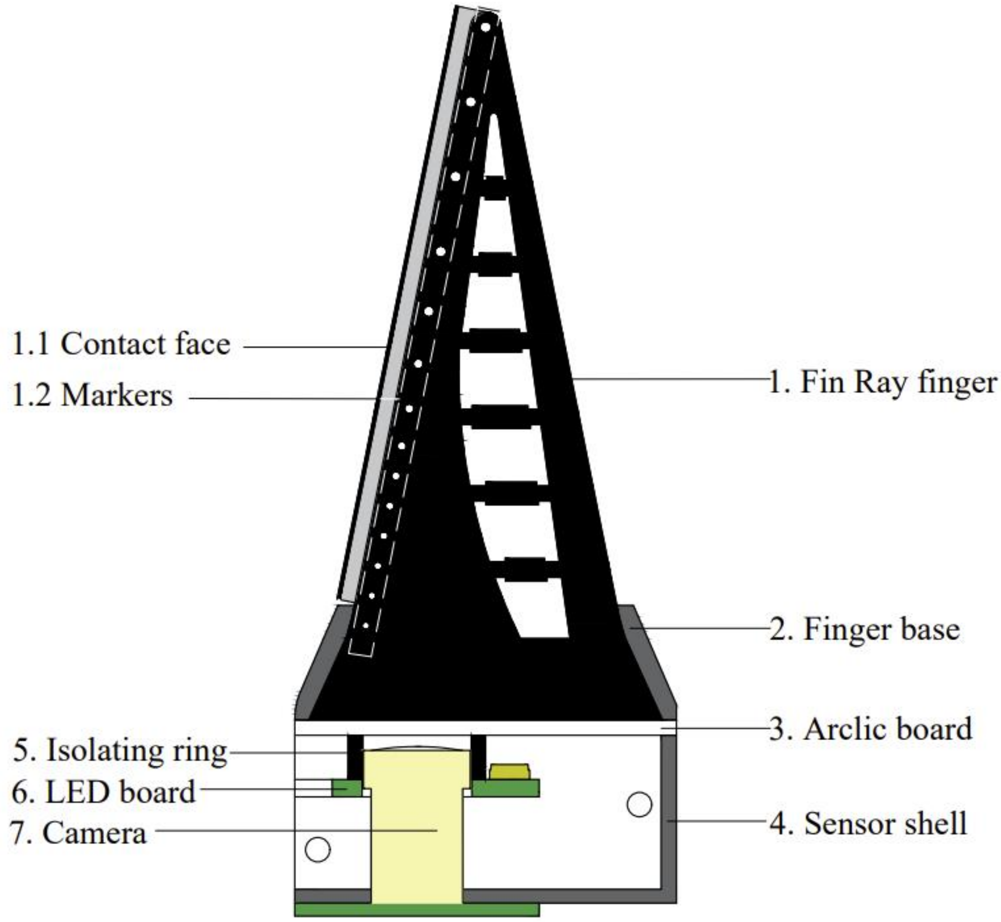
How to make a AllTact Fin Ray gripper

1. Introduction

AllTact Fin Ray gripper is a compliant, simple-structure gripper embedded visuotactile sensor that can detect contacts from all directions and reconstruct the contact geometries locally and globally. Simplified cutaway view of the finger is as the image below:



Structurally, the finger is glued to the base and secured with an acrylic board. Its widened base ensures a tight fit with the mount. The finger base and sensor shell feature a split design, connected by screws. The camera is screw-mounted at the base of the sensor shell, directly facing the finger's contact surface. LED is installed in the sensor shell slot, with the camera passing through the LED board's aperture, ensuring stable positioning. A black isolation ring is placed between the camera and LED board to prevent direct light interference.

The Fin Ray finger body is made of transparent elastic silicone, coated with black silicone to block ambient light. A series of point-like markers are laser-engraved on the finger's side. These markers are tracked in real-time images to obtain reference images for reconstruction. The radius and spacing of these markers are proportionally increased with distance to ensure a consistent size and spacing in the captured images.

The purpose of this tutorial is to quickly learn how to mold and assemble an AllTact Fin Ray finger to reduce the learning cost.

