Resonating with Students in the Undergraduate Physics Laboratory:

Comprehending Acoustic Vibrations

BETHEL UNIVERSITY Physics

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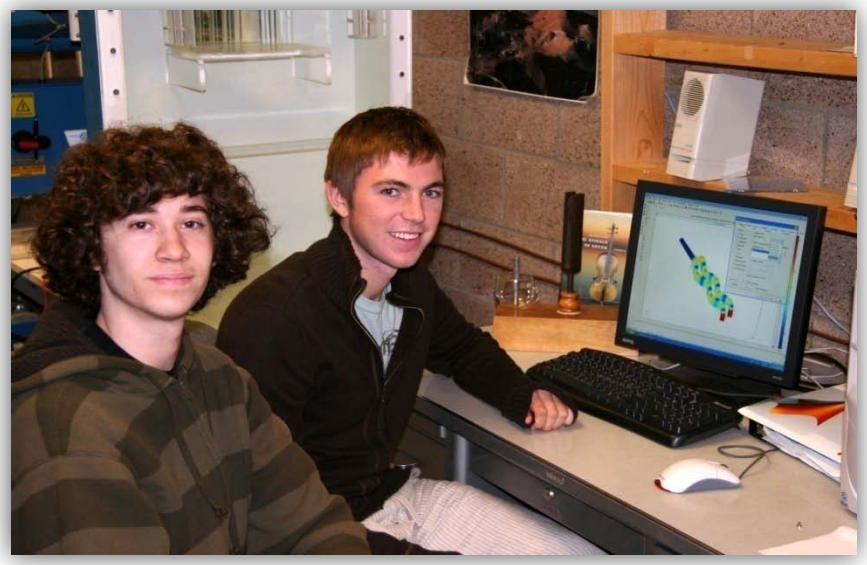


BETHEL UNIVERSITY

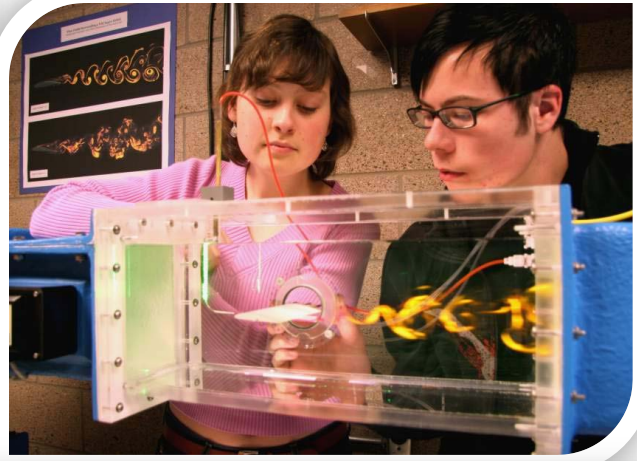
Dr. Richard Peterson, Jack Houlton, Justin Knapp,
Brandon Peplinski, Chris Scheevel, David Swenson

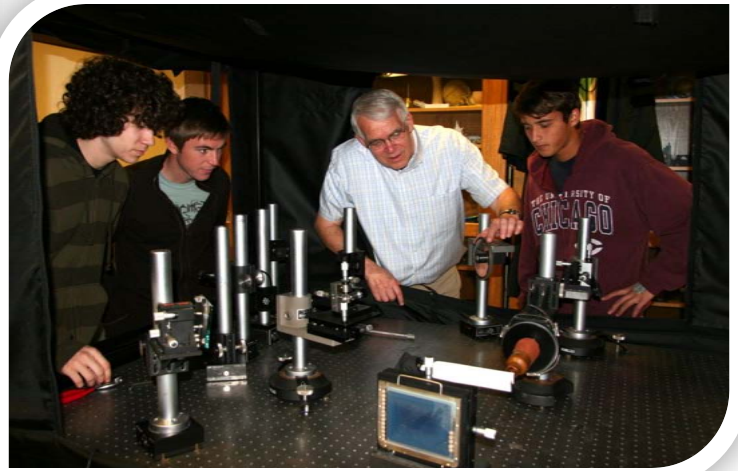
Outline

- Introduction: The Advanced Lab Concept
- Approach
  - Optical Diagnostics: Stroboscopic Holography
  - Computational Modeling: COMSOL Eigenfrequency Analysis
- Examples
  - Vibrational Modes of a Handbell
  - Vibrational Modes of a Coffee Cup
  - Vibrational Modes of a Tuning Fork
- Concluding Remarks

Introduction:

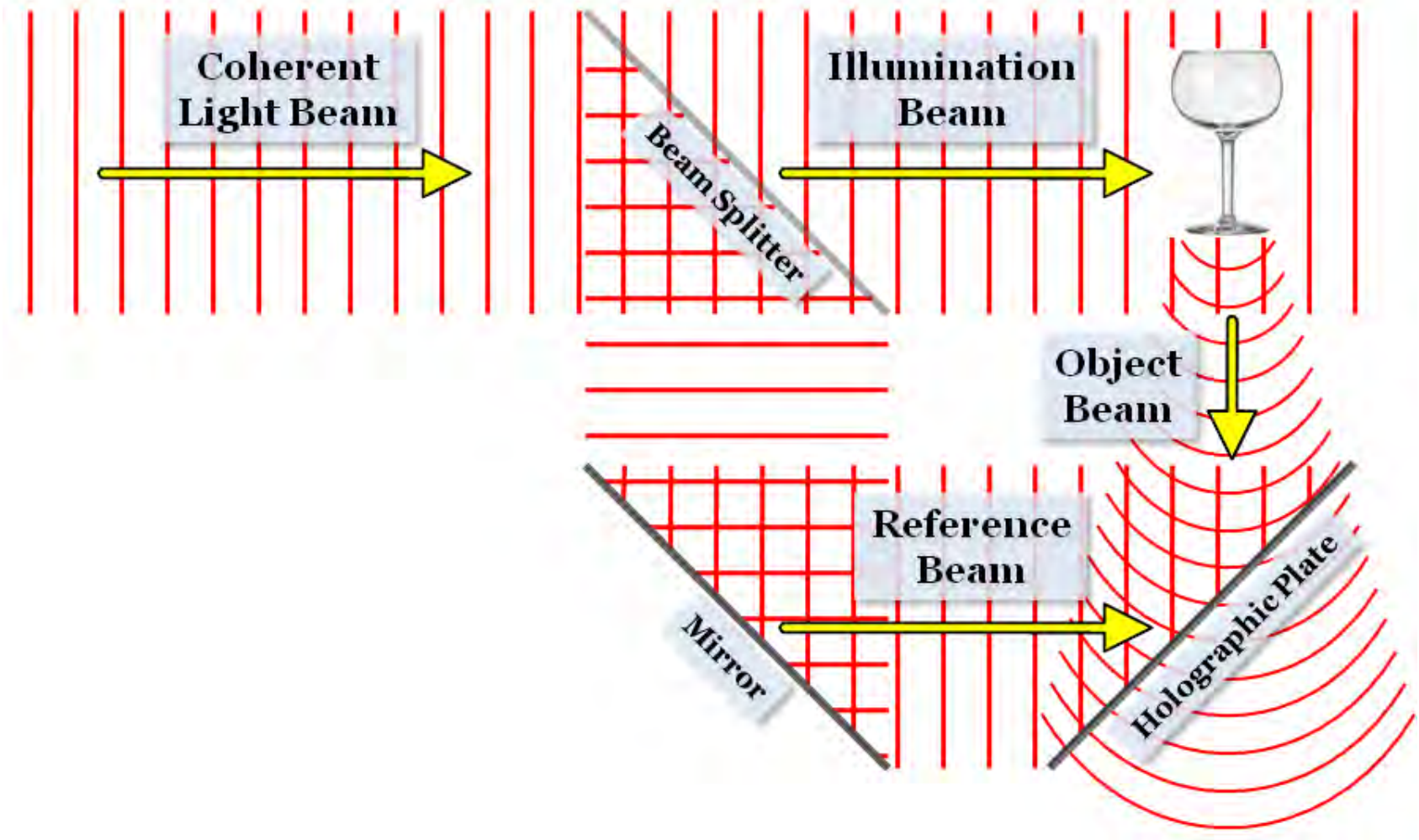
The Advanced Lab Concept





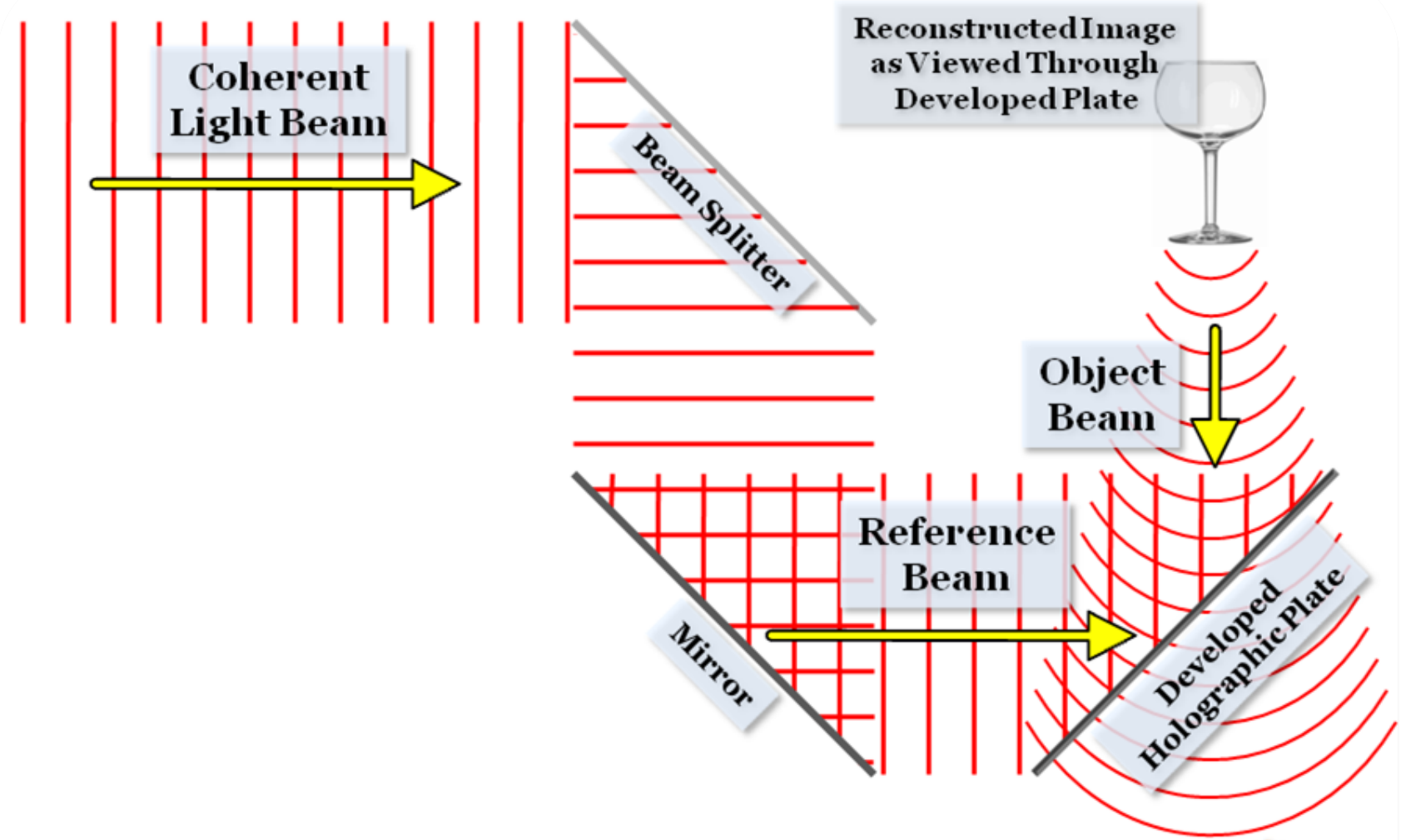
Optical Diagnostics Approach:

Real-time Stroboscopic Holography



Optical Diagnostics Approach:

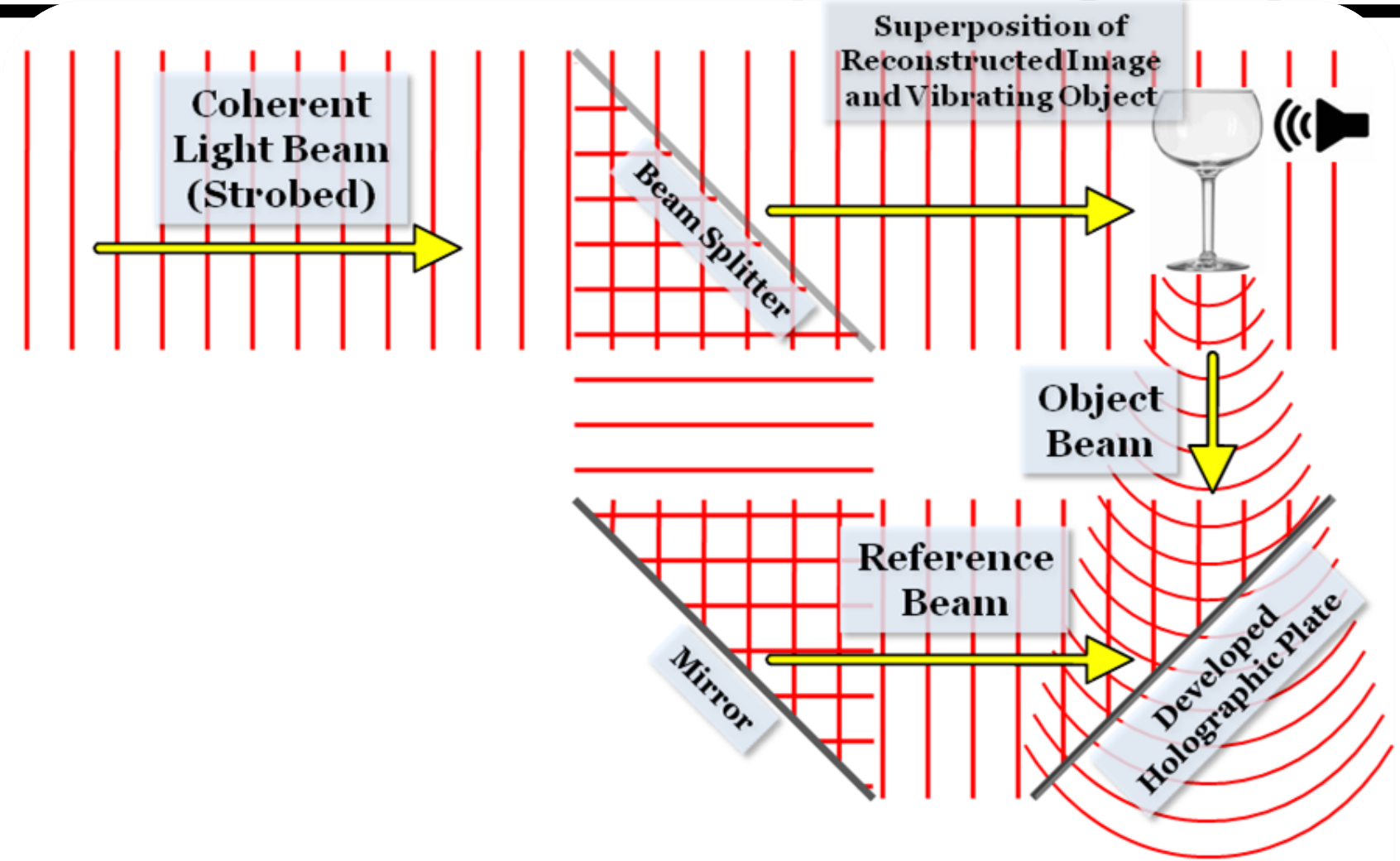
Real-time Stroboscopic Holography



Viewing of Reference Hologram

Optical Diagnostics Approach:

Real-time Stroboscopic Holography



Stroboscopic Viewing

Computational Approach:
COMSOL Eigenfrequency Analysis

- **Eigenvalue Analyses**
  - **Linear Elasticity**
  - **Undamped vibrations**
  - **Three objects**
