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# Hydrofoil Flow Induced Vibration Mitigation by Passive Resonant Piezoelectric Shunt

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## Context

Hydrofoils are subjected to flow induced vibrations.

⇒ **Structural fatigue + acoustic noise**

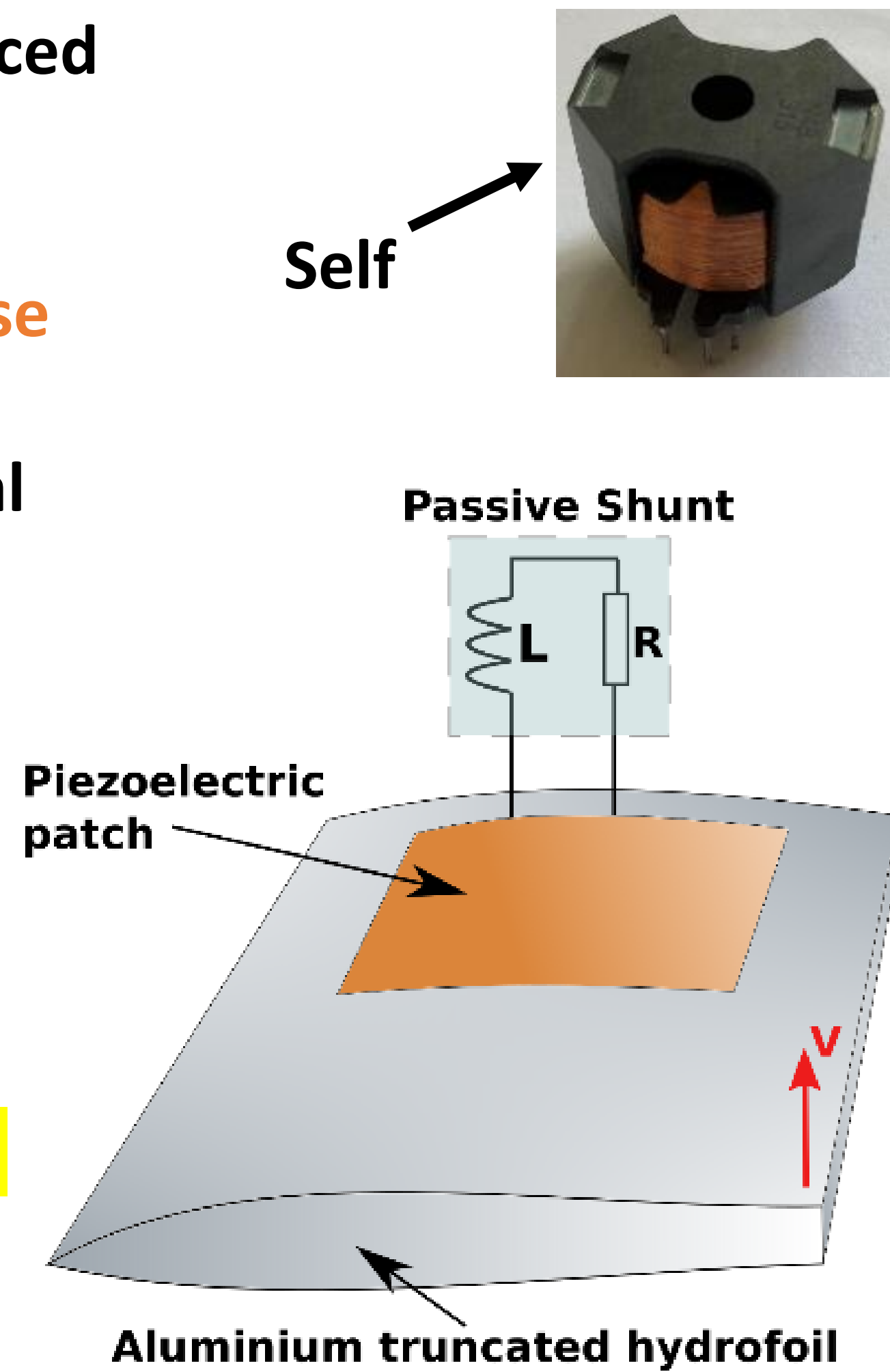
If vortex shedding frequency = natural frequency.

