

JLC QC support system

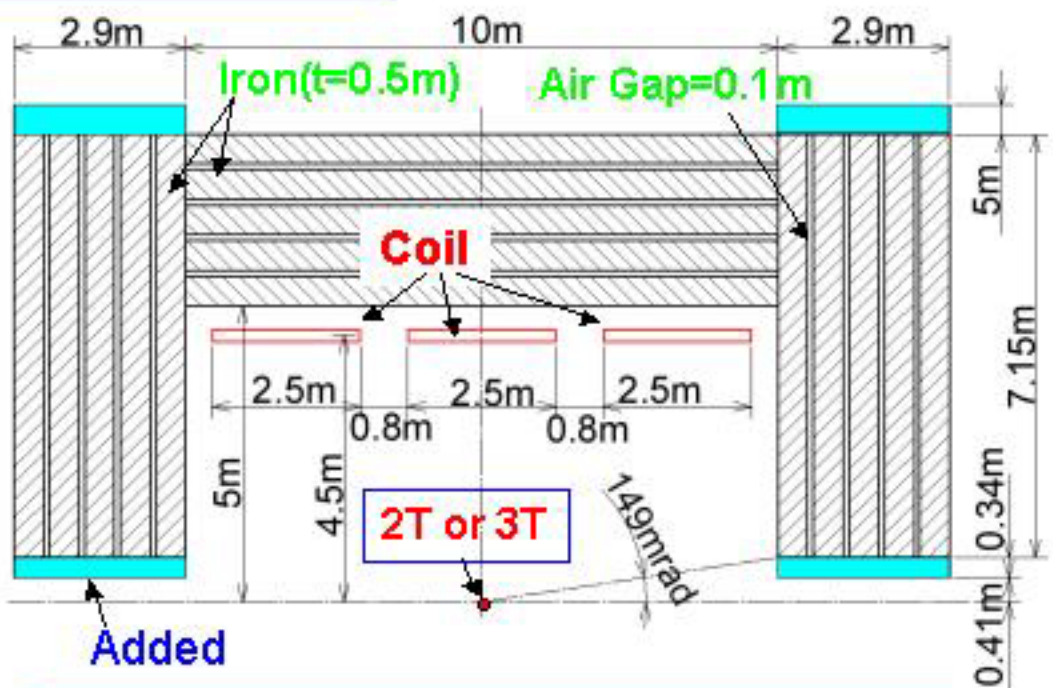
KEK Hiroshi Yamaoka

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1. Introduction

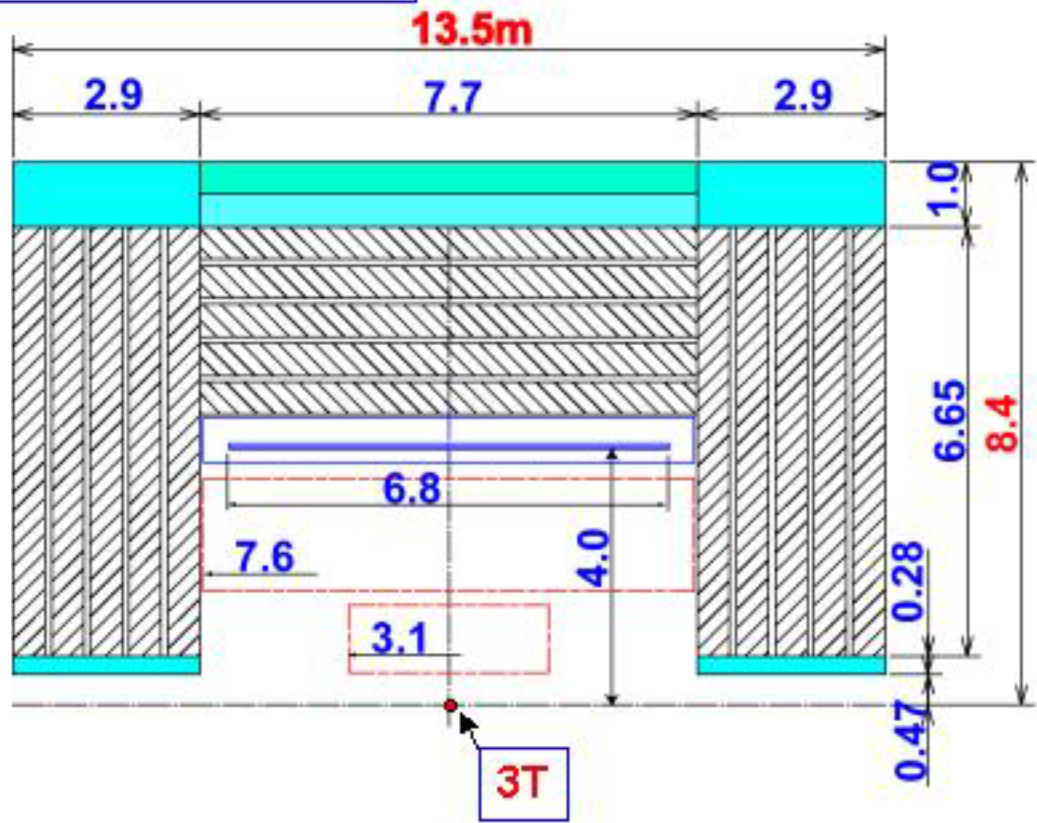
Initial Configuration



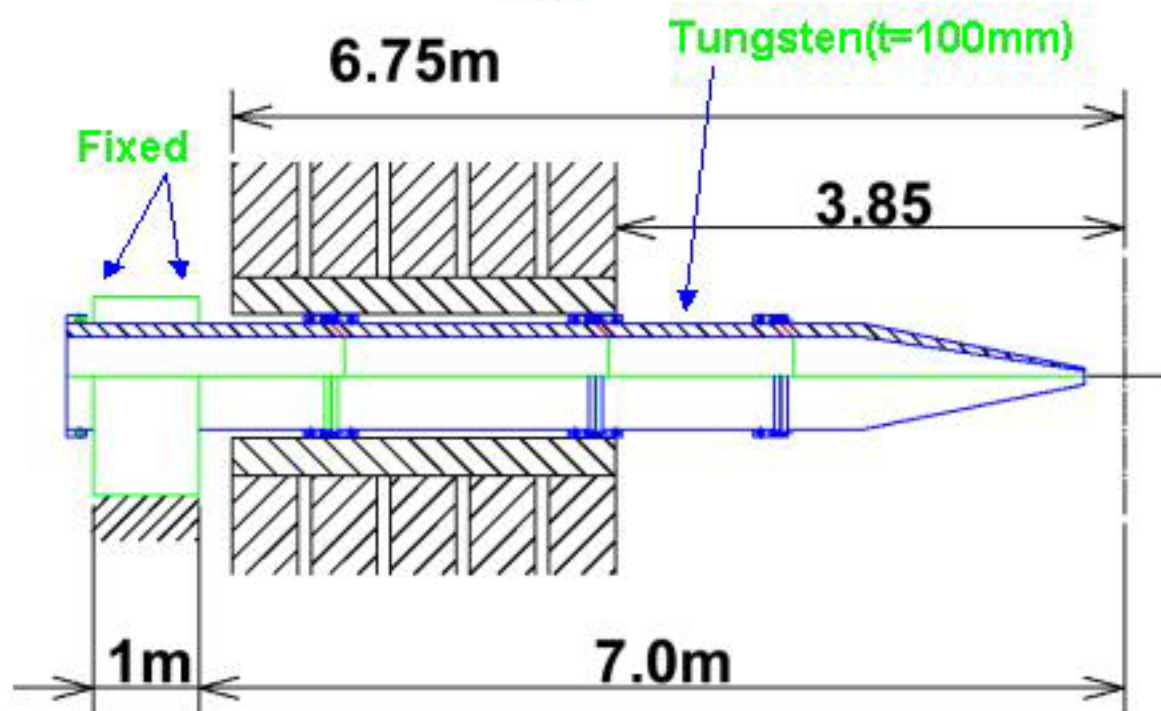
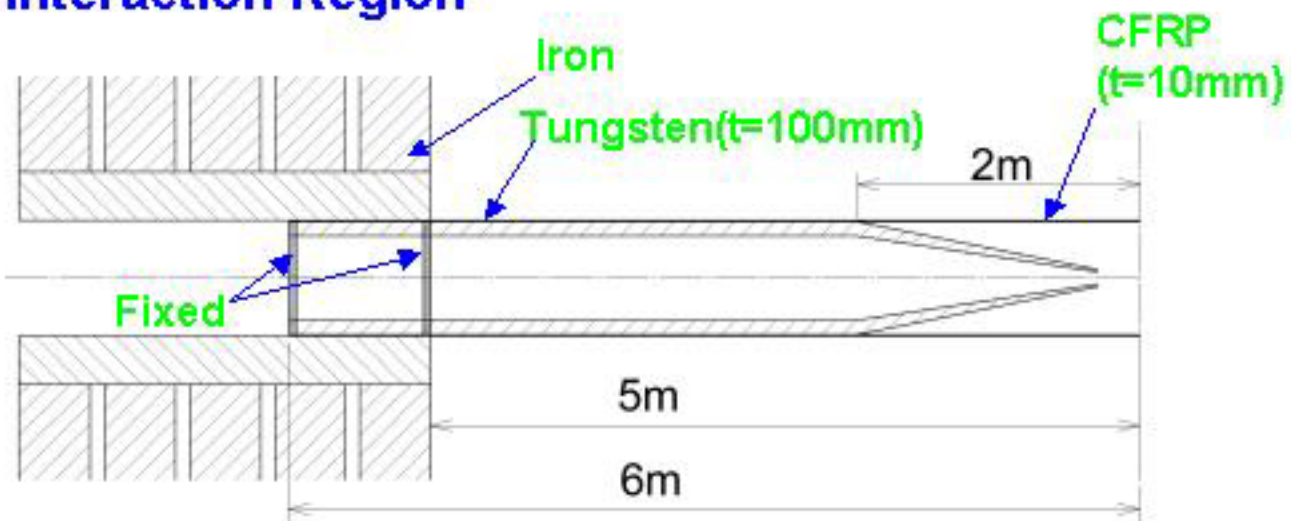
➔ **Detector size can be smaller (@3T)**



Present Configuration



Interaction Region



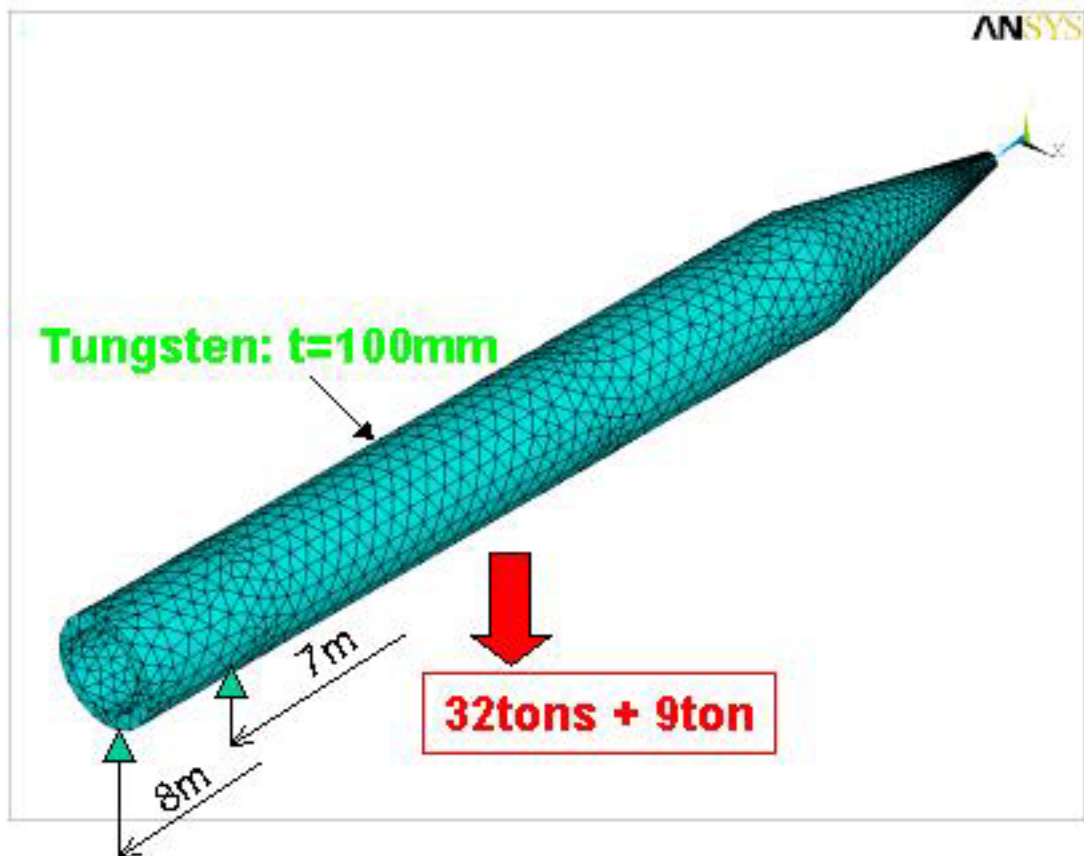
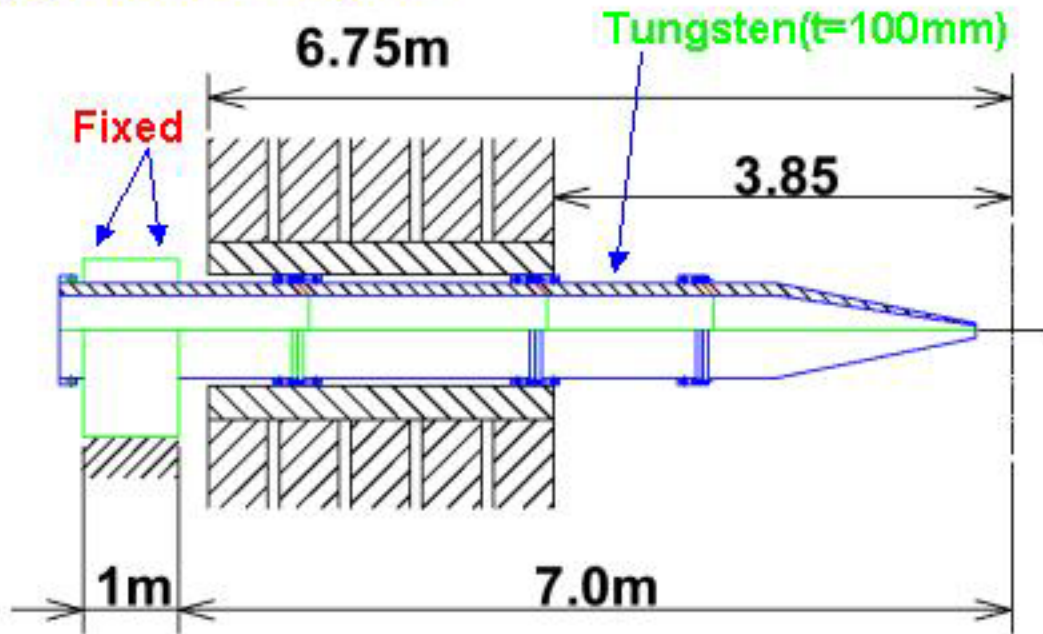
• Total weight: 81 tons, Grand motion

