Characterization of Droplet Injection Process of a Microinjector

F.-G. Tseng, C.-J. Kim and C.-M. Ho

Mechanical and Aerospace Engineering Department
University of California, Los Angeles

C. Shih
Mechanical Engineering Department
FAMU-FSU College of Engineering
Florida A&M University and Florida State University

This Work is Partially Supported by the Office of Naval Research

Outline

- MEMS/Micro-injector System
- Design Issues
- Virtue Chamber Neck Concept
- Droplet Characterization
  - **Visualization, PIV and PDPA**
- Summary

Micro-Electro-Mechanical Systems

- Mechanical/Electrical Devices made by microfabrication techniques
- Miniature in Size (< 1mm)
- Readily Integrable with electronic control system
- Can be massively produced using batch process to lower per unit cost
- Successful examples
  - Air-bag release sensor
  - Inkjet printer

Applications of a Micro-Droplet Injector

- Inkjet Printing
  - Large array
  - High frequency response
  - High spatial resolution
  - High droplet quality

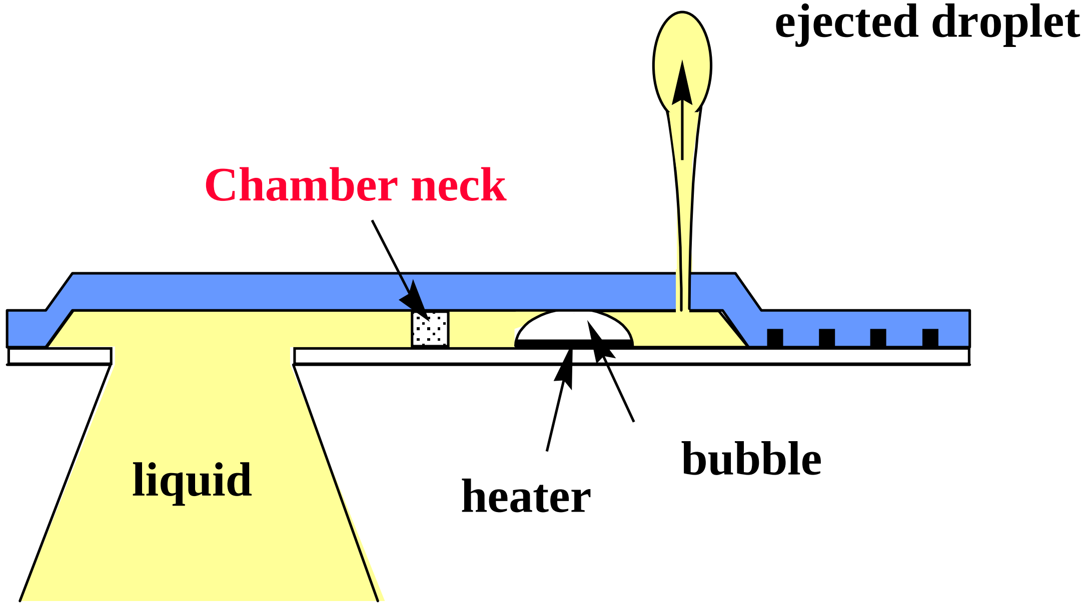
- Micro Drug Delivery Device
  - Precise dosage control
  - Integrated with MEMS
  - Local treatment

- Distributed Micro-injector Array
  - Inject micro fuel droplets
  - Reduce evaporation time
  - Improve fine scale mixing
  - Spatial & temporal perturbations
  - Modify large scale vortices

→ Mixing enhancement

→ Efficient combustion

Operational Principle of a Thermal Bubble Injector



- Electric current pulse vaporizes liquid to form bubble
- Bubble functions as a pump ejecting droplets
- Bubble collapses and chamber is refilled by capillary force

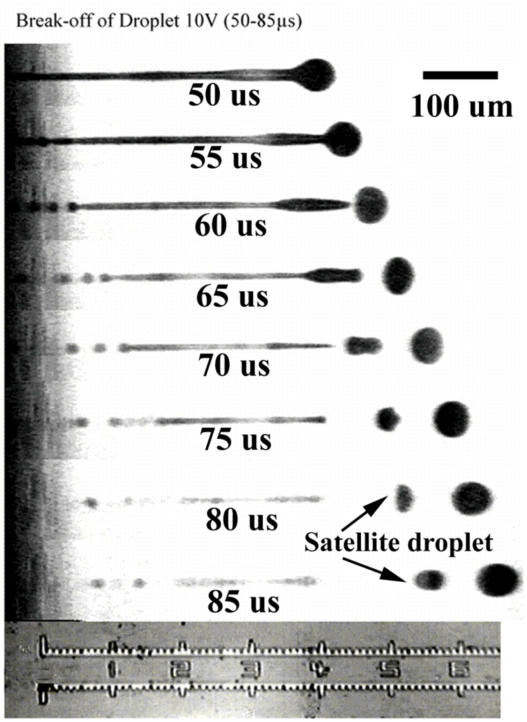
Design Issues of a Thermal Bubble Injector

- Frequency response is restricted by the presence of chamber neck
- Heat loss to substrate
- Cross talk and overflow
- Satellite droplet formation
- Ink Puddle formation
- Multi-layer packaging is required