⇒ **Resonance**

⇒ **High amplitude vibrations**

## Objective

**Use a resonant piezoelectric shunt to mitigate flow induced vibrations at resonance**



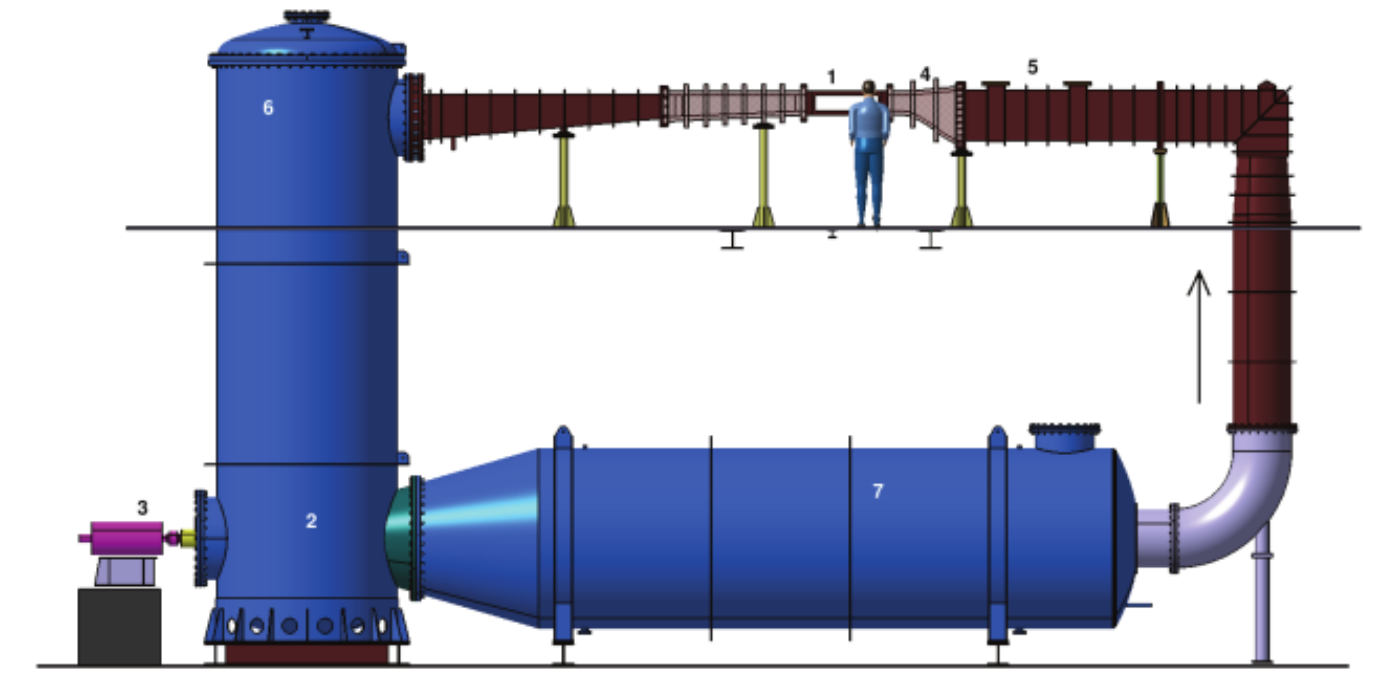
