Using Microjets to Suppress Resonance in a Mach 2 Cavity Flow

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Outline

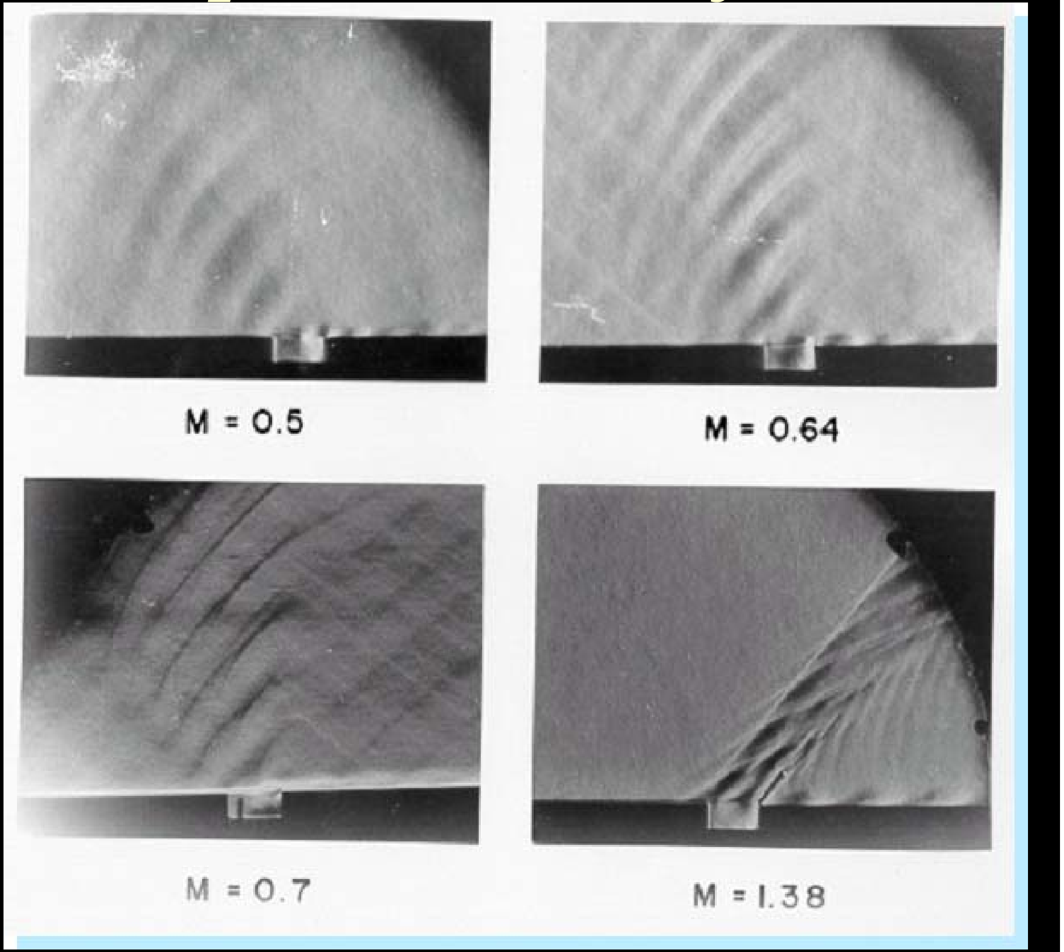
- **Introduction & Background**
- **Experimental Setup**
- **Selected Results** (L/D= 5.1)
  - **Baseline Cases (No Control)**
    - Flow Visualization
    - Acoustics/Unsteady pressures
    - Velocity Field
  - Effect of ***Microjet Control***
- **Summary**

Background

Supersonic Cavity Flows

- Flowfield governed by a feedback loop

- Leads to a highly unsteady flowfield accompanied by
  - High dynamic loads inside cavity
  - Multiple cavity tones



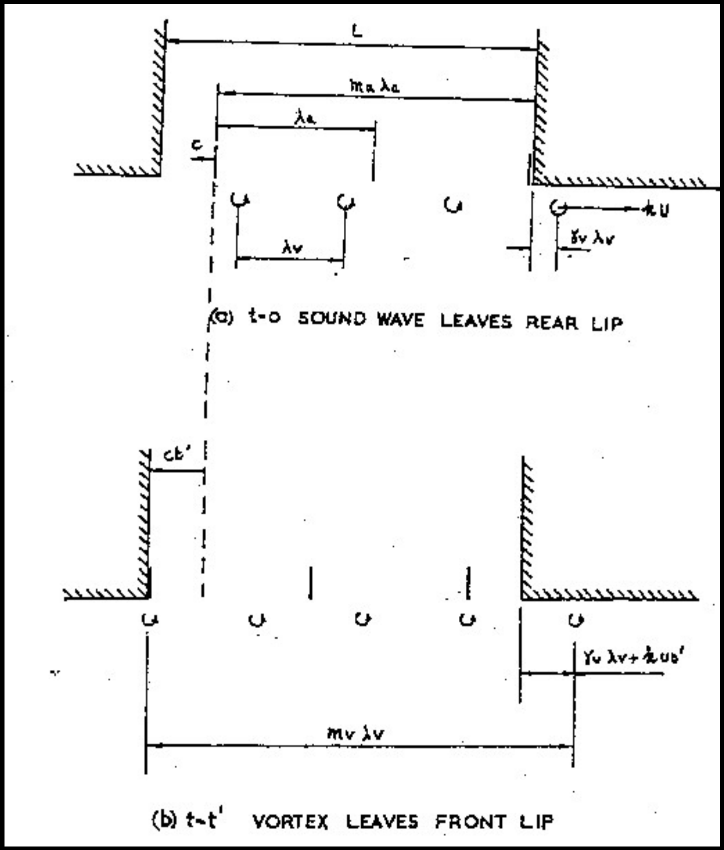
High Speed Cavity Visualization
(Krishnamurti, 1955)

Background
Supersonic Cavity Flows

Rossitor's model (feedback loop)

$$St = \frac{fU}{L} = \frac{(m - r)}{\left(M\left(1 + \frac{\gamma - 1}{2} M^2\right)^{-0.5} + \frac{1}{k} \right)}$$

f – Frequency of **m**th mode
r – Phase constant/lag
k– Average convective speed vortical structures/U_∞

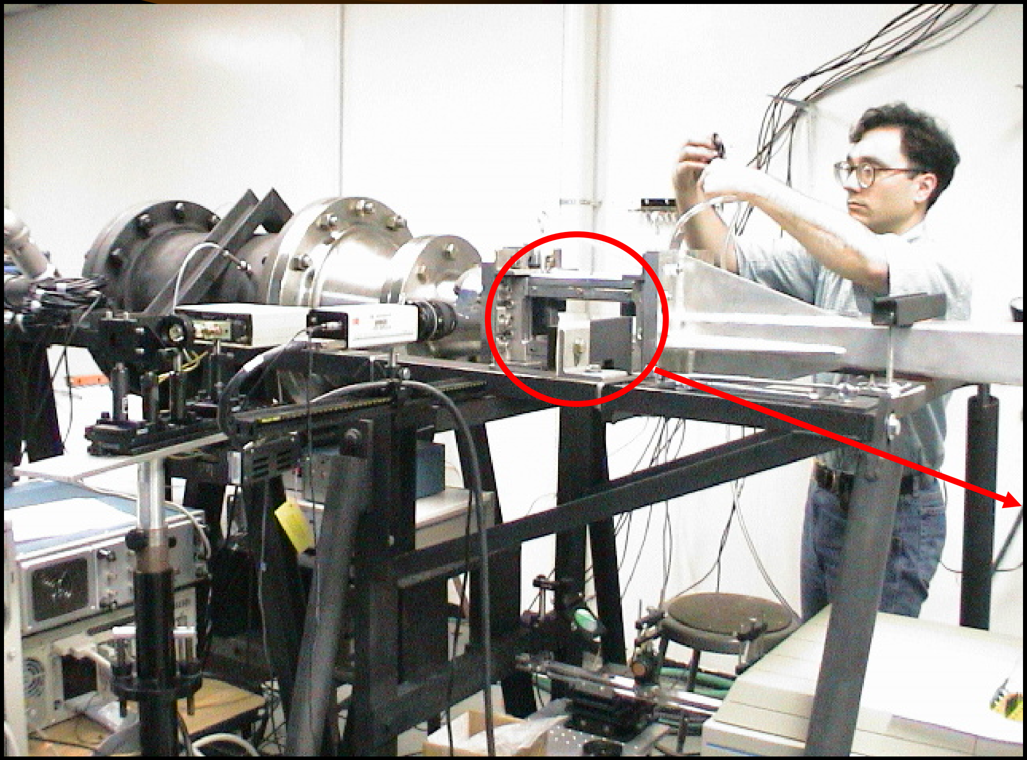


(Rossitor 1964)

