Standard Operating Procedure for HUMMINK1

Before beginning, START your reservation in the Kiosk section of the iLab website.

ATTENTION: For ANY movements you make during the operation of the Hummink (particularly Z movements of the pipette), be prepared to click the **Movement Stop** button: This will STOP all motion in the event of a pending collision of the pipette with the sample. Do not click the Emergency Stop button (as this will disconnect/shutdown the motion controllers completely)

1 - Powering ON HUMMINK1

a) If the system is ON, proceed to **2 -Starting the Software**

b) If system is OFF, press the Hummink Power button on front panel; the PC will start automatically

c) After Windows loads on the PC, enter the password: Hummink

2 - Starting the Software

a) Click the icon centered on the Desktop: Then click "Initialize" at the top/right of the UI

b) Click "Connect" button on the Hardware connection pop-up

Note: if software was left running from previous user, you may need to click the "Hardware connection" button in the Initialize menu at the top of the UI:

c) Wait for "Hardware is connected" message, then click "Next" button

d) The hardware is now connected, proceed to **3 -Hardware Initialization**

3 - Hardware Initialization

a) Click "Set Home Position"… Wait for "Hardware is initialized" message, then click "Next" button

b) The hardware is now initialized

4 - Installing a Pipette

a) If closed, open the Hummink glass door. Carefully lift up door and flip it back gently so that it rests atop the body of the tool. Please be gentle!

b) Put on gloves

c) Load the transfer needle with the fluid of your choice

(NOTE: The SMIF supplied needle/syringe is to be used ONLY with SMIF supplied silver ink!)

(NOTE: If you are using your own ink, you must supply your own needle & syringe for filling the pipette!)

- For the SMIF supplied silver ink, proceed as follows:
  - Uncap the ink vial
  - Pre-set the 3mL syringe to 1mL → remove plastic protective tube from needle
  - Insert needle into ink → pull the syringe to the 2mL mark and hold 10 seconds
  - Release the plunger and wait another 10 seconds
  - Remove needle from ink, wipe excess ink off the needle onto the inside edge of the vial

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- Replace the cap on the ink vial

d) Select a pipette, either bring your own or purchase one from SMIF
(if you get a pipette from the SMIF supply, you must record it on the Hummink Pipette Log sheet)

e) Fill pipette with fluid (NOTE: as of 2024-03 users no longer need to break the glass pipette)
   - For the SMIF supplied silver ink, proceed as follows:
     - Carefully insert needle into pipette (needle should bottom-out at the end of the pipette)
     - Press the syringe plunger to dispense the ink… watch carefully. Fill the pipette so that the ink in the pipette is ~ 1mm long (this is an extremely small volume of ink, but sufficient for several hours of printing)
     - After you fill your pipette to ~ 1mm, remove the needle
     - Dispense remaining ink in the needle onto a disposable wipe
     - Place the syringe/needle back onto the holder
     - At this point you should be holding the pointed glass pipette, filled with ~1mm of ink (NOTE: You may have some ink on your glove at this point. Please take care not to transfer this inadvertently to various surfaces.)

f) Insert pipette into the holder on the resonator fork and secure the clamp at the midpoint of the pipette (~25mm of the pipette should be above the clamp). DO NOT ever touch the pointed end of the pipette; the glass tip will break and your pipette will be ruined.

g) Replace the plastic protective tube on the needle → place syringe on holder → Dispose of your gloves

5 - <u>Tuning Fork Autotune</u>

a) At this point the hardware is initialized (from step **3 -<u>Hardware Initialization</u>**)… and a pipette should be installed in the tuning fork

b) Click “Start Autotune” button

c) The autotune procedure will sweep the frequency 3 times (coarse, medium and fine), whilst plotting the amplitude and phase shift of the tuning fork
(NOTE: If autotune does not start within 30s, click “Stop Autotune,” wait 10s… then click “Start Autotune”)

d) Wait for “Autotune complete” message, then click “Next” button
(Typical values for frequency and Q-factor are: 1500Hz +/- 50Hz and 350-2000, respectively)

6 - <u>Inserting Your Sample/Substrate</u>

a) Place your sample onto the X/Y stage of the Hummink, taking care to avoid touching the glass pipette!
(There are tiny pins on the X/Y stage to aid in sample placement; Please DO NOT lose these!)
Notes on samples/substrates:

- Samples should be relatively flat (the piezo z-height controller has +/- 125um range IF centered perfectly (250um total travel))
- For reflective samples, viewing the reflection of the pipette on the sample surface can aid in the initial pipette approach
- If a sample has existing features, those features can aid in the initial pipette approach
- Flexible samples (e.g. thin sheets) should be secured to a rigid substrate (e.g. by taping the edges)

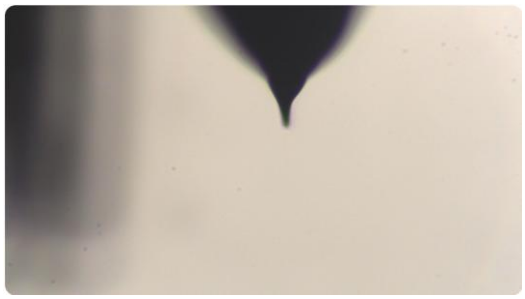
b) If not already ON, turn ON the LED panel by pressing & holding the round button on the panel

c) The optional (but not very useful) vertical light bars can be turned on by pressing the physical button on the front panel of the Hummink (to the right of the Power button)

7 - <u>Camera Calibration</u>

a) Adjust the "Camera Offset" value so that the camera is focused on the end of your pipette:
- Increment the value ~1mm at a time (Values should be negative)
- Enter a value, press "Move," The camera will move down the pipette (toward the pointed end)
- Keep incrementing until you see the pointed end of the pipette (decrease the increment value as you get closer to the end of the pipette).
- With the tip of the pipette in view, you may need to adjust the physical X- and Y- positioning knobs and the focus knob on the imaging system to center and focus the pipette tip.
- Typical final values for the camera offset are: -5 to -12mm (depending on the length of pipette you left above the clamp in step "**4 -f)**"

b) A well-focused image of your pipette tip should look something like this:
(You may also use the manual X and Y knobs on the imaging system to center the pipette on screen)



c) Click "Next"

8 - <u>Pipette Coarse Approach</u>

a) We will now bring the pipette very close to the sample surface. This is a manual process, and it is entirely possible to crash the pipette into the sample, ruining the pipette. <u>Proceed with caution!</u>

b) Note **Pipette Height** at the bottom of the screen (default is 49mm after hardware initialization/homing)

NOTE: **Pipette Height** value **DOES NOT** represent the actual pipette-to-sample distance! This is a somewhat arbitrary value. In other words: You will NOT be reducing this value to ZERO! The pipette will be in physical contact with the sample long before you reach a value of ZERO!

c) Visually observe the pipette-to-sample distance (looking directly at the pipette, not on the PC screen), gradually reduce the **Pipette Height** by changing the value (1-2mm at a time to start).
(Note: After updating the value, you must click "Move" on screen or press Enter on the keyboard)

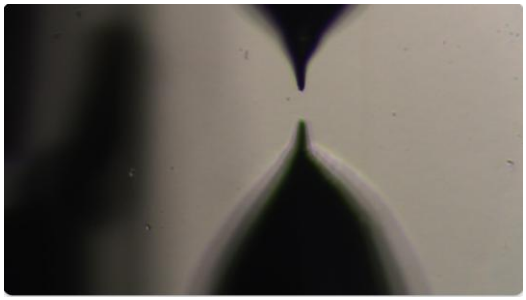
d) Repeatedly update the **Pipette Height** value (remembering to click "Move" or press Enter) until the pipette is ~ 2-3mm from the surface of the sample (again, this is confirmed visually by looking directly at the pipette, NOT the PC screen)

e) Now the pipette is ~2-3mm from the sample… a typical **Pipette Height** value on screen is ~20mm – 30mm for a thin sample (e.g. silicon wafer)

f) Use the physical zoom knob on the camera to zoom in to level 1, or 2 or 3 (as high as you can… ultimately we want to be at 3)

g) Use the camera view on the PC screen to increment the tip down even closer. Use very small values (0.01mm increments can be made using the arrow key, followed by the Enter key; this is SLOW… but SAFE). Iteratively increase zoom as you can until you get to zoom 3.

h) At zoom level 3, you want to increment the **Pipette Height** until the pipette tip is ~ 1 finger width (or 1-1.5cm) from its reflection on the sample surface <u>AS VIEWED ON THE PC SCREEN</u>. See image below:



i) The tip of the pipette is now ~100 – 150um from the sample surface

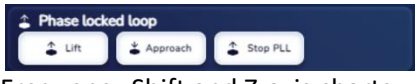
j) Click "Finish Initialization"

9 - <u>Fine Approach & Test Print</u>

a) At this point all hardware is initialized and your tip should be ~100 – 150um from the sample surface

b) You may opt to close the glass door on the front of the Hummink (this reduces dust on your sample)

c) Before starting your actual print, it is recommended you manually perform a test print:

i. Click "Approach" under the Phase locked loop section: 

ii. Immediately click "Clear Charts" to clear the data on the Frequency Shift and Z-axis charts.