## Methodology

### Hydrodynamic tunnel

$U_0 = 3.0$  to  $5.5$  m/s

$Re = 2.40 \times 10^5$  to  $4.40 \times 10^5$

Incidence =  $0^\circ$



### Laser Vibrometry + TR-PIV + POD

### Hydrofoil natural frequencies

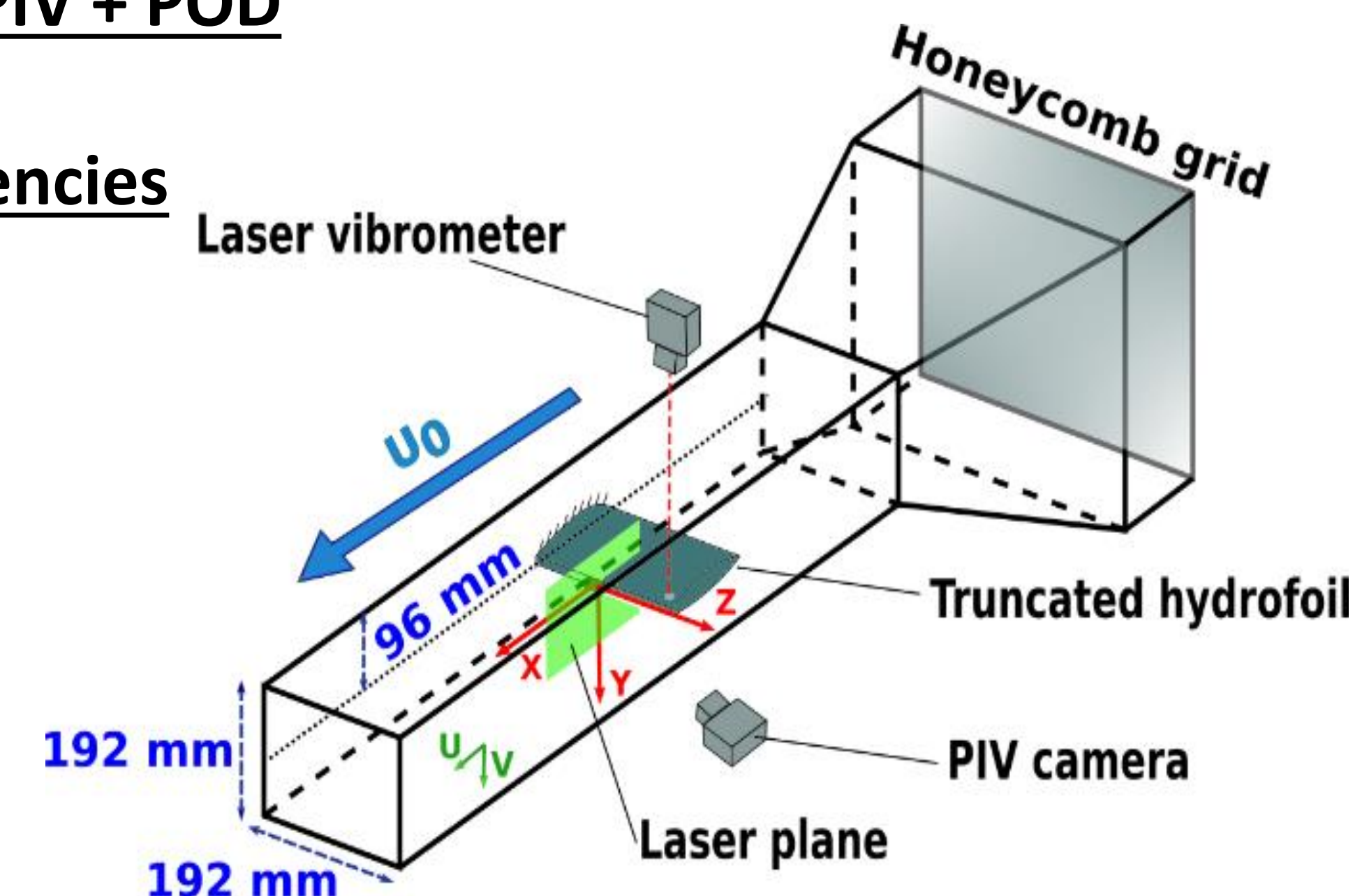