Motivation

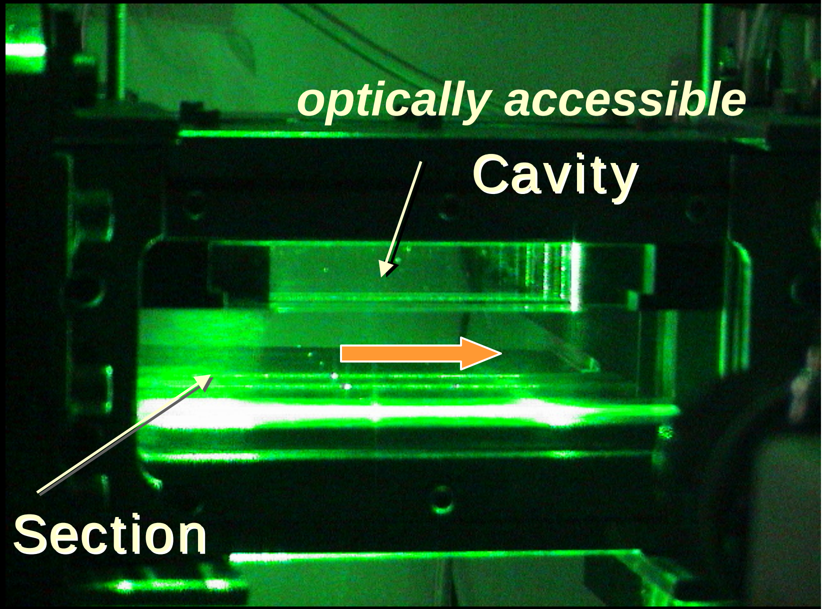
- To better understand supersonic cavity flows
- To control the unsteadiness of the flow

