM_BLOCKED** - Whilst /BEAM_BLOCKED is asserted low, the machine motion **must be** disabled.
   - **/BEAM_LOW** - Machining can continue, however the source of the alarm should be investigated and maintenance performed.
   - **/OVERSPEED** - Whilst /OVERSPEED is asserted low the machine motion **must be** disabled.
2. The axis must include physical limit switches which, when tripped, will stop axis motion before damage occurs (soft limits alone are insufficient). Note that in the case of thermally compensated systems, positional corrections of several hundred ppm are possible. This should be taken into account when defining the relative positions of soft and hard axis limits.
3. Cable breakage detection (encoder disconnect). The position feedback is provided as differential line driven pairs. Failure in the cable or of the line drivers can be detected by checking these differential pairs are always being driven in opposing states. If the lines are not in opposing states, the motion **must be** stopped.

4. Motor torque monitoring. If the motor torque exceeds an expected limit, the axis of motion **must be** stopped.
5. The machine **must** include an emergency stop button.
6. Following error detection. If the difference between the controller demand position and the axis feedback position exceeds an expected limit, the axis motion **must be** stopped.
7. Guards, viewing windows, covers and interlocks may be used to prevent user access to hazardous areas, and to contain ejected parts or materials.
8. If the machine includes an independent tacho (velocity) feedback system, this should be cross-checked with the position feedback. For example, if the tacho indicates the axis is moving, but the position feedback doesn't, the axis motion **must be** stopped.
9. In the case of synchronised parallel motion systems (for example twin rail gantry drive systems), the relative positions of master and slave axes should be monitored. If the difference in their positions exceeds an expected limit, axis motion **must be** stopped.

Important note: In the case of measures 6 to 9, the limits need to be selected carefully depending on the application and the type of position compensation selected to avoid false alarms.

For further advice, consult the appropriate machinery safety standards.

Secondary fault protection measures

It is the responsibility of the system integrator to ensure that in the event of a failure of any part of the Renishaw Laser System that the motion system remains safe. In the case of motion systems with powers or speeds capable of causing injury, secondary protection measures must be included in the design. Refer to the General Safety Information in the Introduction for details of suitable secondary safety measures. It is recommended that such secondary measures be tested during system integration by deliberately introducing single faults into the system. (Obviously such tests need to be carried out carefully to ensure injury cannot occur if such secondary systems fail to operate)

Operation overview

The HS20 laser head can be incorporated into the position control loop of any motion-control system that can be configured to accept digital or analogue quadrature format encoder signals. The laser head can be fitted as a direct replacement for linear encoder systems both in OEM and retrofit applications.

HS20 laser scale kit

The following is a list of the major components, and their basic function:

HS20 laser head

Part No: A-8003-6000

The HS20 laser head is a class II (maximum output power < 1mW) visible helium/neon laser source with integrated fringe detection and processing circuitry. The HS20 can be configured for digital output resolutions of 79, 158, 316, 633 nm or analogue 1Vpp sin/cos signals of 316 nm. The HS20 laser head is powered from 24V DC. One HS20 laser head is required per axis. The HS20 may be used with either standard (up to 30 m) or long range optics (up to 60 m).

Linear measurement optics

There are two types of linear optics are available: standard (up to 30 m) and long range (up to 60 m) See figure 1 and 2 (page 10) for typical setup examples.

Standard optics for applications with an axis length of up to 30 m.

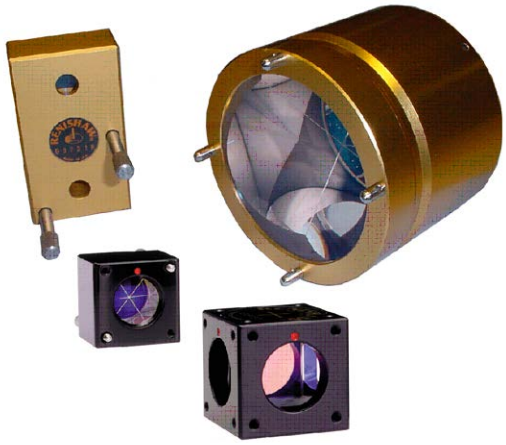
Part No: A-8003-0440

The kit includes:

- two retroreflectors & clamp screws
- one beamsplitter
- two targets

Long range optics kit

Part No: A-8003-2222



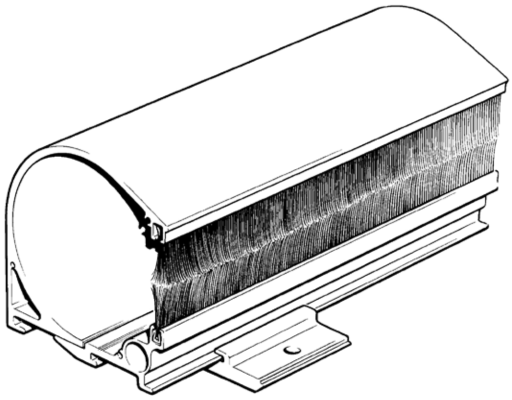
For applications with an axis length up to 60 m.

The kit includes:

- one retroreflector, clamp screws & target
- one long-range retroreflector & target
- one beamsplitter
- one long range periscope

One set of linear optics is fitted to each axis.

HS20 beam protection ducting



The beam protection ducting system can be used with either the long range or short range linear optics, to protect the beam path from debris and coolant, whilst also providing a stable thermal environment for the laser measurement beam.

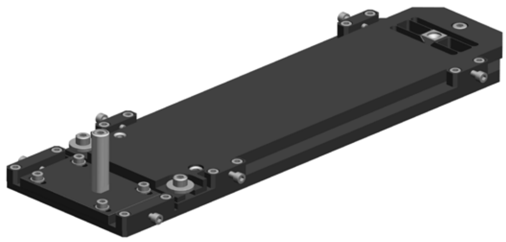
Although the Renishaw ducting system is primarily designed for long range applications, certain harsh operating environments and those with frequent rapid temperature changes or environments that could generate thermal gradients may also require the ducting system to be fitted even at relatively short axis lengths.

Please refer to the HS20 beam protection ducting installation manual (M-8003-5184) for further details about kit contents, part numbers ordering and installation.

Alignment plate kit

Part No: A-8003-2362

An alignment plate has been specially designed to ease HS20 laser alignment on larger machines This plate, in combination with the three adjustment feet fitted to the HS20 laser head, provide the user with both horizontal and vertical plane translation and rotation adjustments. The plate is supplied in kit format and includes a clamp block for external linear optic mounting.



HS20 adjuster tool kit

Part No: A-8003-2401

The HS20 laser head has three adjustment feet to provide translation and rotation during laser alignment. Ease of alignment is achieved by fitting a tool to each adjuster foot throughout the alignment process.

LS06 laser steerer

Part No: A-8003-2898

The laser steering mechanism or 'beam steerer' is an alignment aid for the HS20 laser scale. The device allows easy adjustment of both the pitch and yaw of the laser beam. and can greatly simplify system alignment.

The LS06 provides an angular adjustment range of 0.6 mrads.

Reference mark switch assembly

Part No: A-8003-2380

An optical or mechanical reference mark switch is typically used to determine the home position of each machine axis. Renishaw can supply a mechanical reference switch that is compatible with RCU. The assembly consists of a switch, which is repeatable to ±2 µm and a cable gland, which accepts cables with nominal outside diameter of 4 to 8 mm.

The reference mark switch assembly is an optional extra. One reference mark switch should be used per axis.

RCU compensator kit

The RCU10 compensates for environmental variations during use of the HS20 laser system. Air and material temperature is measured and compensated through remote sensors. One RCU10 compensator is required for each HS20 laser system. RCU10 compensation units are available with or without an integral pressure sensor (RCU10-PX-XX and RCU10-XX-XX respectively). One RCU10-PX-XX is used per machine.

Refer to the RCU manual M-9904-1122 for full details.

Storage and handling

The HS20 laser encoder can be stored at temperatures between -20 °C and +70 °C (-4 °F and +158 °F). Do not store the HS20 laser encoder in conditions of high humidity or otherwise subject it to conditions which may cause condensation to form on the optics.

Renishaw's HS20 laser encoders and associated equipment are precision optical and electronic tools used for obtaining precise measurements and must therefore be treated with appropriate care.

Ensure protection is provided for both the HS20 and the associated optics when transporting a machine with the equipment already installed. Refer to Appendix B for maintenance and cleaning instructions.

Machine requirements summary

The following defines the minimum requirements, which must be provided to successfully install the HS20 laser head.

- The machine controller must accept digital encoder feedback inputs of RS485/422 format differential AquadB or analogue sin/cos (1 Vpp).
- The straightness of travel of any axis to which HS20 is to be fitted must be within ±0.5 mm to maintain beam alignment.
- If beam protection ducting is required there must be sufficient clearance.
- The mounting location for the HS20 laser heads must remain within 0 to 40 °C (32 to 104 °F).
- The beam path must be reasonably thermally stable. Otherwise suitable beam protection (such as HS20 beam protection ducting) must be used.
- Access is required to a 24V DC power supply for each HS20 laser head.

HS20 laser with long range linear optics

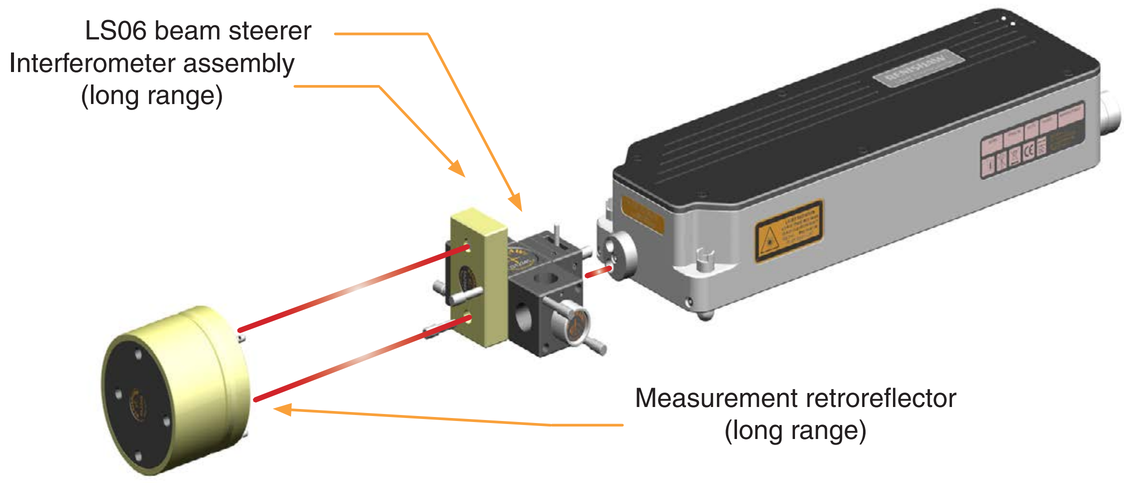


Figure 1 - HS20 with long range linear optics

HS20 laser with standard linear optics

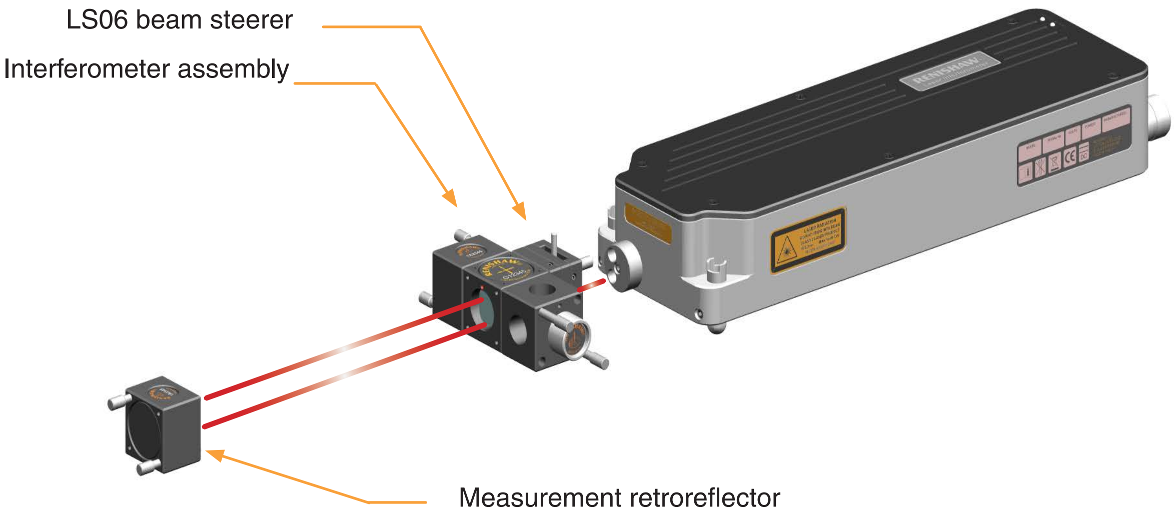


Figure 2 - HS20 with standard linear optics

Typical HS20 installation

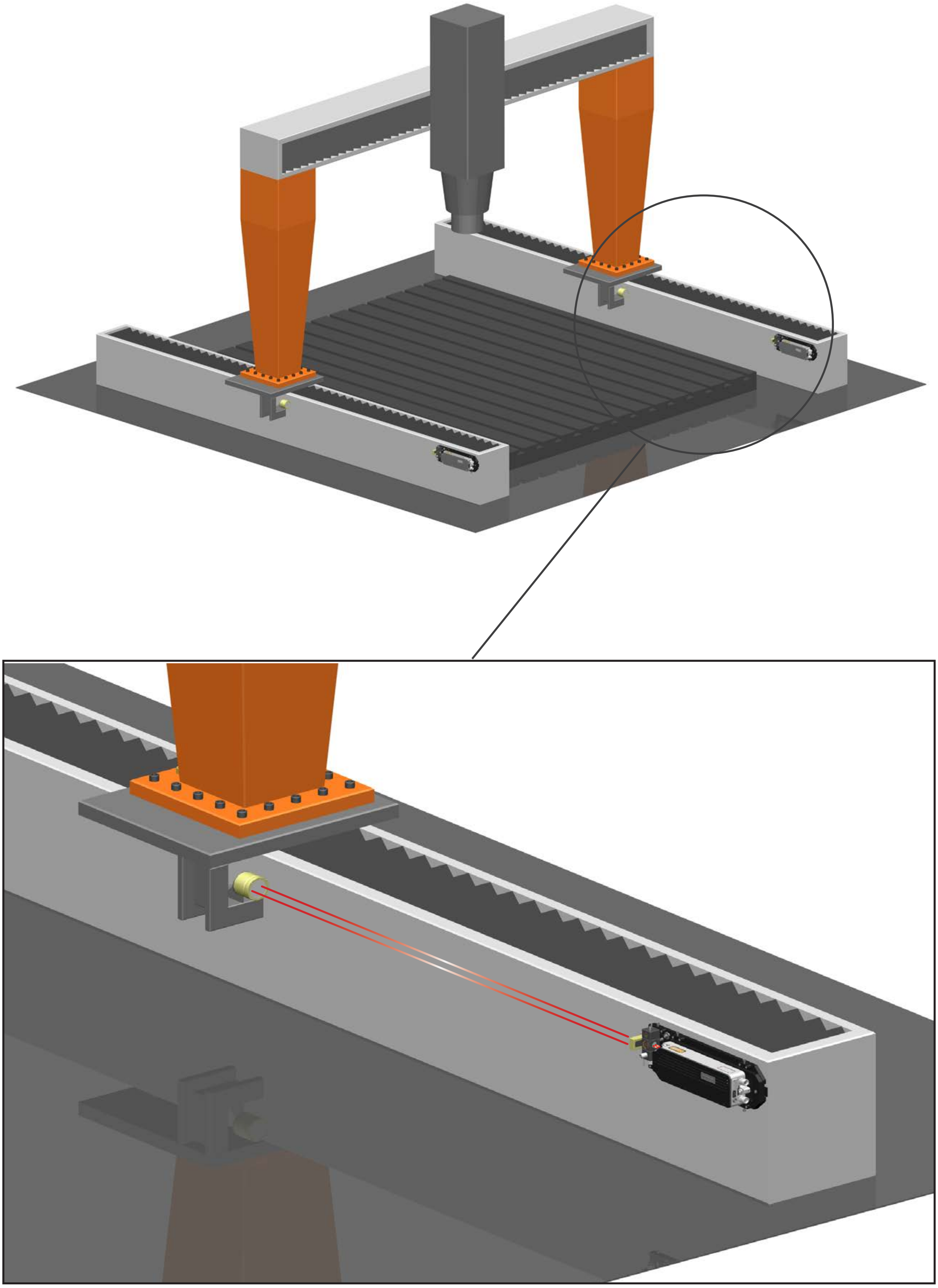


Figure 3 - Typical HS20 installation

Section 2 - Mechanical installation

Contained in this section

Space requirements for the HS20

Before mechanical installation of the HS20 can be performed a mounting location must be decided. The position should be chosen by consideration of the following:

Clearance required to adjust HS20:	Minimum 250 mm (10 in) above the HS20 laser head
Clearance required to adjust alignment plate:	Minimum 150 mm (6 in) on each side

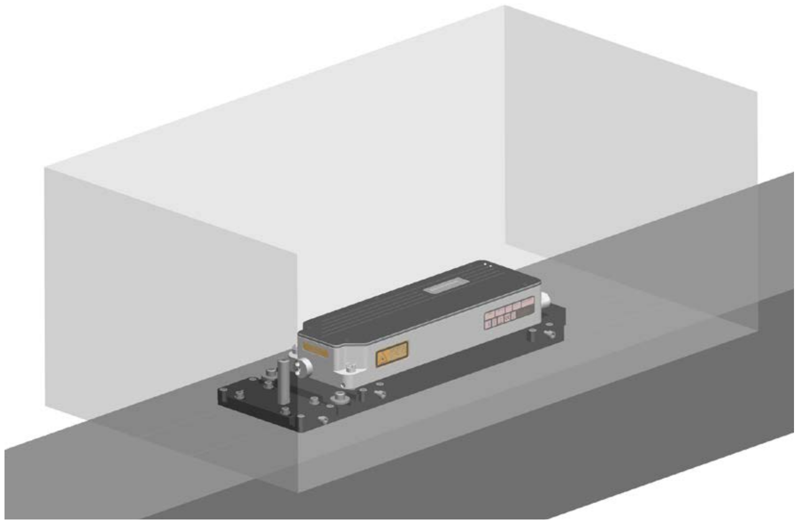


Figure 4 - Space requirements for HS20

Beam path requirements To enable the measurement retroreflector to travel unimpeded down the full length of the axis requires the clearances detailed below:

Standard linear optics kit:

With ducting:	Minimum 60 mm x 60 mm (2.4 in x 2.4 in)
Without ducting:	Minimum 50 mm x 50 mm (2 in x 2 in)

Long range optics kit:

With ducting:	Minimum 130 mm x 160 mm (5.2 in x 6.3 in)
Without ducting:	Minimum Ø 90 mm (Ø 3.6 in)

Golden rules of mechanical installation

The HS20 system provides position feedback of changes in linear distance between a reference and target optic. Any movement in the HS20 laser, or interferometer assembly has the potential to cause measurement errors or the signal strength to drop. Follow these 'golden rules' to help prevent mechanical installation issues during use.