$f_1 = 40$  Hz : Bending

$f_2 = 282$  Hz : Twisting

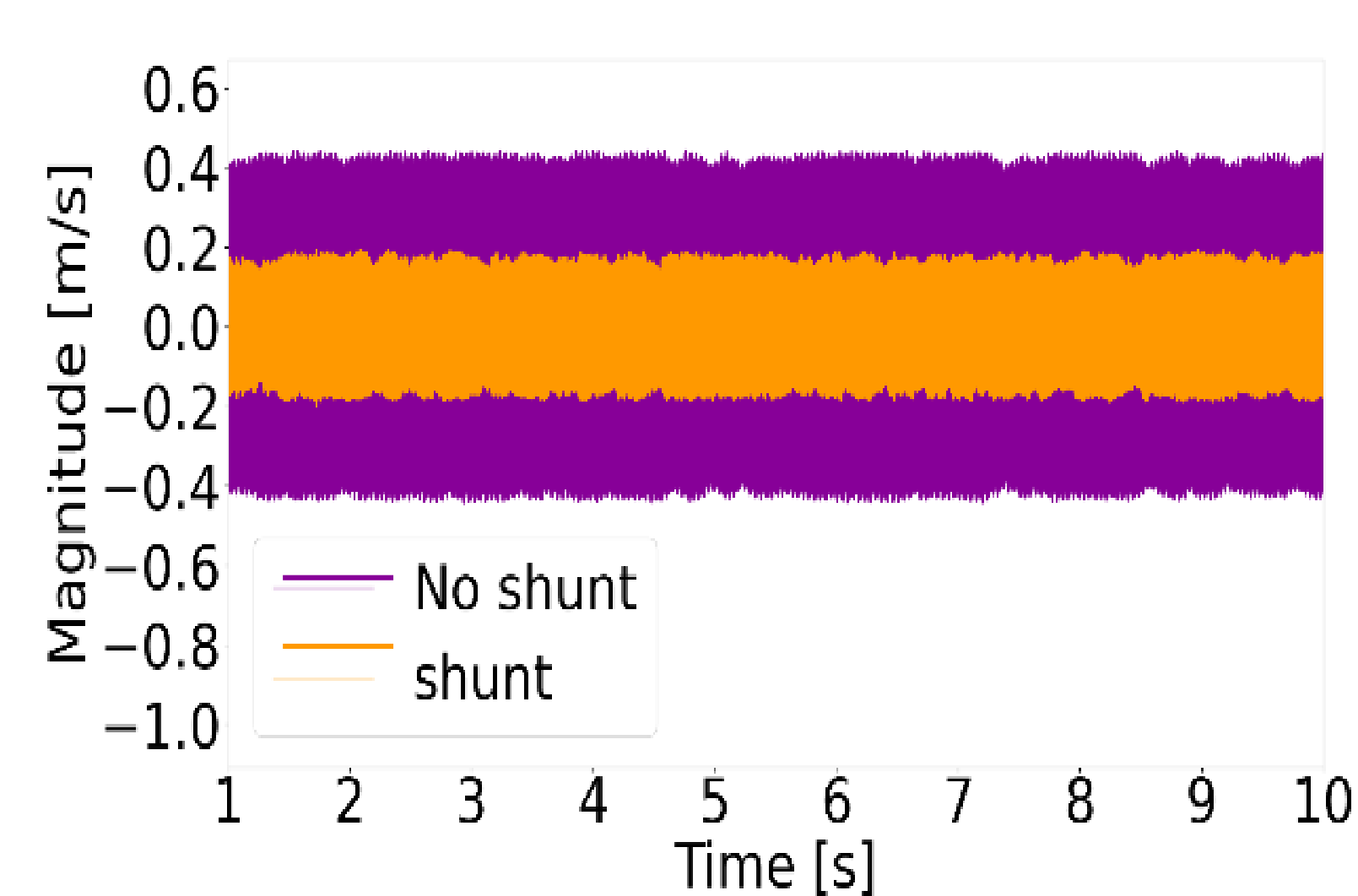
$f_3 = 320$  Hz : Bending

### Shunt tuning

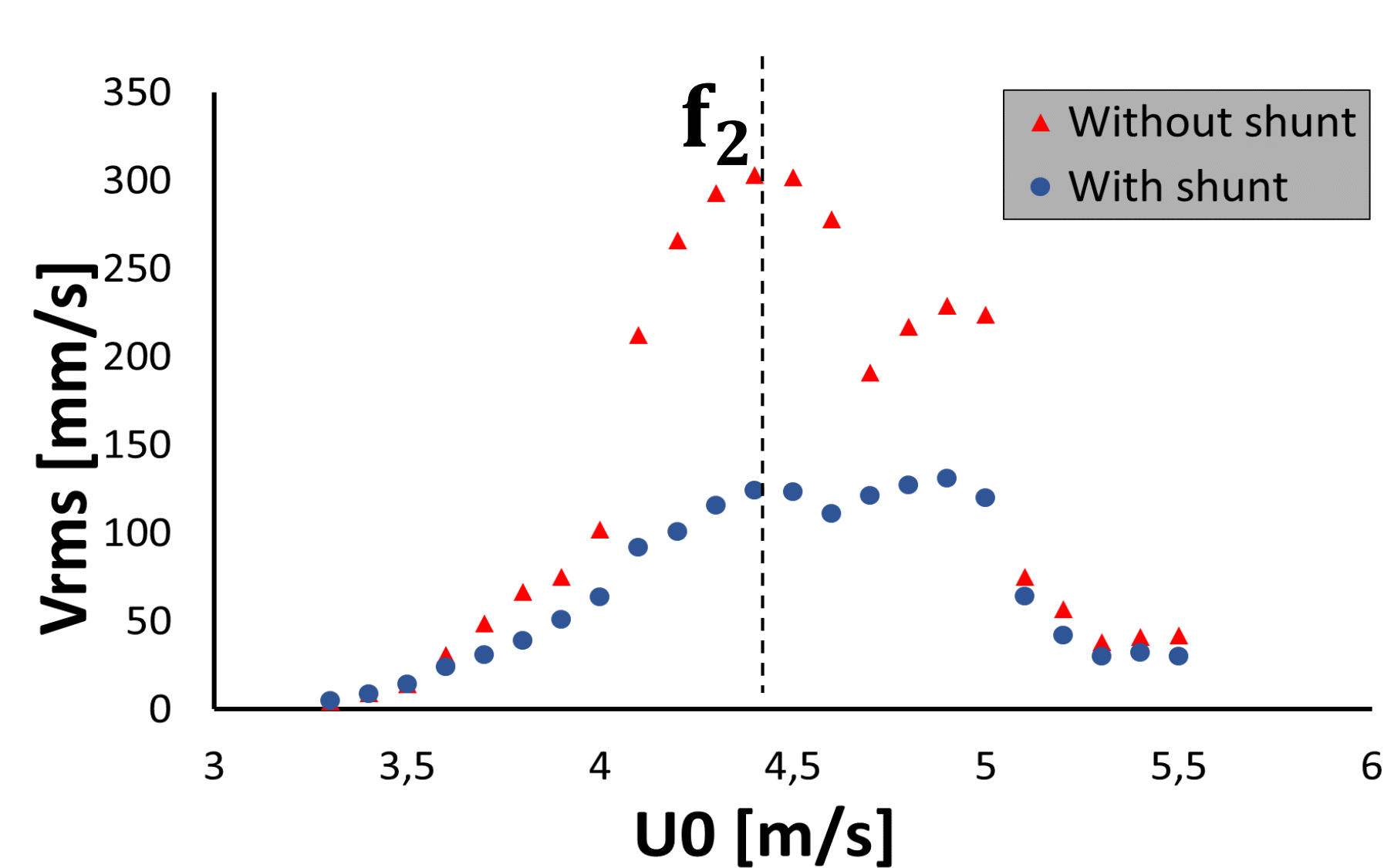
At twisting mode frequency ( $f_2$ )