FMRL Cavity Facility

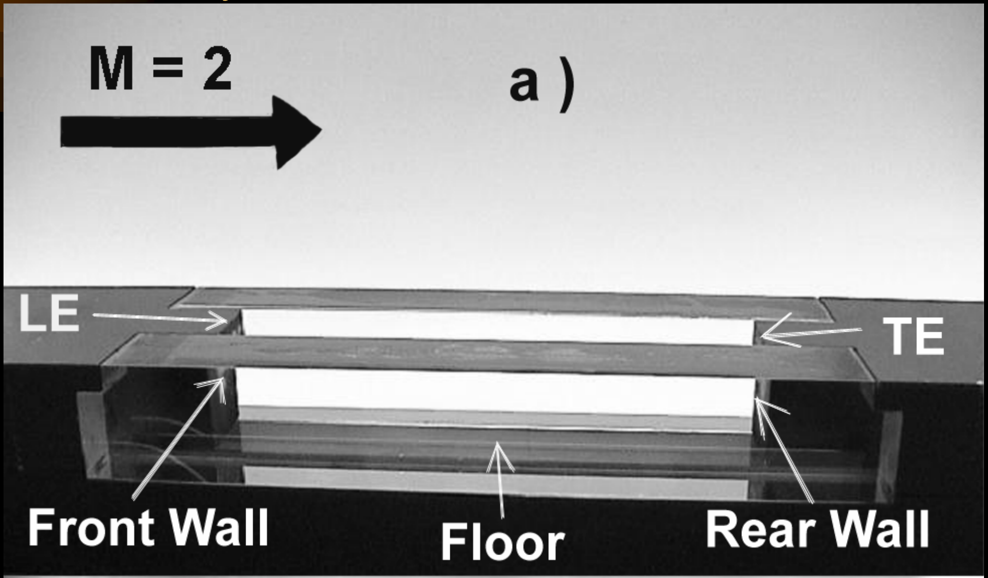


$M = 2$

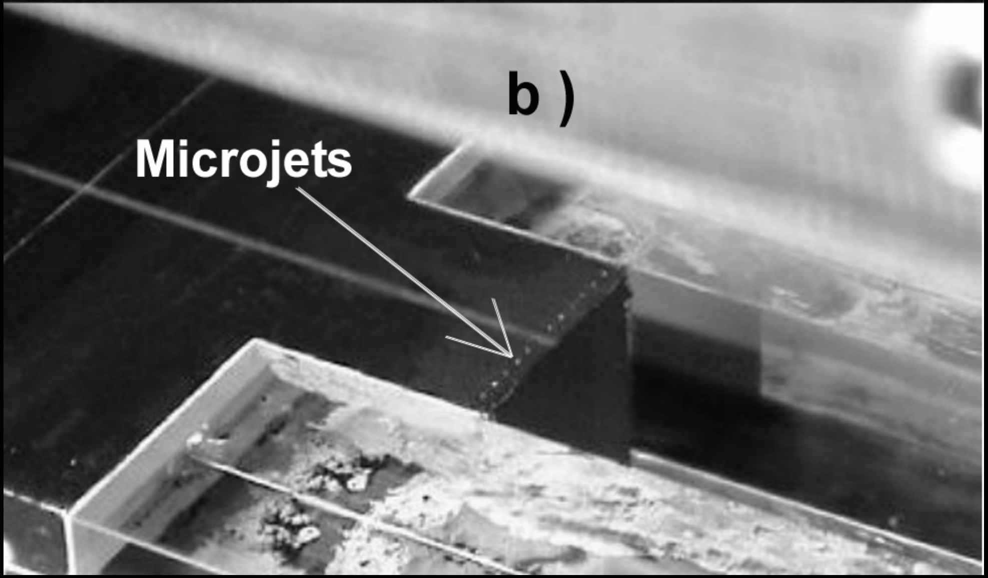
$Re = 23 \times 10^6\ /m$



Experimental Setup



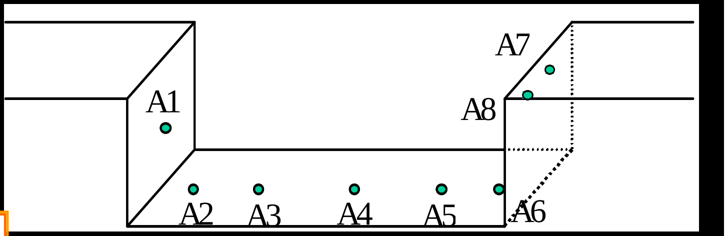
L/D=5.1 cavity

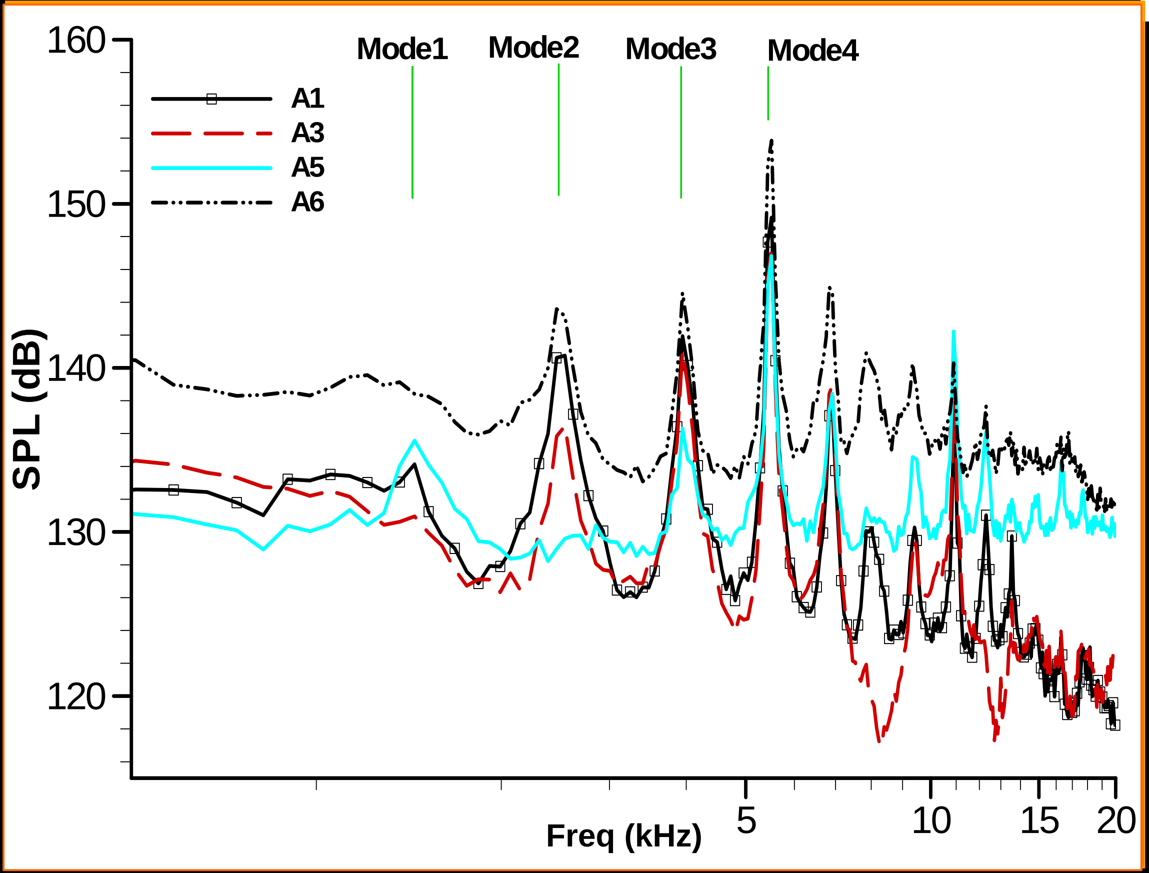


Microjet actuators

L / D = 5.1

Pressure Spectra





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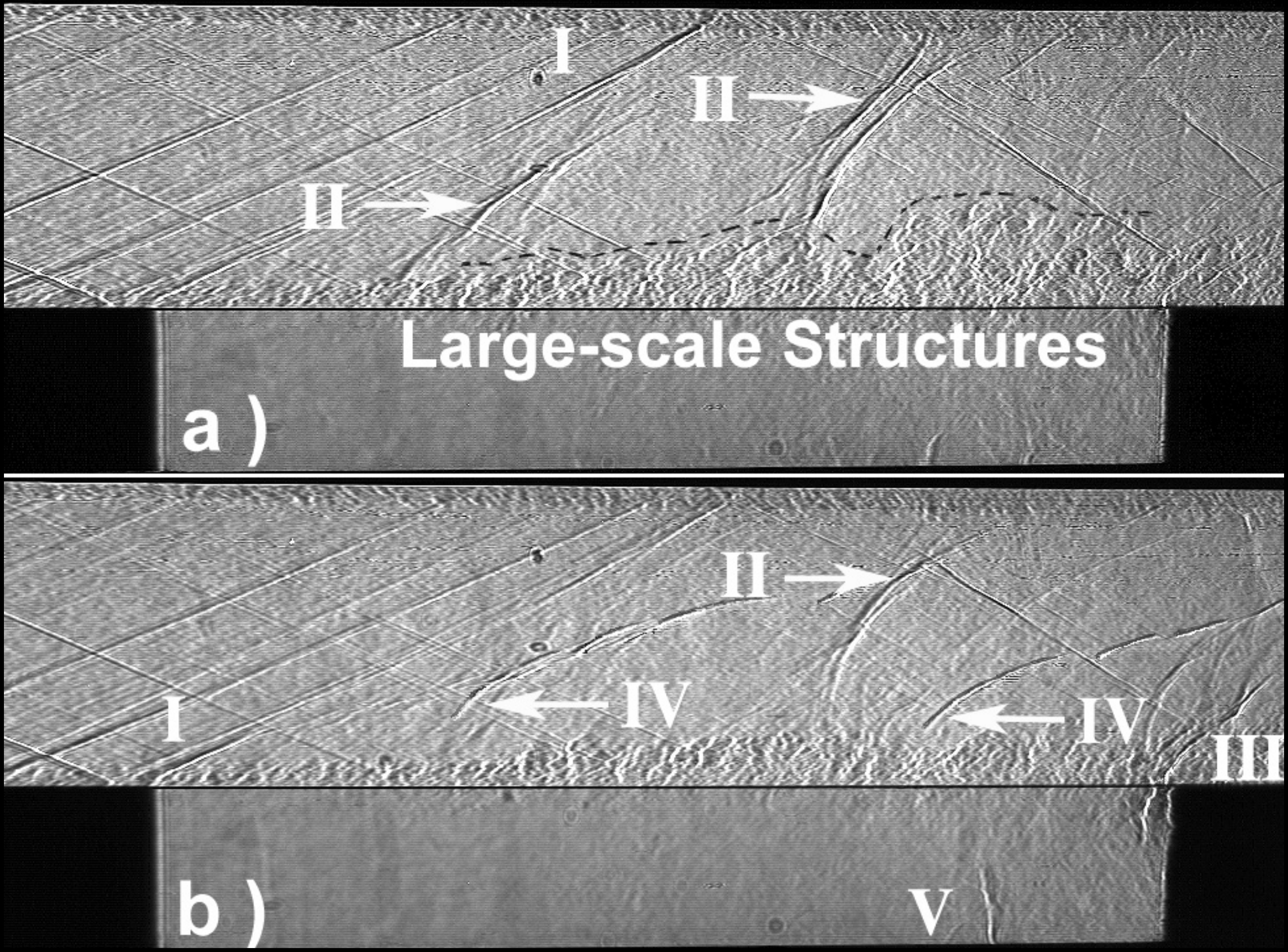
L / D = 5.1

Wave propagation reveals the feedback loop

Flow visualization



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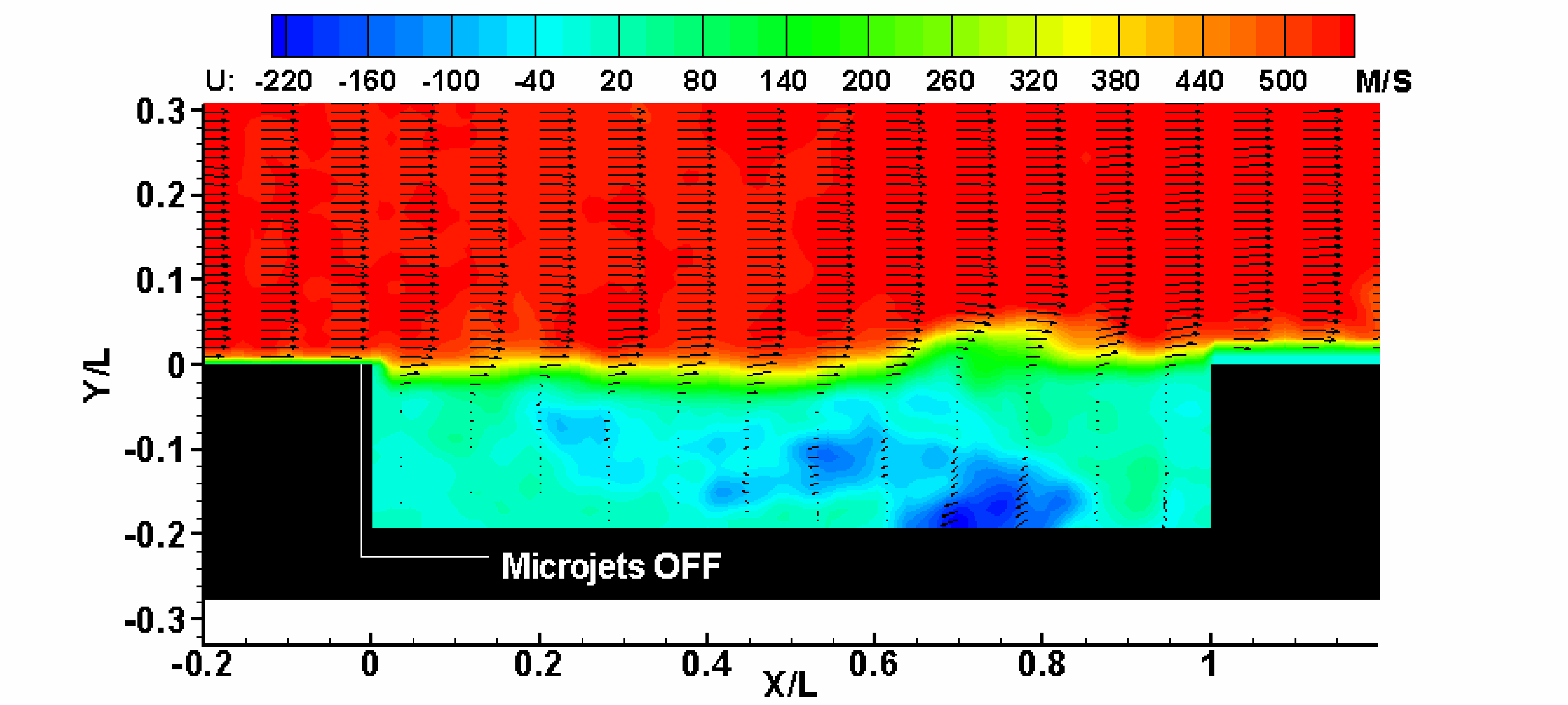
L / D = 5.1