(Note: If the chart data is not well centered vertically, you can press Recenter, but this MUST be done prior to the pipette touching the surface. DO NOT recenter after contact is made!)

iii. Watch the Z-axis chart as the pipette approaches… the value will decrease (negative slope) as the piezo controller brings the pipette closer to the surface. The value will bottom out at some point when the ink droplet at the end of the pipette contacts the sample:

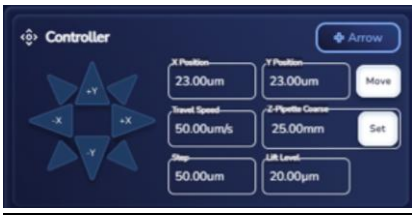
iv. The piezo z-height controller is now maintaining steady contact using the phase locked loop.

NOTE: Ideally the piezo z-axis value will be in the middle of its range of motion (~125um, which is half of 250um). If extremely far from 125um (e.g. <50um or >200um), lift the pipette (click the "Lift" button on the Phase locked loop section a few times then click Stop PLL)… then use the Controller section to adjust pipette height accordingly (10um at a time). Return to step **c)i** above.

v. You can now set the **Travel Speed**, **Step** and **Lift Level** in the Controller section:

(For precision printing set Travel Speed to: 50 – 150um/s)

(Typical Lift Level: 20 – 50um; ensure this accounts for non-planarity of your sample!)

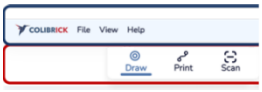


vi. Take care when entering Controller values! Make sure units are **um** (recommended).

vii. Perform a test print by moving the stage with the pipette in contact. Pressing an X or Y arrow button in the Controller section will move the stage 1 **Step** value (user defined). Pressing a diagonal direction will move the stage 1 Step in X and 1 step in Y simultaneously, to form a diagonal line of length $L = (Step^2 + Step^2)^{1/2}$

viii. After confirming the pipette is printing, click "Lift" in the Phase locked loop section to lift pipette from the surface. You can now proceed to **10** -**Draw Mode**.

10 -Draw Mode

a) Click “Draw” in the Menu at the top of the UI: 

b) Draw your pattern using built-in shapes by clicking the “Shape” button -OR- import your own .SVG file.

c) Select the appropriate pipette size and spreading factor:

d) Select Filling options (Spiral is typically used)

e) Click “Convert to print”; this creates a .GCODE file and switches the software to the Print screen.

f) Begin your print by clicking: ▶ **Print**

g) The pipette will be automatically lowered to contact and the Phase locked loop process will take control to maintain pipette z-height. Your print will begin.

h) You can visually confirm that objects are filling properly (i.e. you input an appropriate Spreading Factor).

i) If you need to STOP your print to correct your spreading factor,

- press STOP

  NOTE: Pressing STOP ends your print, you cannot continue where you left off.

- Click “Draw” and go back to step c) above.

j) Wait for your print to finish

k) You can move to a new location and print more if desired (taking care to lift the pipette before moving!)

l) When finished with all your prints, proceed to **11** -**Removing your sample**

11 -Removing your sample

a) Ensure pipette is lifted from surface (click “Lift” if needed)

b) Click “Stop PLL” under Phase Locked Loop; this stops the phase locked loop height control

c) Set Z-Pipette Coarse to a large value (e.g. 49mm) to raise the pipette far away from your sample

d) Remove your sample, taking care to NOT touch the pipette.

e) If desired, another sample can be loaded → return to step **8** -**Pipette Coarse Approach**; if no other sample will be printed, proceed to **12** -**Shutdown**

12 -Shutdown

a) At this point you have completed your final print and removed your sample

b) Make sure the Z-Pipette Coarse value is set to 49mm

c) Remove your pipette (this can be done with tweezers; be careful of the sharp pipette tip!) → dispose of the pipette in the sharps container.

d) Click File → Close to shutdown the Colibri software.

e) Shutdown the PC… wait 15 seconds → Turn OFF the power to the Hummink by pressing the physical power button on the front panel.

f) Close the Hummink glass door if still open.

g) FINISH your reservation in the Kiosk section of the iLab website.

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