Satellite Droplets

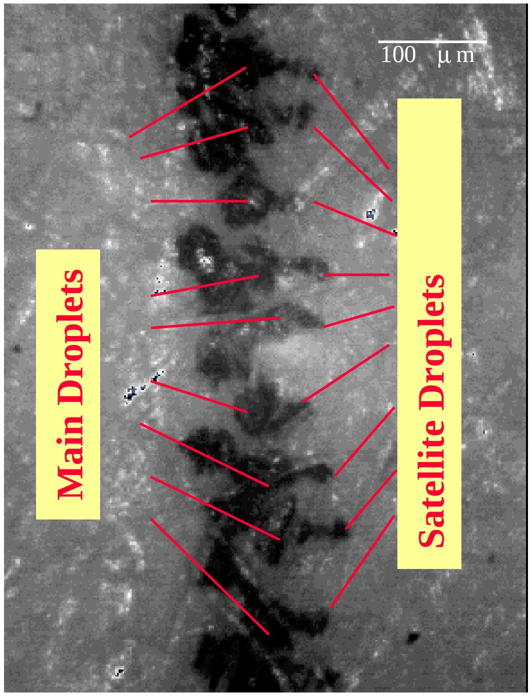
Puddle Formation

HP Printhead



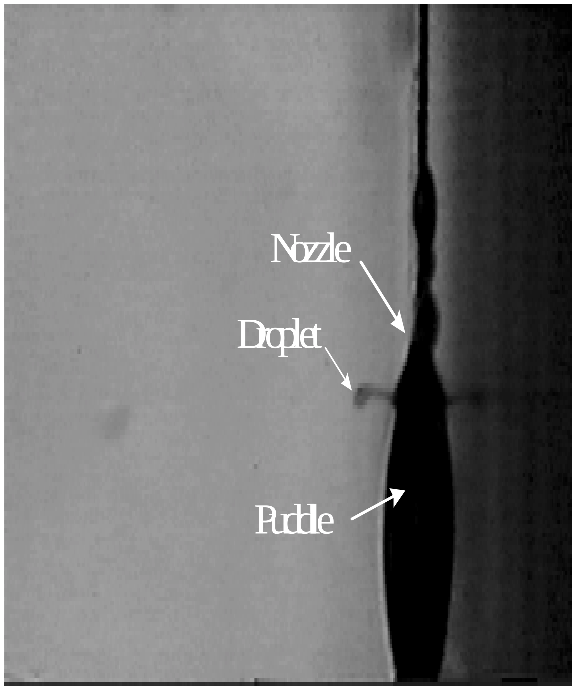
Droplet ejection sequence

HP Printhead



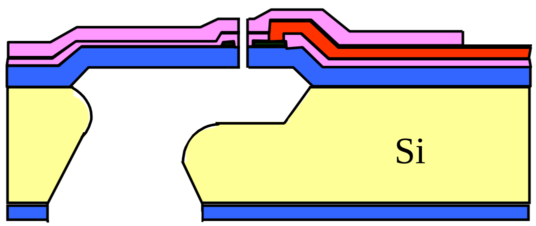
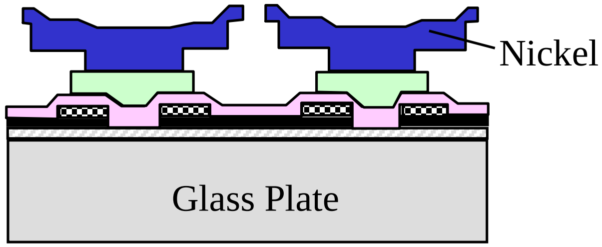
Sample straight-line printing

Microinjector with 30 µm Nozzle

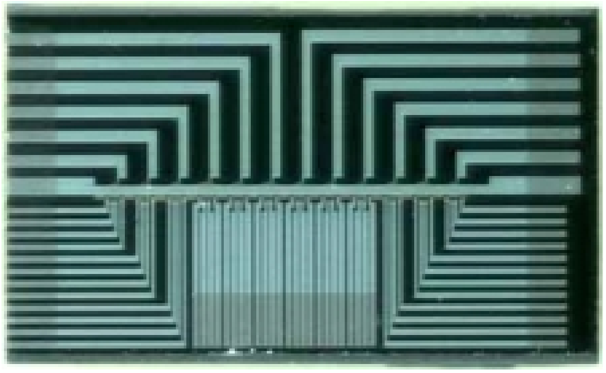


Puddle interferes droplet ejection

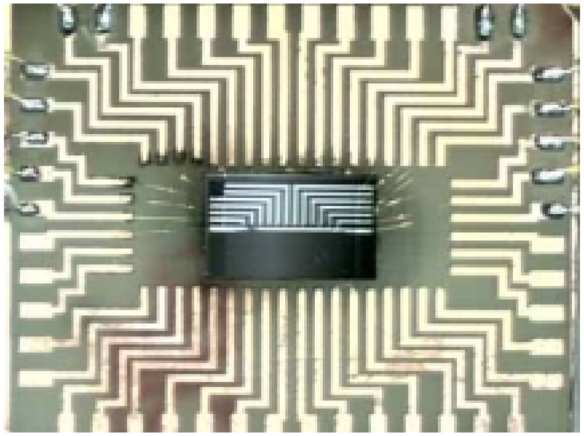
Fabrication Process Comparison

Microinjector	Commercial Inkjet Printhead
	
• Monolithic fabrication, accuracy ~ 1µm	• 3 different substrates, accuracy > 5µm
• No need of bonding process,	• Needs bonding Process,
• Can be fabricated in high spatial resolution, 1200 dpi	• Spatial resolution depends on bonding process~ now 300 dpi

Packaging

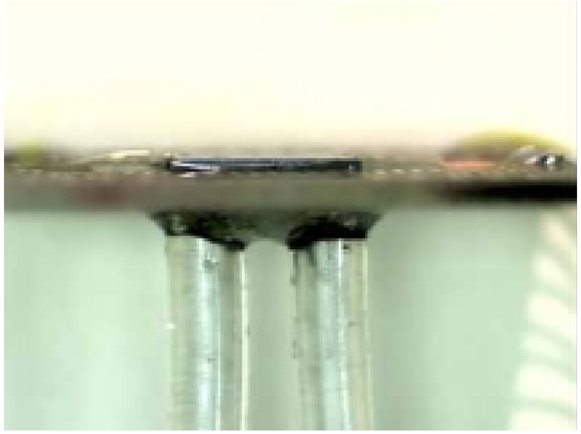


Front view of a microinjector array with temperature sensors



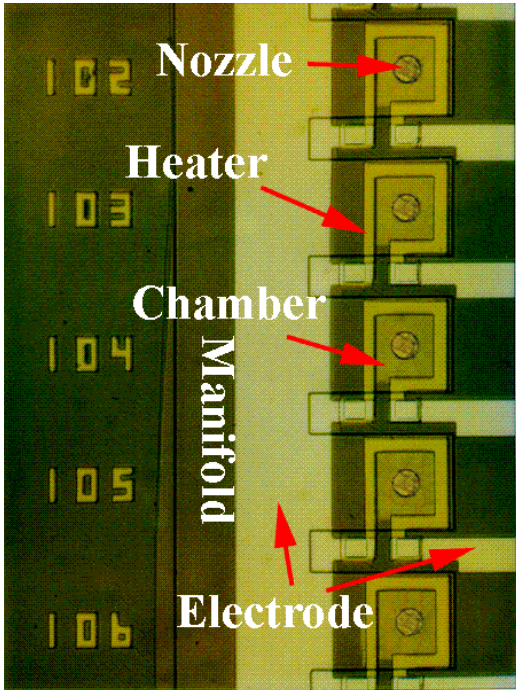
Microinjector array packaged on a PC board

