Mar. 20, ’05

Summary of Support tube R&D

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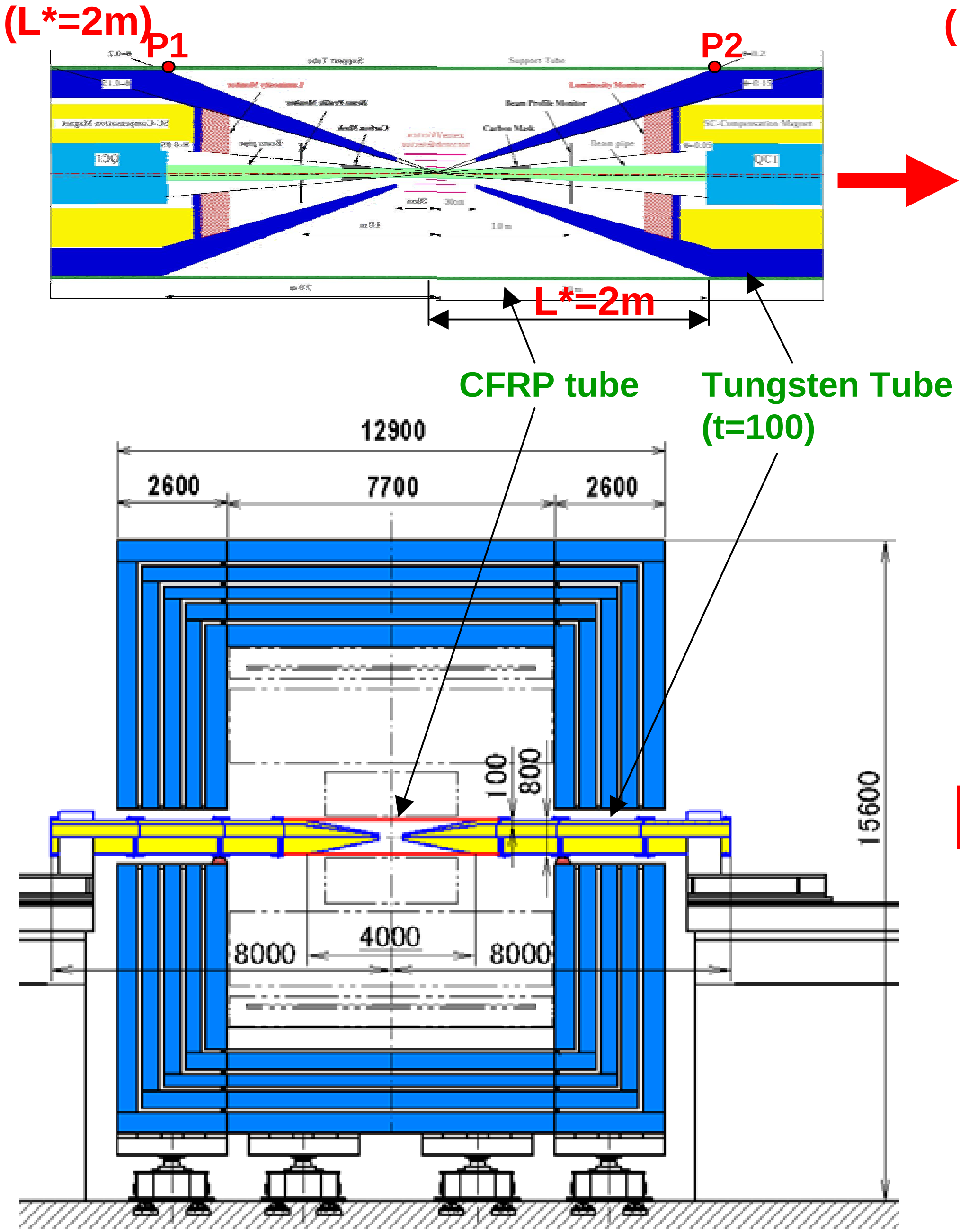
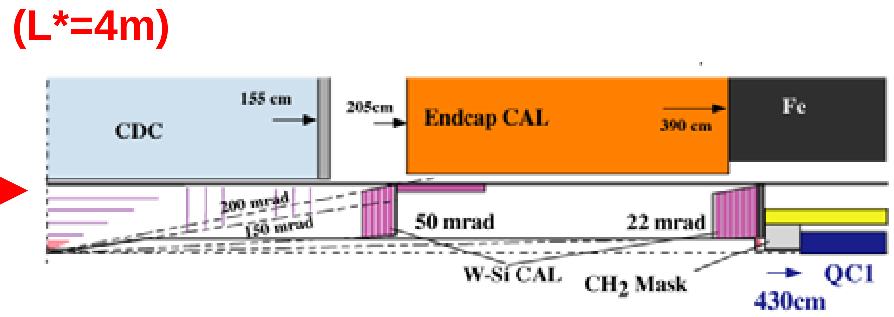
Introduction





- Components at IR region
  Supported by
  Tungsten tubes, CFRP tube
- For high luminosity
  Effects of;
  Ground motion, culture Noise
  have to be eliminated.

→ Analyses, Excitation tests

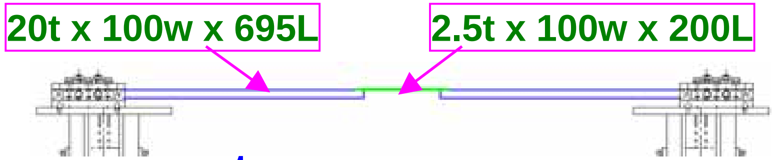
Study Items;

- Check consistency
  Analyses ⇔ Excitation test
- Is necessary CFRP tube?

→ If yes, how much thickness?

- How much is relative amplitude?
  |P1-P2| < 2nm(Criteria)