- Ensure all components are rigidly located with the recommended fixings. A lack of rigidity between the optics and the machine will result in measurement errors.
- Lock the alignment plate position after alignment to prevent creep when the system is in use.
- Do not touch the glass surfaces of the optics as this will reduce signal strength.

This section covers mounting the alignment plate, HS20 and the measurement optics.

Mounting options for the HS20 laser head

There are two typical mounting methods for the HS20, detailed below. The application will generally govern the most practical method of mounting the HS20. Both options assume that the HS20 is mounted on the HS20 alignment plate.

1. Mounting directly to the machine rail with the HS20 laser beam parallel to the axis travel.

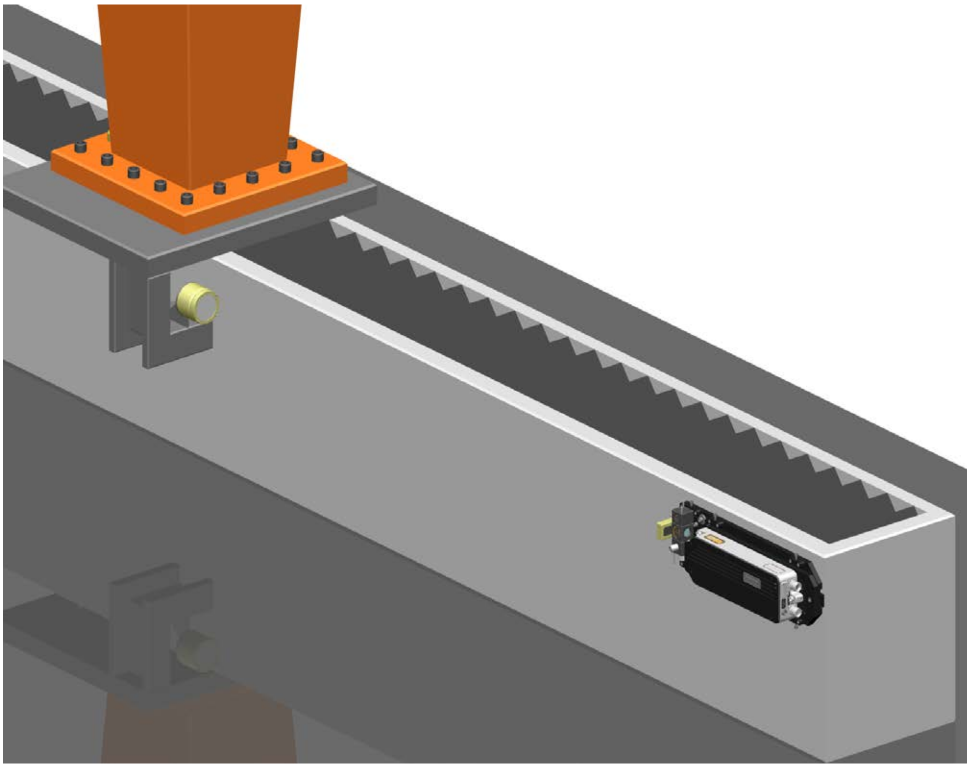


Figure 5 - Direct mounting onto machine rail

2. Mounting on a concrete plinth off the machine (as shown below). Although concrete has a coefficient of expansion that is similar to steel, the structure's thermal mass will provide a far greater degree of laser alignment stability than a support fabricated from steel. Again the HS20 laser beam will run parallel to the axis travel.

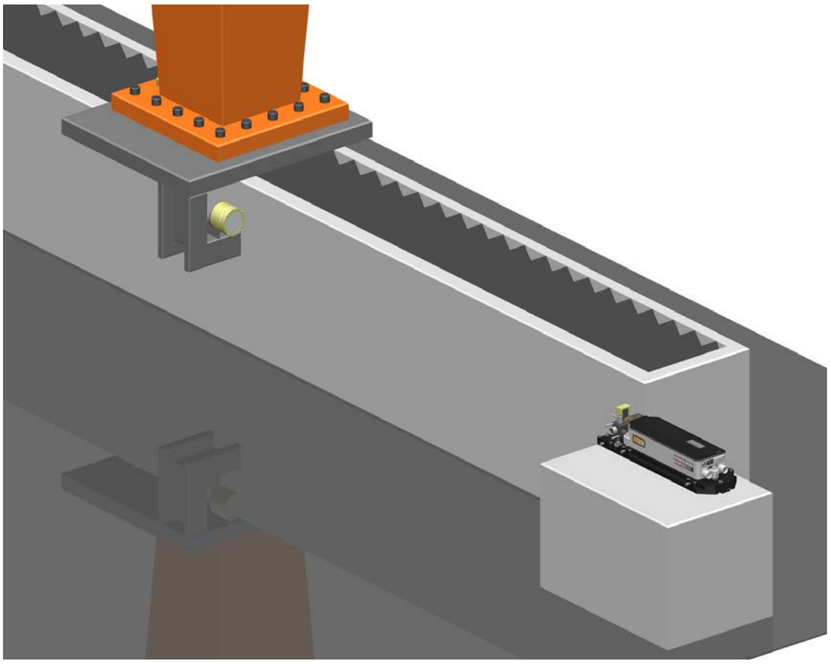


Figure 6 - Plinth mounting arrangement

When designing the mounting scheme for the HS20 laser system the main criteria should be rigidity and stability of both the laser and the linear optics. It is important that the mounting scheme ensures the laser beam alignment remains stable to within ±0.5 mm at the far end of the axis. This is easy to achieve on short axis machine axes, but on very long machine axes, the stability of the mounting scheme becomes crucial. Under these conditions it is strongly recommended that the Renishaw alignment plate is used since it has been designed to accommodate the small expansion of the HS20 laser during preheat without disturbing beam alignment.

HS20 external dimensions and mounting holes

This section details the key external dimensions along with the locations of mounting holes.
(All dimensions are in mm)

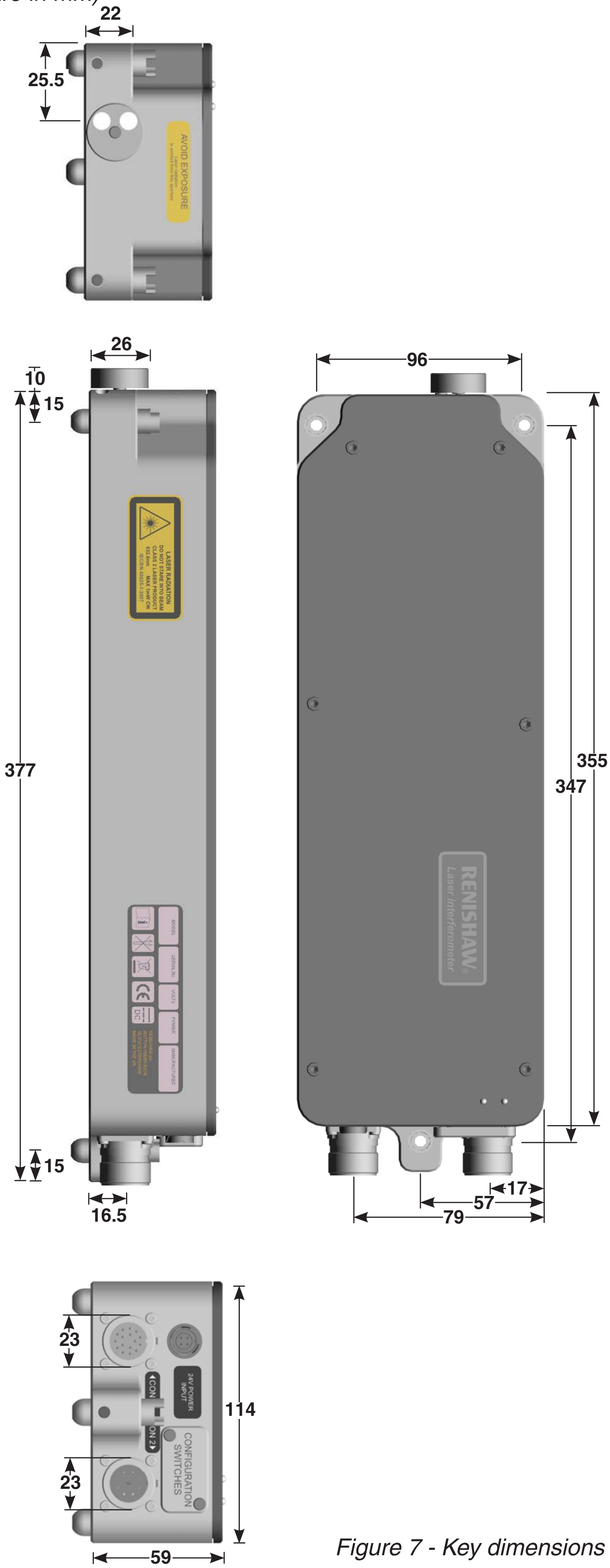


Figure 7 - Key dimensions for HS20 laser head

HS20 mounting plate external dimensions and mounting holes

This section details the key external dimensions along with the dimensioned locations of mounting holes.
(All dimensions are in mm)

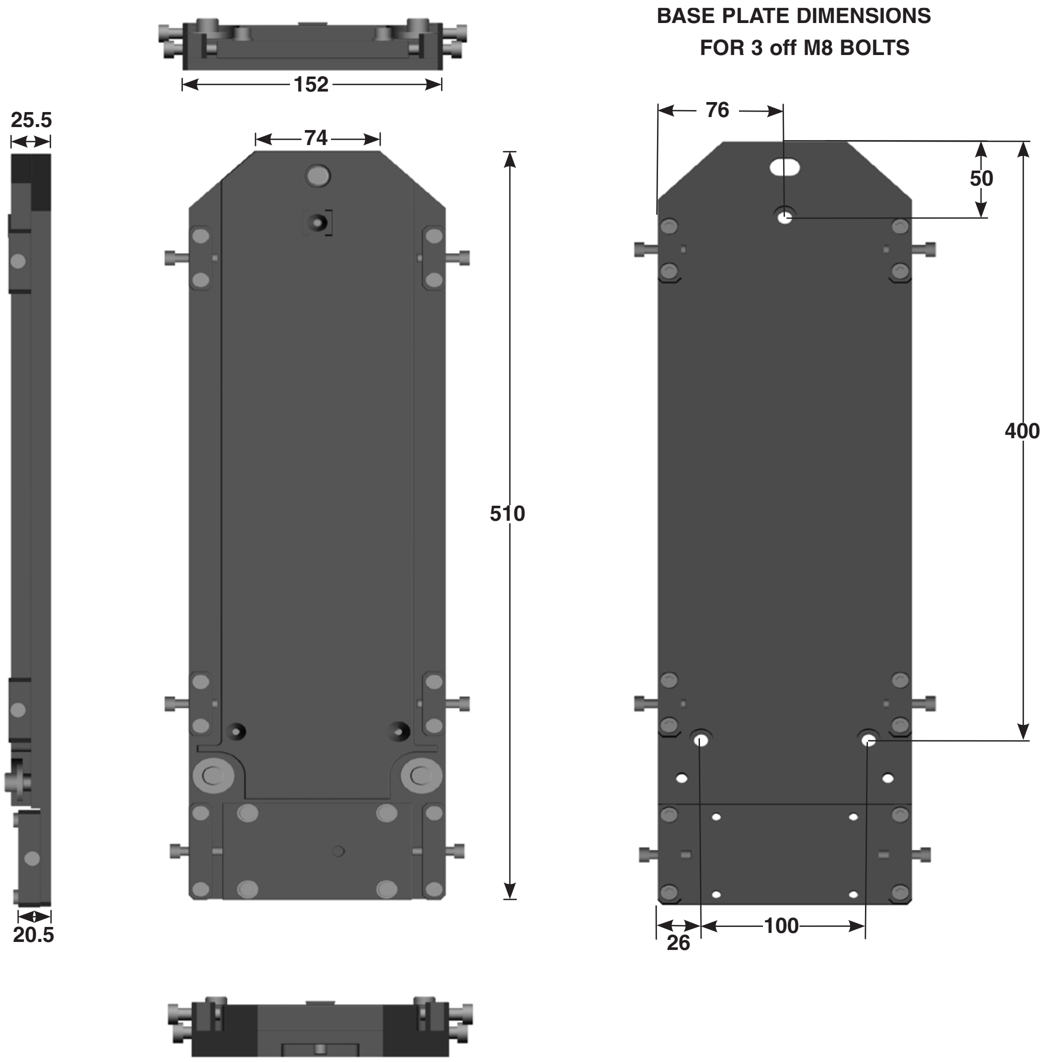


Figure 8 - HS20 alignment plate dimensions

HS20 alignment plate

The HS20 alignment plate, in combination with the HS20's adjustment feet, provides both translation and rotation in both vertical and horizontal planes, in a manner that is stable and controllable. The plate also provides an adjustable mount for the optical components, allowing translation and rotation in vertical and horizontal planes.

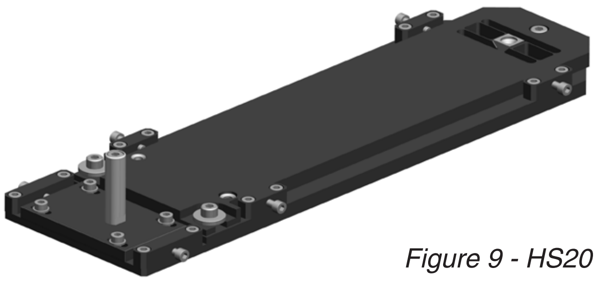


Figure 9 - HS20 alignment plate

HS20 alignment plate adjustments

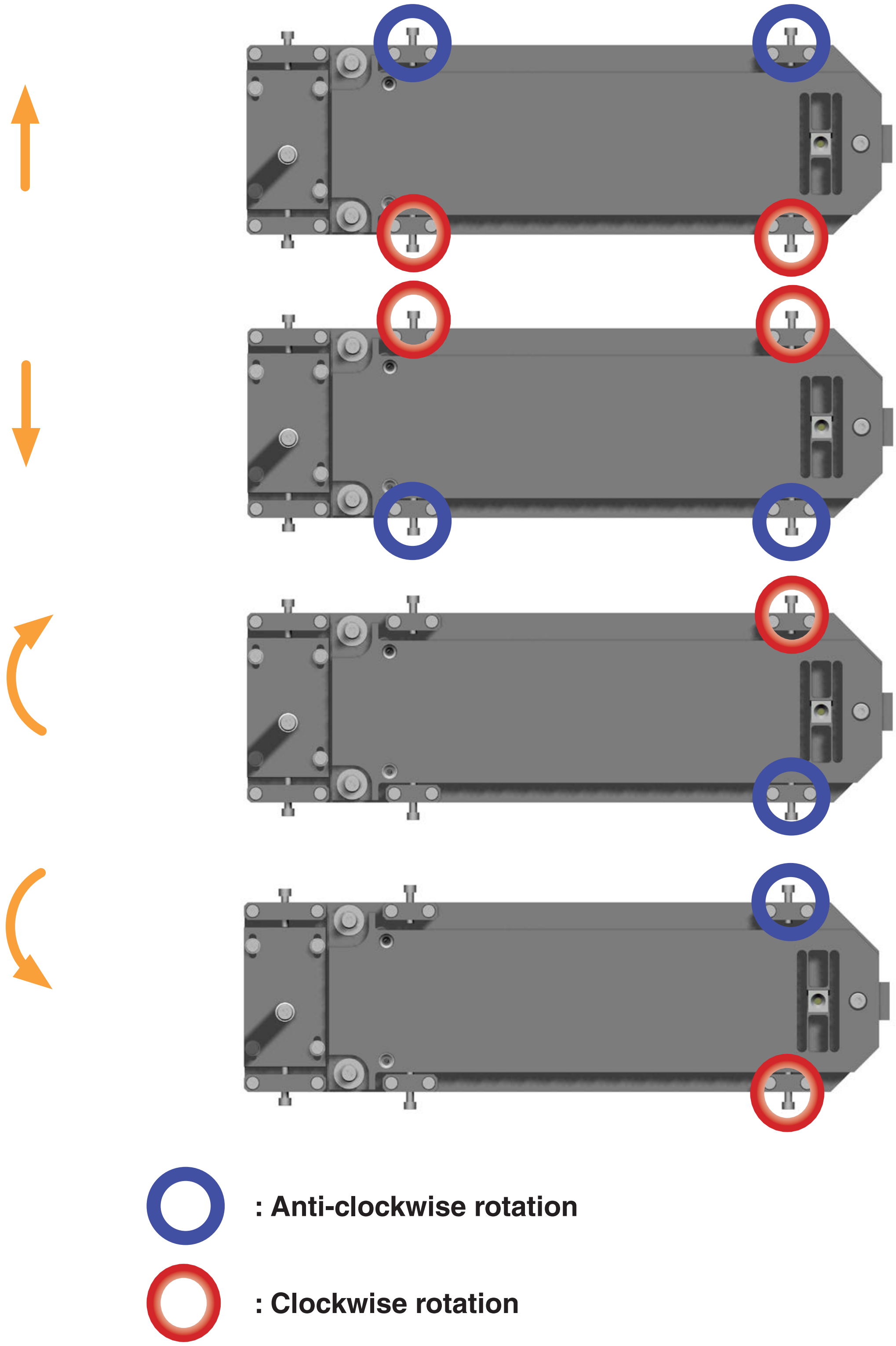


Figure 10 - Alignment plate adjustments

Measurement retroreflector mounting detail

Dimensions of the measurement retroreflectors used in both the standard linear measurement kit, and the long range measurement kits are detailed in figure 11.

