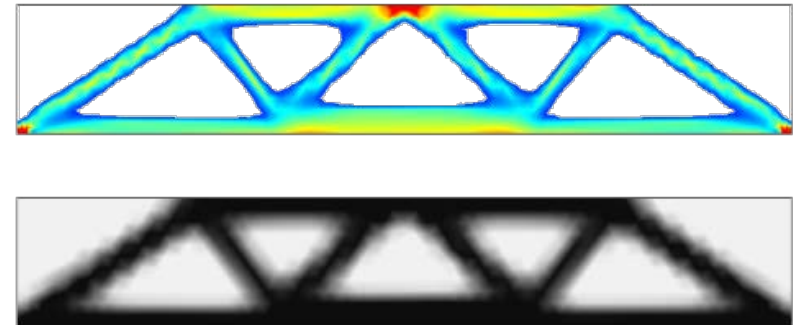


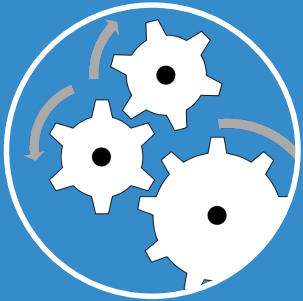
Multi-scale Modeling and Optimization



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Andy.cai@comsol.com
COMSOL, Inc.



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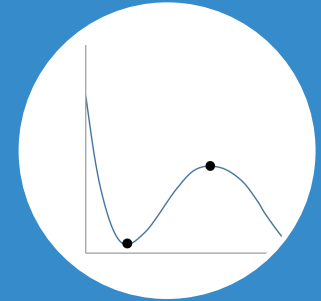
Understand



Predict



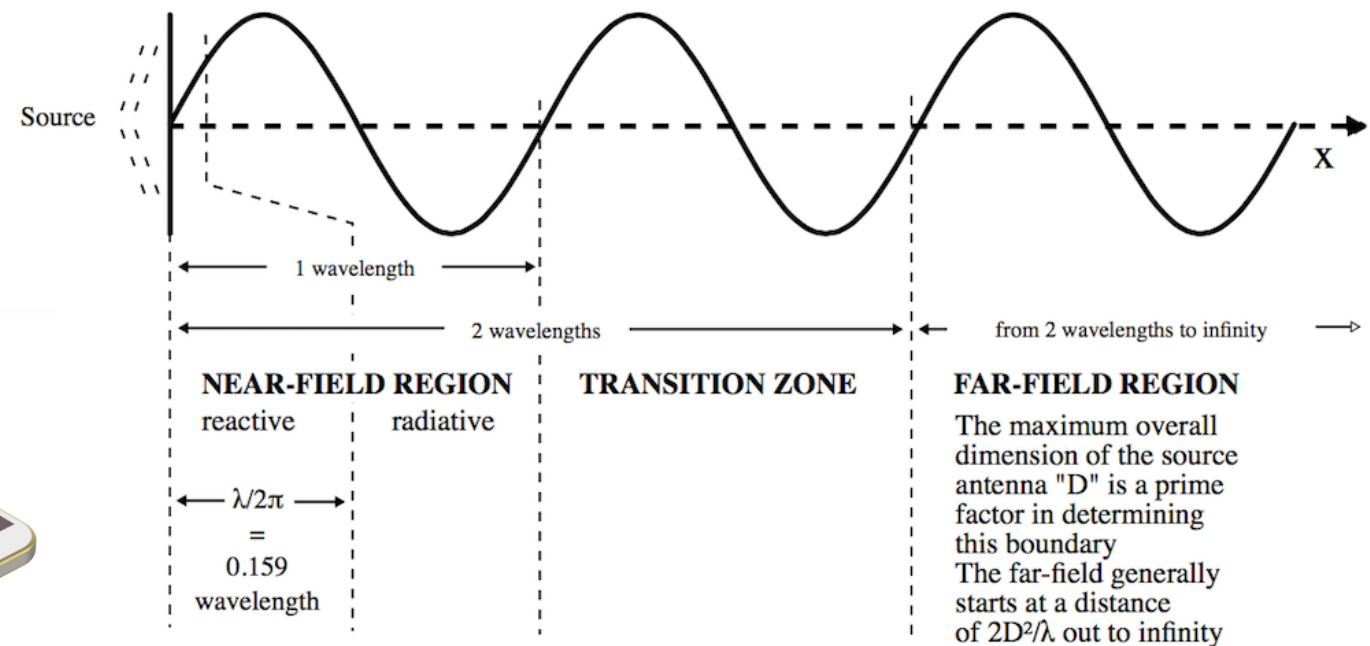
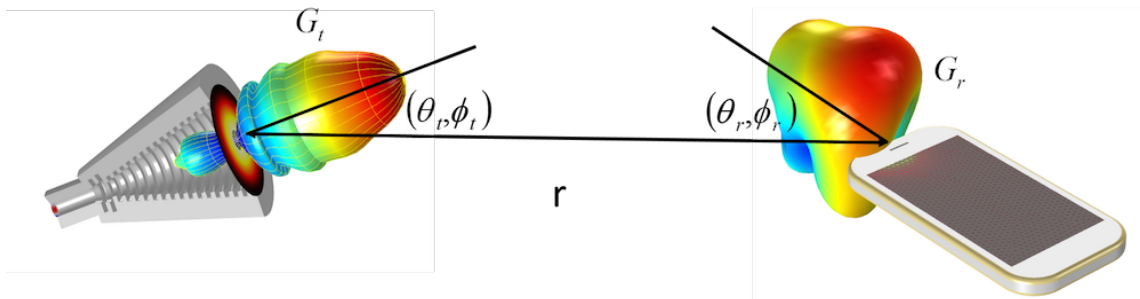
Innovate



Optimize

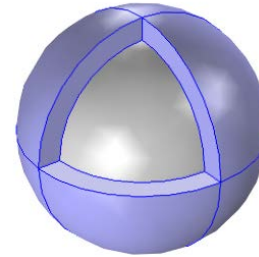
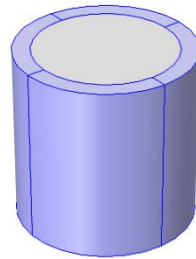
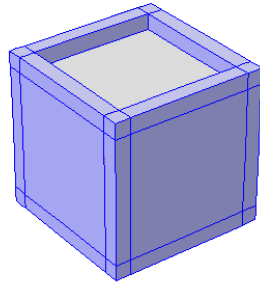
Multiscale Modeling

- Electromagnetics

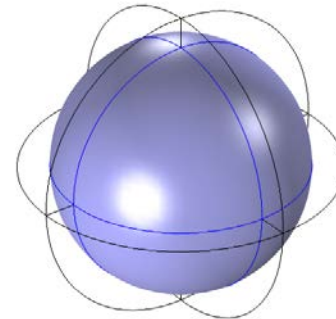
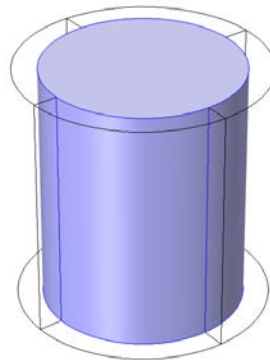
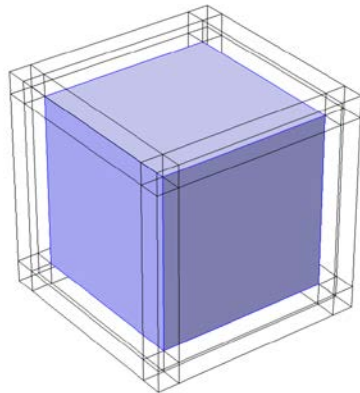