Exciting Test

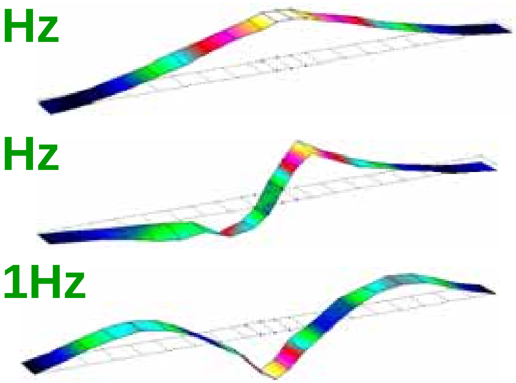


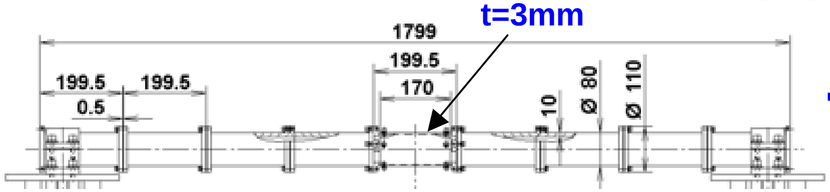
Measurement | **FEM**

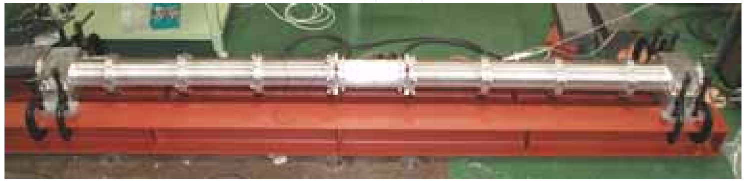
1: 26Hz ↔ 1: 30Hz

2: 40Hz ↔ 2: 43Hz

3: 161Hz ↔ 3: 184Hz



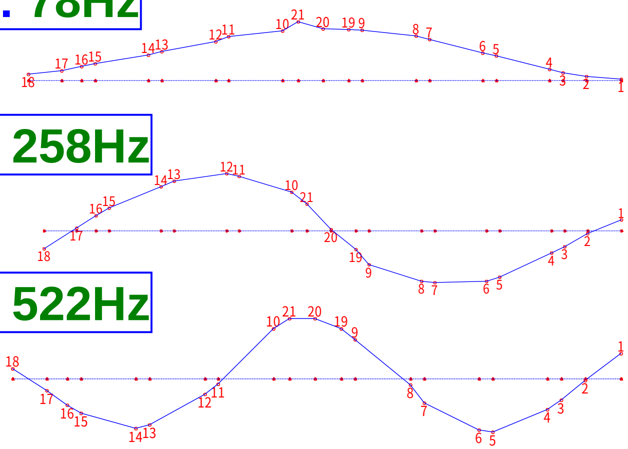


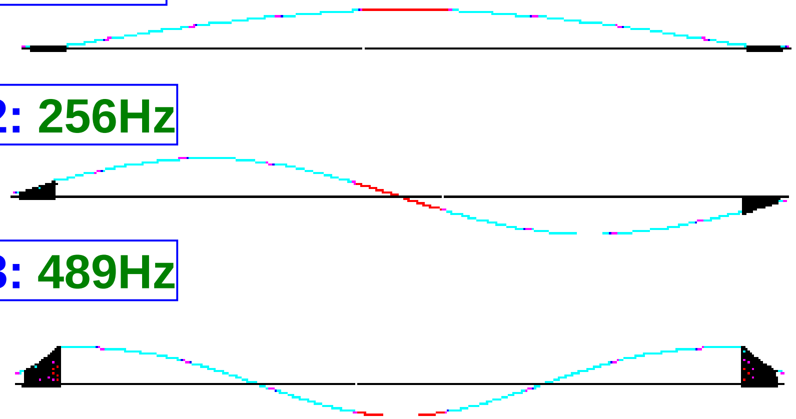


1: 78Hz ↔ 1: 76Hz

2: 258Hz ↔ 2: 256Hz

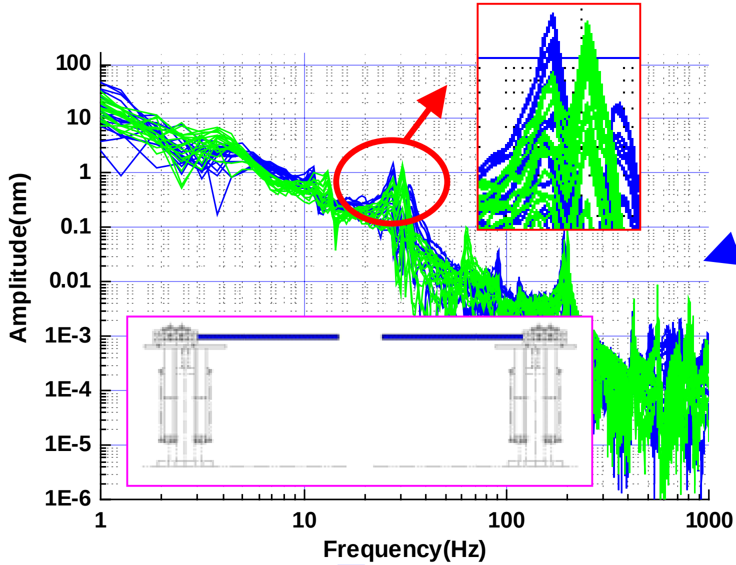
3: 522Hz ↔ 3: 489Hz

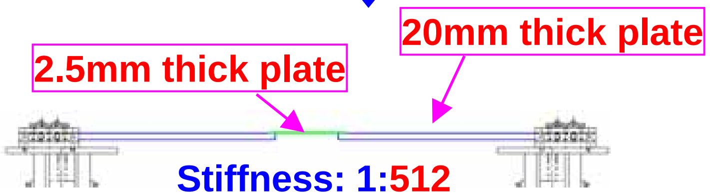


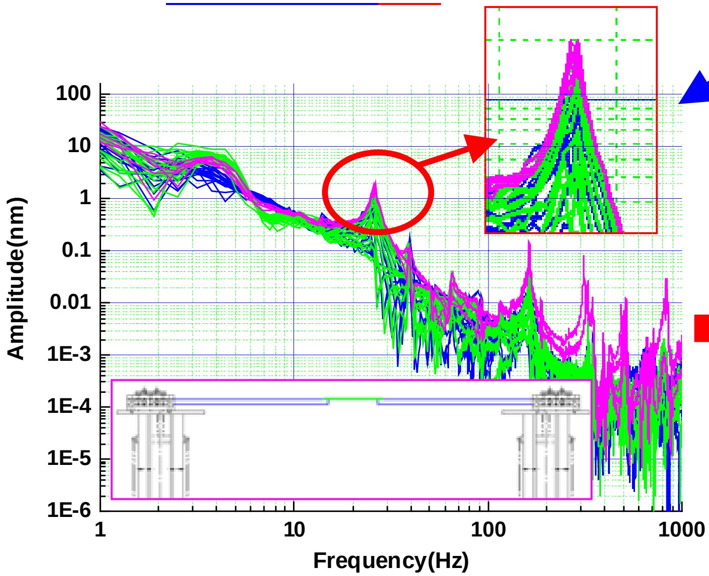


1st ～3rd mode: Good agreement with FEM

Support structure should be modeled in FEM.





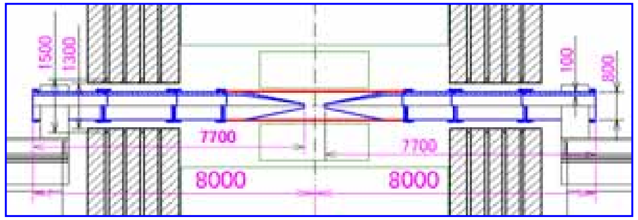


By connecting very weak structure,

- **Deviation can be absorbed.**
- **Correlation can be given.**

→ Relative amplitude can be estimated.

