Vibration measurements on the final doublets and the Shintake Monitor

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7th ATF2 project meeting, 16/12/08

Introduction

- ✓ **To have only 2% error on the beam size measurements at the IP, tolerance of vertical relative motion above 0.1Hz between:**
  - ➢ Shintake Monitor and QF1: 20nm
  - ➢ Shintake Monitor and QD0: 7nm

- ✓ **Tolerances are about 0.5µm in direction perpendicular to the beam and 10µm in direction parallel to the beam**

- ✓ **Tolerances are less strict if QD0 and QF1 move in the same way**

- ✓ **2 sources of excitation which can make final doublets vibrate:**
  - ➢ Ground motion: amplitude depends on time (coherence does not)
  - ➢ Cooling water: flow already specified for ATF2 final doublets

Plan of my presentation

1) Instrumentation used for vibration measurements

2) Ground motion measurements during 72 hours (week-end and one day of the week) to analyse the evolution of amplitude with time

3) Measurements of vibrations only due to ground motion between:

- [QD0; QF1] and the floor *(LAPP team responsable for support)*
- QD0 and QF1
- Shintake and the floor *(Shintake team responsable for support)*
- Shintake and [QD0; QF1]

4) Vibration measurements between [QD0; QF1] and their support with flowing cooling water

5) Conclusion on the tolerance achievement

1) Sensors used for vibration measurements

✓ **In order to measure vibrations in the 3 directions from 0.1Hz to 100Hz, 3 models of vibration sensors were needed:**

Model	CMG-40T	86	MG-102S
Manufacturer	Guralp Systems	Endevco	TOKKYO KIKI
Sensor Type	Geophone	Accelerometer	Accelerometer
Frequency range	[0.03; 50] Hz	[0.01; 100] Hz	[0.1; 400] Hz
Direction	3-direction	vertical only	1-direction each

LAPP sensors

Sugahara sensors

✓ **In fact, because of sensor noise, ground motion can be measured:**

- From about 0.2Hz to 50Hz with geophones
- From few Hz (1Hz: ATF / 10Hz: LAPP) to 100Hz with accelerometers

➔ GURALP data: from about 0.2Hz to 50Hz in X, Y, Z direction

➔ ENDEVCO data: from few Hz to 100Hz in vertical direction

➔ MG-102S data: from few Hz to 100Hz in X, Y, Z (only used in part 3)

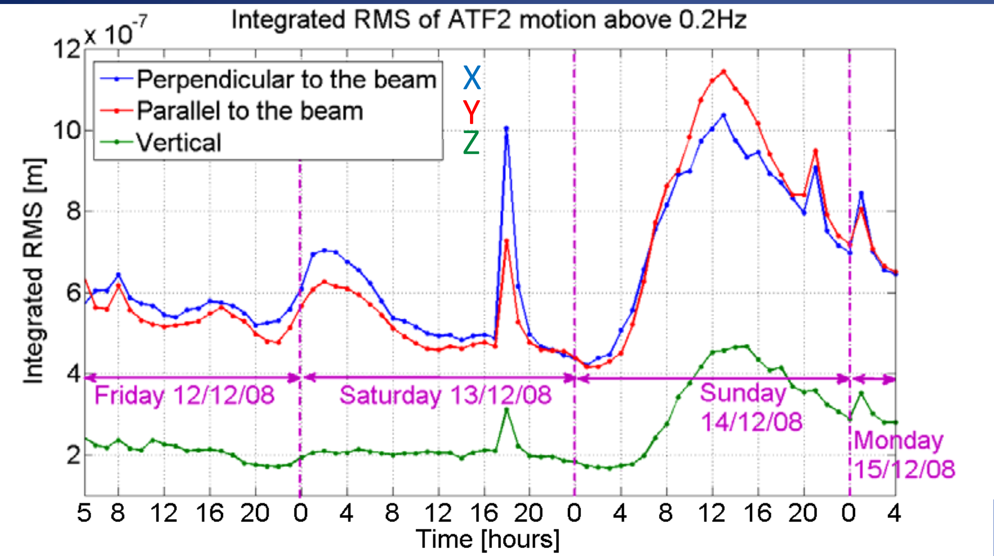
2) Ground motion measurements at ATF2 during 72 hours

Introduction

- ✓ **Ground motion measurements done during 72 hours non-stop**
  - ➢ Near the final doublets
  - ➢ From Friday 11/12/08 at 4:00 to Monday 14/12/08 at 4:00

