

# 3D-Printed, Internally Fed Electro spray Thrusters for Cubesats



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## Introduction

Electrospray propulsion is achieved by electrohydrodynamically ejecting the propellant. It is attractive for small satellites due to its high specific impulse and potential for miniaturization. However, most electro spray thrusters are fabricated in a semiconductor cleanroom, which is very expensive and time-consuming, and not compatible with in-space manufacturing. This research focuses on an alternative approach, using 3D-printing to fabricate internally fed electro spray emitters array. The main challenge is to create microfluidic channels that can uniformly distribute the propellant to the emitters array, despite the possibility of a nonuniform electric field on emitters because electro spray only works within a specific flow rate range. To address this issue, the microfluidic channel design was optimized for uniform flow distribution using high hydraulic resistance to withstand dynamic outlet conditions, considering the limitations in 3D-printing. Additionally, the photopolymer resin used for 3D-printing was modified to create small internal channels.

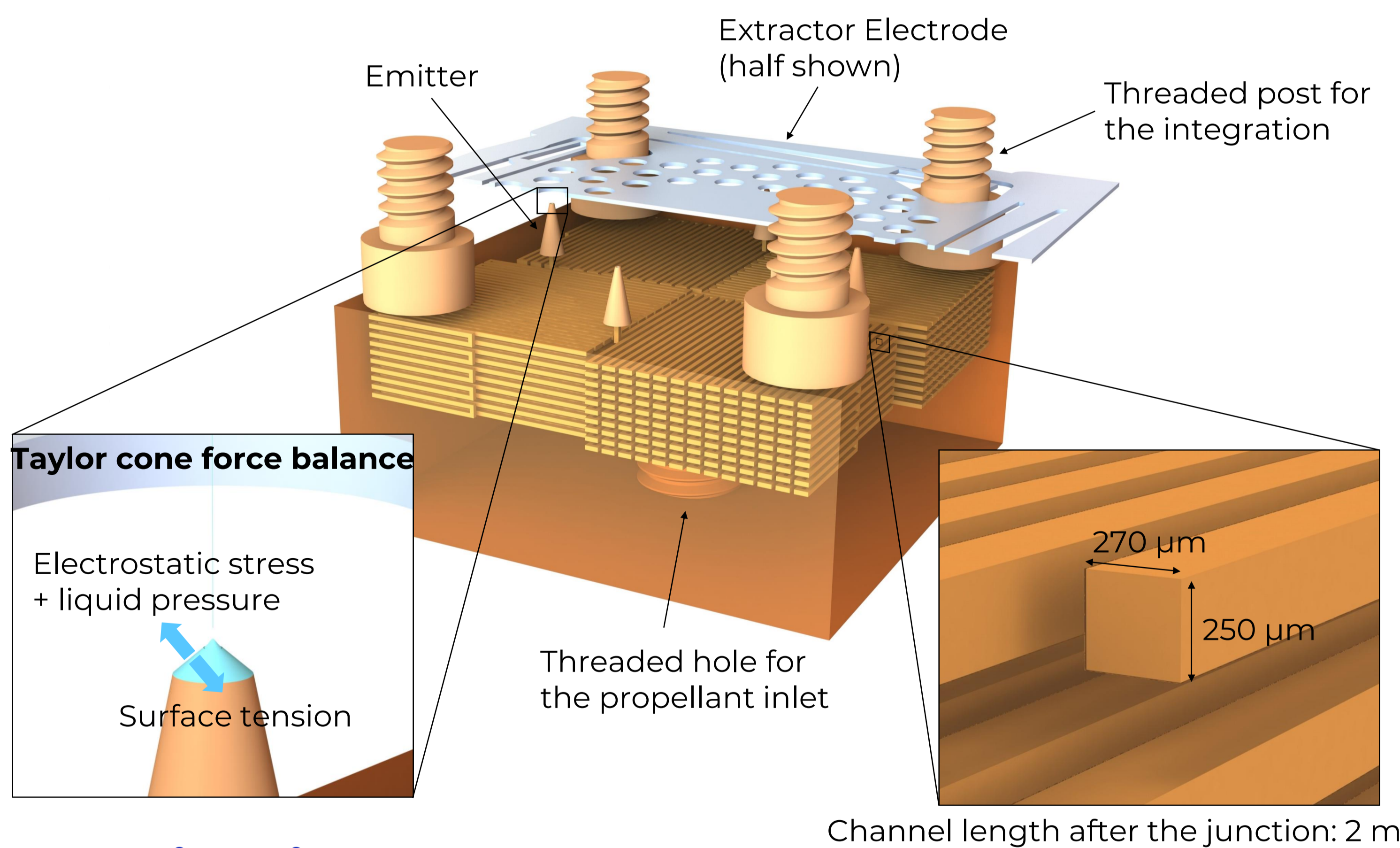
## Device Design

### Channel design optimization

Two sources of flow nonuniformity:

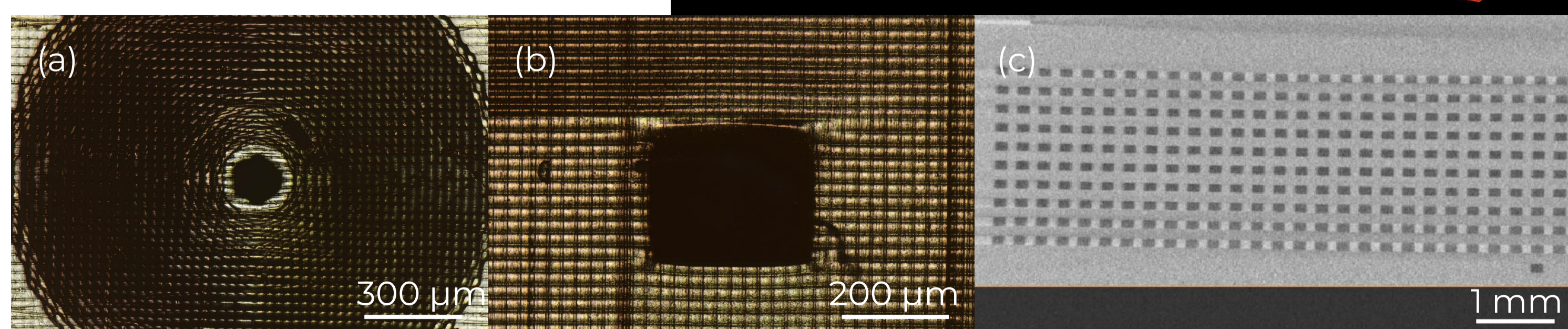
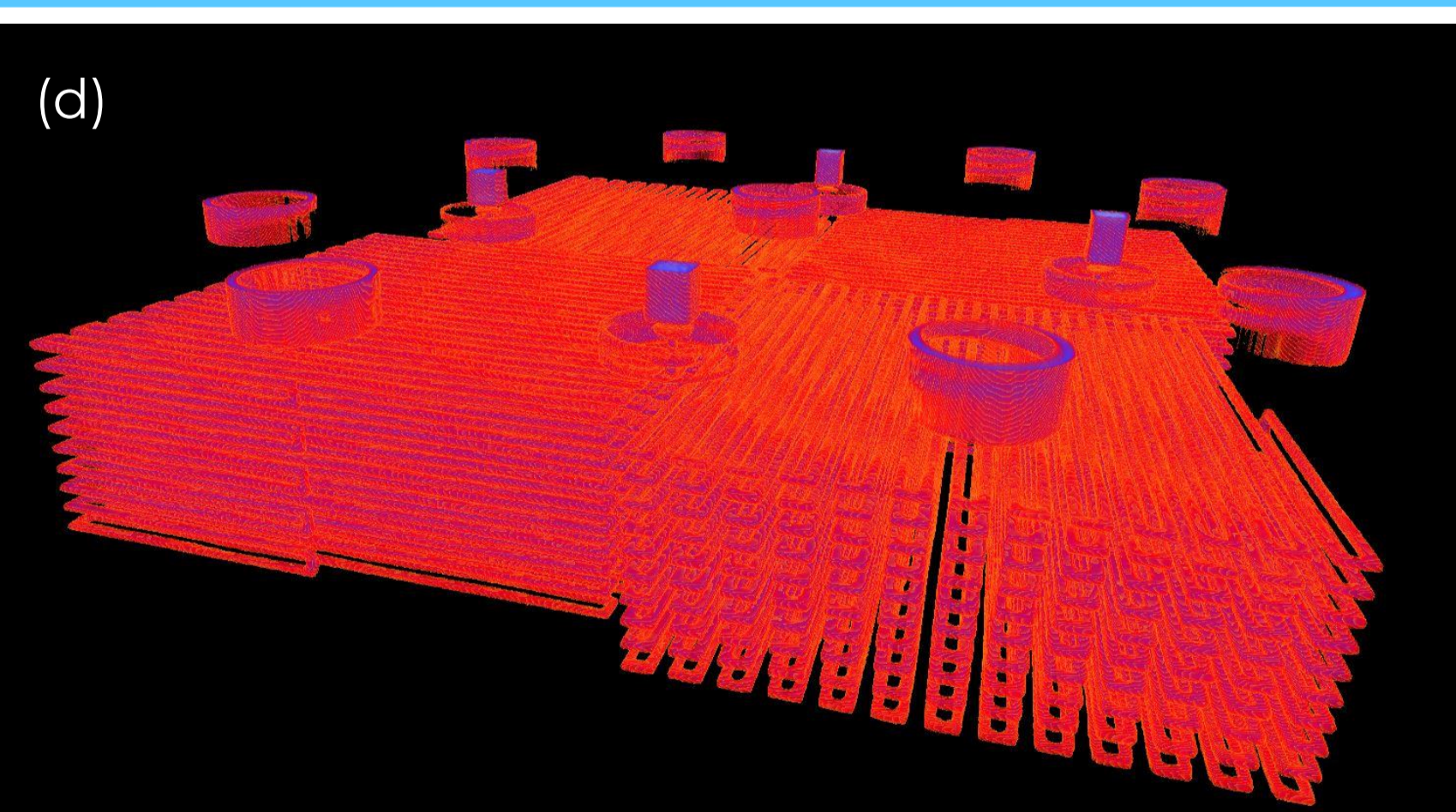
- Disturbances at outlets (e.g., nonuniform electric field)
- Differences in hydraulic resistance caused by fabrication errors