Multiscale Modeling

- Perfectly Matched Layer / Infinite Element Domain

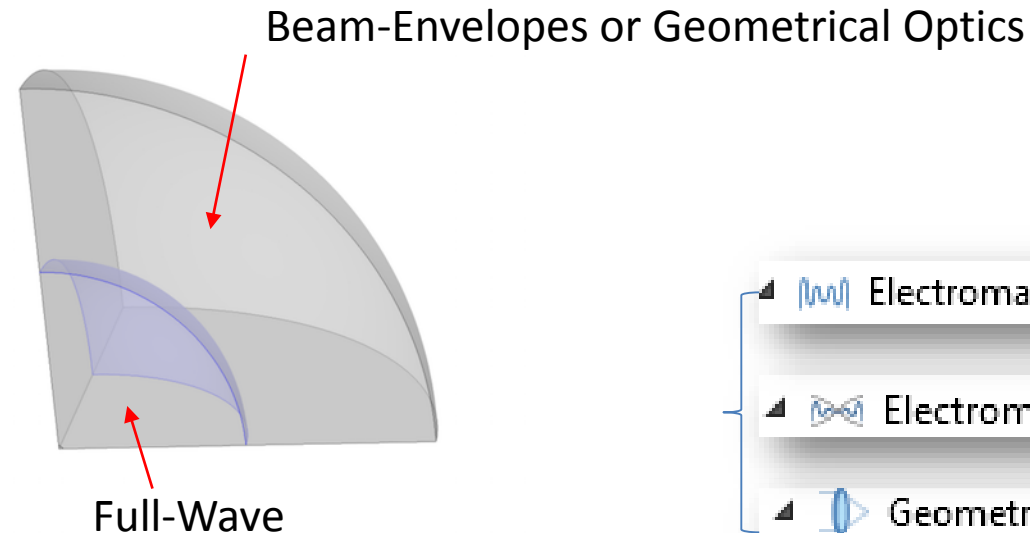
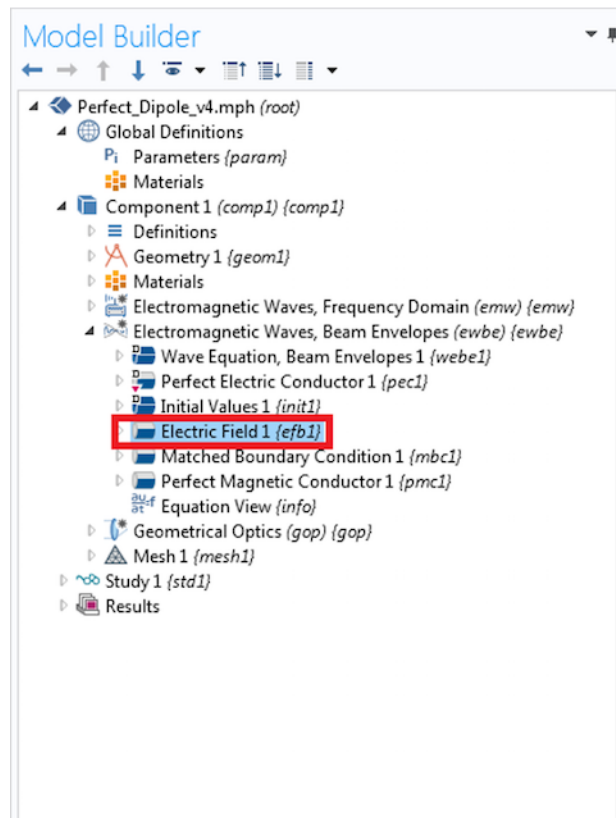


- Far-field Calculation



Multiscale Modeling

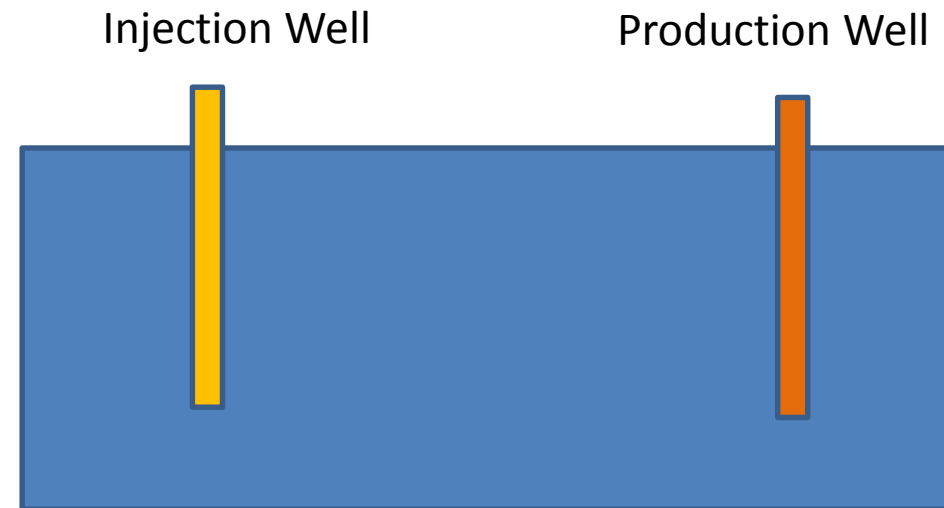
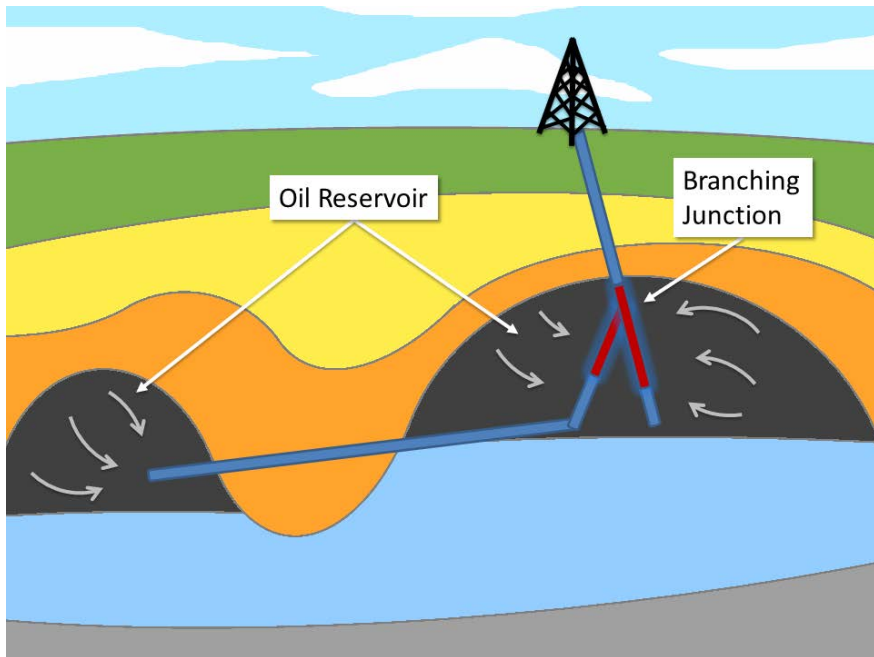
- Different Physics Interfaces Coupling