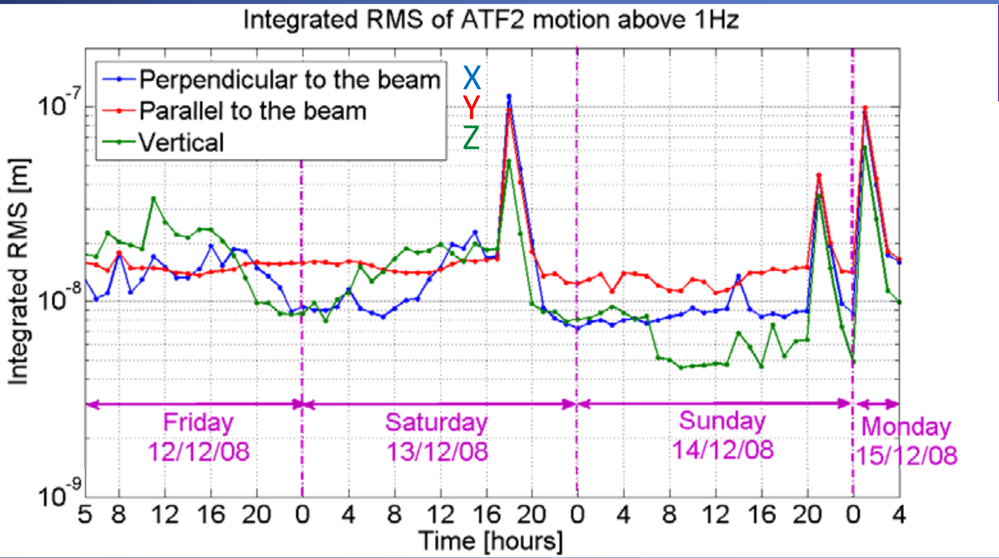
- ✓ **Vibration sensors used:**
  - ➢ Guralp geophones from 0.2Hz to 50Hz in X, Y, Z direction
  - ➢ ENDEVCO sensors from 50Hz to 100Hz in vertical direction

- ✓ **FFT parameters:**
  - ➢ Window: Hanning
  - ➢ Overlap: 66.67%
  - ➢ Frequency resolution: 0.016Hz
  - ➢ Time resolution: 1 hour
  - ➢ Averaging: Exponential (2*Tau=1216s) and 195 averages



Earth motion (Natural)

- ✓ Z direction: from 200nm to 470nm
- ✓ X and Y direction: from 420nm to 1100nm!



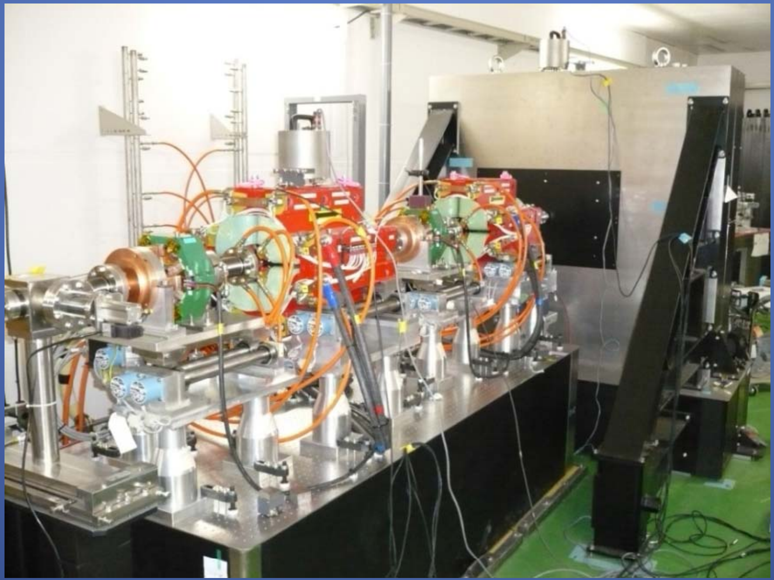
Cultural noise (Human)

- ✓ Z direction: from 5nm to 30nm
- ✓ X direction: from 8nm to 20nm
- ✓ Y direction: around 15nm
- ✓ Very big peak up to 100nm when people working around

➔ Need to measure relative motion between Shintake Monitor and [QD0; QF1] during a very long time

3) Measurements of vibrations only due to ground motion between:

- ✓ [QD0; QF1] and the floor
- ✓ Shintake Monitor and the floor
- ✓ QD0 and QF1
- ✓ Shintake Monitor and [QD0; QF1]



Measurements with Shintake Group (T. Yamanaka et al.)