## Vibration mitigation



Vibration velocity signal at  $U_0 = 4.4$  m/s



Effect of the shunt on  $V_{rms}$  at various flow velocities.

⇒ **High vibration level reduction at resonance (50 % on  $V_{rms}$ ).**

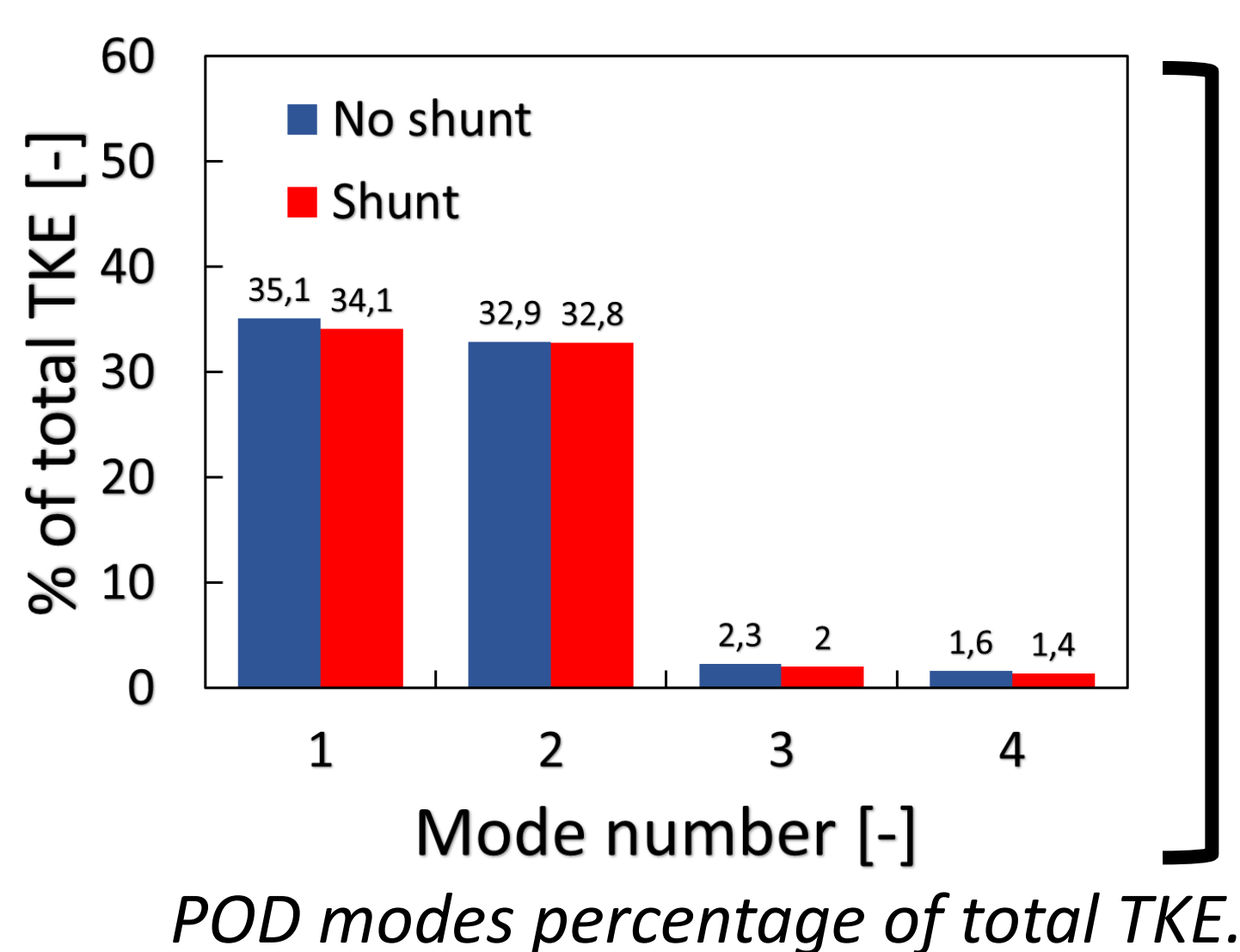
⇒ **Twisting mode resonance observed at  $U_0 = 4.4$  m/s.**