→ • Deformation, Stress

• Oscillation at QC1

2. Calculation

2-(1) Static Analysis



○ Tungsten

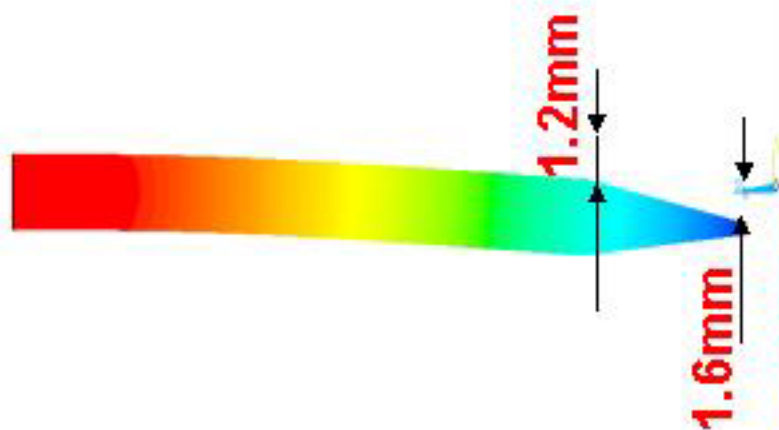
Young's modulus: $4.15 \times 10^4 \text{ kg/mm}^2$ (415GPa)

Density : $19.3 \times 10^{-6} \text{ kg/mm}^3$

Tensile strength : 900MPa

Results

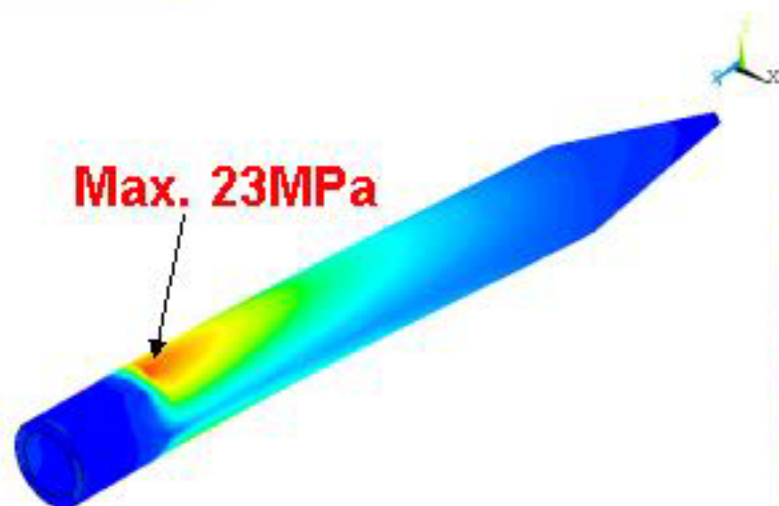
Deformation



ANSYS 5.4
FEB 14 2000
15:58:02
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
UY (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =1.586
SMN =-1.586
SMX =.135E-04

■	-1.574
■	-1.487
■	-1.4
■	-1.301
■	-1.214
■	-1.115
■	-1.029
■	-.929369
■	-.842626
■	-.743492
■	-.65675
■	-.557616
■	-.470873
■	-.371739
■	-.284997
■	-.185863
■	-.099121
■	.135E-04

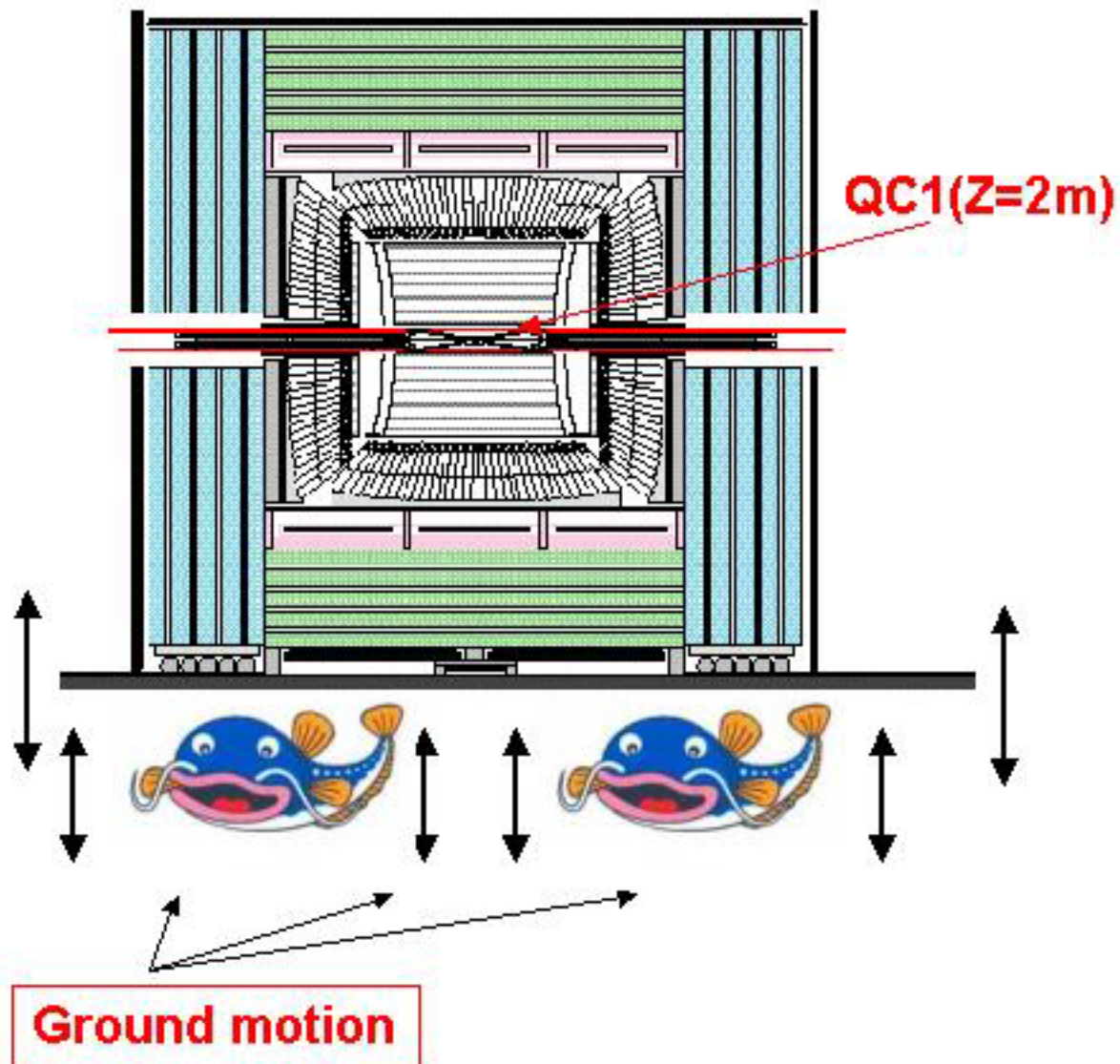
Stress



ANSYS 5.4
FEB 14 2000
15:58:52
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (AVG)
PowerGraphics
EFACET=1
AVRES=Mat
DMX =1.586
SMN =.316E-03
SMX =2.332

■	.018531
■	.146039
■	.273546
■	.401053
■	.52856
■	.656068
■	.783575
■	.911082
■	1.039
■	1.166
■	1.294
■	1.421
■	1.549
■	1.676
■	1.804
■	1.931
■	2.059
■	2.186
■	2.332

2-(2) Dynamic Analysis

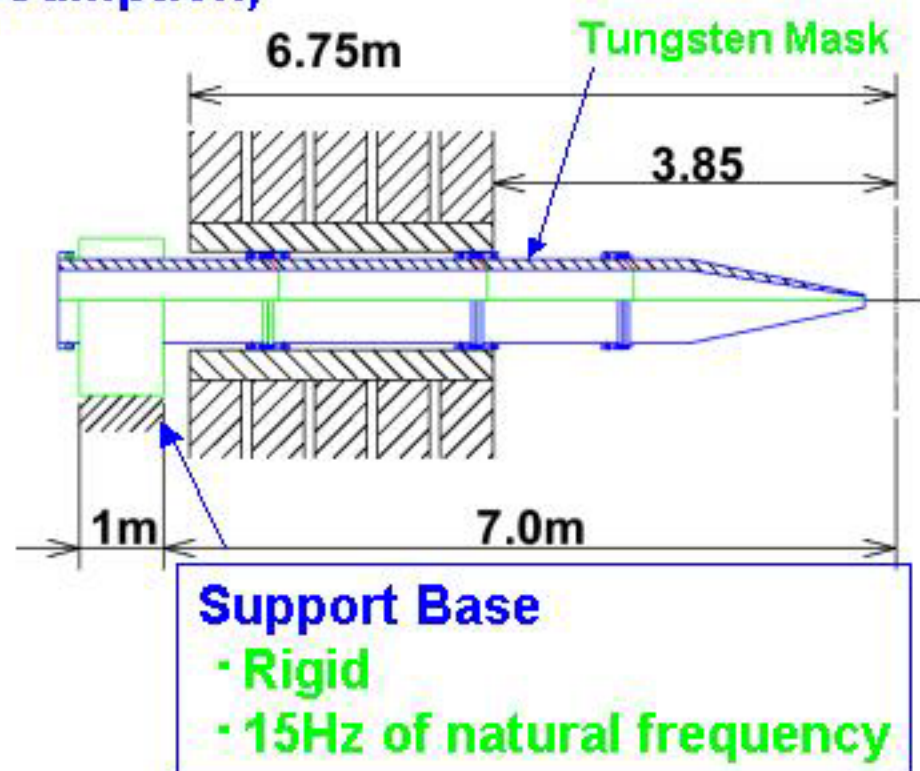


How much deformation at QC1?

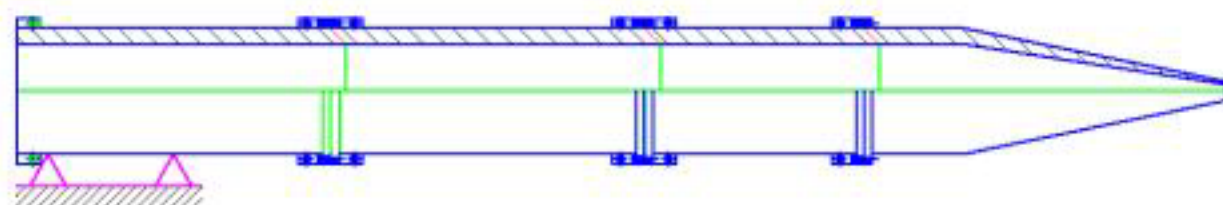
- Modal Analysis(Natural frequency)
- Harmonic response analysis
- Spectrum analysis

2-(3) Modal Analysis(Natural frequency)

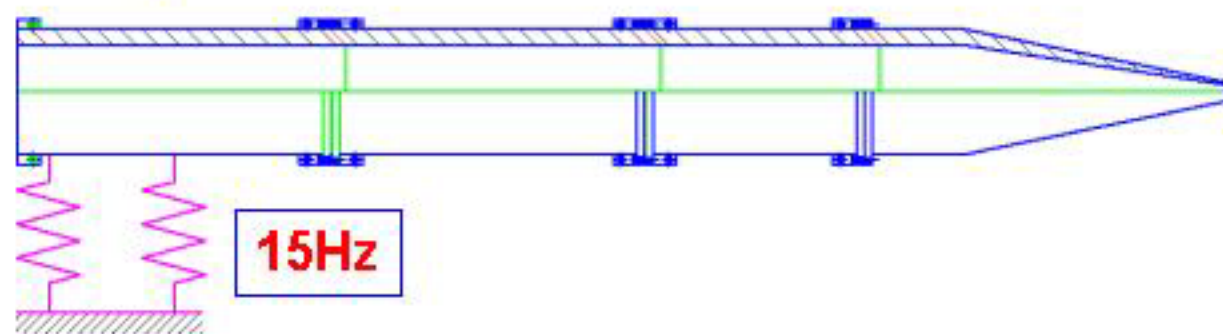
(Assumption)



(Model-A)

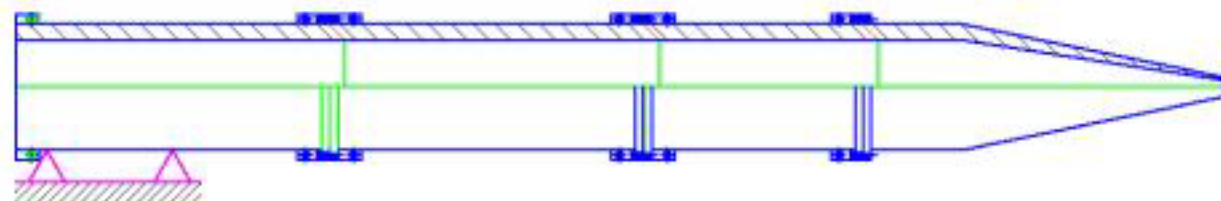


(Model-B)

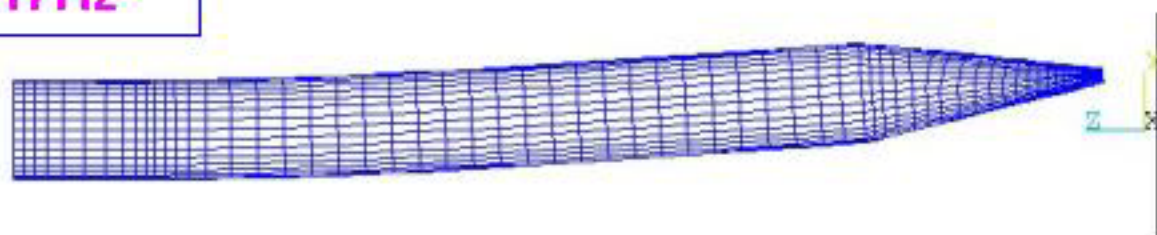


Natural Frequency(Vertical)