Instantaneous Velocity Field

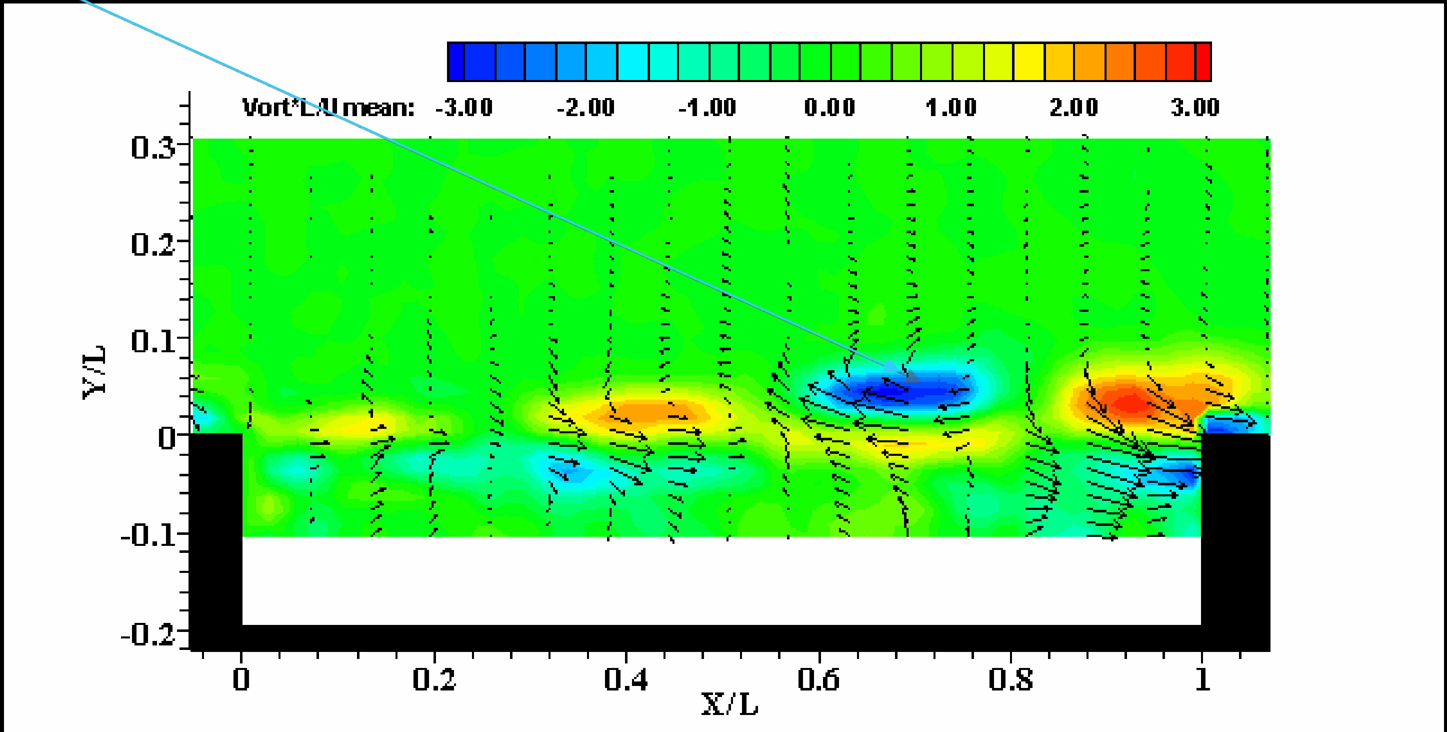


Click to Play video file

L / D = 5.1

Phase conditioned Velocity Field

Large- scale structure



$$< \omega >= \omega - \overline{\omega}$$

Periodical term

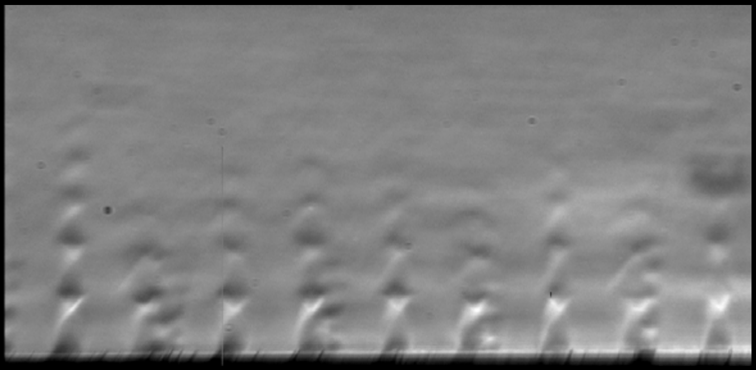
Phase lock conditioned term

Ensemble averaged term

Click to Play video file

Microjet Actuators

- Flow Visualization
- Unsteady Pressures
- Velocity Field



12 microjet with diameter ϕ= 400 μm normal to the surface

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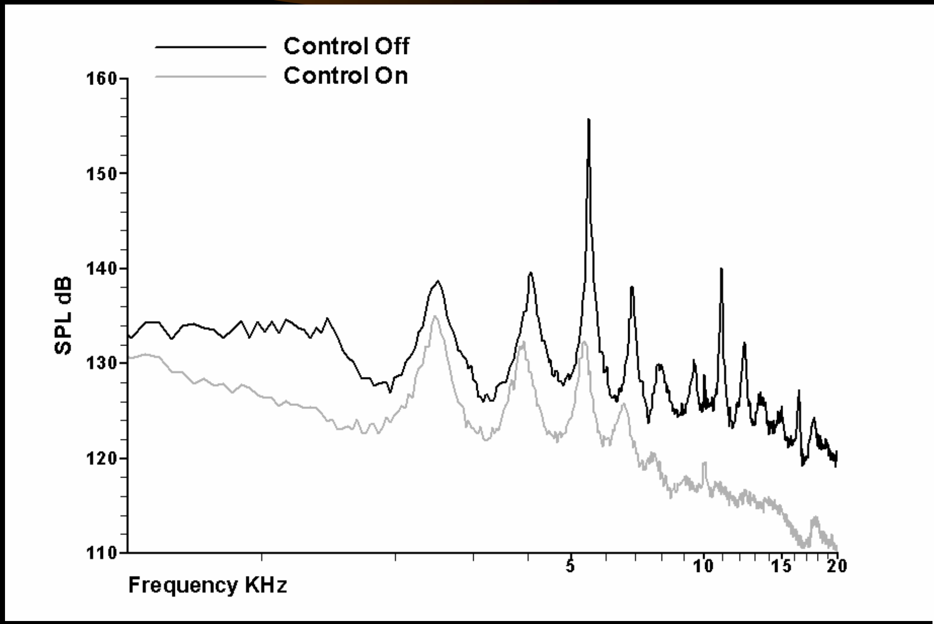
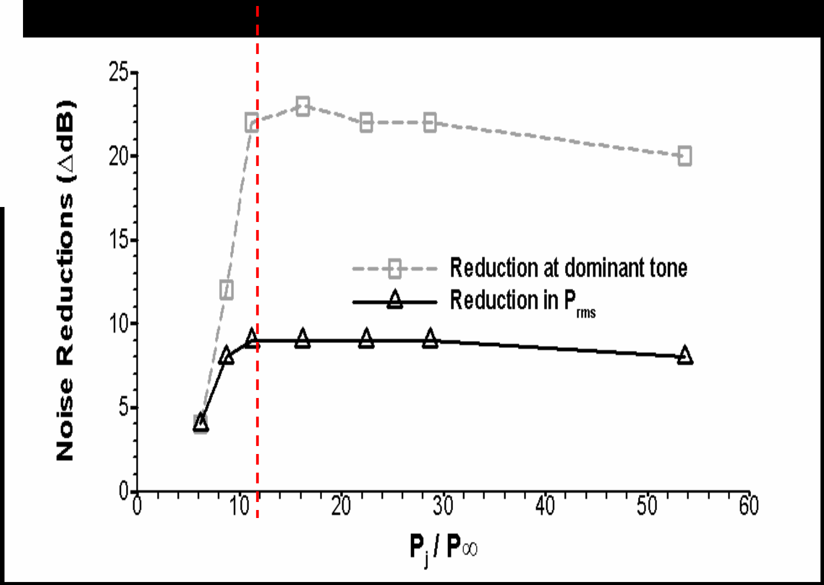
Effect of Control on Unsteady Pressures

