1. Overview

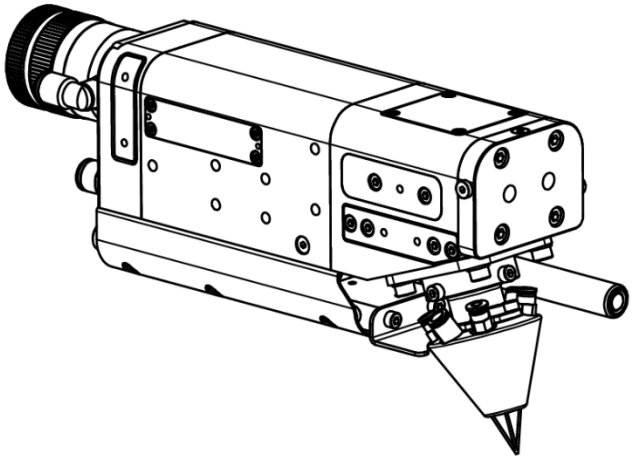
This manual provides a general description of the basic installation, factory settings, operation, maintenance and service of the ZR-X1 series products. Due to the large number of specific optical-mechanical components and customized configurations, this manual only introduces the main unit parts.

The ZR-X1 series laser cladding head is a proven high-performance processing head, suitable for various laser cladding and quenching applications. It supports integrated internal and external processing, featuring flexibility and high efficiency. Its overall optimized optical focusing system, annular air path, turbulent air flow, nozzle cooling design, built-in water cooling unit, and fine adjustment of focus position fully meet the requirements of industrial laser processing environments for cladding of pipes and medium-thick plates, as well as other customized needs. With a variety of flexible optical fiber interface options and optical collimation-focusing configurations, it is compatible with mainstream fiber lasers in the industry.

1.1 Product Features

- Full water cooling design for the main body and powder feeding nozzle, ensuring excellent cooling effect.
- Compact size and light weight, facilitating equipment integration.
- Horizontal optical fiber insertion, enabling easy internal and external circular cladding operations.
- Equipped with intelligent monitoring function, which can trigger alarm and stop operation to effectively protect lens components.
- Adjustable spot size (2.5-5mm) with a wide adjustment range, convenient for process implementation.
- 4-channel powder feeding, ensuring high powder convergence, smooth powder discharge, and powder utilization rate up to 90%.
- Optional visual tracking and monitoring unit for real-time monitoring of internal pipe cladding status.

图 1



1.2 Function Introduction

Markings in Figure 2 are as follows:

- a1: QBH water cooling interface, for connecting water pipes with outer diameter of 6mm.
- a2: Optical fiber QBH interface (not available if the laser has no QBH interface).
- a3: Internal pressurized air interface, for connecting air pipes with outer diameter of 8mm (usually for clean nitrogen or argon).
- a4: Powder feeding interface, for connecting powder pipes with outer diameter of 6mm.
- a5: Electrical interface (4-core cable), mainly used for power supply inside the laser head and transmitting alarm signals.
- a6: Water cooling interface, for connecting water pipes with outer diameter of 8mm (can be used as water inlet or outlet, no direction restriction).
- a7: QBH water cooling interface, for connecting water pipes with outer diameter of 6mm.
- a8: Upper protective lens drawer, with an upper protective lens (specification: D30×2) inside. The lens replacement method is detailed below.

- a9: Lower protective lens drawer, with a lower protective lens (specification: D40×3.5) inside. The lens replacement method is detailed below.
- a10: 4-channel powder feeding nozzle water cooling interface, for connecting water pipes with outer diameter of 6mm.
- a11: Powder inlet of the powder feeding nozzle, for connecting powder pipes with outer diameter of 4mm.