(All Dimensions are in mm)

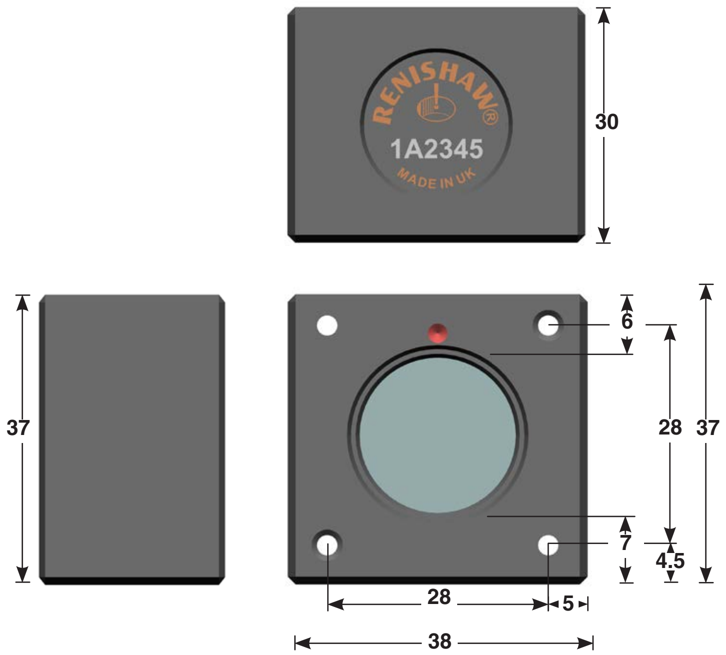


Figure 11 - Standard retroreflector outline drawing

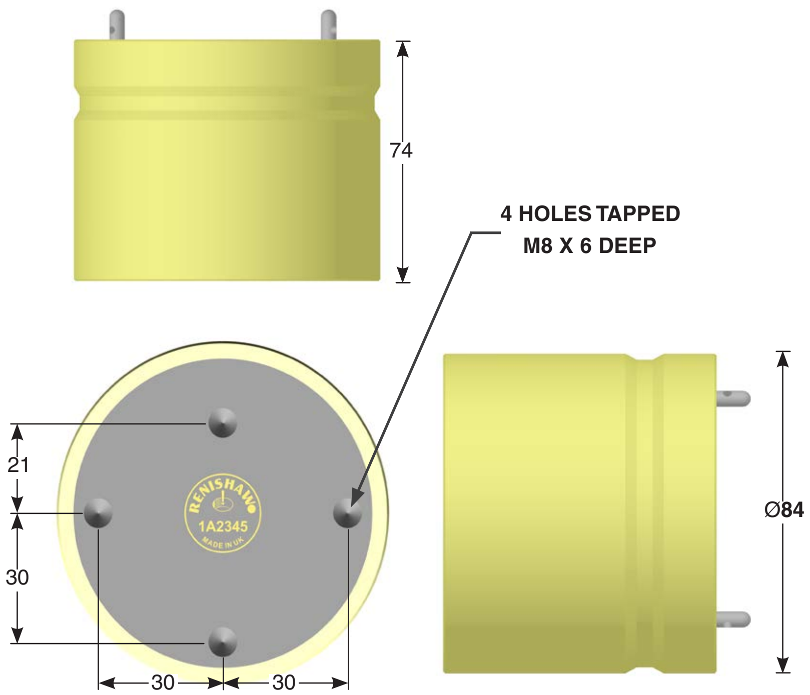
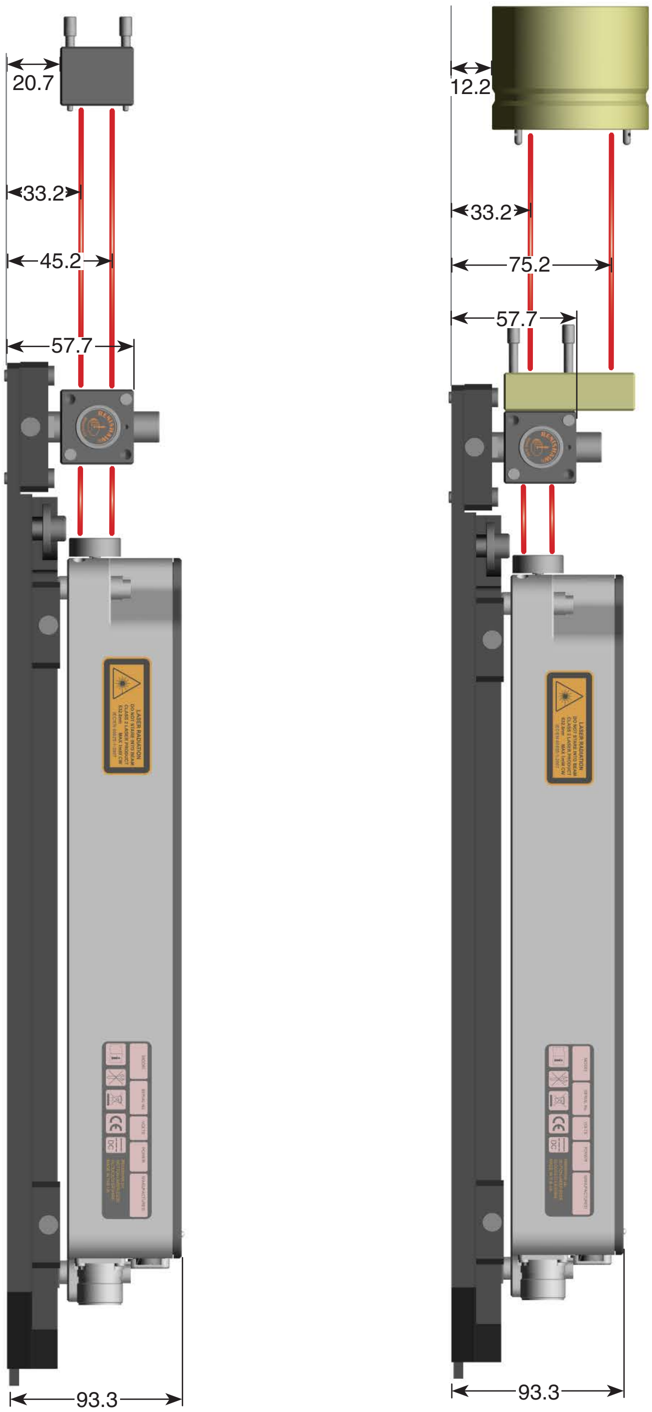


Figure 12 - Long range retroreflector outline drawing

Beam position relative to the laser, optics and ducting

All Dimensions are in mm and all positions are relative to the centre of the beam.
In this example the HS20 laser head feet are set a nominal 15 mm from the base.



HS20 laser head with standard optical setup

HS20 laser head with long range optical setup

Figure 13 - Shows the beam heights from the HS20 laser head

Beam protection ducting

Fundamental to the reliability of position feedback is that a stable, accurate laser alignment needs to be maintained along the full axis length. Alignment stability can be affected by temperature gradients formed through the beam; these are usually caused by rapidly changing environmental conditions.

Temperature gradients across the beam cause fractional changes in wavelength through the cross section of the beam, with the warmer side of the beam having a fractionally longer wavelength than the colder side. The resultant effect is "beam bending" and, ultimately, misalignment.

These gradients can vary slowly or quickly as a machine's environment changes in response to a change, such as a door opening, a heater switching on, or sunlight shining on the machine.

The HS20 beam protection ducting system protects against the formation of thermal gradients by including an "air feed" system that stirs the air over the entire axis length. It also acts as an effective protection from swarf, oil and other contaminants usually found in machine tool applications.

For full details please refer to the HS20 beam protection ducting manual, a summary is given below.

The HS20 beam protection ducting system is based upon a standard extrusion supplied in 3 m lengths. To provide application flexibility, this extrusion can be mounted by either of two methods: with standard brackets, a cross section of 155 mm x 121 mm is required along the axis whereas, with low profile brackets, the required section is reduced to 118 mm x 121 mm. The extrusion was designed primarily for use with long-range optics, but is also suitable for standard optics.

Note: Do not fit any ducting to the machine before aligning the HS20 laser heads

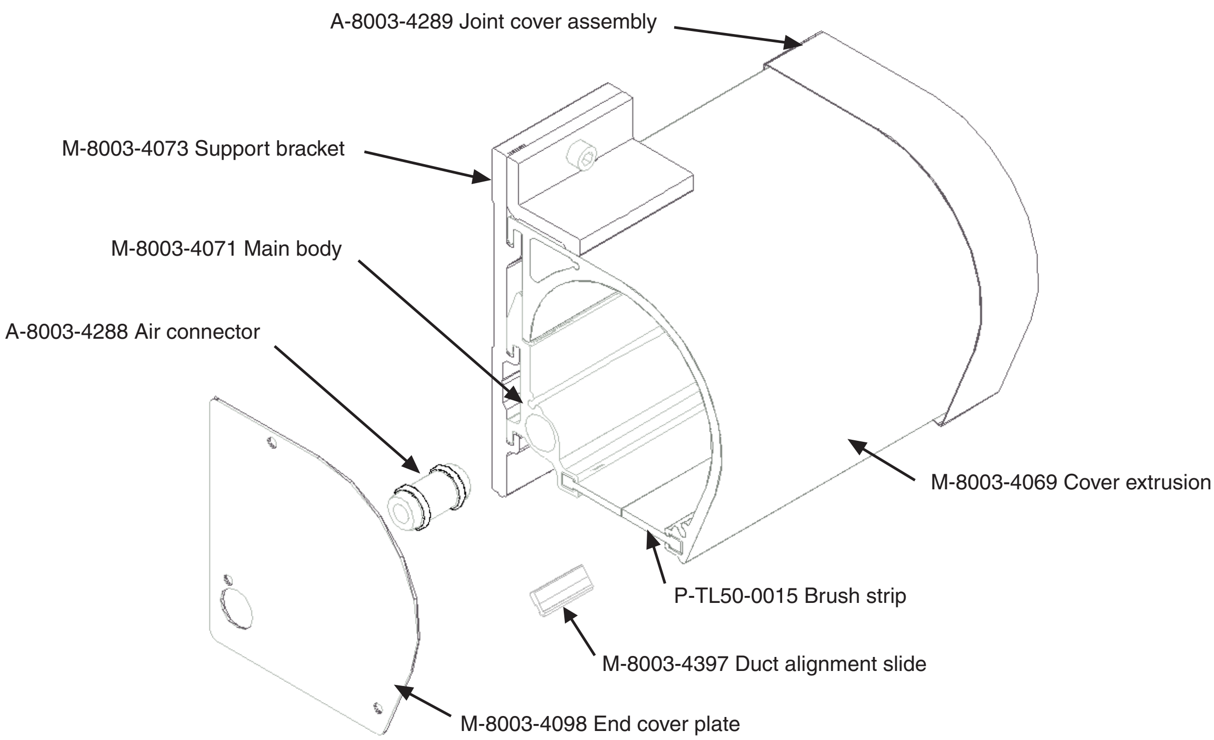


Figure 14 – HS20 beam protection ducting assembly drawing

To prevent contamination of the air inside the duct from oil or water, a recommended pneumatics kit is available from Renishaw. This offers double filtration through a 5 µm filter and 0.3 µm mist separator. Both of these items automatically drain to prevent the system from becoming blocked. However, if the user chooses to supply an alternative feed, then it is essential that the air feed is well filtered, clean and dry, and meets the following specification:

Basic filtration	5 µm (with autodrain)
Mist separation	0.3 µm (with autodrain)
Output pressure	2 bar - 3 bar (29 psi - 44 psi)
Output flow rate	200 l/min

Particle filtration and mist separation units must be autodraining to prevent moisture being sprayed into the beam path.

LS06 laser steerer

The LS06 laser steerer is an alignment aid for the Renishaw HS20 laser scale. The steerer allows easy adjustment to both vertical and horizontal planes reducing the need for final adjustment at the laser head.

The laser steerer is mounted onto the side of the interferometer nearest to the HS20 laser head using the clamp screws provided (see figure 15). When installing ensure that the two adjustment levers on the laser steerer are accessible and approximately in mid-position. This will guarantee full adjustment range. Total steering range is ±0.6 mrad (0.6 mm/m).

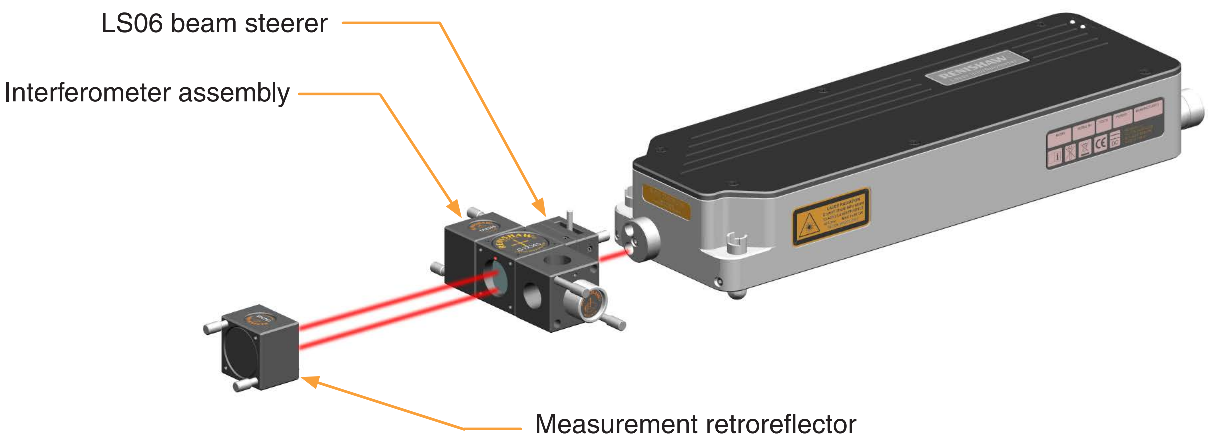


Figure 15 - HS20 with long range linear optics and LS06 beam steerer

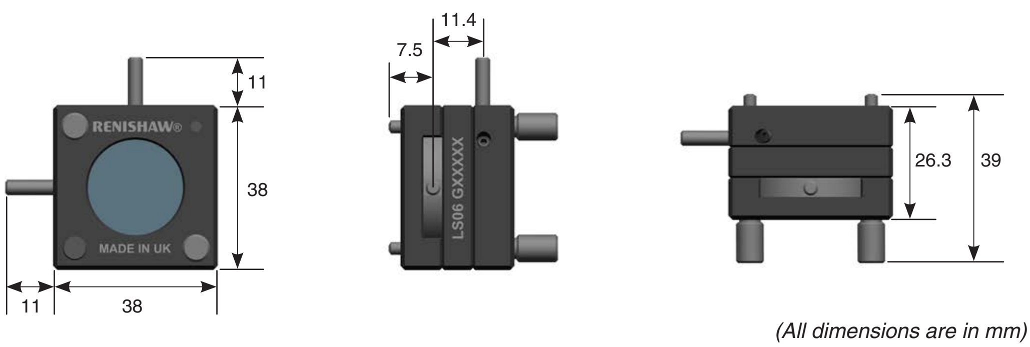


Figure 16 - LS06 beam steerer dimensions

Reference mark switch bracket and actuating cam

The reference mark switch is shown in figure 17 with fixing centres given. One reference mark switch is required for each axis using a HS20 laser head. The mount for the actuating cam must allow the position of the cam to be adjusted so that simultaneous switch operation can be achieved on split axis machines. An adjustment range of ±5 mm should be sufficient as long as switches and cams are accurately mounted to the machine with respect to one another.

The reference mark-actuating cam must be manufactured with an approach angle of 30°. Suitable cams can be purchased directly from a balluff switch distributor.