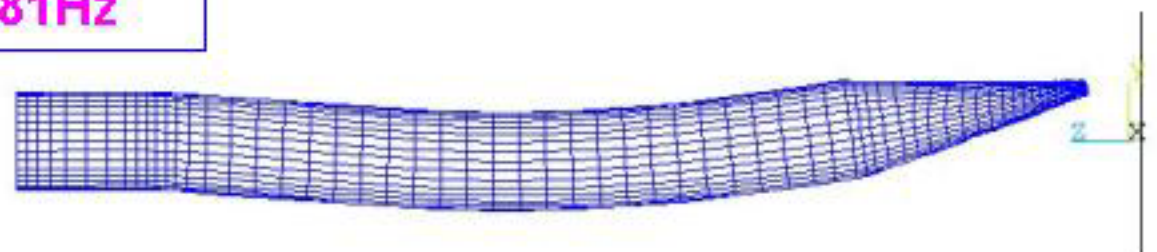
- (Model-A)



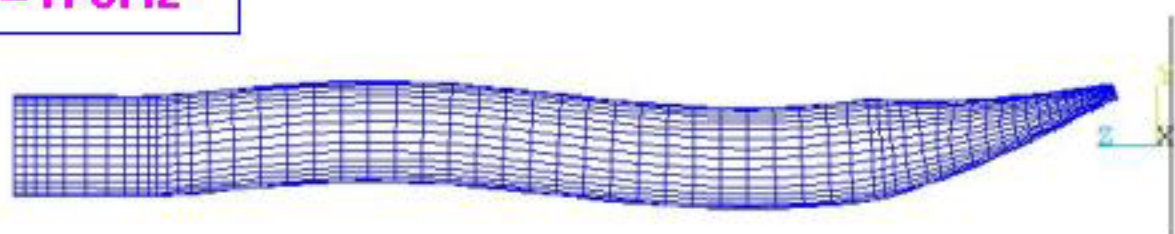
1st mode
 $f=17\text{Hz}$



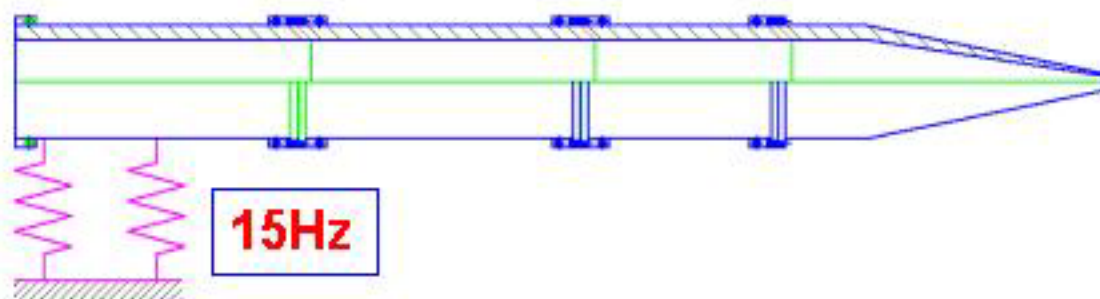
2nd mode
 $f=81\text{Hz}$



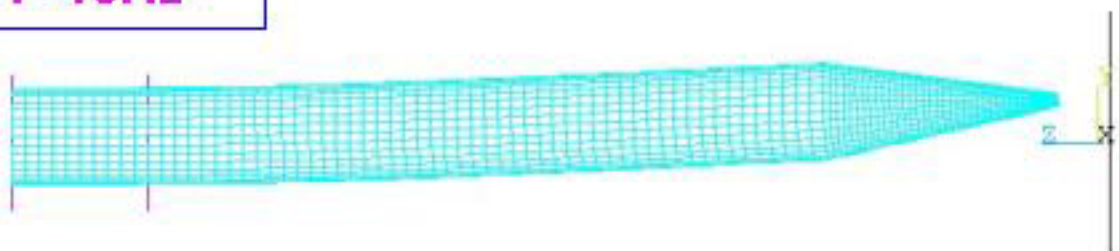
3rd mode
 $f=173\text{Hz}$



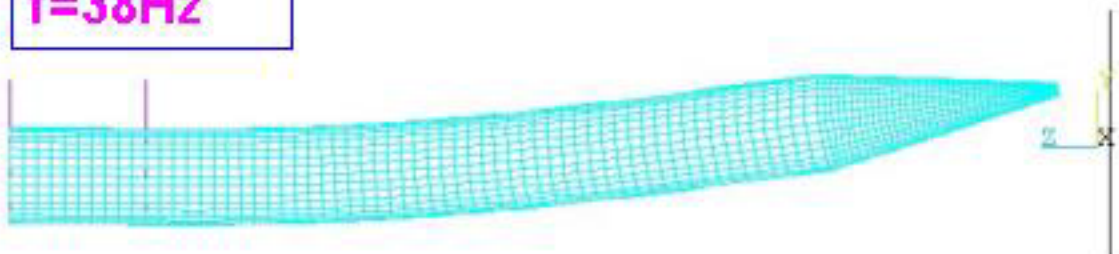
- (Model-A)



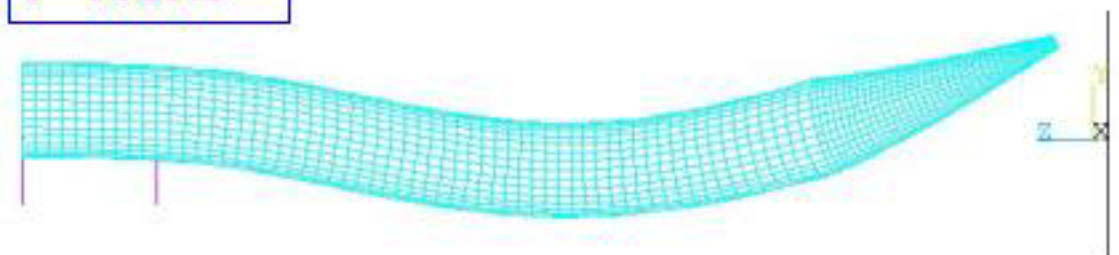
1st mode
 $f=15\text{Hz}$



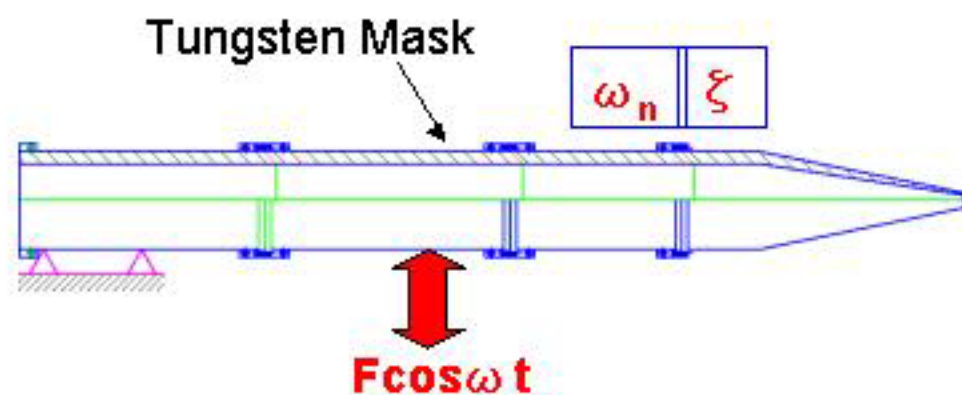
2nd mode
 $f=38\text{Hz}$



3rd mode
 $f=105\text{Hz}$

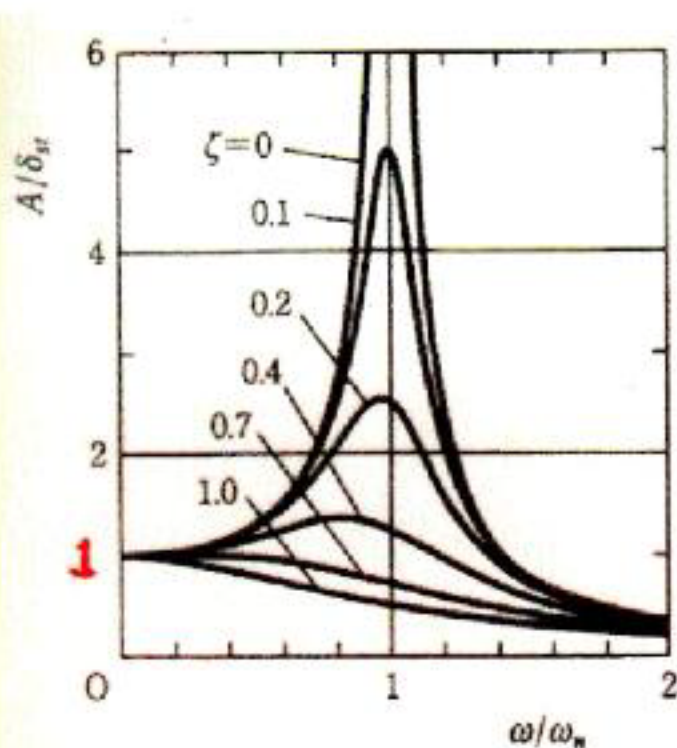


2-(4) Harmonic response analysis



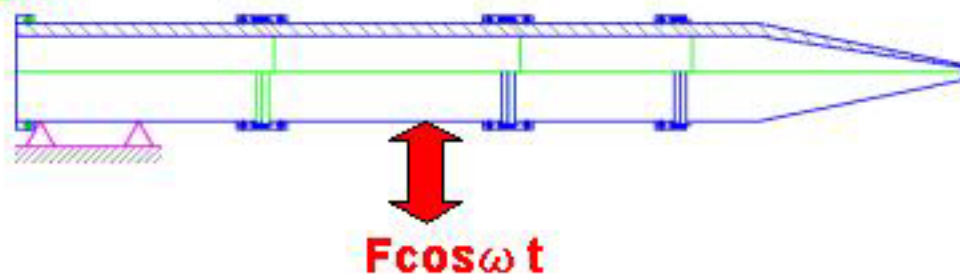
$$A = \frac{\delta_{st}}{\sqrt{\left\{1 - \left(\frac{\omega}{\omega_n}\right)^2\right\}^2 + \left(2\zeta \frac{\omega}{\omega_n}\right)^2}}$$

- A:** Amplitude
- δ_{st} : Static deformation
- ζ : Damping ratio (2%)
- ω_n : Natural frequency (Support tube)
- ω : Frequency

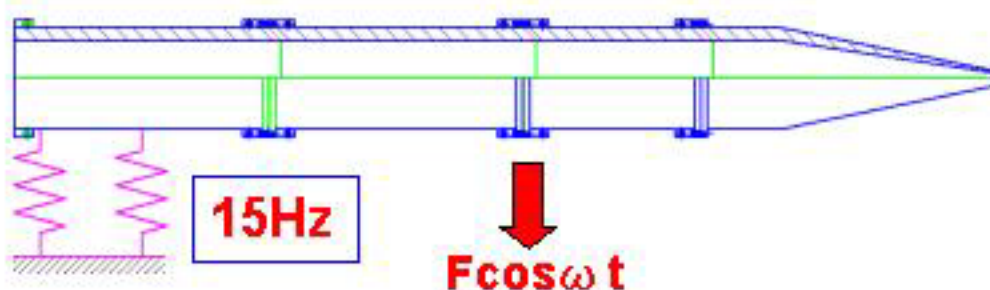


Model

• Rigid



• 15Hz



Ground motion (Tsukuba exp. hall, KEK)

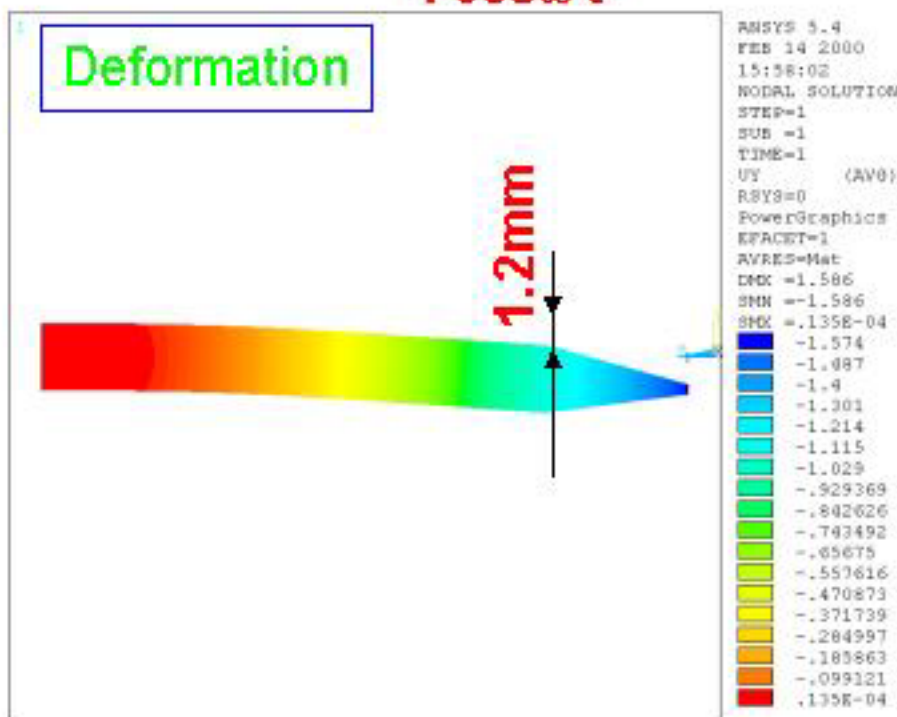
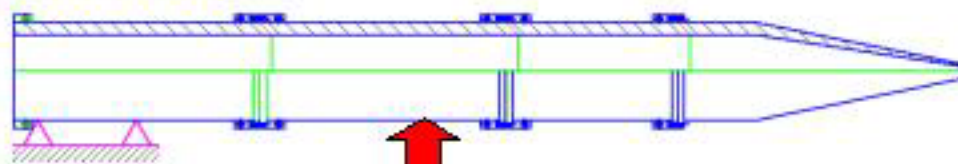
Frequency: f	Amplitude: X	Acc.(gal): α
3mHz	$3 \mu m$	1×10^{-7}
100mHz	$1 \mu m$	4×10^{-5}
1Hz	10nm	4×10^{-5}
3Hz	5nm	$2 \times 10^{-4} (F)$

Applied!

