A GUIDE TO CONVERGING NOZZLES

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Enschede

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2 INTRODUCTION

The converging nozzle is a type of nozzle that has a converging etched channel designed to produce liquid sheets that can be used for liquid phase studies that use X-ray spectroscopy, high-power optical lasers or electron scattering. By creating a thin sheet of liquid, it's possible to better understand the behavior and properties of the liquid at a molecular level.

Liquid sheets provide a free-standing medium that is constantly replaced in a consistent and customizable form giving highly reproducible results without the possibility of accumulated sample or container degradation.

"Converging nozzles operate in a manner similar to the more commonly used colliding jet nozzles.1,8 14 Both rely on a transfer of momentum transverse to the direction of the jet travel to generate a pressure gradient that spreads out the liquid into a sheet… . The momentum generated by the liquid flow within the converging channel results in a transfer of momentum flux to a plane perpendicular to the flow of the channel. Ultimately, surface tension causes the jet to collapse and again, this inward momentum flux generates another sheet orthogonal to the first. This can continue on as a "chain" of sheets until breakup." *[1] C. J. Crissman, M. Mo, Z. Chen, J. Yang, D. A. Huyke, S. H. Glenzer, K. Ledbetter, J. P. F. Nunes, M. L. Ng, H. Wang, X. Shen, X. Wang and D. P. DePonte, "Sub-micron thick liquid sheets produced by isotropically etched glass nozzles," The Royal Society of Chemistry, no. 22, pp. 1365-1373, 2022.*

Micronit's converging nozzle forms a sheet orthogonal to the plane of the chip which can be tunable – width and thickness can be changed by changing the applied flow rate.

Figure 1 Converging nozzle Micro 2

3 RECOMMENDED EXPERIMENTAL SETUP

We recommend using the following experimental setup:

- Chip holder (Neptune Fluid Flow Systems LLC)
- Super Flangeless™ Nut, 6-32 Flat-Bottom, for 1/16" OD (IDEX Part Number: M-660)
- Peek ferrule 1/16" (can be found on Micronit's webstore)
- Clamping fixture (included with chip holder)
- O-rings (included with chip holder)
- 1/16" OD ETFE tubing (can be found on Micronit's webstore)
- Converging nozzle chip
- Digital USB microscope or optical microscope
- Microscope holder or stand
- HPLC pump or other pump that can withstand high pressures (at least up to 50 -100 bar) and/or can provide highly accurate and precise flow rates
- DI water or solution to be analyzed
- Clean workspace
- Tweezers or a suitable tool for handling O-rings and the chip
- Safety gloves (if necessary)

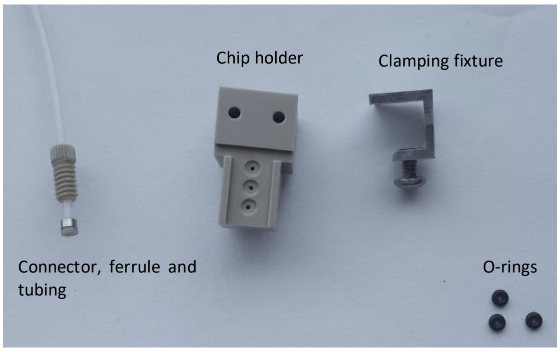


Figure 2 Chip holder, clamp fixture, ferrules, tubing and connectors

<u>Procedure:</u>

1. Prepare the workspace: Ensure that your workspace is clean and free from any dust or debris that may contaminate the chip or O-rings. If necessary, wipe the surface with a lint-free cloth and an appropriate cleaning agent.
2. Place the O-rings on the chip holder: Using clean and dry tweezers or a suitable tool, carefully pick up an O-ring and position it onto the designated recess on the chip holder. Gently press the O-ring into place, ensuring it sits securely in the recess.
3. Repeat step 3 and place the other two O-rings on the holder to make sure that the chip will be levelled and kept in the correct place.

Figure 3 Chip holder with ferrules

4. Place the chip on top of the O-rings: Using clean and dry tweezers or a suitable tool, carefully pick up the chip, aligning it with the O-rings on the chip holder. Slowly lower the chip onto the O-rings, ensuring that the inlet hole of the chip aligns properly with the O-ring.

Figure 4 Chip holder with ferrules and chip

5. Clamp the chip: carefully position the clamping fixture over the chip to apply gentle and even pressure. Fasten the screw to eensure that the clamping force is sufficient to hold the chip securely in place without causing any damage.

