Fabrication and experiments for a 25 W class porous electrospray array

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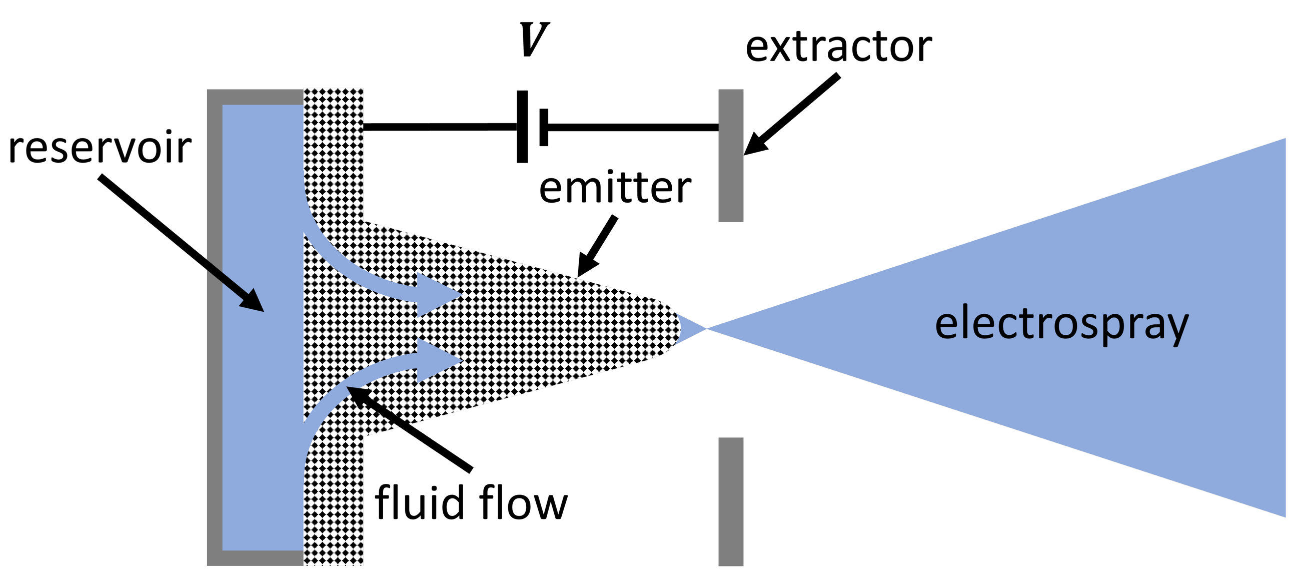
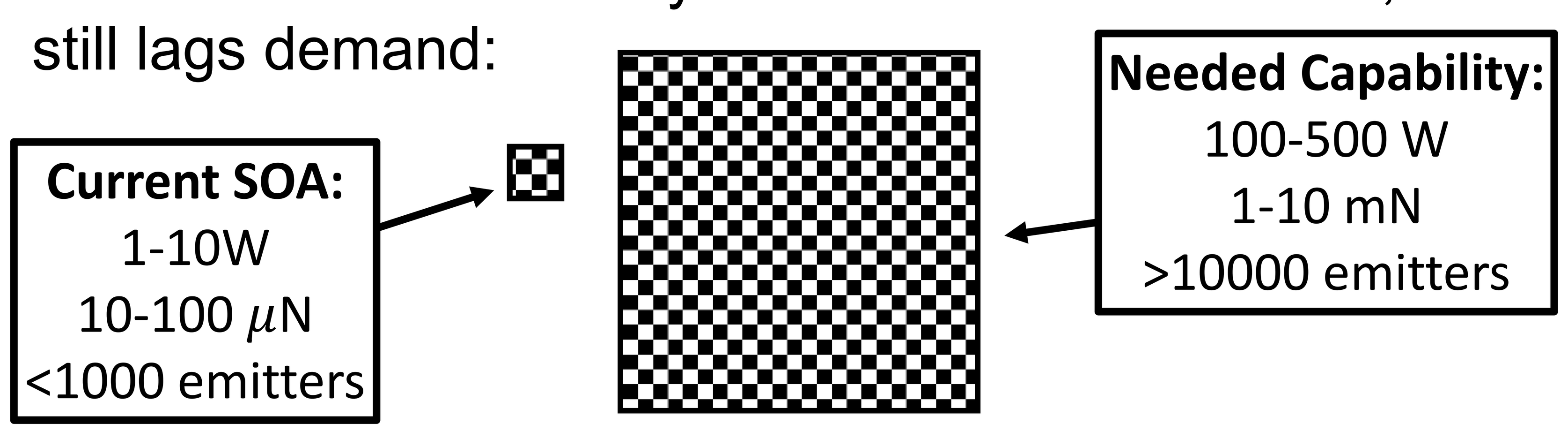
Motivation

