Understanding Cabling Noise in LIGO

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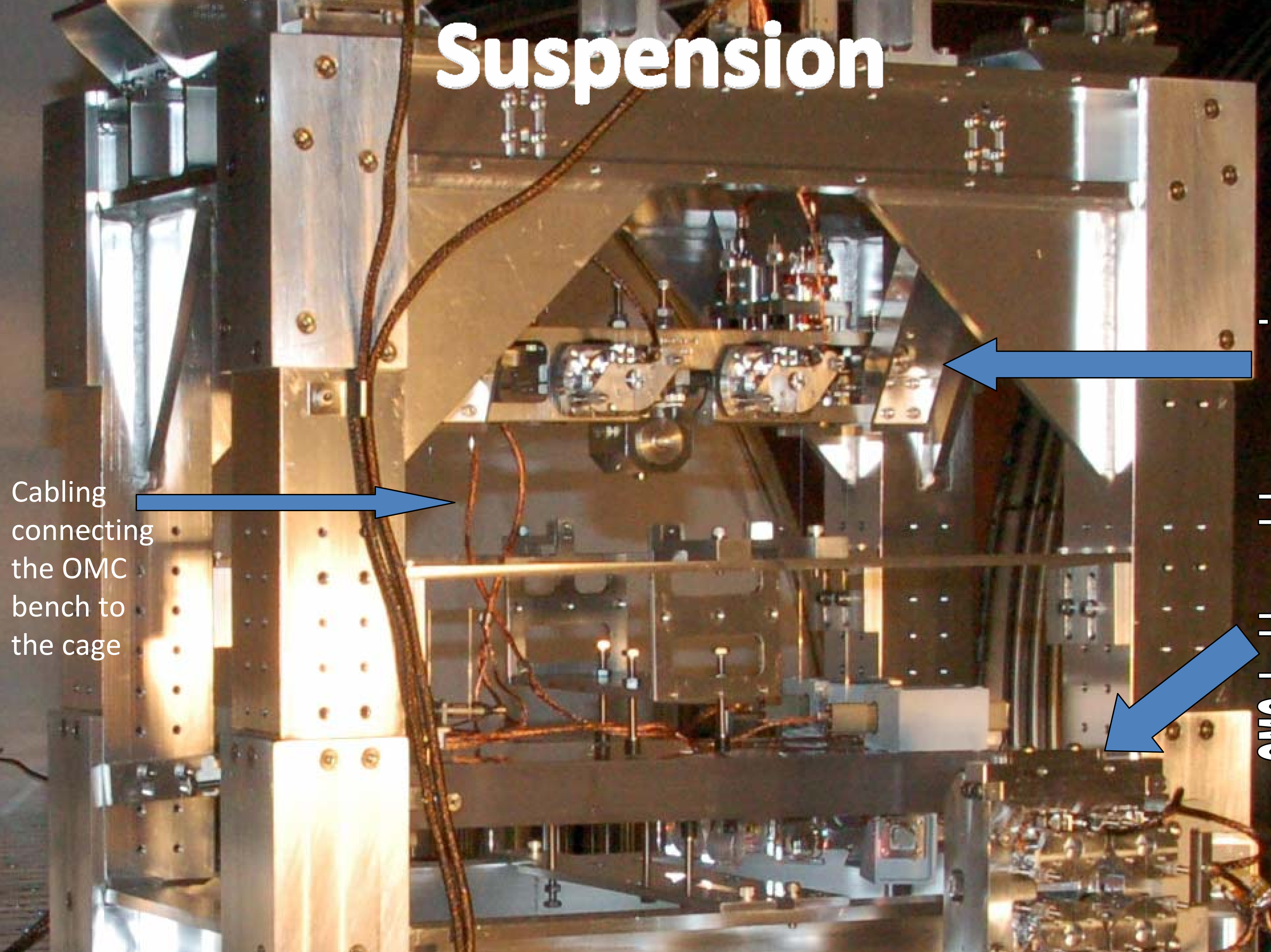
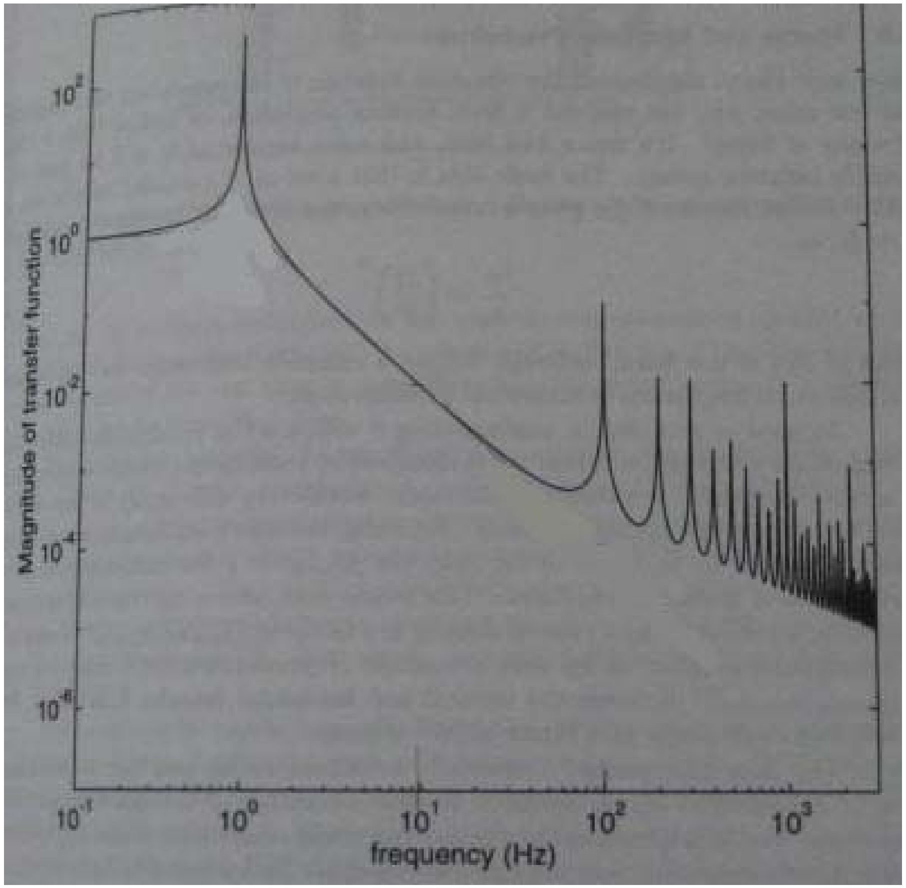
LIGO-G080566-00-R