$$\begin{aligned}\alpha &= \omega^2 \cdot X \\ &= (2\pi f)^2 \cdot X\end{aligned}$$

$$\begin{aligned}1 \text{ gal} &= 1 \text{ cm/s}^2 \\ 1 \text{ G} &= 980 \text{ gal}\end{aligned}$$

Estimation



3Hz → 5nm (Measurement data)

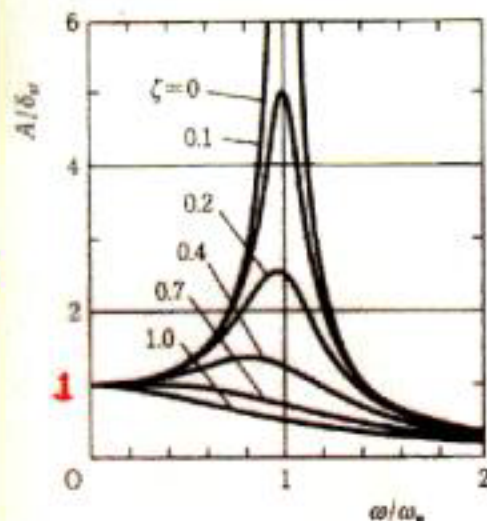
$$\alpha = (2\pi f)^2 \cdot X \quad \alpha : \text{Acc. force} = 2 \times 10^{-4} (\text{gal})$$

δ_{st} : Static deformation

$$\begin{aligned} \delta_{st} &= 1.2 \times (2 \times 10^{-4} / 980) \\ &= 3.3 \times 10^{-7} \text{mm} \\ &= 0.25 \text{nm} \end{aligned}$$

If $\omega / \omega_n = 1$, $\xi = 0.02$

$$\begin{aligned} A &= 25 \times \delta_{st} \\ &= 25 \times 3.3 \times 10^{-7} \\ &= 8.2 \times 10^{-6} \text{mm} \\ &= 6.3 \text{nm} \end{aligned}$$



A: Amplitude

$$A = \frac{\delta_{st}}{\sqrt{\left\{1 - \left(\frac{\omega}{\omega_n}\right)^2\right\}^2 + \left(2\zeta \frac{\omega}{\omega_n}\right)^2}}$$

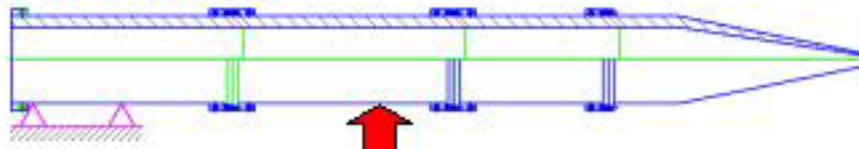
Damping ratio

Ferroconcreate structure	: 5.0
Steel frame structure	: 2.0
Welding structure	: 1.0
Bolt/Rivet structure	: 2.0
Laying pipes	: 0.5~2.5
Duct for the air conditioner	: 2.5
Cable tray	: 5.0
Liquid in the tank	: 0.5
.	
.	
.	

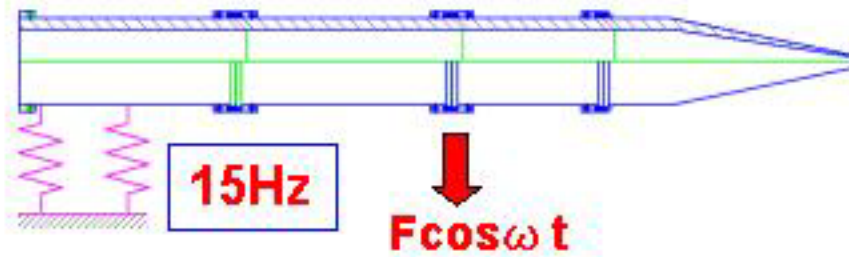
Reference: JEAG 4601-1987

Calculation(FEM)

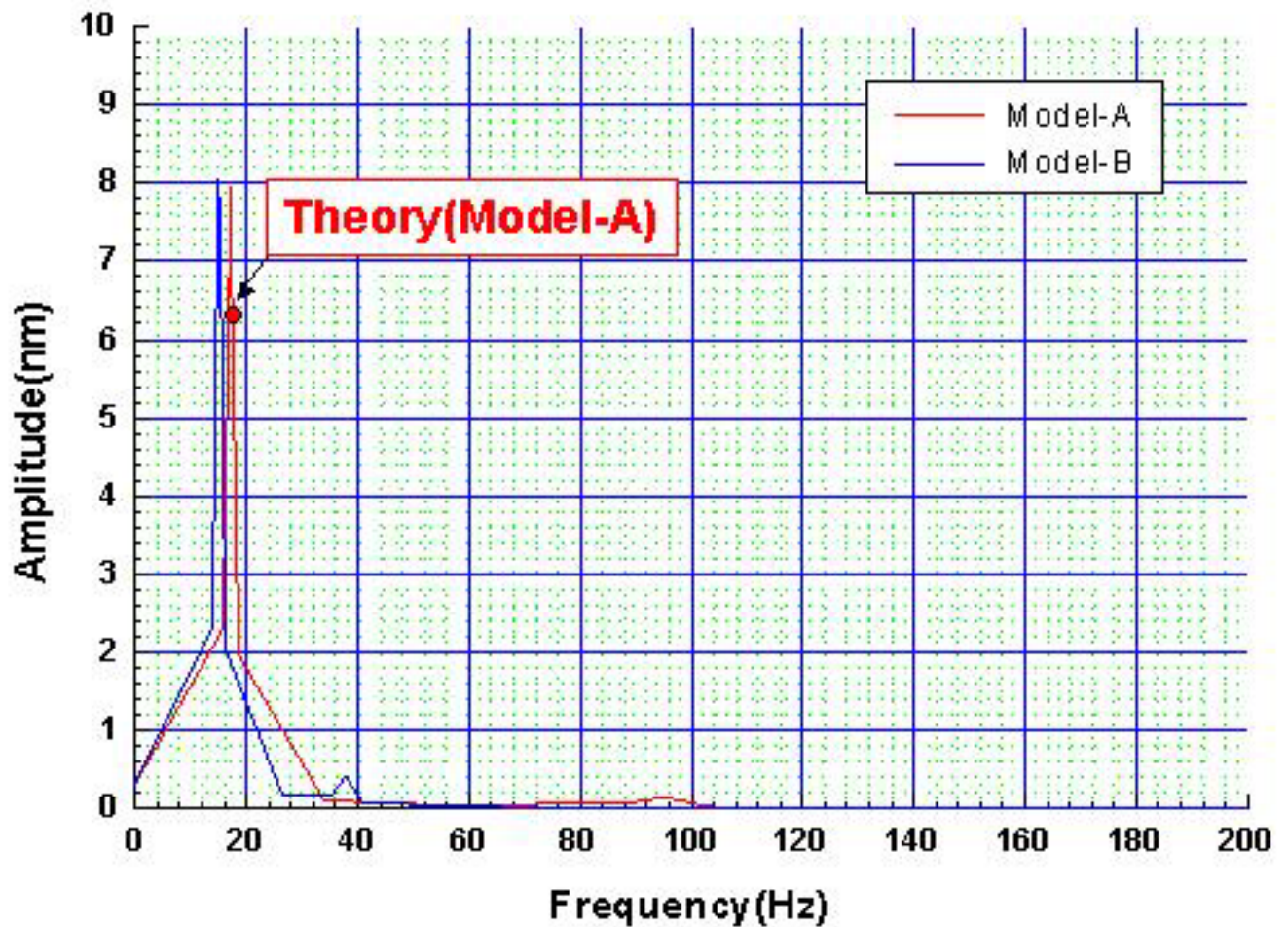
(Model- A: Rigid)



(Model- B: 15Hz)

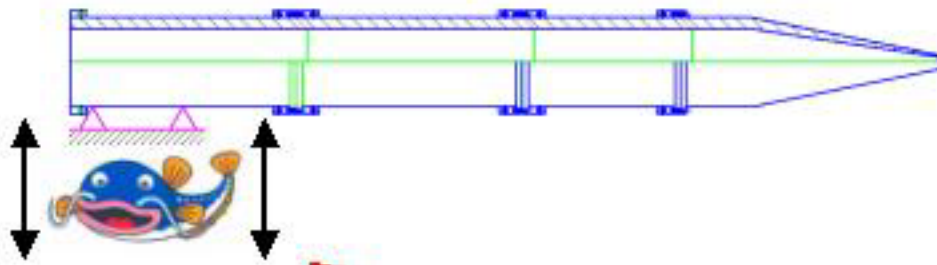


FEM Results



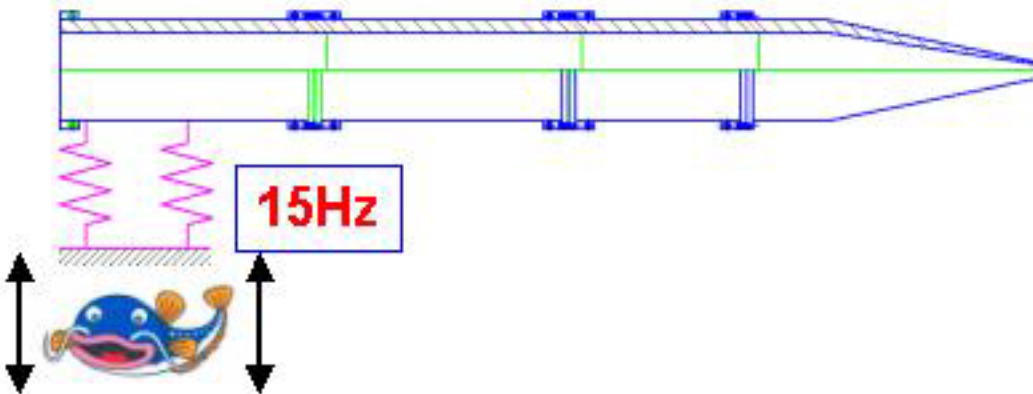
2-(5) Spectrum analysis

(Model- A)



Frequency: f	Amplitude: X
3mHz	$3\ \mu\text{m}$
100mHz	$1\ \mu\text{m}$
1Hz	10nm
3Hz	5nm

(Model- B)

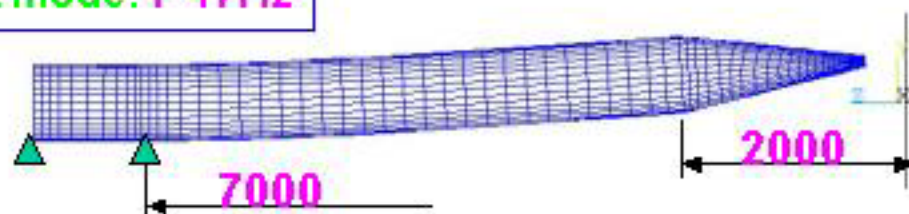


 Response deformation

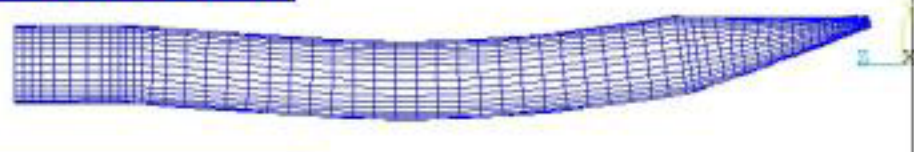
Results

(Model- A)

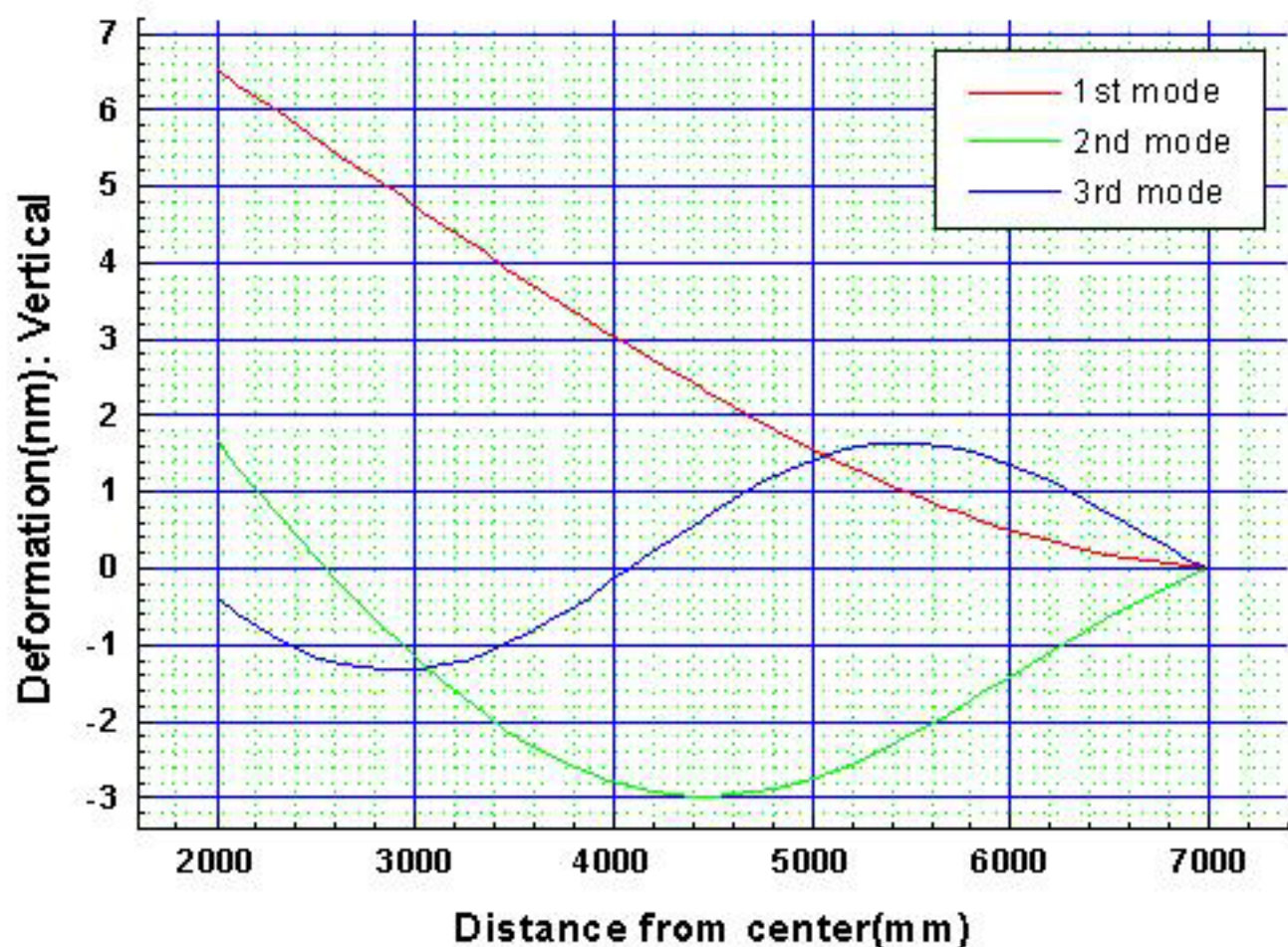
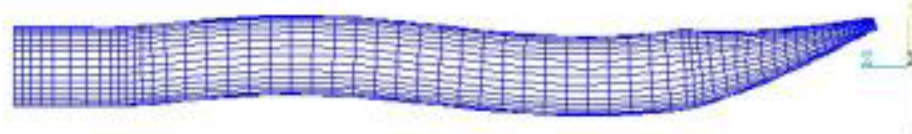
1st mode: $f=17\text{Hz}$