Figure 5 Chip holder with clamping fixture

6. Verify proper alignment and sealing: Inspect the chip holder to confirm that the chip is securely clamped and aligned with the O-rings. Check that the O-rings form a proper seal and there are no visible gaps or misalignments.
7. Insert the 1/16" OD tubing in the connector and ferrules and connect it to one of the outlets in the chip holder

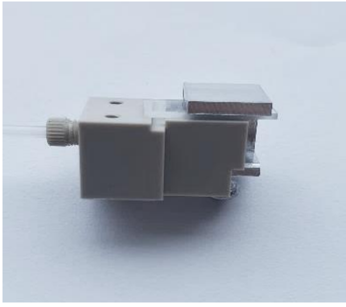


Figure 6 Chip holderwith connector and 1/16" tubing

8. Connect the other end of the tubing to the pump.
9. In case you are using an USB microscope, place it on the holder and adjust the height and position to ensure that sheet generated by the converging nozzle is captured.
10. Connect the USB microscope to the computer and start recording.
11. Turn on the HPLC pump (or other) and make sure that the selected solution will be dispensed by the pump
12. Select the desired pressure/flow rate to be tested and start the experiment

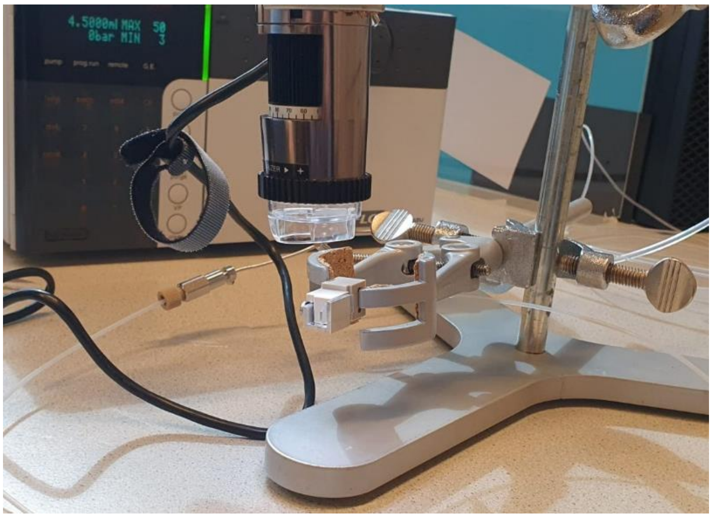


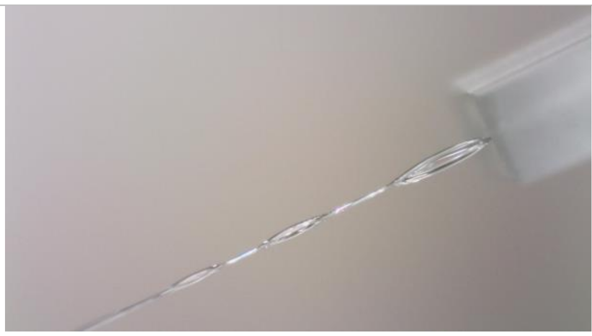
Figure 7 Experimental setup

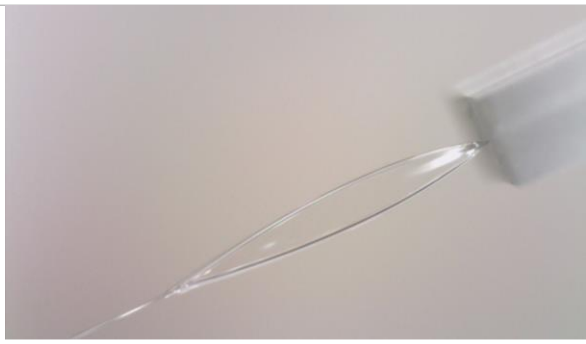
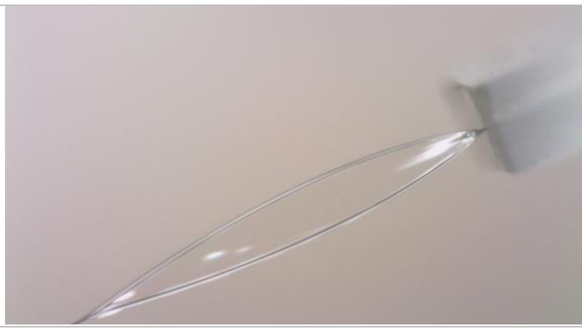
4 RECOMMENDED PRESSURE RANGE

In the table below it is possible to observe the sheet formed by the converging nozzle Micro 2N (orthogonal to the plane of the chip) and how the flow rate can influence the width and length of the sheet.

The experiments were conducted using DI water as the reagent, and an HPLC pump was employed for the fluid delivery.

The recommended pressure range for sheet formation is between 13 bar and 23 bar. Higher pressures up to 100 bar can be tested without breakage of the chip; however it is important to note that once we reached pressures above 25 bar, leaks began to occur, possibly due to limitations in the setup/chip holder and clamp fixture.

Flow rate (mL/min)	Pressure (bar)	Sheet formed
1	4	
1.5	6	
2	9	

2.5	11	
3	13	
3.5	18	
4	21	
4.5	23	

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