Suspension



Pendulum as a vibration isolator



Single pendulum resonant at 1 Hz

$$\frac{x}{x_g} \approx \frac{{f_0}^2}{f^2}$$

$$\frac{x}{x_g} \approx \left(\frac{{f_0}^2}{f^2}\right)^N$$

? How would the cabling deteriorate the isolation?

$$k_T(1 + i\emptyset_T) = k_p(1 + i\emptyset_p) + k_c(1 + i\emptyset_c)$$

$$k_T(1 + i\emptyset_T) = k_p + k_c(1 + i\emptyset_c)$$

$$\emptyset_T = \frac{k_c\emptyset_c}{k_c + k_p} = \frac{k_c\emptyset_c}{k_T} = \frac{k_c\emptyset_c}{f^2 I}$$

$$Q \sim \frac{1}{\emptyset}$$

$$Q = f^2\left(\frac{I}{k_c\emptyset_c}\right)$$

For structural damping $\emptyset_c = constant$

For velocity damping $\emptyset_c \sim f$

Method

Experimental characterization of the cabling's damping function.

-Jimmy Chen

Computer modeling to apply the damping function to specific cabling-attached-to-suspension systems.

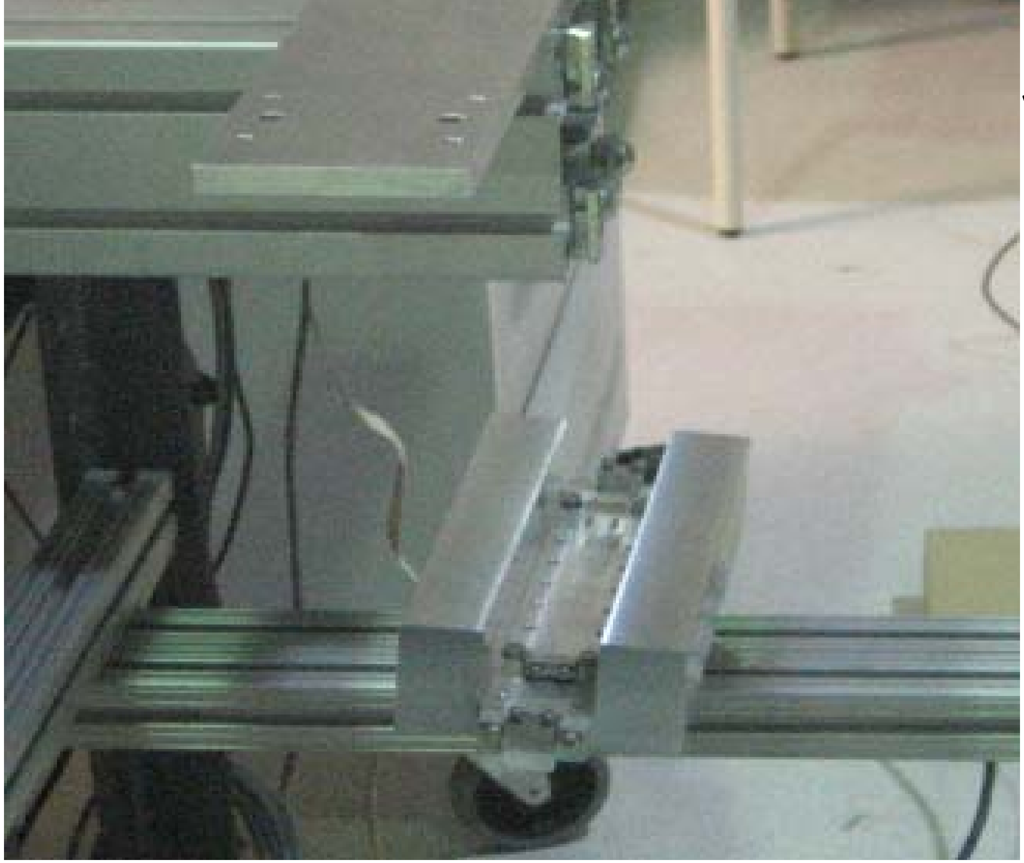
-Julian Freed-Brown

Apparatus

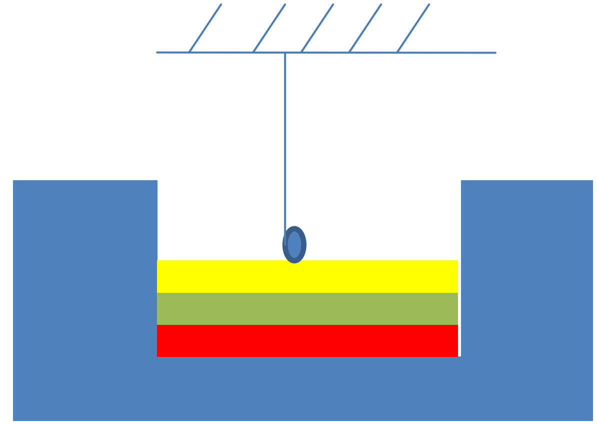
- Two wire torsion pendulum
- Support structure for the pendulum
- Cabling

