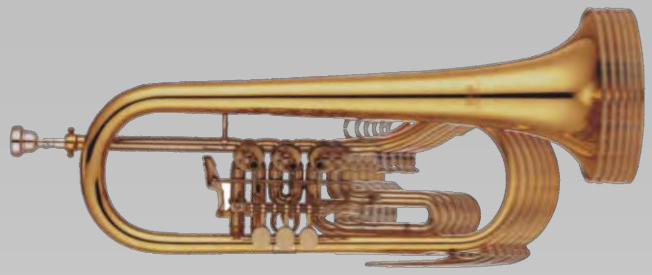

Modelling the Wall Vibrations of Brass Wind Instruments

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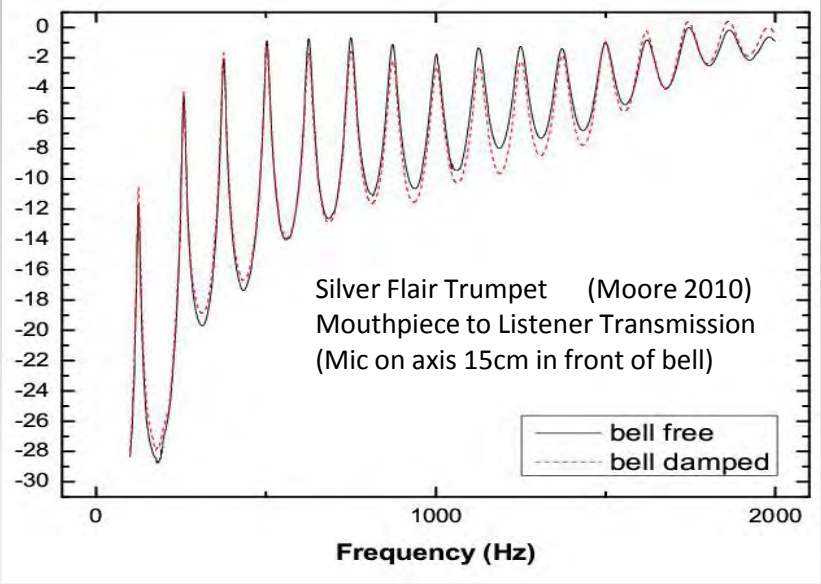
COMSOL CONFERENCE STUTTGART 2011

Motivation

- differences observed between damped and undamped instruments (players & measurements)

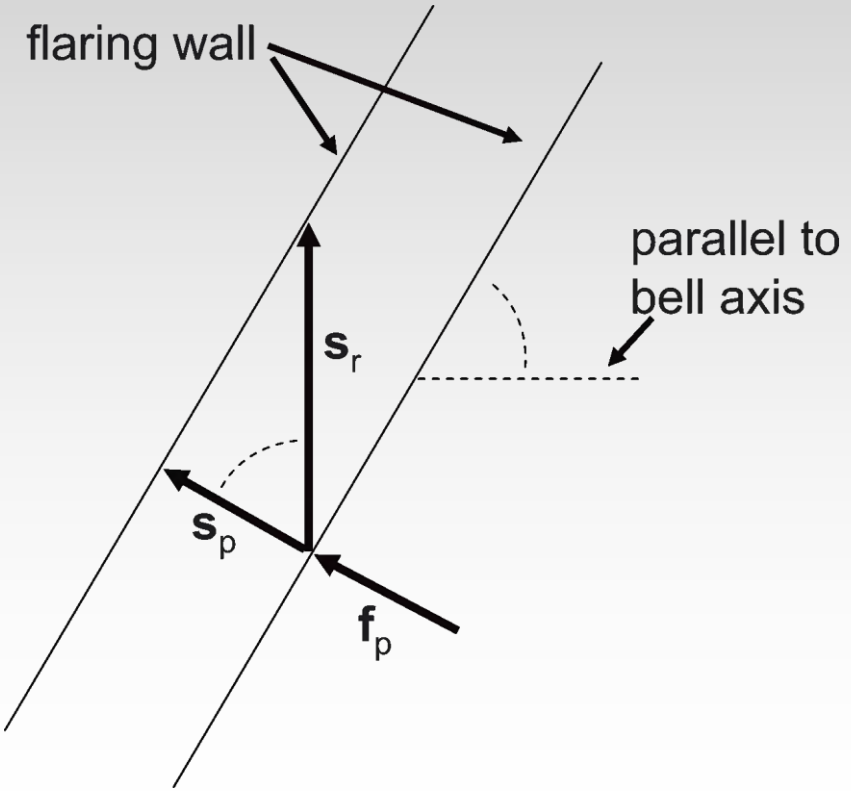


- wall vibration mechanism not easily explained
- COMSOL can couple structural mechanics with pressure acoustics