2nd mode: $f=81\text{Hz}$

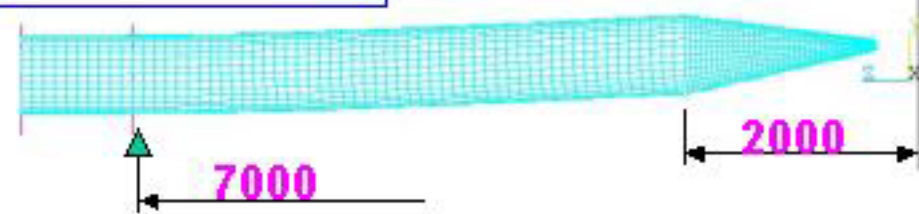


3rd mode: $f=173\text{Hz}$



(Model- B)

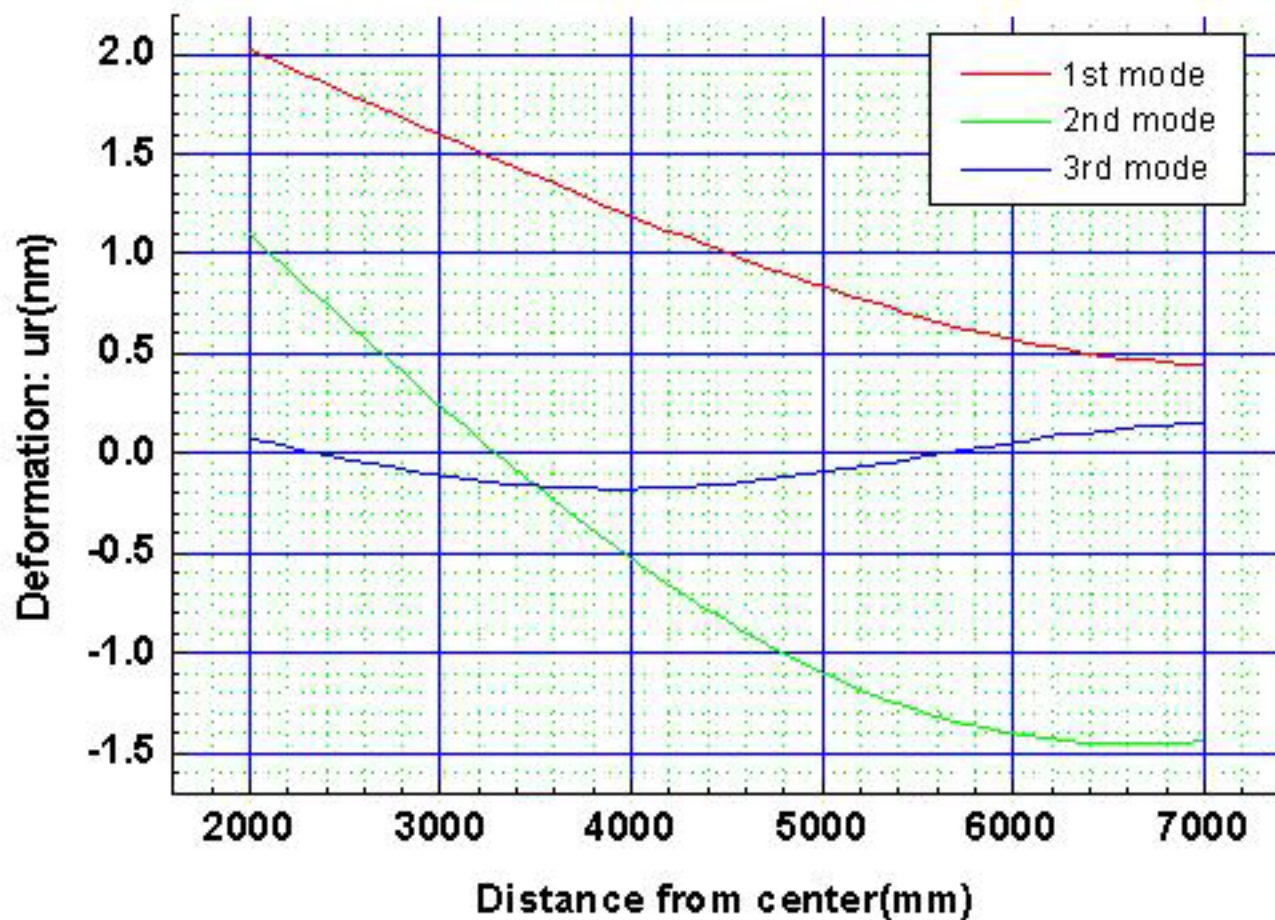
1st mode: $f=15\text{Hz}$



2nd mode: $f=38\text{Hz}$

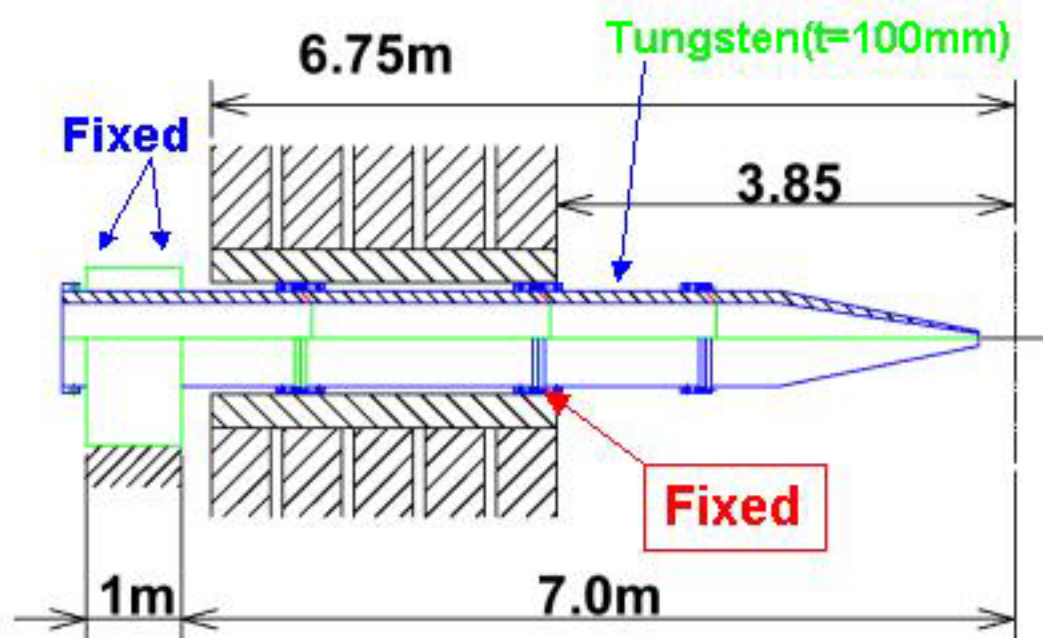


3rd mode: $f=105\text{Hz}$



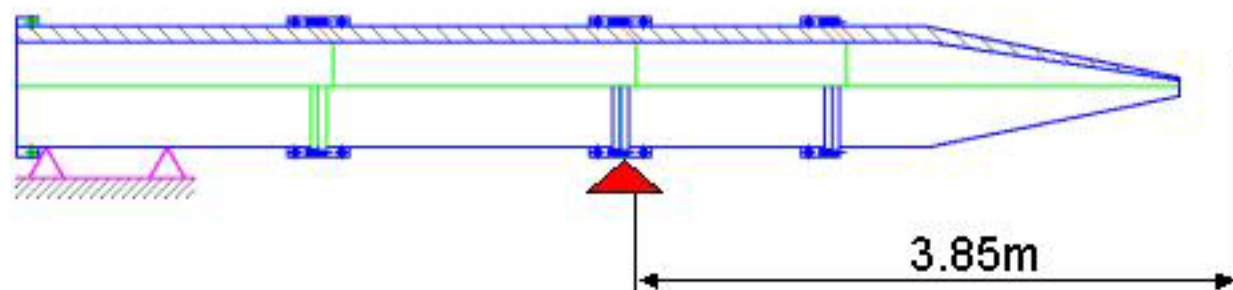
3. Improvement

- To reduce the deformation/stress;

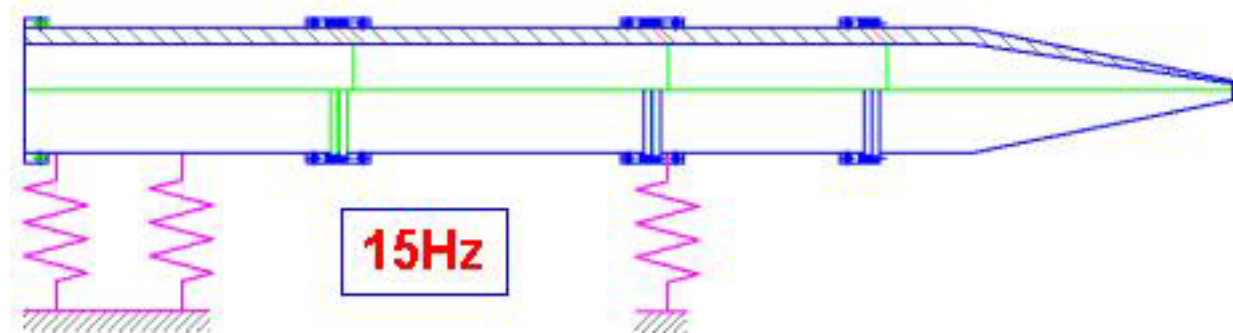


FEM Model

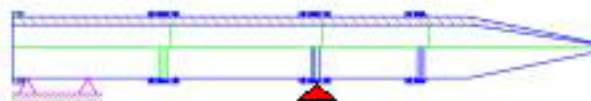
(Model- A)



(Model- B)



3-(1)Results

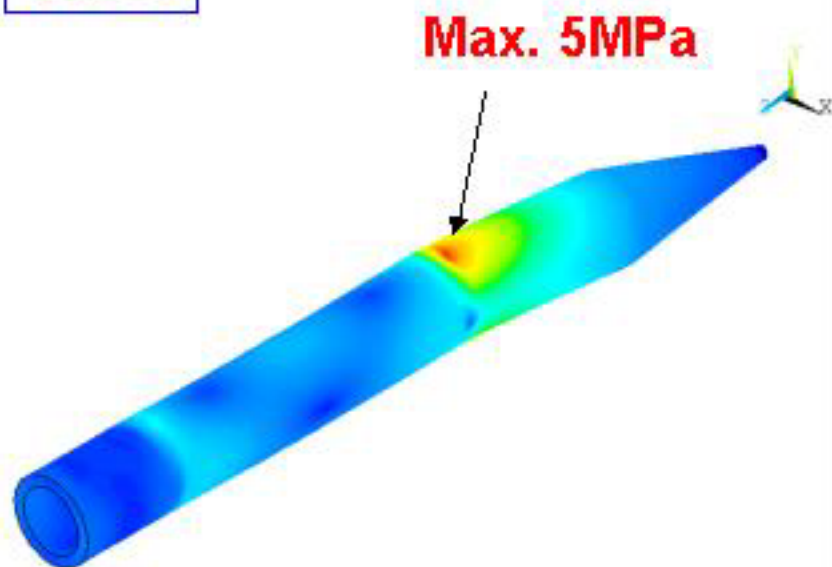


Deformation



ANSYS 5.4
FEB 15 2000
19:52:32
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
UY (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.091022
SMN =-.091003
0 -.090292
-.085315
-.080339
-.075362
-.070385
-.065408
-.060432
-.055455
-.050478
-.045502
-.040525
-.035548
-.030571
-.025595
-.020618
-.015641
-.010664
-.005688
0

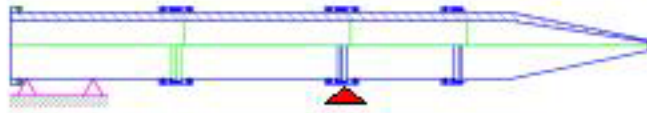
Stress



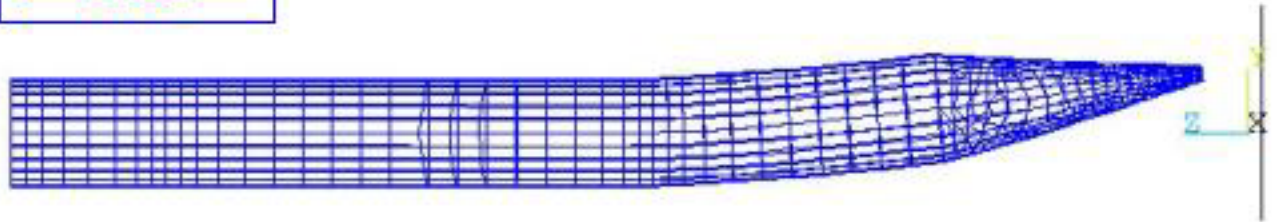
ANSYS 5.4
FEB 15 2000
19:51:39
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (AVG)
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.091022
SMN =.317E-03
SMX =.471154
0 .003995
.029744
.055493
.081242
.106991
.13274
.158489
.184237
.209986
.235735
.261484
.287233
.312982
.338731
.36448
.390228
.415977
.441726
.471154

3-(2) Natural Frequency(Vertical)