Apparatus Design Goals

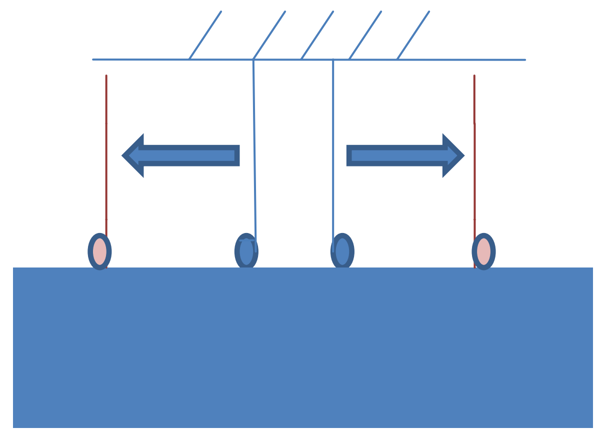
- 1. An order of magnitude variability in yaw and pitch frequency
- 2. Cases that can be easily modeled
- 3. Stiff support structure



Varying pitch frequency

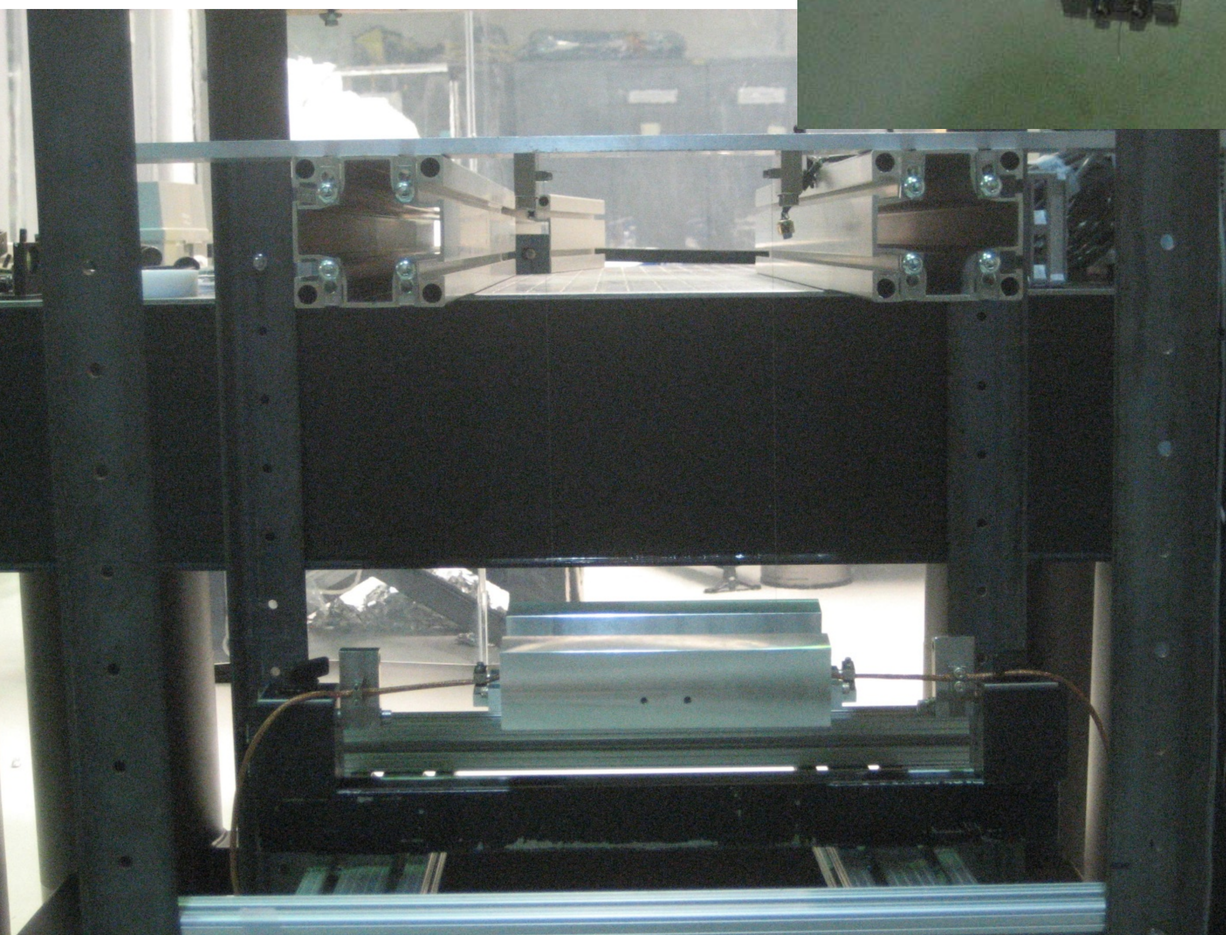