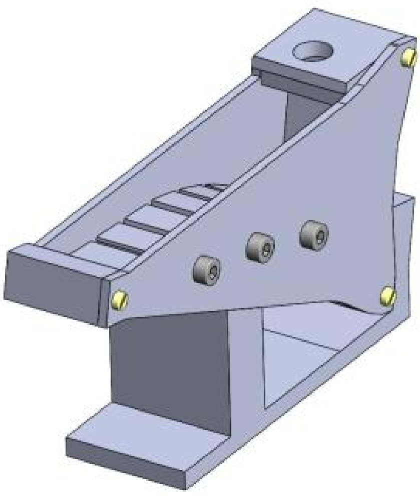
Making an AllTact Fin Ray finger consists of the following five steps, each of which is described in detail in this chapter.

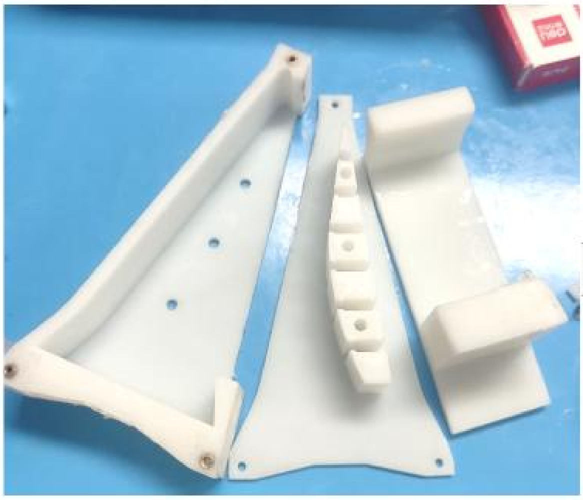
1. **Preprocess the required parts**
2. **Cast finger body**
3. **Cast translucent and semi-transparent layers on the body**
4. **Demoulding, assembling and overpainting**
5. **Black and dot.**

2. Preprocess the required parts

2.1 Mold for casting

The finger body is formed by one-time casting, so it is necessary to prepare a set of casting molds. The molds are 3D printed with white ductile resin (Greatsimple Technology® UTR8360). The current design is shown below, where the left side is the assembly model diagram and the right side is the physical drawing.



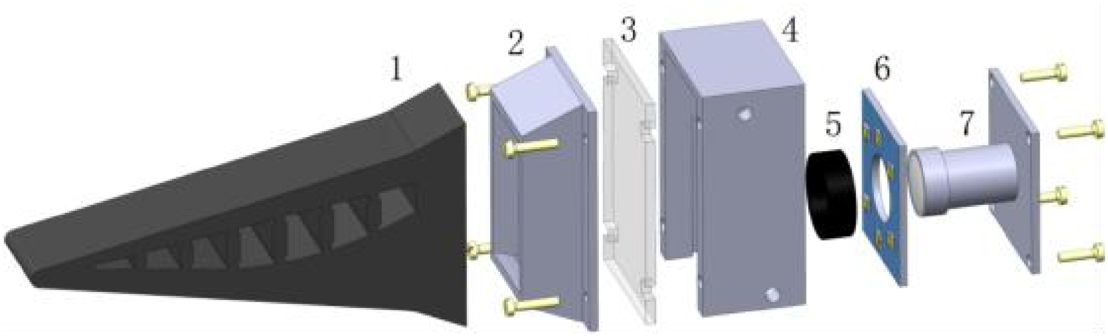


The mold comprises a convex mold (core), a concave mold (cavity), and a supporting block. In the casting process, the core and cavity are locked and closed using three screws at the corners and three bolts passing through central through-holes. This assembly is then placed on a pad to maintain a horizontal and upward-facing orientation of the mold's top surface. As this surface will be the contact area of the finger, and a translucent silicone layer will be added for deformation reconstruction, ensuring uniform thickness is essential.

Due to the widened structure at the bottom of the finger, casting would result in unfilled voids at the corners. To address this, a supplemental casting hole was created in the upper part of the female mold, allowing for the injection of transparent silicone to fill these inaccessible areas.

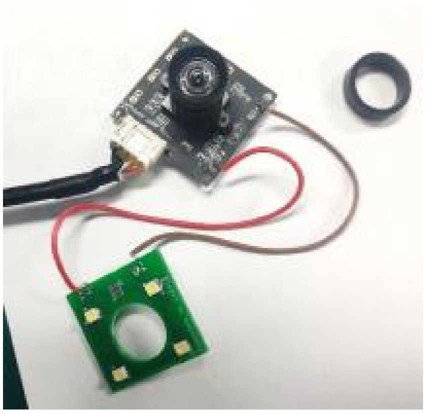
2.2 Sensor components

The following picture shows the part explosion diagram of the sensor and finger, and the label is the same as the cutaway view.