Hypothesis

axi-symmetric oscillations are responsible for the observed differences

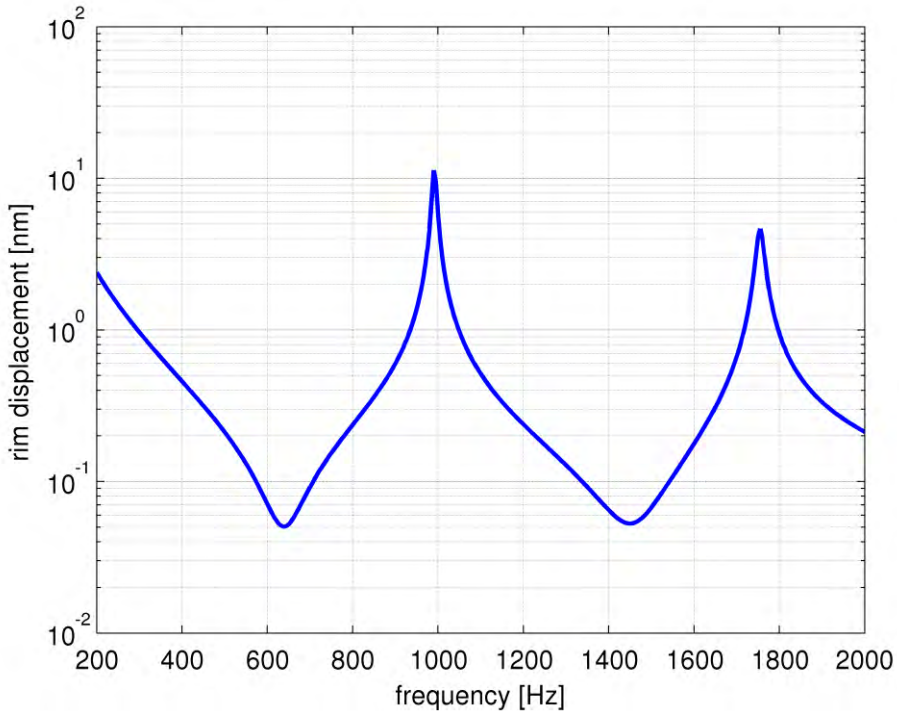
Even though smaller in amplitude, their effect is magnified at the high-flaring regions of the bell