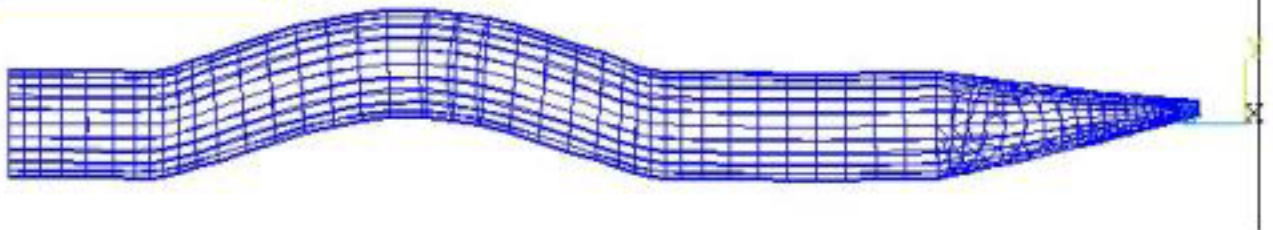
(Model- A)



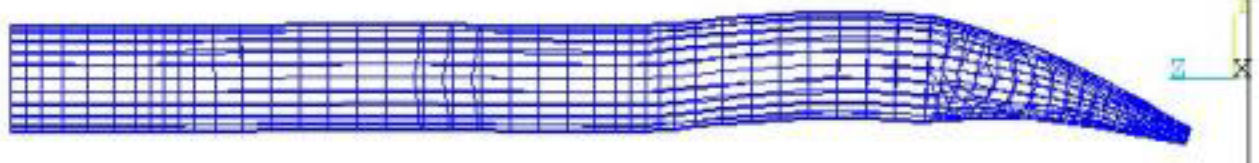
1st mode
 $f=71\text{Hz}$



2nd mode
 $f=179\text{Hz}$

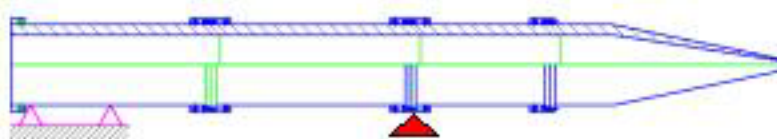


3rd mode
 $f=202\text{Hz}$

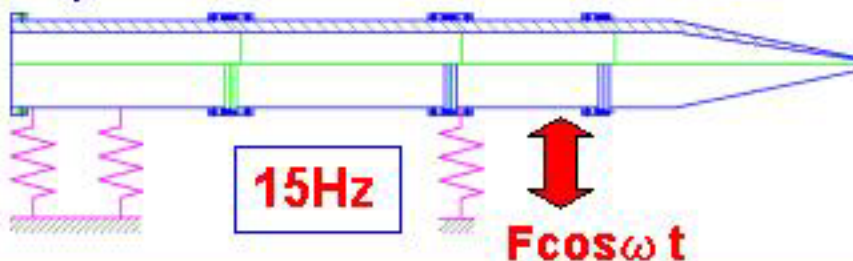


3-(3) Harmonic response analysis

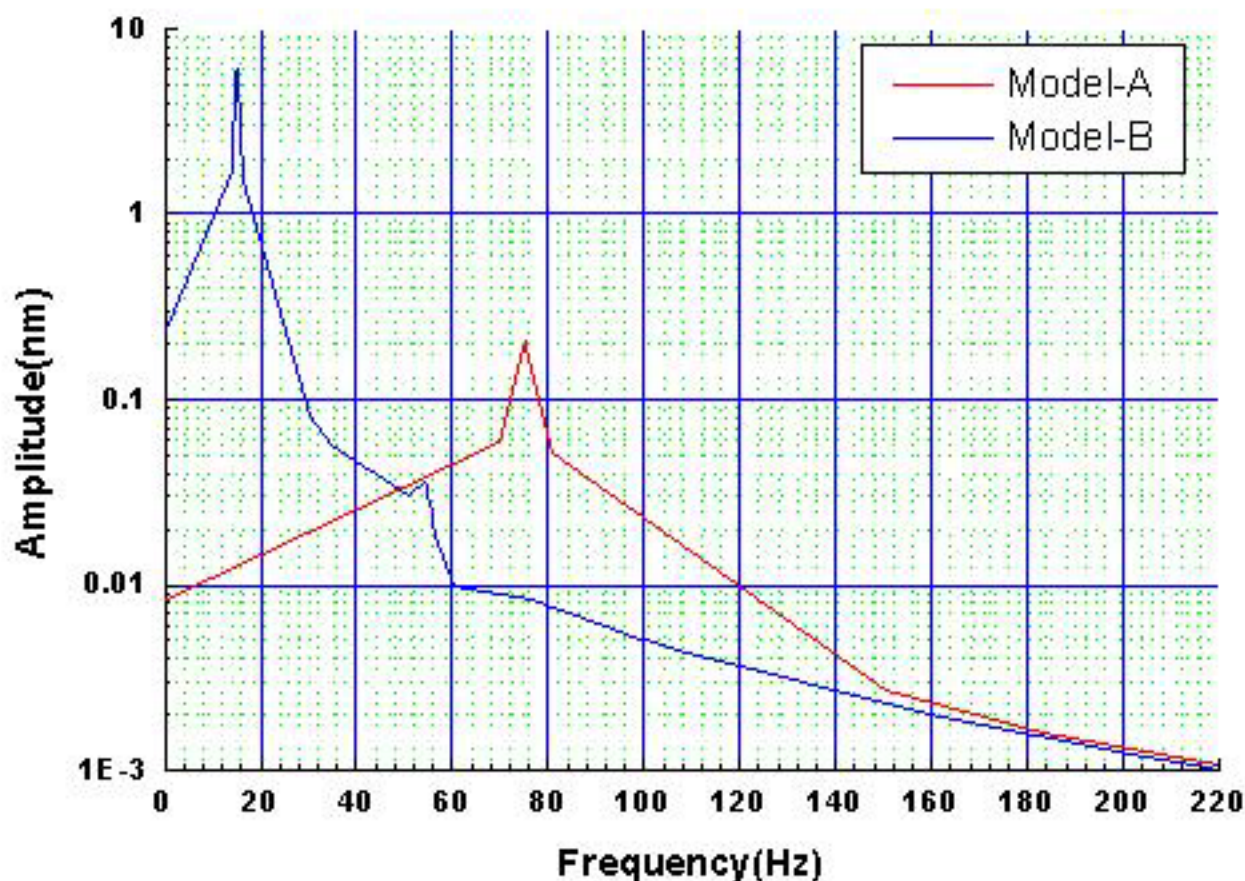
(Model- A)



(Model- B)



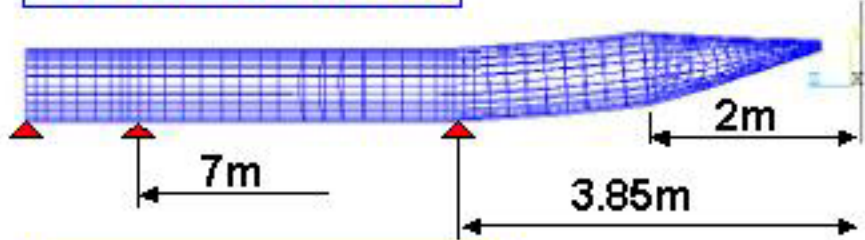
Frequency: f	Amplitude: X	Acc.(gal): α
3mHz	$3 \mu m$	1×10^{-7}
100mHz	$1 \mu m$	4×10^{-5}
1Hz	10nm	4×10^{-5}
3Hz	5nm	$2 \times 10^{-4}(F)$



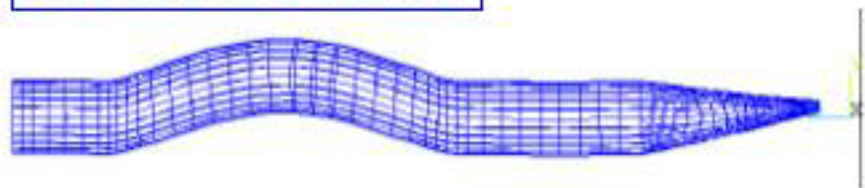
3-(4) Spectrum analysis

(Model- A)

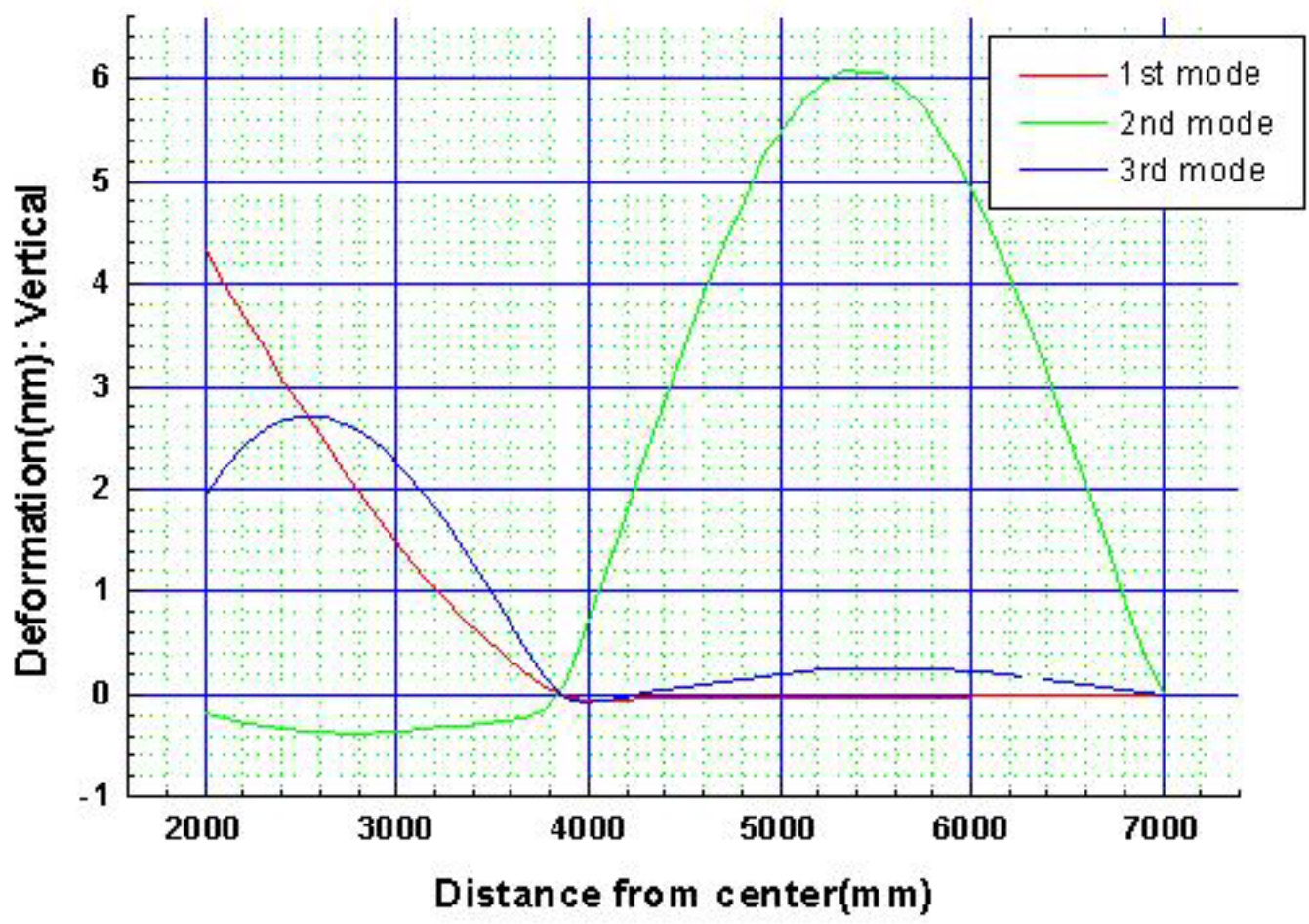
1st mode: $f=71\text{Hz}$



2nd mode: $f=179\text{Hz}$

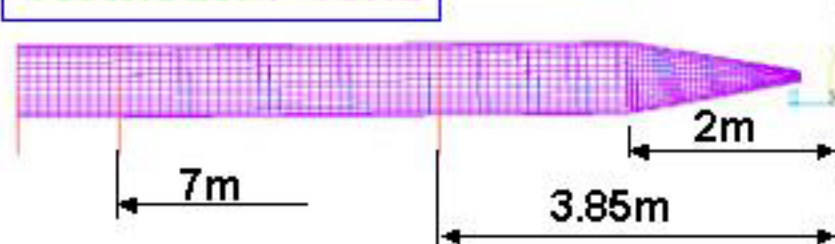


3rd mode: $f=202\text{Hz}$

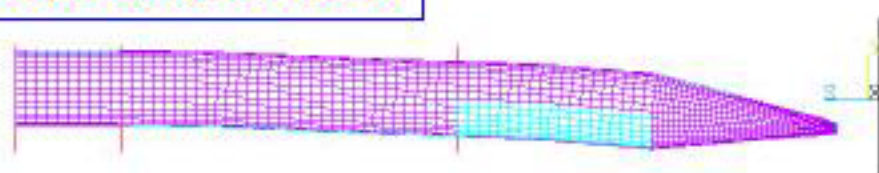


(Model- B)