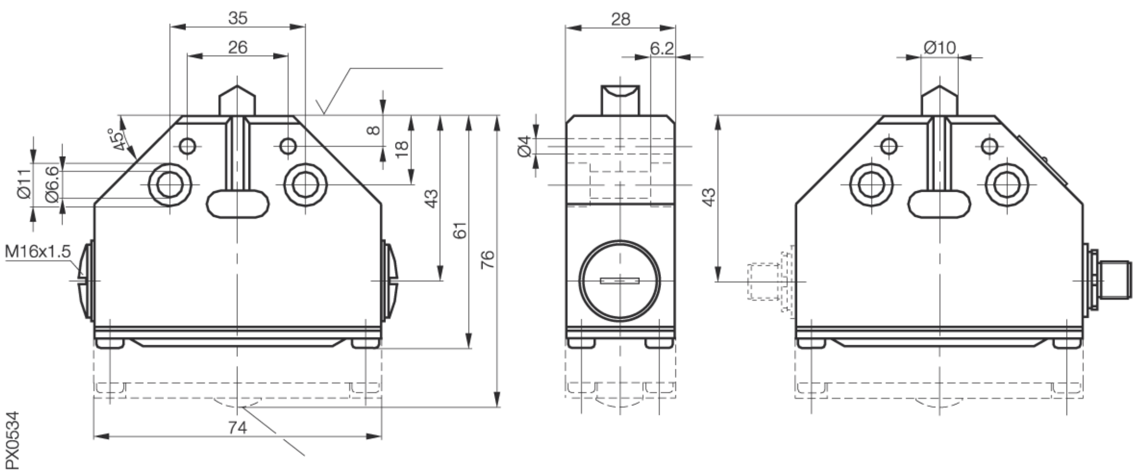


Figure 17 - Reference mark switch outline drawing

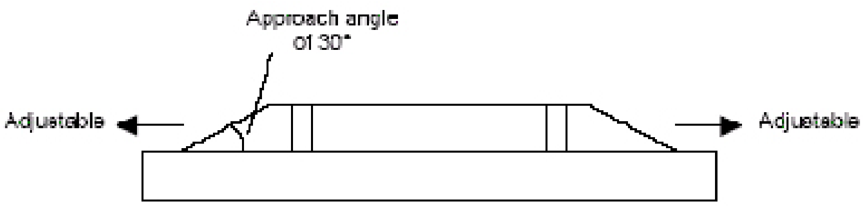


Figure 18 - Reference mark actuating cam approach angle

Mounting the HS20 laser onto a machine

Fitting the baseplate to the machine

Information related to the specific dimensions and mounting hole locations can be found within the under the headings *HS20 external dimensions and mounting holes* and *Mounting plate external dimensions and mounting holes* within this section.

1. Place an M8 washer over each of the three mounting holes on the machine. The washers must be fitted to avoid distortion of the baseplate. (Note: additional washers may be added if required) as shown in figure 19.
2. Lower the baseplate onto the washers ensuring the holes remain aligned.
3. Secure the baseplate to the machine using two M8 x 16 mm cap head screws.

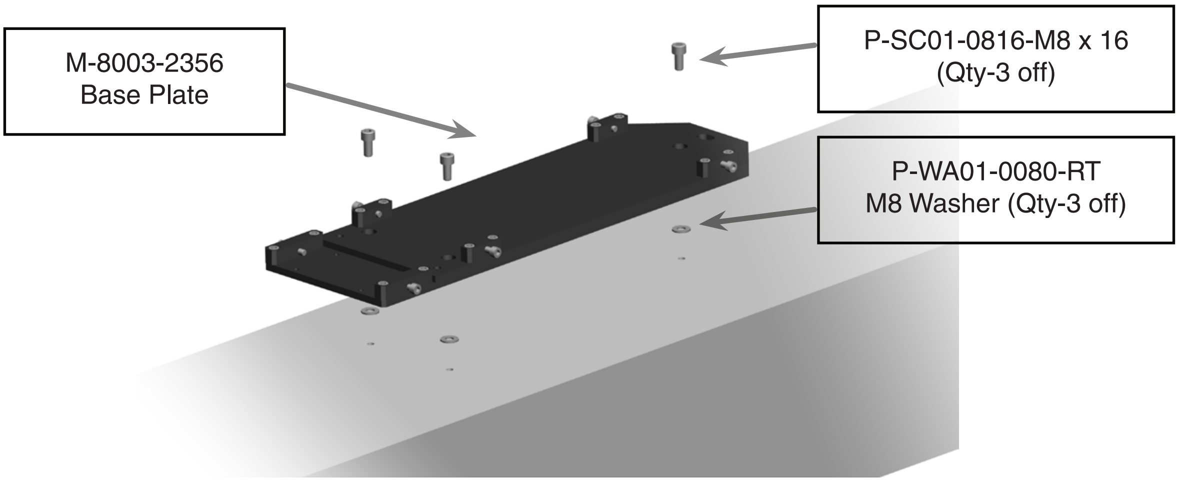


Figure 19 - Fixing the baseplate

Fitting the alignment plate to the baseplate

1. Lower the alignment plate onto the baseplate ensuring that the holes remain aligned.
2. Fit the rectangular nut under the rear of the baseplate.
3. Fit (but pinch tighten only) as shown in figure 20
   - one M8 x 20 mm cap head screw at the rear
   - two M8 x 20 mm cap head screws and custom washers at the front

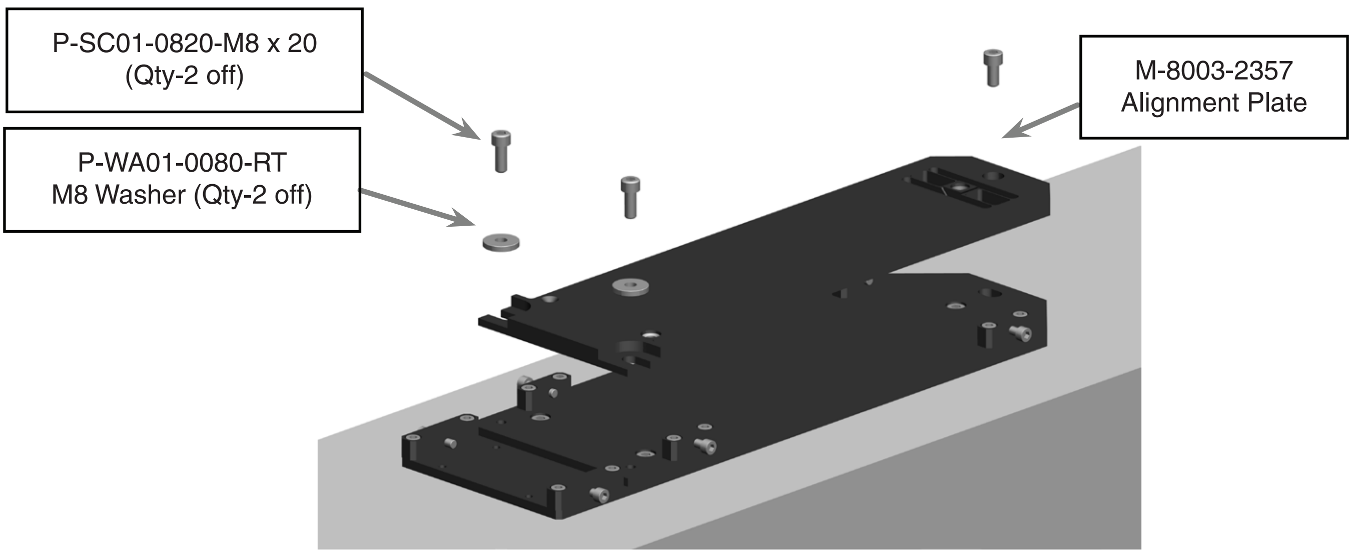


Figure 20 - Fixing the alignment plate to the baseplate

Fitting the optical plate to the alignment plate

1. Take the M8 x 16 mm cap head screw and fit into the pillar
2. Hold the flat on the pillar parallel to the beam path using a 13 mm spanner
3. Whilst maintaining the pillar orientation, tighten the cap head screw

Fitting the HS20 laser

1. Fit the three adjustable feet to the HS20 laser head, setting them mid-way along their threaded section to allow full adjustment in both directions. as shown in figure 21.
2. Take the semi-circular spacer and place it in the rear foot mounting position on the alignment plate. Take the conical washer (P-WASH-0003-RT) and fit this into the counterbore at the front left foot mounting position.
3. Mount the laser head carefully onto the alignment plate.
4. Place 3 copper wave washers (P-WA16-002-RT) (supplied) into the adjustable feet.

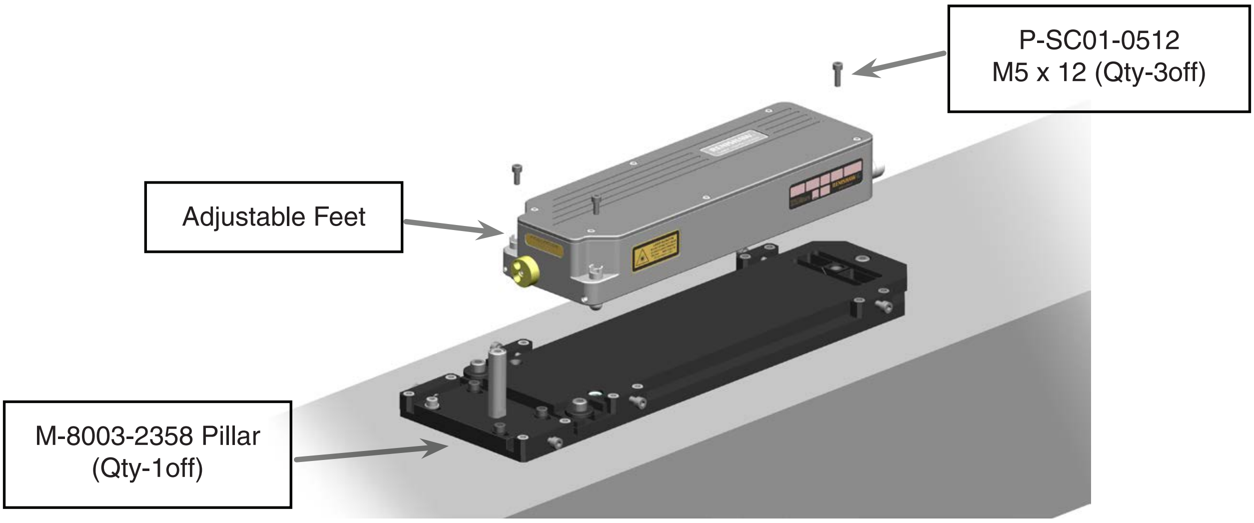


Figure 21 - Fitting the laser to the alignment plate

5. Insert three M5 x 12 bolts (P-SC01-0512) into the adjustable feet and take up slack but do not fully tighten.
6. Screw the pillar (M-8003-2358) into the position shown in figure 21.

Protecting the HS20 laser head

In most cases the laser head will have some form of primary protection, such as the machine way covers. If this is not the case then it will be necessary to protect the laser head from physical impact and contamination by using an enclosure that covers the laser and alignment plate assembly.

Additionally in cases of extreme conditions, where excessive coolant mist, graphite or composite material dust are present, the way covers may not be sufficient to protect the laser head. In this instance, additional protection should be considered.

Design of the measurement retroreflector mounting

The retroreflector is mounted on the moving element of the machine, this arm of the optical configuration is often termed the measurement arm.

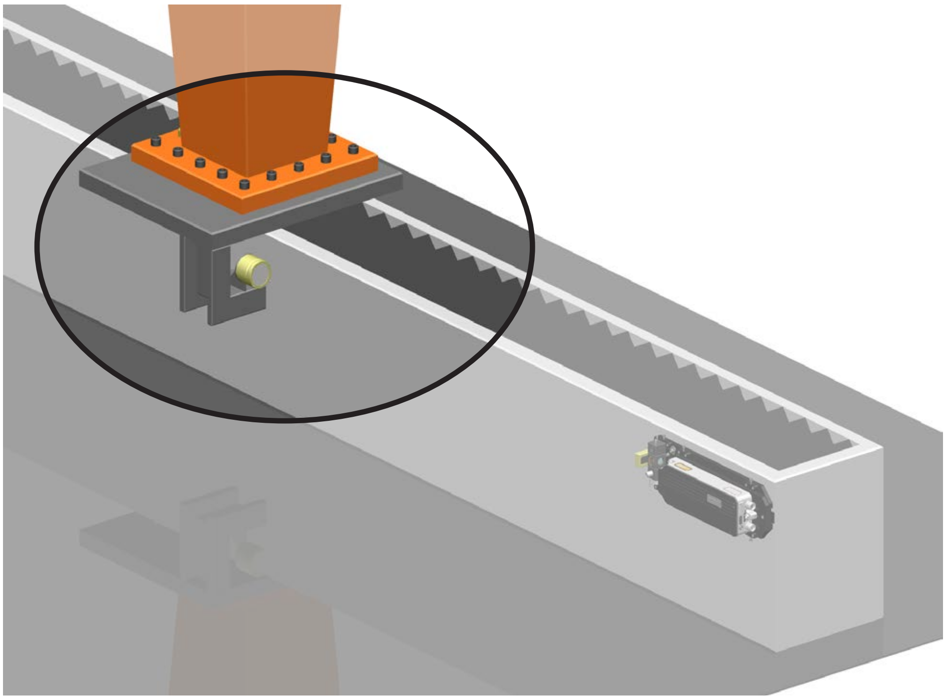


Figure 22 - typical retroreflector mounting

The bracket design must ensure that:

- If beam protection ducting is being used the retroreflector is positioned in the middle of the beam protection ducting.
- The distance between the machine moving element and the measurement retroreflector is kept as small as possible to minimise possible vibration effects. The bracket and mounting should be rigid in the axis of movement, this is extremely important to avoid vibration being induced in the axis.

Section 3 - Electrical installation and system configuration

Contained in this section

General

This section covers the electrical connections for the HS20 laser system. The HS20 laser head has three connectors on the rear of the unit that are used for signal and power communication.

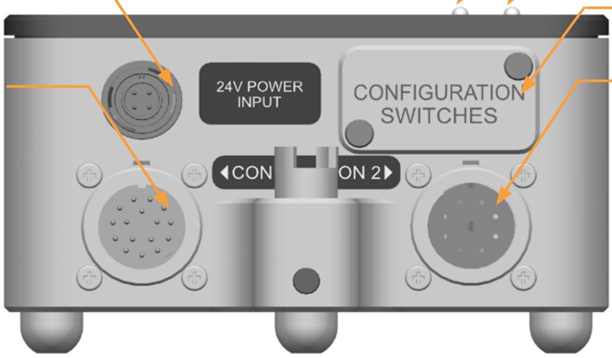


Figure 23 - HS20 connector and switch locations

WARNING: Before any electrical connections are made, ensure that the HS20 and machine controller are unpowered.

System grounding (earthing)

The HS20 laser head uses electrical feedback signals which can reach high frequencies, and which often run over relatively long distances on a large machine. Therefore, the correct grounding (earthing) of the system components and the screening of the interconnecting cables is a paramount to ensure the reliability and performance of the laser head.

Several factors in the overall electrical characteristic of the installation will be relevant.

- The machine structure should be well bonded at the same potential.
- The HS20 laser head should be connected to earth via the 24V power input on the rear of the unit.
- The laser head cables should be grounded with the following premise:
  - i. Connect the outer (braided) screen at both ends of each cable by connecting it to the connector shell.
  - ii. Connect the inner (foil & drain wires) screen at the HS20 (signal source) end only.
- The 0V line should be connected wherever it is present.

To achieve optimal noise immunity it is essential to achieve a low impedance path from the various system units to ground.

If the HS20 laser head is powered using the 16-way circular connector then it is recommend that the unit is earthed using the 24V dedicated input connector. Either the 3 or 4 pin from this connector can be connected to the machine or a suitable ground position.

HS20 cables and connectors

Both supplied connectors are solder terminal versions. Care should be taken during assembly as poor termination can cause poor connection reliability and intermittent states from the laser system.

Cable preparation

Note: For cable lengths in excess of 10m it is suggested that the ‘spare core’ in the cable be used to connect an additional 0V line. This provides two lines for the 0v and can help offset voltage drop on longer length cables. For lengths over 30m it may be necessary to use cable with 20AWG conductors for the power lines.

The cabling for the laser head is a critical component in terms of the performance of the installation. This is primarily because of the harsh electrical environment around most machine tools, and also the high frequency nature of the signals used in the system. EMC (Electro Magnetic Compatibility) is very important, and Renishaw have done a considerable amount of research in selecting the optimum performance cables and specifying the way in which they are used. It is strongly recommended that the exact cables identified below (or a direct equivalent) should be used for the installation.

Signal strength cable

- 24 AWG EcoMini 2 pair
- Nominal diameter 4.22mm (0.166”)

An example of this cable is ‘**Alpha Wire**’- Mfr. Part No. 78172

This cables nominal diameter correctly fits the recommended Binder cable back shell clamp (max allowed diameter 5mm)

Belden 8166

Six pair, 24 AWG low capacitance ‘datalene’ cable used for:
- Connections from HS20 to RCU10.

Note: Belden 8166 cannot be used to carry 24V DC power to an HS20 laser head over distances greater than 10m (30ft) due to voltage drop. In this case Belden 9874 may be used but does have inferior screening.

24 V power cable

4 core 18 AWG if used with voltage sense or 2 core 18 AWG if just required for laser head grounding.
Maximum outer diameter: 7.3 mm
It is recommended that a screened cable is used

Figure 25 shows how the screen should be connected to the body of the 16 way connector to ensure that these conditions are satisfied.

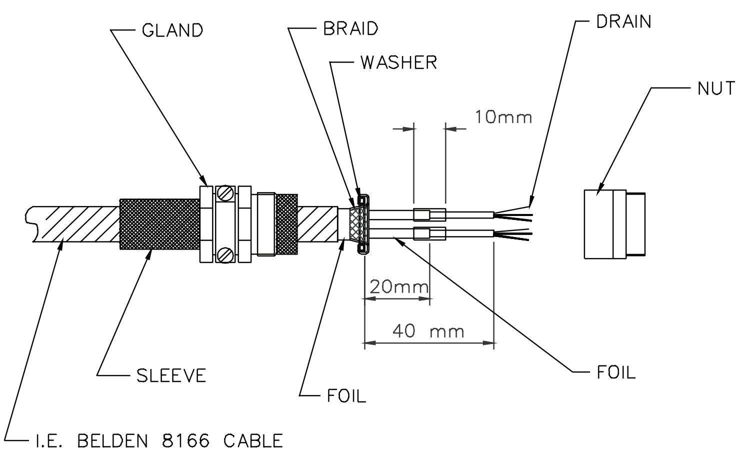


Figure 25 - Circular connector termination details

HS20 interface connector

Figure 26 shows the pin out of the HS20 interface connector. It also shows the corresponding RCU pin connections for applications involving the RCU compensator.