Varying yaw frequency



Yaw frequency range:
0.14 Hz – 1.27 Hz

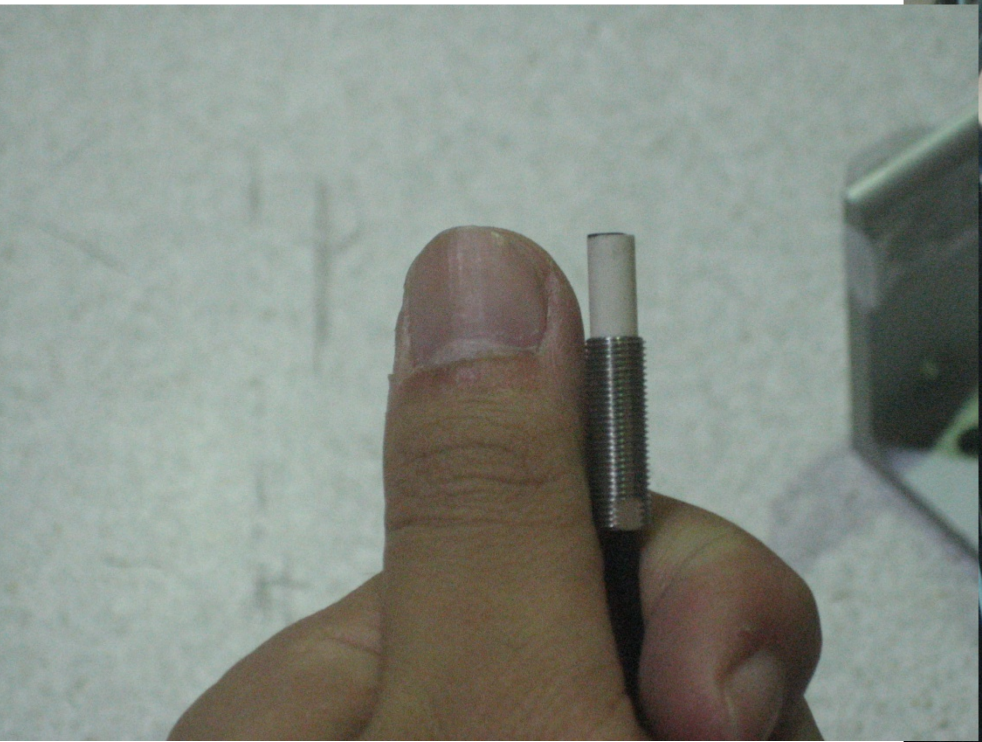
Pitch frequency range:
0.41 Hz - 2.97Hz

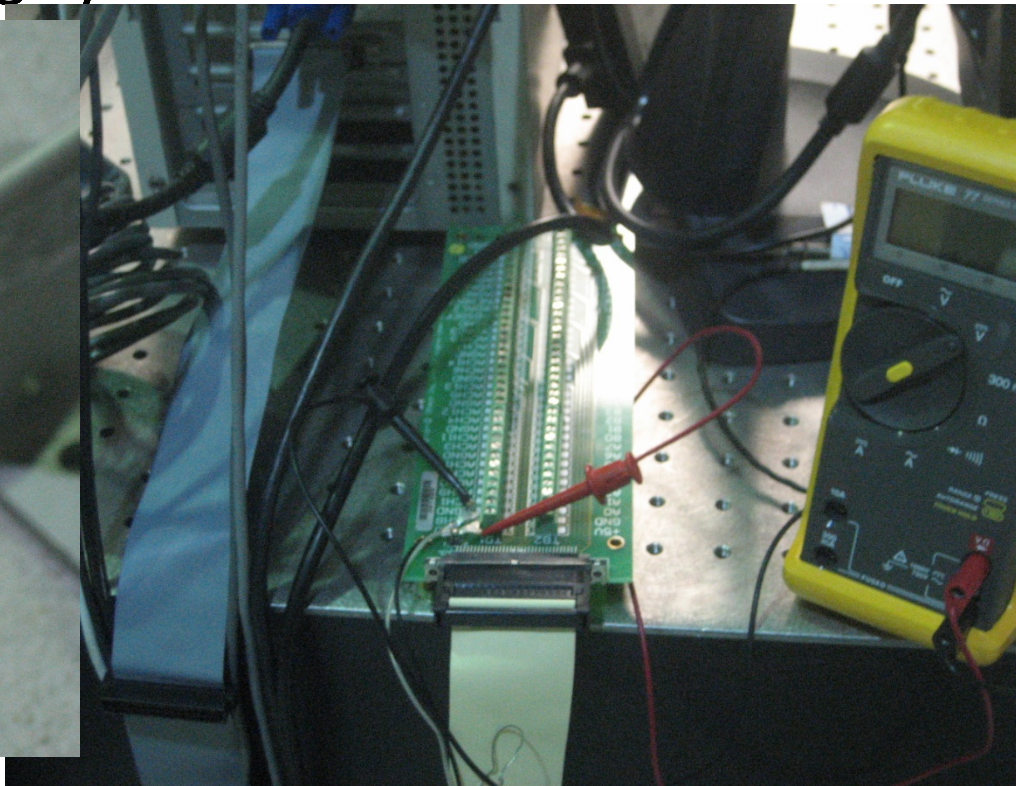


1. Clamps ensure straight connection pts.