Final doublets and Shintake Monitor with their supports at ATF2

Introduction

- ✓ **Contribution of Shintake team and Sugahara sensors (MG102S)**

- ✓ **Vibration sensors used:**
  - ➢ Guralp geophones from 0.2Hz to 13Hz in X, Y, Z axes
  - ➢ MG-102S accelerometers from 13Hz to 100Hz in X, Y, Z axes
  - ➢ ENDEVCO accelerometers from 13Hz to 100Hz in vertical axe

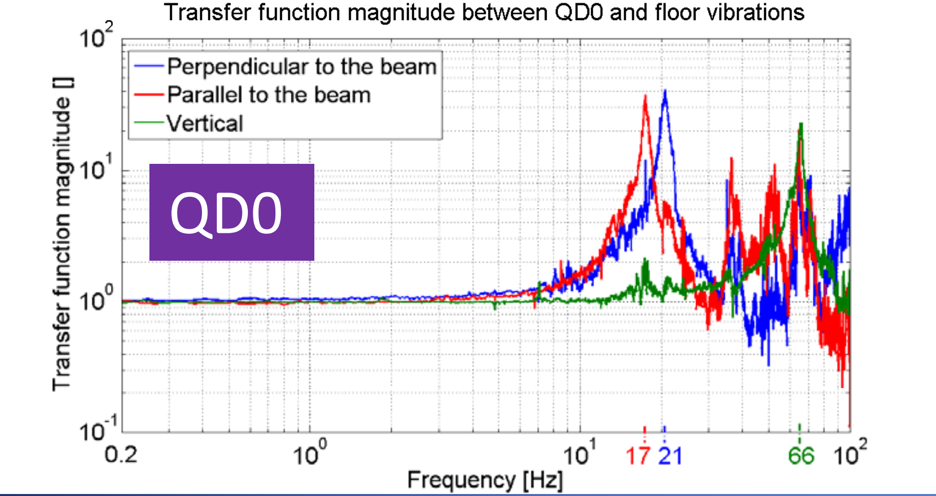
- ✓ **FFT parameters:**
  - ➢ Window: Hanning
  - ➢ Frequency resolution: 0.016Hz
  - ➢ Averaging: Linear, 50 averages, 66.67% overlap

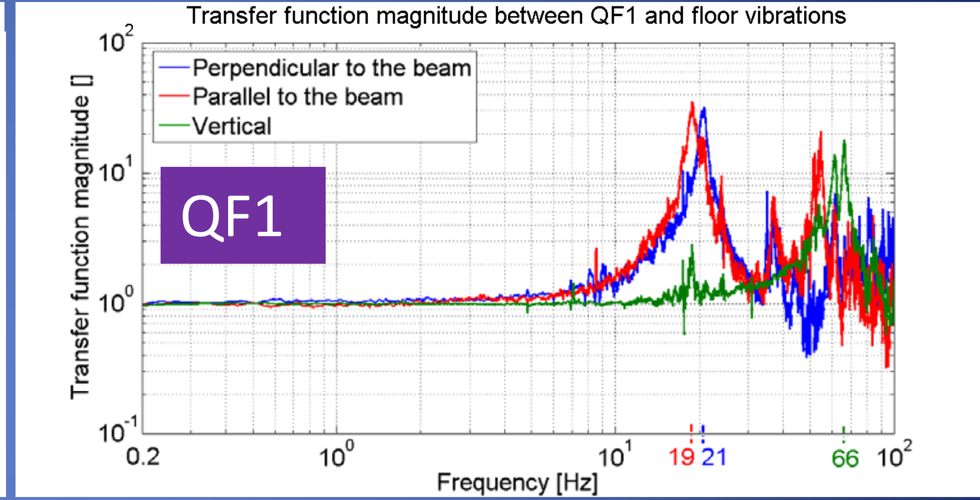
- ✓ **Integrated RMS of relative motion:**

$$RMS_{\text{int y-x}}(k) = \sqrt{\sum_{k_1}^{k_2} [H(k)-1][H^*(k)-1] PSD_x(k) \Delta f}$$