L / D = 5.1





Control Effect Saturates ~ 30 psig
OASPL reduction ~ 9dB
Dominant tone attenuation ~ 23 dB

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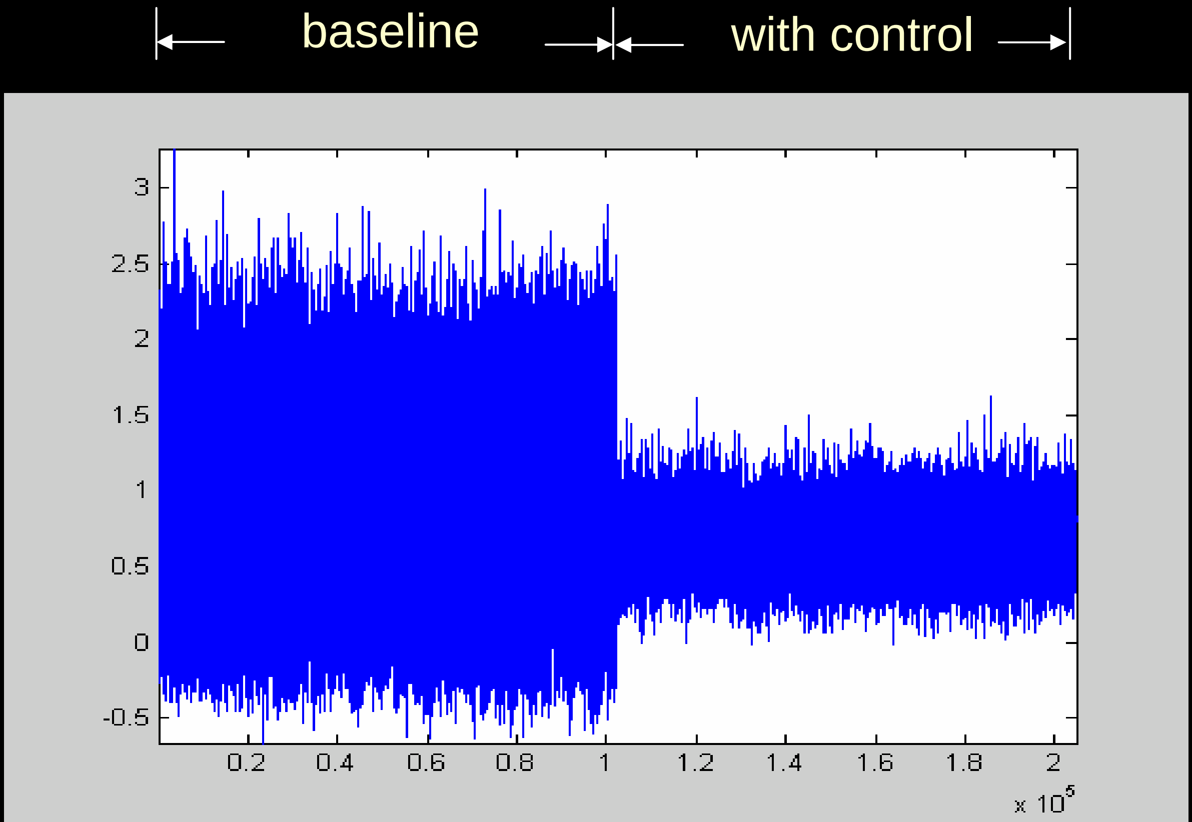
Effect of Control on Unsteady Pressures