⇒ **Bending mode resonance at  $U_0 = 4.9$  m/s.**

⇒ **Impact of the shunt from 4.0 to 5.0 m/s.**

## Impact on the wake at twisting resonance, $U_0 = 4.4$ m/s

### Turbulent Kinetic Energy (TKE)



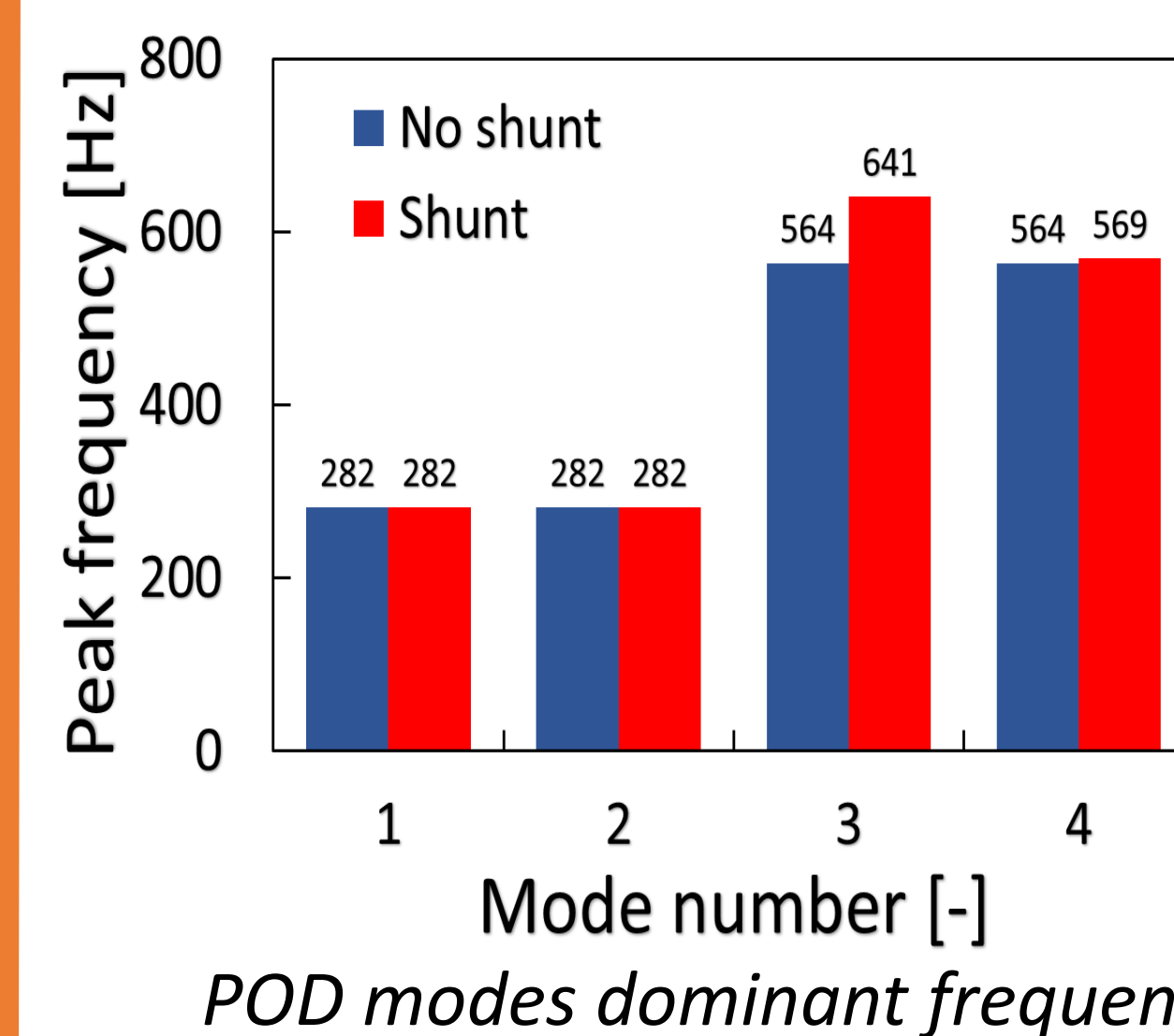
POD modes percentage of total TKE.