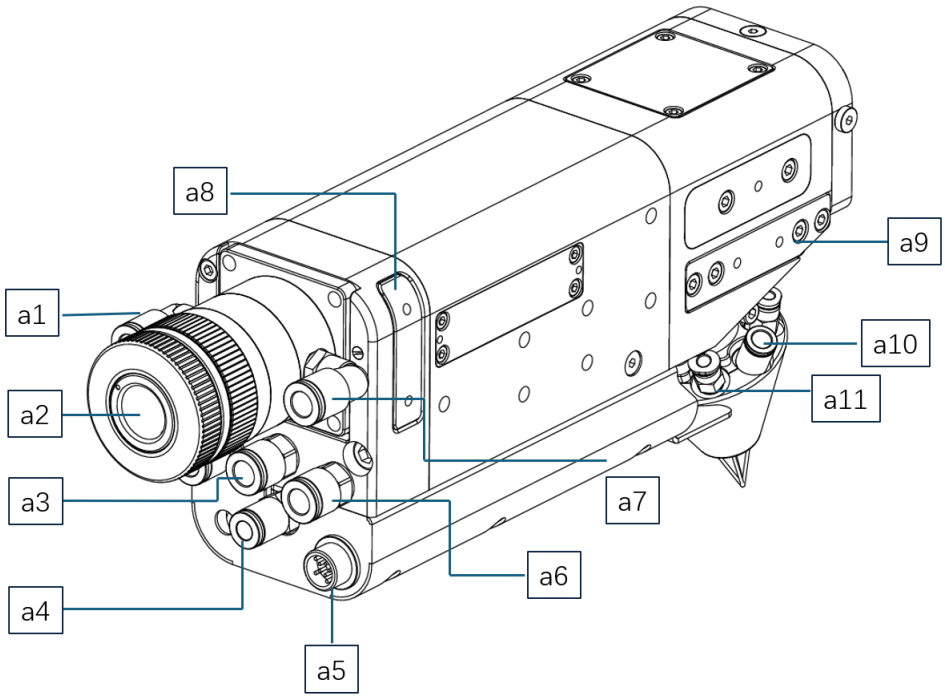


图 2

Markings in Figure 3 are as follows:

- b1: Signal indicator area.
- b2: Camera position, for real-time observation of cladding status.
- b3: External cable interface for the camera (optional function).
- b4: Water cooling interface, for connecting water pipes with outer diameter of 8mm.

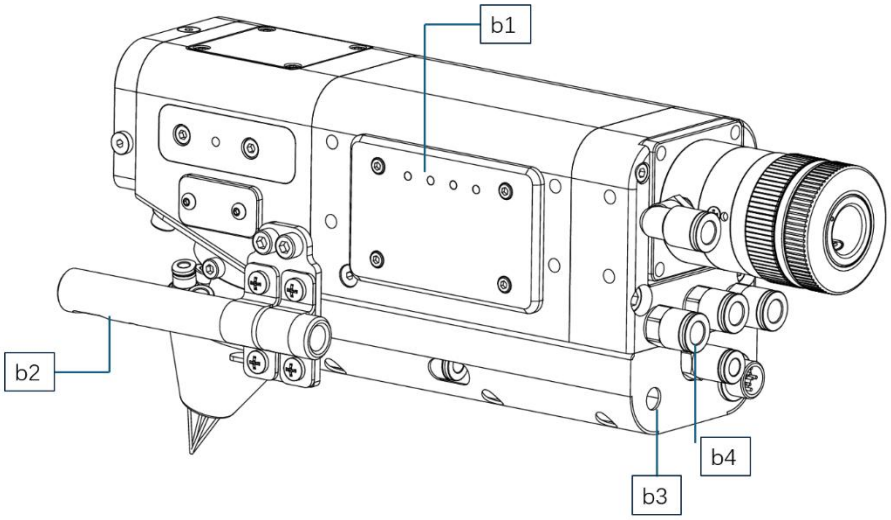


图 3

Markings in Figure 4 are as follows:

- c1: Powder inlet pipe of the powder feeding nozzle, for connecting powder pipes with outer diameter of 4mm.
- c2: Powder inlet pipe of the powder feeding nozzle, for connecting powder pipes with outer diameter of 4mm.
- c3: 4-channel nozzle water cooling interface, for connecting water pipes with outer diameter of 5mm.

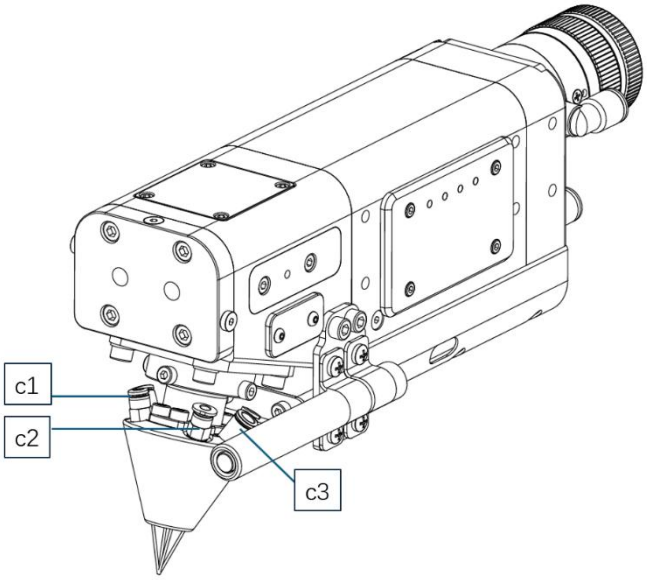


Figure 4

2. Installation

2.1 Mechanical Part

The dimension diagrams of the ZR-X1 product are shown in Figures 5-7. The M6 threaded holes on both sides can be used for installation and connection. Note that during connection and fixation, the mounting plate must not block the signal indicator or the adjustment window.

