University of Colorado **Boulder**

MACLab

Thermal Bubble-Driven Micro-Pumps: The Building Blocks to Bring Microfluidics to the Masses

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PROJECT OBJECTIVES & GOALS

Microfluidics is poised to drastically transform healthcare by bringing miniaturized state-of-the-art medical laboratories (lab-on-a-chip) to regions previously lacking comprehensive healthcare infrastructure. However, development has been slow for two primary reasons[1]:

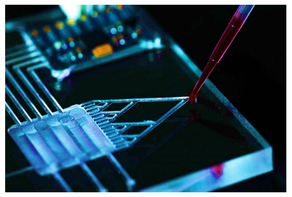
(1) Lack of integration infrastructure

(2) Lack of a scalable internal pump source.

Solution: Thermal Bubble-Driven Micro-Pumps

Aim 1:
Low-Cost, Rapid Fabrication

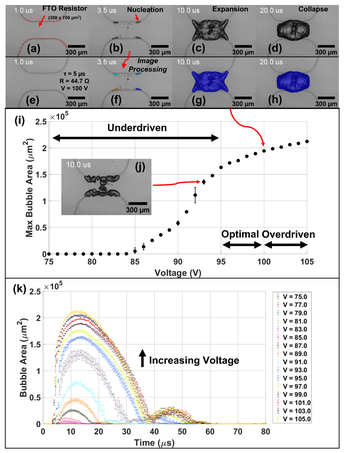
Aim 2:
Fluid & Bio Applications



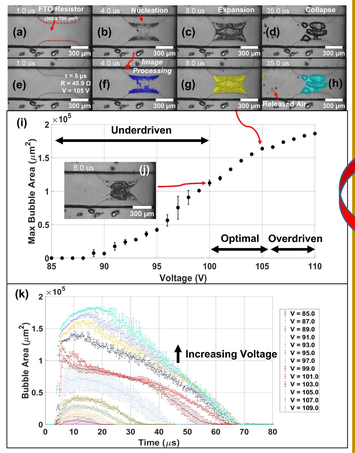
DATA & RESULTS. BUBBLE DYNAMICS

Bubble dynamics are dependent on the applied resistor firing conditions. Vapor bubbles should be fully developed for maximum net flow. As such, resistor firing settings were determined by varying the firing voltage. Imaged at **2 Mfps**.

Open Reservoir



Confined in a Channel

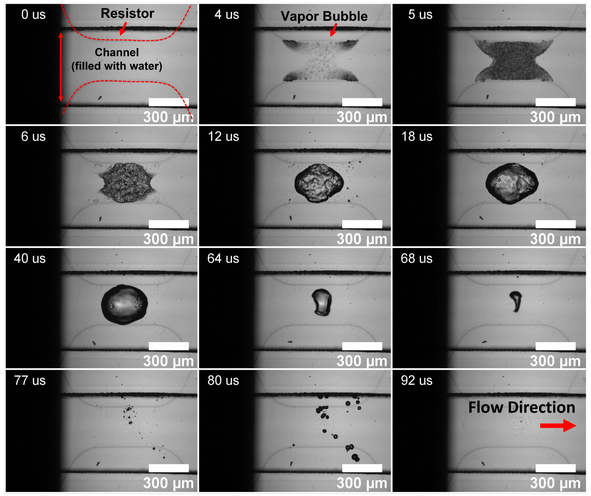


BACKGROUND

Thermal bubble-driven micro-pumps are high power, thin film thermal inkjet resistors (TIJ).

- Fluid heated to near its critical temperature (300 °C) in us's[2]
- Explosive nucleation creates a high pressure vapor bubble
- Vapor bubble expansion and collapse results in net fluid motion when placed asymmetrically in a channel[3]

