Dynamic Measurements Hands On Session

O. Sacristan, S. Hoell

MECHANICAL & MATERIALS ENGINEERING
FOR PARTICLE ACCELERATORS AND DETECTORS

Session Outline

1. **Introduction**

2. **Practical Cases**

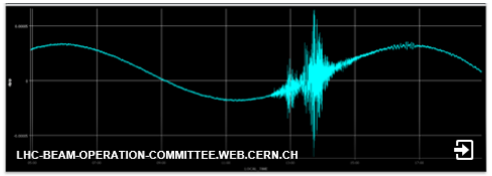
    1. Live acquisition

    2. Impulse excitation technique – Materials Elastic Properties

Context: High Energy Accelerators Vibration Sensibility

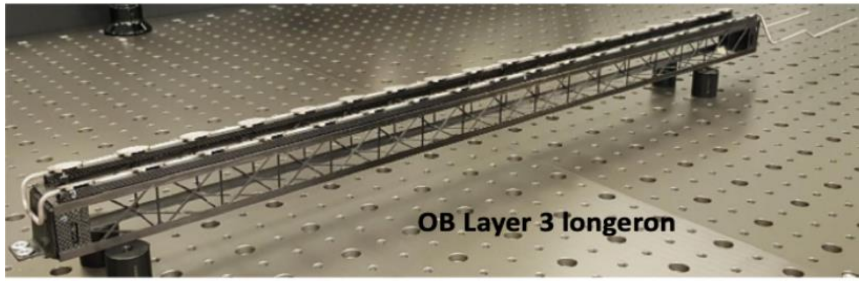
High energy accelerators as the LHC:

- Beam sizes around 0,25 mm at top energy on 27 kms
- Stability of the magnetic field center (depending operation) should stay in µm scale for safe operations

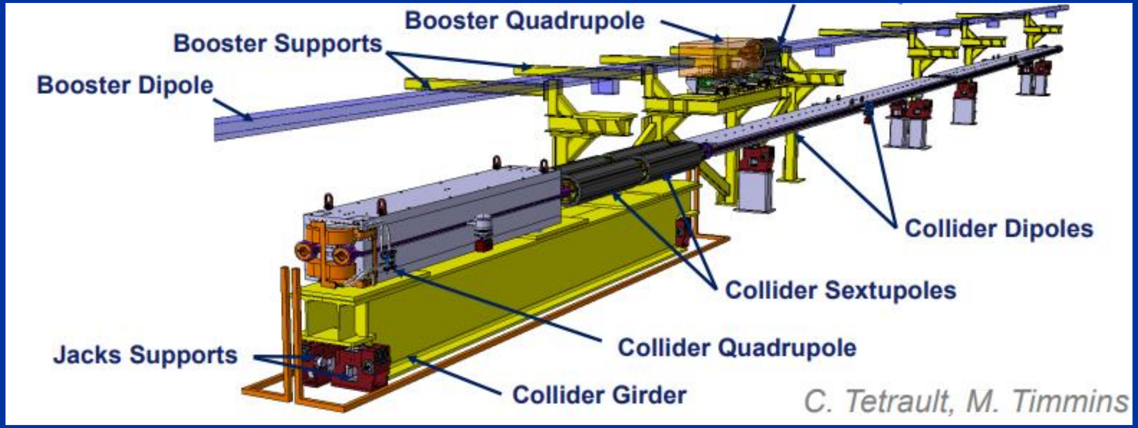


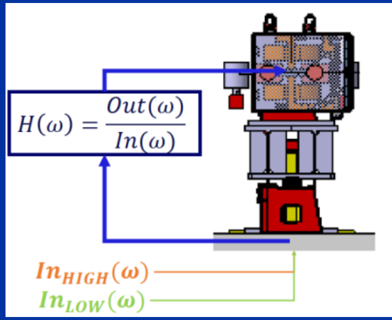
Particle detectors:

- Trend to increasingly lighter and stiffer supporting structures
- Particles tracking in sub-nm scale