Calculation of relative amplitude



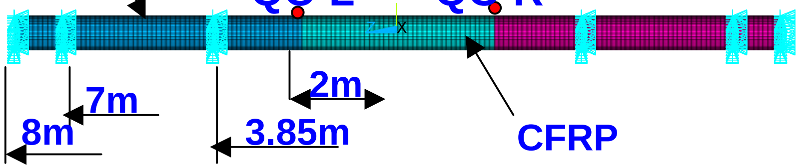
(Model-A)

$F_0\cos(\omega t)=(m \cdot a)\sin(\omega t)$

QC-L: Tungsten(100mm)

ω= 0 – 1000Hz

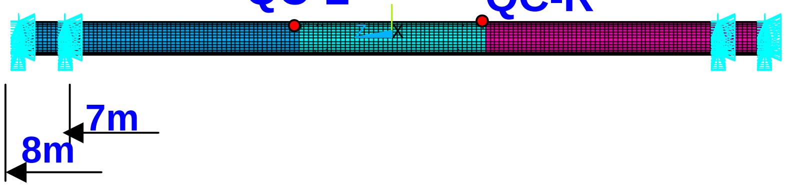
QC-L QC-R



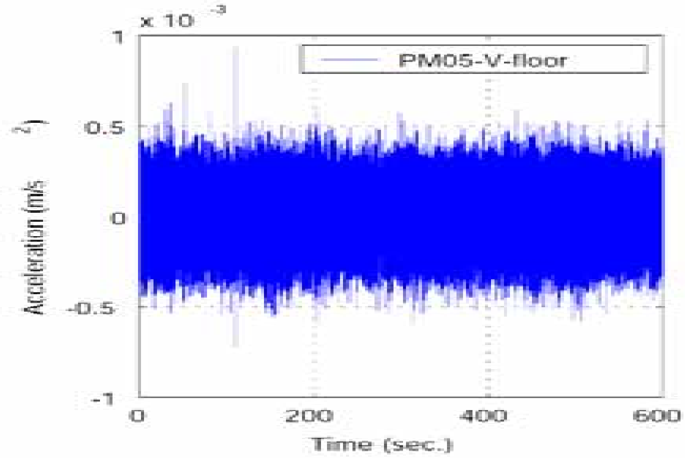
CFRP

(Model-B)

QC-L QC-R

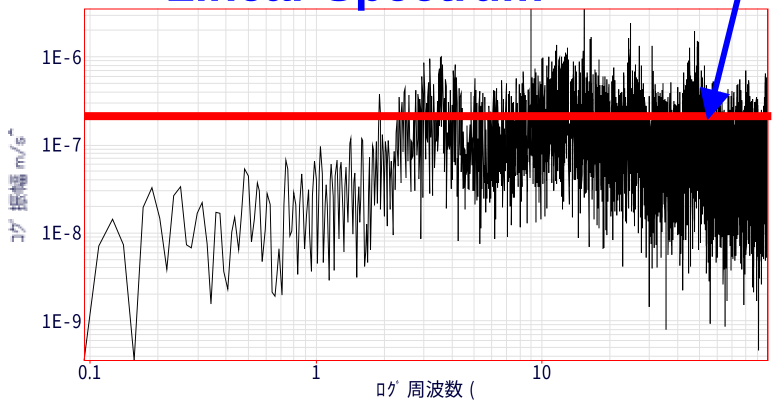


Data: Vertical @KEK: ATF(17:00 Feb. 10, 2004)



Linear Spectrum

2×10^{-7}m/s^2



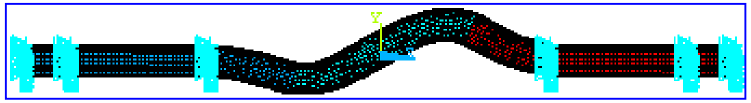
Input Acc. = 2×10^{-7}m/s^2

Mass=90tons/9.8[m/s^2]

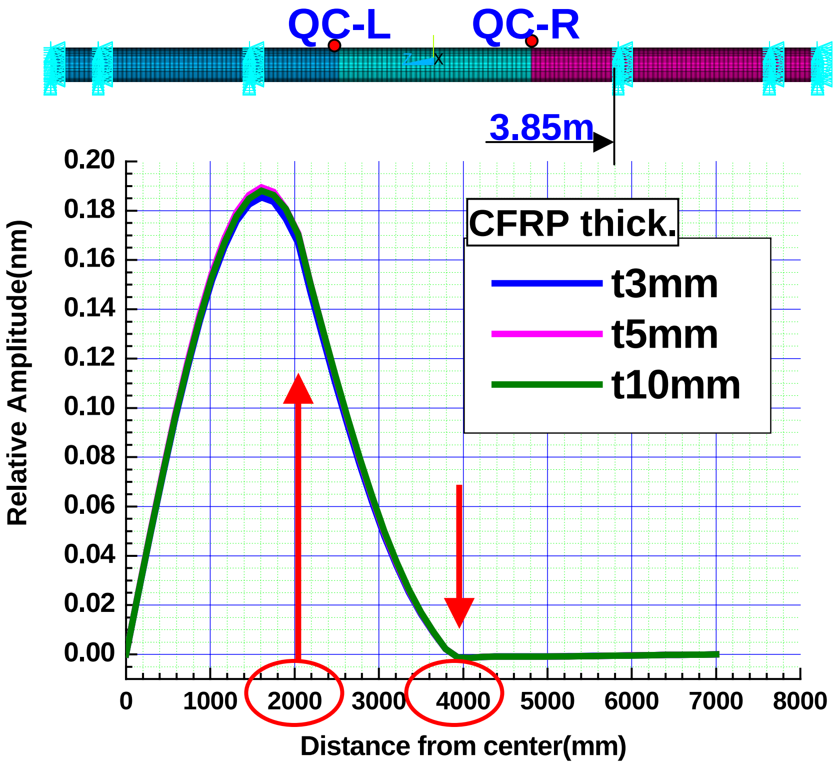
Self weight

How much is relative amplitude?