Measurements between [QD0; QF1] and the floor

Transfer function magnitude

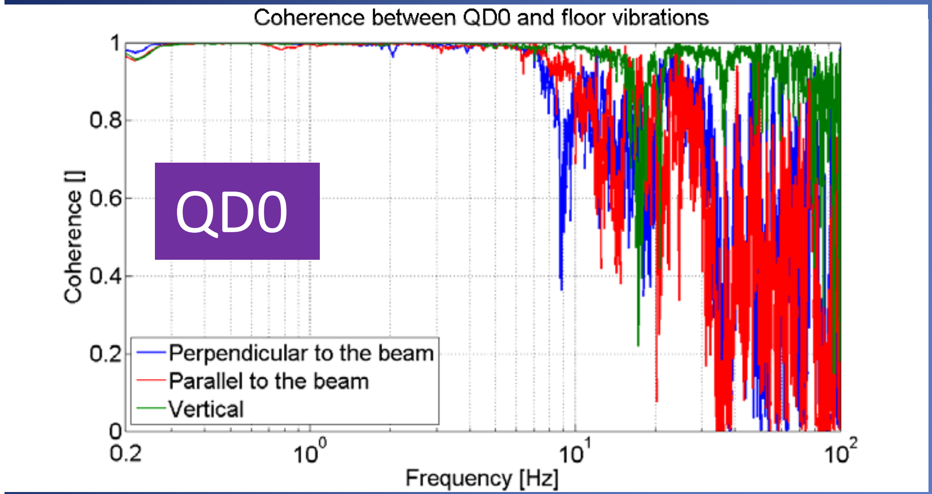


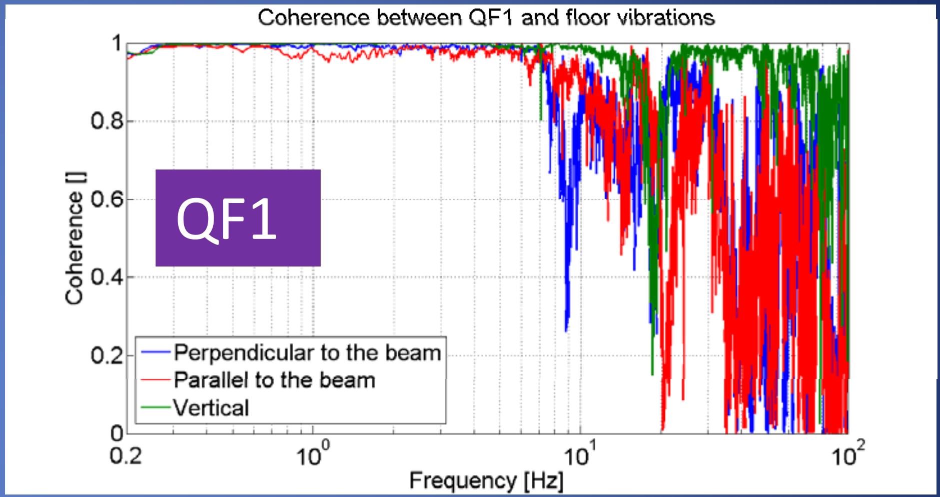


- ✓ Almost the same for QD0 and QF1
- ✓ Totally flat below 10 Hz
- ✓ In horizontal directions: first resonance around 20 Hz
- ✓ In vertical direction: only one resonance at 66Hz