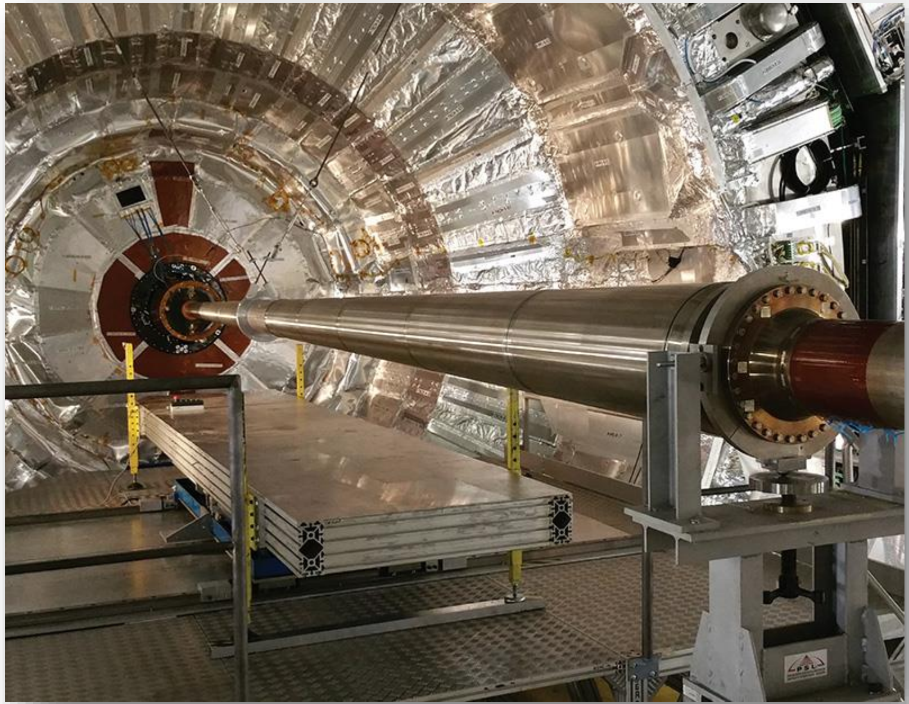
... and beyond!
FCC demands even more stringent requirements

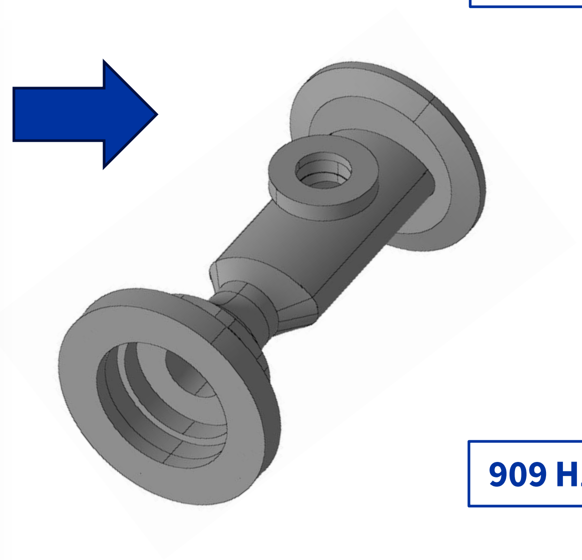


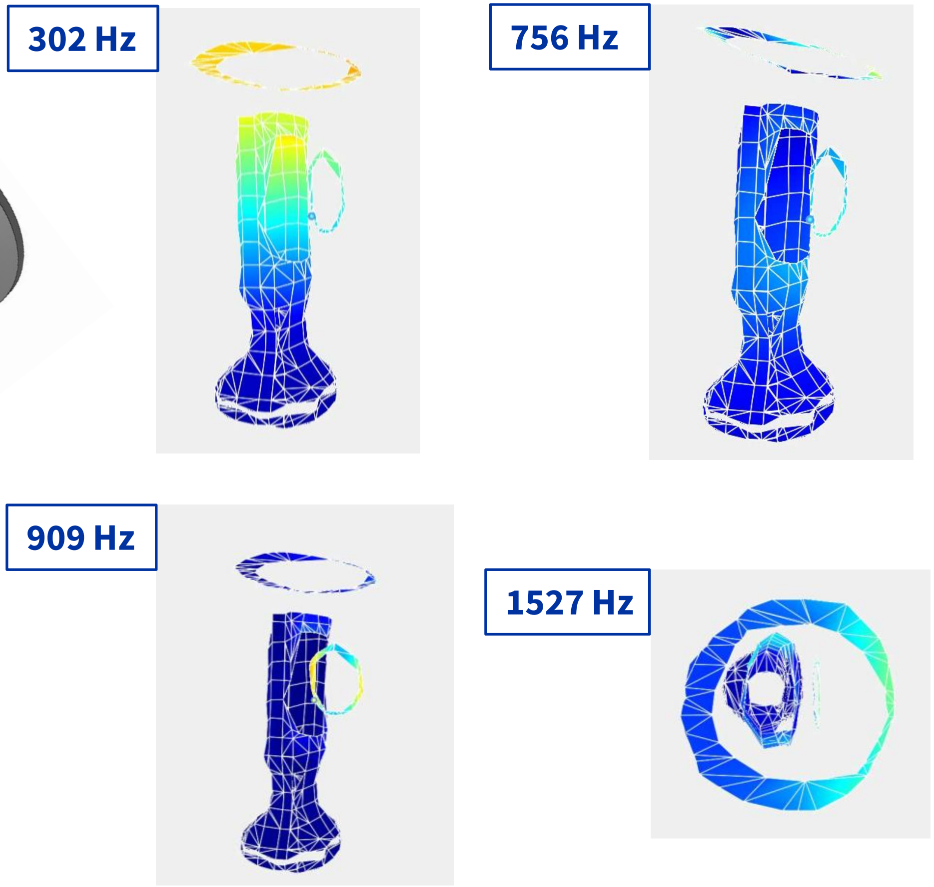


Frequencies	Tolerance at beam level
1 > f > 0.01 Hz	100 nm
10 > f > 1 Hz	20 nm
100 > f > 10 Hz	5 nm
f > 100 Hz	1 nm