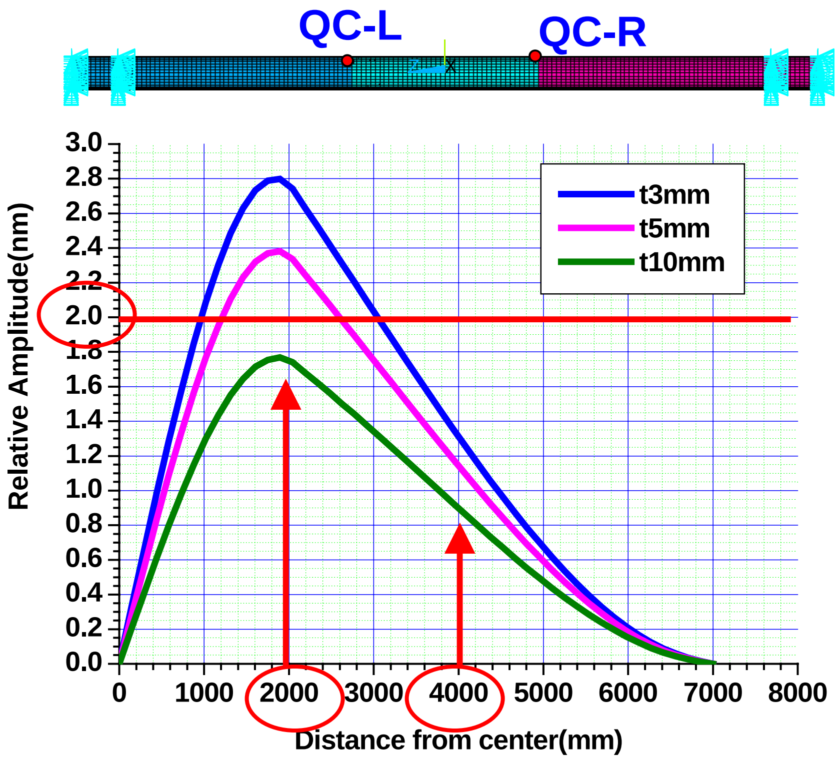
Relative amplitude at 2^{nd} mode



(Model-A)



(Model-B)



Model-A

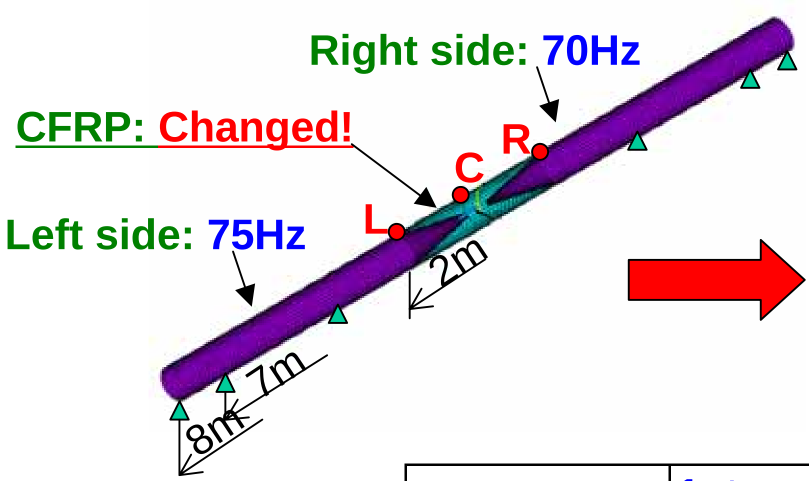
Less than 2nm. Small enough at 4m.

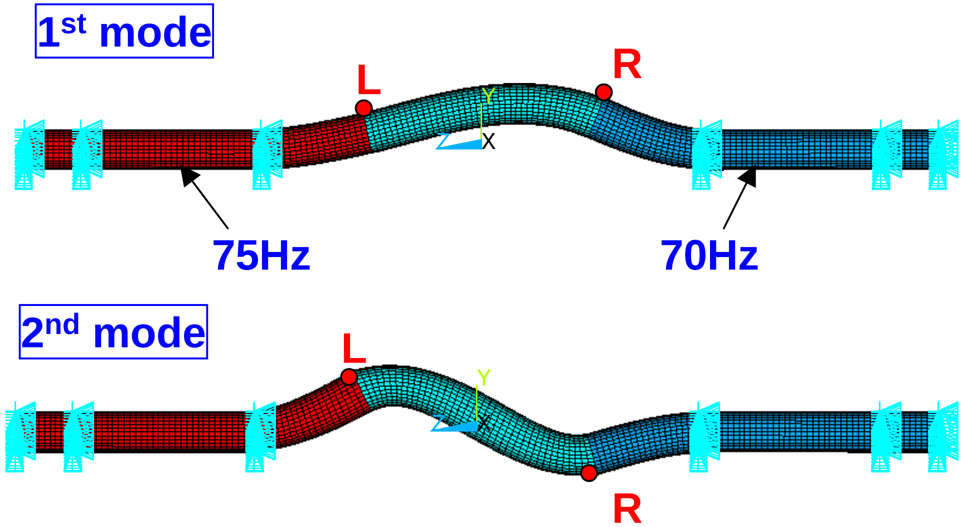
Model-B

Lager than 2nm at L*= 2m except for 10mm thick of CFRP.

Less than 2nm at L*= 4m.

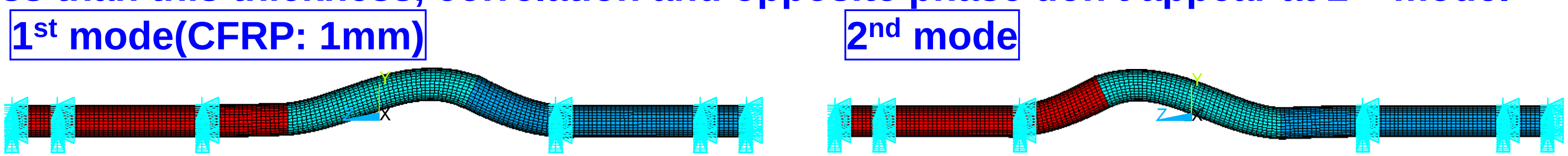
Optimization of CFRP tube thickness





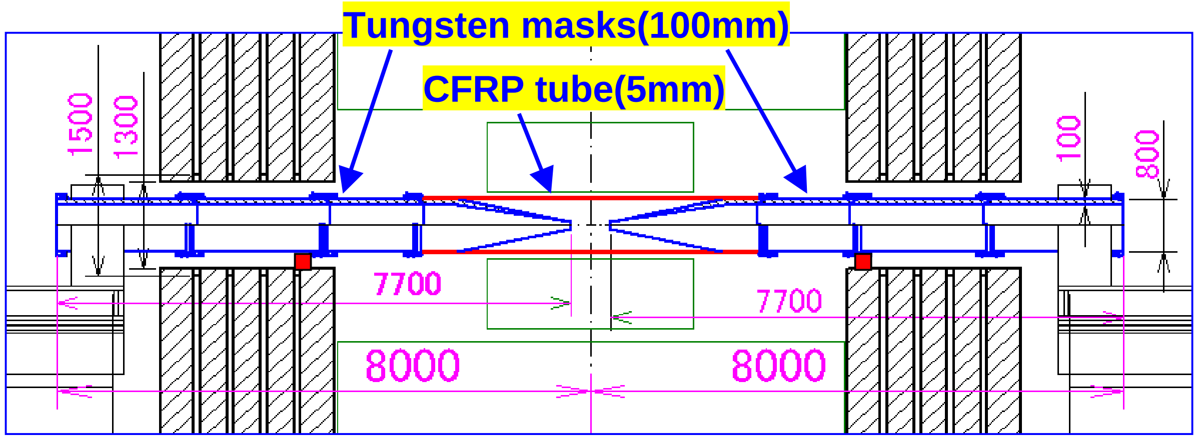
CFRP(mm)	1st mode Freq(Hz)	2nd mode Freq(Hz)
20	73.6	85.2
10	72.9	80.1
5	75.5	78.4
3	72.0	76.5
1	71.5	75.7

Less than this thickness, correlation and opposite phase don't appear at 2nd mode.