The finger base and sensor housing are also 3D-printed from white, tough resin. Threaded inserts (nuts) are embedded in areas where screws are used, as directly tapping threads into the resin can easily strip. The isolation ring is printed from black, tough resin (Somos® Taurus). The acrylic board is custom-designed with clearance holes for screws at its four corners. The camera specifications for this finger are: resolution = 1920×1080, FPS = 30, FOV = 85°, and no distortion. The LED board is rectangular with a central hole for the camera to pass through. The board's width is slightly less than the width of the sensor housing slot to prevent interference with the connection platform during gripper closure. The LED board and resistor were custom-made.

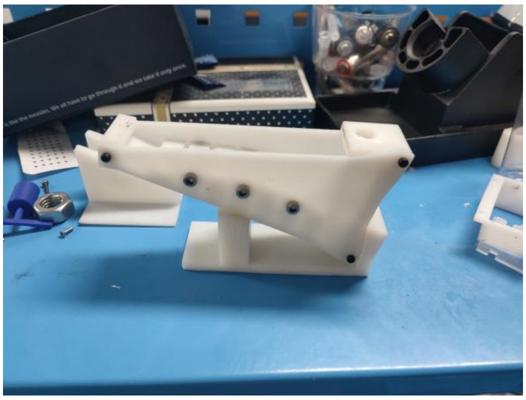
Furthermore, the LED bo requires power. We designed it so that the LED board's supply voltage (5V) matches the camera's voltage requirement. Consequently, after soldering the LED board to the camera, a single USB data cable from the camera can power both components simultaneously, as shown in the figure to the right.



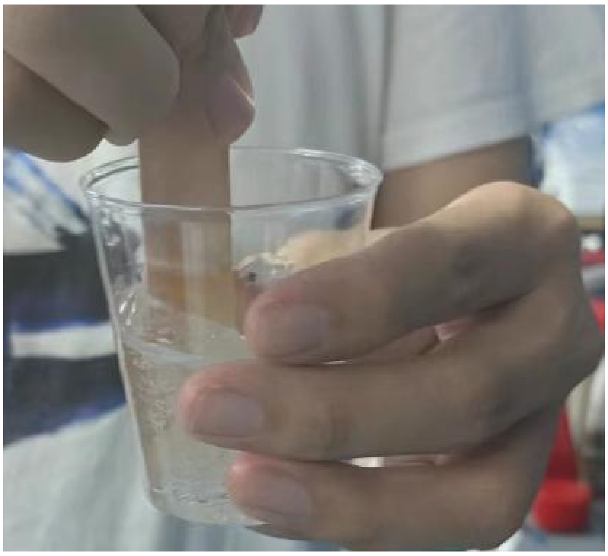
3. Finger body cast

1. Before casting, the molds are thoroughly cleaned, and a mold release agent (Mann®Release Technologies) is evenly applied to the mold's interior surfaces to aid in demolding.

2. After spraying, the molds are secured with screws and bolts. The upper surface of the mold is then leveled using supporting block in preparation for casting.



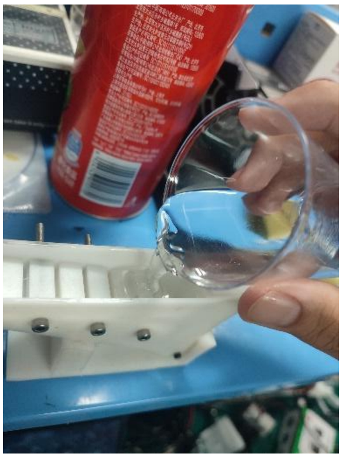
3. During preparation, the silicone is weighed on an electronic scale according to the specified ratio and then thoroughly mixed. For the illustrated mold, casting one finger requires approximately 40g, with a slight excess allowed to account for residue adhering to the cup and mixing rod. We use transparent elastic silicone (ELASTOSIL(®) RT 601, A:B = 9:1 ratio) to create the Fin Ray fingers, enhancing their stiffness. This silicone is harder than the translucent layer, resulting in less localized deformation upon contact and improved reconstruction. Its lower overall deformation also allows the resulting gripper to withstand greater force and grasp heavier objects.



4. The silicone mixing process generates numerous air bubbles that are difficult to eliminate on their own. A vacuum degassing chamber is used to remove these

bubbles. When degassing, aim the vacuum port towards the container opening. This allows you to vent the vacuum as needed (e.g., when the bubbles are close to overflowing) to break the surface tension and accelerate the degassing process.