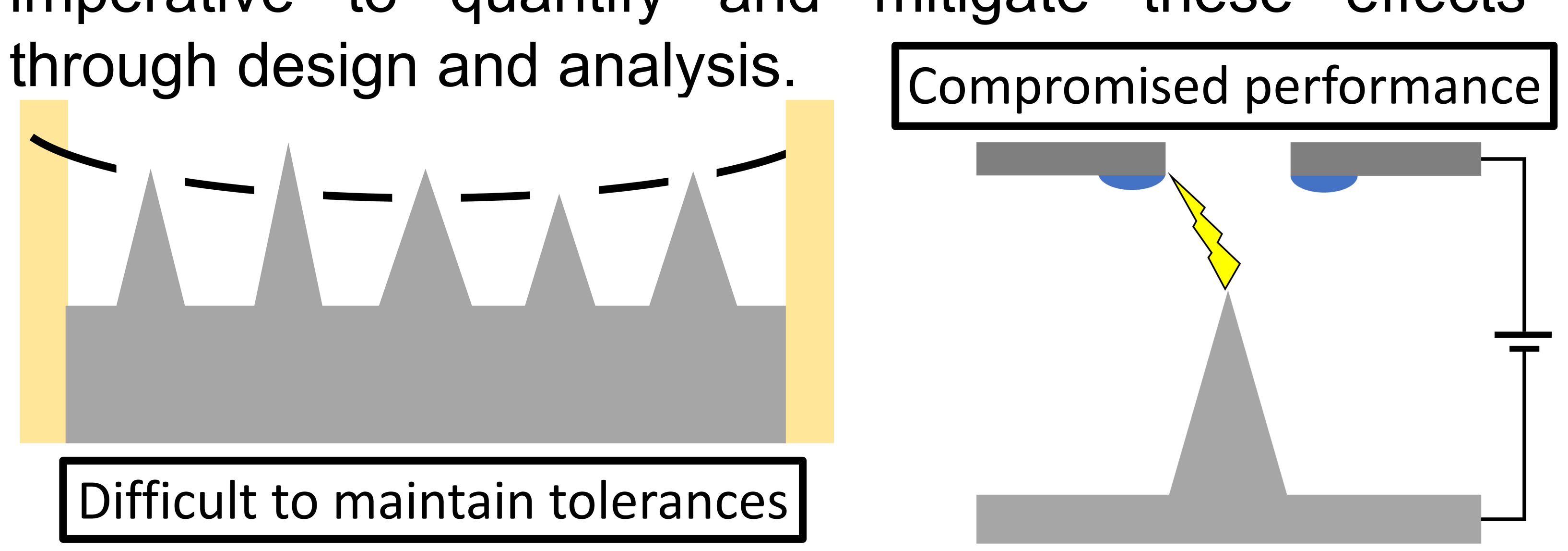
Electrosprays are electrohydrodynamic devices that emit energetic beams of charged particles by biasing a conductive fluid (e.g., an ionic liquid) to high voltage.



This technology is well poised for smallsat scale electric propulsion, where heritage EP systems (Hall & ion thrusters) suffer performance losses. However, individual emitters operate at the microscale, so many must be aggregated together to increase power. While SOA has achieved arrays of hundreds of emitters, this still lags demand:



Tolerances in geometry and alignment are more difficult to maintain at scale, which can have a negative effect on device performance, especially lifetime. It is imperative to quantify and mitigate these effects through design and analysis.