Back side liquid entrance slot

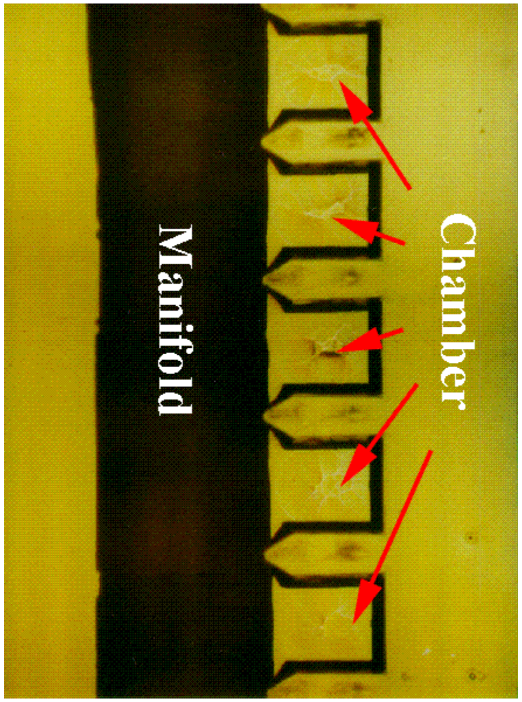


Pipe connection at the backside of PC board

MEMS Fabricated Micro-injector Array



Top view of a completed micro-injector array

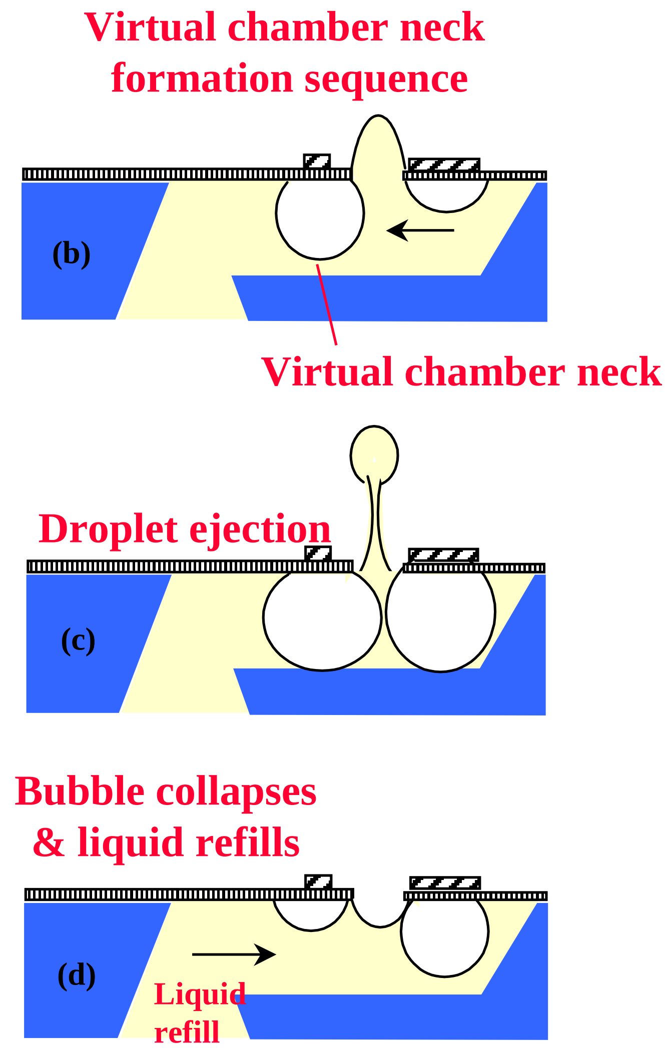


Chamber inner structure

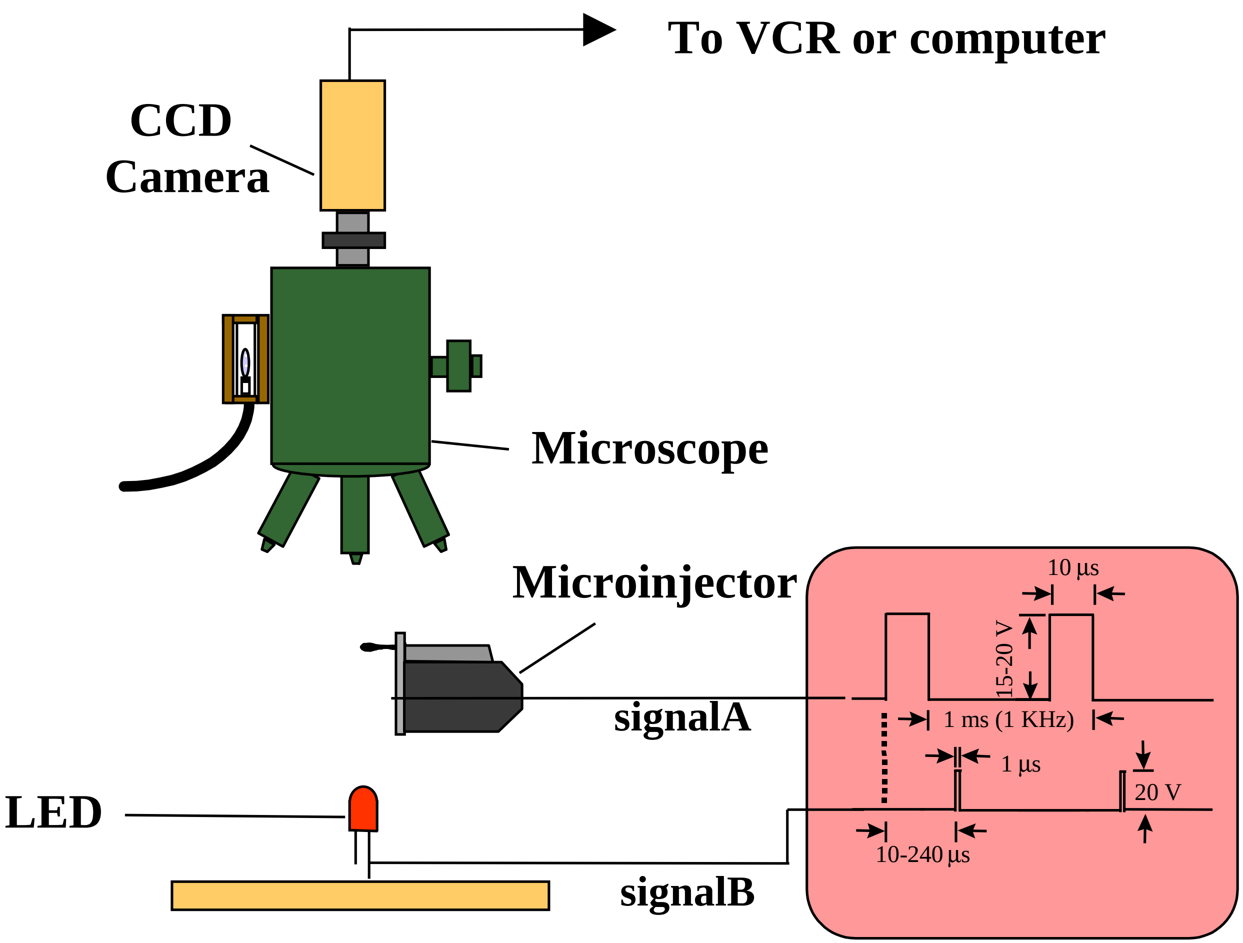
- 300 nozzles in an array
- Integrated circuits for spatial and temporal injection sequence control

Virtue Chamber Neck Concept
(patent pending)

- Reduced cross talk
- No satellite droplets
- High frequency response (>30 kHz)