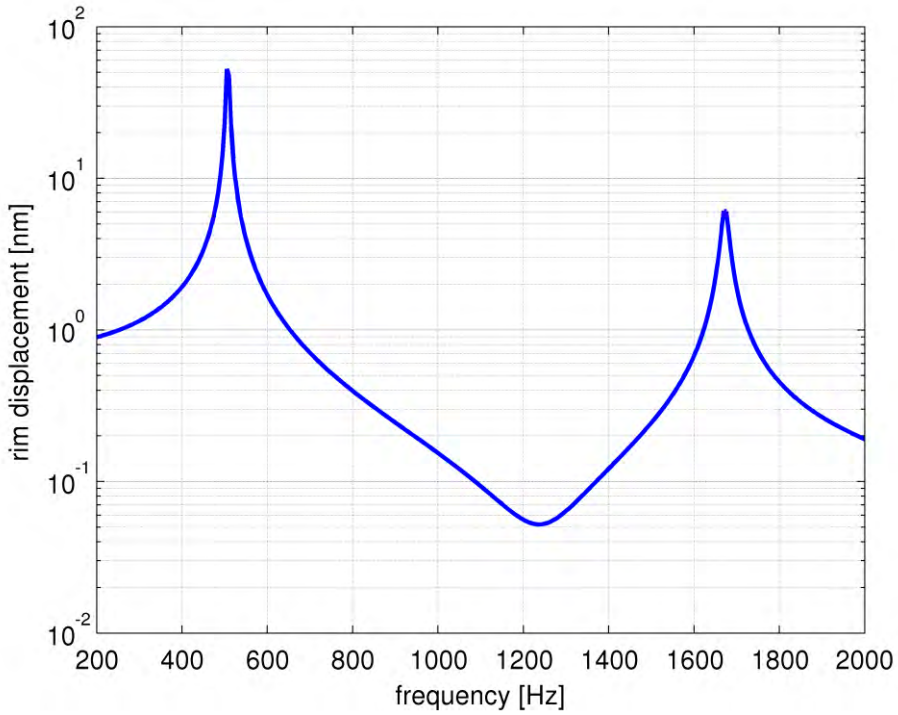
Axial resonance

Structural frequency domain study

trumpet free to vibrate



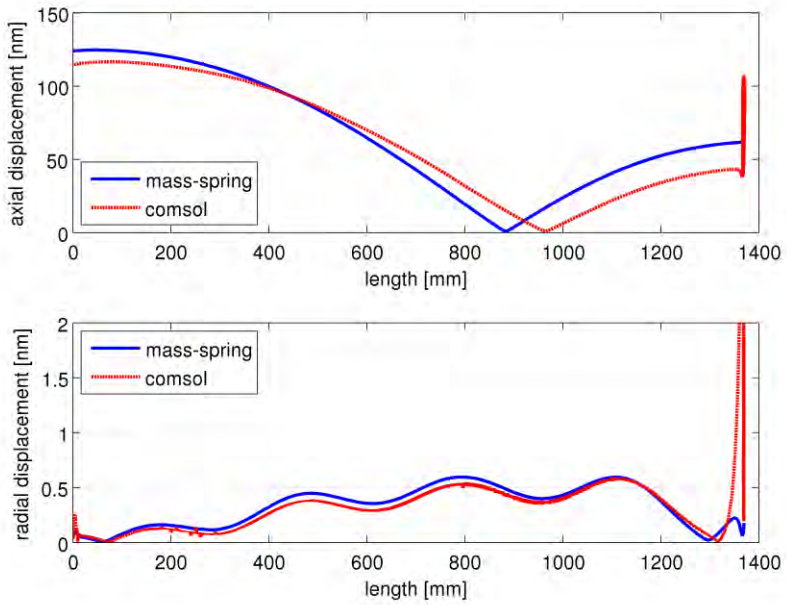
40 cm fixed at mouthpiece end

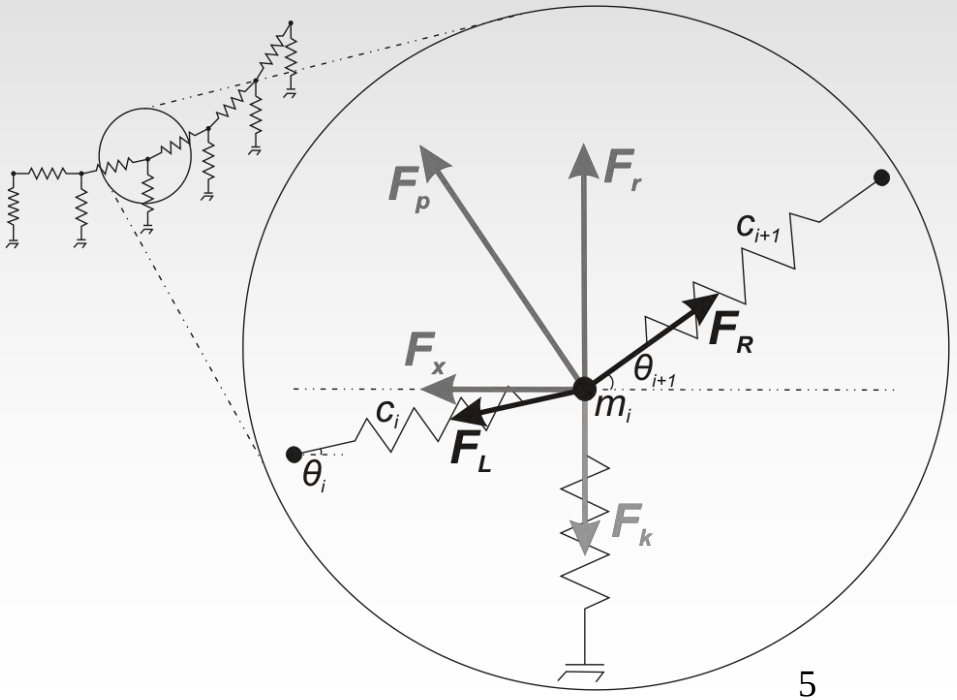


Comparison with a simplified model

Modelling the trumpet walls using a mass-spring model (Finite-Difference method)