Electric Field		
Electric field:		
emw.Ex	x	V/m
emw.Ey	y	
emw.Ez	z	

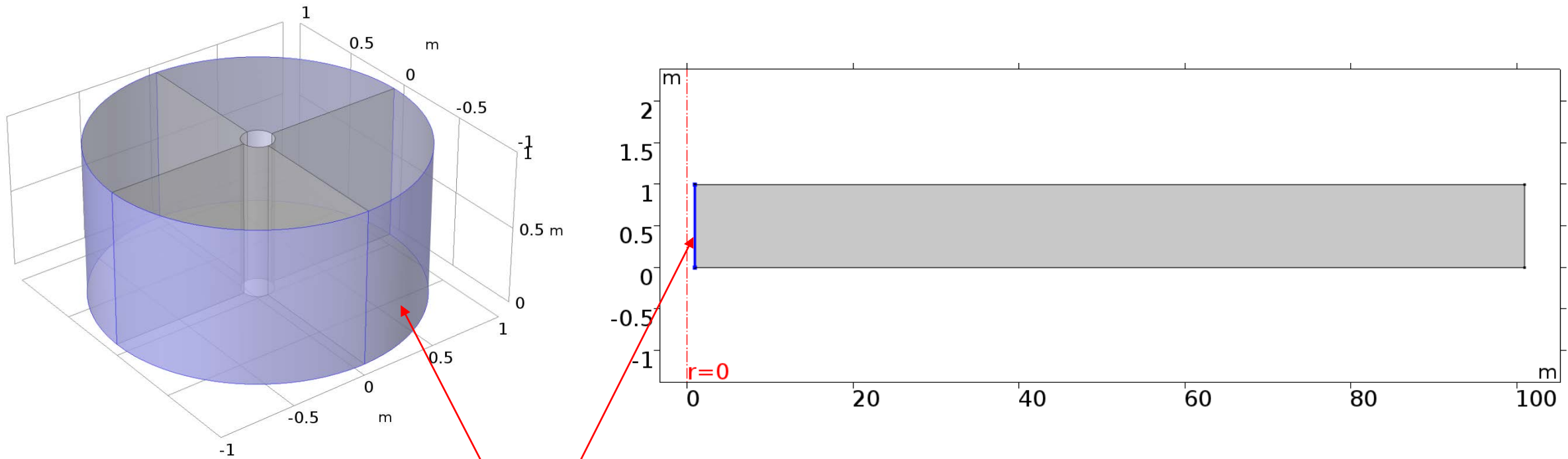
Multiscale Modeling

- Geomechanics /Subsurface



Multiscale Modeling

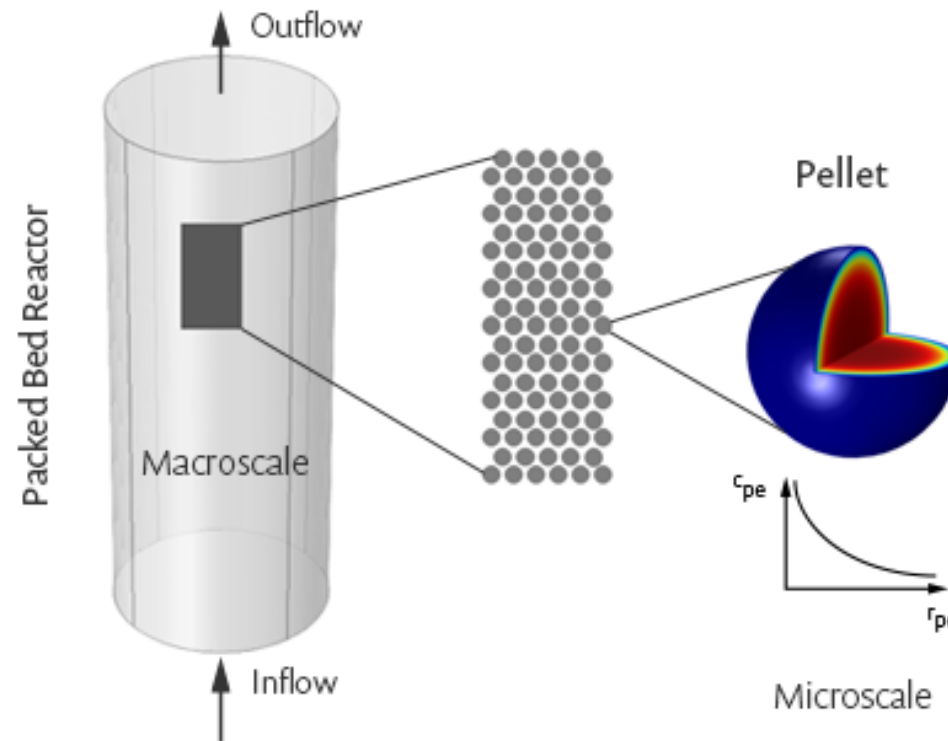
- Different Dimension Coupling



General Extrusion

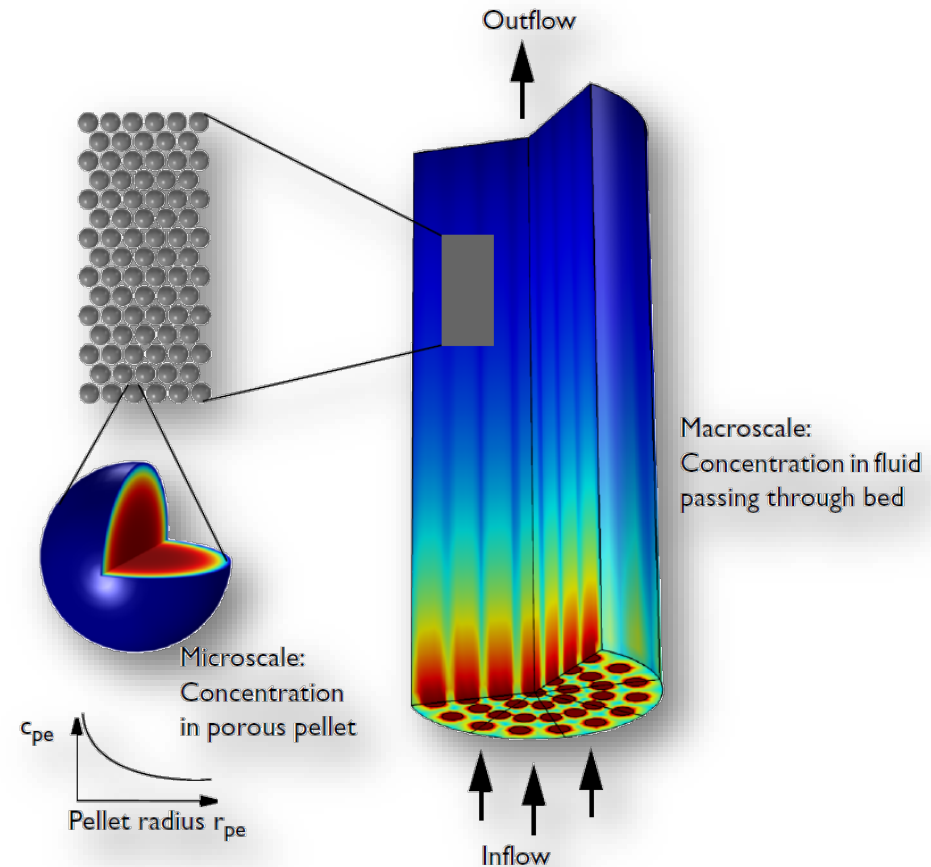
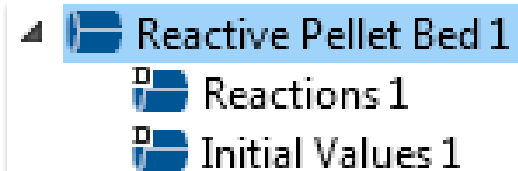
Multiscale Modeling

- Chemical Industry
 - Extra Dimensions



Multiscale Packed Bed Reactor

- An extra dimension approach to model the mass and reaction distribution along the 3D reactor and within each catalyst pellet along the reactor length. The pellet radial dimension constitutes the extra 4th dimension through the “Reactive Pellet Bed” feature

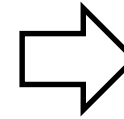
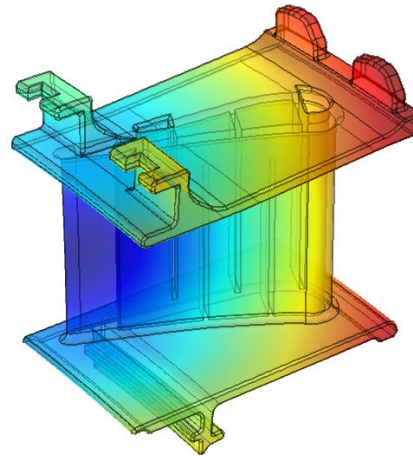
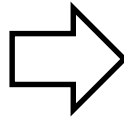


How Our Customers Use COMSOL®



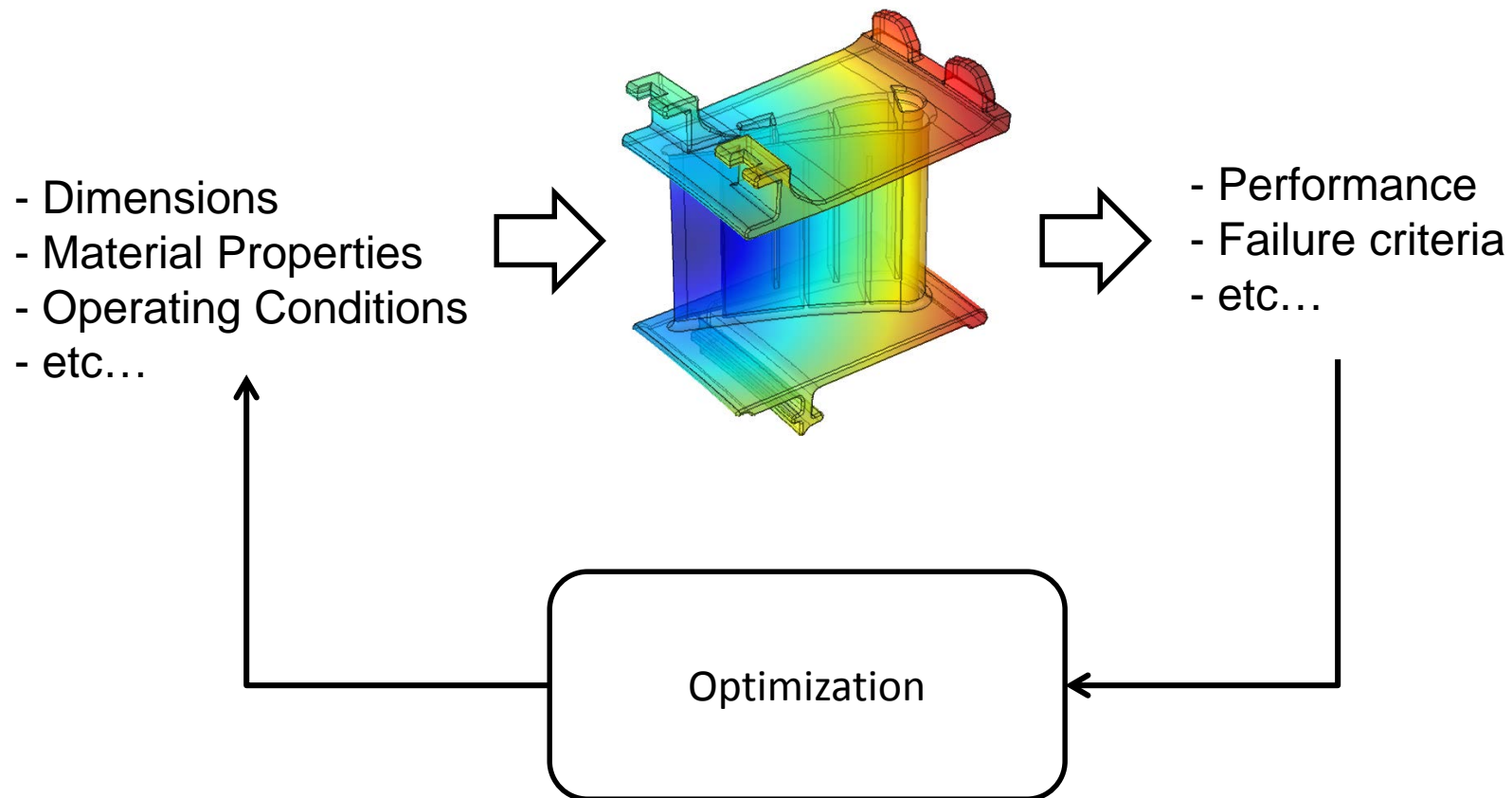
What is Optimization?