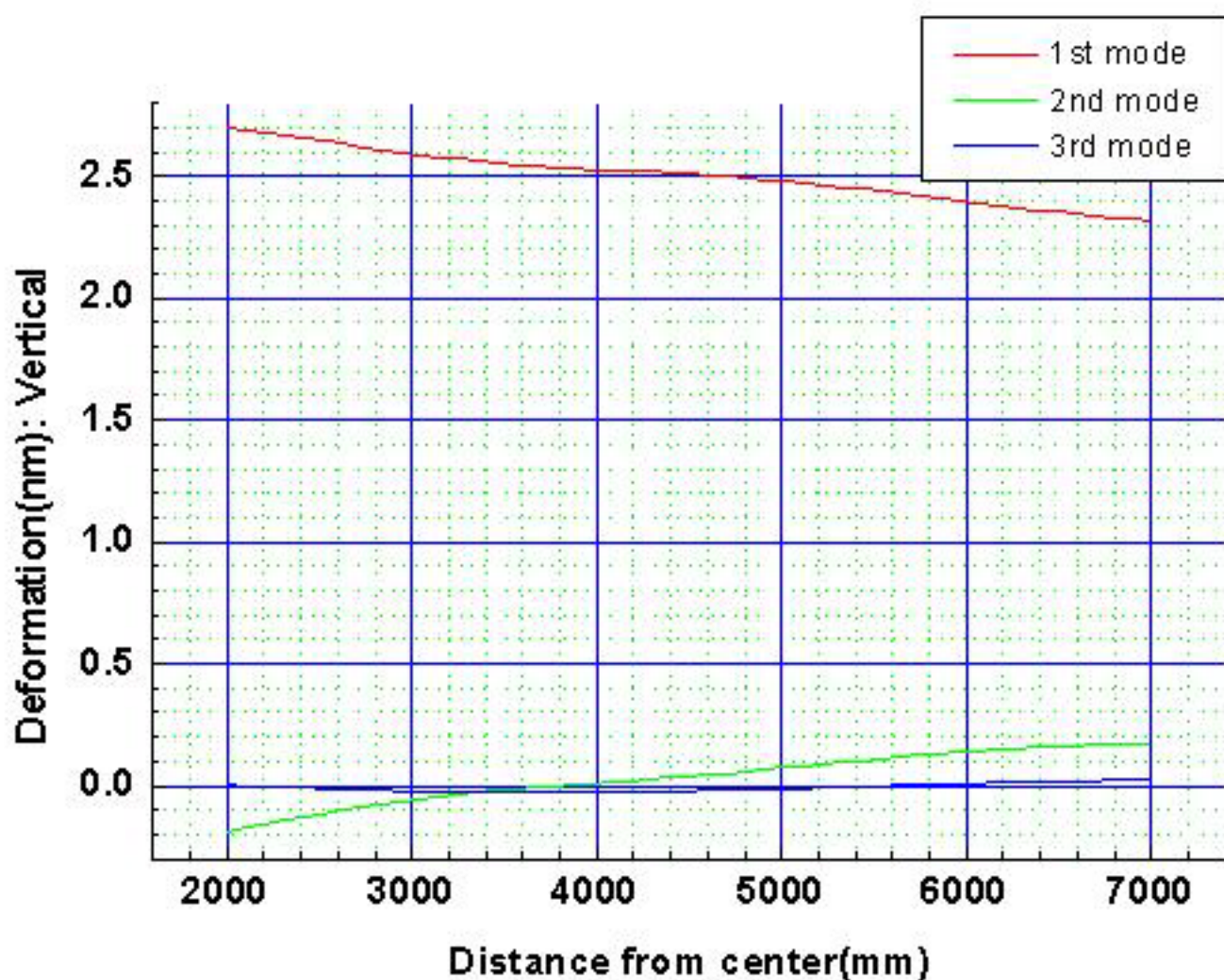
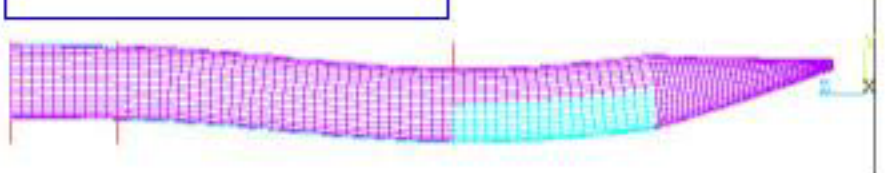
1st mode: $f=15\text{Hz}$



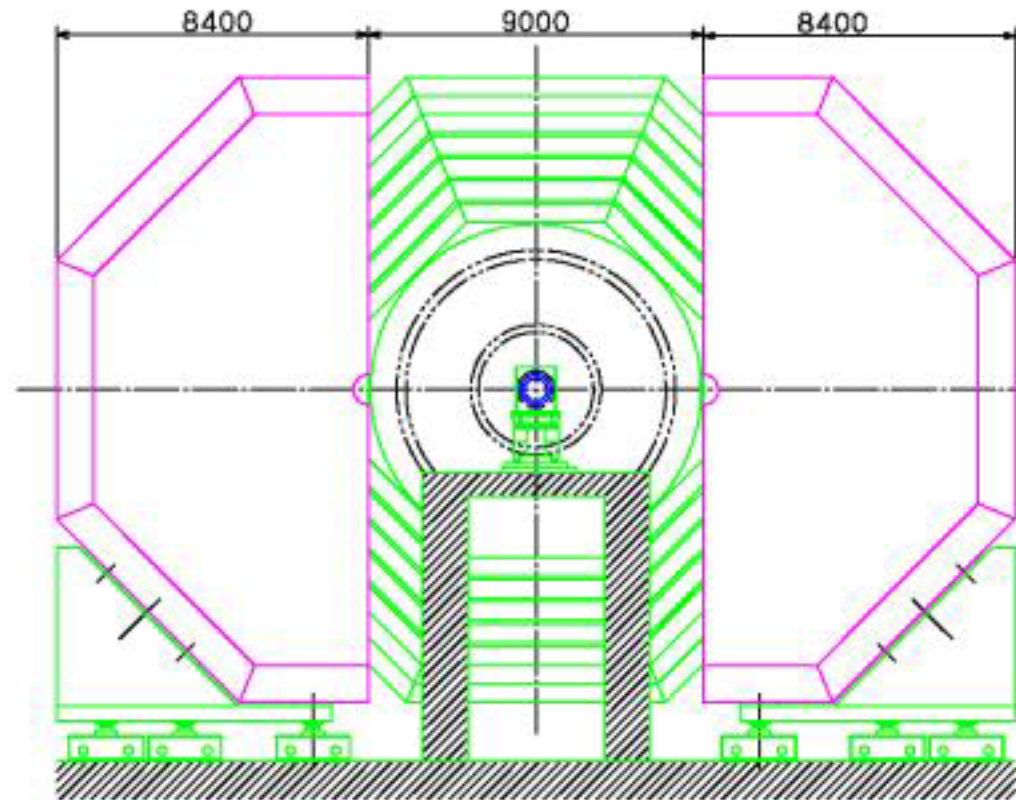
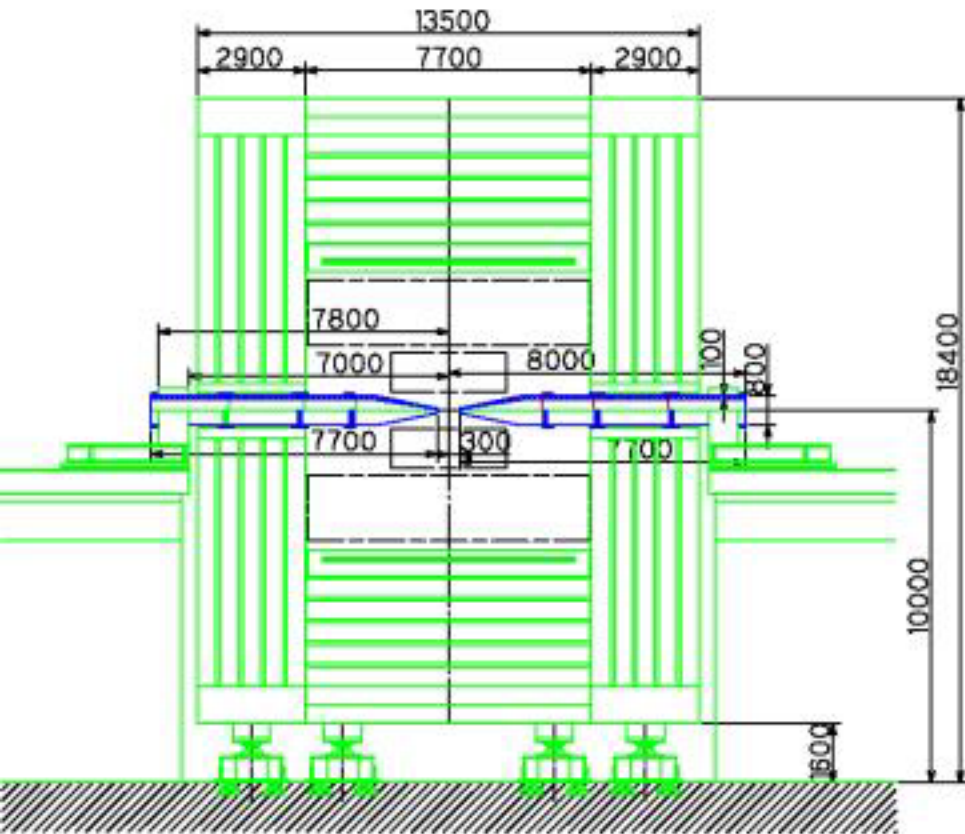
2nd mode: $f=54\text{Hz}$



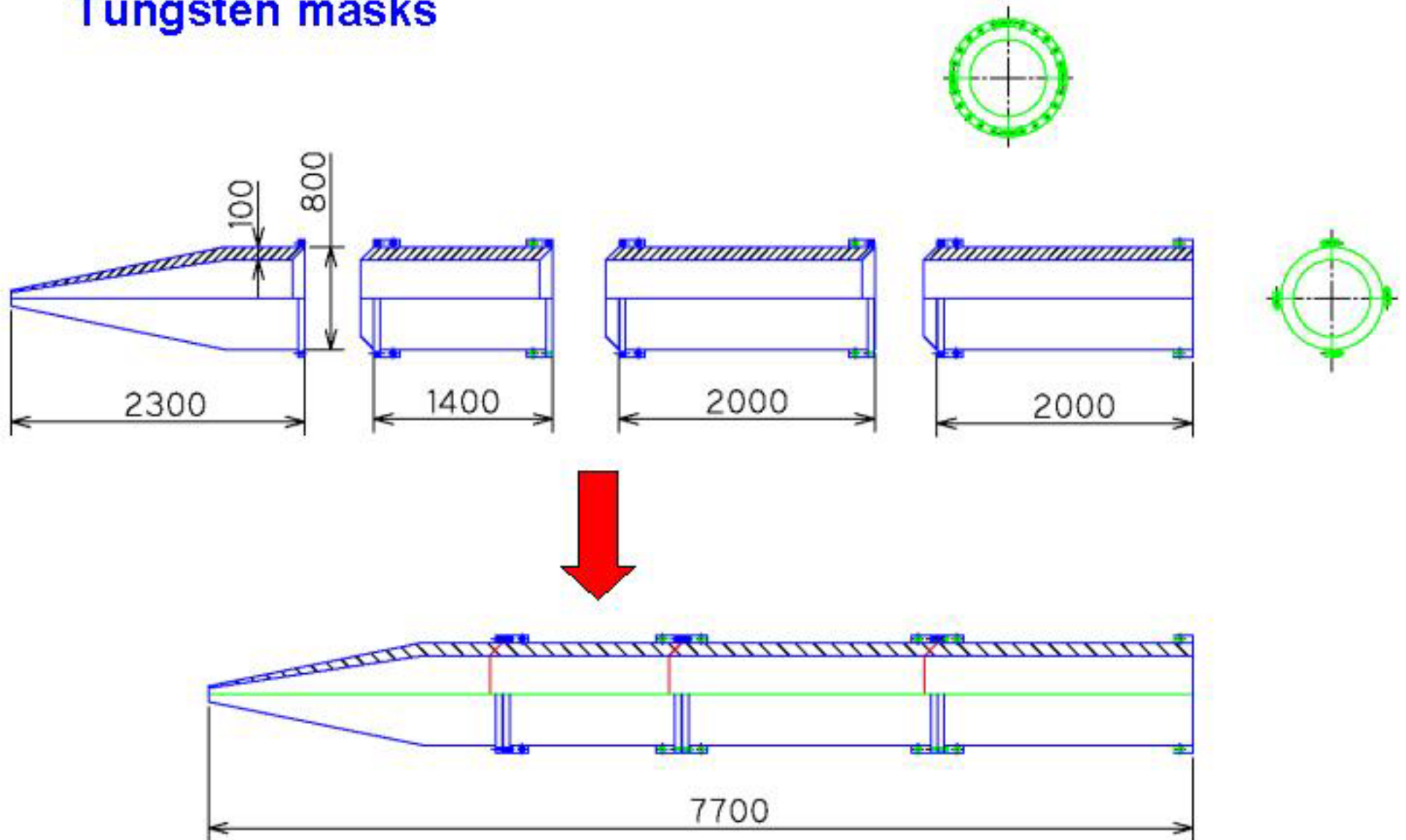
3rd mode: $f=93\text{Hz}$



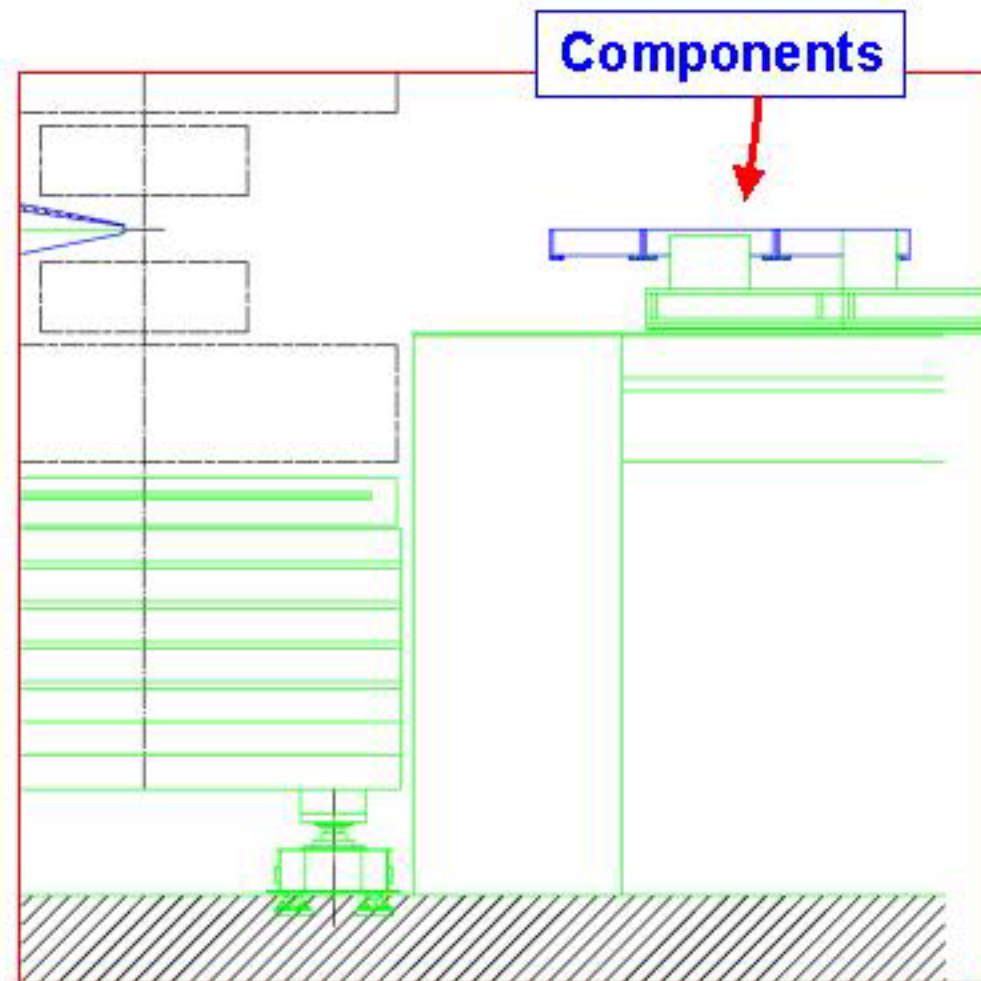
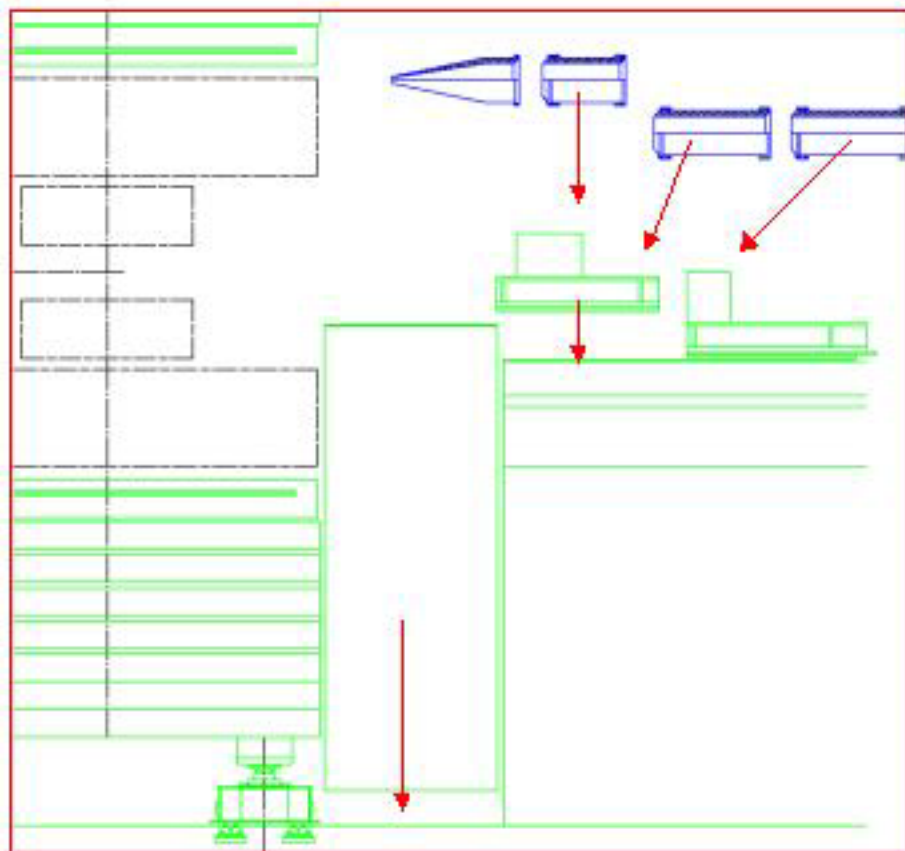
4. Configuration

