Experience on Vibration Isolation System

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KEK

and

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ILC S&A Group Meeting at DESY 29 May, 2007

1. Introduction (ground motion at ILC site)

2. Vibration isolation table commercially available

3. Vibration isolation table developed at KEK

4. Summary

1. Introduction

Beam size at ILC-IP (nominal value) is

6 nm in vertical direction and

640 nm in horizontal direction

--> Stability of final quadrupole magnets should be

1nm or higher in vertical direction

Amplitude of ground motion is bigger than 1nm in low frequency region

--> What is the frequency region we should care?

1-1. Ground motion in various grounds

(See Paper [1] in detail)

(1) KEK site ..... soft ground

- Diluvium in Kanto plane
  (alternative layers of sand, gravels and clay)
- Measured on the ground surface and in the KEKB accelerator tunnel (10m deep underground)
- There is a main public road about 1km far from the measurement place.

(2) SPring-8 (8 GeV synchrotron light source lab.)
..... constructed on hard bedrock

- Kamigori metagabbro rock area
- Measured on the bedrock near to the accelerator ring

(3) Mitsuse road tunnel in **Sefri area** ..... granite rock area

- Penetrating Sefuri mountain chain (granite rock)
- Located in border between Fukuoka and Saga prefectures
- Measured at a point about 10m far from near edge of the road on the concrete floor in a shelter area, which is located about 800m inner from the entrance of the tunnel.

(4) Esashi area ..... granite rock area

- Measured in Mizusawa Earth Tide Observatory
  About 150m long horizontal tunnel constructed in Abara mountain (granite rock)
- Measuremed on a granite base plate fixed on the bedrock.

2. Ground Motion in Various Grounds

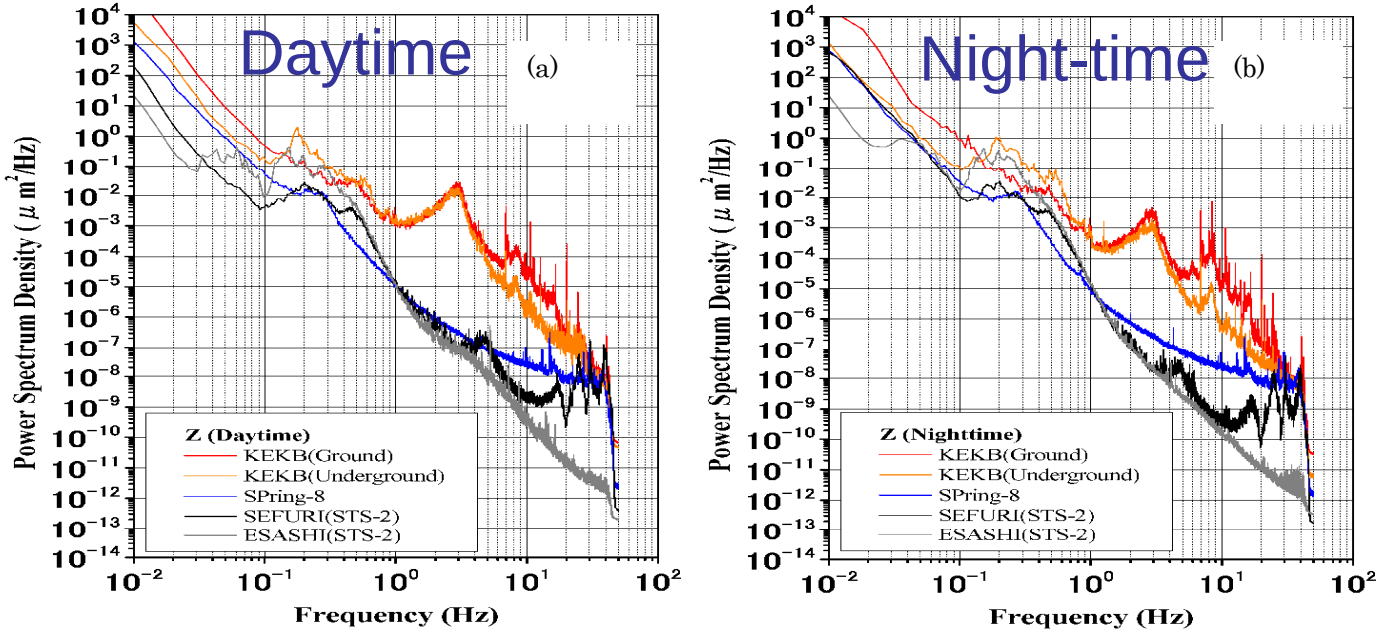


Fig.1 PSD (Power Spectrum Density) measured in 5 areas.

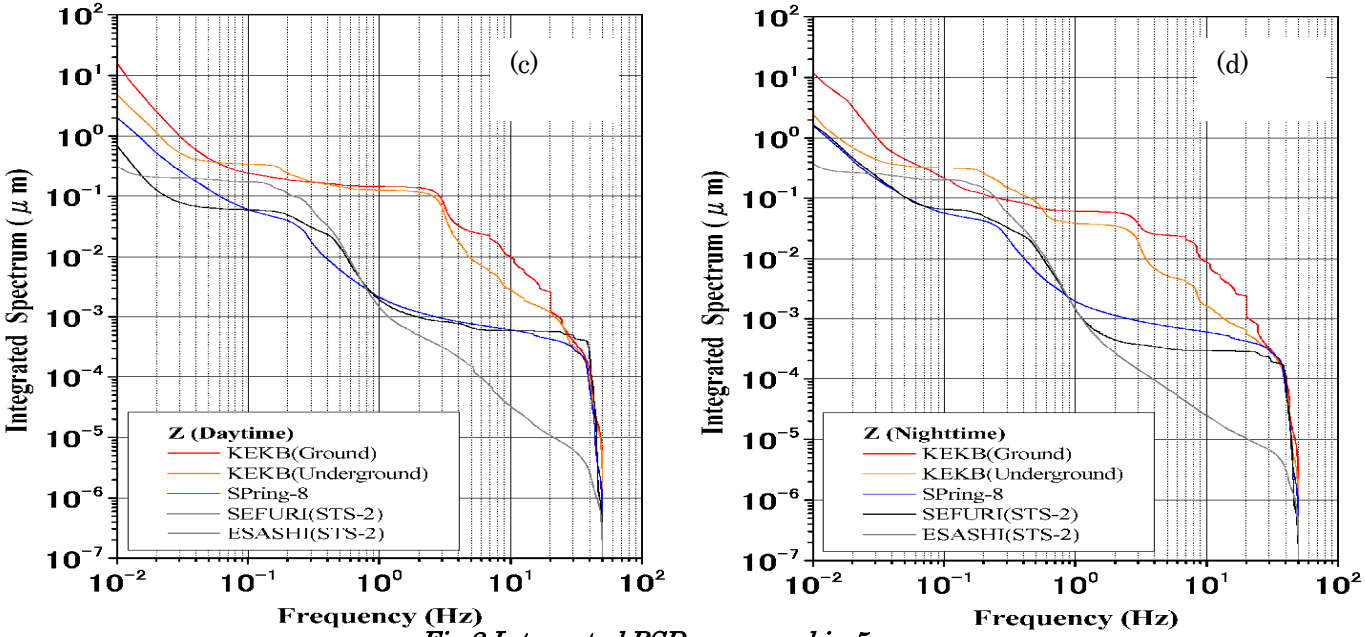
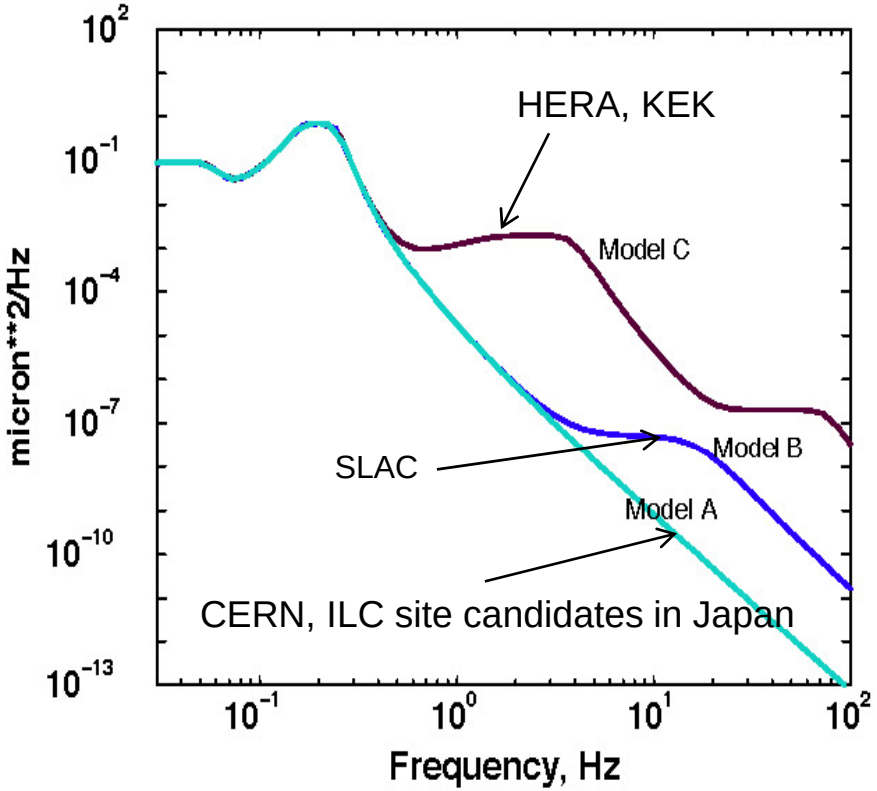