At least, thickness of CFRP: >3mm

Conclusion



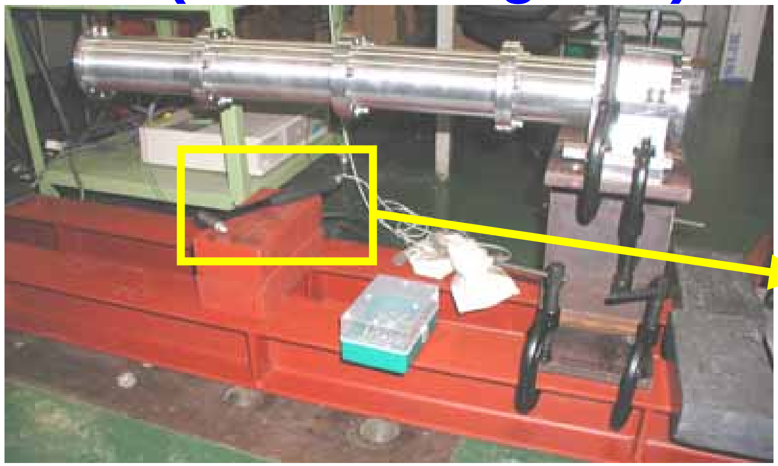
- Tungsten tube: 100mm thick, CFRP: 5mm thick
  → Correlation is given to both-sides tubes in oscillating behavior.

- In case of L*= 2m;
  Support position: Both ends + 3.85m from I.P.
- In case of L*= 4m;
  Support position: Both ends

- Active vibration isolation system is necessary.
  → - Amplitude is magnified if support tube is mount on a support stand.
    - To eliminate culture noise.
    - CFRP tube is not efficient to reduce amplitude less than 2nm.

- It is necessary to design the stiff support base as possible
  → Natural frequency becomes high.
    → Amplitude decreases in proportion to frequency.

○ Tests(Hammering test)

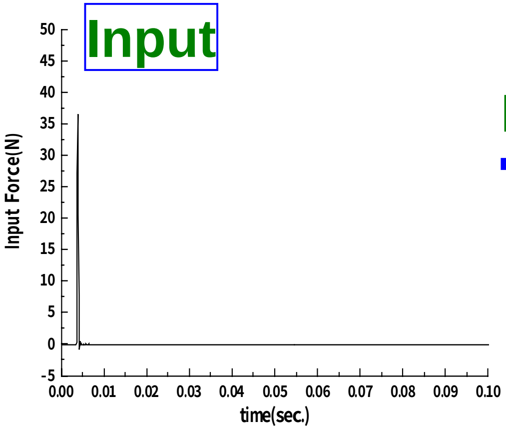


FRF(Frequency Response Function)