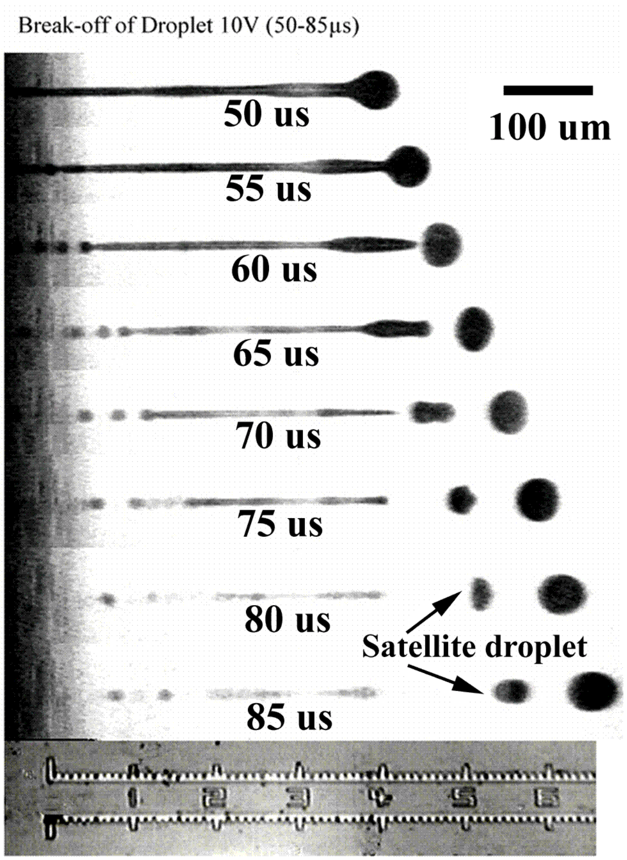


Droplet Visualization



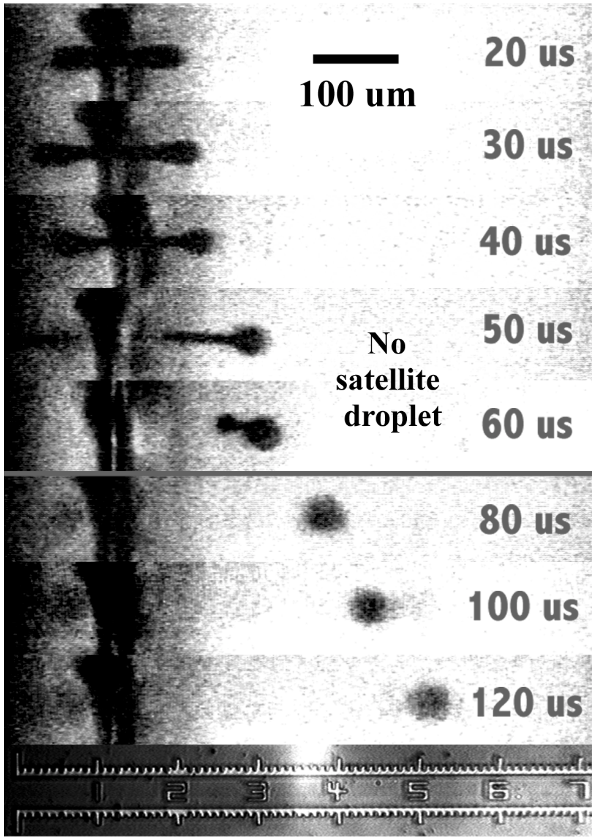
Satellite Droplet Formation

HP 51626A Printhead



Nozzle: 60 μm
Droplet: 50 μm
Frequency: 1 kHz
Speed: 10 m/s