2. Optics table helps stiffen the support

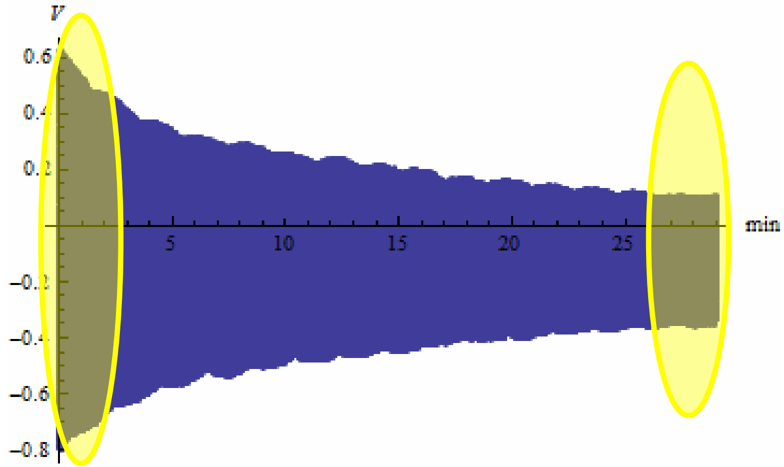
Data Collecting

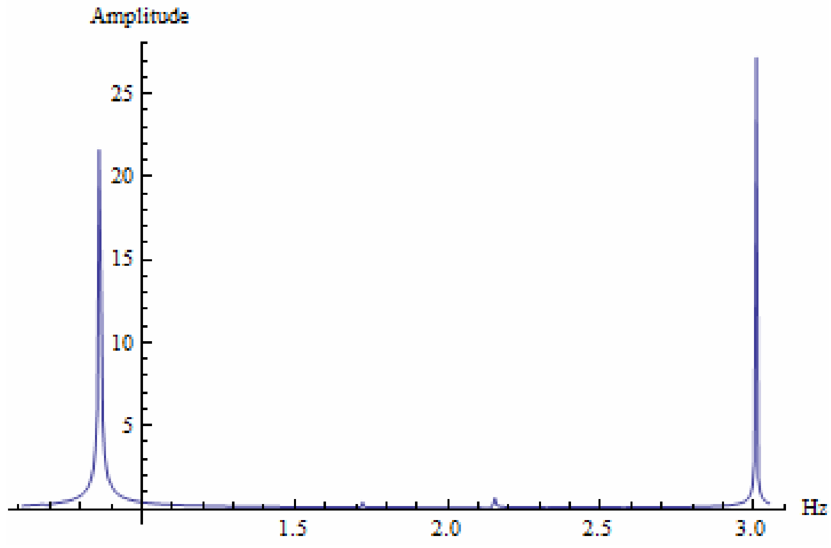
- Equipment used:
  - Kaman eddy current displacement sensor
  - LabVIEW data logging system