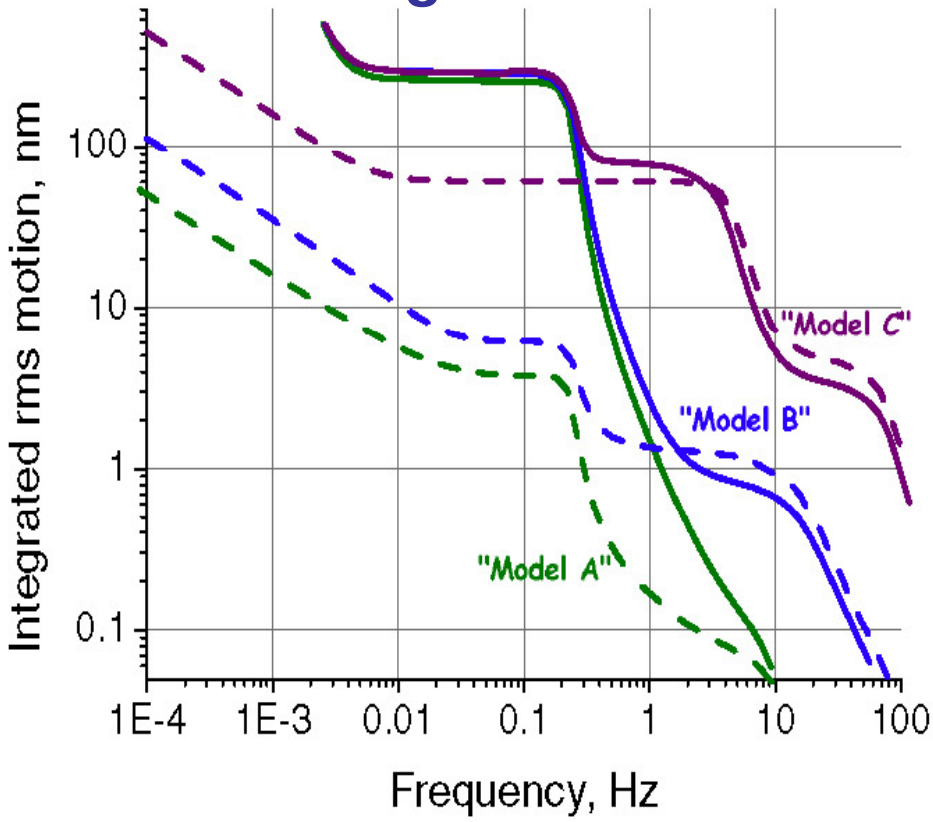
Fig.2 Integrated PSD measured in 5 areas.

(From TESLA TDR)

PSD



Integrated PSD



積分絶対値スペクトル（実線）

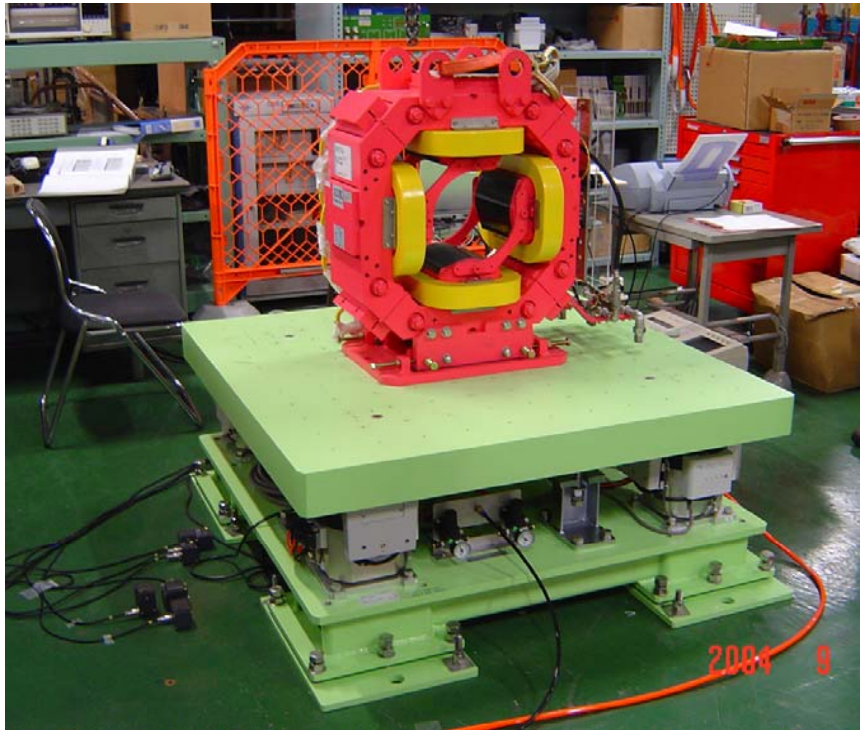
	Main Linac	BDS area
Site GM	C is OK	C/3 or 3*B
Mechanical noise	< 30nm	< 10nm

2. Vibration isolation table-I

(See Paper [2] in detail)

- An active vibration isolation system was made at KEK in order to have some experience on vibration isolation technique.
  One of essential techniques to future linear colliders.