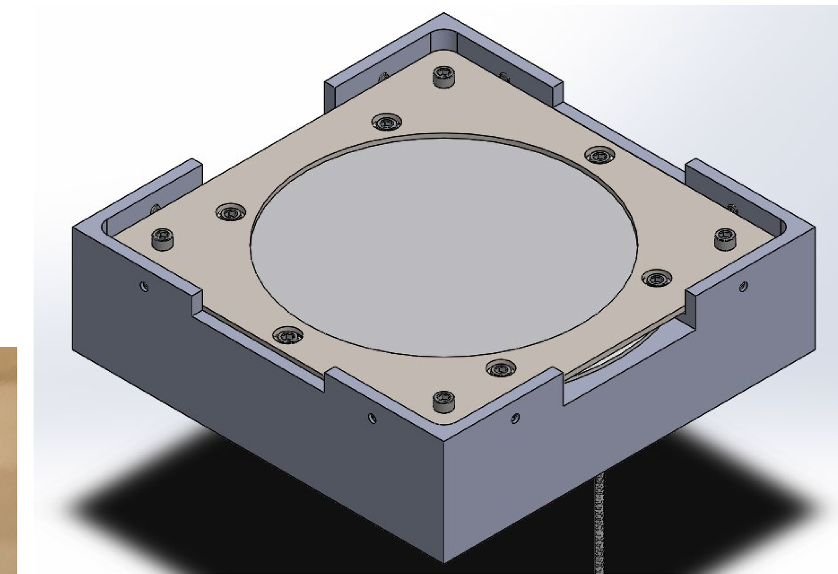


Objectives

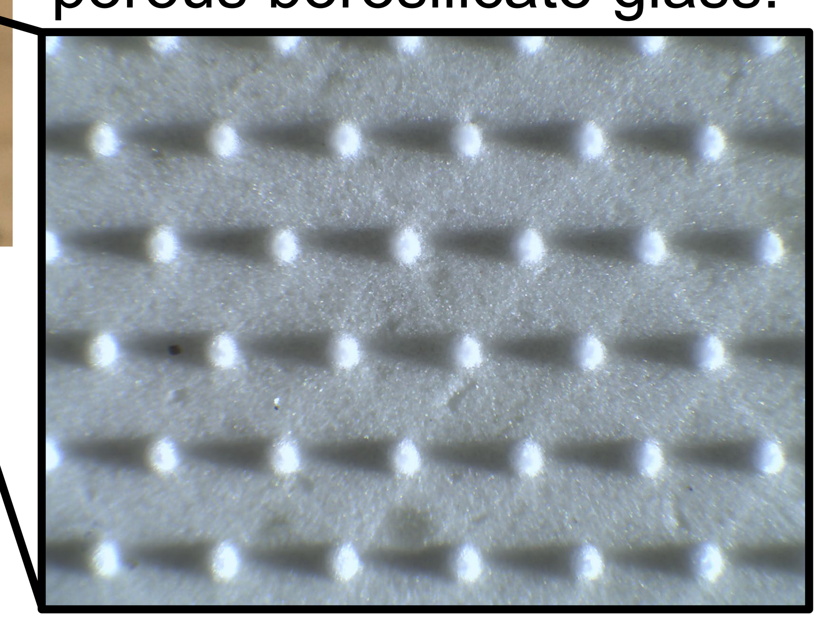
- Extend manufacturing methods to produce 25 W class thruster to test scalability of design
- Operate thruster to provide proof of concept and first insights

Fabrication

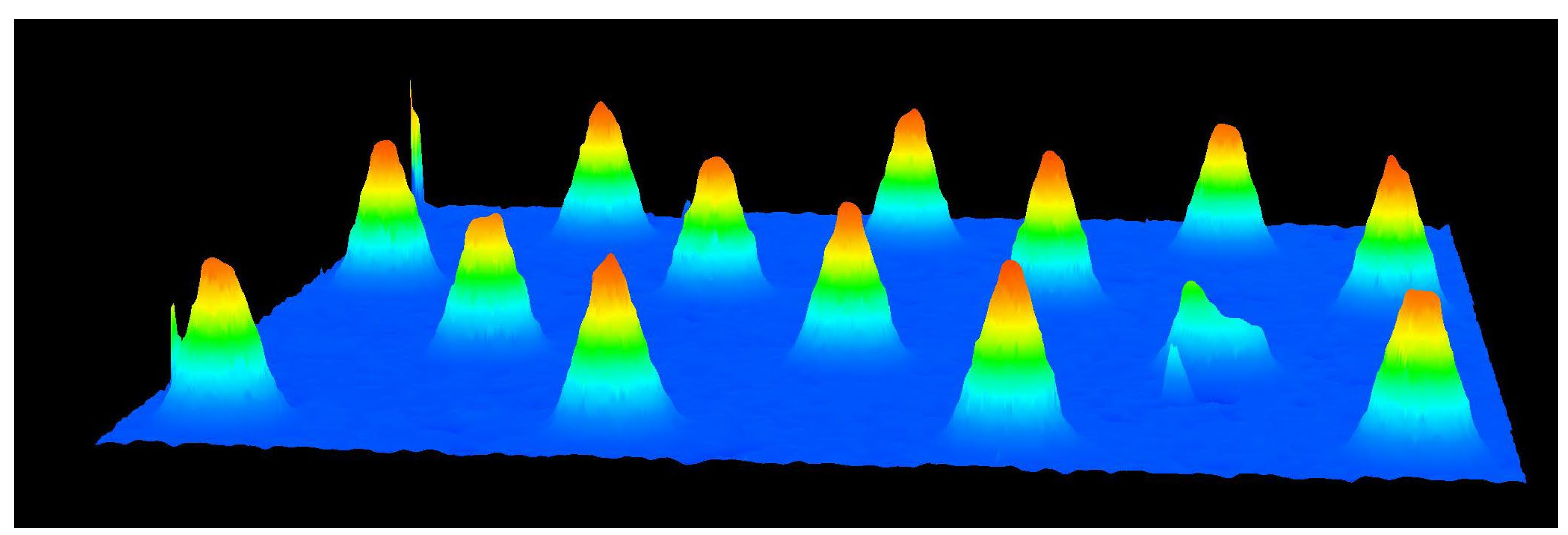
Taking heritage from the AFET-2 [1], we designed the MEAT-1, a 25 W class electrospray array thruster.