5. After degassing, the silicone can be poured into the mold until the liquid level reaches the marked line. A few new bubbles may form during pouring, and these should be removed with tweezers or a similar sharp object. After pouring, the silicone typically needs 2-4 hours to solidify at room temperature, or 20 minutes in a 60°C oven.

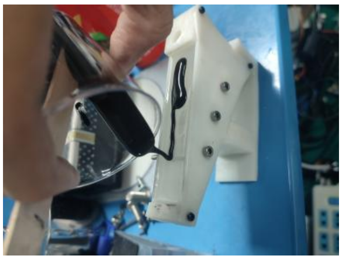
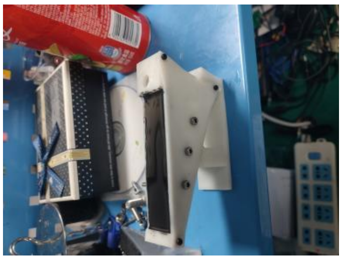
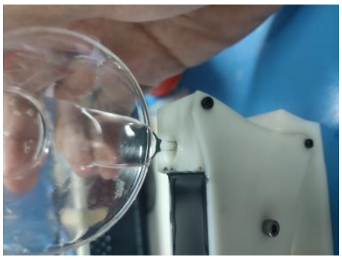


4. Contact layer cast

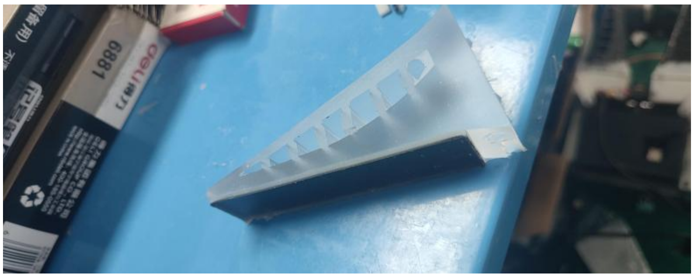
1. After the finger body solidifies, the contact surface is cast in the open face of the upward-facing mold. Since the transparent silicone casting liquid only reached the marked line, space remains within the mold for the translucent silicone. First, the translucent layer (POSILICONE®, ratio A:B = 1:1) is cast. The silicone preparation and degassing steps are the same as above. The translucent layer is relatively soft, and the bubbles can typically be removed in a single vacuum cycle. The prepared quantity should be less than 10g, just enough to bring the liquid level flush with the mold's top surface.

2. After the finger body solidifies, the contact surface is cast in the open face of the upward-facing mold. Since the transparent silicone casting liquid only reached the marked line, space remains within the mold for the translucent silicone. First, the translucent layer (POSILICONE(®), ratio A:B = 1:1) is cast. The silicone preparation and degassing steps are the same as above. The translucent layer is relatively soft, and the bubbles can typically be removed in a single vacuum cycle. The prepared quantity should be less than 10g, just enough to bring the liquid level flush with the mold's top surface.

3. After the translucent layer solidifies, prepare the same translucent silicone again, and mix in black pigment (from SILC PIG®, BLACK) to create black silicone, and evenly apply the black silicone over the translucent layer to form an opaque layer. At the same time, since the solidified translucent layer has now sealed the inaccessible areas, prepare another batch of transparent silicone and pour it into the supplemental casting hole. Let both layers solidify simultaneously to save time. The amount of silicone used in each of these steps is small, less than 5g.

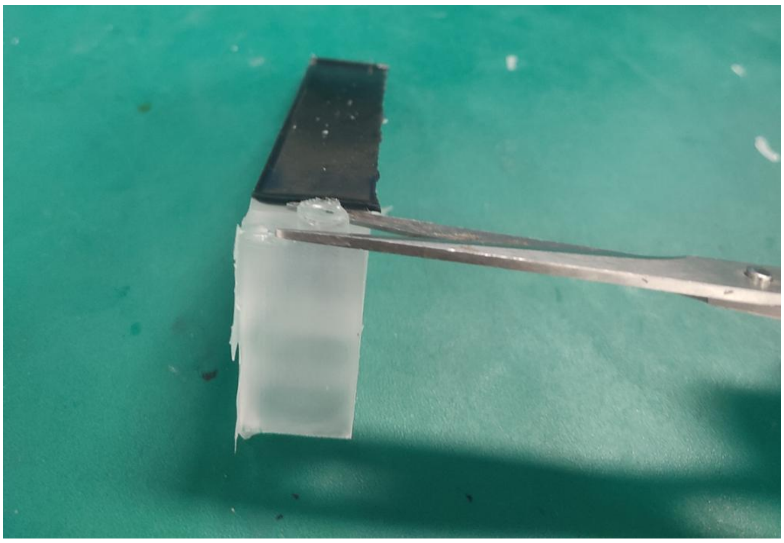




3. After all materials have solidified, demold the finger. Because the contact surface is cast directly onto the finger body, a strong bond is formed during solidification. This strong connection is crucial to prevent delamination between the two silicone phases when the finger undergoes significant deformation under load.