$$H_{ij}(f)=\frac{X_i(f)}{F_j(f)}$$

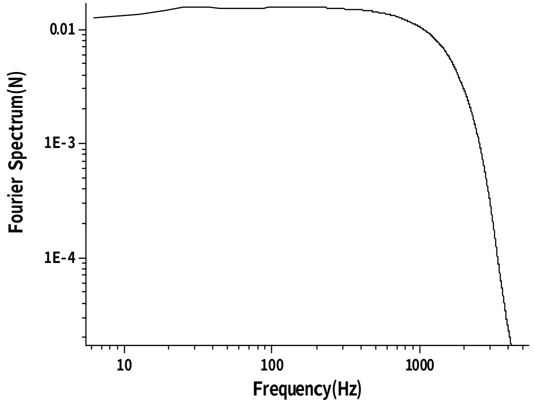
X_i: Output Acc.
F_j: Input force

Input

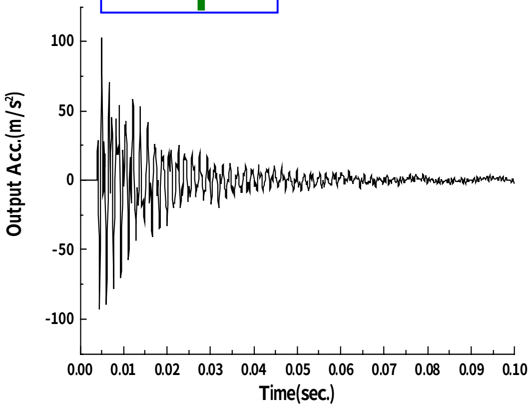


FFT

Input

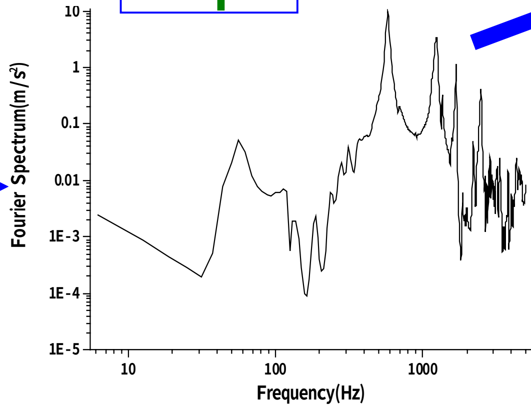


Output



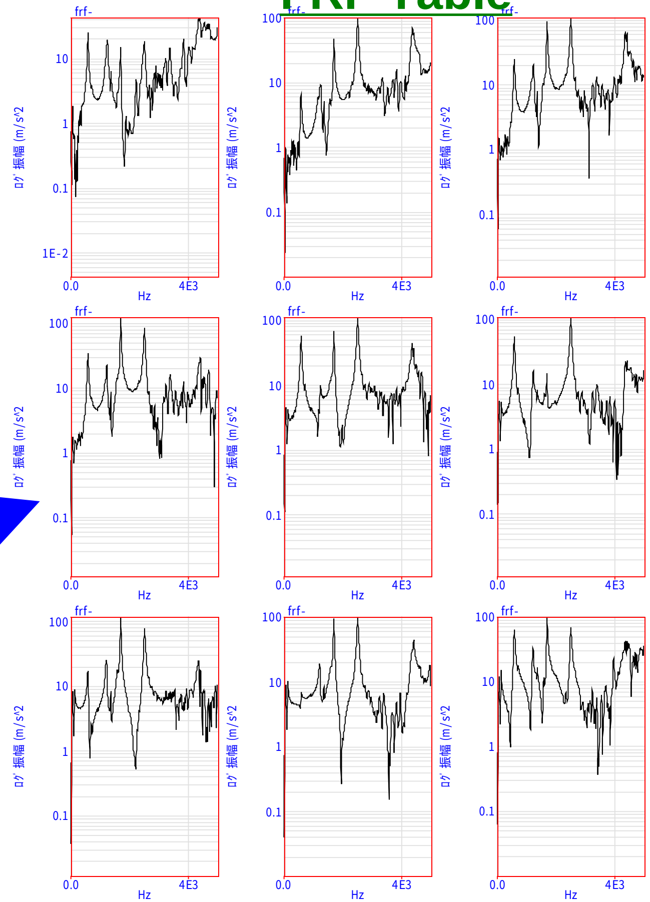
FFT

Output



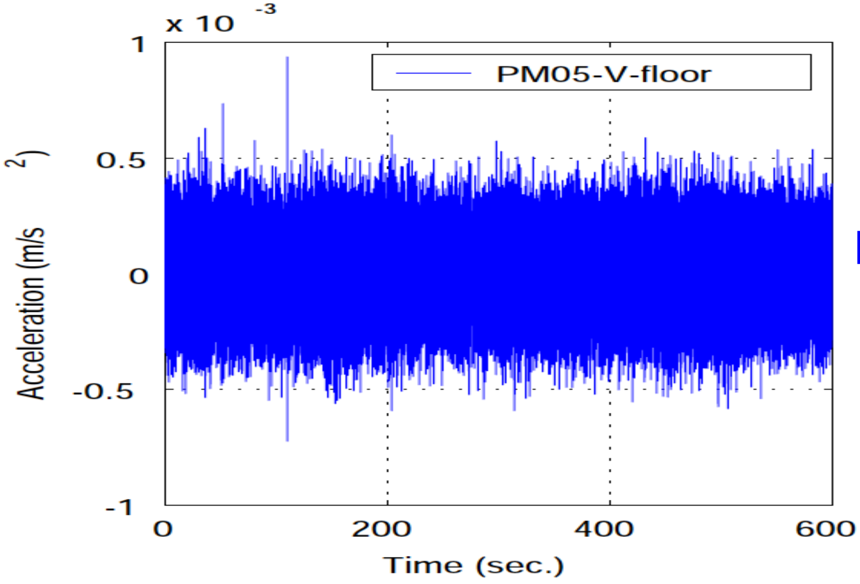
FRF

FRF Table

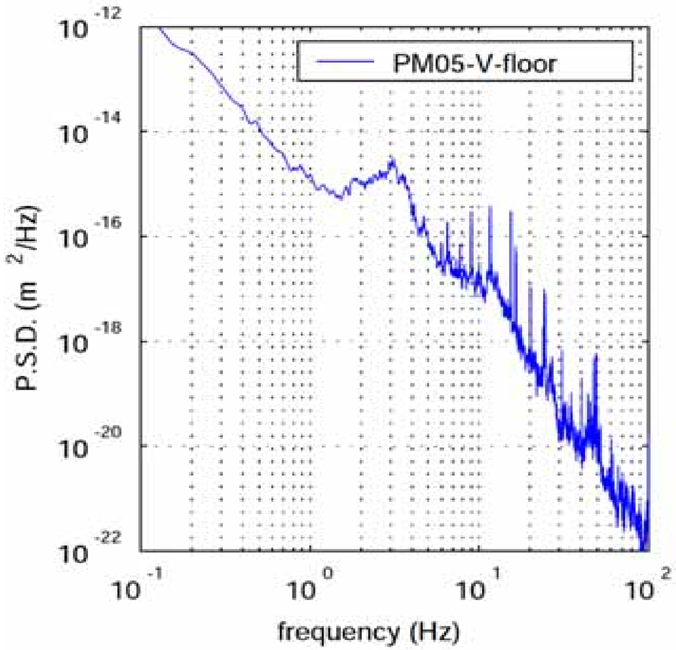


Estimation of Input Acc.

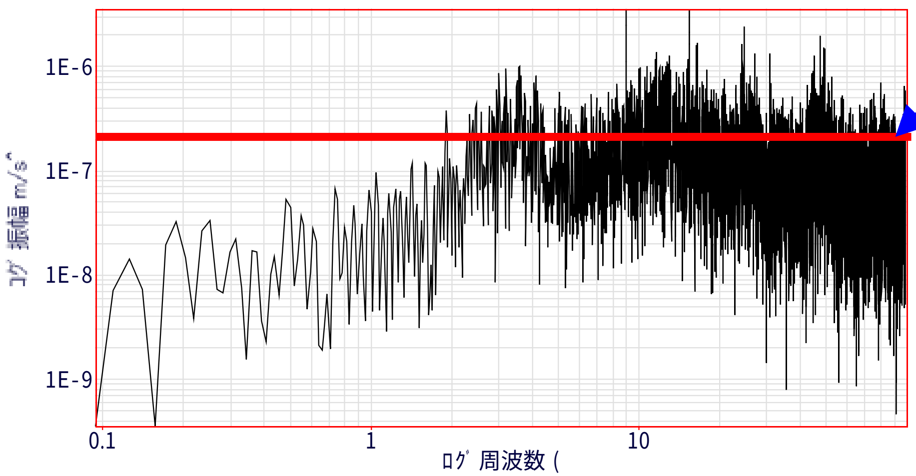
Data: Vertical @ATF(17:00 Feb. 10, 2004)



P.S.D.