⇒ **Modes 1 and 2 : High TKE**

⇒ **Modes 3 and 4 : Low TKE**

⇒ **Weak impact of shunt on TKE**

### Modes dominant frequencies



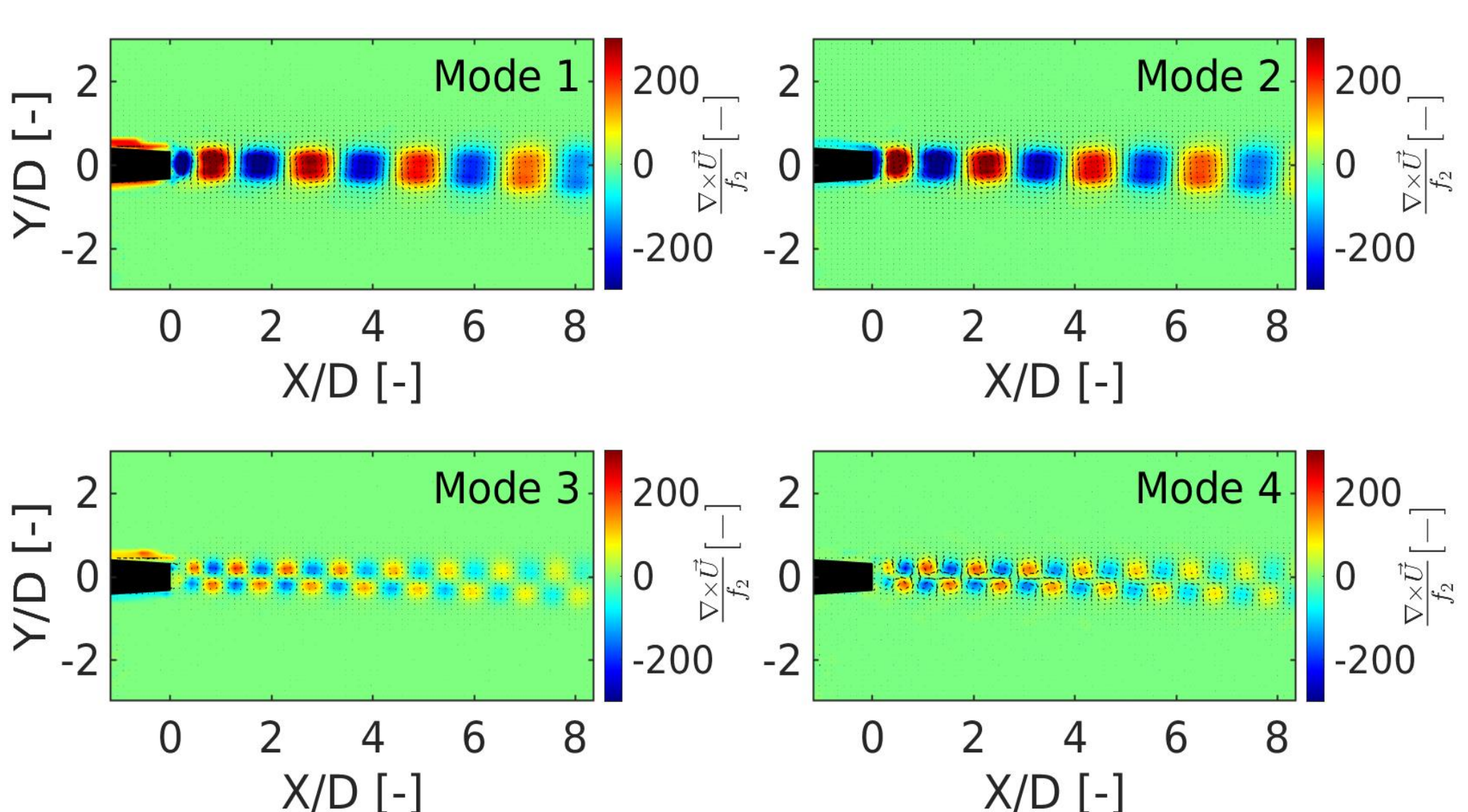
POD modes dominant frequencies.