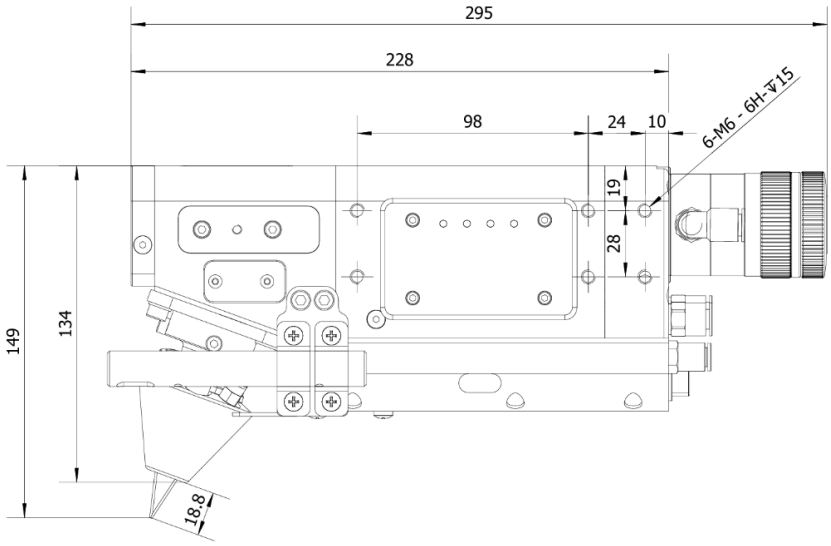


图 5

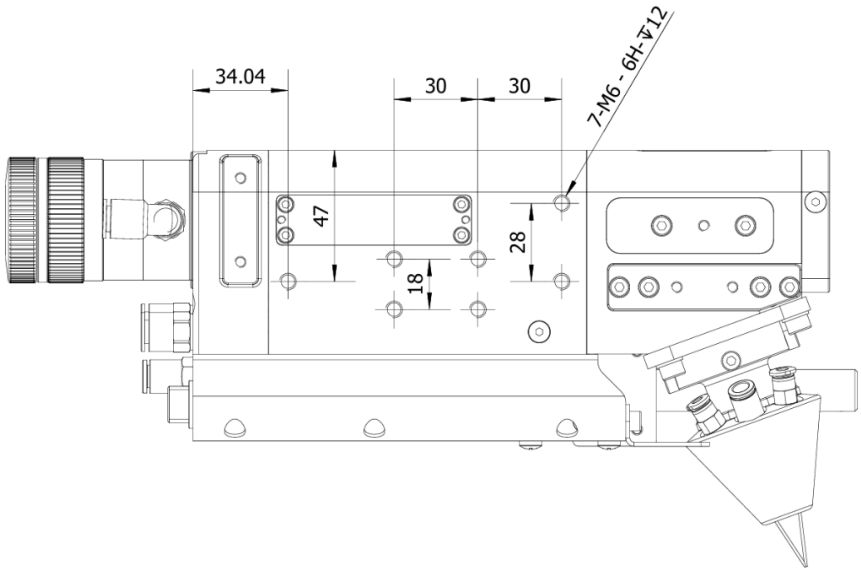


图 6

Figure 7 is a front view, simulating the dimensional relationship with a workpiece of inner diameter 160mm. The cladding head can easily enter the pipe for cladding operations.