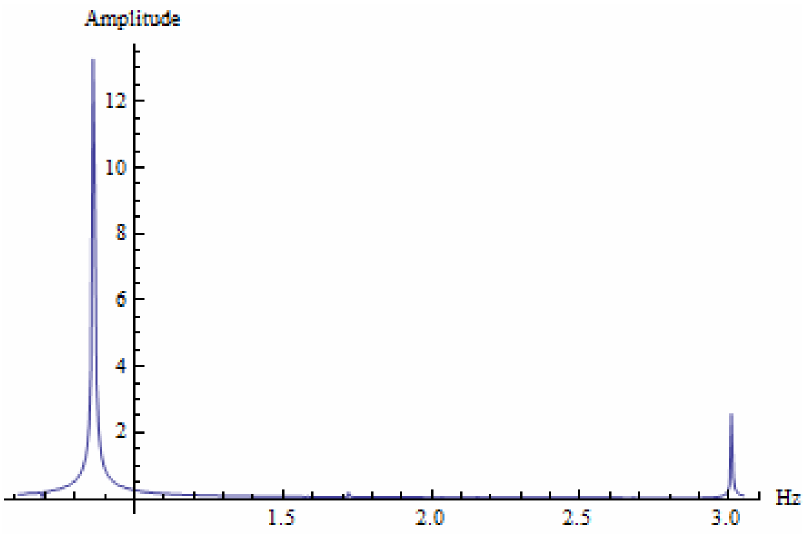




Data Analysis







Data analysis method and computer program by Mark Barton

Results

Yaw mode

	frequency	
	measured	predicted
n=1 cm	0.134	0.1366
n=3 cm	0.4089	0.4098
n=5 cm	0.6836	0.683
n=7 cm	0.958	0.956
n=9 cm	1.227	1.229