- similar wall displacement as in COMSOL
- differences mainly located at the rim of the bell



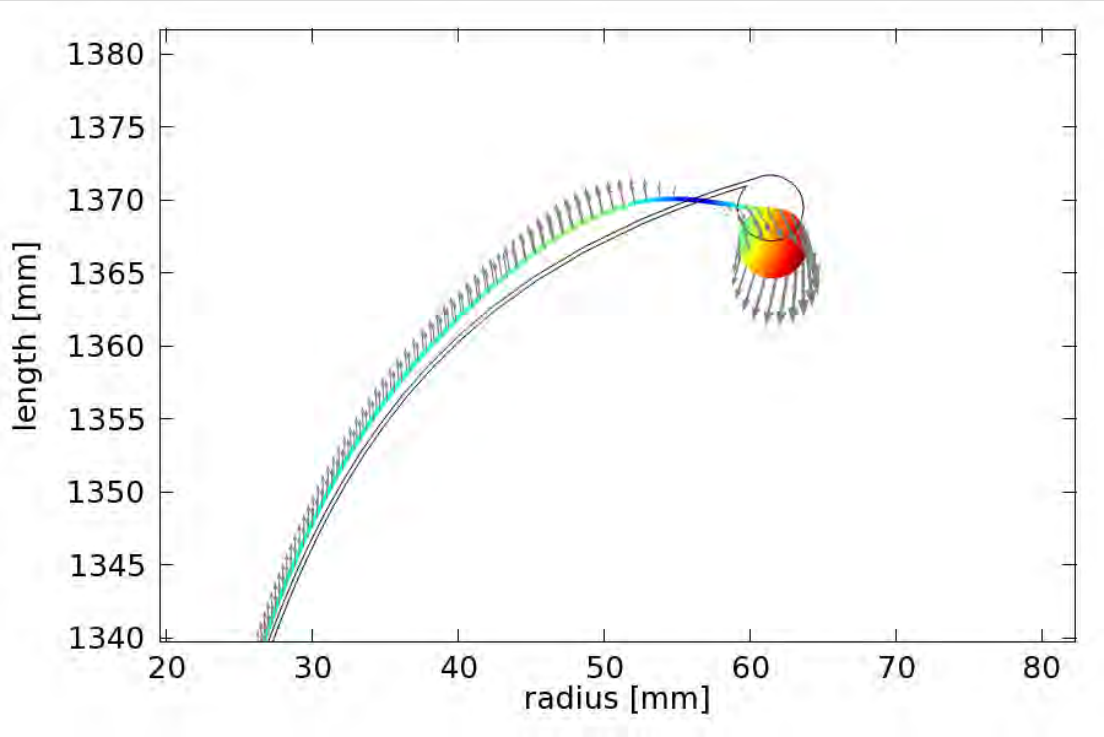


Axial resonance (2)

Resonance frequencies affected by:

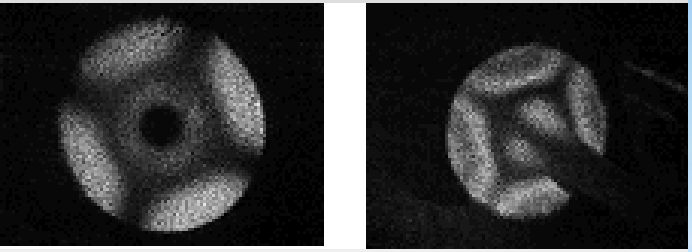
- Rim wire (rotational motion)
- Calculation method

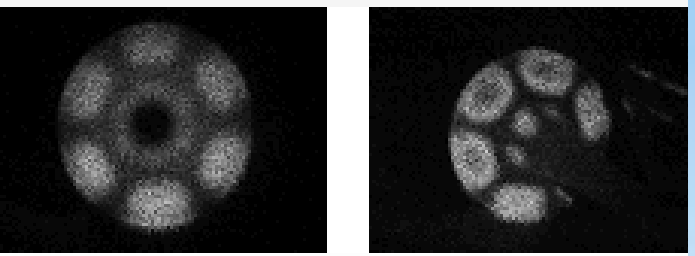
	FEM 2D	FEM 3D	FD
f_1	991	1011	1018
f_2	1754	1722	2413