Example: Vacuum Chamber Experimental Modal Analysis



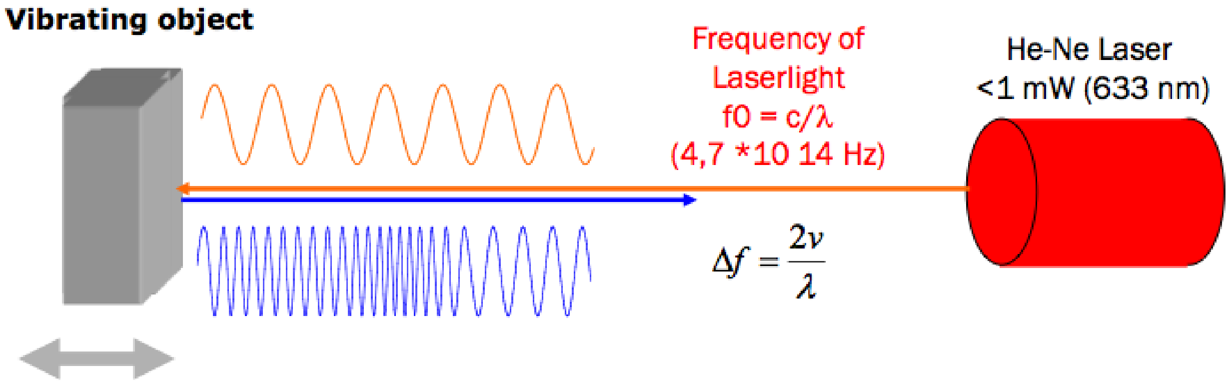




- Identifying and solving structural vibration related issues
- Predicting the interaction of the structures with the neighbouring excitation functions

Scanning Laser Doppler Vibrometer

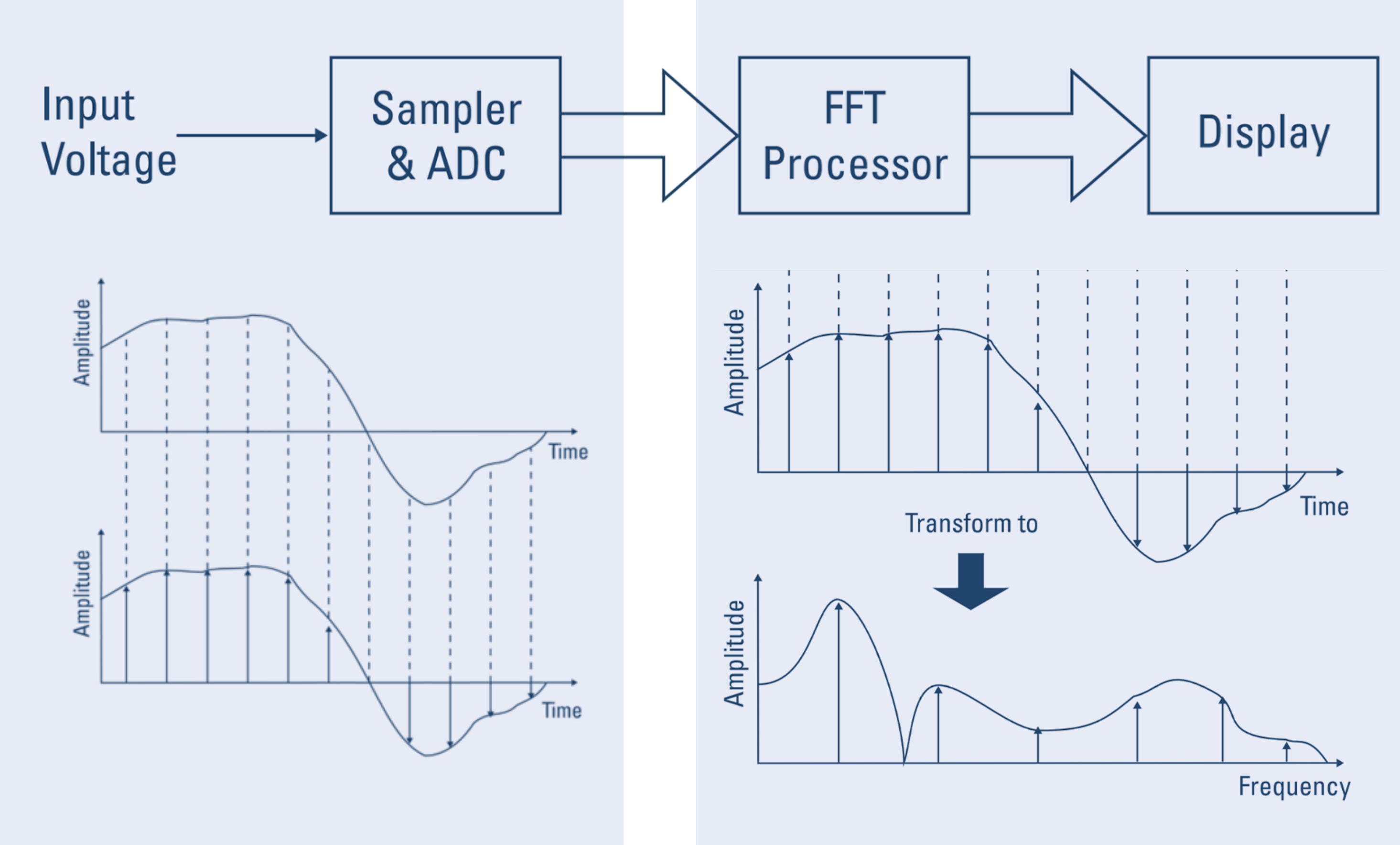
- Laser vibrometry is conventionally used to measure the velocity of a vibrating surface.
- The velocity is derived from the change in phase of the light returning from the target.
- Scanning laser vibrometers have been used successfully for years now in the research and industry markets.