⇒  **$f_2 = 282$  Hz : twisting frequency, Karman modes.**

⇒  **$2 \times f_2 = 564$  Hz : Harmonic of twisting frequency.**

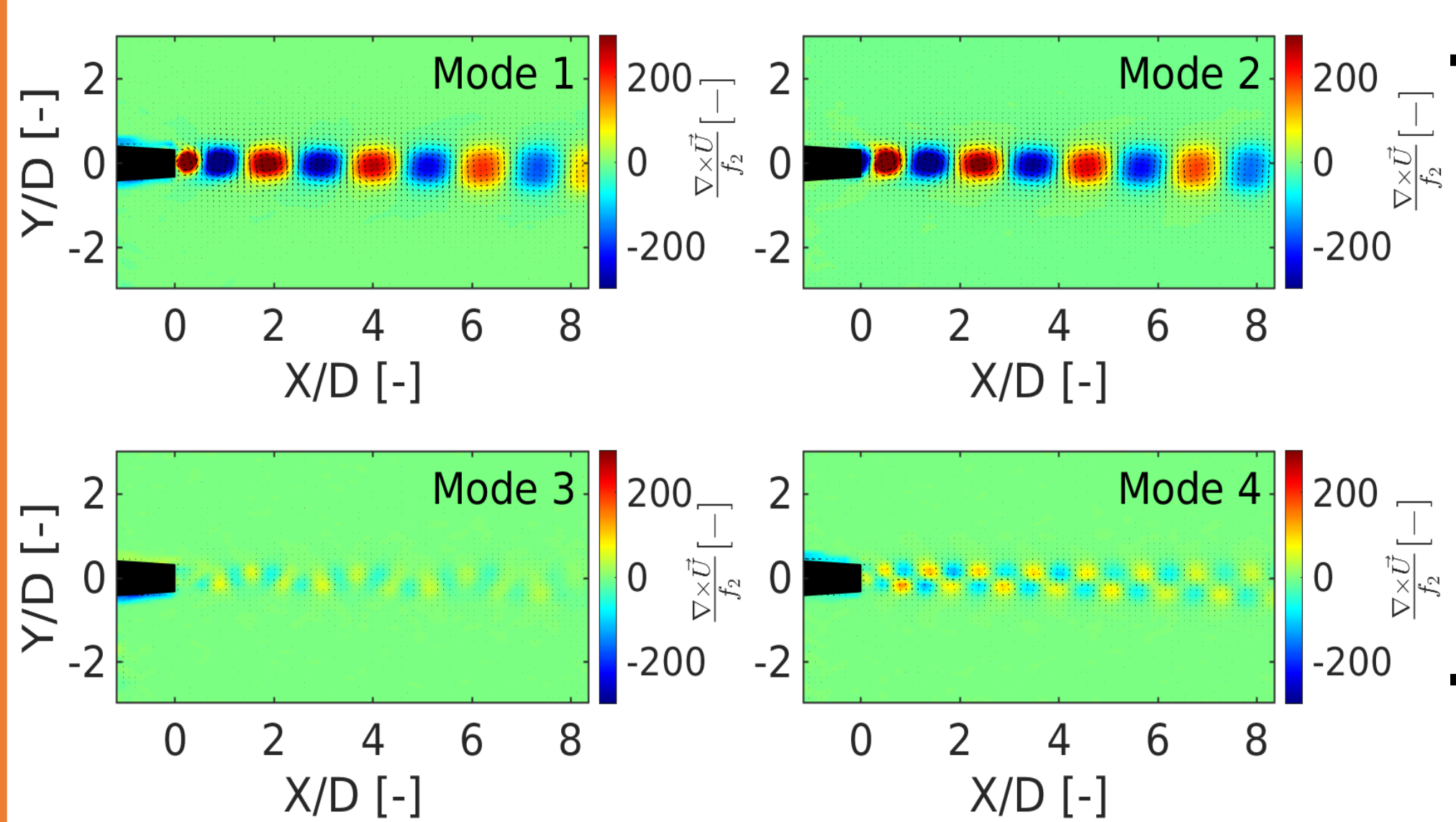
⇒  **$2 \times f_3 = 641$  Hz : Harmonic of bending frequency.**

### POD spatial modes, without shunt



(x,y) cartography of vorticity at  $U_0 = 4.4$  m/s, without shunt.

### POD spatial modes, with shunt



(x,y) cartography of vorticity at  $U_0 = 4.4$  m/s, with shunt.

⇒ **Modes 1 and 2 : Karman type coherent structures, no alteration by the shunt.**

⇒ **Modification of spatial modes 3 and 4 by the shunt.**

## Further work

⇒ **Investigate the impact of the shunt on the wake by vortex detection algorithm.**

⇒ **Apply POD to various main flow velocities.**

## Reference

- L. Pernod, B. Lossouarn, J.-A. Astolfi, J.-F. Deü, Vibration damping of marine lifting surfaces with resonant piezoelectric shunts, JSV, 2021

- Y. Watine, C. Gabillet, J.-A. Astolfi, L. Pernod, B. Lossouarn, J.-F. Deü. Vortex Induced Vibrations Analysis of a Cantilevered Blunt Plate by Proper Orthogonal Decomposition of TR-PIV and Structural Modal Analysis. Proc. ASME-FEDSM 2020