L / D = 5.1



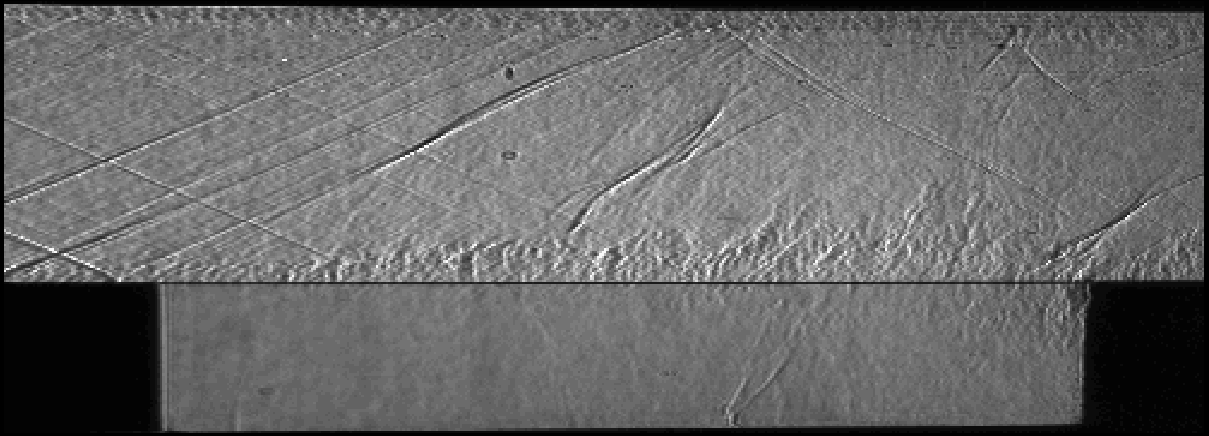
Click to Play sound file

Flow visualization

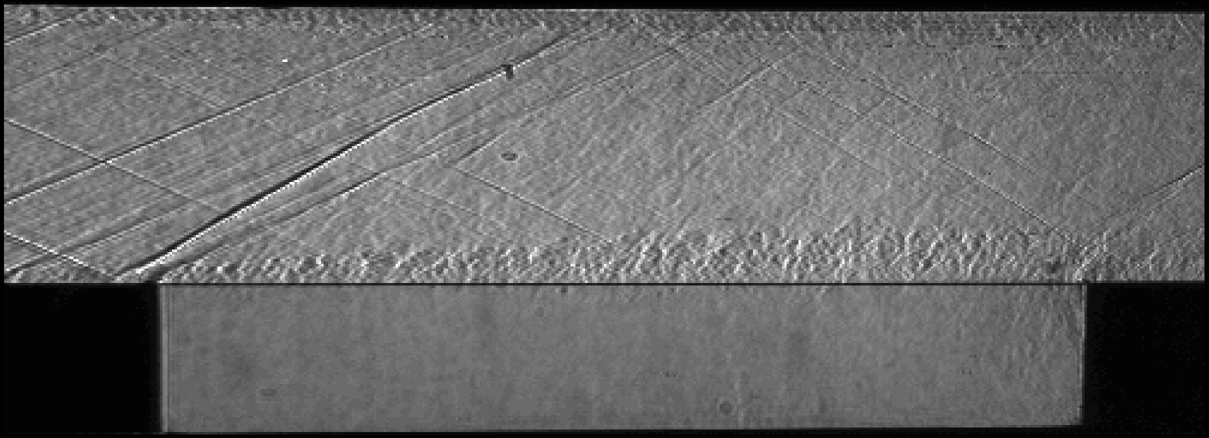
Instantaneous Shadowgraph comparison

L/D=5.1

Baseline case
with microjets OFF



Microjets ON
control pressure P_j=30psig
P_j/P_s=11



Click to Play video file

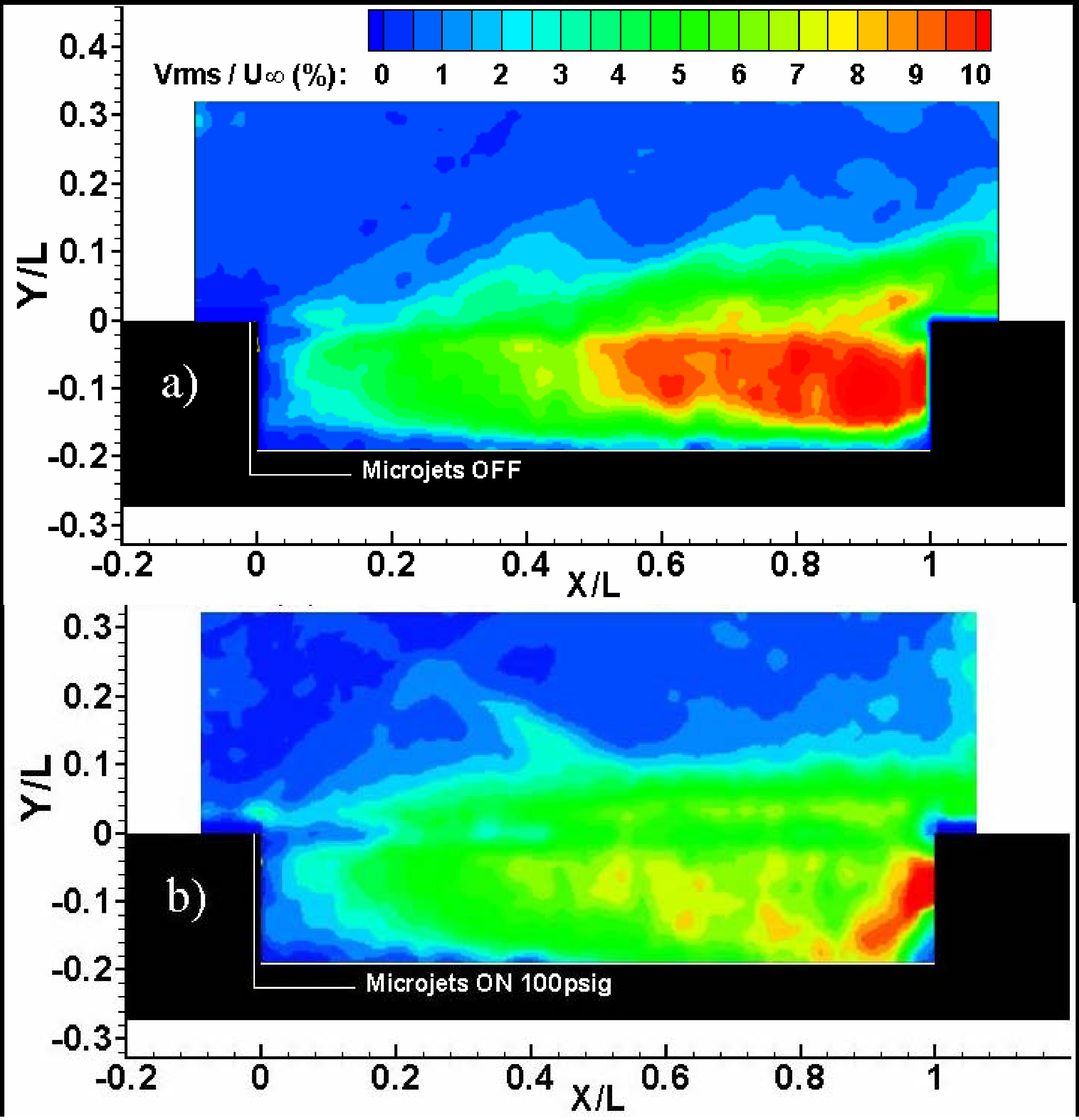
Fluctuating Velocity Field

L/D = 5.1

Effect of Control on V_{rms}

Control OFF

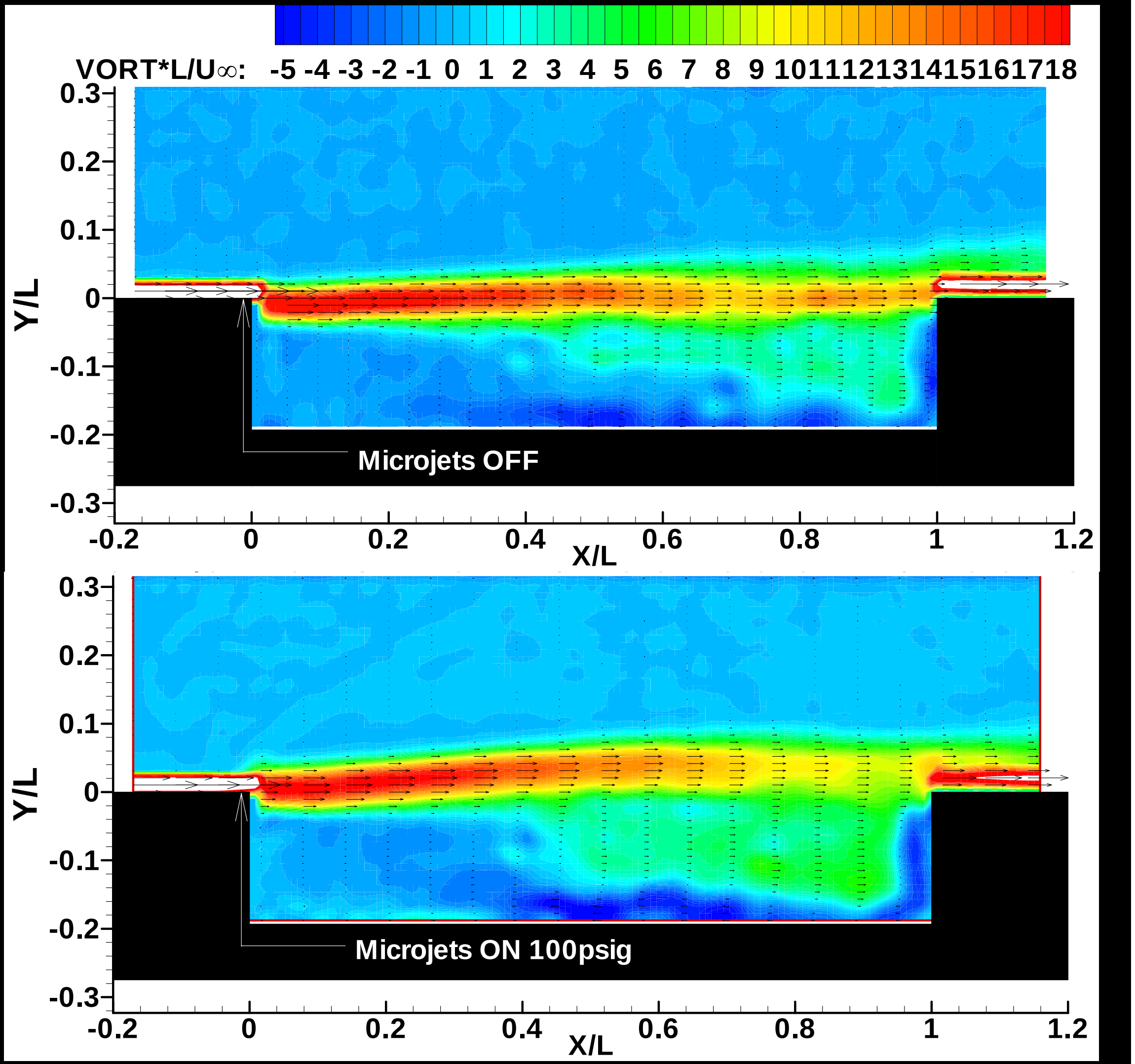
Control ON



Vorticity Field
L/D = 5.1
Effect of Control on V_{rms}

Control OFF