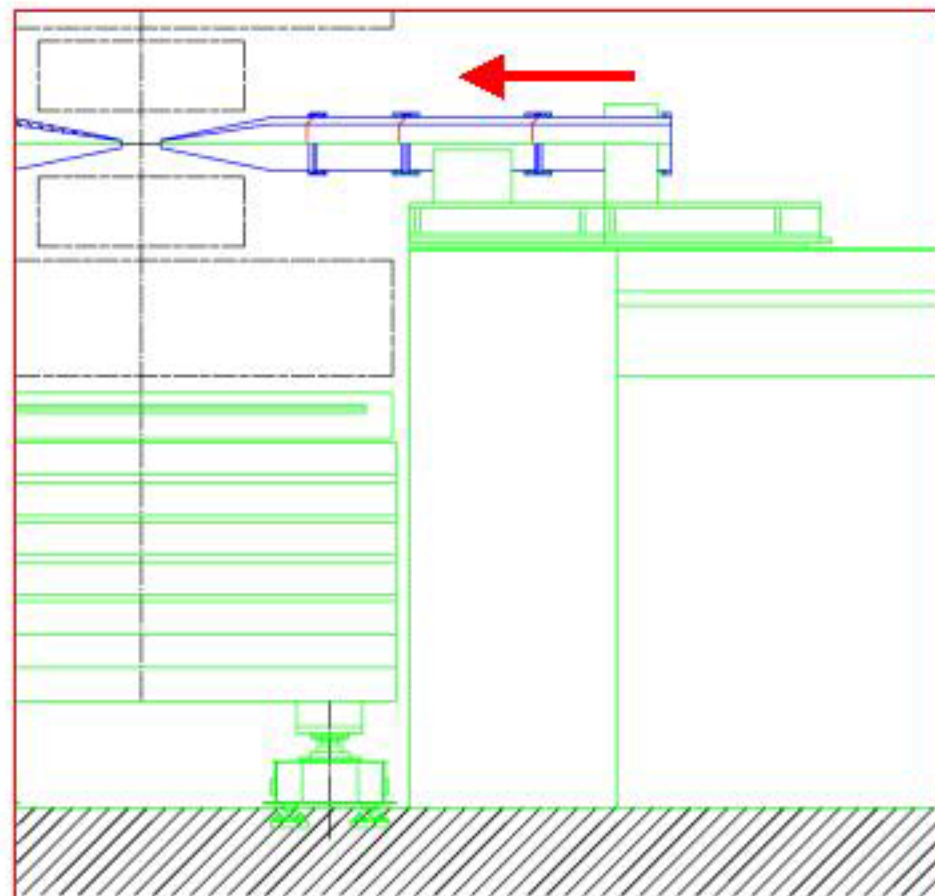
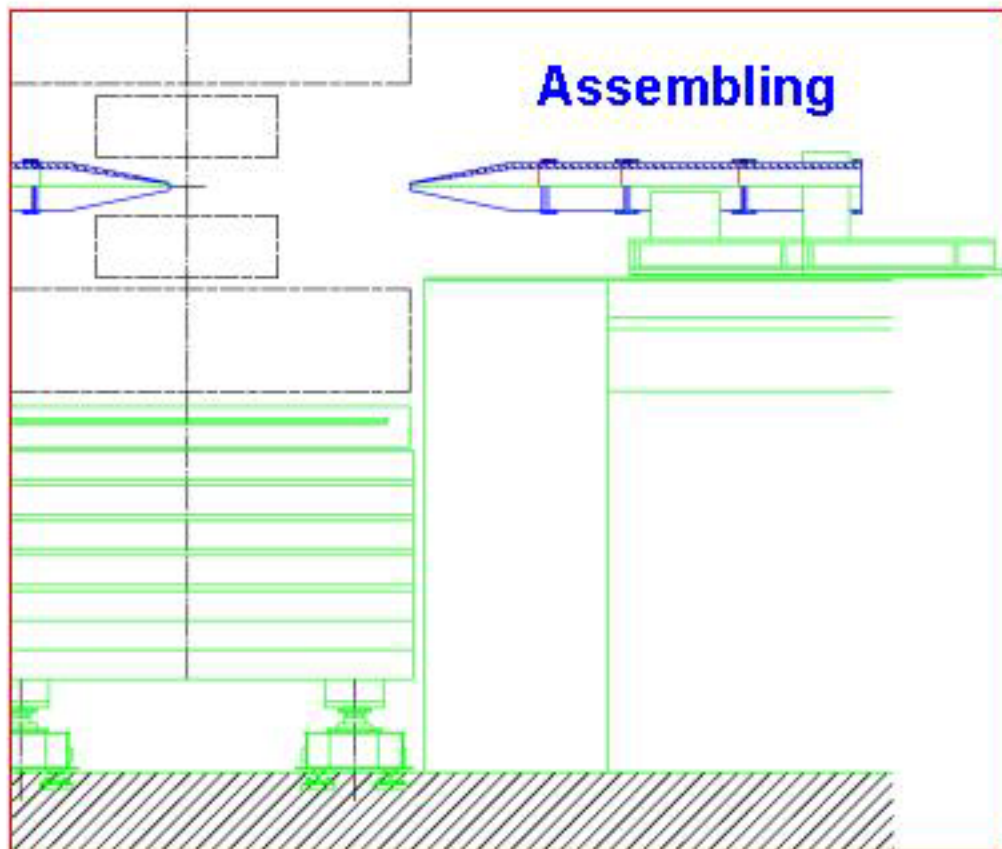


Tungsten masks

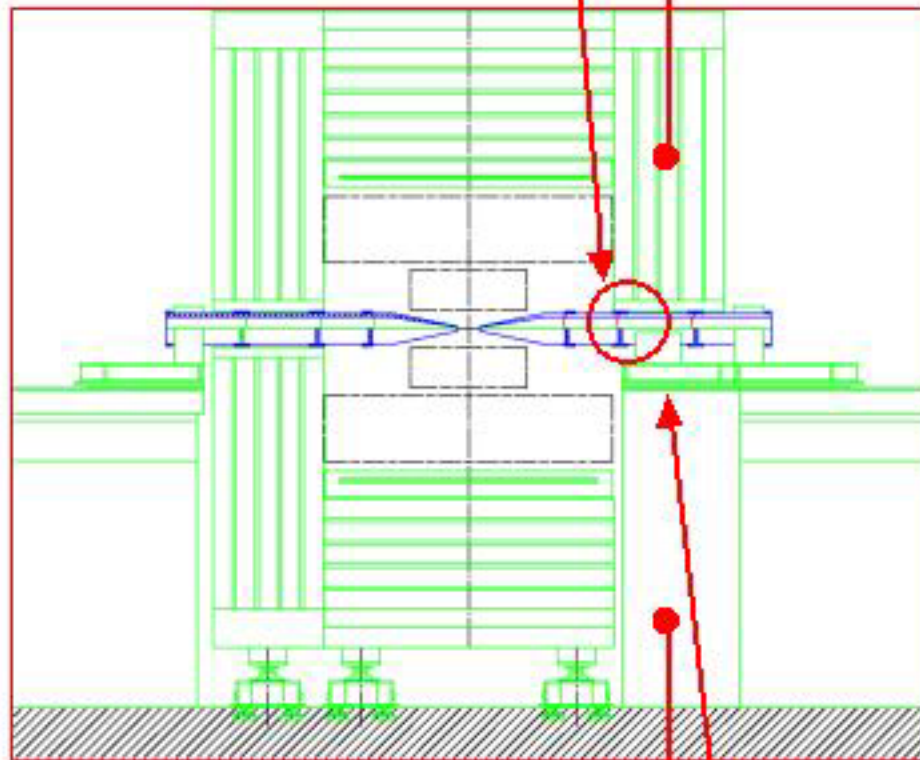


5. Assembling



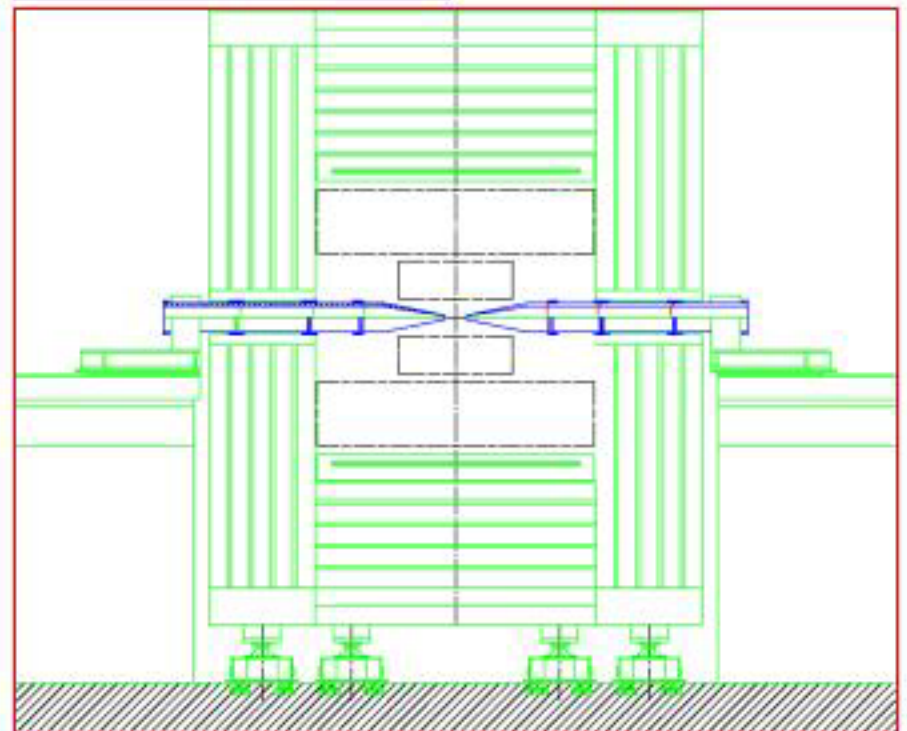


1. Close(one side)
2. Fix



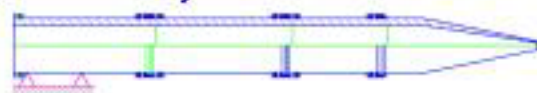
3. Remove

Completion!!

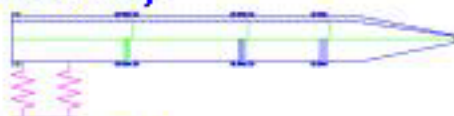


Summary

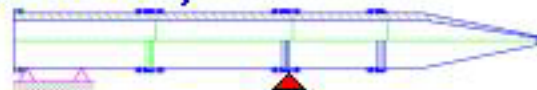
(Model-1A)



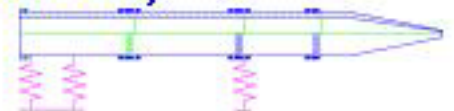
(Model-1B)



(Model-2A)



(Model-2B)



		Model-1A	Model1-B	Model-2A	Model-2B
Deformation(mm)		1.6	-	0.09	-
Stress(MPa)		23	-	5	-
Natural frequency(Hz) (Vertical)	1st mode	17	15	71	15
	2nd Mode	81	38	179	54
	3rd mode	173	105	202	93
Harmonic response(nm) @QC1		8.0	8.0	0.2	6.0
Spectrum analysis(nm) @QC1	1st mode	6.5	2.0	4.3	2.7
	2nd Mode	-1.7	1.1	0.2	0.2
	3rd mode	-0.4	0.1	1.9	0.002

Deformation is too large!!

Further studies

- How much is the relative position between QC1?
- How support the masks at iron structure?
 - Deformation due to the magnetic force.
- Support configuration
 - CFRP → High young's modulus (150GPa → 900GPa)
 - Masks → Other materials
 - We may not need to support at iron structure.