HS20 16 way circular Pin	Signal name	Comments	RCU 15 way D-Type Male	Pair number
1	24V DC		n/c	1
2	GND - 0v DC	Power ground	2	1
3	Chassis GND	Cable Inner screens		
4	AQUAD	RS485 format digital quadrature	14	2
5	/AQUAD	RS485 format digital quadrature	6	2
6	BQUAD	RS485 format digital quadrature	13	3
7	/BQUAD	RS485 format digital quadrature	5	3
8	/RESET	Active low reset line, 24v Input	15	6
9	Reserved	No connection		
10	Reserved	No connection		
11	Reserved	No connection		
12	/BEAM_BLOCK	Active low, latched laser status line asserted when beam strength at 10% or less of maximum level. 24v output.	11	4
13	/OVERSPEED	Active low, latched laser status line indicates invalid quadrature transition has occurred. 24v output.	3	4
14	/UNSTABLE	Active-low laser status line indicates state of laser tube stability. 24v output.	4	5
15	/BEAM_LOW	Active low laser status line asserted when beam strength at 20%or less of maximum level. 24v output.	12	5
16	Reserved	No connection		

Figure 26 - HS20 interface connector pin-out

24V DC input connector

HS20 24V DC input connector (4 way circular)		
Pin	**Standard PSU**	**PSU with remote sense**
1	+24 V supply	+24 V supply
2	---	+ Sense
3	0V	0V
4	0V	0V
5	Case (screen)	Case (screen)

Figure 27 - HS20 24V DC input connector

HS20 diagnostic connector

The pin out of the HS20 connector is as follows.

HS20 diagnostic connector (9 way circular)		
Pin	**Signal name**	**Comments**
1	0V	0V
2	Beam strength	0 to 1 V DC output representing 0 to 100% return signal strength.
3	Analogue sine	1V peak to peak centred at 2.5V
4	/Analogue sine	1V peak to peak centred at 2.5V
5	Analogue cosine	1V peak to peak centred at 2.5V
6	/Analogue cosine	1V peak to peak centred at 2.5V
7	Status	RS485 digital comms
8	/Status	RS485 digital comms
9	Reserved	No connection

Figure 28 - HS20 diagnostic connector pin-out

Powering down and disconnecting the HS20

To disconnect power to the HS20, first turn off the 24 V DC power supply, then unplug the HS20 interface connectors or disconnect the 24 V input connector.

Ensure that the connectors on the rear of the HS20 are accessible by the operator.

Power requirements

The HS20 requires a 24 V power supply conforming to the following specification.

24 V DC ± 1 V @ 2.0 A	Inrush (first 10 ms)
24 V DC ± 1 V @ 1.2 A	Warm-up (~10 mins)
24 V DC ± 1 V @ 0.7 A	Operation at room temperature (20 °C)

The 24 V power supply should be single fault tolerant certified to EN (IEC) 60950-1.

Output quadrature format

The HS20 can output digital quadrature signals in two-channel A quad B format, A and B signals having a 90° phase shift in RS485 format.

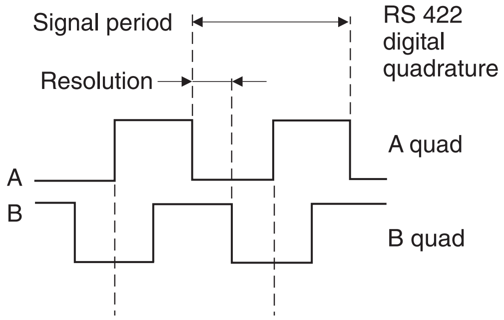


Figure 29 - Digital quadrature format

Analogue quadrature - 1V analogue interface

The HS20 outputs analogue quadrature sin/cos signals with a period of 316nm.

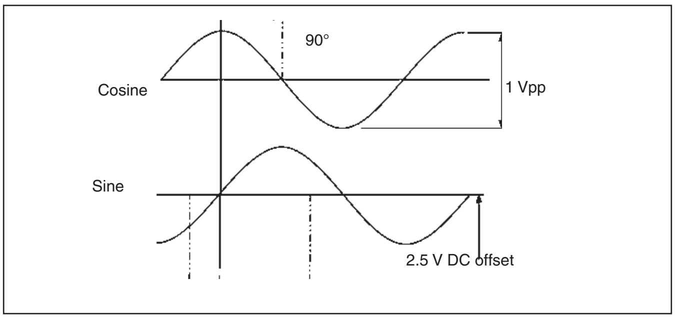
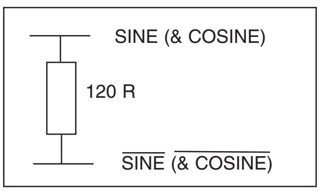


Figure 30 - Analogue (Sin/Cos) waveforms

The analogue quadrature signals are 1V peak to peak signals (at 100% signal strength) when terminated with 120Ω resistors.



Signal strength

Depending on the type of quadrature required (analogue / digital), the way in which the signal strength is measured may vary.

There are two methods of reading the signal strength from the HS20 as shown below:

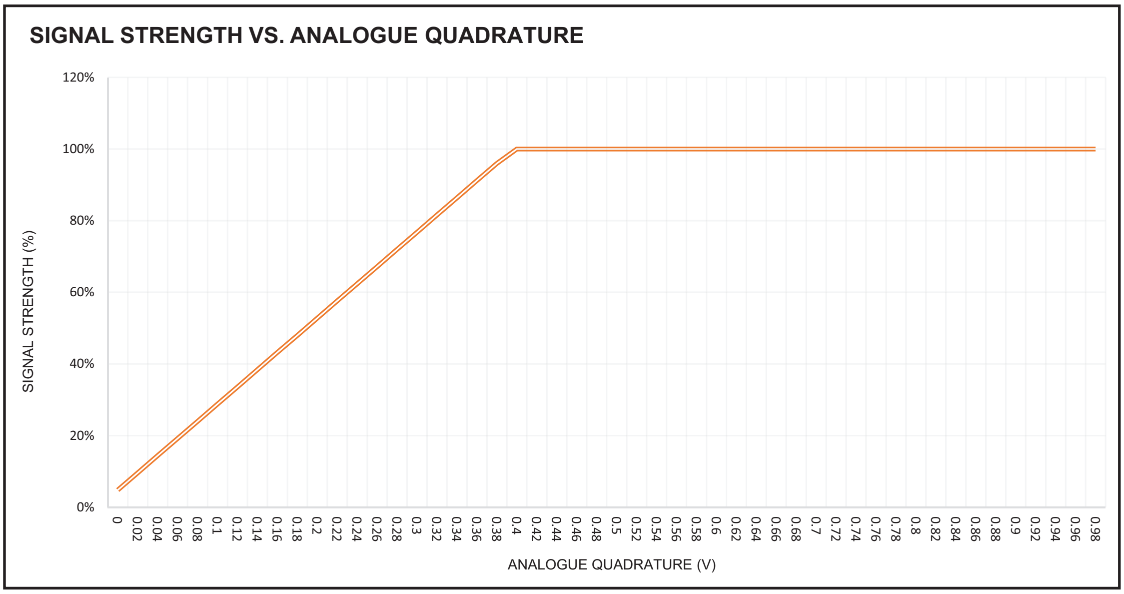
- **Digital signal strength output** - The digital representation of the signal strength is also available through the diagnostics connector in an RS485 format which can be connected to the RCU10 and a live signal strength viewed within the RCU-CS software.
- **Analogue signal strength output** - The analogue representation of the signal strength is available through the diagnostics connector in a 0 to 1V format that can be easily read with a multi-meter.

Using digital quadrature

When the digital quadrature is used, the signal strength can be measured using the analogue or digital signal strength output.

Using analogue quadrature

When analogue quadrature is used, it may be required that the signal strength is measured more accurately. This is because the analogue and digital signal strength outputs are digitally generated and 100% signal strength measured at these outputs represents a signal amplitude of => 0.42 Volts. This means that regardless of the actual signal amplitude, when it is > 0.42 Volts then this will be shown as 100% from both the analogue and digital signal strength outputs as shown within the chart below:



Therefore to maximise the performance of the analogue quadrature by minimising interpolation errors, it is recommend that the signal is maximised to 1V. This can be achieved by using a oscilloscope on the analogue quadrature outputs to measure the true analogue signal amplitude.

Reference mark wiring

Wiring to the reference mark switches must be to the normally open contacts identified as pin numbers 3 and 4. Figure 24 shows the wiring of the actual inside of a wired reference mark switch. Ensure that the screen is connected to the shell of the switch as shown in the diagram.

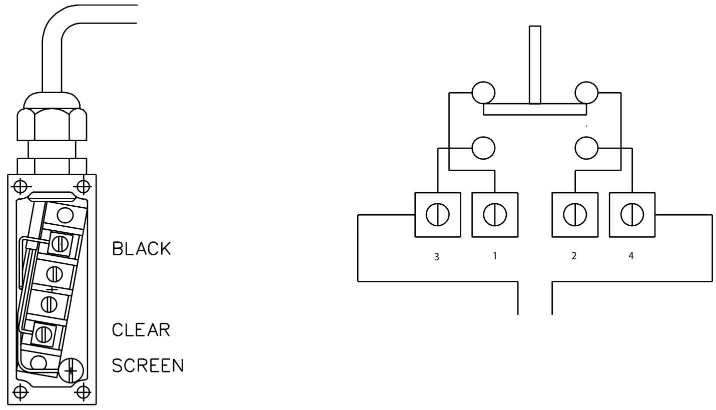


Figure 24 - Reference Mark Switch Wiring

HS20 configuration

The output of the HS20 may be configured by adjusting the configuration switches. There are four configurable functions available to the user on the HS20 via configuration switches mounted on the rear of the laser head as shown in figure 31 below.

WARNING: It is important to set the output resolution of the HS20 laser encoder to match the controller's input resolution. If the quadrature resolution is set incorrectly, the axis may move for distances and at speeds that are not expected. For example, if the output resolution from the HS20 system is set to double that of the controller input, the axis may move twice as far and twice as fast as expected.

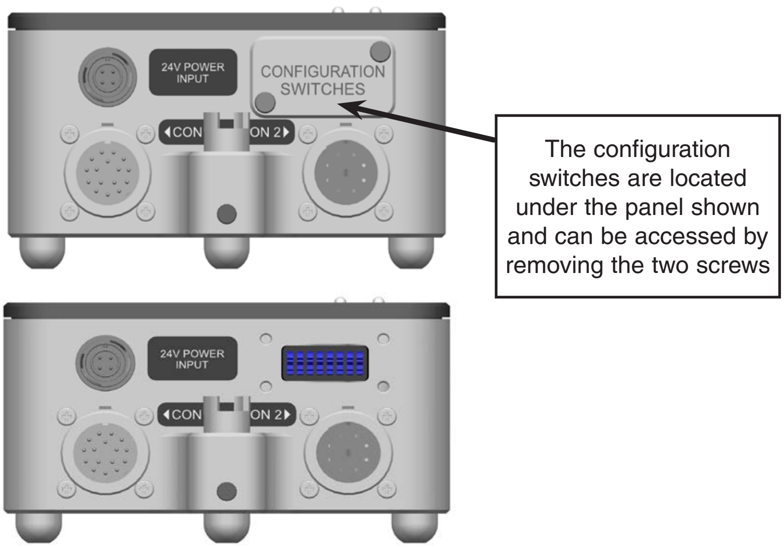


Figure 31 - HS20 Configuration switches

Configuration switch function

Switch	Function	Notes
1	No Function	Should be set to OFF
2	Quadrature Hysteresis	ON = Disabled OFF = Enabled
3	Quadrature Resolution	see information later in this section
4	Quadrature Resolution	see information later in this section
5	Quadrature Clock Frequency	see information later in this section
6	Quadrature Clock Frequency	see information later in this section
7	Quadrature Clock Frequency	see information later in this section
8	Parity	Set to ensure an odd number of 'ON' DIP switch states

Figure 32 - Configuration switch function

Quadrature hysteresis

The quadrature hysteresis function can be switched on/off using configuration switch number 2.

Electrical noise or axis vibration can cause multiple edges on the digital quadrature lines when passing through a transition. These multiple edges are caused by multiple transitions across the switching threshold within the analogue to digital converters from which the digital quadrature is directly derived. Edges may be produced even if there is no movement, due to noise being present within the vicinity of the switching threshold. These edges can occur at any frequency up to the output update rate.

This effect can be removed by including positional hysteresis on the quadrature outputs. This ensures that a transition can only occur once within one unit of resolution.

Quadrature hysteresis may be enabled on all of the digital output lines. In each case, a transition on the A line allows a change on the B line to be transmitted and vice versa. This does mean that, when selected, this hysteresis function will introduce a one unit of resolution offset when a direction change is made.

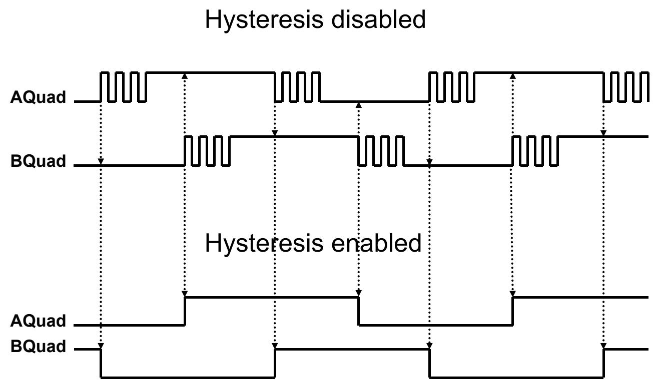


Figure 33 - Hysteresis

Quadrature resolution selection

The quadrature resolution function can be selected using DIP switches 3 and 4. Four output resolutions are available as detailed below.

Switch 3	Switch 4	Quadrature resolution (nominal) µm
OFF	OFF	0.6329905770
OFF	ON	0.3164952885
ON	OFF	0.1582476443
ON	ON	0.07912382213

Figure 34 - Quadrature edge to edge resolution selection

NOTE: Resolution is the edge to edge separation of the digital quadrature signals

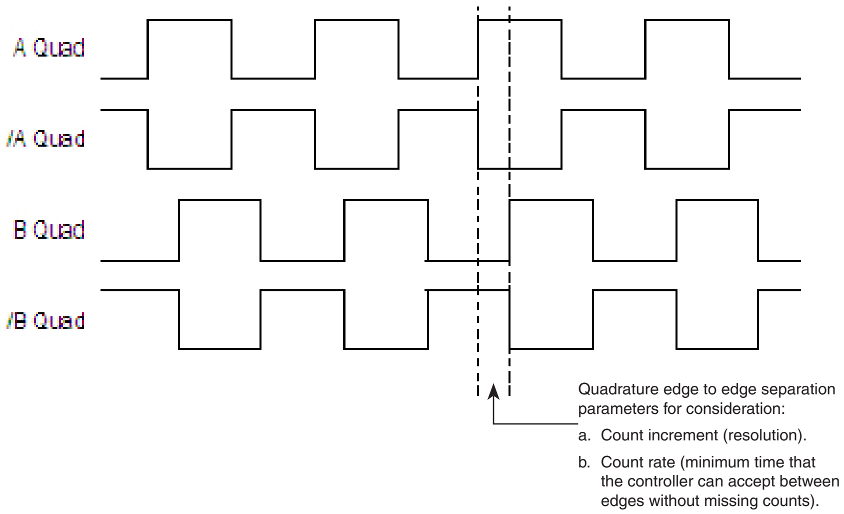


Figure 35 - RS422/485 Quadrature waveforms

Digital quadrature update rate

The HS20 laser head allows the output update rate of the digital encoder output signals to be selected. The clock frequency can be selected using DIP switches 5,6 & 7.

$$\text{Update rate (MHz)} = \frac{\text{maximum velocity (m/s)}}{\text{output resolution (µm)}}$$

WARNING: The controller must have an input bandwidth which is at least 25% greater than the update rate of the HS20 when using digital quadrature. If this update rate is set too low (below the count rate), the system will flag an overspeed error. If the update rate is set too high for the controller input bandwidth, the controller may miss some of the incoming pulses, resulting in a loss of feedback integrity.

The clock frequency options are detailed in figure 36 below, along with the maximum recommended system velocities shown in figure 37.

Switch 5	Switch 6	Switch 7	Update rate
OFF	OFF	OFF	1MHz
OFF	OFF	ON	2MHz (default)
OFF	ON	OFF	4MHz
OFF	ON	ON	8MHz
ON	OFF	OFF	16MHz

Figure 36 - HS20 quadrature clock frequency selection

Quadrature Resolution (nominal) µm	Quadrature update rate (MHz)				
	1	2	4	8	16
0.632818846	0.632 m/s	1 m/s	2 m/s	2 m/s	2 m/s
0.316409423	0.316 m/s	0.632 m/s	1 m/s	2 m/s	2 m/s
0.158204712	0.158 m/s	0.316 m/s	0.632 m/s	1 m/s	2 m/s
0.0791023558	0.079 m/s	0.158 m/s	0.316 m/s	0.632 m/s	1 m/s

Figure 37 - Maximum system velocities

Parity

The parity function can be switched on/off using configuration switch 8. The parity switch has been included as a safety feature. It prevents the accidental mis-configuration of a single switch. **This switch must be used to maintain an odd number of switches in the enabled position. If this switch is set incorrectly, an error will be asserted and the signal LED will show flashing red.**

The default shipment state is with a parity error enabled. This is a safety feature so that a user must check the configuration before using the HS20. It also allows the electronics to detect the failure of a DIP switch in service and assert an error by tri-stating the quadrature output lines.