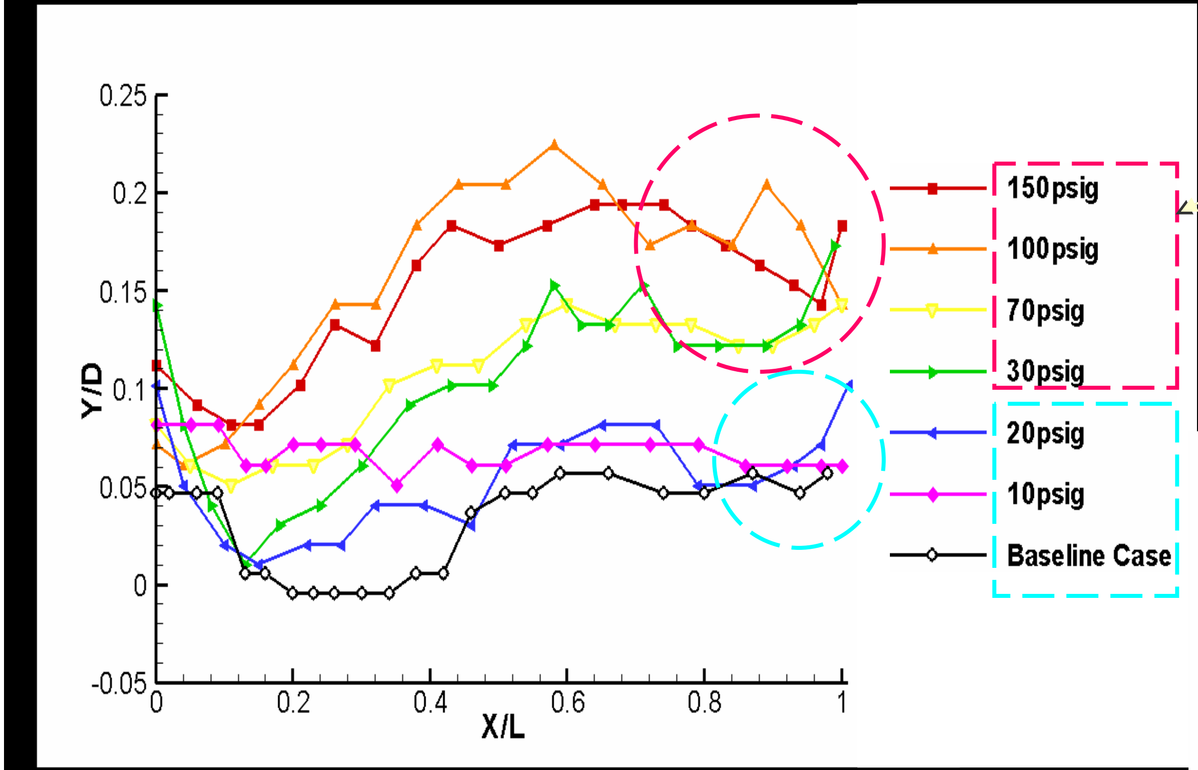
Control ON



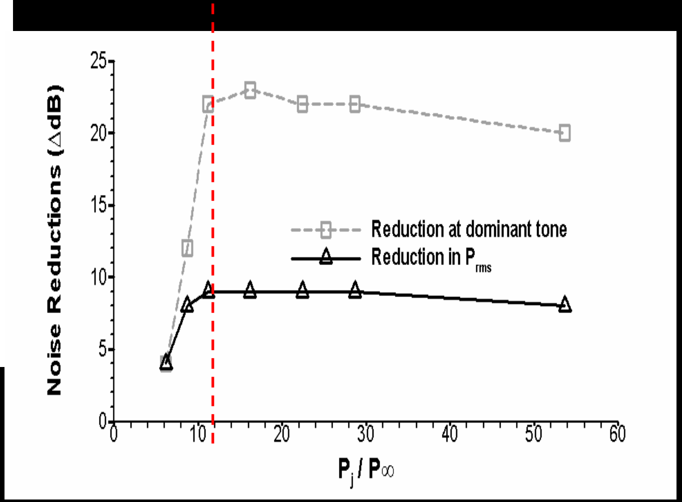
Effect of Control on the Shear Layer

L/D = 5.1

Shear layer Centerline



Saturated

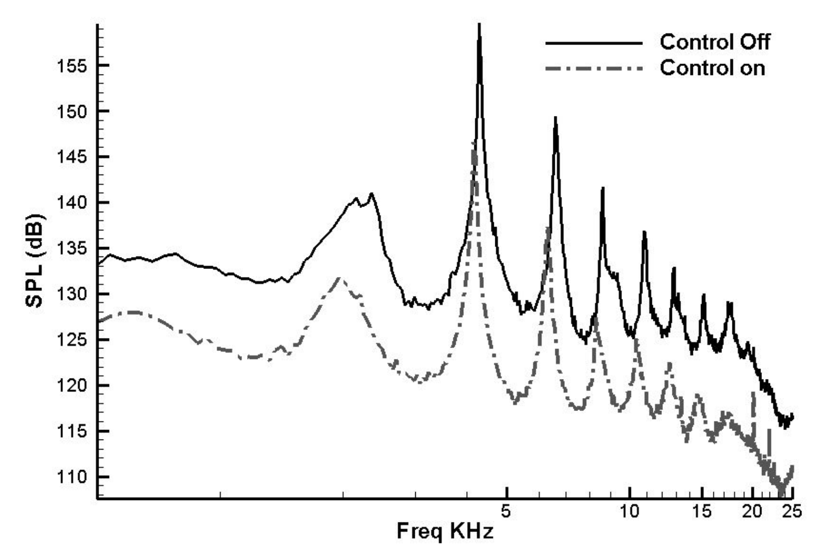


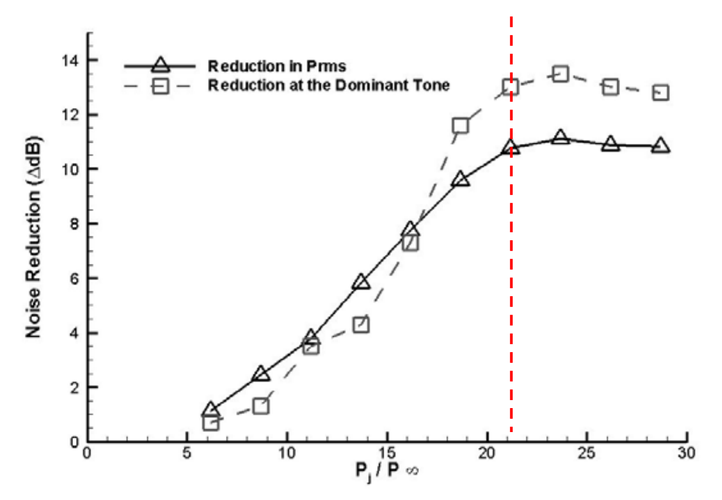
Summary

- Microjets can effectively control the flow unsteadiness
  - The pressure/acoustical fluctuations inside the cavity are significantly attenuated
  - A reduction of velocity fluctuations with a weaker reversing flow
- Control approach is *simple, robust* and achieved with *minimal mass flow*.

