Fluid Management and Pressure Control System

The Rister-Toolchanger platform incorporates a fluid management system to ensure precise and reliable aspiration and dispensing of liquids (e.g., $FASnI_3$ ink, Al_2O_3 sol-gel ink, and UV-cured resin) through the wick holder. This system addresses the non-obvious challenge of maintaining stable pressure at the pipette tip, which is critical for preventing dripping, air bubbles, inconsistent dispensing, and meniscus instability.

This is diagrammed in Figure 1 to 3 are illustrations showing the components of the fluidic management system. Figure 1 is a simplified graphic that shows one syringe pump set up, whereas Figure 2 shows a multichannel syringe pump (4 in this drawing) set up where each syringe is connected to a 3-way valve through tubing. Figure 3 is the back side view of the instrument that shows the tool connected to four pipettes and also shown is a wash and waste collection station which is used for priming the tubing for accurate liquid handling (aspiration and dispense).

The loading module loads pipettes before aspirating which is diagrammed in Figure 4. During the sample loading process,, the material is aspirated into the pipette using the syringe pump. After sample aspiration, the pipettes (dispensers) are loaded. During the nanoarray fabrication process the material is dispensed through the dispensers. After fabrication, the pipette tip assembly is removed.

System Components:

- Pressure Compensation Reservoir: A vessel equipped with a liquid level sensor maintains a consistent fluid supply. When the sensor detects a drop below the set point, a peristaltic pump automatically refills the reservoir from a water bottle, ensuring a stable liquid level.
- Fluid Dispensing Operation: A stepper motor-driven syringe pump connected to a servo-controlled 3-way valve controls fluid movement:
    - Input Position: The servo directs the valve to the pressure compensation vessel, where the syringe pump aspirates fluid into the syringe.
    - Output Position: The servo switches the valve to direct fluid from the syringe through the pipette for dispensing.
    - Pipette Position: The servo directs the valve to the pipette, allowing the syringe pump to aspirate small volumes (1-10 µL, adjustable to sub-nL via multiple cycles) from sample sources (e.g., Eppendorf tubes or 96-well plates) at a controlled flow rate (e.g., 1 µL/s), with the syringe pump also capable of dispensing in this position.
    - Bypass Position: The valve seals the system, maintaining consistent pressure at the tip to stabilize the liquid column.
- Automated Cleaning System: When the pipette is positioned over a wash basin, the system performs automated cleaning:
    - The syringe pump pushes cleaning fluid (e.g., IPA) through the internal channels.

    - A separate peristaltic pump provides external washing of the pipette exterior.
    - A third peristaltic pump removes waste fluid to a waste bottle, creating a closed-loop system.

Importance of Pressure Control: Stable pressure prevents common issues:

- Dripping: Low pressure causes uncontrolled liquid loss and contamination.
- Air Bubbles: Pressure fluctuations introduce air, disrupting volume accuracy.
- Inconsistent Dispensing: Variable pressure leads to unpredictable droplet formation.
- Meniscus Instability: Unstable liquid surfaces impair precise volume delivery. The bypass position of the 3-way valve creates a sealed, pressure-regulated environment, ensuring repeatable dispensing critical for sub-nanoliter accuracy in wick-based doctor blading applications.

Graphic Inclusion: A visual representation of this fluid management system is provided in Figure 1, illustrating the pressure compensation reservoir, 3-way valve positions, syringe pump, and automated cleaning components.