→ Optimized channel size exists as a function of a channel length with a longer channel exhibiting better uniformity



### Fabrication

- DLP printer resolution: 27 μm in XY and 25 μm in Z
- Photopolymer resin: Solus Proto + 0.5 wt% NPS\*
- Minimum channel height: Decreased from 600 μm to 270 μm by adding NPS

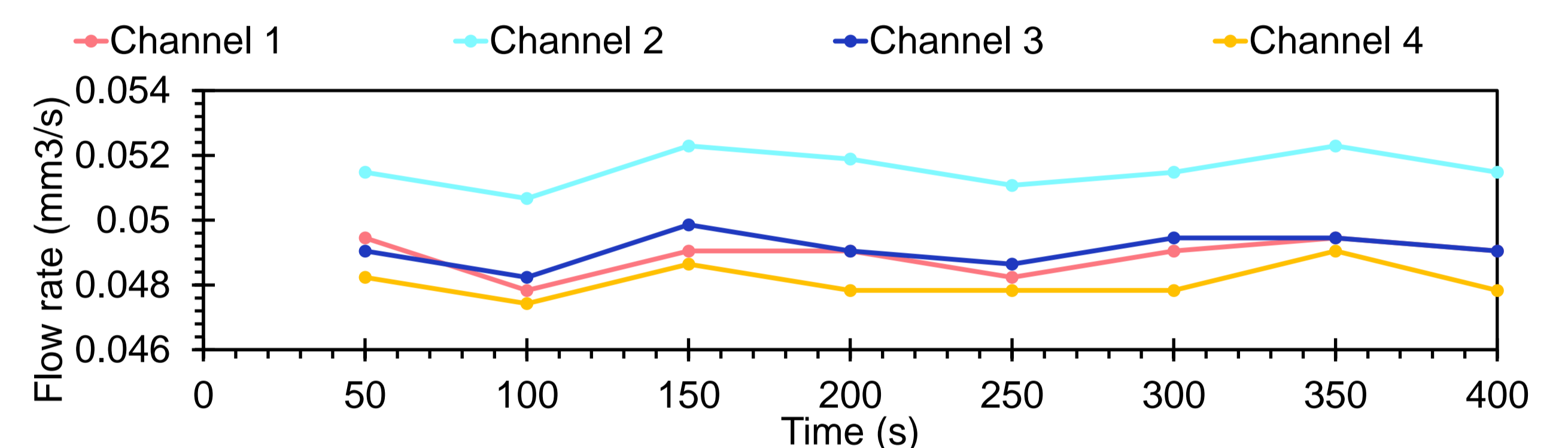


Images of the 3D-printed device: (a) Confocal microscope images of an emitter from the top, and (b) channel cross-section. (c) X-ray scan image of the device cross-section, and (d) a 3D model constructed from X-ray scan images.

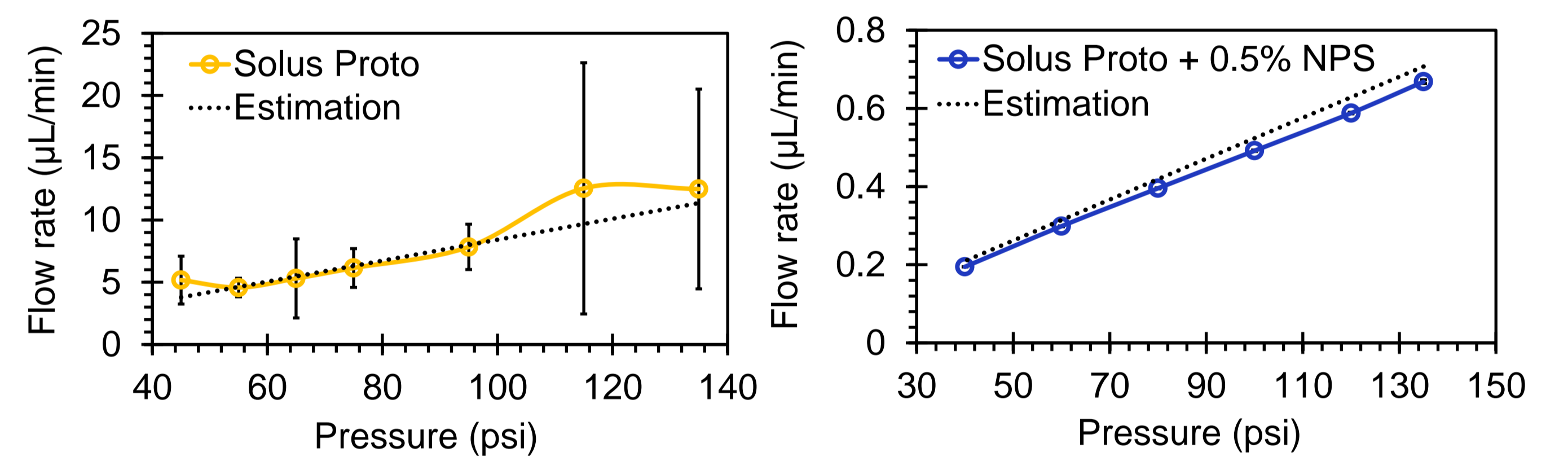
\* 2-nitrophenyl phenyl sulfide (photo absorber)