- Dimensions
- Material Properties
- Operating Conditions
- etc...

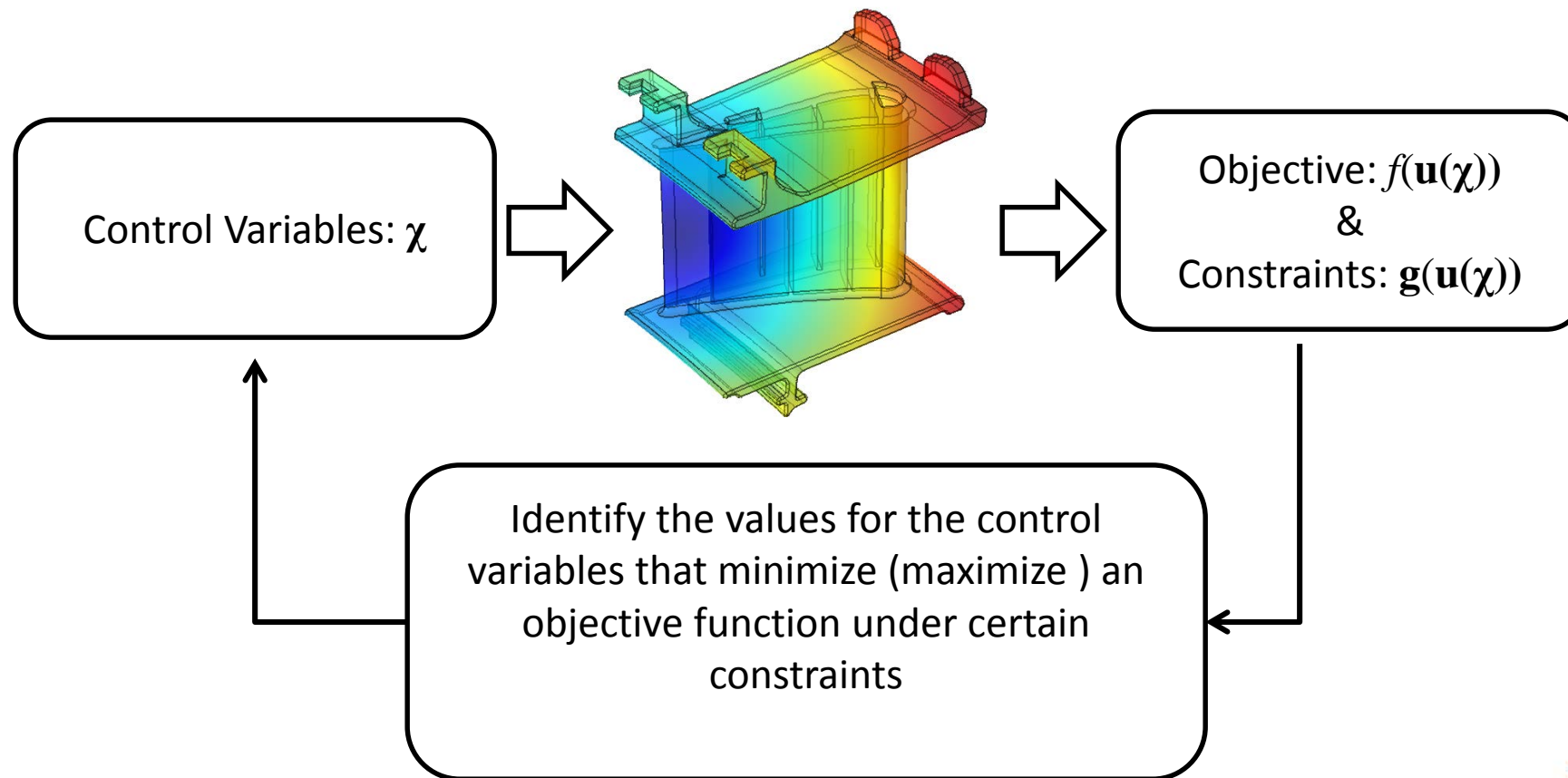


- Performance
- Failure criteria
- etc...

What is Optimization?

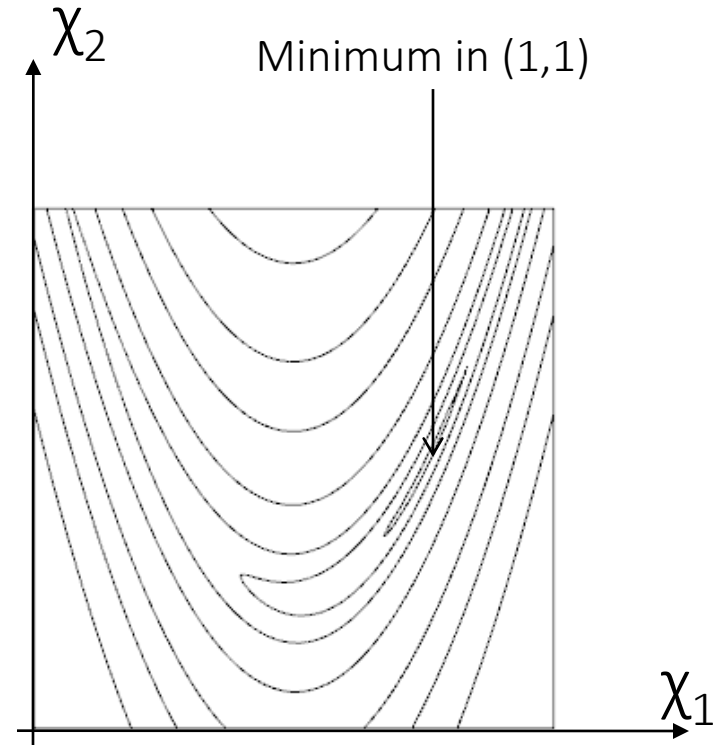
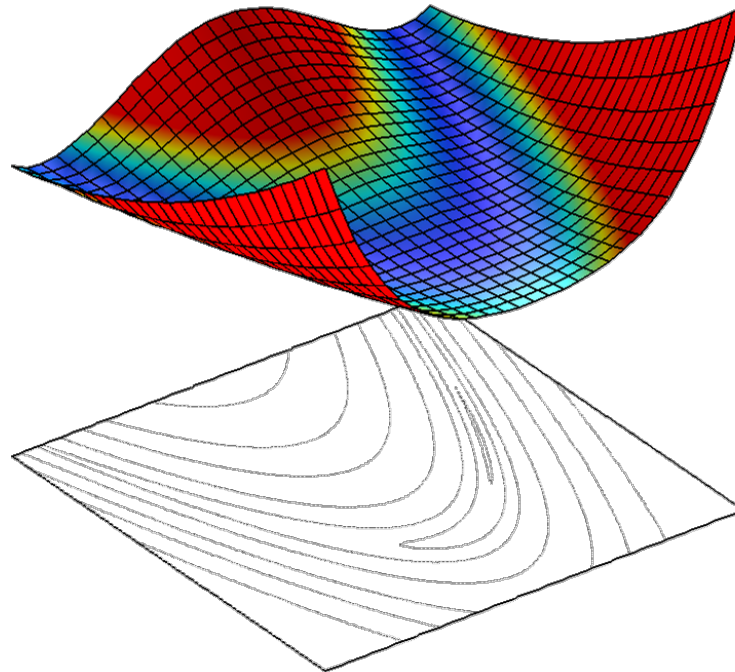


What is Optimization?