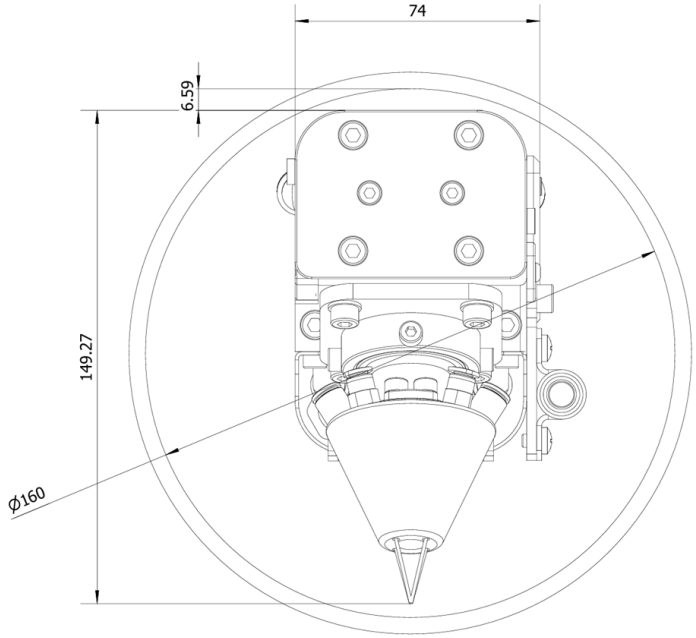


图 7

2.2 Water Cooling Interface

The ZR-X1 laser processing head is equipped with a set of cooling water circuits, and the direction of water inlet and outlet can be arranged arbitrarily. Note that water cooling is recommended when the laser power exceeds 3000W. The positions and quantities of water cooling interfaces can be seen from a6 in Figure 2 and b4 in Figure 3. The recommended water flow rate is detailed in the table below.

This water cooling interface is designed for a closed-loop water cooling system and can also be used with external free water supply, but it must meet the requirements listed in the table.

Outer Diameter of Water Pipe	**8 mm**
Minimum Flow Rate	1.8 L/min (0.48 gpm)

Outer Diameter of Water Pipe	**8 mm**
Inlet Pressure	170-520 kPa (30-60 psi)
Inlet Temperature	⩾ Room Temperature / ＞ Dew Point
Hardness (Relative to $CaCO_3$)	＜ 250 mg/liter
pH Range	6 to 8
Allowable Particle Size	Less than 200 μm in diameter

Note: Do not replace the air pipe joints arbitrarily, especially do not use raw material tape to seal the joints, otherwise it will cause air path blockage and affect normal operation.

2.3 Auxiliary Air Interface

Impurities (such as hydrocarbons and water vapor) in the auxiliary air can damage the lens, cause fluctuations in cladding power, and lead to inconsistent workpiece quality before and after cladding. The table below lists the recommended specifications for the auxiliary air. Higher gas purity results in better cladding section quality.

Impurities can be filtered out in the gas supply pipeline, but oxygen and water vapor can penetrate into the optical path system through non-metallic materials, which is the source of dust and hydrocarbons. It is recommended to use stainless steel accessories and a filter capable of removing particles as small as 0.01 μm for purification.

It is recommended to use a pressure gauge with a stainless steel diaphragm. Industrial pressure gauges with rubber diaphragms will suck in air and generate hydrocarbons due to aging.

Gas Type	Purity	Maximum Water Vapor Content (ppm)	Maximum Hydrocarbon Content (ppm)
Nitrogen	99.99%	＜ 5 ppm	＜ 1 ppm
Argon	99.998%	＜ 5 ppm	＜ 1 ppm
Helium	99.998%	＜ 5 ppm	＜ 1 ppm
Outer Diameter of Auxiliary Air Pipe	Outer Diameter of Auxiliary Air Pipe	8 mm	8 mm

2.4 Laser Head Cable Connection

This section mainly introduces the connection method between the cladding head and cables. The ZR-X1 cladding head requires connection of 2 cables: one is the 4-core cable for power supply, as shown in a5 in Figure 8.

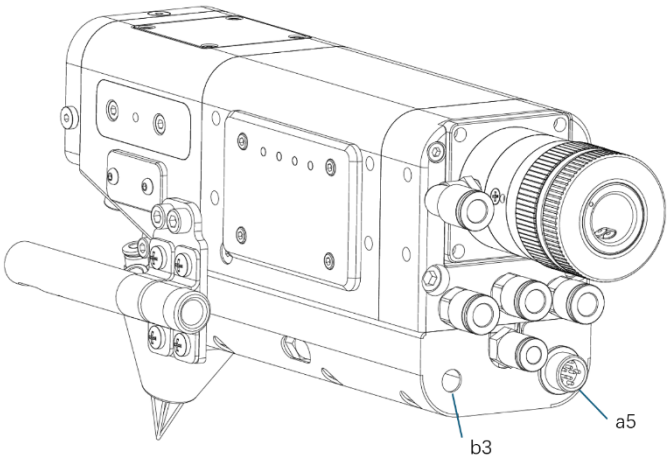


图 8

The additional 4-core cable has an aviation thread on one end, which is directly connected to the a5 port of the cladding head. The other end has 4 separate wires, as shown in Figure 9. The definitions of these 4 wires are as follows:

- X1: +DC24V
- X2: 0V
- C0: GND
- Y0: 24V

C0 and Y0 need to be connected to the 24V relay coil. During normal operation, it is at low level (no voltage output). When the cladding head alarms, a 24V voltage is output. At this time, the laser should stop emitting light, the machine tool should stop moving, and the operator should check whether the lower protective sheet of the cladding head is burned under the condition of ensuring equipment safety. If burned, the lens should be replaced before resuming operation.