- The laser light is backscattered introducing a Doppler shift.
- The Doppler shift is proportional to the velocity of the vibrating object: 1 m/s = 3,16 MHz

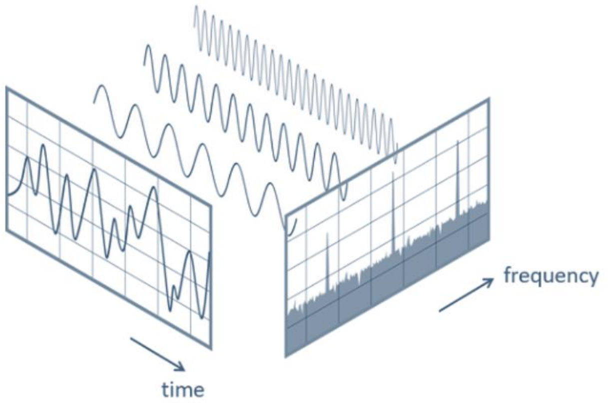
Introduction

The Digital Signal Processing (DSP) Process in practice



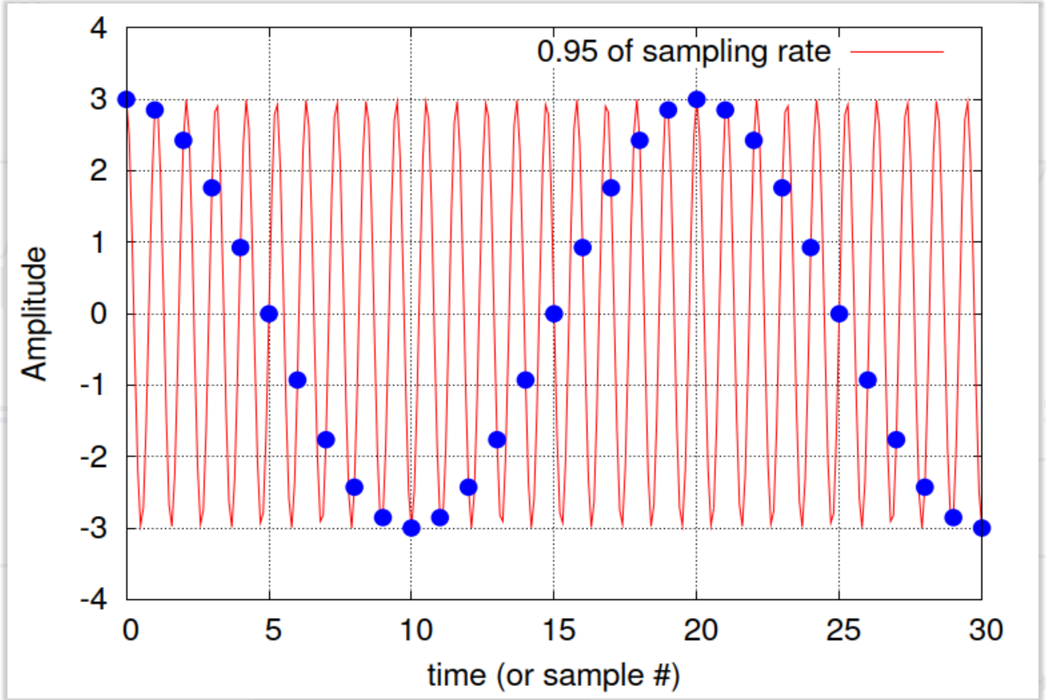
ADC resolution

If our ADC converter has 24 bits, what does this means in terms of quantization?