The centerpiece of the thruster is an emitter chip of 10,663 conical emitters micro-machined from porous borosilicate glass.



By improving this process, we've increased manufacturing throughput from <200 emitters/hour to >3000 emitters/hour.

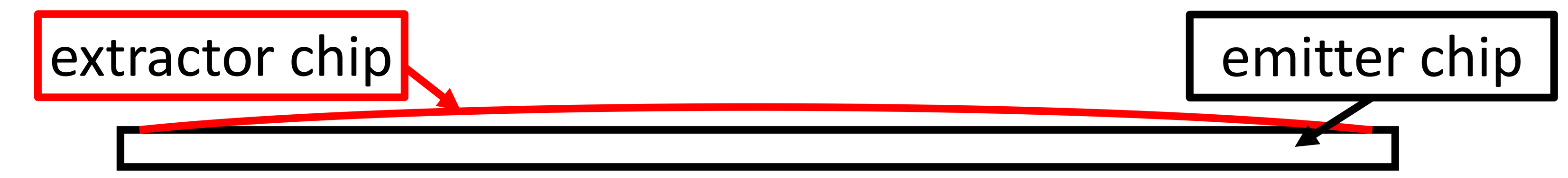


Through surface profilometry and geometric modeling, we can measure variability (tolerances) in the emitters.

	MEAT-1 sample*	AFET-2 nominal [1,2]
Emitter height	255±12 um	248-276 um
Emitter tip radius	17.9±5.2 um	10-20 um

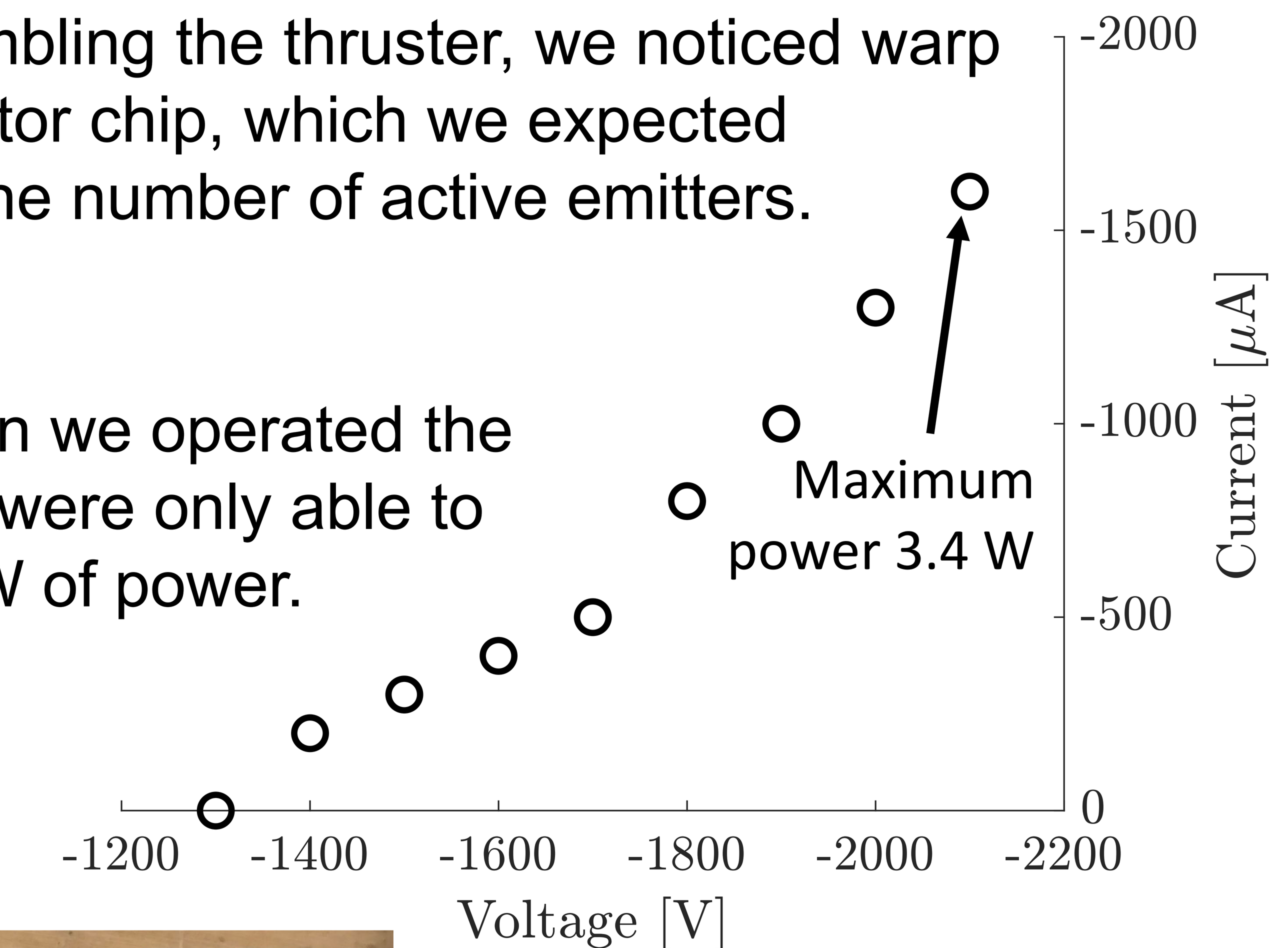
For this sample (excluding the broken emitter), we found that we were able to produce emitter geometries comparable to the nominal geometry of the AFET-2 [1].