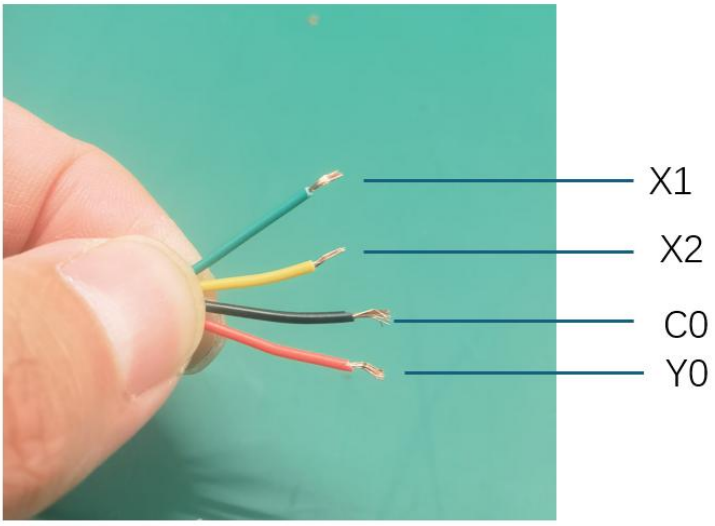


图 9

Note: All wiring must be done when the power is off. After wiring is completed and checked correctly, power on for debugging.

The other cable is a USB cable from b3 in Figure 8. The other end of this cable is connected to a display, which is used to observe the cladding status inside the pipe. A 2-meter cable is provided as standard. A USB extension cable can be used for extension if needed.

The display is powered by 5V and can be connected to power supply in real time during cladding operations. Note that the display must be fixed stably and kept away from heat sources.

2.5 Optical Fiber Connection

The ZR-X1 is compatible with most industrial laser generators and is equipped with a collimating lens assembly.

The connection part between the end of the optical fiber and the cutting head is called the optical fiber connector. Common optical fiber connectors include QBH, QD, Q+, LOE, etc. Each type of optical fiber connector has a unique fixing method. Please refer to the corresponding optical fiber connector user guide. Figure 9 shows the installation interface of the QBH connector.

Warning: Optical components must be kept clean, and all dust must be removed before use. If the optical fiber is inserted vertically into the laser head, the laser head must be rotated 90 degrees to a horizontal position before inserting the optical fiber to prevent dust from entering through the interface and falling on the lens surface. Fix the laser head after inserting the optical fiber.

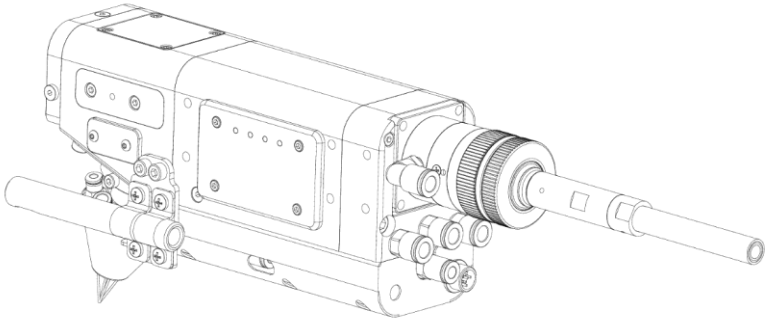


图 9

图 9.1

Specific optical fiber insertion method:

1. First, loosen the locking nut at 9.2 (counterclockwise direction, as shown by the red arrow in the figure).
2. Second, rotate the snap ring at 9.3 counterclockwise (as shown by the red arrow in the figure).

3. Align the red dot on the optical fiber interface with the red dot in the QBH interface at 9.2, and insert the optical fiber slowly.
4. As shown in Figure 9.2, after inserting the optical fiber, first rotate 9.3 clockwise until it is fully tightened.

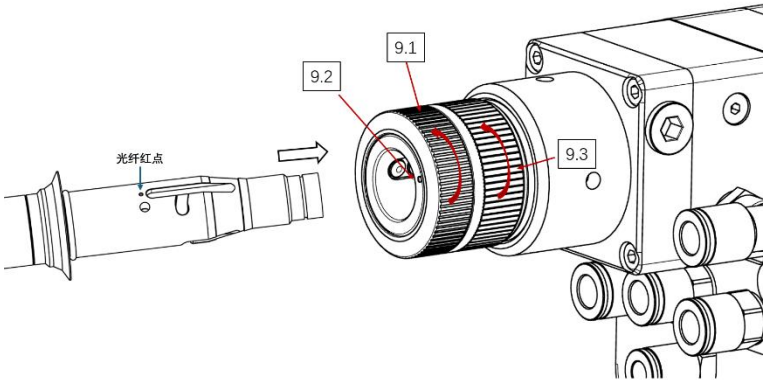


图 9.2

Then rotate the locking nut at 9.1 clockwise to tighten it.