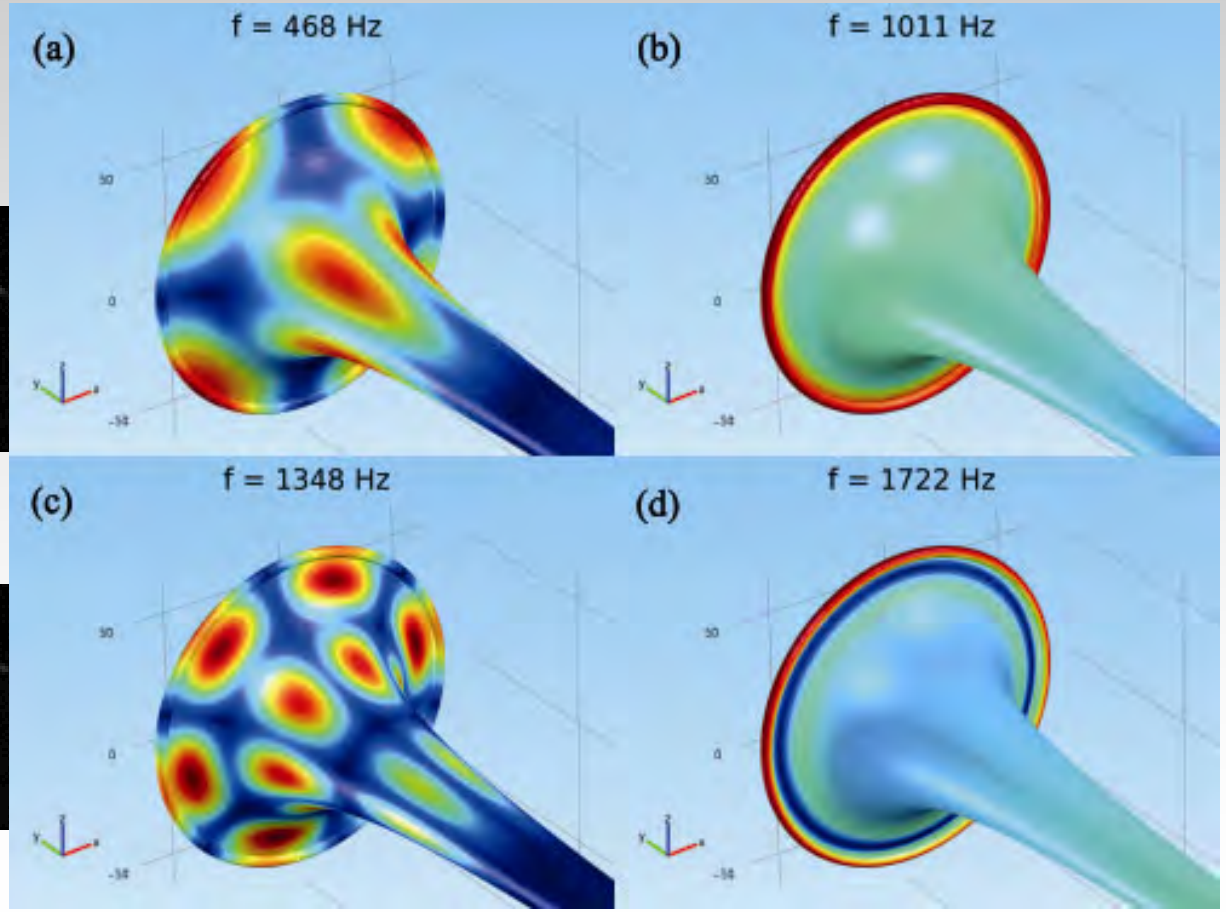


Determination of rim radius

matching of elliptical modes as measured by Moore et al. 2005 [Acustica **91**(1)]



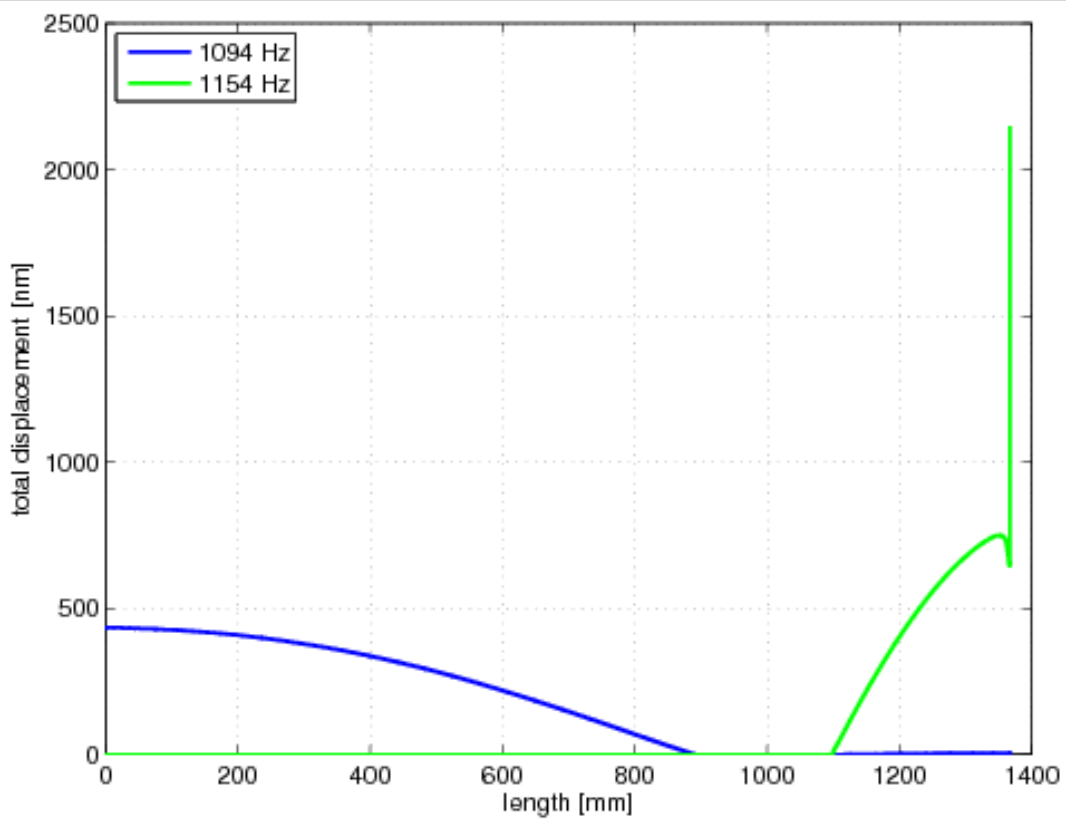




Boundary conditions

Fixing portions of the brass using braces can change the behaviour drastically! The same is true for adding masses.