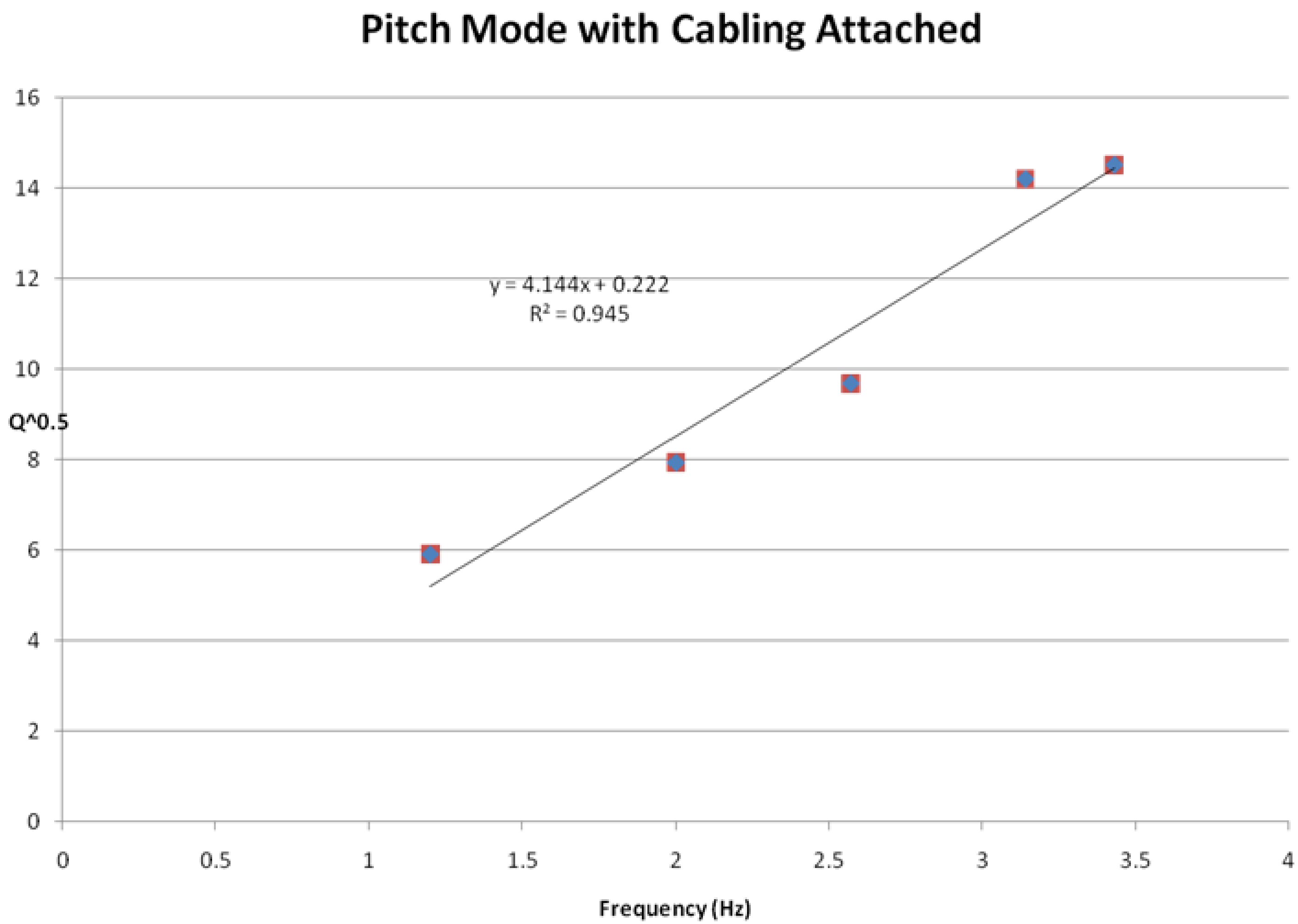
Pitch mode

	frequency	
	measured	predicted
0 plate	0.656	0.414
1 plate	1.56	1.458
2 plates	2.14	2.066
3 plates	2.61	2.559
4 plates	3.01	2.97

Model predictions by
Julian Freed-Brown, based on
equations by Calum Torrie.

Results

	pitch mode				n = 5 cm		
	without cabling				with cabling		
	frequency	Q			frequency	Q	Q^0.5
0 plate	0.656	1703			1.2	34.8	5.899152
1 plate	1.56	2376			2	62.9	7.930952
2 plates	2.14	3775			2.57	93.8	9.68504
3 plates	2.61	4627			3.14	202	14.21267
4 plates	3.01	6293			3.43	211	14.52584



$$Q = f^2 \left(\frac{I}{k_c \emptyset_c} \right)$$

Results

$$k_c = {f_T}^2 I - {f_p}^2 I$$

$$k_c = \pm 0.002 \frac{Nm}{rad}$$

$$\emptyset_c = 0.03 \pm 0.01$$

Future Work

1. Feed results into Julian's Mathematica model
2. Check for agreement between the model and experiment frequency results.
3. Study the resulting transfer functions and make recommendations on cabling dressing.