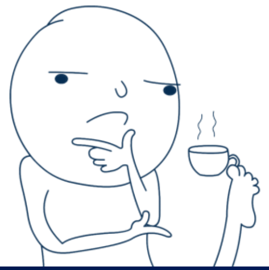


Sampling

- **What acquisition frequency for every signal type to measure**  **?**



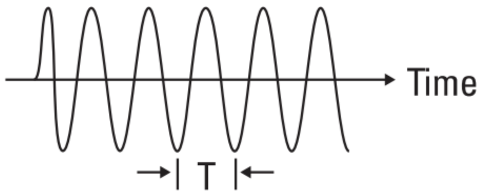
Aliasing

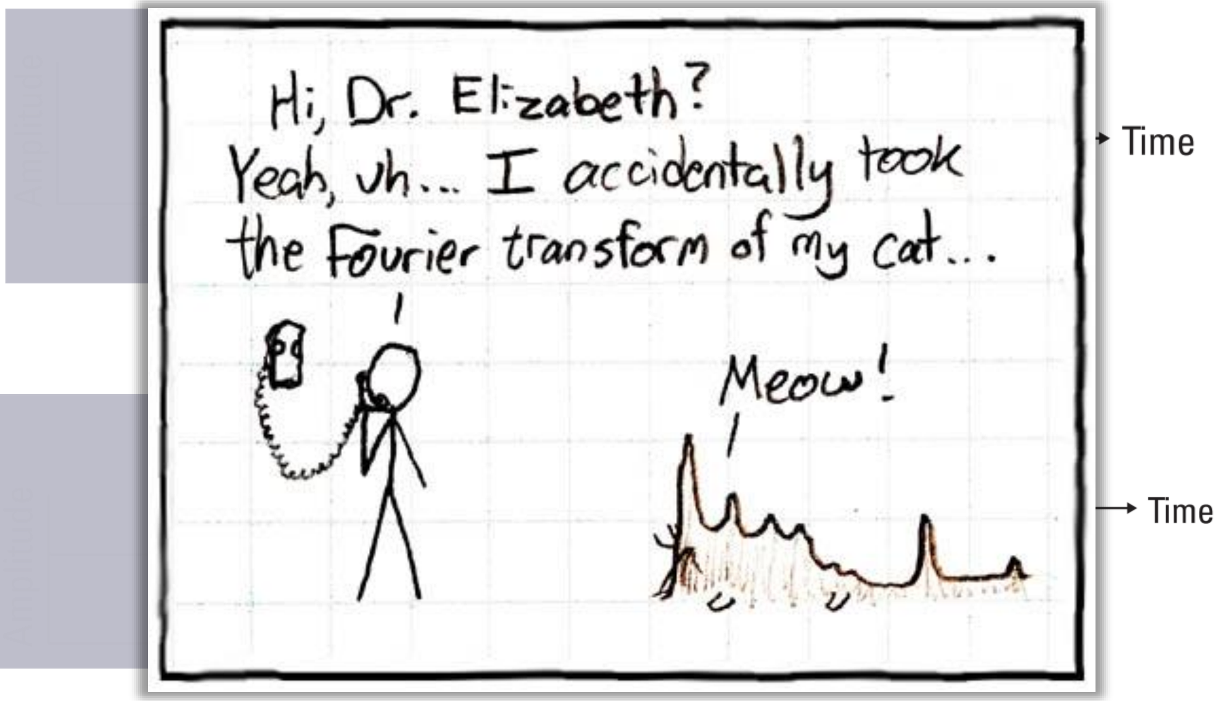


5 minutes to reflect and discuss with your colleagues

How about FFT?