Example: Two fixing points 20cm and 40cm away from the rim:
„Mouthpiece“ resonance
and bell resonance
at separate frequencies!



On top of that:

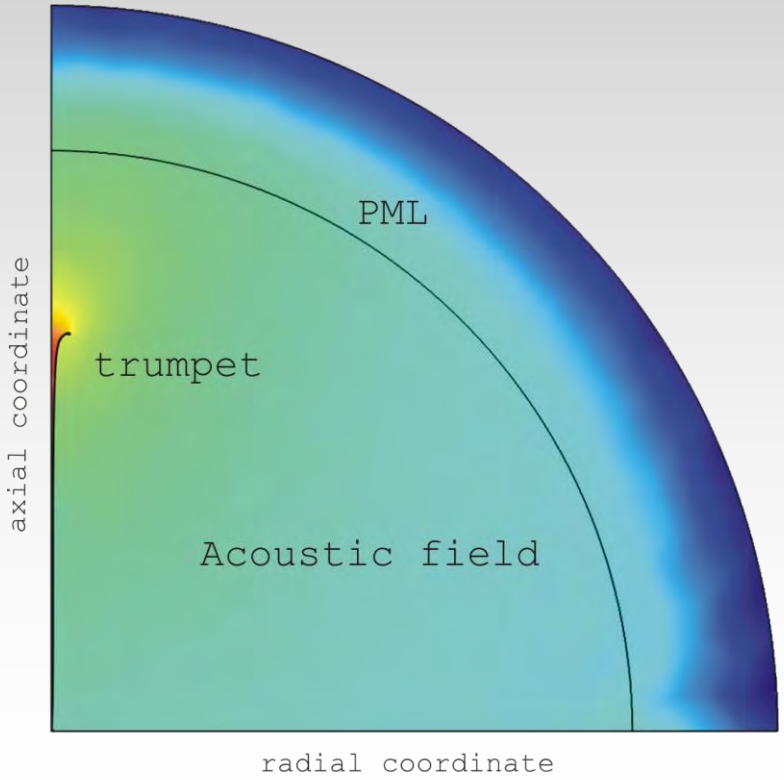
Player’s embouchure
and his grip add mass
and unknown damping!

Acoustic-Structure interation

frequency domain simulations

trumpet modelled as linear elastic material

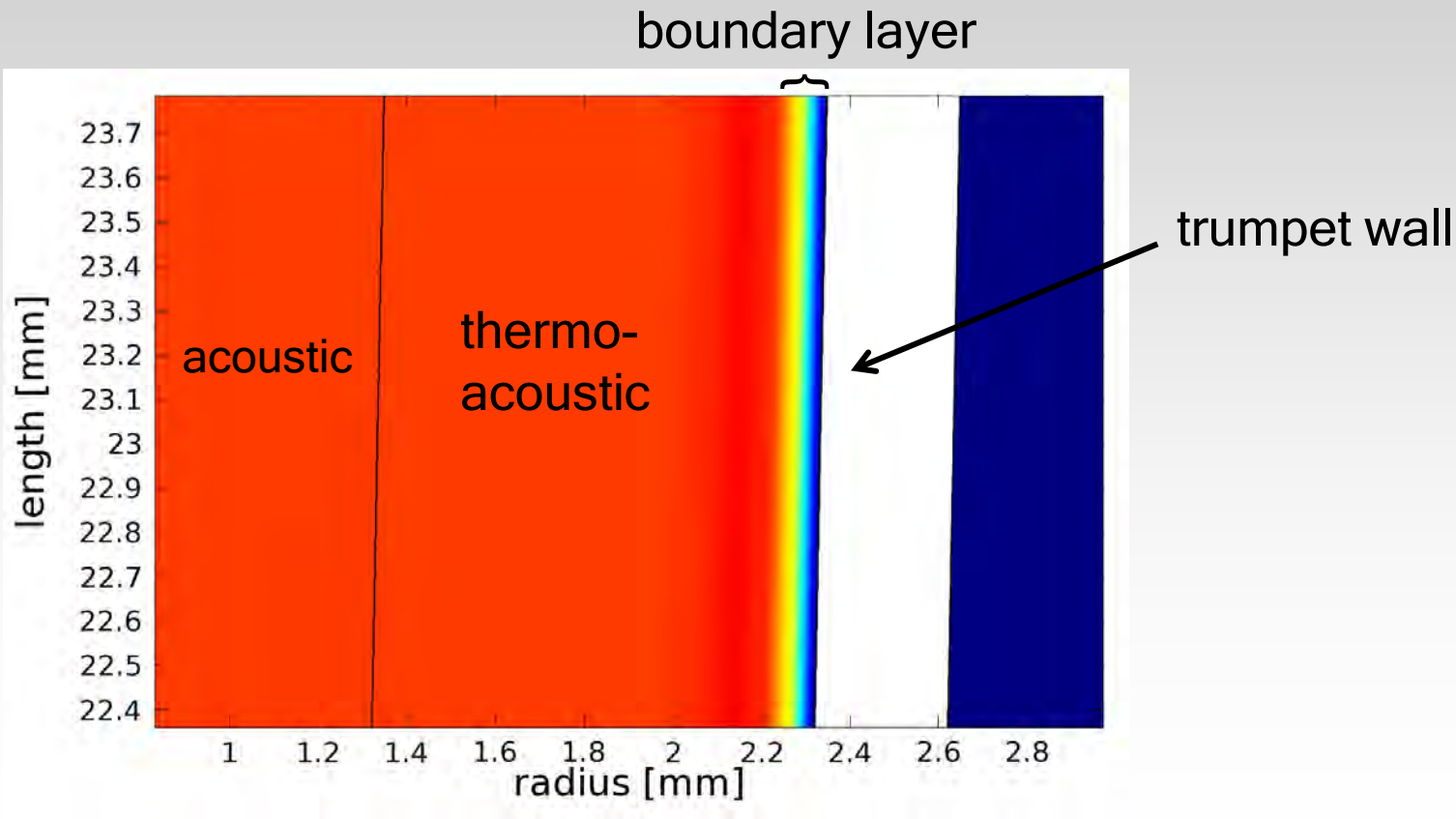
‼ frictional losses at the walls are neglected ‼