Types of Optimization

- Pure optimization (mathematical)



Rosenbrock function " $(x-1)^2+60(y-x^2)^2$ "

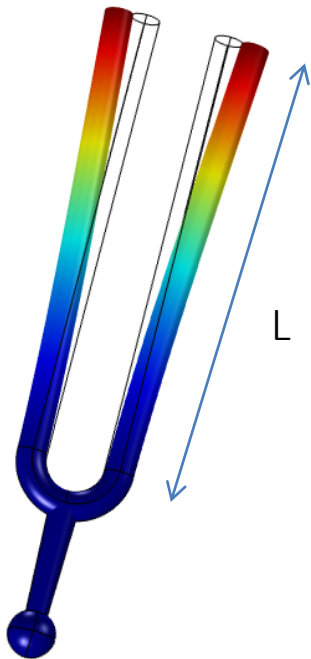
Common hard optimization test as it features a valley which is both narrow and «banana» shaped.

Types of optimization

- Pure optimization (mathematical)

- Geometrical

✓ Dimensional



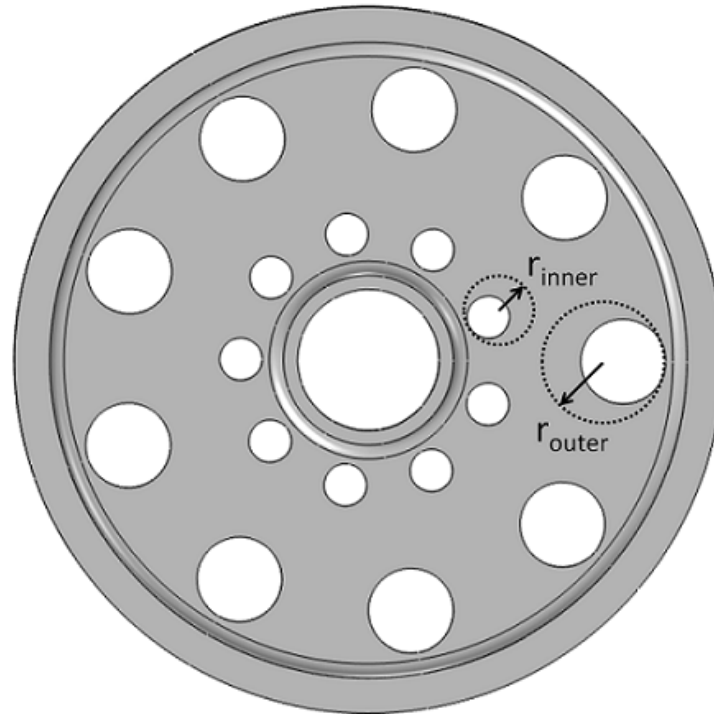
- Find the length L of the arm of the tuning fork in the image which makes the fundamental frequency equal 440 Hz.

Types of optimization

- Pure optimization (mathematical)

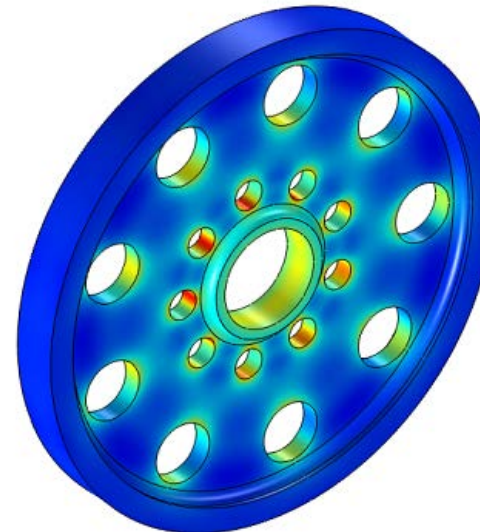
- Geometrical

✓ Dimensional



Structural sizing such that:

- Find hole radii which minimize flywheel mass
- Maximum von Mises stress must not exceed yield limit

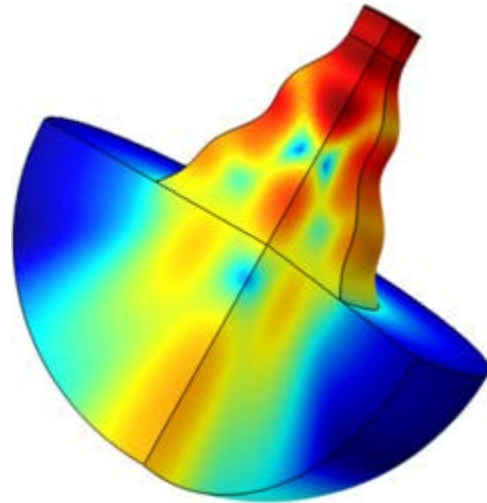


Types of optimization

- Pure optimization (mathematical)

- Geometrical

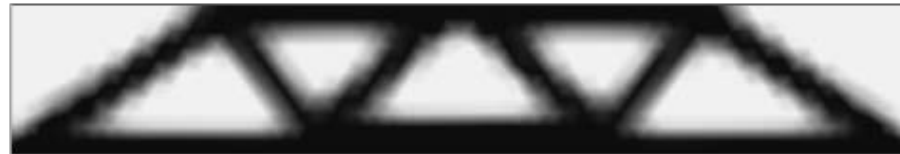
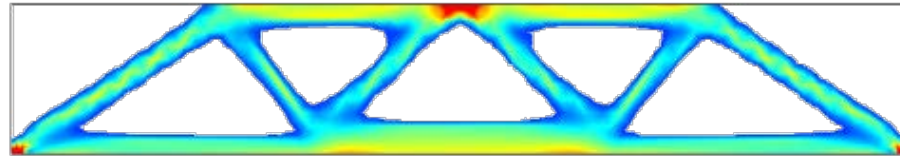
- ✓ Dimensional
 - ✓ Shape



- Example of constraints could include the radius of the loudspeaker or a desired minimum achievable sound-pressure level
 - Maximize pressure at 1[m]

Types of optimization

- Pure optimization (mathematical)
- Geometrical
 - ✓ Dimensional
 - ✓ Shape
 - ✓ Topological
- search for the most rigid structure



Types of optimization

- Pure optimization (mathematical)

- Geometrical

- ✓ Dimensional
- ✓ Shape
- ✓ Topological

- Inverse analysis

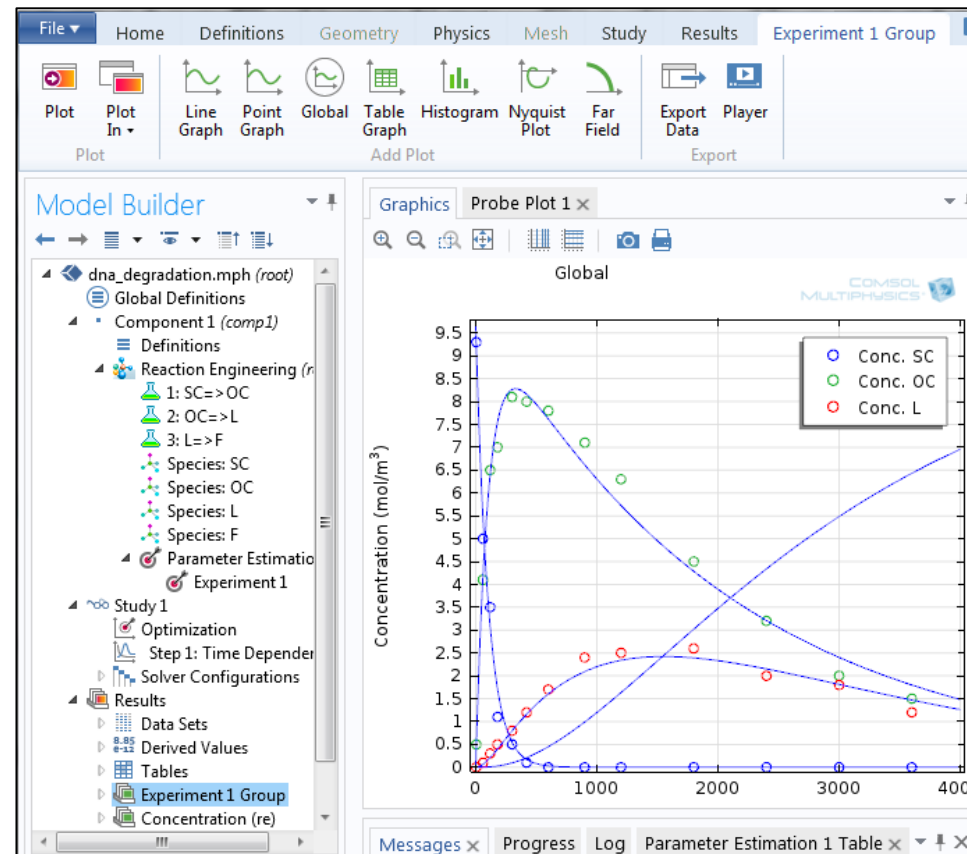
- ✓ Curve fitting
(Parameter estimation)

finding the material properties to reproduce experimental curves (fitting)