...let's think about the FFTs of the previously discussed signals





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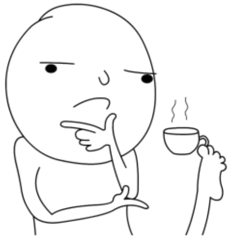
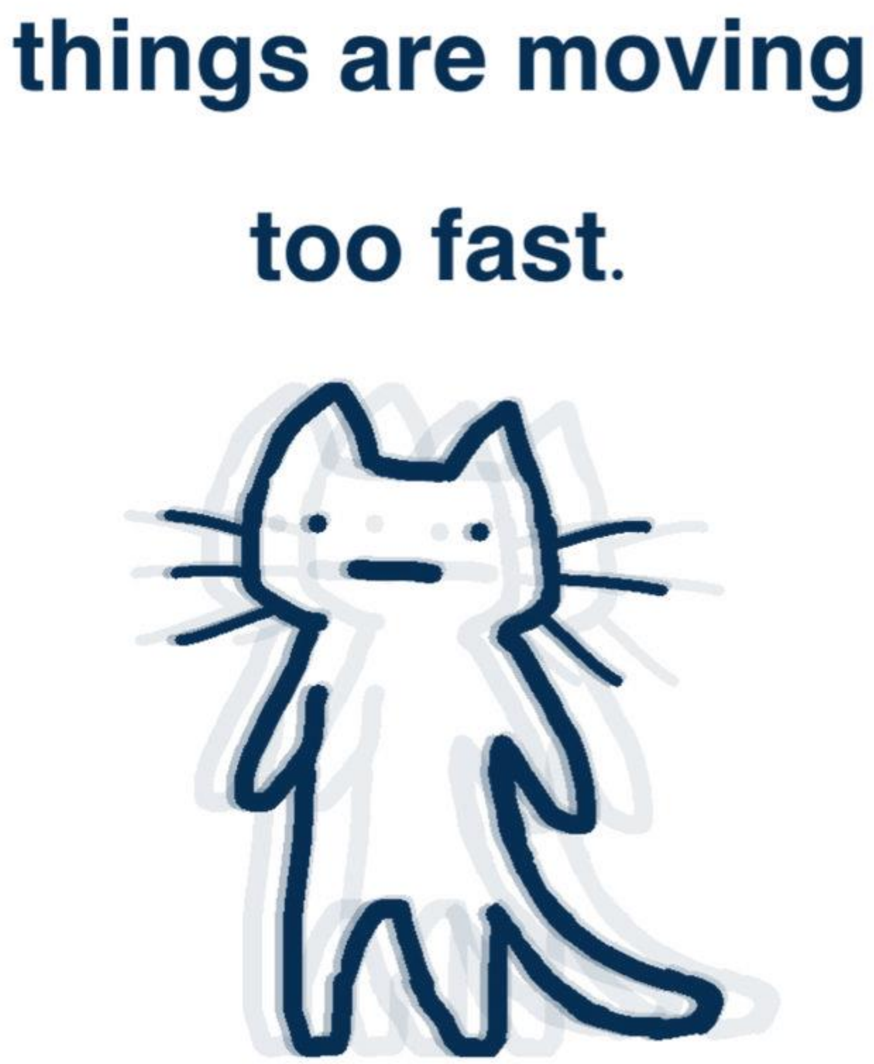


5 minutes to reflect and discuss with your colleagues

Real Time Practice

Start



Let's explore how different signals and acquisition frequencies play together!!

Real Time Practice

Experimental Set-Up

Agilent 33210A Function Generator

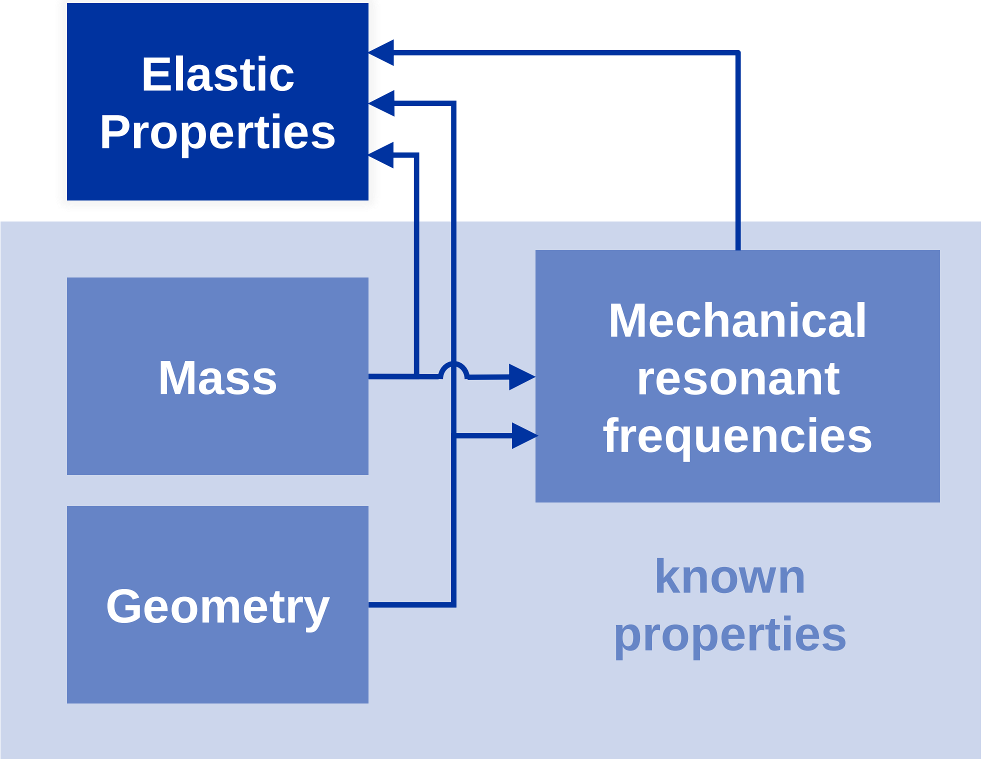
- Sine, square and pulse signals

QuantumX 860B Voltage Meter

- 24-bit analog-to-digital converter per channel
- 300 and 4800 Hz acquisition frequency
- 0-10 V Measurement range