    - **Handbell**
    - **Coffee Cup**
    - **Tuning Fork**

$$\rho\frac{\partial^2\vec{u}}{\partial t^2}-\nabla\cdot\vec{\vec{\sigma}}=\vec{F}$$

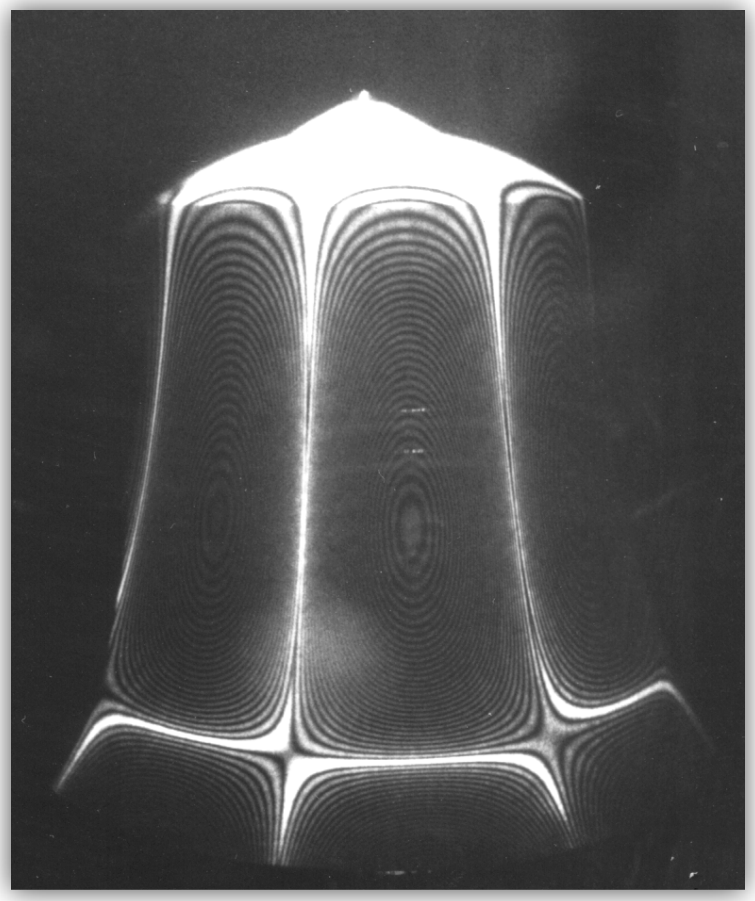
$$\vec{\vec{M}}\ddot{\vec{x}}+\vec{\vec{K}}\vec{x}=\vec{0}$$

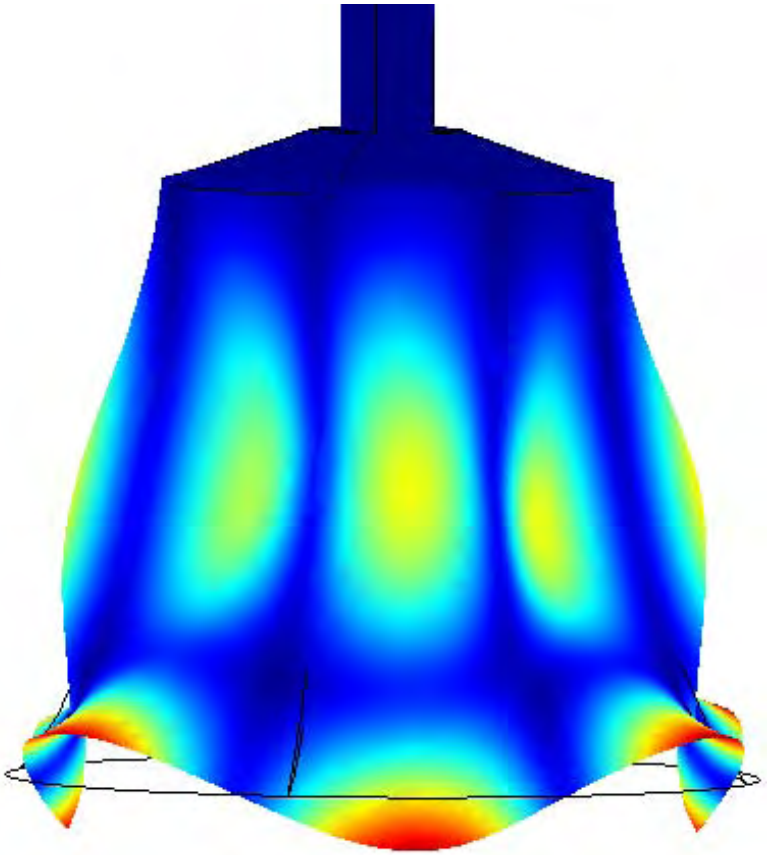
$$\left(\vec{\vec{A}}-\lambda\vec{\vec{I}}\right)\vec{X}=\vec{0}$$