Note: The optical fiber insertion step must be performed in a dust-free workshop, and the insertion should be as horizontal as possible to prevent dust from entering and contaminating the internal lens!

1. 3.1 Coaxial Adjustment of Optical Path
2. After connecting the optical fiber, first turn on the laser's red light and adjust the coaxiality between the red light and the nozzle. Ensure that the red light is coaxial with the nozzle before proceeding to the next step. If they are not coaxial, the nozzle will be burned. Remember this!
3. The specific adjustment method is shown in Figure 10:
4. First, stick white paper tape on the nozzle opening.
5. Then, loosen the 4 M5 hexagon socket cylinder head bolts at position 10.1 in the figure. Push the nozzle by hand and observe whether the red dot moves to the center of the nozzle. Once it reaches the center, lock the 4 bolts.

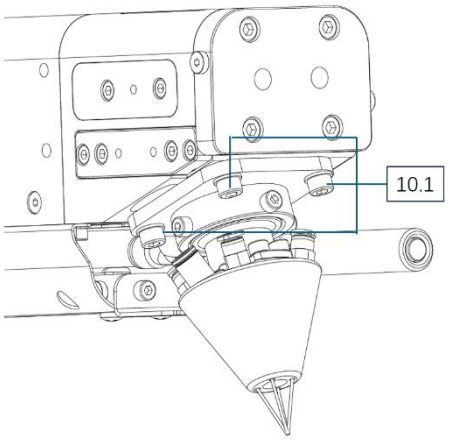


图 10

3.2. Replacement of Lower Protective Lens

As shown in Figure 11:
Loosen the 2 hexagon socket bolts at 11.1.
Pull out the lower protective lens drawer. Lift the stainless steel pressing ring (11.2) with two fingers to take out the lower protective lens (specification: D40-3.5).
When replacing the protective lens, first seal the opening of the laser head with tape to prevent dust from entering. Ensure that your hands are clean during operation! After replacing the lens, insert it back into the laser head quickly.

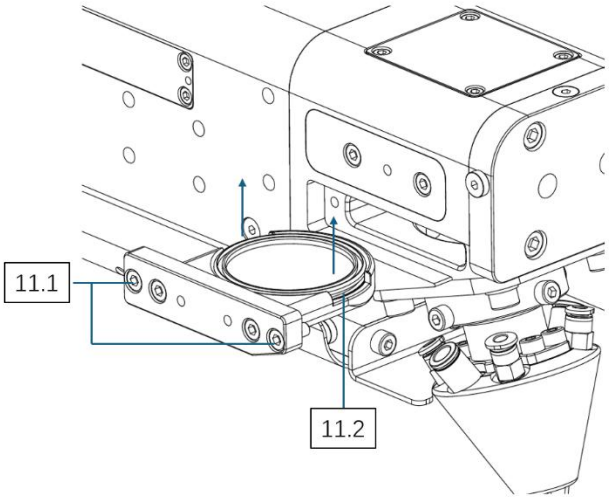


图 11

Note: Do not pull out the elastic sealing ring by directly picking its edge, as this may easily damage it.

3.3 Signal Indicators

The meanings of the signal indicators are shown in Figure 12:

- b: Lower protective lens monitoring light
- c: Red reserved light
- d: Blue power light

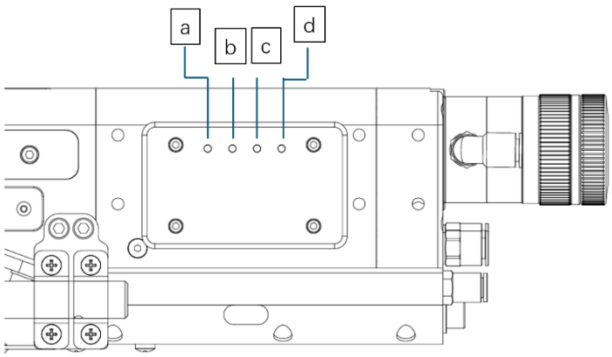


图 12

The lower protective lens monitoring light is normally green (steady on). When the temperature is higher than 50°C, it turns yellow; when the temperature is higher than 60°C, it turns red. At this time, an alarm signal is output. The laser and machine tool operation should be stopped immediately, and check whether the protective lens of the laser head is burned. If burned, replace it in time.