Figure 1

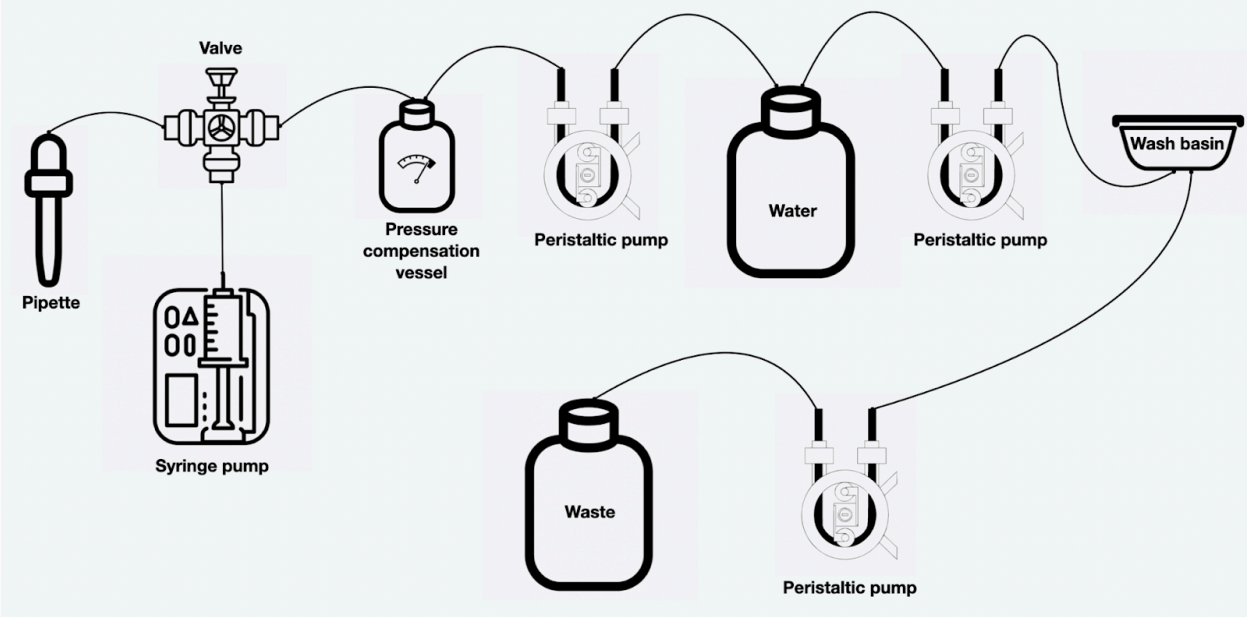

Figure 2

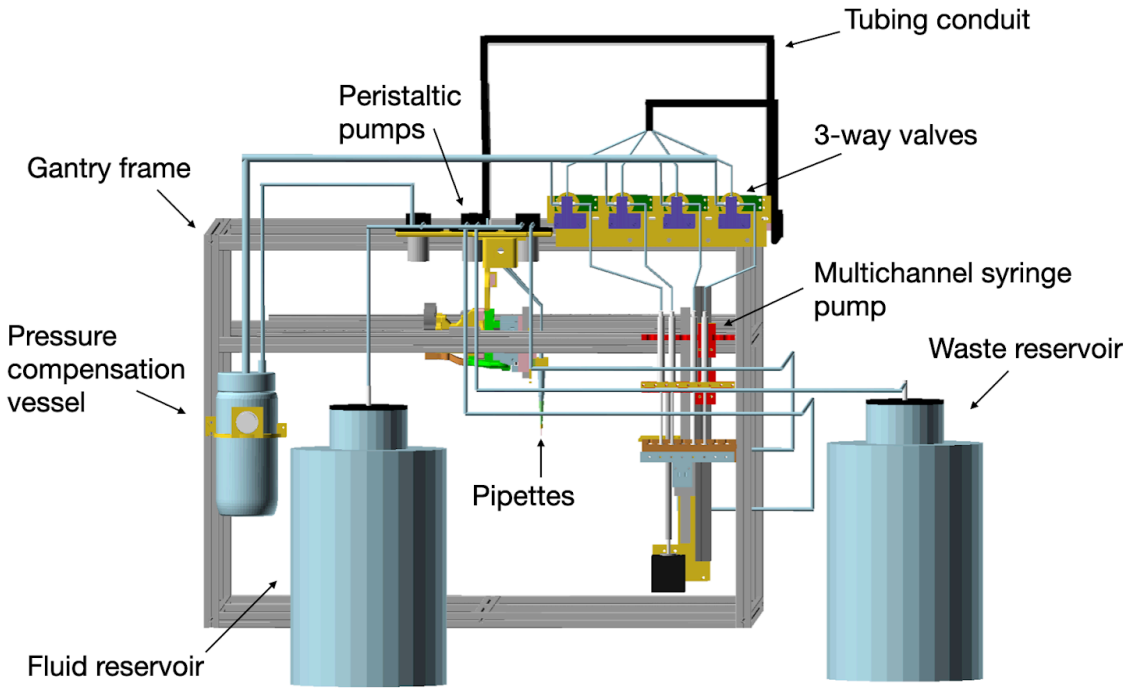

Figure 3

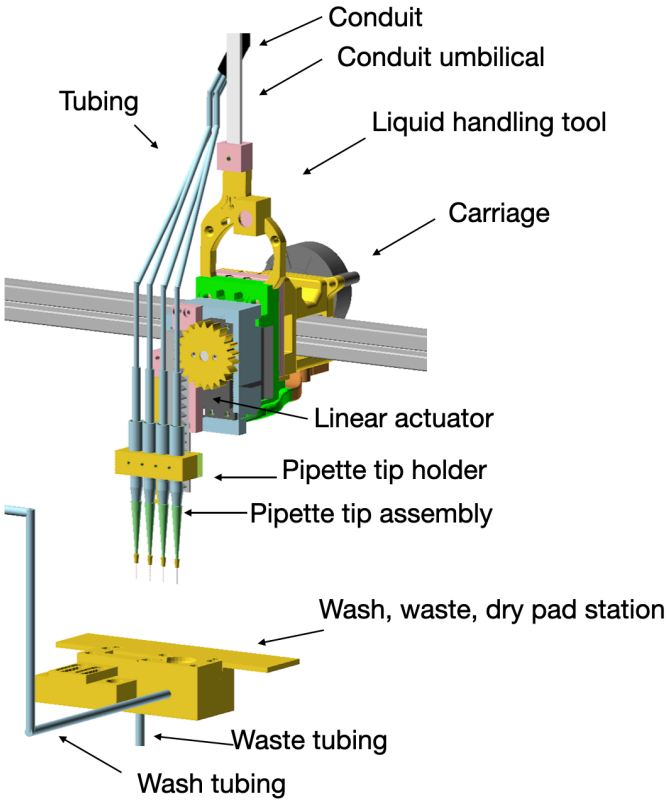

Figure 4