$$\lambda=4\pi^2f^2$$

Results:

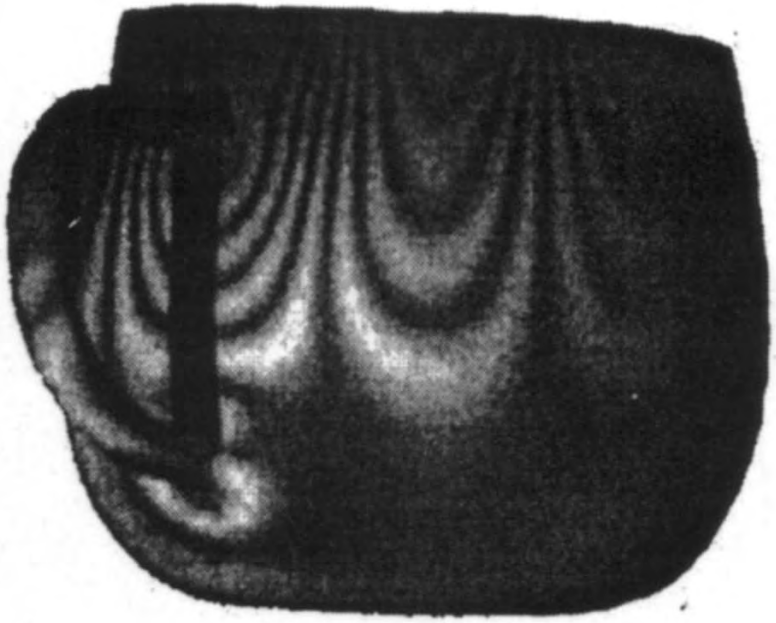
Vibrational Modes of a Handbell

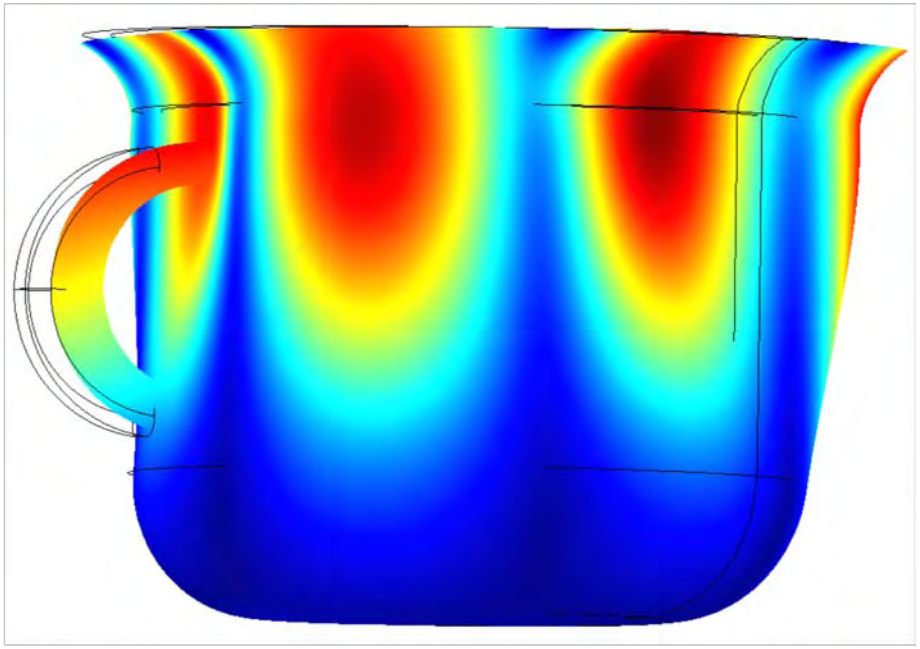




Results:

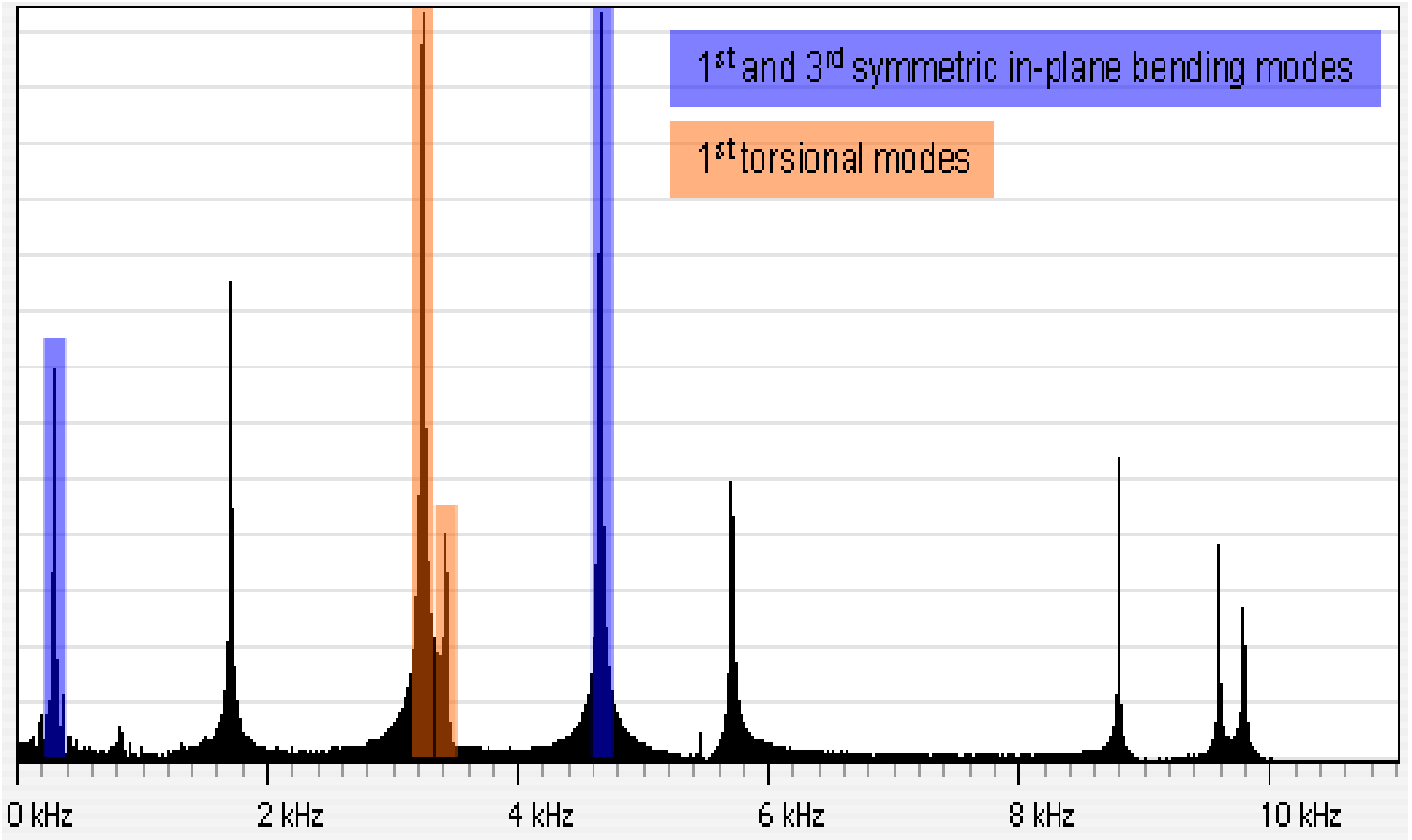
Vibrational Modes of a Coffee Cup





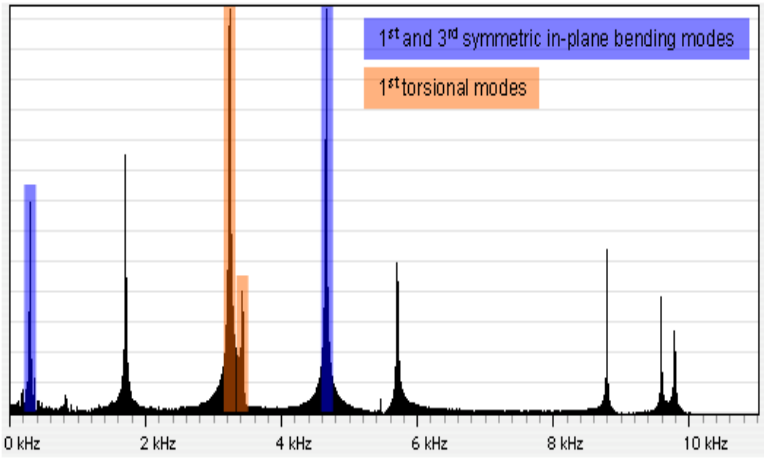
Results:

Vibrational Modes of a Tuning Fork

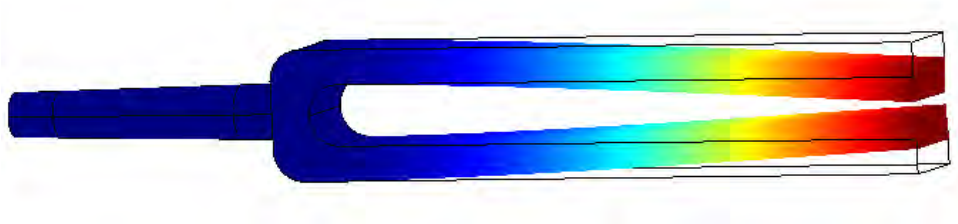


Results:

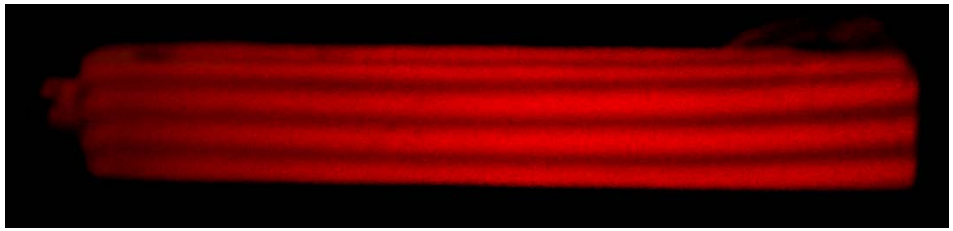
Vibrational Modes of a Tuning Fork



1st in-plane symmetric mode



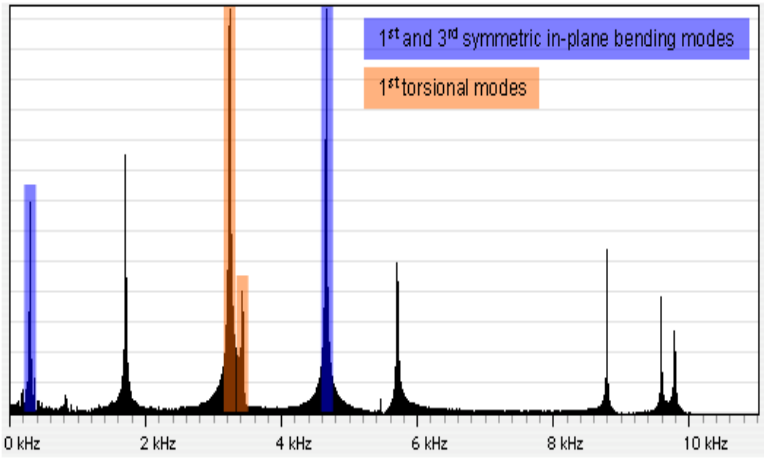
COMSOL (278 Hz)



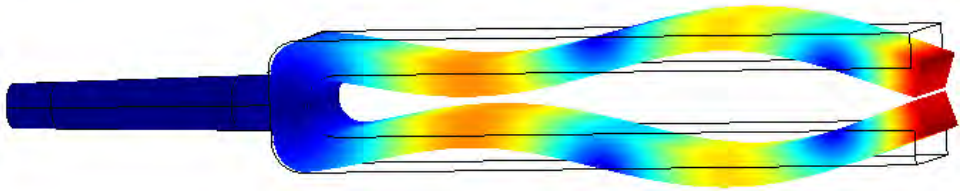
Stroboscopic Holography (273 Hz)

Results:

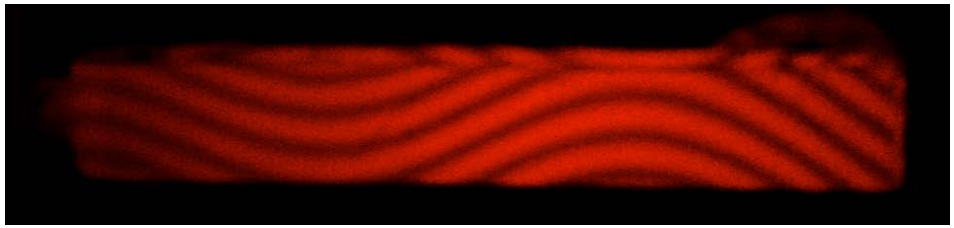
Vibrational Modes of a Tuning Fork



3rd in-plane symmetric mode



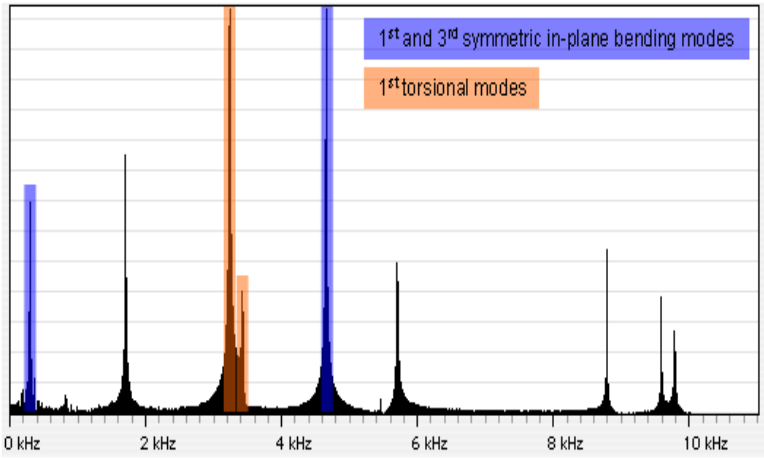
COMSOL (4560 Hz)