Minimize least squares difference with experimental results

Levenberg-Marquardt

Available also for transient analysis



Types of optimization

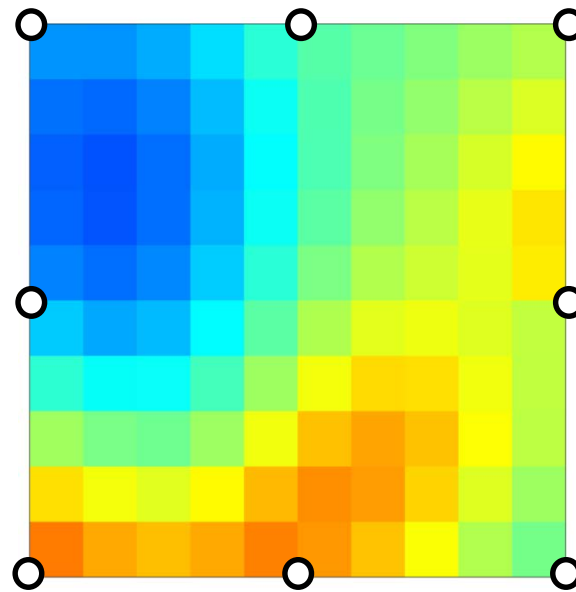
- Pure optimization (mathematical)

- Geometrical

- ✓ Dimensional
- ✓ Shape
- ✓ Topological

- Inverse analysis

- ✓ Curve fitting
(Parameter estimation)
- ✓ Tomography



finding the material properties in a domain to match many cross-measurements (imaging / tomography)

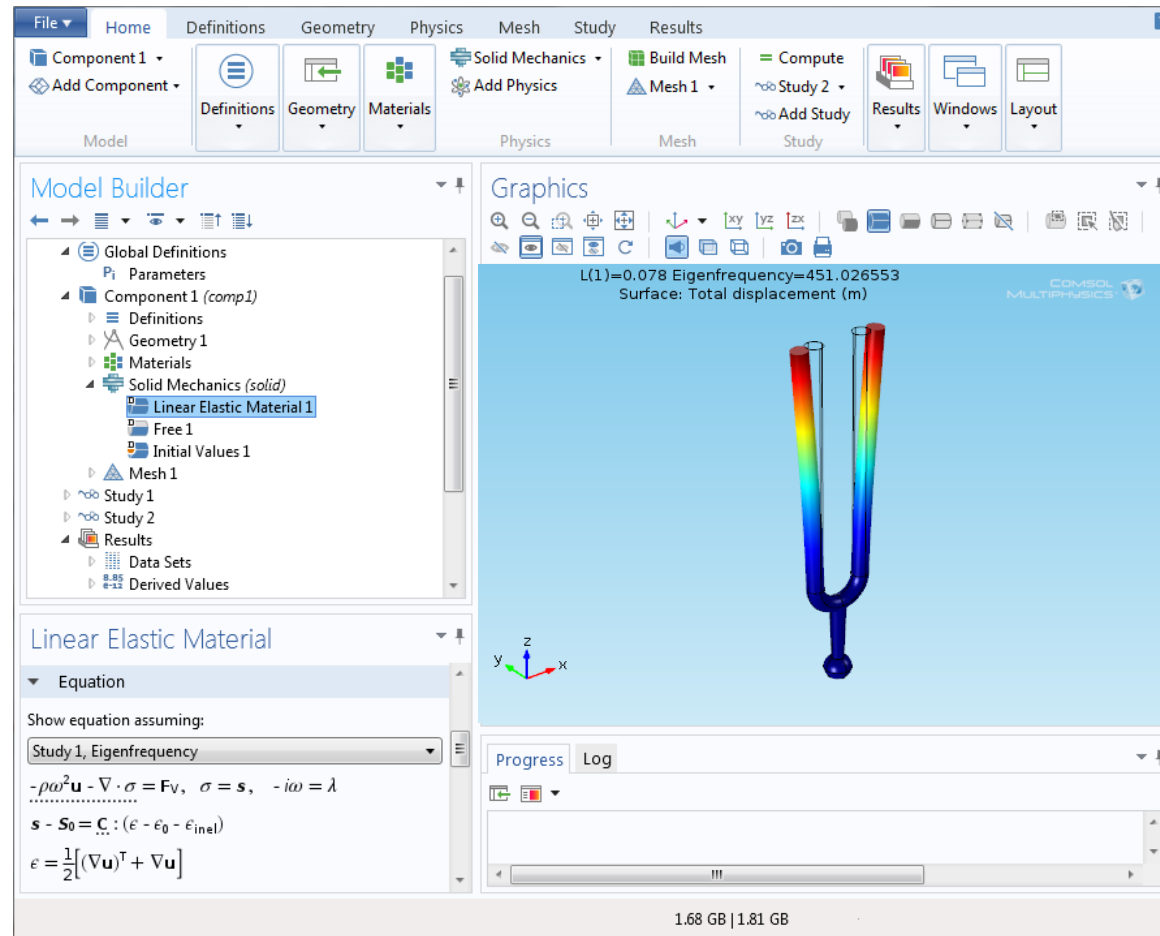
How do we optimize?

- Start with a solved COMSOL model
- Define your object function: What do you want to make better?
- Choose the design variables: What do you want to change?
- Specify your constraints: What limits cannot be exceeded?
- Optimize!



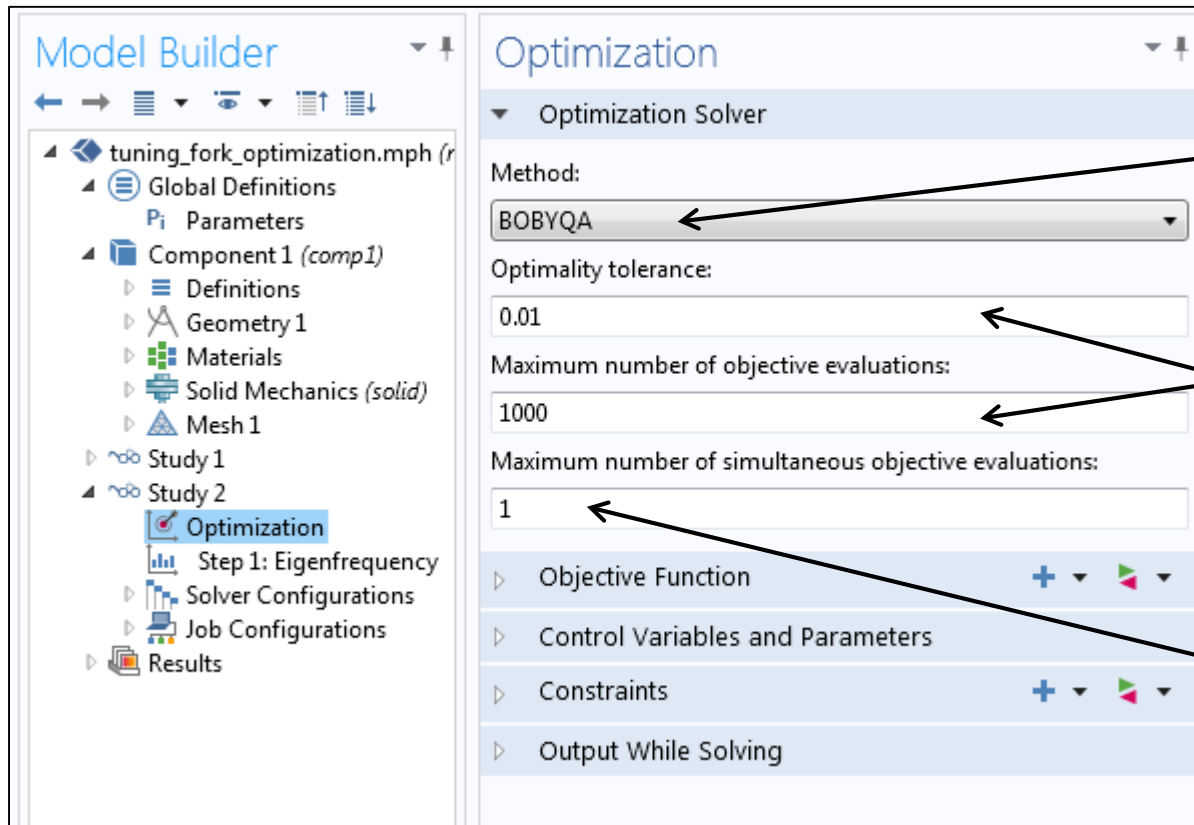
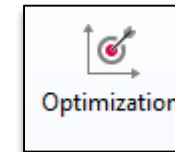
*Tuning fork,
Desired resonance
at 440Hz*

Start with an existing model



For clarity, the COMSOL Desktop is here shown as it appears on a low-resolution screen.