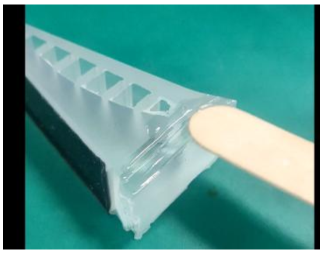
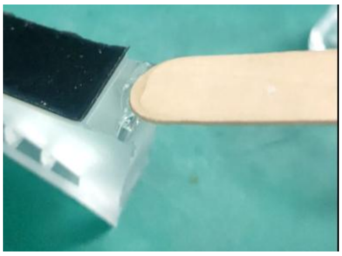
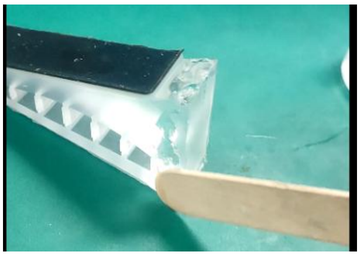
The silicones and black paint used to create the Fin Ray fingers, from left to right, are: transparent ELASTOSIL® RT 601 A, B; transparent Solaris A, B; and translucent POSILICONE® A, B. Solaris was the silicone material used in earlier versions of the finger, but it was discontinued due to its excessive softness.

4. After demolding, trim any excess silicone flashing from the finger's edges with scissors. Also, cut off the small cylinder that resulted from the supplemental casting hole.

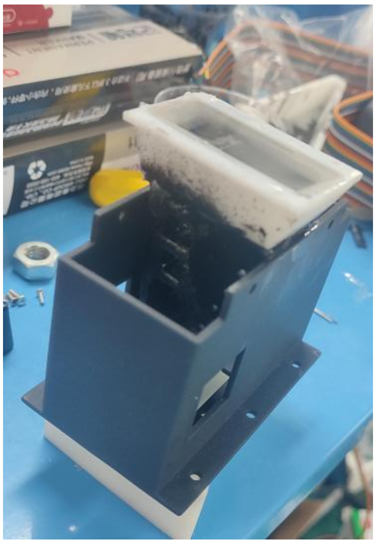


5. Fabrication

1. Once the finger body is demolded, it can be assembled with the sensor components. The finger is attached to the finger base via adhesive bonding. Prepare up to 5g of transparent silicone to use as glue. Apply the freshly prepared transparent silicone to all four sides of the finger base, as shown in the figure.

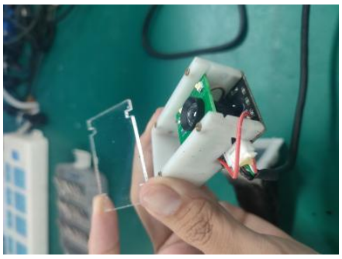
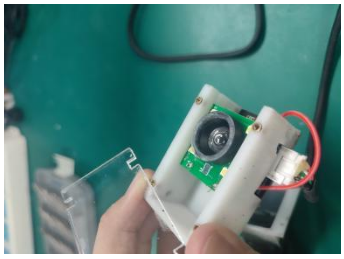




Then, insert the finger into the base, and using a suitable method, orient the finger with its bottom surface facing upwards so that it lies flat. Apply another layer of transparent silicone to the bottom surface. The mold used was not polished, so its inner walls are rough, and the surface of the demolded finger is also rough, making it difficult to see the contact surface clearly. Therefore, another layer is applied. The images below show the observation results with and without silicone applied to the finger's bottom surface.

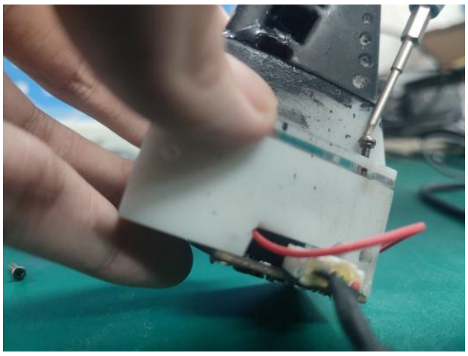



After applying the silicone and positioning the finger, wait for the silicone to fully solidfy. The newly prepared silicone acts as glue to fix the finger to the base. Furthermore, for structural defects at the bottom caused by the supplemental casting hole, we can leverage the upward-facing orientation of the finger base and its tight fit with the finger to effectively perform an on-the-spot casting, with the finger base acting as a mold in this instance.