Error signal monitoring

WARNING: The HS20 laser encoder continuously checks for any errors that may cause invalid position feedback signals. This includes an overspeed, beam block, laser unstable or an internal error. It signals a fault by tristating the digital and analogue quadrature lines. In the case of closed loop motion systems, for safe operation this must be monitored. If the quadrature is tristated, the position feedback signals may be incorrect and the axis of motion **must be** stopped.

NB: In the event of power loss from the HS20 tristated quad will become inactive and the axis of motion **must be** stopped.

Status lines

The status lines are all available via the 16-way HS20 interface connector on the HS20, all lines operate between 24V DC and 0V and are active low. When the lines are unasserted (i.e. at 24V) the HS20 laser head sources 12mA and when the lines are asserted (i.e. at 0V) the HS20 laser head can sink up to 600mA. A detailed explanation of each of the status lines is shown below. The status lines should be monitored so that suitable status messages can be displayed on the controller's display .

Signal Name	Function	Machine Response
/UNSTABLE	Indicates that the HS20 laser head is unstable (or in warm-up). During this process the quad lines will remain tri-stated. When the HS20 laser head becomes stable, this error will clear automatically.	Whilst /UNSTABLE is asserted low the machine motion **must be** disabled. **See safety warning below.**
/BEAM_BLOCKED	Indicates that the return signal strength has fallen below 10% of full signal strength. Until the error has been cleared the quad lines will remain tri-stated.	Whilst /BEAM_BLOCKED is asserted low the machine motion **must be** disabled. **See safety warning below.**
/BEAM_LOW	Indicates that the return signal strength has fallen below 20% of full signal strength.	Machining can continue, however the source of the alarm should be investigated and maintenance performed.
/OVERSPEED	Indicates that invalid quadrature transitions have been detected. During this process the signal will remain tri-stated until the error is cleared.	Whilst /OVERSPEED is asserted low the machine motion **must be** disabled. **See safety warning below.**

Figure 38 - HS20 status lines (machine I/O inputs)

WARNING: If UNSTABLE, OVERSPEED or BEAM BLOCK warning is generated the machine motion **must be** stopped.

Section 4 - HS20 laser beam alignment

Contained in this section

HS20 laser beam alignment

Achieving an optimum alignment of the laser and optical components forms a very important part of the installation of the system, and therefore care should be taken in aligning the optical components.

There are many different techniques for aligning a laser system and which technique is used is often a matter of personal preference. This manual describes a simple method using the HS20 alignment plate.

It is recommended that the HS20 laser head is aligned using the alignment plate for coarse alignment of the beam along the axis. Then using an LS06 Beam Steerer (A-8003-2898) to fine tune the laser alignment.

WARNING: DO NOT STARE INTO BEAM - CLASS 2 RADIATION

WARNING: If the laser beam is misaligned during beam alignment, the tristated quad will be asserted due to low signal strength. Also if the laser beam is misaligned such that the return beam enters the laser output port, it is possible that the laser will be destabilised. This is normal behaviour, and again the tristated quad may be asserted. Under either circumstance the laser position feedback signals may be invalid. For this reason initial beam alignment should be performed with the machine under manual or open loop control.

Firstly the HS20 and alignment plate are fitted to the machine as described in Section 2 ‘Mechanical Installation’. Then the alignment plate adjustments and HS20 adjustment feet are set to the mid-point of travel. It is assumed that the measurement retroreflector cannot be adjusted, so that any adjustments are performed with the interferometer assembly and/or HS20 laser head. It is often easier to have two people work together when performing alignment; one to make adjustments at the laser end, and a second to call out directions from the far axis position. It can also save time to perform the alignment for both sides of a split feedback axis at the same time. This reduces the amount of machine movements required.

The laser beam-path ducting should not be fitted at this time, as this will make the alignment process much easier.

LS06 operation

Horizontal and vertical adjustment is achieved by using a ‘triple-wedge-prism’ system. This involves two adjustable wedges and one fixed. The adjustable wedges are rotated by means of external levers, which direct the laser beam onto the desired target.

The operation of the laser steerer is explained in figure 39. Lever ‘A’ controls the vertical plane of the laser beam as it passes througth the unit and lever ‘B’ controls the horizontal plane. Once the desired alignment has been achieved the external levers need to be locked into position using the rotational locking screws provided.

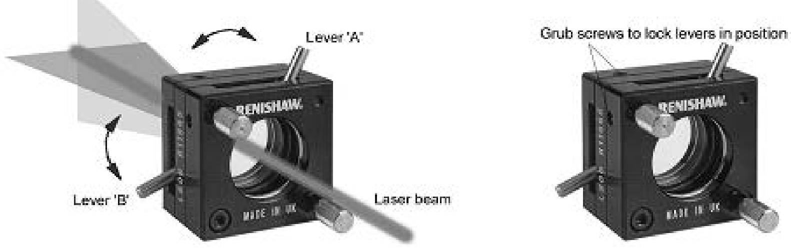


Figure 39 - HS20 status lines (machine I/O inputs)

Alignment procedure

1. Align the laser visually so that the beam runs roughly along the axis. This can be done by holding a piece of card at the far end of the axis to show the beam position. For information relating to mounting the HS20 onto the machine then refer to Section 2: Mechanical Installation.

   Note: It is recommended that when adjusting the locking screws on the alignment plate that there is no slack, as this can cause further movement when finally tightened.

2. Mount the interferometer in front of the laser.

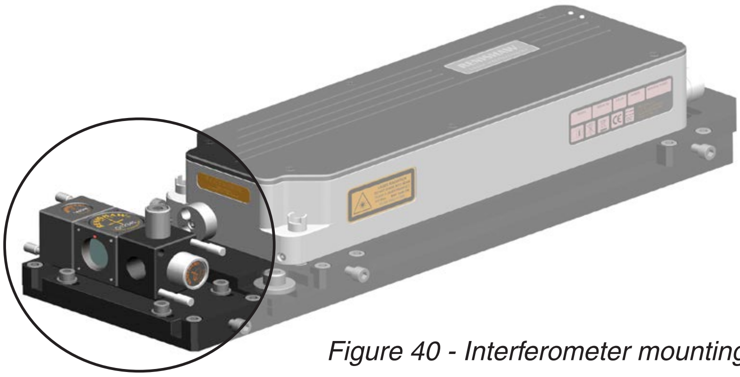


Figure 40 - Interferometer mountings

Translate the optic assembly so the return beam from the interferometer assembly enters the lower aperture on the laser head. Make sure the interferometer assembly is nominally square with the laser head.

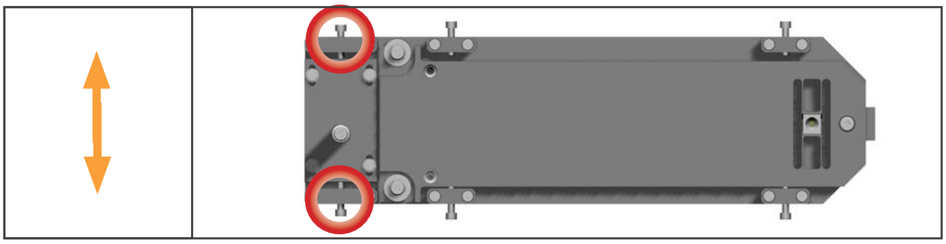


Figure 41 - Interferometer translation adjustment

Correct return beam position on the HS20 shutter is shown below

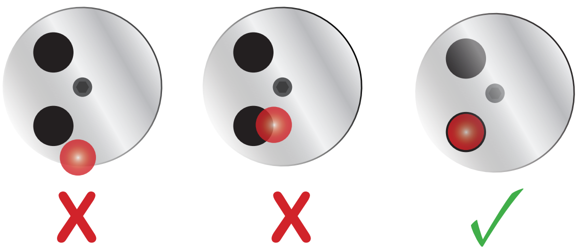
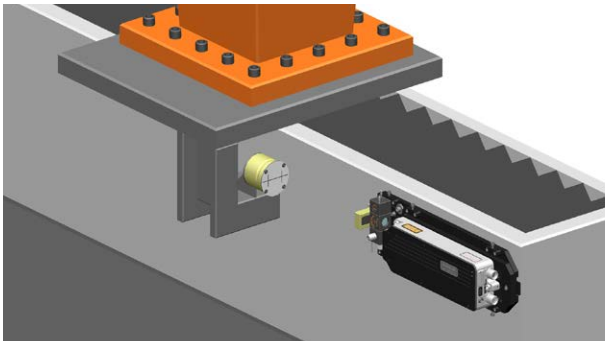


Figure 42 - Correct return beam position

3. Move the axis so the moving optic is a close as possible to the laser and interferometer. Place the alignment target onto the retroreflector.



Translation adjustment should be made to the laser to ensure the laser beam hits the correct area of the target.

Figure 43 - Alignment target fitted

Note: If the laser has been translated by a large amount then it may be necessary to translate the interferometer to match so that the beam is not clipped when passing through the interferometer.

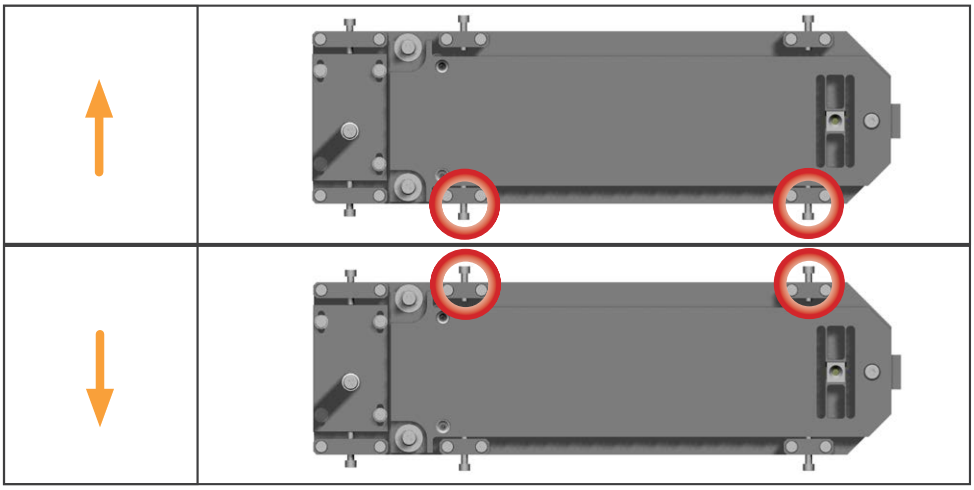


Figure 44 - Laser translation adjustment

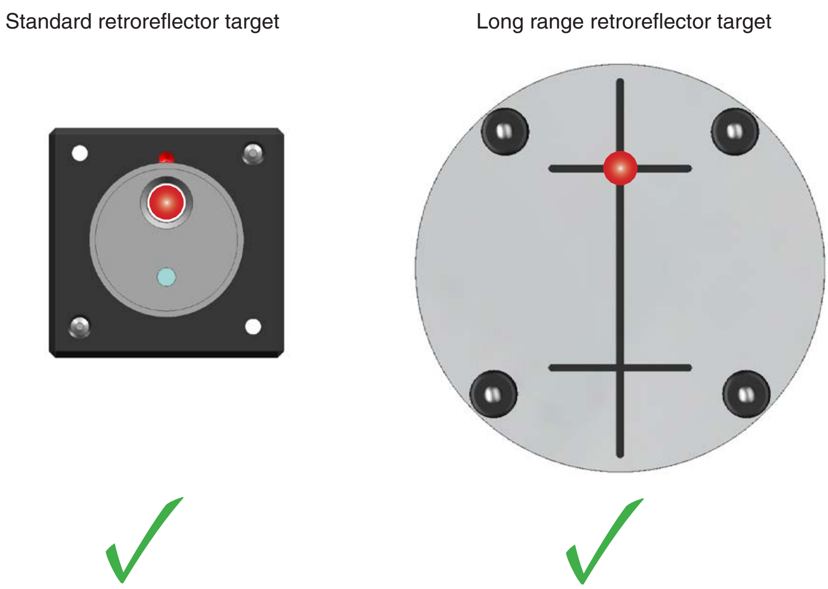


Figure 45 - Correct beam position on alignment target

4. Move the axis so that the measurement retroreflector is furthest away from the laser.

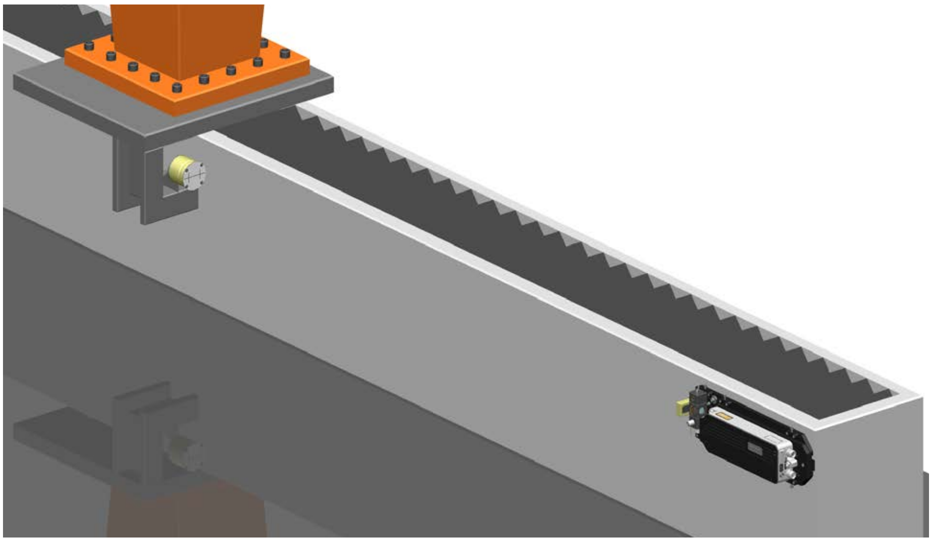


Figure 46 - Axis furthest away from laser

At this point make pitch and yaw adjustments to the laser to bring the beam onto the correct position on the target.

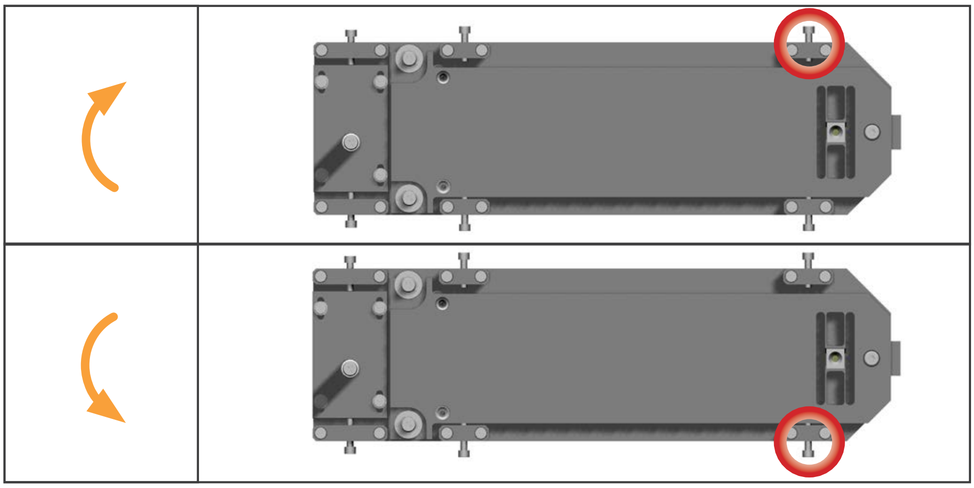


Figure 47 - Yaw adjustment

5. Repeat steps 3 & 4 until the beam position is maintained on the target for the entire axis stroke.
6. Remove target from the measurement retroreflector and attach a voltmeter to the diagnostic connector of the HS20 in order to monitor the signal strength.
7. With the measurement retroreflector near to the laser head, check and adjust the position of the interferometer to ensure both beams are concentrically placed on the return aperture, and that maximum signal strength (1V) is indicated on the voltmeter.
8. Now move the axis whilst checking the signal strength along the full length of the axis. It is recommended that the signal strength remains above 70% (0.7v) for the entire range of the machine. It may be easier to do this using the LS06 beam steerer.

   - Firstly tighten all the screws on the HS20 laser head and alignment plate.
   - Fit the LS06 beam steerer to the front of the interferometer. Take care not to move the optics.
   - Run the machine along the axis whilst making small adjustments on the beamsteer to ensure that the machine stays aligned.
   - When the machine is aligned, complete another run to ensure that the beam is correctly aligned along the length of the axis.

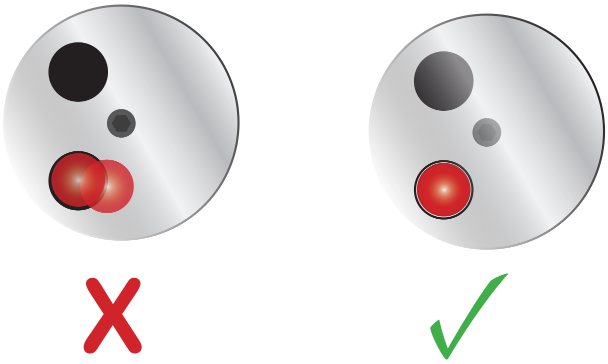


Figure 48 - Correct return beam position

9. Tighten all locking screws (including locking screws for the LS06 steerer levers) and then recheck alignment / signal strength all the way down the axis (if not completed in previous step).

Section 5 - System Integration

Contained in this section

System integration

For systems where the HS20 is indirectly connected to the motion controller via an RCU compensator, please refer to The RCU10 quadrature compensation unit - Installation and User's Guide.

Before closing the feedback loop using signals from HS20 it is essential that the checks defined below are carried out for HS20 each axis in turn. The objective of these tests is to confirm that the following:

- Motion of the appropriate axis drive is stopped immediately an HS20 signals an error or if its power supply fails, and that the controller display correctly indicates the source of the error.
- The direction sense and resolution settings on each HS20, RCU and the associated machine axis have all been set correctly.
- The controller logic has been correctly configured to allow each HS20 to be reset (as required to clear an error), and to handle the laser's warm- up period (during which the laser will indicate an unstable error).