Add the Optimization Study feature

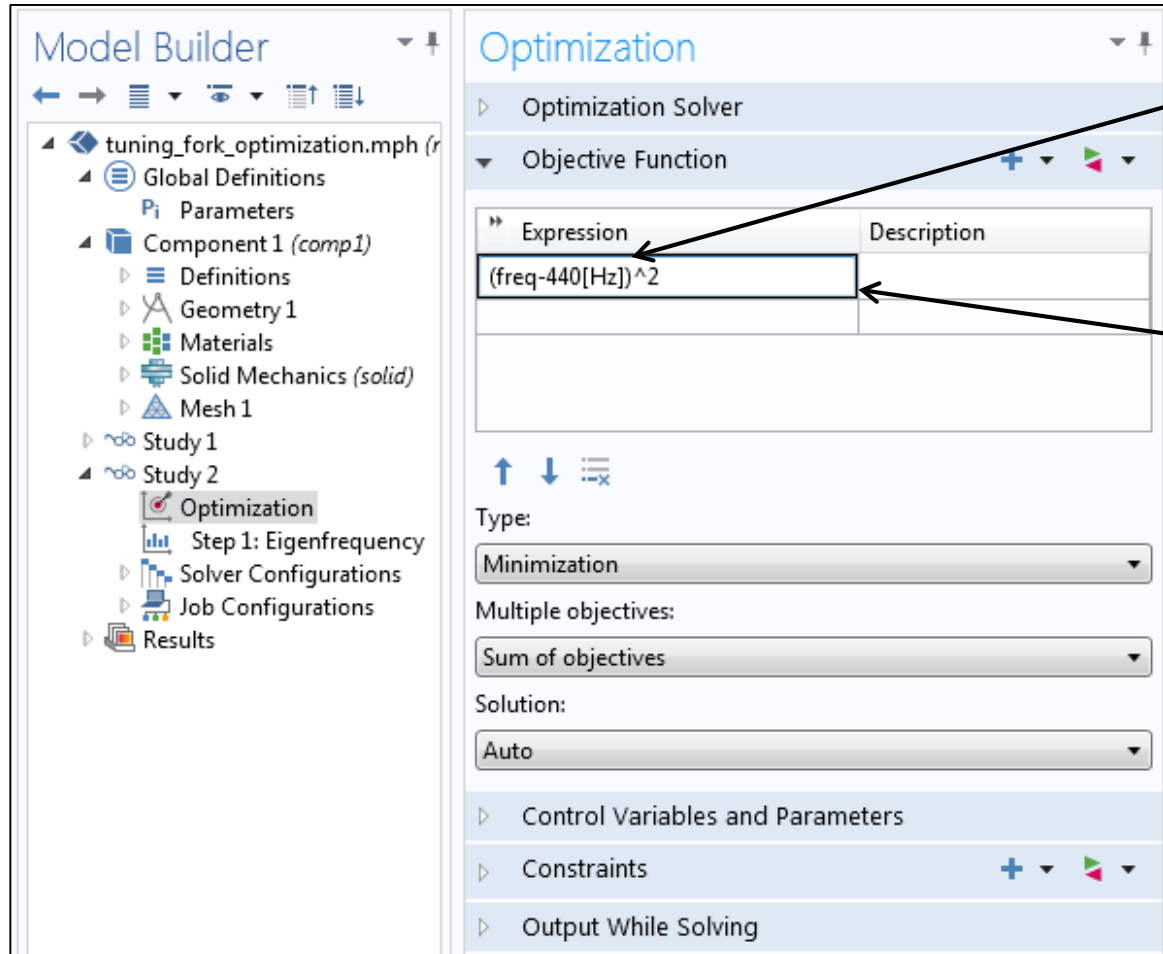


Select from a suite of optimization algorithms

Set tolerance and the maximum number of model evaluations

If solving on a cluster, can distribute solutions and run in parallel

Specify an objective function

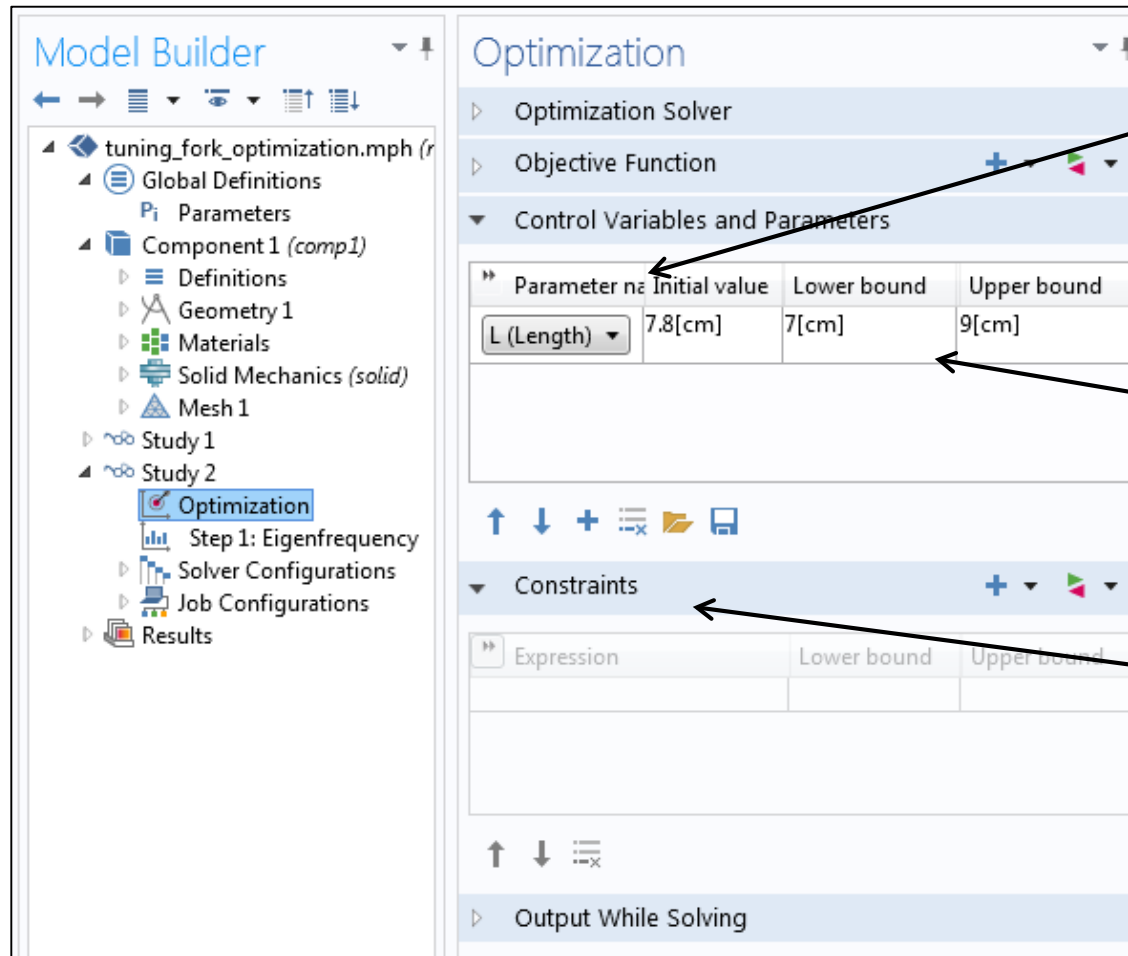


freq: the resonance
computed by the
eigenfrequency solver

The objective is to
make the resonant
frequency 440Hz

Minimize/maximize the
minimum/maximum or
the sum of different
contribution to the
objective function