Measurements between [QD0; QF1] and the floor

Coherence

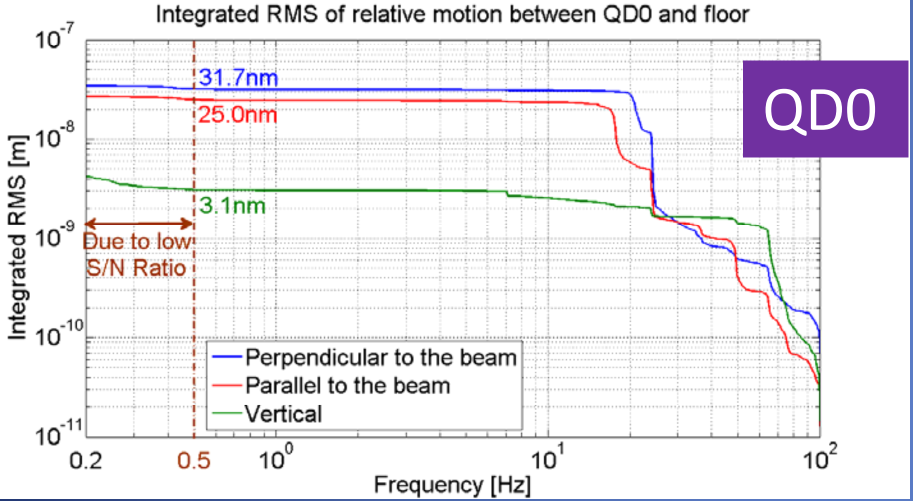


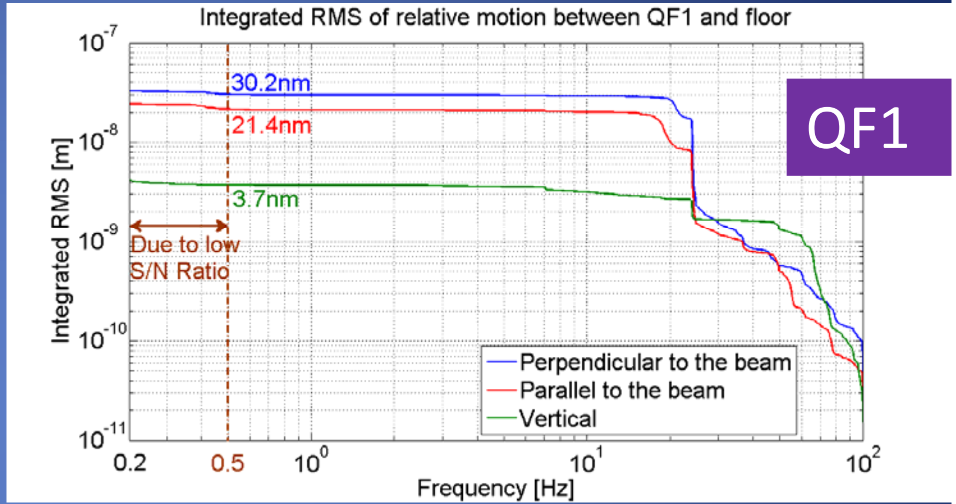


- ✓ Almost the same for QD0 and QF1
- ✓ Equal to one below 10Hz
- ✓ In horizontal directions: decrease above 10Hz
- ✓ In vertical directions: very good up to 80Hz