Effect of Control on Unsteady Pressures

L/D = 3

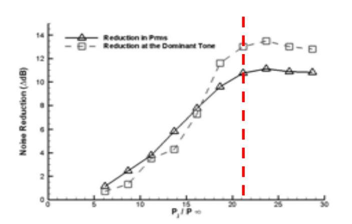




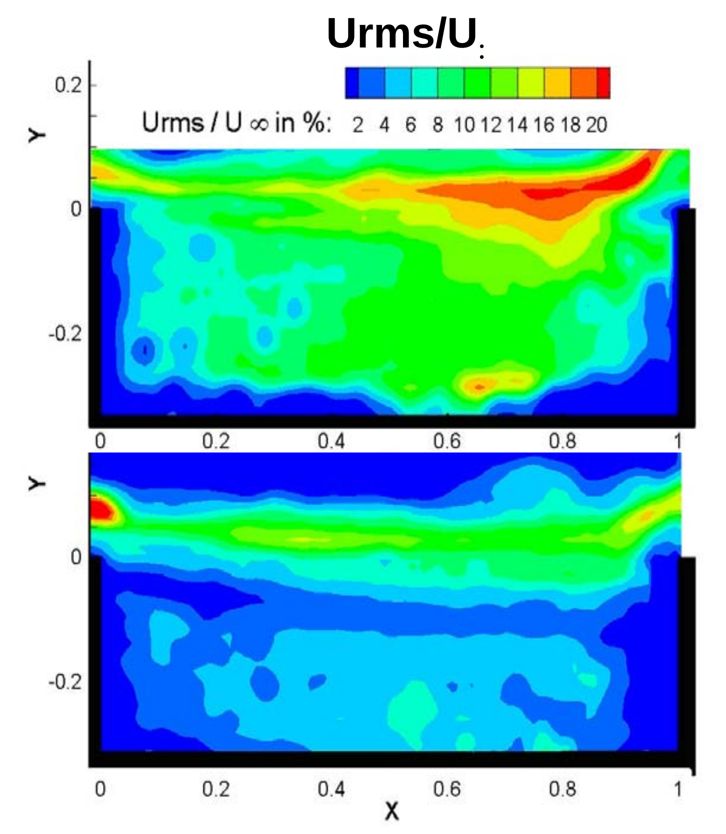
Control Effect Saturates ~ 70 psig
OASPL reduction ~ 11dB
Dominant tone attenuation ~ 13 dB

Fluctuating Velocity Field

L/D = 3



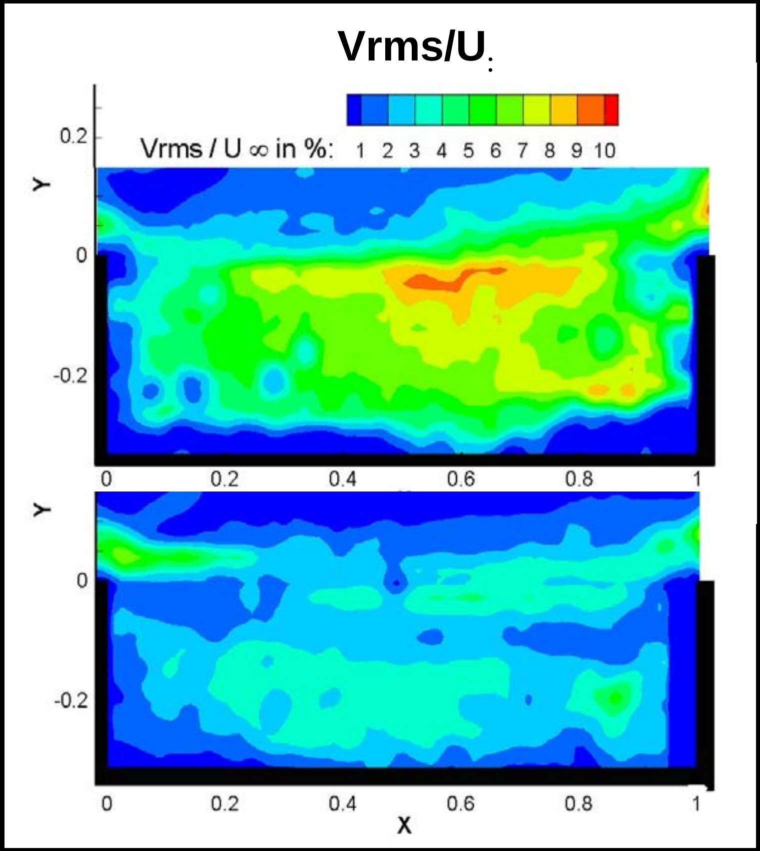
U_{rms}



No control

70 psig

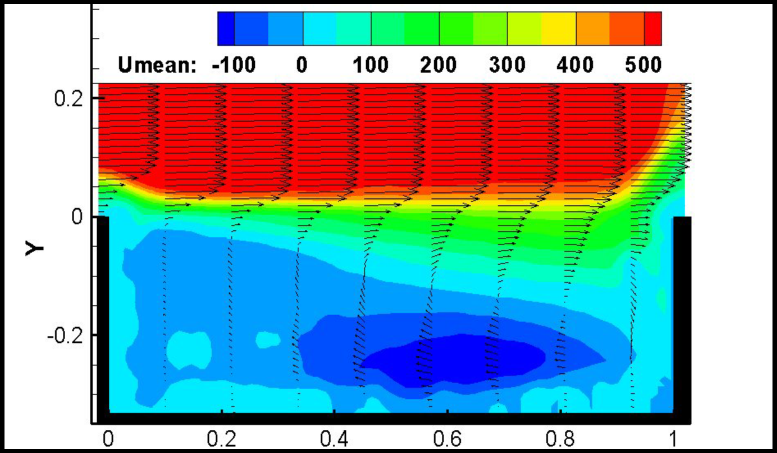
V_{rms}



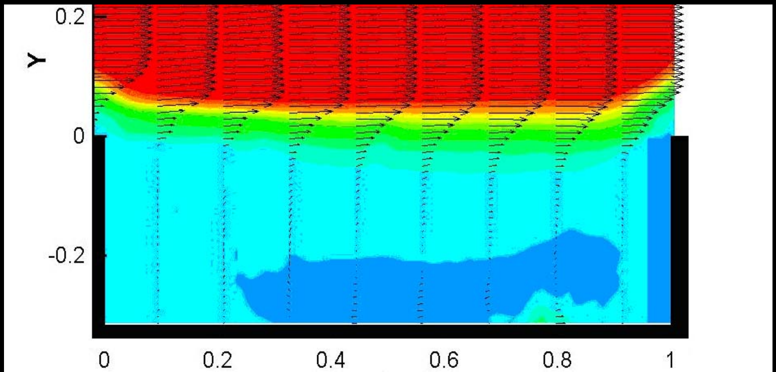
Ensemble-Averaged Velocity Field

(L/D = 3)

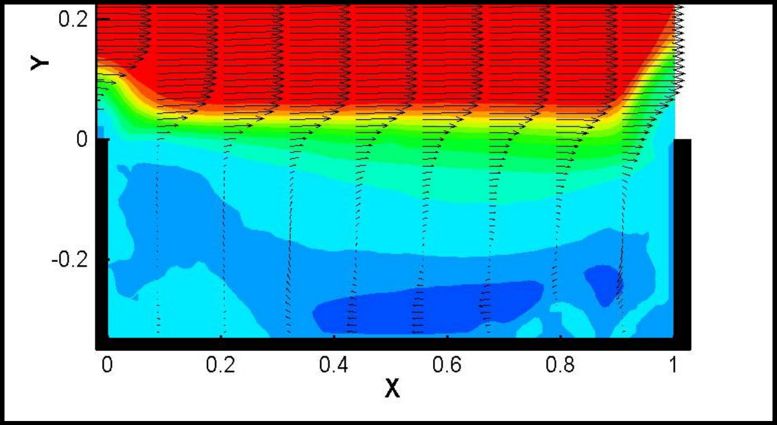
As Control Becomes More Effective:
Reverse flow vel. decreases
Control pressure increased beyond saturation:
Reverse Flow velocity increases



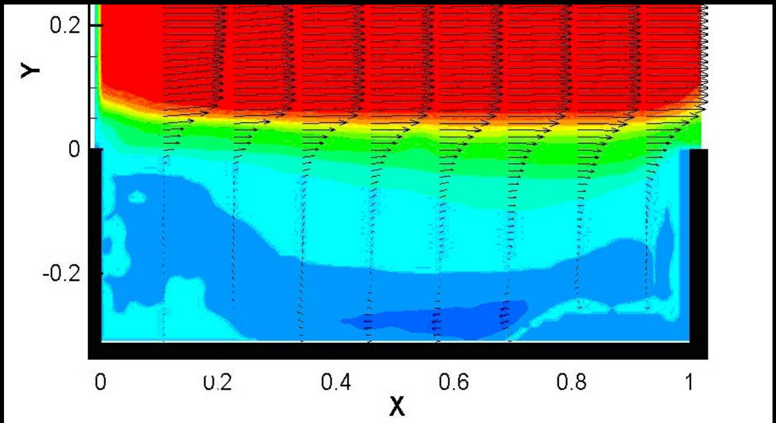
No control



70 psig (optimal)



30 psig



100 psig