- Principle of control is almost the same to those commercially sold



1200**x**1200 mm^2 and 497mm high

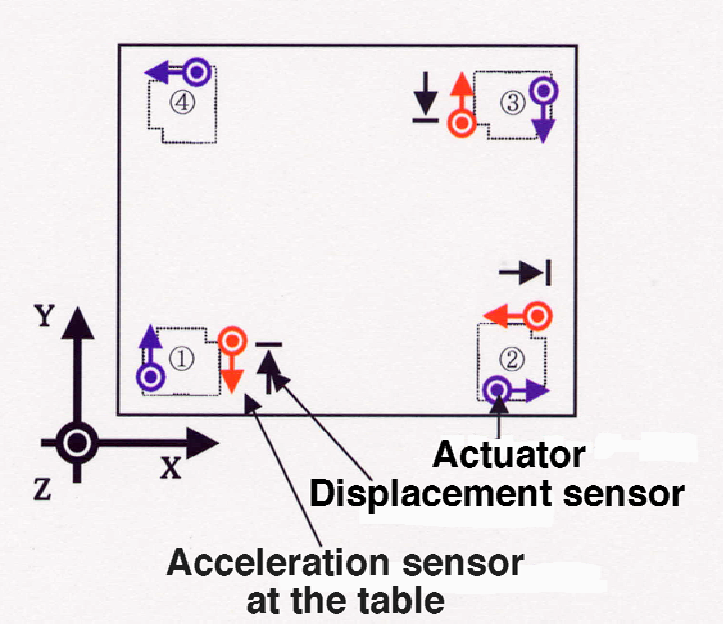
Weight is 1300 kg.

It can bear 500kg.

- A pair of horizontal and vertical actuators are installed to each of four pillars as shown by violet arrows. Two actuators for X-movement, two for Y and four for Z.

- Those actuators can control not only parallel movements but also rotations around X, Y and Z axis.

- Those actuators are pneumatic control valve type with 0.3 MPa air.



Sensors:

Six **acceleration sensors** to table (shown by red arrows)

One for X, two for Y and three for Z

Six **displacement sensors** to measure relative displacement between table and base (shown by black arrows)

One for X, two for Y and three for Z

Three **acceleration sensors** to base

Each for X, Y and Z.

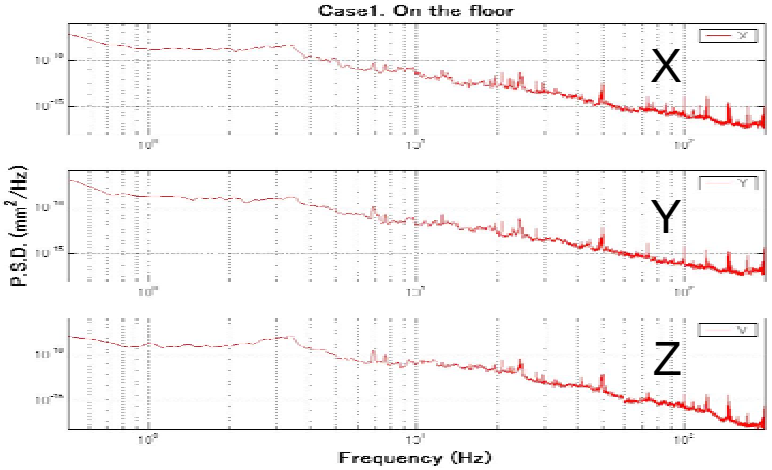
Acceleration sensors have

resolution 0.1 mGal and frequency range 0.1 - 200Hz

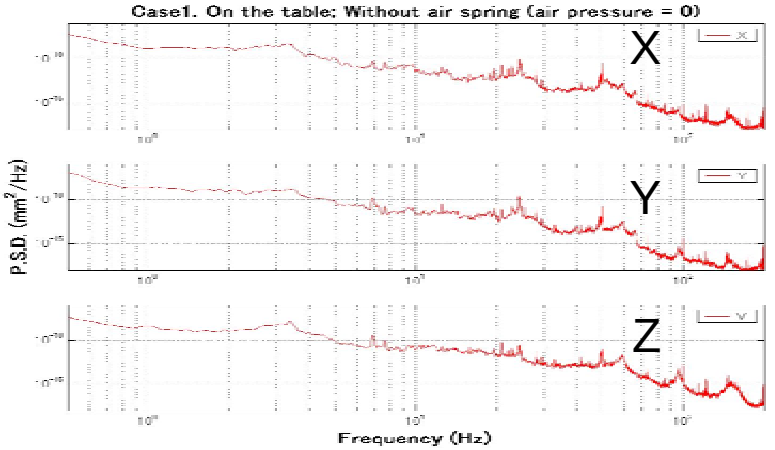
Displacement sensors have resolution 5 μm.

Vibration of floor and table

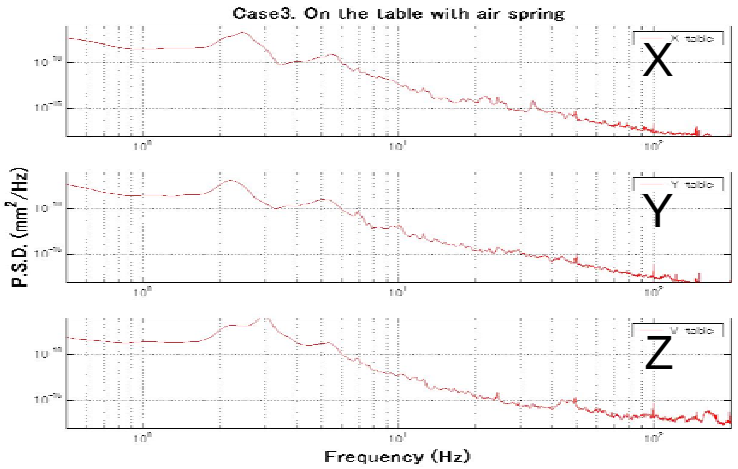
(a) Floor



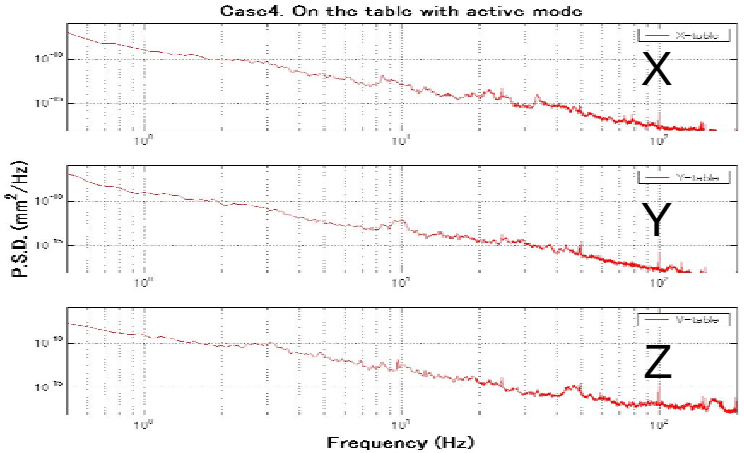
(b) Without air spring



(c) With air spring (passive mode)