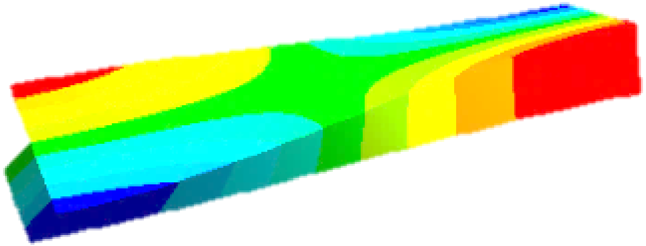
Practical Case: Impulse Excitation Testing

A fast and accurate way to determine materials elastic properties



E → First Flexural Mode

G → First Torsional Mode



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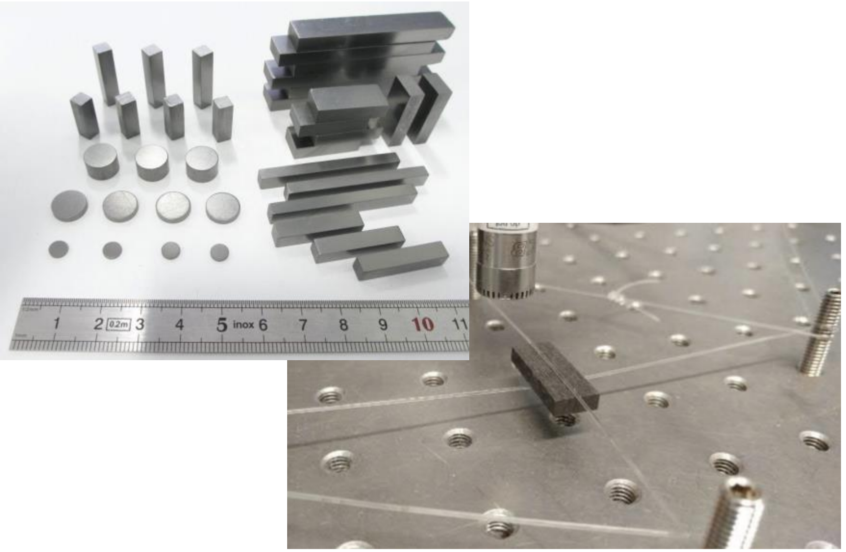
Materials Elastic Properties determination

Impulse Excitation Technique

A fast and accurate technique

Useful when dealing with small amounts of material



Tensile Test	Dynamic Methods
• "Engineering value" for modulus • Generation of stress-strain curve • Widely available test equipment	• Quick, simple, non-destructive • Good inherent accuracy • Uses small specimens • Easy high temperature measurement
• High accuracy strain measurement required • Difficult gripping (bending) • Larger specimens required • Accurate high temperature measurements are difficult	• Small strains regime (engineering value?) • Sensitive to dimensional tolerances • Composites need simulations • Equipment not widely available

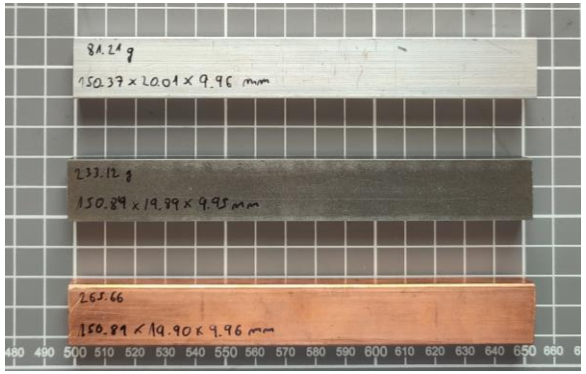
Impulse Excitation Testing

Experimental Set-Up

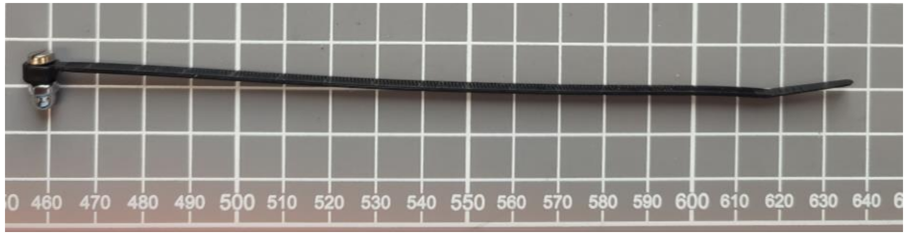
PCB 378B02 Microphone

- **Frequency Range: (±2dB)3.75 to 20000 Hz (3.75 to 20000 Hz)**
- **Inherent Noise: 15.5 dB(A) re 20 µPa**
- **Dynamic Range: 137 dB re 20 µPa**