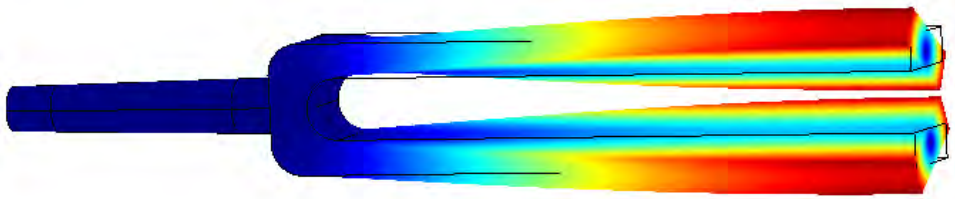
Stroboscopic Holography (4647 Hz)

Results:

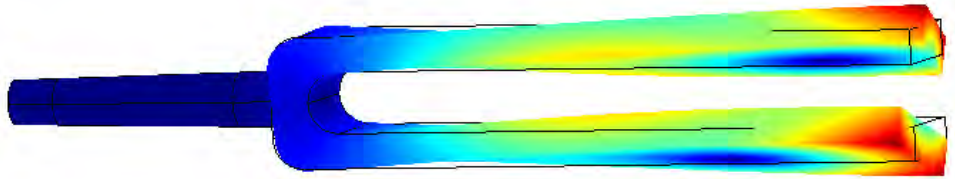
Vibrational Modes of a Tuning Fork



1st torsional modes



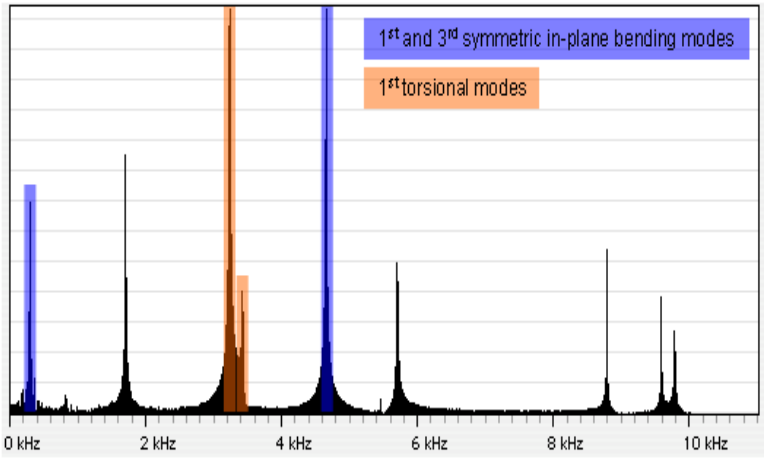
Out-of-phase torsional mode (3240 Hz)



In-phase torsional mode (3462 Hz)

Results:

Vibrational Modes of a Tuning Fork



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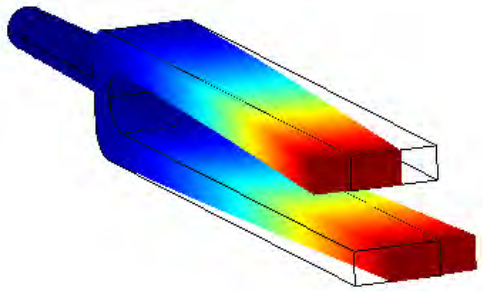
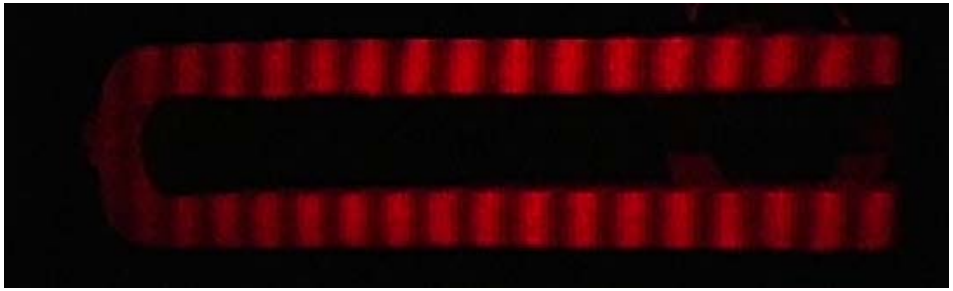
1st out-of plane bending mode



COMSOL (582 Hz)



Stroboscopic Holography (530 Hz)

Concluding Remarks

- COMSOL and optical diagnostics can serve as complementary tools in the undergraduate advanced laboratory.
- Together, COMSOL and optical diagnostics can provide students of applied physics, optics, and engineering with a fuller and richer understanding of acoustic vibrations.
- COMSOL can serve to illuminate aspects of acoustic vibrations that might be overlooked by purely experimental approaches (and vice versa).