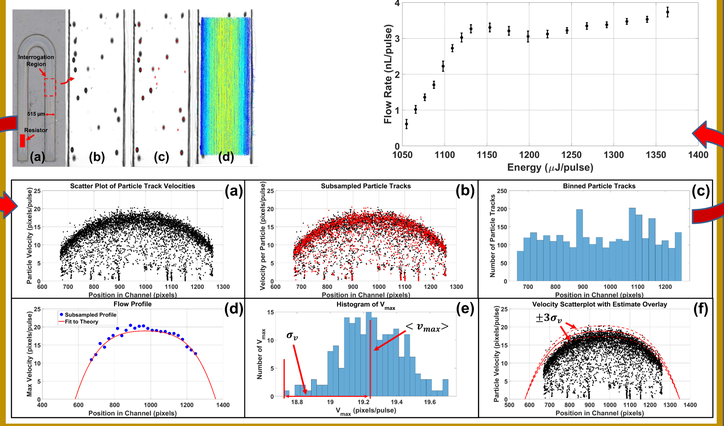
Conventional fabrication takes weeks/months[4]. Laser cutting **single material** thin films reduces lead time to hours/days.



DATA & RESULTS. FLOW RATE ANALYSIS

Particle tracking was used to measure the net flow rate, but particles are non-uniformly distributed so we cannot simply take the distribution average.

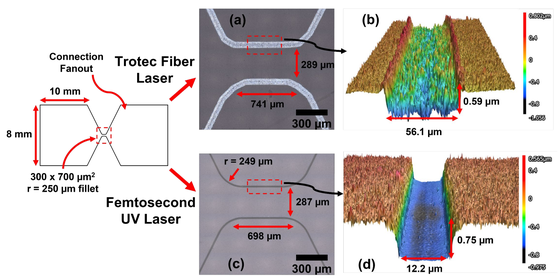
Solution: estimate the maximum velocity and use theory to map to the average velocity



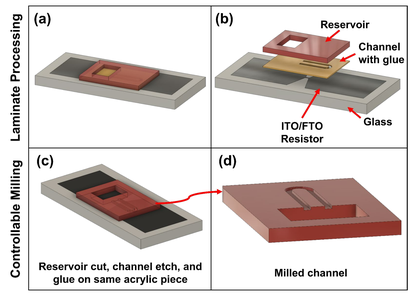
EXPERIMENTAL SETUP

Resistor + Microfluidics FAB

Laser Cutting of Resistors (ITO/FTO)

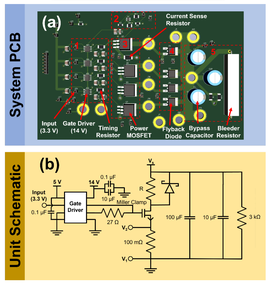


Cut/Etch of Microfluidics



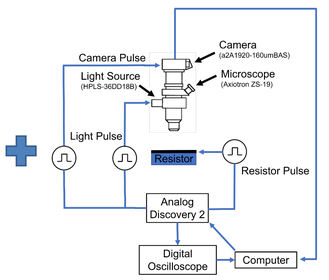
Driving Electronics + Imaging

High Power PCB



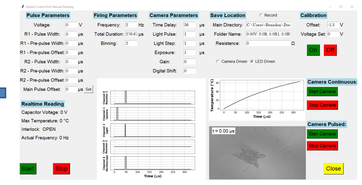
Pulse: 0-300 V, 0-5.6 A, > 200 ns

Stroboscopic Imaging



Max Frame Rate: 20 Mfps

Custom GUI Controller



CONCLUSIONS

- Fabrication time of TIJ resistors reduced from weeks/months to **hours/days**
- Low-cost **(< $6,000)**, custom, open-source control and imaging system developed
- Saturated flow rate of **3.34 nL/pulse** with a 300 x 700 μm² resistor in a 515 x 315 μm² channel of length 13.268 mm
- Laser ablation of thin films is a low-cost, rapid way to make these micro-pumps

FUTURE STUDIES

In future studies, fluid and biological applications (aim 2) of thermal bubble-driven micro-pumps will be investigated such as inertial focusing, cell sorting, and cell lysing.

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PUBLICATIONS

1. Hayes, B., Smith, L., Kabutz, H., Hayes, A., Jayaram, K., and MacCurdy, R. Rapid Fabrication of Low-Cost Thermal Bubble-Driven Micro-Pumps. *Micromachines*, 2022 (submitted August 2022)

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3. A. Govyadinov, et al. Single-pulse dynamics and flow rates of inertial micropumps, *Microfluidics and Nanofluidics*, 2016
4. L. Y. Hsieh, et al. A throughput management system for semiconductor wafer fabrication facilities: Design, systems and implementation. *Processes,* 2018