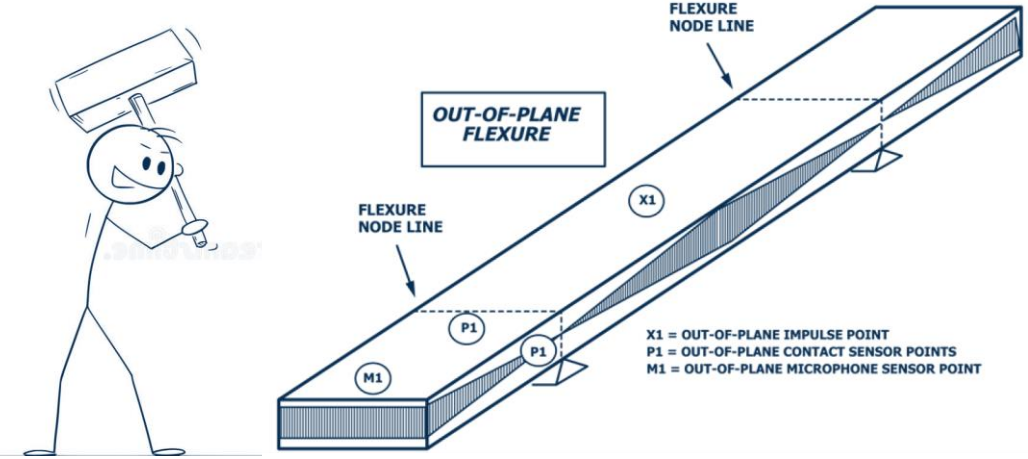
Aluminum, Steel and Copper Bars



Hammer



Impulse Excitation Testing in Practice



Start

1. Measure and weigh the samples
2. Start acquisition, excite with a small hammer and observe the response of the samples
3. Determine the first bending and torsional modes frequencies

Impulse Excitation Testing

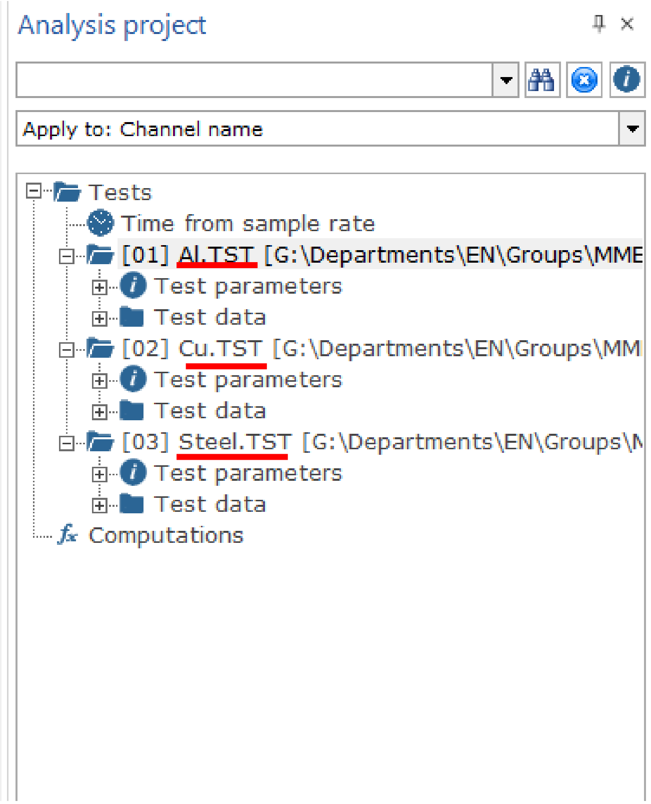
We just obtained a rough idea of where to locate the different modes. Now it's your turn to analyse the files in order to get the modes accurately

1. Fill the excel file with the geometries and masses

Specimen	m [g]	L [mm]	b [mm]	t [mm]	ff [kHz]	ft [kHz]	E [GPa]	G [Gpa]
Aluminum							#DIV/0!	#DIV/0!
Copper							#DIV/0!	#DIV/0!
Steel							#DIV/0!	#DIV/0!

2. Use fft of the acquisition to determine the first bending and torsional mode.

3. Discuss the results



Impulse Excitation Testing BONUS!

In the previous exercise we used a pre-configured FFT.

Now it is time to see how the configuration affects our results.

1. Calculate FFTs with extreme block durations and note the first bending and torsional mode frequencies obtained
2. Input the obtained frequencies in excel file
3. Observe the impact in the E modulus results

What is the effect in the frequency resolution?

$$f_{Resolution} = \frac{fs}{N}$$

What do we trade in exchange of frequency resolution?

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