Having followed through the manual the following stages should now have been completed.

- HS20 is mounted on the machine,
- The laser beam is aligned,
- The HS20 is electrically connected to the controller
- An axis reference mark signal is connected to the RCU.
- The RCU must have been configured in accordance the RCU10 manual (M-9904-1122)
- Although the electrical connections have been made, the associated machine axis drives have NOT yet been enabled (machine is in E-stop).

The following steps prepare the system for switch over to HS20 feedback

Reset input signal

The HS20 laser head also requires one control line input. The function of this line is to reset the HS20 laser head in the event of an error. This line is active low and must be held at 24V (high) during normal operation.

Operation of system on power-up

Following an initial power up, the HS20 laser heads take a period of between 10 and 15 minutes to stabilise. During this period of laser instability the /UNSTABLE status line is asserted and the digital quadrature lines are tristated.

For this reason it is advisable that the HS20 laser heads are powered from a supply that remains on even when the machine controller is powered-down. This will avoid a 15 minute delay each time that the machine control is powered-up.

Note: Ideally each HS20 laser head will have its own independent machine generated /RESET line. Once the HS20 laser heads become stable, indicated by the /UNSTABLE line being pulled high, the quadrature lines and HS20 status lines have the tristate (high impedance) state removed and are activated.

WARNING: The HS20 laser encoder continuously checks for any internal errors that may cause invalid position feedback signals, and signals a fault by tristating the digital and analogue quadrature lines. In the case of closed loop motion systems, for safe operation this must be monitored. If the tristated quad is asserted, the position feedback signals may be incorrect and the axis of motion must be stopped.

NB: In the event of power loss from the HS20 tristated quad become inactive and the axis of motion must be stopped.

HS20 diagnostic LEDs

Two LED's are fitted in the rear (opposite face to the laser beam aperture) of the HS20. When viewed from the rear of the HS20 with the connectors situated at the bottom they are termed laser status LED (left LED, LED closest to warning label) and signal condition LED (right LED).

The significance of the colour of the Laser status LED is as follows:

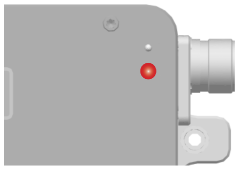
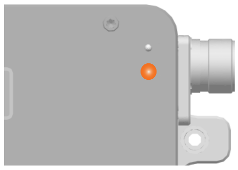
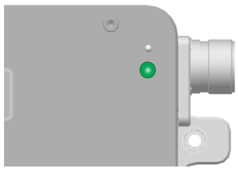
Laser status LED	
LED colour	**Significance**
RED 	Laser fail
AMBER 	Unstable
GREEN 	Stable

Figure 49 - Laser status LED

The significance of the colour of the signal condition LED is as follows:

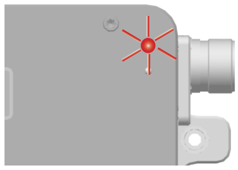
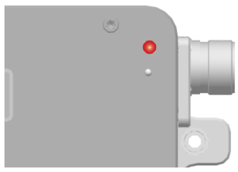
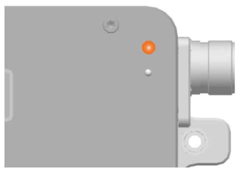
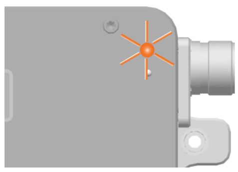
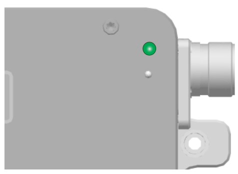
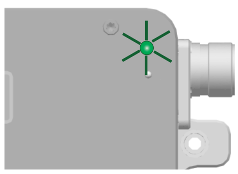
Signal status LED	
LED Colour	**Significance**
 FLASHING RED	Parity error
 RED	Beam block
 AMBER	Beam low
 FLASHING AMBER	Beam low & overspeed
 GREEN	Good signal
 FLASHING GREEN	Good signal & overspeed

Figure 50 - Signal condition LED

Stage 1 - Pre HS20 feedback testing

Prior to system integration it is necessary to complete a number of sub-system tests. The results of all of the following tests should be logged on the test sheets provided in Appendix C.

Laser power fail test

Switch off the 24v power to the HS20 laser in turn and confirm that the controller flags “encoder error” on the associated axis and check that this error would cause the axis motion to be disabled.

Laser unstable test

Restore 24V power to the HS20 laser, the laser will start a preheat cycle. During this period the left hand LED (laser status LED) on HS20 should be AMBER, the /UNSTABLE status output line will be LOW and the digital quadrature lines will be tristated. Confirm that during preheat the controller flags “encoder error” on the associated axis. Confirm that axis motion will be disabled by this error, and that any additional diagnostic information presented on the controller screen is correct (e.g. “Axis X - Laser Unstable”).

Wait for the preheat cycle to finish (10-15 minutes). At this point both LEDs on the HS20 should turn GREEN, the /UNSTABLE status output line will go HIGH and the digital quadrature lines will become active. Confirm that the “encoder error” shown by the controller clears and that any additional diagnostic information on the display is correctly updated.

Beam low test

Partially block the beam from the HS20 (e.g. by rotating the shutter slightly) so that the right hand LED (signal condition LED) on HS20 goes AMBER. The /BEAM_LOW status output line will go LOW but the digital quadrature lines will remain active. Confirm that the controller flags an “encoder warning” on the associated axis, and that any additional diagnostic information presented on the controller screen is correct (e.g. “Axis X - Low signal”). It is not necessary for axis motion to be disabled by /BEAM_LOW status.

Restore full signal strength. At this point both LEDs on the HS20 should turn GREEN and the /BEAM_LOW status output line will go high. Confirm that the “encoder warning” shown by the controller clears and that any additional diagnostic information on the display is correctly updated.

Beam block test

Totally block the beam from the HS20 (e.g. by rotating the shutter) so that the right hand LED (signal condition LED) on HS20 goes RED. The /BEAM_BLOCK status output line will go LOW and the digital quadrature lines will be tristated. Confirm that the controller flags “encoder error” on the associated axis. Confirm that axis motion will be disabled by this error, and that any additional diagnostic information presented on the controller screen is correct (e.g. “Axis X - No signal”). Note that it’s not unusual that blocking the beam will also cause an /OVERSPEED error, so an “Axis X - Overspeed” message may also appear (see below),

Restore full signal strength. At this point the right hand LED on the HS20 should remain RED, the /BEAM_BLOCK status output line will remain LOW, and the digital quadrature lines will remain tristated. (This is because BEAM_BLOCK errors are latched).

Use the appropriate controller function to send a /RESET signal to the HS20. Check that both LEDs on HS20 turn GREEN. At this point the /BEAM_BLOCK status output line will go HIGH and the digital quadrature lines will become active again. Confirm that the “encoder error” shown by the controller clears and that any additional diagnostic information on the display is correctly updated.

Overspeed test

This line is set low when an overspeed condition is detected by the laser head. An overspeed condition occurs if the quadrature processing circuitry detects that an invalid quadrature transition has occurred between two consecutive clock cycles.

The overspeed condition is a difficult one to simulate, because it is not usually possible to cause real axis movement at 2 m/s or above. This error will however been seen about 50% of the time whenever a beam block is caused. This is because the loss of the beam can cause an invalid transition in the laser detection circuitry. Therefore the overspeed condition can usually be tested by causing a beam block.

Quadrature check (direction and resolution)

The objective of this test is to confirm that the encoder sign convention and resolution settings in the controller and HS20 are set correctly The machine axis should be moved by a small, known amount under manual control (i.e. without closing the loop using HS20 - perhaps by using motor encoder feedback), whilst the axis position is monitored. The distance actually moved should be recorded perhaps using motor encoder readings or using a digital vernier calliper. This distance should be compared with the displayed readout. If the sign correction is incorrect, then change the appropriate setting in the controller, or on the controller axis card, or swap AQUAD /AQUAD wires from HS20. If the distance moved does not match, adjust the HS20 resolution using the dip switches or adjust the controller settings. Repeat the test until the direction sense and distance moved and the axis readout agree.

WARNING: It is important to set the system direction sense correctly. If it is set incorrectly, the machine will move in the opposite direction to that expected, and may accelerate until it reaches the axis limits. In the case of parallel twin rail drives, it is important that the direction sense of the slave axis is set to match the master axis. Failure to do this will cause opposite ends of the cross-member to move in opposite directions, possibly causing damage to the machine.

Successfully completing these tests provides confidence to move onto the next stage where machine movements are made using HS20 for closed loop control.

Stage 2 - Switching machine control to HS20 feedback

Having successfully completed the pre-integration testing the feedback system is ready to be integrated into the machine position control loop.

The integration is completed in the following steps:

1. Ensure machine feed rate is turned down to 1% on all axes
2. Complete the integration by converting all axes concerned directly to Laser Feedback.
3. Move all axes and ensure that machine responds accordingly.

Prior to the integration of the HS20 laser head, the machine will have been running on its primary feedback source (i.e. motor encoders or tape scale).

The process of integrating the laser scale into the machine's feedback loop is the point in the installation where there is the most potential to cause problems with the machine if the operations are or have not been carried-out correctly. Therefore it is essential that great care is taken when integrating, and that the installer understands fully the operation of both the laser head, and the machine control.

WARNING: It should also be noted that during the integration process certain safety features may not be fully operational, hence the machine should only be operated by personnel who are aware of this, and able to take appropriate action in the event of a problem. During the integration process the machine should be kept clear of personnel until all functions have been enabled and tested.

Stage 3 - Machine under HS20 feedback testing

Objectives

The purpose of this section is to define a series of tests to be performed once the machine is operating under HS20 feedback. The test operations detailed within this chapter are:

1. Testing the status line operation.
2. Testing the HS20 laser head reset.
3. Testing the machine home sequence.

Upon successful completion of this section the installation is complete. Use the test sheets in appendix C to record the results of each test.

Whilst some tests are repeated from earlier it is still important to verify operation now that all axes are operating on laser feedback.

Status-line verification

Now that integration is complete it is vital to verify that the machine responds in a safe, predictable manner in response to each status line being asserted.

It is an important safety requirement that the machine controller shuts down all drives and applies brakes when any fatal error occurs. This is necessary to avoid a potential 'run away' situation if feedback is lost. There should however be other fail-safes built into the machine controller such as 'encoder disconnect' which detects the absence of feedback signals to the encoder inputs and similarly shuts down the drives.

Repeat the HS20 laser head status line tests. In particular the operation of the beam block error must be confirmed to safely shut down the drives and apply safety brakes.

Record the results on the test sheet provided.

HS20 reset from machine control

A reset line is provided for each laser. This line will reset any latched errors that have occurred, such as beam block. The method in which this line is used depends on the installer.

The most common ways to reset the lasers are either by providing a 'reset' button on the machine control which will operate all of these reset lines at once, or by including an operation in the controller's ladder logic that will operate these lines on power-up.

Machine home operation

The next stage is to confirm the correct operation of the machine home (or reference) cycle. At this stage the machine controller must have the software in place to deal with a homing operation once the machine is switched over to operate under HS20 laser head feedback.

Please refer to the RCU10 installation manual (M-9904-1122) for home cycle operation.

Home cycle simulation

- Manually simulate a home cycle by moving the axis at a low feed rate at a safe distance and manually operating the reference mark switches.
- Ensure that the signal is seen correctly by the machine controller.

Automated home-cycle

Perform a normal machine home operation, if possible set the feed rate to a low value and ensure that the procedure operates safely and correctly.

APPENDIX A – System specification

HS20 laser head specification

Laser type Wavelength	HeNe Class II 632.8 nm	Maximum output power from laser tube <1 mW
Laser beam diameter	6 mm	12 mm centre to centre (outward and return beams)
Vacuum wavelength accuracy	±0.1 ppm	
Range	0 m to 30 m 0 m to 60 m	with standard linear optics with long range linear optics
Analogue output signal period	316 nm	Retroreflector interferometer
Digital quadrature output resolutions	79.12382213, 158.2476443, 316.4952885 and 632.9905770 nm	selectable through the configuration switches
Output update rates	1, 2, 4, 8 and 16 MHz	selectable through the configuration switches
Maximum velocity	2 m/sec (at 16Mhz update rate)	≥ 158 nm
Output formats	RS485 differential digital quadrature 1 V peak to peak sine/cosine signals	 terminate with 120 Ω resisitor
Laser status outputs (24 V active low signals)	Beam block Overspeed Unstable Beam low	Asserted when signal strength ≤10% Asserted if invalid quadrature transition detected Asserted if laser unstable Asserted if signal strength ≤20%
Power supply requirements	24 V DC ± 1 V @ 2.0 A 24 V DC ± 1 V @ 1.2 A 24 V DC ± 1 V @ 0.7 A	Inrush (first 10 ms) Warm-up (~10 mins) Operation at room temperature (20 ºC)
Internal fuse	Thermal resetable	
HS20 weight	3.1 kg	
Operating environment Indoor Use: Pressure Humidity Temperature Altitude	 650 mbar to 1150 mbar 0% to 95% RH Maximum relative humidity 80% 0 ºC to 40 ºC 0 to 2000m	 Normal atmospheric Non-condensing for temperatures up to 31˚C decreasing linearly to 50% relative humidity at 40˚C

APPENDIX B - Maintenance

The HS20 laser head will require very little in terms of routine maintenance, but the work that is required is primarily optical component cleaning.

There are no user serviceable components inside the HS20 laser head

Two forms of optical maintenance may be required during the lifetime of the HS20 laser head. This maintenance will either be to remove contamination from the optics or to re-establish optical alignment between the HS20 laser head and the optical elements which make up the linear measurement kit. The frequency with which these operations need to be undertaken will be a function of the conditions within which the system is operated, the beam protection ducting and the mounting schemes used for the HS20 laser head and linear interferometer optics.

Signal strength problem diagnosis

The HS20 system provides two alarms to the controller, which indicates that the optical arrangement (HS20, interferometer and retroreflectors) needs attention. These signals are termed beam low and beam block, asserted at 20% of full signal strength and 10% of full signal strength respectively.

The beam low maintenance alarm has been incorporated into the system to flag that either the optics need to be cleaned or the optical alignment needs attention, the system will continue to operate even with beam low asserted with no reduction in positional accuracy.

Beam block is a fatal error which will immediately result in the quadrature feedback signals being removed from the encoder inputs and all of the lines become tristated. Therefore the machine controller should shut down so that no machine movement is possible whilst beam block is asserted.

These two alarms may be generated from contamination on the optical surfaces, misalignment of the optical components or air turbulence. To investigate the source of any alarm the following procedure should be instigated:

1. In the case where beam low is asserted, ensure that the machine is positioned in the region where the alarm occurs. In a beam block situation the machine cannot be moved until corrective action has been completed. However, to ensure that the beam block condition is consistently maintained, reset the HS20 laser head. If the reset clears the beam block condition then the original cause of beam block has been removed.
2. Remove beam path protecting ducting to enable access to the laser beam to be obtained between the HS20 laser head and interferometer and between the interferometer and measurement arm retroreflector.
3. Observe the two beams entering the lower aperture of the HS20 laser head on a white target. Identify which of the two beams is produced by the reference retroreflector (attached to the interferometer) by blocking the beam path between the interferometer and the measurement retroreflector attached to the moving element of the machine. Observe the following:

   i. The relationship between the two return-spots and the relationship between these spots and the return aperture on the HS20.

      Under ideal (near field) conditions these two beams will appear as one spot on the target i.e. the reference beam and measurement beam will be concentrically positioned. The further away the measurement arm retroreflector is from the HS20 the larger the return spot will be at the HS20 return-aperture. In this case the two beams should still be positioned concentrically with respect to one another and the return aperture in the HS20 laser head shutter. If both beams and the aperture are not concentric in all cases refer to Section 4 HS20 laser beam alignment.

ii. The intensity distribution of the individual spots.

The intensity distribution of each spot should be such that the spots appear as circular dots with maximum intensity in the centre, little flaring and virtually no speckle outside the perimeter of the main spot. At distance diffraction rings concentric with the main spot are expected.

It will be possible from the above observations to determine if the problem is caused by contamination (uneven intensity distribution) or misalignment (return beams not positioned correctly) or possibly a combination of both.

Cleaning external optics

NOTE: The system optics are delicate components, to avoid damaging component coatings/surfaces cleaning should only be undertaken with the correct materials following the guidelines below.

It is recommended that the optical surfaces be cleaned only when necessary. If the signal strength is low, first ensure that the beam alignment is optimised, as this may be the cause of the reduced signal strength.

In some cases it will be possible to clean the optics on the machine, other cases will dictate that the optics be removed for cleaning. To minimise the realignment exercise in cases where the optics need to be withdrawn, remove one optical element (Interferometer or measurement arm retroreflector) at a time. Reposition the cleaned element and check optical alignment before removing the second optical component.

Only the external surfaces that are exposed to the environment will require cleaning. This should be performed using the procedure outlined in the optical cleaning procedure below

Cleaning the HS20 window

NOTE: Cleaning the HS20 window is an extremely delicate operation, cleaning should only be undertaken after cleaning and alignment adjustment of external optics. The correct materials should be used and performed by following the guidelines below. This procedure should be preformed with extreme caution as damage to the window cannot be rectified in the field. The unit must then be returned to Renishaw.

There are no user-serviceable parts inside the HS20. The only parts of the system that may require attention throughout their life are the exposed optics. If the system is not operated in a clean environment, surface contamination will accumulate on the optics over a period of time. This contamination will eventually affect the system performance by causing deterioration in the signal strength. In extreme cases it may be necessary to clean the window on the front of the HS20.

To clean the HS20 window the shutter must first be removed from the front of the unit.