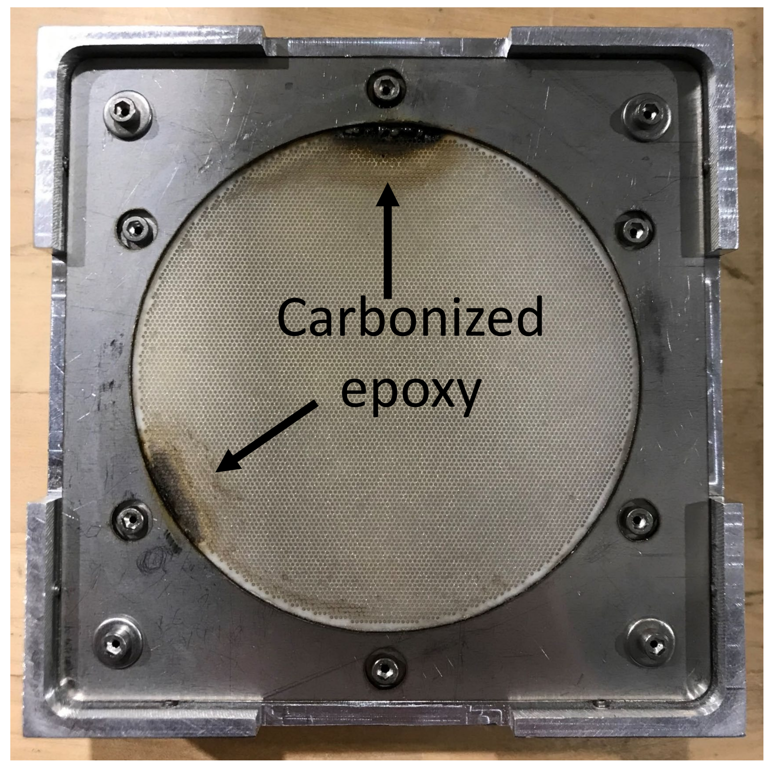
Experiments



When assembling the thruster, we noticed warp in the extractor chip, which we expected would limit the number of active emitters.

Indeed, when we operated the thruster, we were only able to extract 3.4 W of power.





Eventually, the thruster began to arc between its electrodes. This arcing was heavily localized to where we had applied conductive epoxy to repair a discontinuity in the electrode, suggesting it provided a short to the emitter chip.

Conclusions

- Extended manufacturing to make 25 W class emitter chip (>10,000 emitters) in 3 hours machine time
- Bow in extractor limited thruster to 3.4 W over throttle range, and conductive epoxy eventually caused arcs
- However, power still greater than that of AFET-2 system, suggesting viability
- Moving forward, will introduce support struts to mitigate bowing and improve connectivity to the chip

References & Acknowledgements

[1] Natisin *et al*, J. Micromech. Microeng. 30, 115021 (2020).

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