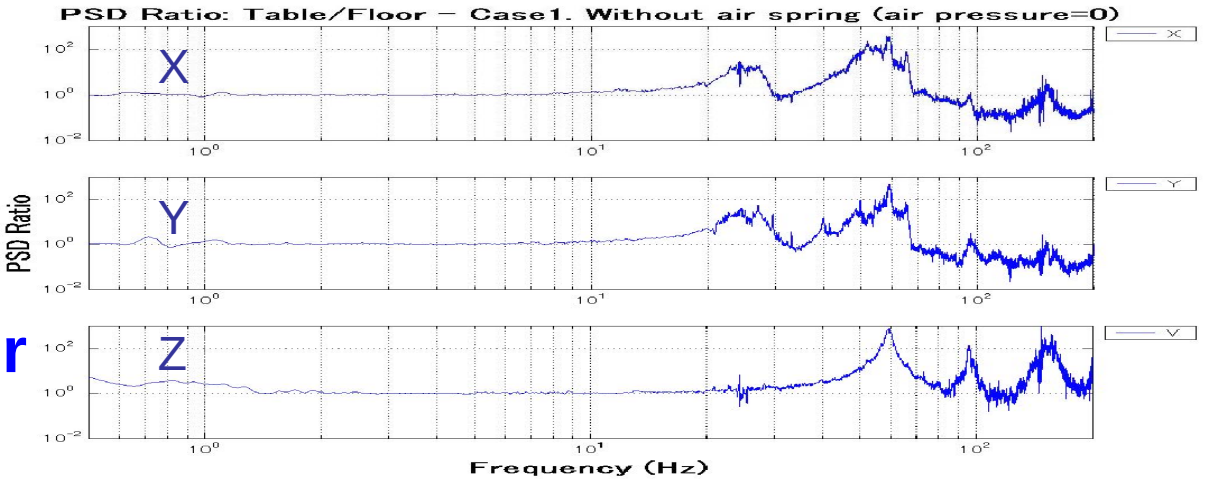


(d) Active mode

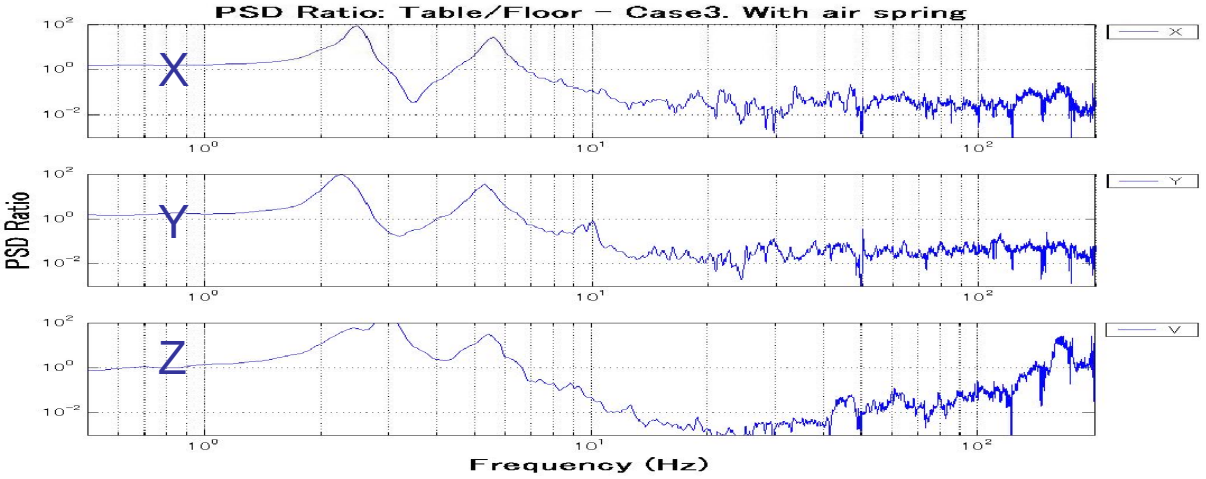


(a) Without air sprin

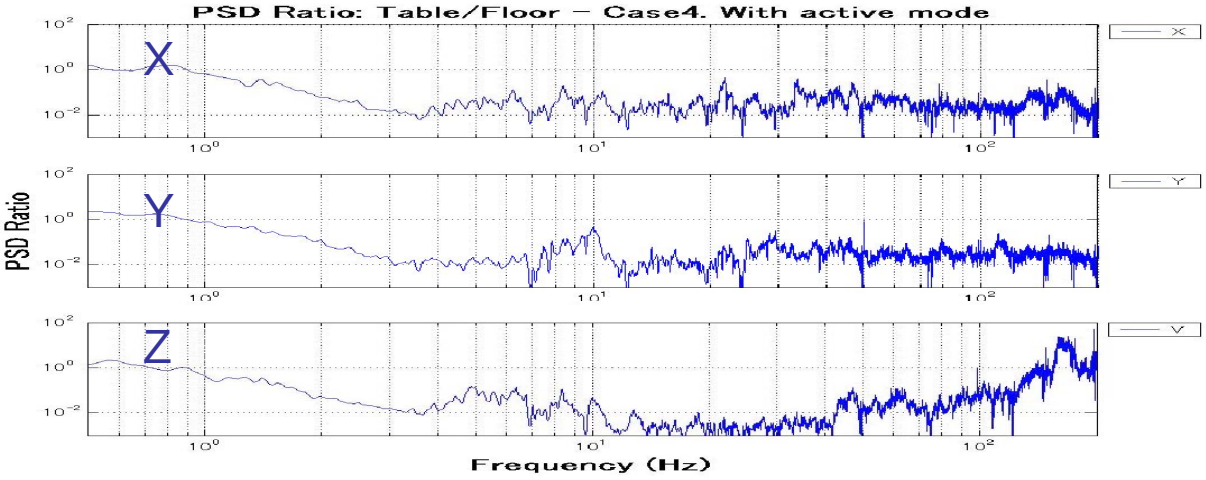
PSD ratio of vibration of table to that of floor



(b) With air spring (passive mode)



(c) Active mode



Problems

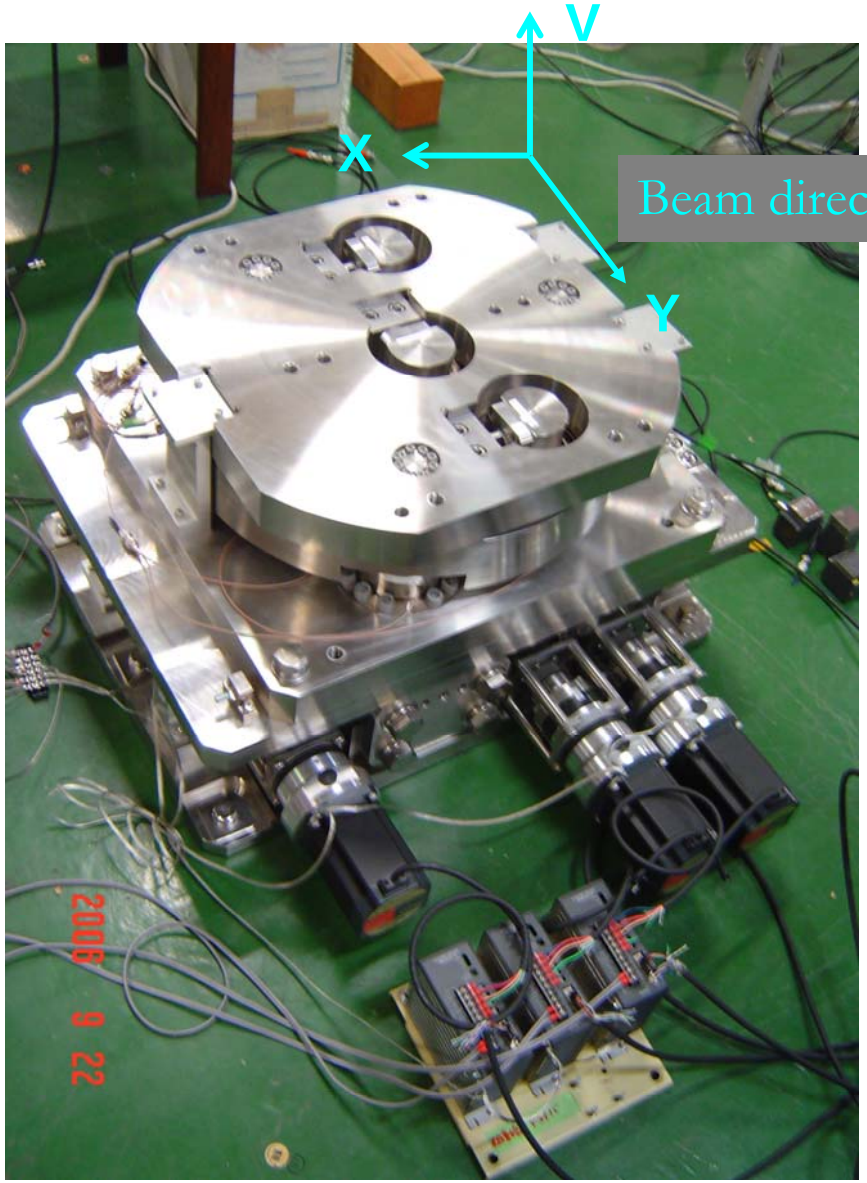
- **As the feedback is based on the signal from seismometers, slow speed displacement cannot be eliminated. The system itself sometimes causes drift.**