Note the shutter retaining bolt is secured using Loctite adhesive. Care should be taken when removing the bolt and adhesive will be required for reassembly.

To remove the shutter use a 2.5 mm allen key to remove the central bolt, which will expose the windows for cleaning. The window can now be carefully cleaned using the procedure described below.

Reassemble the shutter onto the HS20 using one M3 x 10 Cap Head Screw and the brass M3 Crinkle Washer. Use Loctite 222 on the Cap Head Screw. Do not fully tighten the cap screw, instead adjust the screw to allow the shutter to rotate smoothly. Leave assembly 24 hours for Loctite 222 to fully cure.

The optical surfaces should only be cleaned using one of the materials prescribed below.

Do use

- ✓ Ethanol, methanol, propanol and combinations
- ✓ Spectacle cleaning fluid
- ✓ Non-abrasive, lint-free cleaning wipes
- ✓ Microfibre cloths

Under no circumstances should the following be used for cleaning as they will permanently damage the optics.

Do not use

- ✗ Acetone
- ✗ Abrasive materials
- ✗ Chlorinated solvents
- ✗ Benzine

Optical cleaning procedure

1. Apply one of the recommended cleaning solutions to the lens cleaning tissue.✓
2. **IMPORTANT** Allow cleaning solution to evaporate so that tissue is only damp rather than wet. (when too much cleaning solution is used it can creep into internal joints within the optic further where it cannot be removed.
3. Gently wipe the optic with the lens cleaning tissue from the centre of the optical surface to the outside of the optic.
4. Re-wipe the optic with a piece of dry cleaning tissue.
5. Observe contamination on optic, if significant contamination still present repeat from 1.

Optical system realignment

To realign the HS20 laser head and interferometer optics the principles discussed in section 5.1 should be adhered to.

Routine checking of safety functions

It is advisable to re-check the correct operation of the system safety functions on a regular basis to ensure that no degradation of safety has occurred through wiring, connector, or component failure.

This is achieved by repeating the testing procedures which are detailed in section 6 (pre-integration testing).

APPENDIX C - Test sheets

The following sheets should be used as part of the testing procedures detailed in *Section 8 - System Integration*. This section can be removed and stored as part of the installation report.

Customer		
Machine		
	Axis Name	Serial No
Axis 1		
Axis 2		
Axis 3		
Axis 4		
	No of Axes	
Notes		
Installation Engineers		
Date		

Stage 1 - Pre HS20 Feedback Testing

Test	Details		Notes		☑
Pre-1	Installation inspection	Lasers, sensors & switches mounted?			
Pre-2	Safety	Machine on Encoders?			
Pre-3	HS20 alignment procedure	Signal strength	Near	Far	
		1			
		2			
		3			
		4			

Stage 1 - Pre HS20 feedback testing (continued)

Test	Details	Axis	Notes	☑
Pre-4	Laser Beam Power Fail	1		
		2		
		3		
		4		
Pre-5	Laser Unstable	1		
		2		
		3		
		4		
Pre-6	Beam-low	1		
		2		
		3		
		4		
Pre-7	Beam-block & reset test	1		
		2		
		3		
		4		
Pre-8	Overspeed	1		
		2		
		3		
		4		
Pre-9	Quadrature check (Direction & Resolution)	1		
		2		
		3		
		4		

Stage 2 - Switching machine control to HS20 feedback

Test	Details	Axis	Notes	☑
Post-1	Integration procedure	1		
		2		
		3		
		4		

Stage 3 - Machine under HS20 feedback testing

Test	**Details**	**Axis**	**Notes**	☑
Post-3	Status line verification Axis 1	US		
		BL		
		BB		
		OS		
Post-4	Status line verification Axis 2	US		
		BL		
		BB		
		OS		
Post-5	Status line verification Axis 3	US		
		BL		
		BB		
		OS		
Post-6	Status line verification Axis 4	BS		
		BL		
		BB		
		OS		
Post-7	HS20 reset test	1		
		2		
		3		
		4		
Post-8	Machine Home Sequence in each Axis	1		
		2		
		3		
		4		

APPENDIX D - Safety information

The following appendix covers important safety information, which should be read before installing or operating any part of the laser scale system.

It is the responsibility of the manufacturer and/or encoder installation authority to ensure that, in safety critical applications of the HS20 laser encoder, any form of signal deviation from specification or from the limits of the receiving electronics, however caused, shall not cause the machine to become unsafe. It is also their responsibility to ensure that the end user is made aware of any hazards involved in operation of their machine, including those mentioned in Renishaw product documentation, and to ensure that adequate guards and safety interlocks are provided.

When mounting and using Renishaw laser encoder products on machines, beware of pinch and/or crush hazards that can be created depending on how and where the equipment is mounted. This warning is particularly relevant to the mounting of the optics

General safety information - system integration

The Renishaw HS20 laser encoder and compensator systems are designed for integration into the primary position feedback loop of a motion system. It is essential that the system is installed in accordance with the instructions in the installation manuals and it is the responsibility of the system integrator to ensure that, in the event of a failure of any part of the Renishaw laser system, the motion system remains safe.

In motion systems with powers or speeds capable of causing injury, safety protection measures must be included in the design. It is recommended that satisfactory operation of these protection measures is verified **before** the feedback loop is closed. The following are examples of safety protection measures that can be used. It is the sole responsibility of the system integrator to select appropriate measures for their application.

1. The HS20 quadrature will go into a tristate condition (open circuit) under faulty conditions. All status lines must also be connected. The control system must be designed to stop the axis motion if this error output is asserted.
2. The axis must include physical limit switches which, when tripped, will stop axis motion before damage occurs (soft limits alone are insufficient). Note that in the case of thermally compensated systems, positional corrections of several hundred ppm are possible. This should be taken into account when defining the relative positions of soft and hard axis limits.
3. Cable breakage detection (encoder disconnect). The position feedback and error signal lines are all provided as differential line driven pairs. Failure in the cable or of the line drivers can be detected by checking these differential pairs are always being driven in opposing states. If the lines are not in opposing states, the motion must be stopped.
4. Motor torque monitoring. If the motor torque exceeds an expected limit, the axis of motion must be stopped.
5. The machine must include an emergency stop button.
6. Following error detection. If the difference between the controller demand position and the axis feedback position exceeds an expected limit, the axis motion must be stopped.
7. Guards, viewing windows, covers and interlocks may be used to prevent user access to hazardous areas, and to contain ejected parts or materials.
8. If the machine includes an independent tacho (velocity) feedback system, this should be cross-checked with the position feedback. For example, if the tacho indicates the axis is moving, but the position feedback doesn't, the axis motion must be stopped.
9. In the case of synchronised parallel motion systems (for example twin rail gantry drive systems),

the relative positions of master and slave axes should be monitored. If the difference in their positions exceeds an expected limit, axis motion must be stopped.

Important note: In the case of measures 6 to 9, the limits need to be selected carefully depending on the application and the type of position compensation selected to avoid false alarms.

It is the responsibility of the system integrator to ensure that in the event of a failure of any part of the Renishaw Laser System that the motion system remains safe. In the case of motion systems with powers or speeds capable of causing injury, secondary protection measures must be included in the design. Refer to the General Safety Information in the Introduction for details of suitable secondary safety measures. It is recommended that such secondary measures be tested during system integration by deliberately introducing single faults into the system. (Obviously such tests need to be carried out carefully to ensure injury cannot occur if such secondary systems fail to operate)

For further advice, consult the appropriate machinery safety standards.

Laser beam description and safety labels

1mW continuous wave output, collimated with a gaussian intensity distribution and a full beam diameter of 6 mm. The following safety labels are attached to the HS20 laser encoder:

Figure D.1 - Safety label positioning

Important note: It is advisable to ensure that these labels are attached and visible when the HS20 system is installed.

Quadrature resolution warning

It is important to set the output resolution of the Renishaw system to match the controller's input resolution. If the quadrature resolution is set incorrectly, the axis may move for distances and at speeds that are not expected. For example, if the output resolution from the Renishaw system is set to half that of the controller input, the axis may move twice as far and twice as fast as expected.

Direction sense warning

It is important to set the direction sense correctly. If it is set incorrectly, the machine will move in the opposite direction to that expected, and may accelerate until it reaches the axis limits. In the case of parallel twin rail drives, it is important that the direction sense of the slave axis is set to match the master axis. Failure to do this will cause opposite ends of the cross-member to move in opposite directions, possibly causing damage to the machine.

Error signal monitoring

The HS20 laser encoder continuously checks for internal errors that may cause invalid position feedback signals, and signals a fault by asserting a tristated quad output. In the case of closed loop motion systems, for safe operation the status of this tristated quad must be monitored. If the tristated quad is asserted, the position feedback signals may be incorrect and the axis of motion **must be** stopped.

Important note: In the event of power loss from the HS20, tristated quad become inactive and the axis of motion **must be** stopped.

Incorrect bandwidth setting

The laser system allows you to adjust the maximum update rate of the digital encoder output signals. If this is set too low (for the axis feedrate and resolution required) the laser system will flag when overspeed error occurs. If the update rate is set too high, your controller may not be able to count quickly enough to record all of the incoming pulses, and the axis may travel further than expected. It is important that the output bandwidth of the laser system is set below the maximum input bandwidth of the controller.

Laser alignment

If the laser beam is misaligned during beam alignment, the tristated quad will be asserted due to low signal strength. Also, if the laser beam is misaligned such that the return beam enters the laser output port, it is possible that the laser will be destabilised. This is normal behaviour, and again the tristated quad may be asserted. In either circumstance, the laser position feedback signals may be invalid. For this reason, initial beam alignment is usually performed with the machine under manual or open loop control.

Power supply out of range

The correct power supply voltage is 24 V ±1 V. Power supplies outside this range may give unreliable operation.

APPENDIX E – Laser steering mechanism

The operation of the laser steering mechanism is explained in figure E.1. Lever A adjusts the yaw of the laser beam passing through the unit and lever B adjusts the pitch of the laser beam passing through the unit. Once the system has been aligned the laser steering mechanism should be locked in position using the grub screws shown.

The laser steering mechanism is mounted onto the side of the beam-splitter nearest to the HS20 laser as shown in figure E.1 using the clamp screws provided.

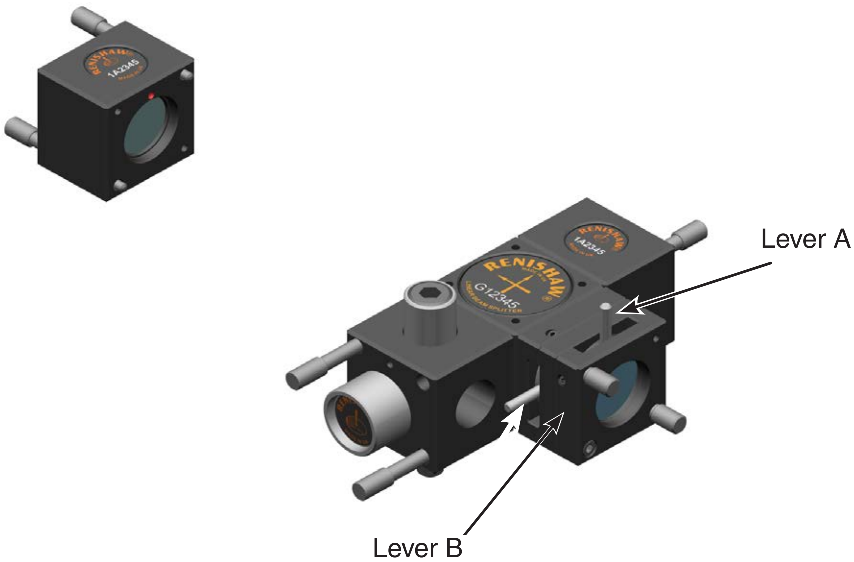


Figure E.1 - Laser steering mechanism fitted to standard optics

Maintenance of the laser steering mechanism

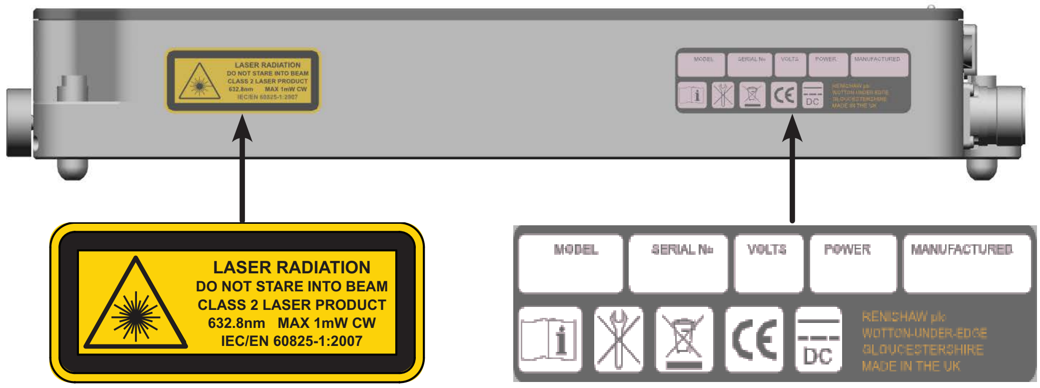
The laser steering mechanism should be cleaned using the same technique as for the standard optical components as described in appendix B. The unit may be disassembled if it is necessary to clean the inside surfaces of the optics, and has been designed to prevent the user reassembling the unit incorrectly.

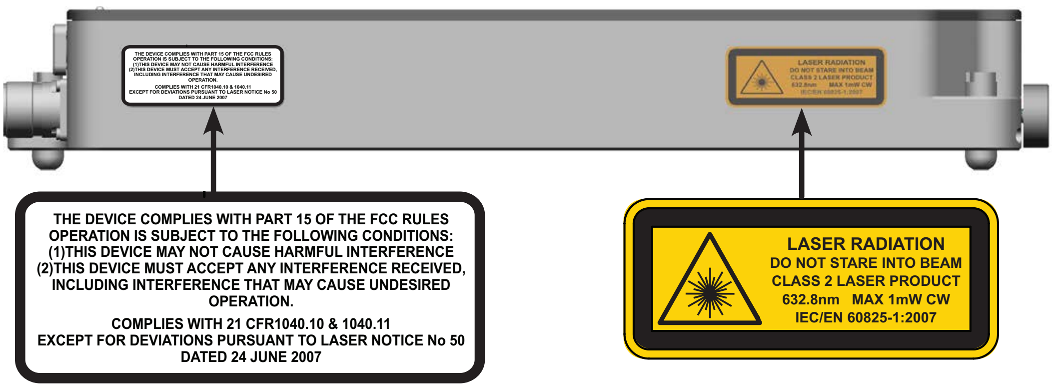
APPENDIX F – Glossary

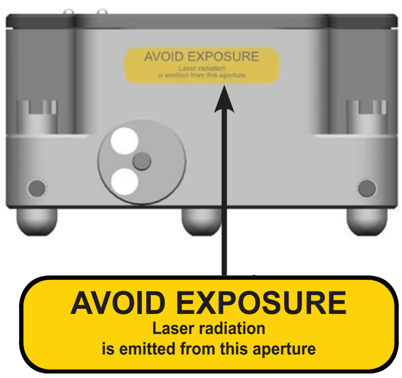
Bandwidth	The maximum count frequency which may be applied to the controller/ counter input. In a quadrature signal, count rate is 4 × signal frequency.
Beam splitter	An optic which is used to split the two polarisation states of the laser beam into measurement and reference arms.
Compensation	The process of applying a defined formula (Edlen) to the environmental conditions in order to correct errors on the laser wavelength to improve accuracy.
Count rate	The rate at which count increments are produced by movement. $\text{count rate} = \frac{\text{feedrate}}{\text{quadrature resolution}}$ This must be below the update rate, otherwise an overspeed error will occur.
Fundamental wavelength	The wavelength of the helium neon laser tube which can be expressed at vacuum or defined conditions such as NTP.
Hysteresis	A method of reducing noise or oscillation in measurement signals by using a positional delay of 1 count.
Measurement beam (arm)	The part of the split laser beam which passes to the moving optic being measured.
NTP	Normal temperature and pressure (20°C, 1013.25 mbar, 50% RH).
Reference beam (arm)	The part of the split laser beam which passes through the fixed reference path in the detector head.
Resolution	The distance separation of the encoder output signal, this being the smallest increment possible.
RS422/485	An electronic line transmission standard using noise immune differential signals.
Stabilised laser	A laser tube which is actively controlled to achieve a constant laser frequency.
Switch parity	A method of detecting errors by checking that the number of switches in the enabled position is odd.
Tristate	An open circuit state condition which may be applied to the laser output signal lines to indicate an error.
Update rate	The rate at which the digital output quadrature is updated. The minimum edge-edge time may be calculated by: $t = \frac{1}{\text{update rate}}$

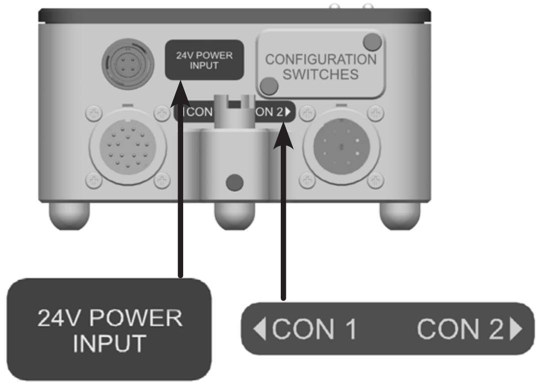
APPENDIX G – HS20 laser head labels

The following safety labels are attached to the HS20 laser head









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About Renishaw

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Products include:

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- Encoder systems for high-accuracy linear, angle and rotary position feedback
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- Gauging systems for comparative measurement of machined parts
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- Laser and ballbar systems for performance measurement and calibration of machines
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- Raman spectroscopy systems for non-destructive material analysis
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