Pick control variables and constraints

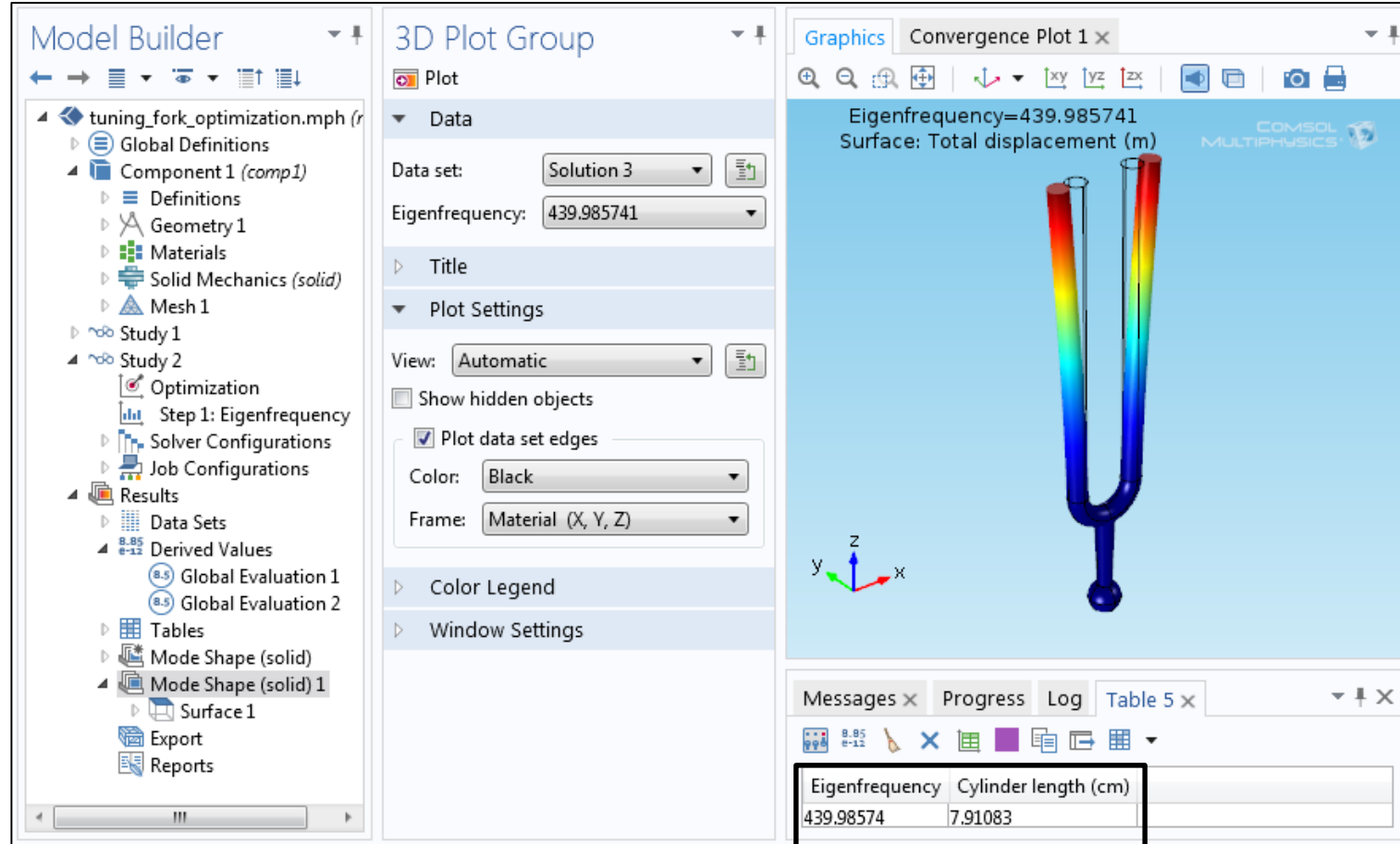


Global Parameter sets the tuning fork length; specify initial value

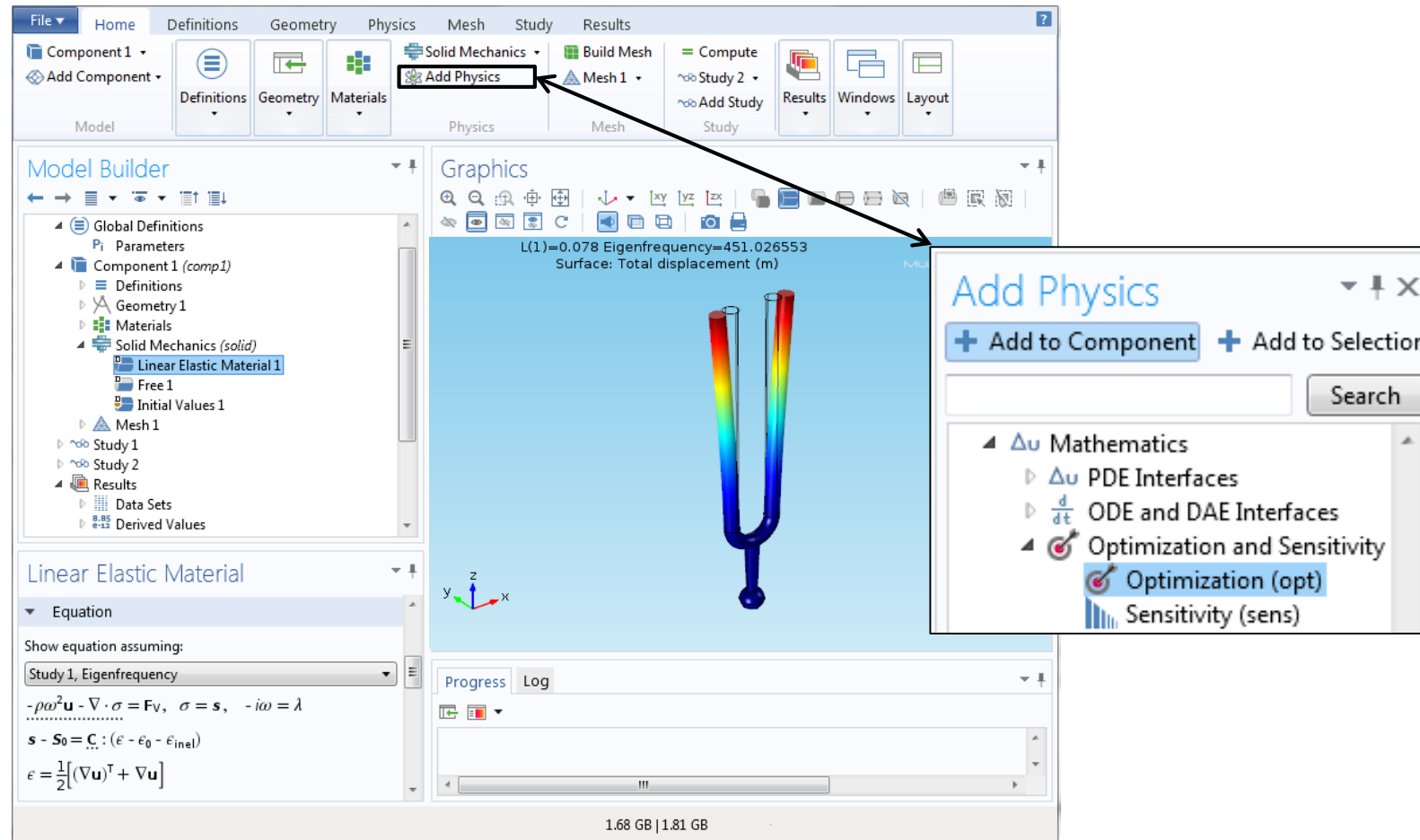
Choose upper and lower bounds (constraints) on the control variables

Can add other constraints, if desired

Solve, and then extract solution



Add the Optimization User Interface






For clarity, the COMSOL Desktop is here shown as it appears on a low-resolution screen.

Use of Optimization User Interfaces

- The Optimization study step
 - Central control panel for all optimization
 - Choose and tune solvers
 - Specify global objective functions, control parameters and constraints
 - Enable/disable contributions from interfaces
- The Optimization interface
 - Set up general objective contributions, including least-squares
 - Define control variable fields
 - Specify general constraints

Add Physics

+ Add to Component + Add to Selection

- ▷ Semiconductor
- ▲ Δu Mathematics
 - ▷ Δu PDE Interfaces
 - ▷ $\frac{d}{dt}$ ODE and DAE Interfaces
 - ▲  Optimization and Sensitivity
 -  Optimization (opt)
 -  Sensitivity (sens)
 - ▷ ∇^2 Classical PDEs