3.4 Replacement of Upper Protective Lens

When the upper protective lens needs to be replaced, first clean the dust on the surface of the laser head (this is also the first step in replacing other lenses). Then, loosen the two set screws at 13.1 in Figure 13, and screw an M3 bolt into the threaded

hole at 13.2 to pull out the drawer, as shown in Figure 1

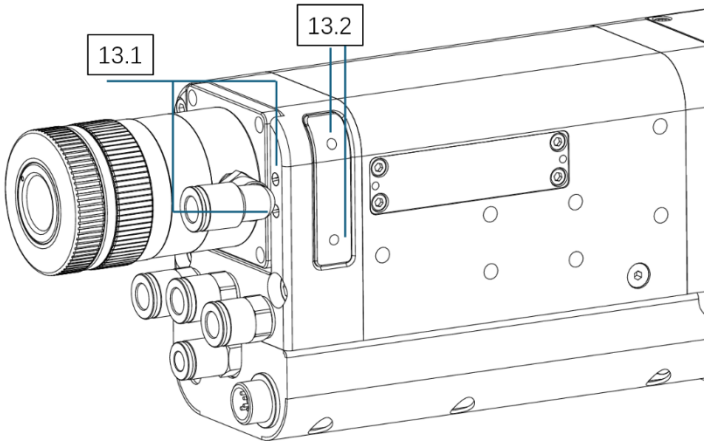


图 13

Pull out the protective cover 14.4, loosen the 4 cross recessed countersunk head screws at 14.1, and remove the upper pressing cover to see 14.2 (the upper protective lens with specification: D30-2). 14.3 is the upper drawer. After replacing the lens, lock the 4 cross recessed countersunk head screws and insert the drawer back into the laser head to complete the lens replacement.

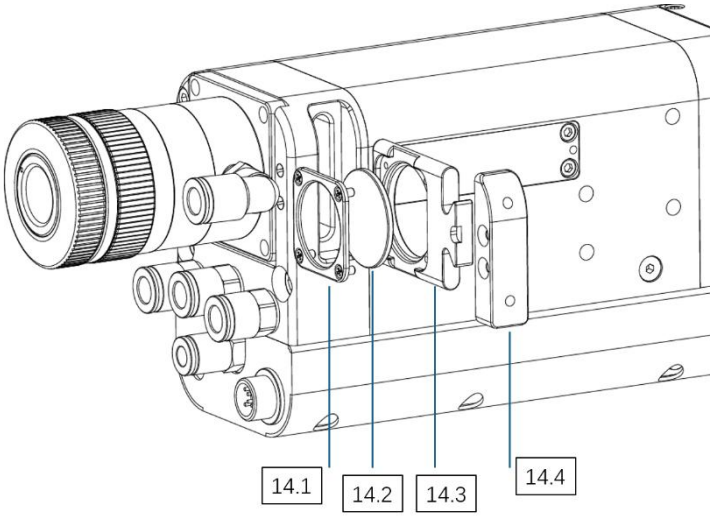


图 14

Note: The upper protective lens is not easily burned, so it does not need to be replaced frequently. Reducing the number of replacements can effectively reduce the risk of dust entering the laser head. Here is a tip: Before replacing the protective lens, you can use a white paper and irradiate it with red light to check if there are black spots on the red light on the paper. If there are, it means there is dust on the lens. If the black spots still exist after replacing the upper and lower protective lenses, it indicates that the black spots may be on the internal collimating lens or copper mirror. In this case, the laser head needs to be returned to the factory for maintenance and inspection. Do not open the laser head by yourself, otherwise the warranty service will not be available due to damage.。

3.5 Adjustment of Cladding Spot Size

During cladding operations, we often need to change the parameters such as laser cladding width, thickness, and overlap according to the workpiece, laser power, and customer requirements. Therefore, we often need to adjust the laser spot size conveniently. This laser head allows customers to adjust the spot size to facilitate the implementation of cladding processes.

The specific operation is as follows (Figure 15):

1. First, before adjustment, clean the floating dust and powder on the surface of the laser head to prevent them from falling into the laser head after removing the cover plate.
2. Second, loosen the 4 hexagon socket cylinder head bolts on the cover plate 15.1 (15.2 shows the hexagon socket bolts).
3. Then, push the lever 15.3 along the direction of the arrow, and at the same time observe the size of the red light spot at a position about 18mm below the nozzle until it reaches the desired size.
4. After adjustment, cover the cover plate 15.1 quickly to prevent dust particles from entering.