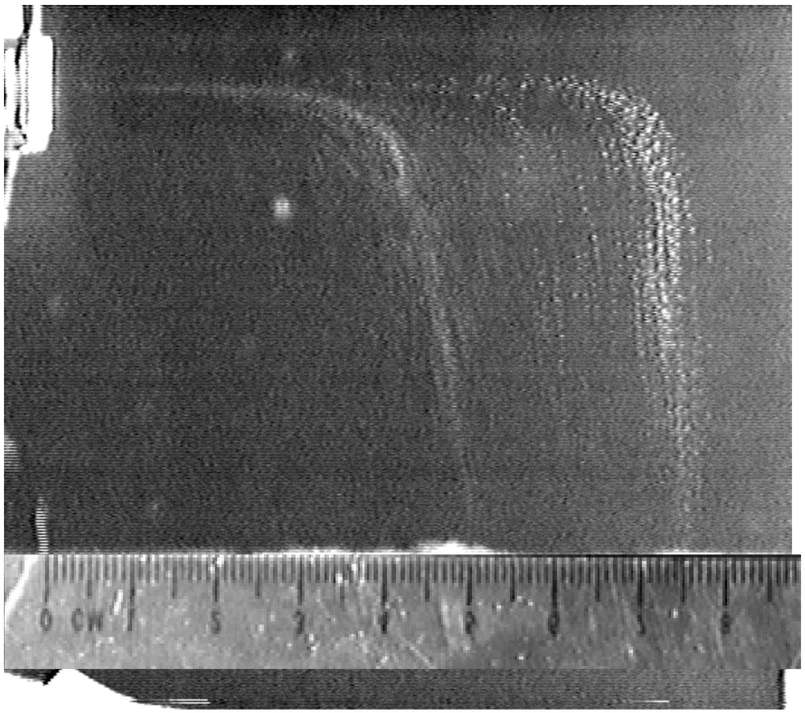
MEMS Micro-injector



Nozzle: 40 μm
Droplet: 45μm
Frequency: 1 kHz
Speed: 6 m/s

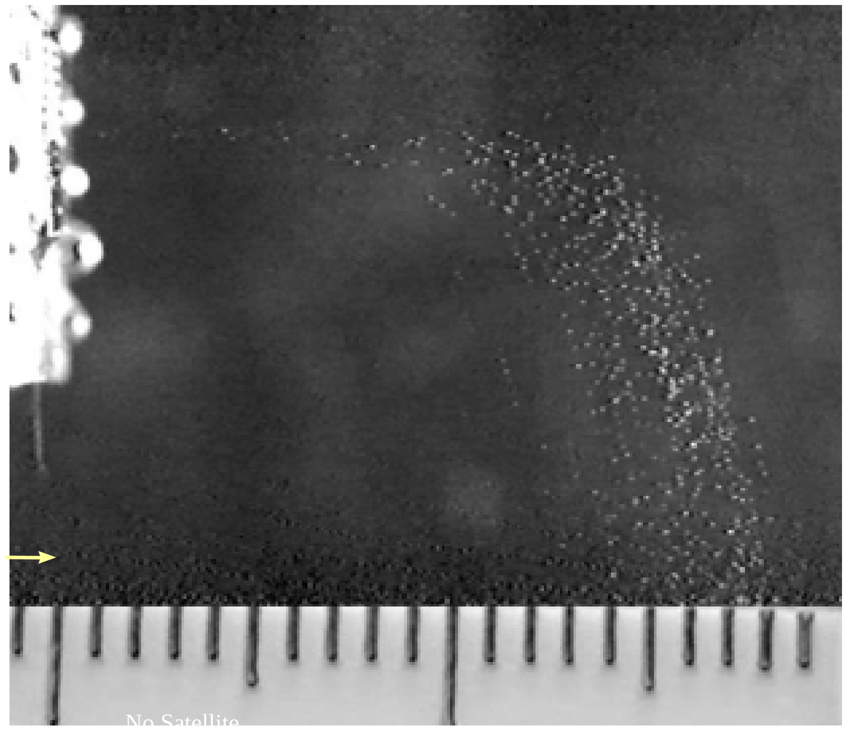
Droplet Trajectory Visualization
(using strobe-light back-illumination)