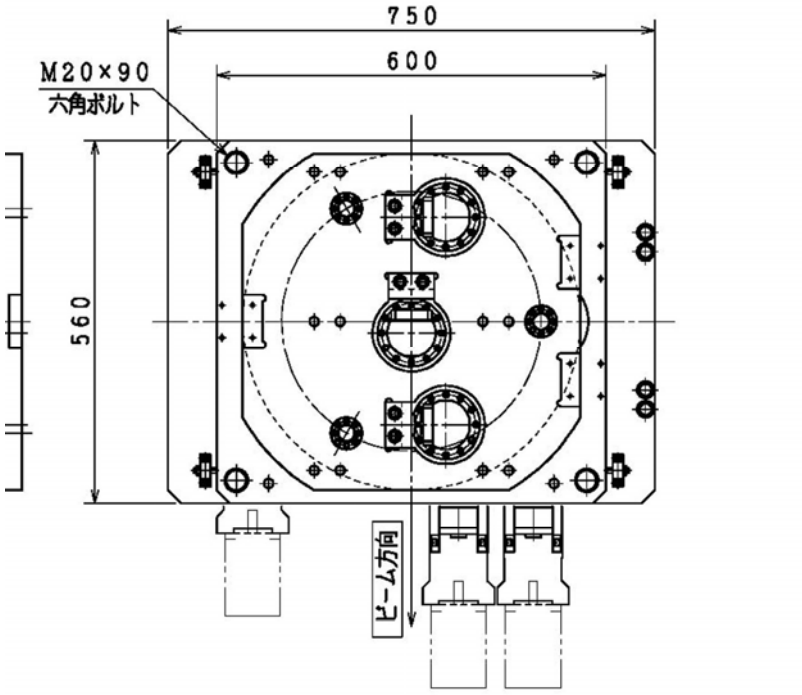
- **This system is very sensitive to sound noise.**

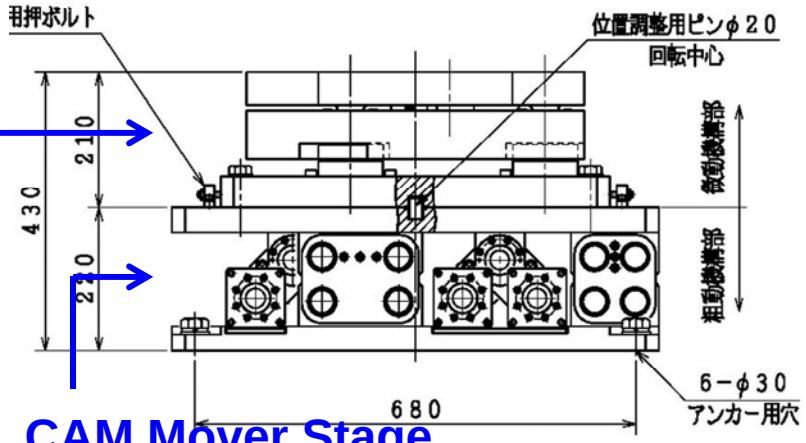
--> How about the feedback system based on the signal from displacement sensors having speed about 10 Hz and the resolution 1nm?

3. Vibration isolation table-II

(See Paper [3] in detail)







CAM Mover Stage

PIEZO Mover Stage

Specification

- Mass 350 kg
- Material SUS303
- Load limit 700 kg

Two stage mover to achieve wide moving range and extra-high precision

CAM mover stage

-3 CAM shafts with motors

-Moving direction 3 directions (X, V and Θy)

-Moving range 4.5mm

-Precision 0.1 μm

Piezo mover stage

-6 piezoelectric transducers

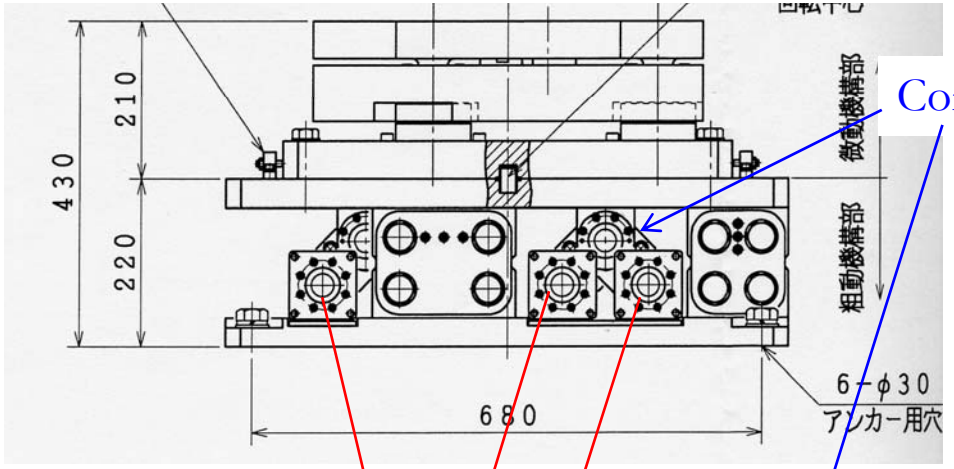
3 for vertical and 3 for horizontal direction