Viscous boundary layer

tube dimensions are small:

viscous and thermal losses at the walls **must** be taken into account.



Multiphysics coupling

Internal pressure

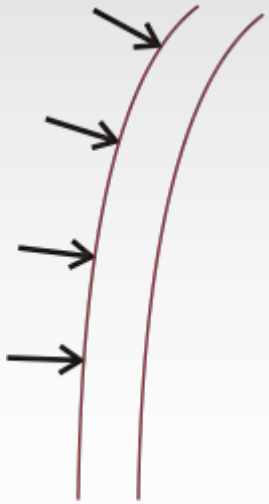
Boundary load

$$\boldsymbol{F}_A = -p\boldsymbol{n}$$

Wall velocity

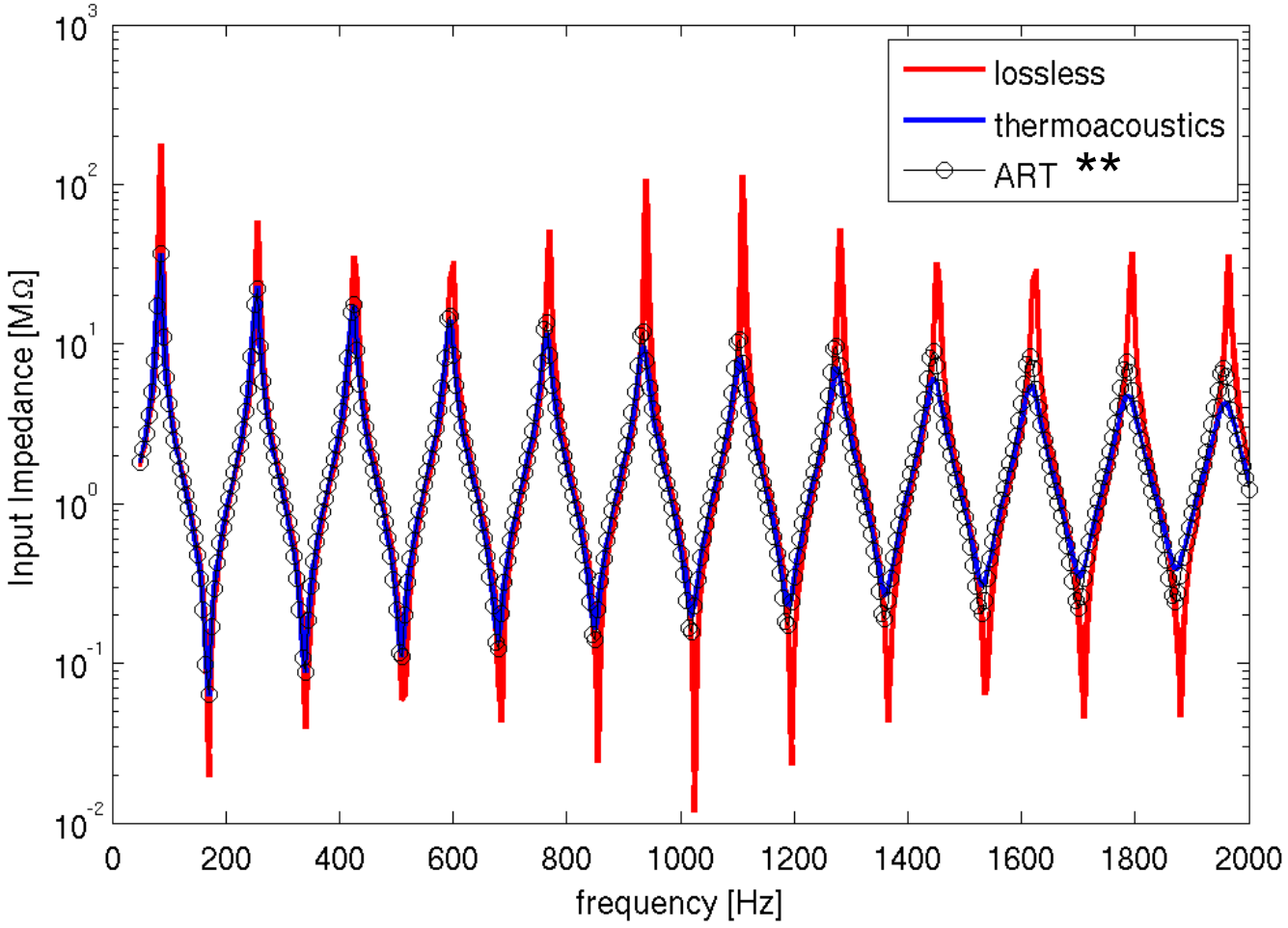
Air velocity at wall

$$\boldsymbol{u}_{air} = \boldsymbol{u}_{wall}$$



Comparison with lossless formulation

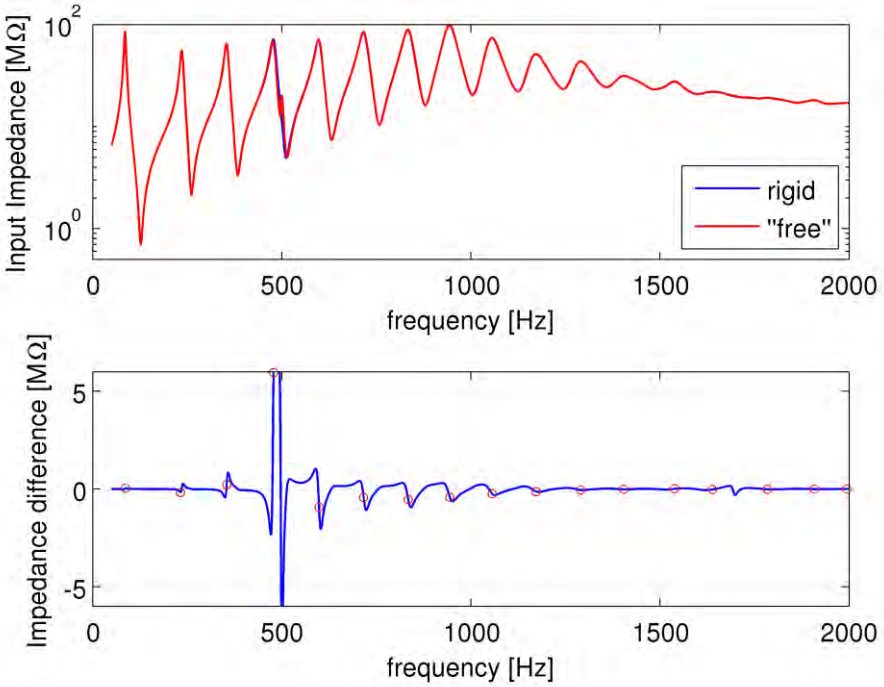
Input Impedance of a 1 meter long cylindrical tube



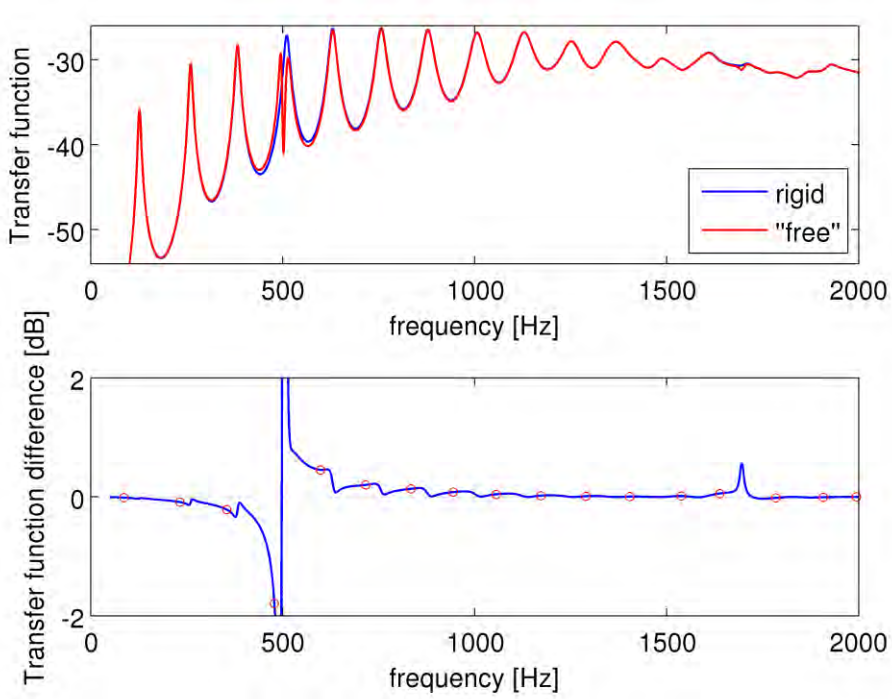
** http://artool.sourceforge.net/

Fixed vs. vibrating walls (COMSOL)