HP 51626A



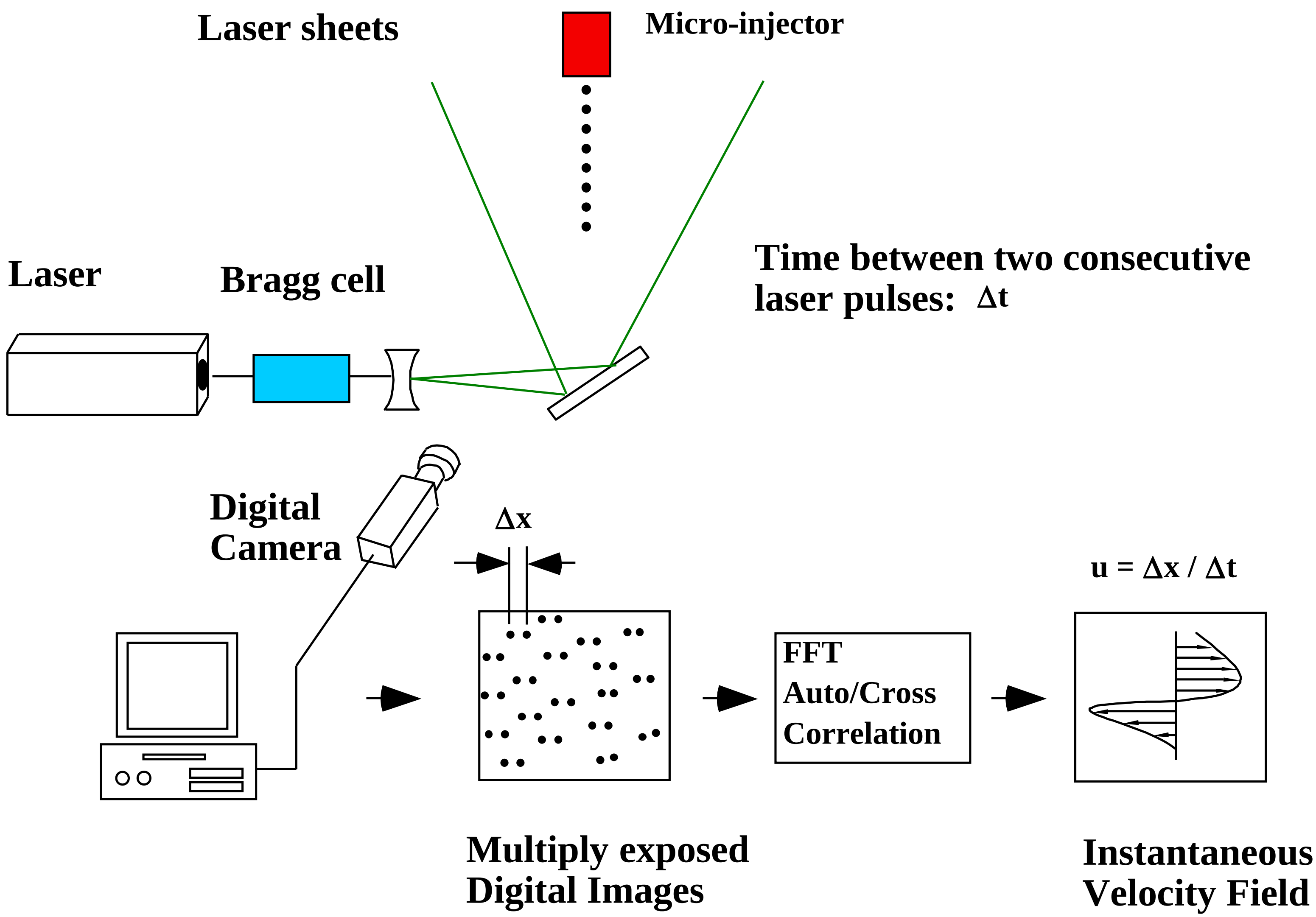
Two streams

Microinjector with 30 µm nozzle



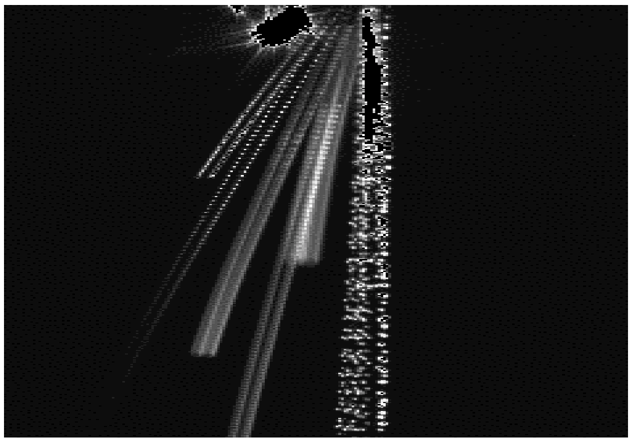
One stream

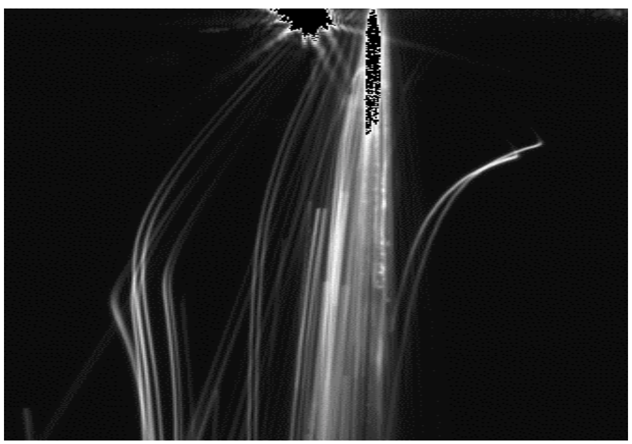
Particle Image Visualization/Velocimetry Setup



Multiply-exposed Particle Images

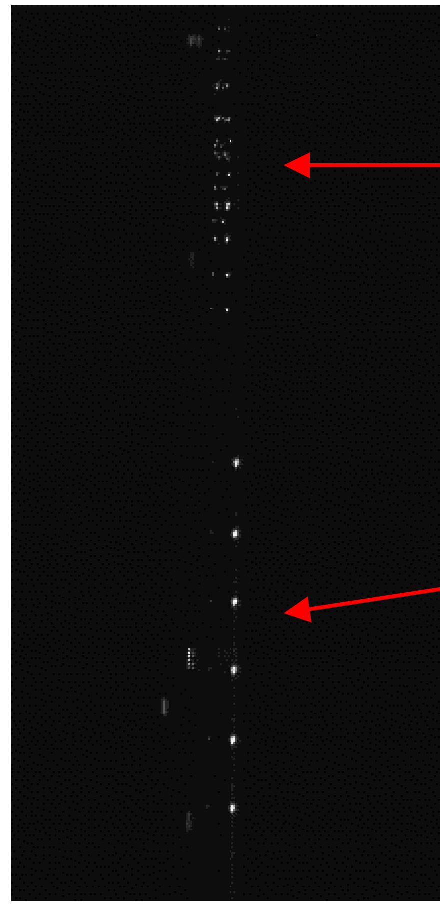
Multiple Droplet Injection





Splash ejection due to puddle formation?