--> Able to adjust X, Y, V, Θx, Θy and Θv

-Moving range 0.4 μm

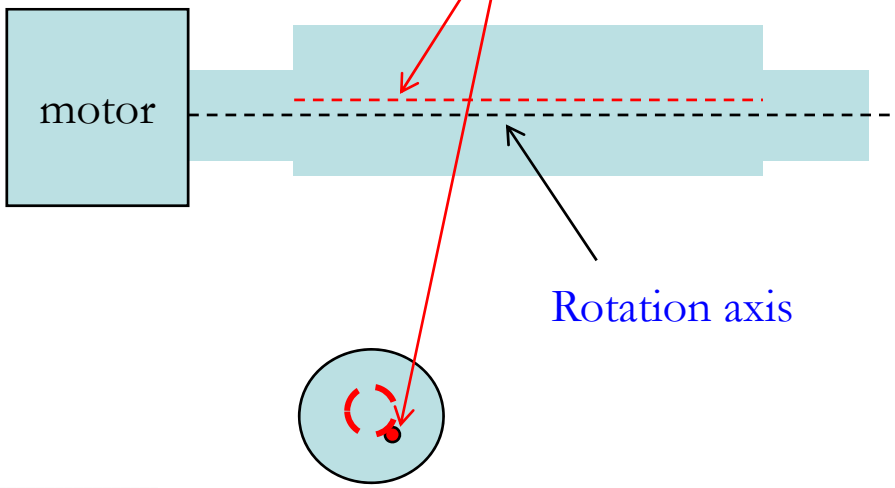
-Resolution 1 nm

Cam mover

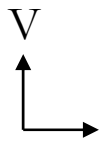


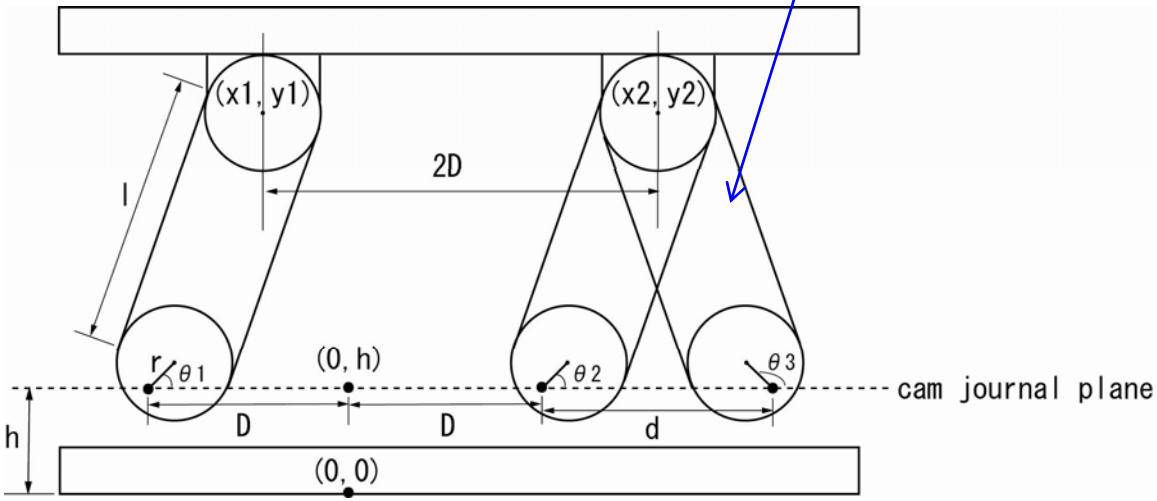
Connecting arm

Center
of the CAM shaft



3 motors
Shafts with offsets



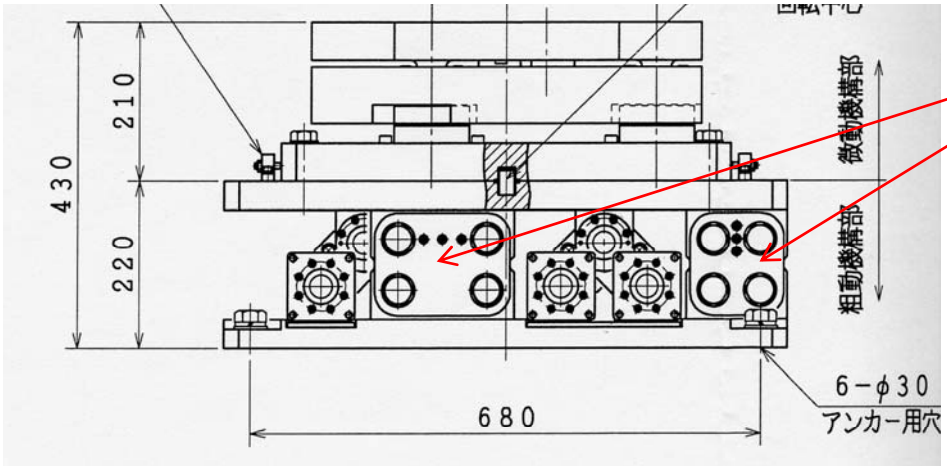


Top table moves in
X, V and Θy directions

Problem!

Cam mover stage lower the natural frequency to 45Hz

Stoppers were installed to make it more rigid

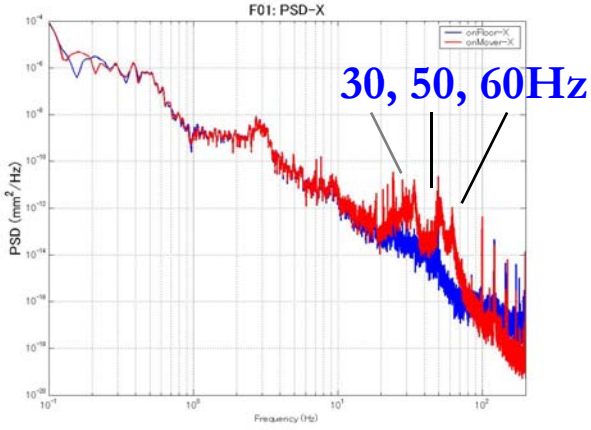


stoppers

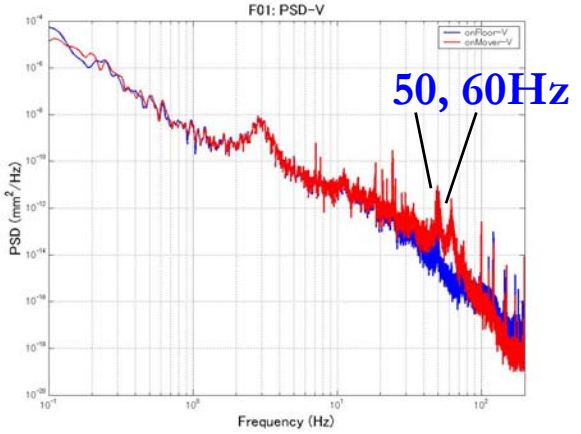
Natural frequency with/without of stoppers