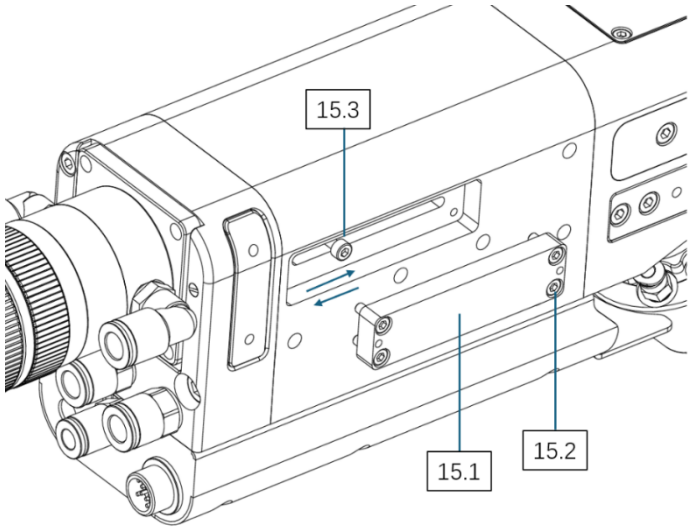


图 15

3.5 Replacement of Reflective Copper Mirror

When the reflective copper mirror needs to be replaced (e.g., for function switching or due to burnout), follow the steps below:

As shown in Figure 16:

1. First, before replacement, clean the dust on the surface of the laser head.
2. Second, remove the 4 hexagon socket cylinder head bolts at positions 16.1.
3. Pull out the copper mirror holder 16.3, noting that it is connected to the reflective copper mirror 16.2.
4. Put the entire assembly into the copper mirror box. Note that the copper mirror should not be separated from the reflective holder to avoid risks such as water leakage.
5. Take out the copper mirror to be replaced, insert it into the laser head together with the copper reflective mirror, and note that the reflective surface of the copper mirror faces downward.
6. Tighten the installation bolts of the reflective holder to complete the replacement.

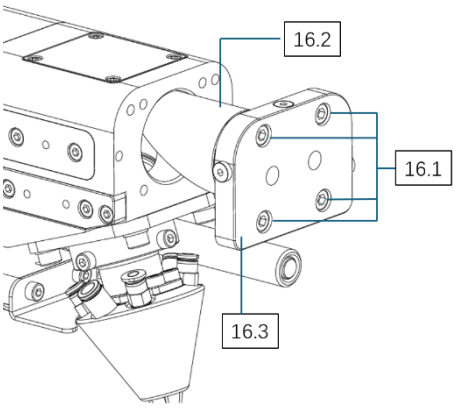


图 16

Note: The replacement of the copper mirror must be performed in a dust-free workbench and in the presence of technical personnel from our company. If the customer replaces it by themselves, the warranty service will not be available.

3.6 Nozzle Distance Adjustment

When adjusting the distance H between the nozzle and the workpiece (as shown in Figure 17), it is recommended that the powder convergence point falls on the workpiece surface. However, for high-power and large-spot operations, the convergence point needs to be far away from the workpiece surface. According to experience, the appropriate distance H is 19-23mm. Other processes shall be determined according to on-site conditions.

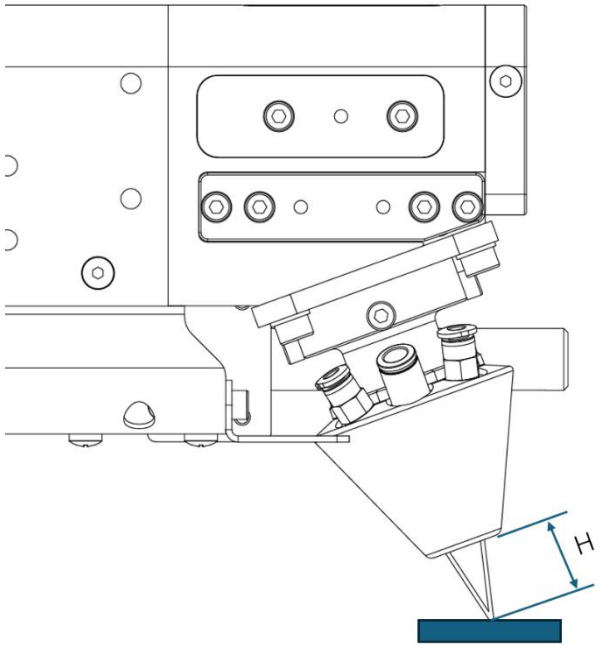


图 17