2. While waiting for the finger to fix to the base, you can begin assembling the sensor shell. First, insert the LED board into the housing, then insert the camera into the circular hole on the LED board and secure it with screws. Finally, place the isolation ring onto the camera.

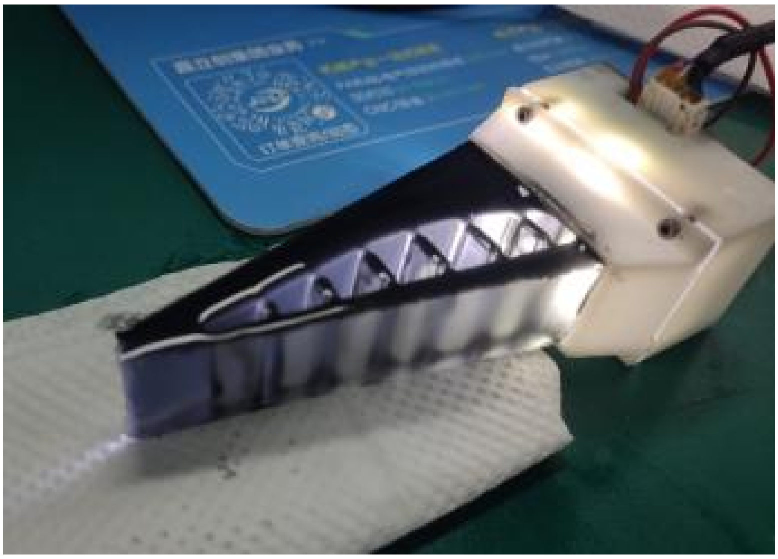
3. Once the applied silicone has fully solidfied, you can screw the acrylic plate and base onto the sensor housing. During this process, it’s normal for air gaps to form between the acrylic plate and the uneven finger base. As long as these gaps don’t obstruct the camera’s field of view and interfere with contact surface observation, they’re acceptable. If there is interference, consider adjusting the tightness of the four locking screws and/or using a knife to trim any excess silicone attached to the base.

6. Black and dot markers

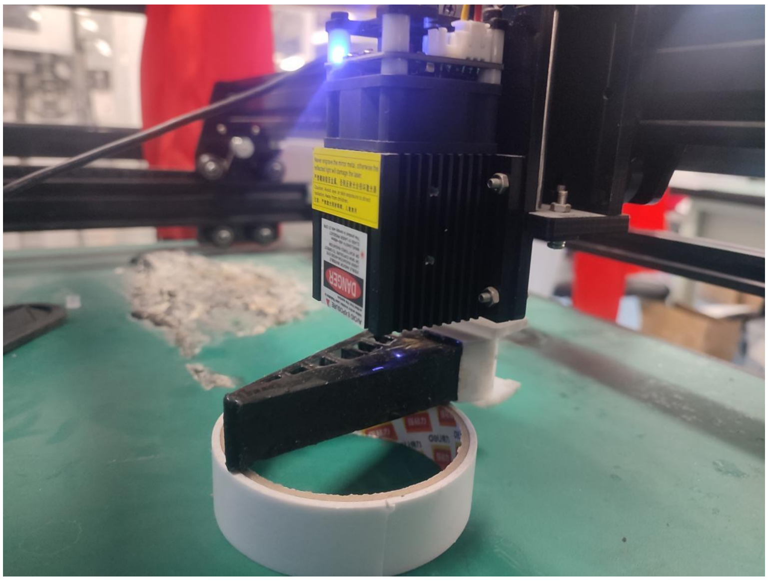
6.1 Black

1. After assembly, prepare transparent silicone, dye it black with black pigment, and apply it to the entire surface of the finger body to block ambient light from interfering with the reconstruction. The silicone usage is also around 5g. When applying the black coating to each surface, use a suitable method to ensure that surface is level.



6.2 Dot markers

Use the laser engraving machine shown in the figure to mark the points used on the sides of the finger. When marking, ensure that the surface is level and properly focused. Generally, mark 6-8 points on each side.



7. Summary

So far, you have finished making an AllTact Fin Ray finger, then try to make another one and start to grasp something!