Red: on the table
Blue: on the floor

Without stoppers

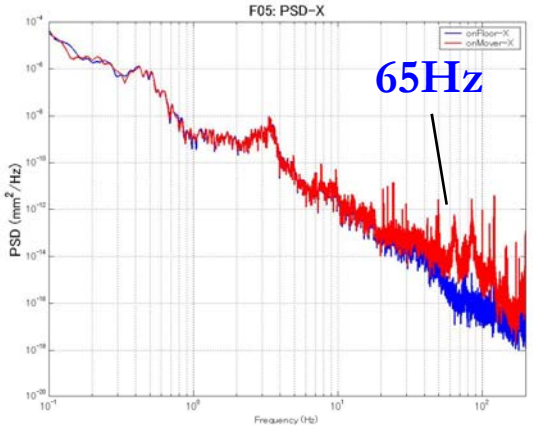


X direction



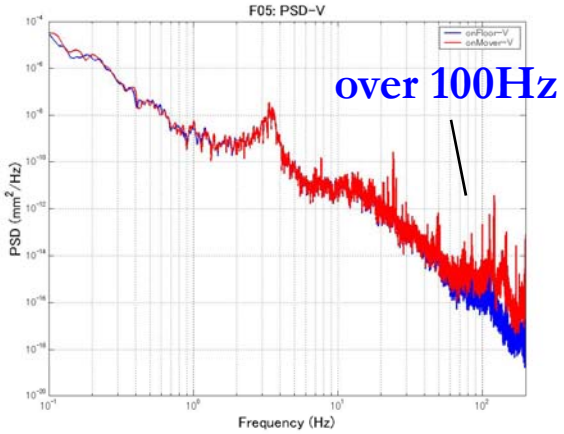
Vertical direction

With stoppers



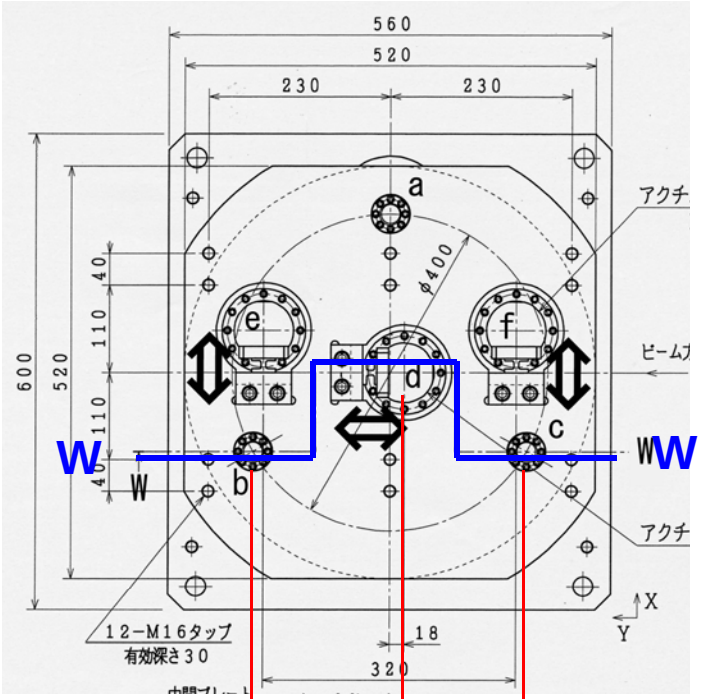
X direction

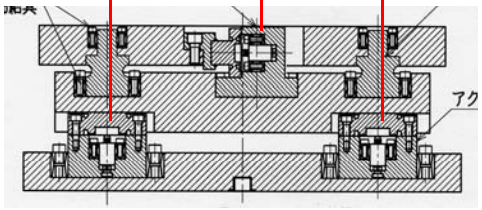
Cam mover stage became more rigid!



Vertical direction

Piezoelectric mover

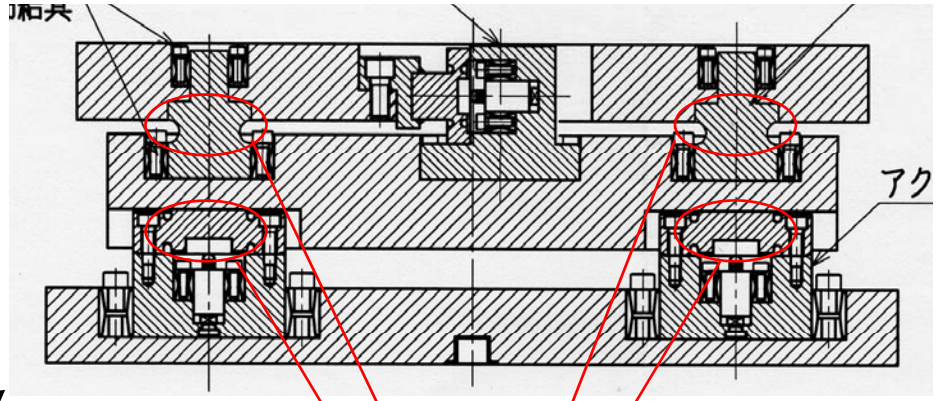




Cross sectional view at W-W

3 piezos for vertical motion and
3 piezos for horizontal motion

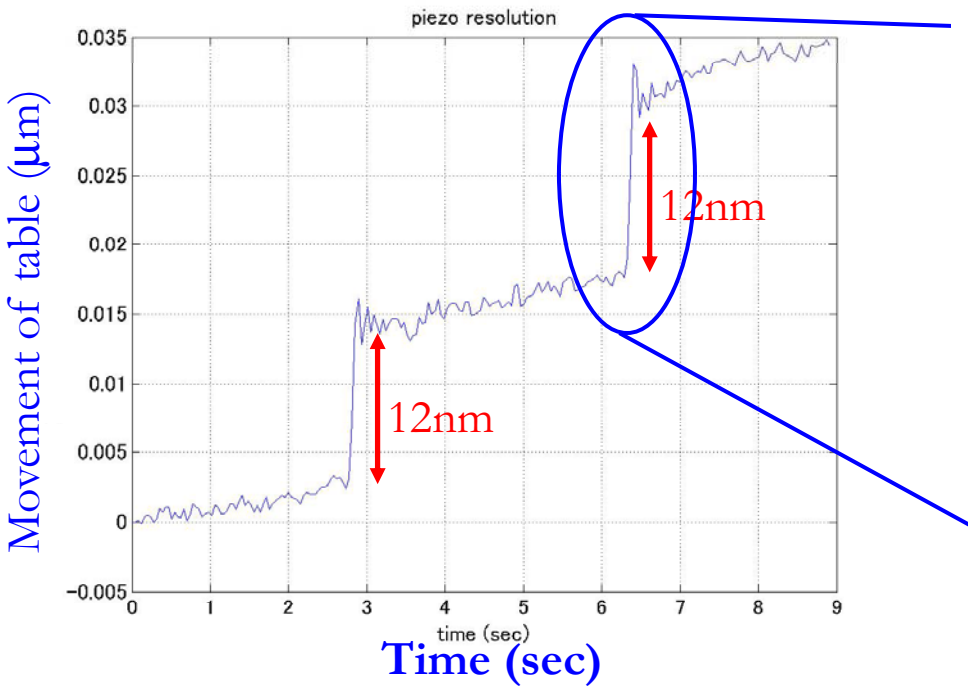
Table moves in
X, Y, V, Θx, Θy and Θv directions



Enlarged view

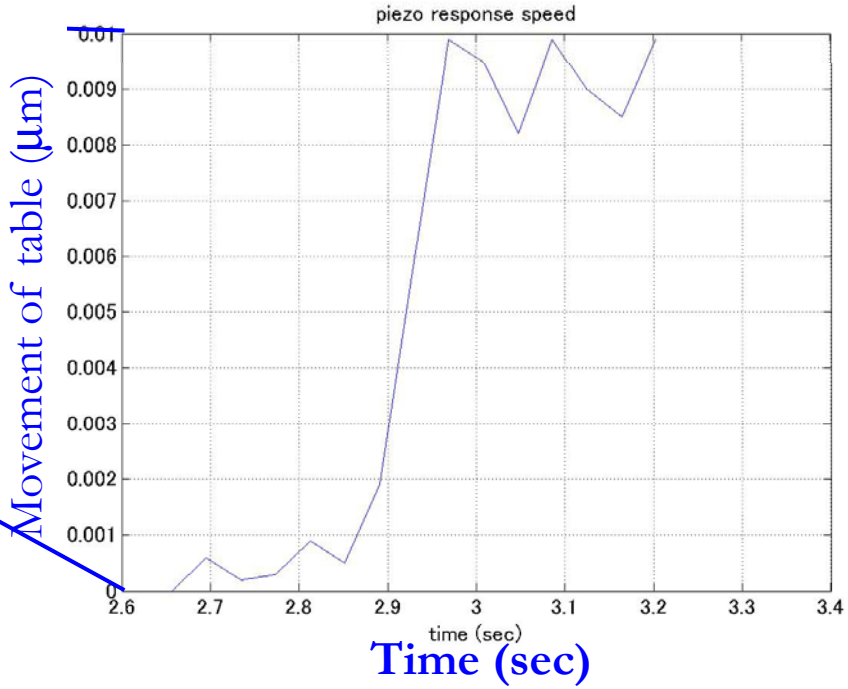
spring structure

Piezo resolution and response speed



Time (sec)

Resolution 1 or 2nm can be expected



Time (sec)

Response speed of piezoelectric transducer is 56 nm/msec

Summary

- Stabilization of 1nm level is required for final quadrupole magnets at ILC-IP

- Amplitude of GM exceeds 1nm in the frequency region less than about 10Hz at the ILC candidate sites except for DESY site

- Vibration isolation table (VIT) was fabricated and its performance was tested
- In this test following problems were found:
  (1) VIT cannot do anythig for low frequency movement, because VIT utilizes seismometers in its feedback or feed forward system.
  (2) VIT itself drifts sometimes
  (3) VIT is sensitive to sound. System has to be covered with acoustic material.