Linear Spectrum



$2x10^{-7}m/s^2$

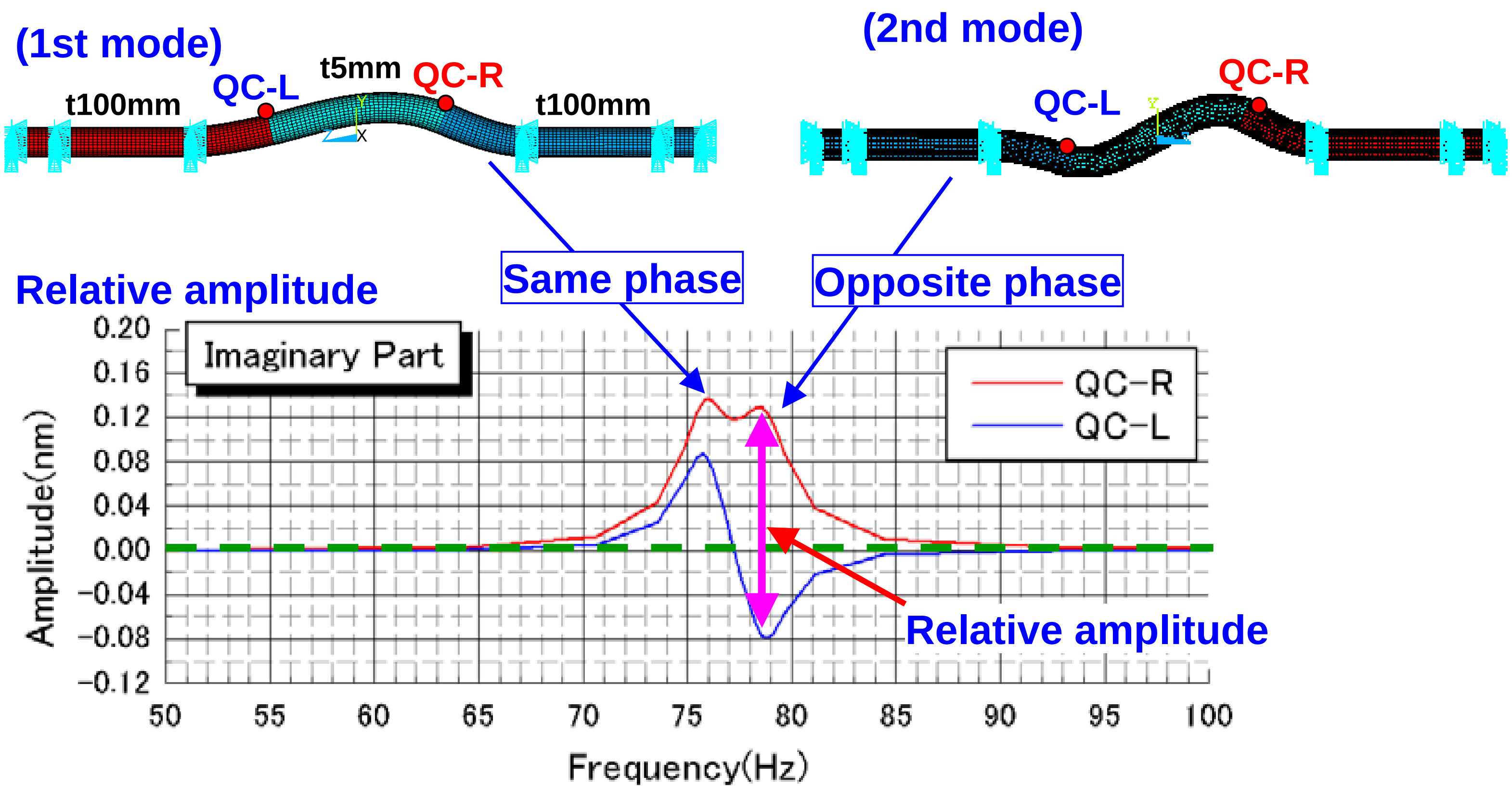
Input data

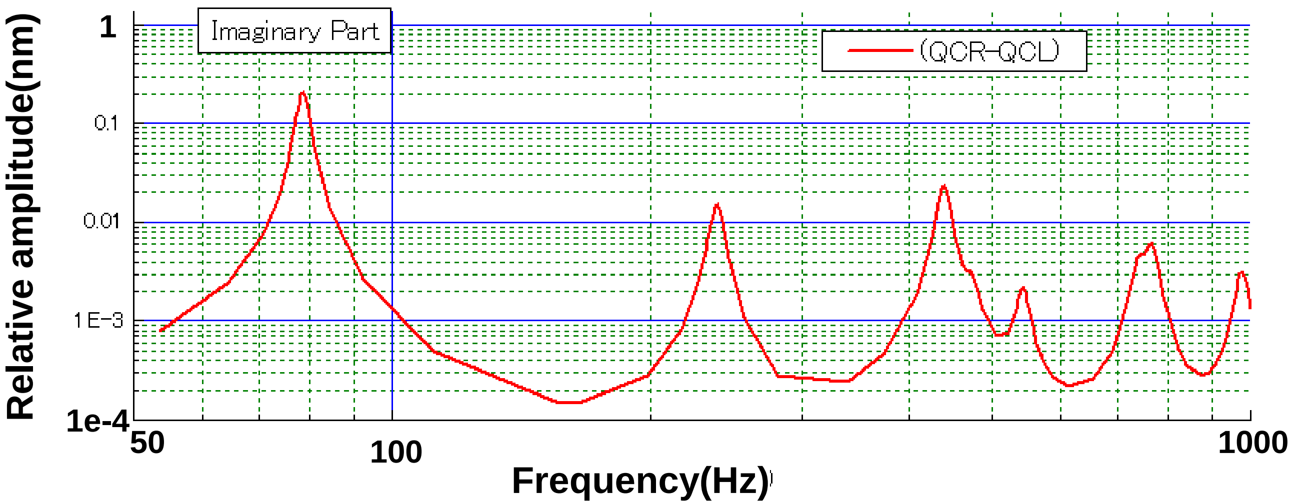
Input Acc. = $2x10^{-7}m/s^2$

Mass=90tons/9.8[m/s²]

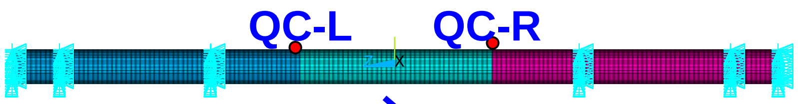
Self weight

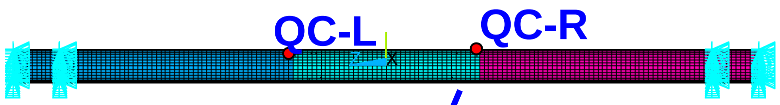
In case of 100mm-5mm(CFRP)-100mm





Other calculations(L*=2m)