Input Impedance



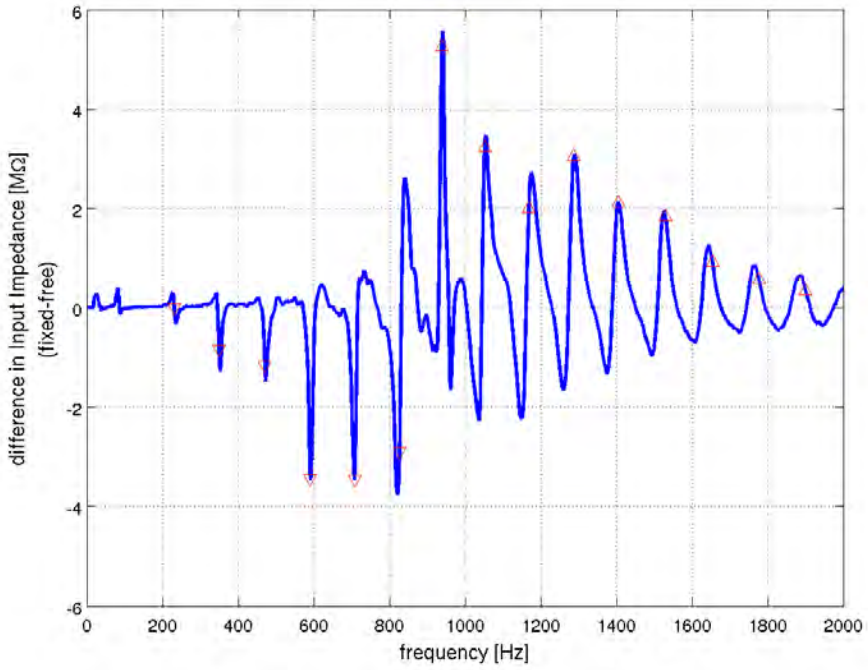
Transfer function



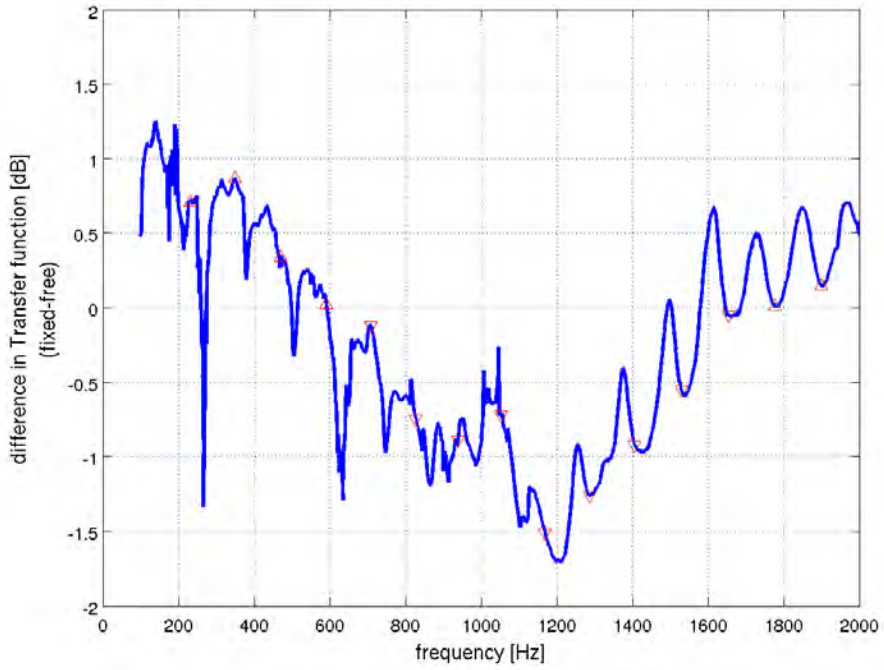
Damped vs. vibrating walls (measured)

[Kausel, Zietlow and Moore, JASA **128**(5)]

Input Impedance

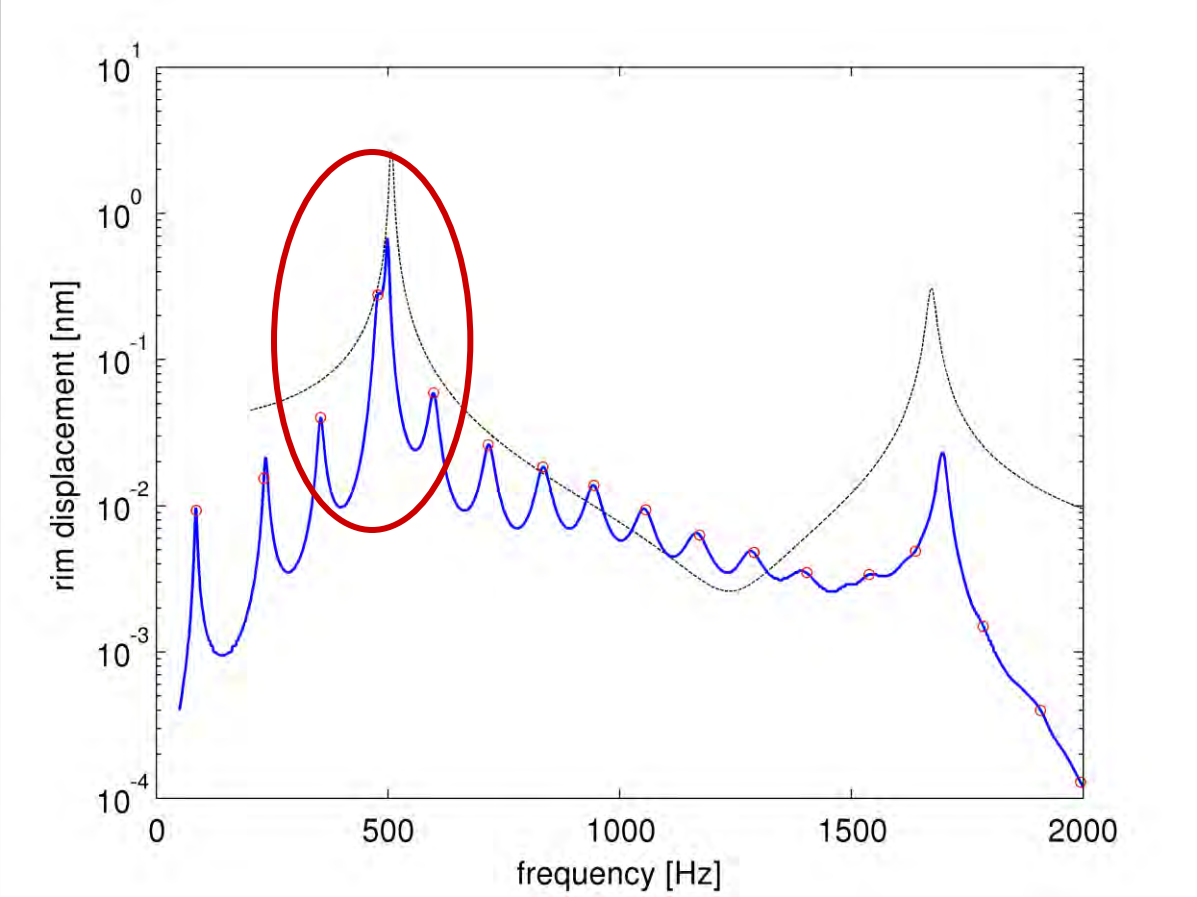


Transfer function



Displacement amplitude (COMSOL)

Bell displacement caused by a vibrating piston stimulus



Conclusions

Axisymmetric modes:

- can affect the Input Impedance and Transfer function of the instrument
- may exhibit a wide band effect
- are strongly influenced by boundary conditions
- can explain measurement differences between damped and undamped brass wind instruments

Thank you for your attention!

Comments

Questions ???