- Instead of VIT, high speed and high resolution mover was developed to damp GM in the frequency region lower than 10Hz
- Resolution of 1nm level and speed of 1kHz can be expected. More study is going on.

References

[1]
"Ground Motion Measurement and Vibration Suppression at KEK", Ryuhei Sugahara et al. KEK-PREPRINT-2005-77, Nov 2005. 13pp; Contributed to the Workshop on Ambient Ground Motion and Civil Engineering for Low Electron Storage Ring, NSRRC, Hsinchu, Taiwan, July 21-22, 2005.

[2]
"PERFORMANCE OF AN ACTIVE VIBRATION ISOLATION SYSTEM",
R. Sugahara, M. Masuzawa, H. Yamaoka, 8th International Workshop on Accelerator Alignment, CERN, Geneva, Switzerland, October 4-7, 2004; KEK-PREPRINT-2004-64, Nov 2004. 9pp.

[3]
"Development of a mover having one nanometer precision and 4mm moving range"
Y. Morita, S. Yamashita (Tokyo U., ICEPP) , Y. Higashi, M. Masuzawa, R. Sugahara, H. Yamaoka (KEK, Tsukuba), KEK-PREPRINT- 2006-42, Nov 2006, 11pp; Proceedings of 9th International Workshop on Accelerator Alignment (IWAA 06), California, U.S.A. 26-29 Sep 2006, pp TH003.

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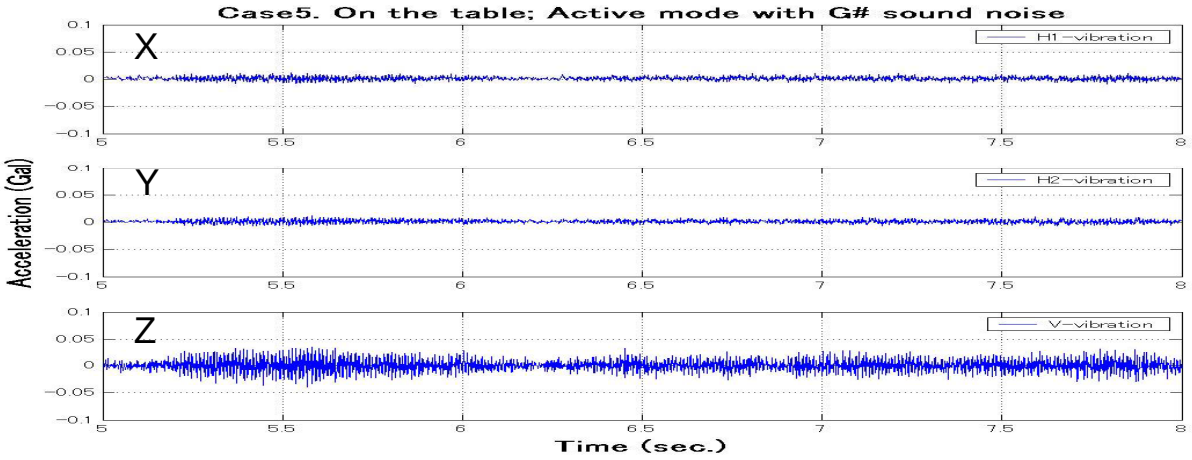
Instruments

VSE355G2 of Tokyo Sokushin Co., Ltd.
Velocity sensor
Used in KEK and SPring-8 areas
f-range 0.012 - 70Hz
Output 2.5V/kine

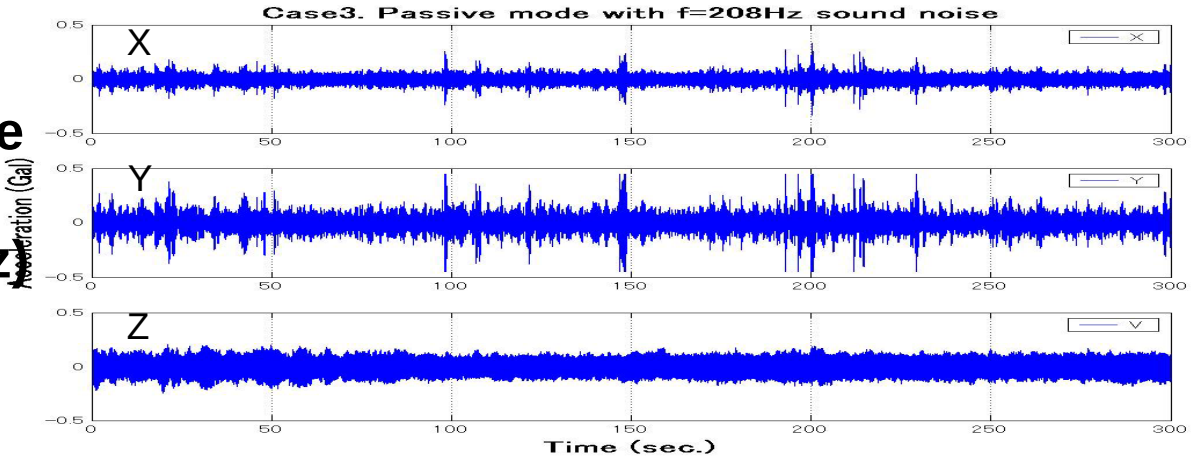
STS-2 of Streckeisen
Velocity sensor
Used in Sefuri and Esashi areas
f-range 0.008 - 50Hz
Output 15V/kine

* kine = cm/sec

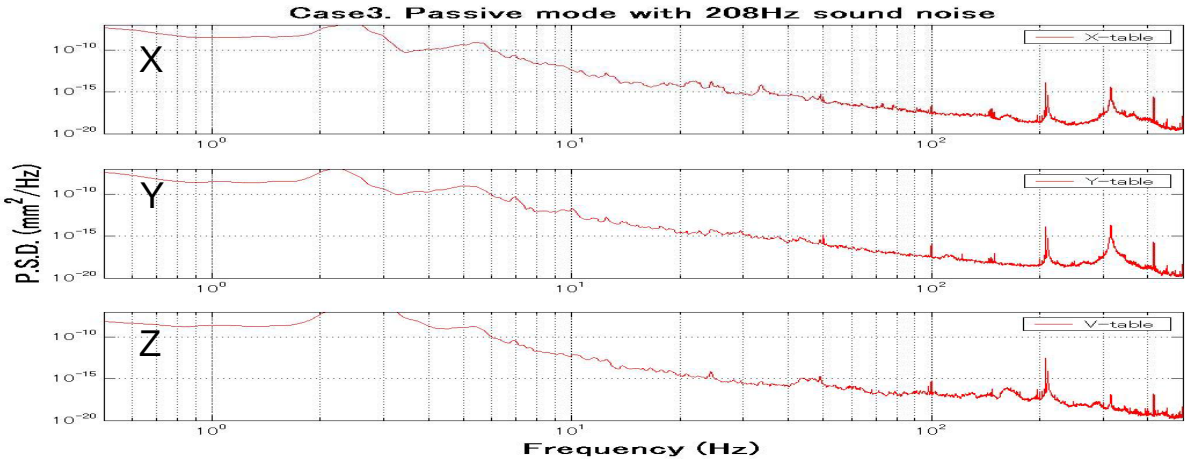
(a) Time series plot for floor



(b) Time series plot for table in passive mode with G# sounds (f=415.3Hz)



(c) PSD for vibration of table



Noise of the capacitive sensor

A capacitive sensor is used to examine the property of the piezoelectric transducers

- **Sampling rate is 2.54kHz**
- **For 10 seconds**
- **Standard deviation is 2.4nm**