## Device Characterization

### Flow rate measurement

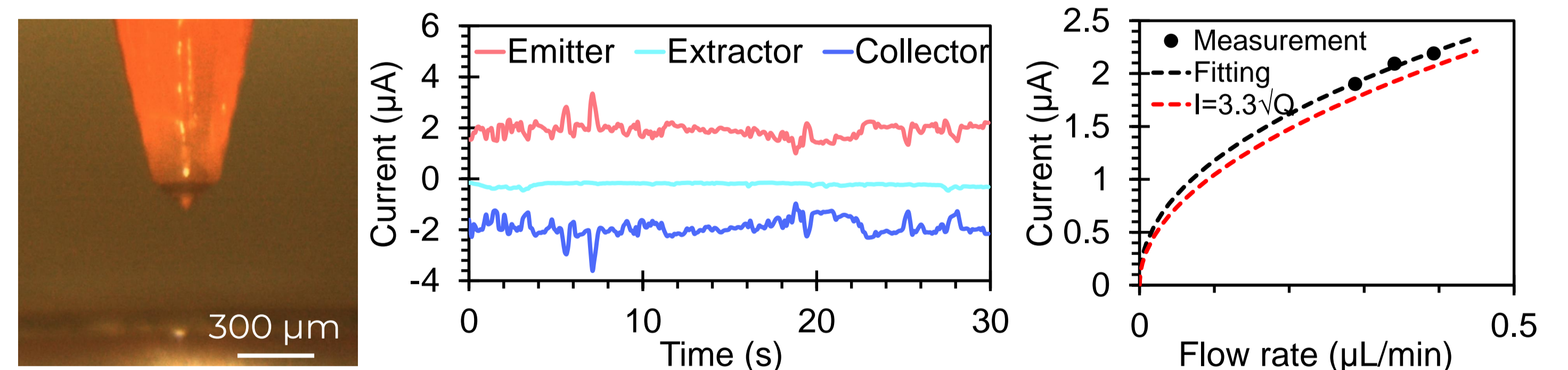


- Uniform flow rate measured for four channels (uncertainty:  $\pm 0.0008 \text{ mm}^3/\text{s}$ )



- Measured hydraulic resistance matched well to the estimation
- Variations in measurements reduced significantly for the device made with the resin modified by NPS

### Electrospray emission



- Stable emission observed visually and electrically
- The similarity of the fitting curve obtained here (black dotted line) and measurements from multiple sources (red dotted line) suggests changing the flow rate correctly controlled electro spray
- Thrust and specific impulse estimation:

Flow Rate	Thrust per Emitter	Specific Impulse
2.94 μL/min	31 μN	49 s
0.393 μL/min	9.40 μN	110 s
0.341 μL/min	8.47 μN	114 s
0.288 μL/min	7.50 μN	120 s

Further reading:

- D. V. Melo Maximo and L. F. Velásquez-García, "Additively Manufactured Electrohydrodynamic Ionic Liquid Pure-Ion Sources for Nanosatellite Propulsion," *Additive Manufacturing*, vol. 36, p. 101719, Dec. 2020.
- H. Kim and L. F. Velásquez-García, "3D-printed, internally fed, MEMS electro spray thrusters", in *2022 21st International Conference on Micro and Nanotechnology for Power Generation and Energy Conversion Applications (PowerMEMS)*, Salt Lake City, December 12-15, 2022, pp. 46-49.
- H. Kim and L. F. Velásquez-García, "3D-printed, internally fed, MEMS electro spray thruster with precise flow rate control for high-impulse Cubesat missions", in *2023 22nd International Conference on Solid-State Sensors, Actuators and Microsystems (Transducers)*, Kyoto, Japan, June 25-29, 2023.

- Future work is focused on increasing emitter density while maintaining the flow uniformity

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