Main Droplet Stream

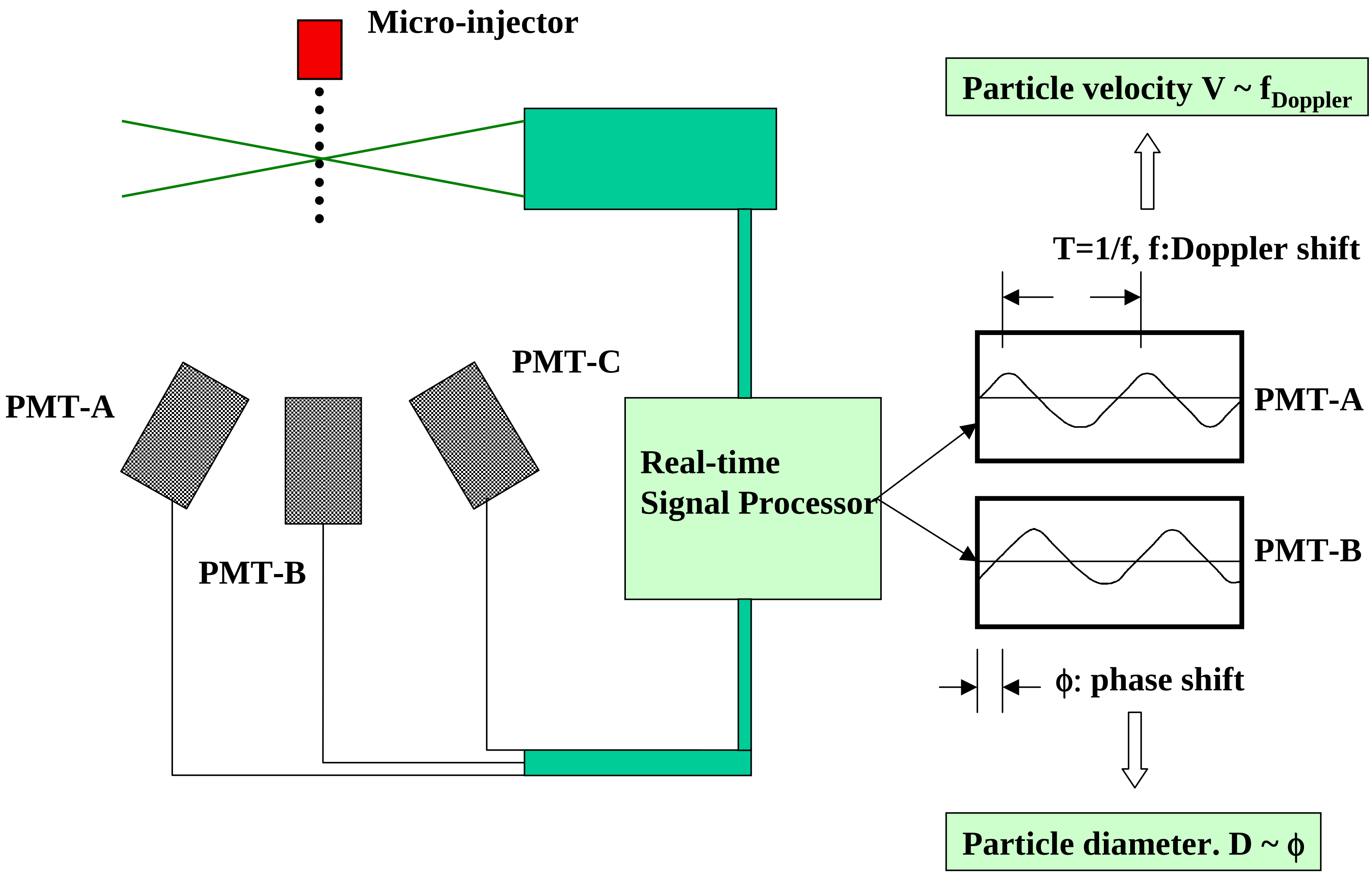


Satellite Droplets

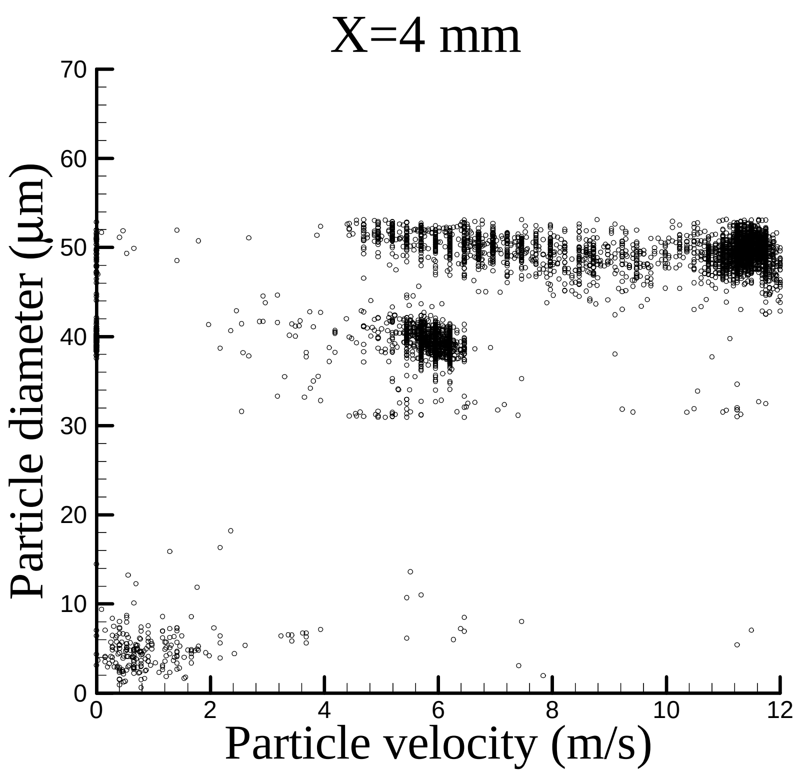
Primary Droplet

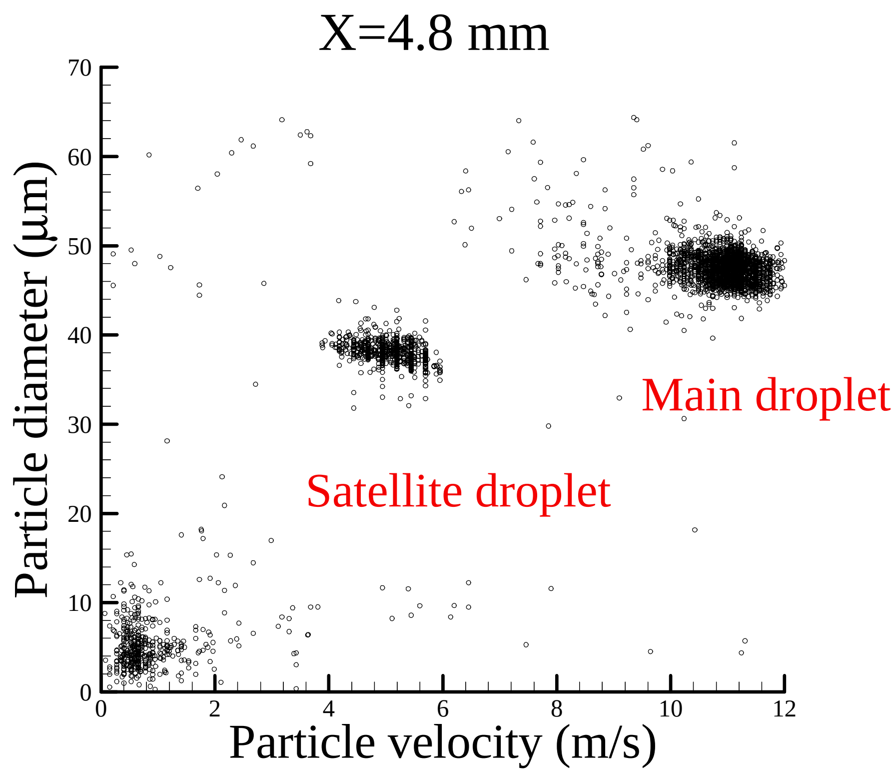
Δt=0.5 μs, ΔT=15.2 μs

Phase Doppler Particle Analyzer (PDPA)



PDPA Size/Velocity Correlation

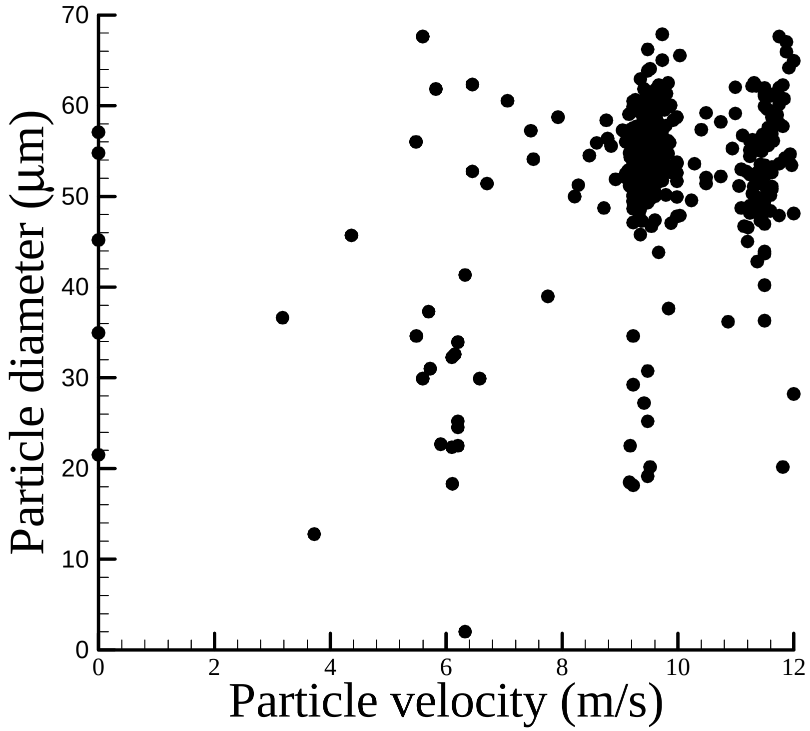




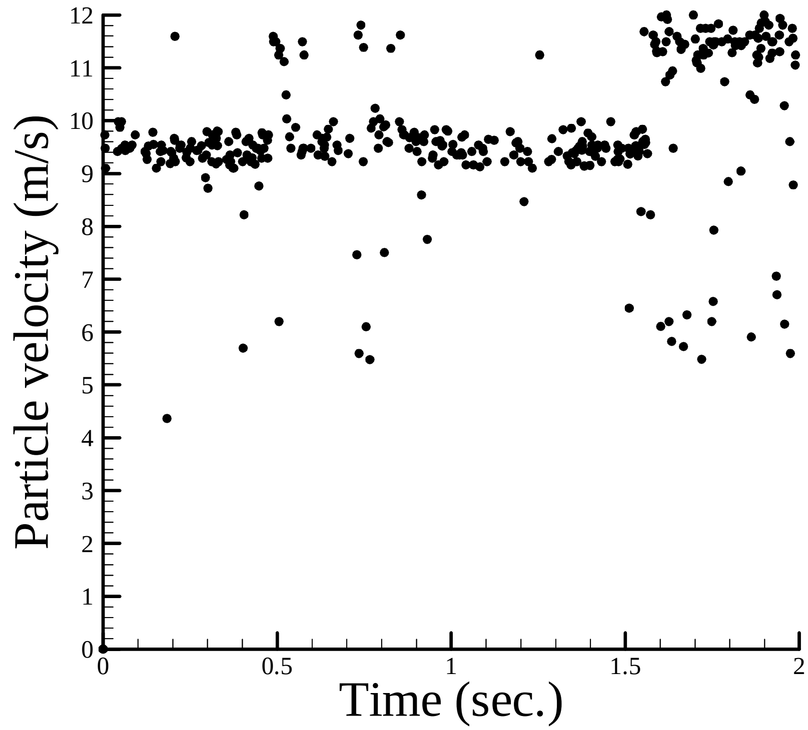
	Avg. diameter (μm)	Avg. velocity (m/s)
Main droplet	48.6	11.1
Satellite droplet	38.2	5.2

PDPA Data (Main droplet only, x=4.8 mm)

Size/Velocity Correlation



Velocity time variation



- Velocity distribution shows bi-stable mode
- Particle sizing distribution shows greater but random scatter

Summary

Microinjector with Virtual Neck & Embraced Heater Design

- No satellite droplets
- Fast frequency response (>30 kHz)
- Reduced cross talk
- Reduced heat loss to substrate

Characterization of the droplet injection process

- Injection splash near nozzle
- Bi-stable velocity distribution
- Detailed comparison between the inkjet printhead and the MEMS microinjector