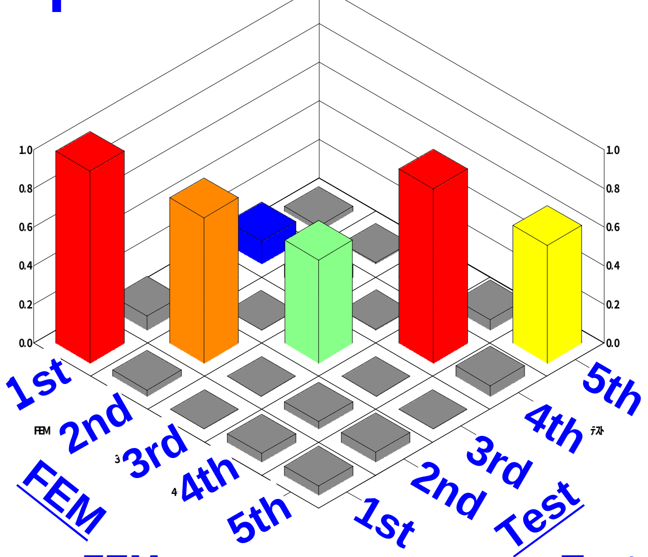


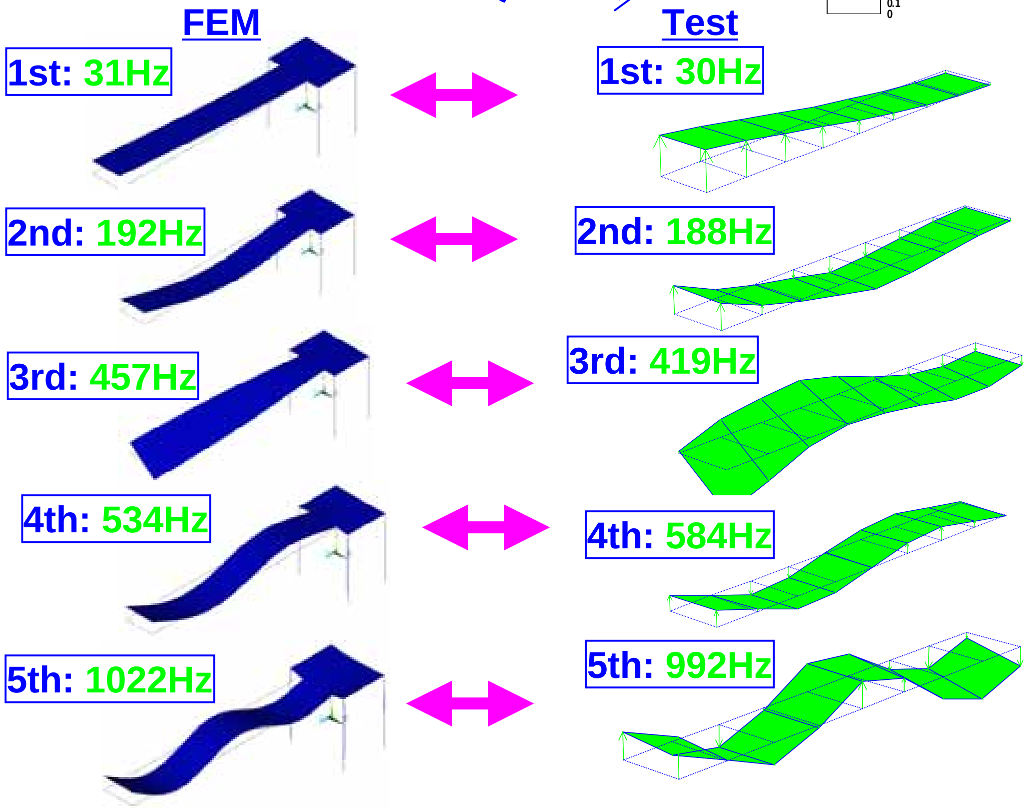


			3-Point fixed(Both end+3.85m)				2-Point fixed(Both end)			
			CFRP			Tungsten	CFRP			Tungsten
Δf	Mode		3mm	5mm	10mm	100mm	3mm	5mm	10mm	100mm
0Hz	1st	Freq.(Hz)	75.8	76.0	76.0	49.2	17.6	17.7	17.9	16.3
		Diff.(nm)	0.098	0.055	0.016	9.09E-05	0.065	0.026	0.008	2.60E-04
	2nd	Freq.(Hz)	77.5	78.6	81.4	113.0	20.2	21.8	25.0	44.4
		Diff.(nm)	0.213	0.206	0.192	0.080	2.816	2.398	1.763	0.325
1Hz	1st	Freq.(Hz)	75.2	75.3	75.5	49.0	17.0	17.1	17.3	16.0
		Diff.(nm)	0.129	0.080	0.035	1.10E-03	0.823	0.480	0.234	3.60E-02
	2nd	Freq.(Hz)	77.0	78.2	80.9	112.6	19.8	21.4	24.7	43.3
		Diff.(nm)	0.174	0.177	0.177	0.081	2.357	2.186	1.696	0.334
3Hz	1st	Freq.(Hz)	73.4	73.7	74.2	48.5	15.6	15.9	16.3	15.3
		Diff.(nm)	0.173	0.133	0.076	3.26E-03	2.339	1.496	0.752	1.30E-01
	2nd	Freq.(Hz)	76.9	77.8	80.4	111.9	19.5	20.9	24.1	41.0
		Diff.(nm)	0.094	0.116	0.143	0.082	1.547	1.726	1.532	0.349
5Hz	1st	Freq.(Hz)	71.5	72.0	72.7	48.1	13.9	14.4	15.1	14.4
		Diff.(nm)	0.204	0.172	0.113	5.62E-03	3.813	2.631	1.396	2.84E-01
	2nd	Freq.(Hz)	76.8	77.6	80.0	111.0	19.3	20.6	23.6	38.4
		Diff.(nm)	0.056	0.078	0.114	0.084	1.077	1.343	1.343	0.359
Canti	1st	Freq.(Hz)	75.6				17.4			
		Amp(p-p)	0.224				3.869			

Diff: Relative amplitude between QC-R and QC-L(ΔZ=4m).

Comparison with FEM





MAC(Modal Assurance Criteria)

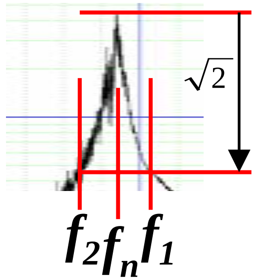
$$MAC_{rr'} = \frac{\left| \{\psi_r^{test}\}\{\psi_{r'}^{FE}\}^* \right|^2}{\left(\{\psi_r^{test}\}\{\psi_r^{test}\}^*\right)\left(\{\psi_{r'}^{FE}\}\{\psi_{r'}^{FE}\}^*\right)}$$

Modal assurance criteria quantitatively compare all the possible combinations of test and analysis mode shape pairs.

MAC=1: Mode shape pairs is exactly match

MAC=0: pairs that are completely independent

Damping ratio

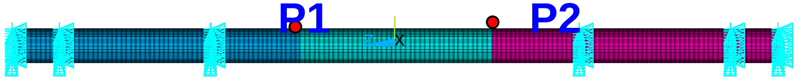


$$\zeta = \frac{f_1 - f_2}{2 \times f_n}$$

Mode	Freq.	Damping(%)
1	30.4Hz	1.68
2	188Hz	0.422
3	419Hz	0.303
4	584Hz	0.113
5	992Hz	8.02E-2

Results

(Model-A)



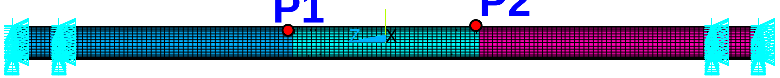
- Natural frequency: 76Hz
- Relative amp. : 0.2nm max. < 2nm(L*= 2m), small enough(L*= 4m)
- This is ideal configuration.
- In case of no CFRP tube(Cantilever): Amplitude=0.2nm <2nm

  CFRP tube is not necessary because of less than 2nm.

  However, it is difficult to amount them on a very stiff base stand.

So realistic natural frequencies must be lower than this value.

(Model-B)



- Natural frequency: 17Hz,
- Relative amp. : 2〜3nm(L*= 2m), 1.2nm(L*= 4m)
- In case of no CFRP tube(Cantilever): Amplitude= 4nm

⇒ Efficient of CFRP tube:

- Relative amplitude can not decrease drastically. But it is about half amplitude of cantilever type.
- Deviation of natural frequency between two tubes can be absorbed.