Measurements between [QD0; QF1] and the floor

Integrated RMS of relative motion



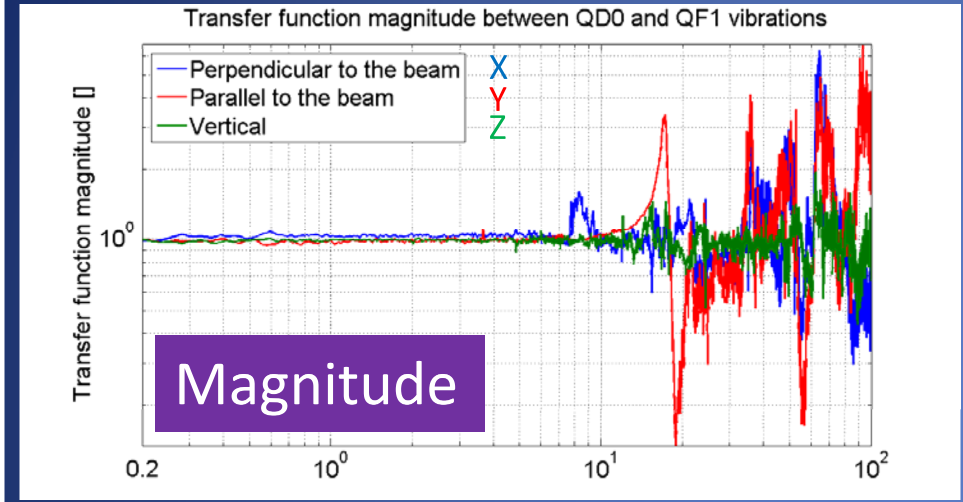


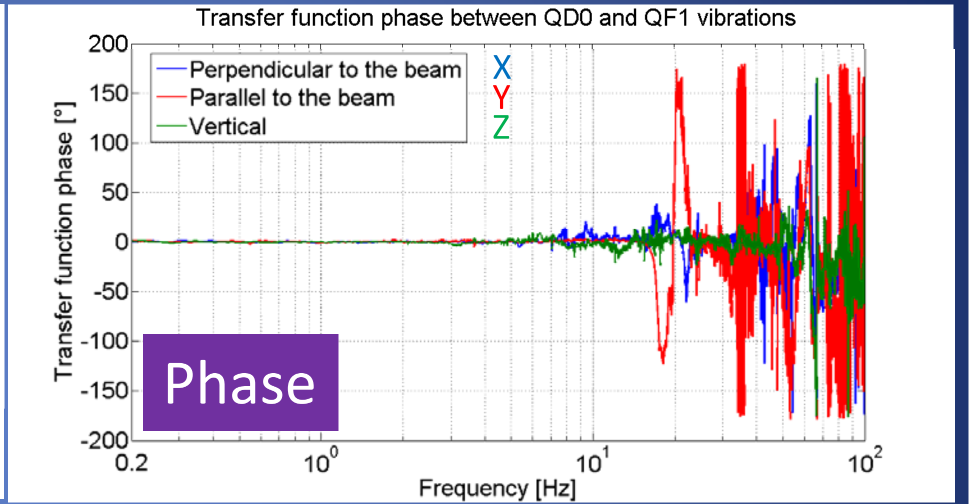
- ✓ Almost the same for QD0 and QF1
- ✓ Almost flat below 10Hz
- ✓ In horizontal directions: 20-30nm due to the resonance at 20Hz
- ✓ In vertical direction: only 1nm due to the resonance at 66Hz

➔ **Final doublet supports of LAPP team validated on site**

Measurements between QD0 and QF1

Transfer function





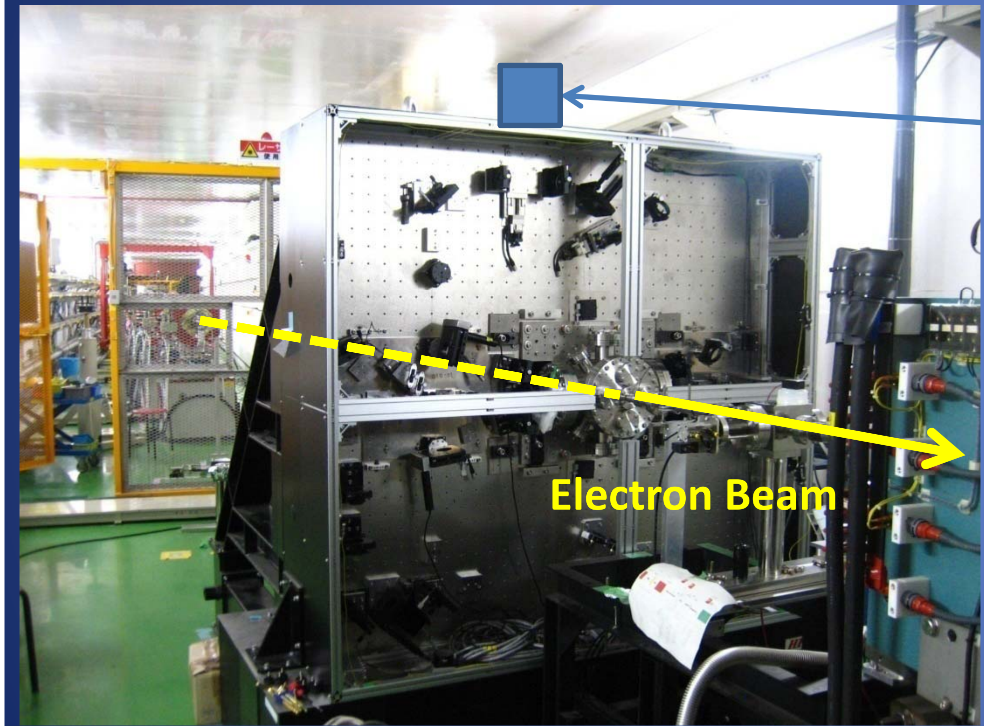
- ✓ Totally flat below 10Hz
- ✓ **Y:** QD0 and QF1 1st resonance (not exactly at the same frequency)
- ✓ **Z and X:** no 1st quad resonance (exactly at the same frequency)

- ✓ Equal to 0 below 10Hz
- ✓ **Y:** high from 1st quad resonance (>10Hz)
- ✓ **X:** high from 2nd quad resonance (>50Hz)
- ✓ **Z:** good up to 60Hz

➔ QDO and QF1 motion in phase in vertical direction and in direction perpendicular to the beam

Measurements between Shintake and the floor

Experimental set-up

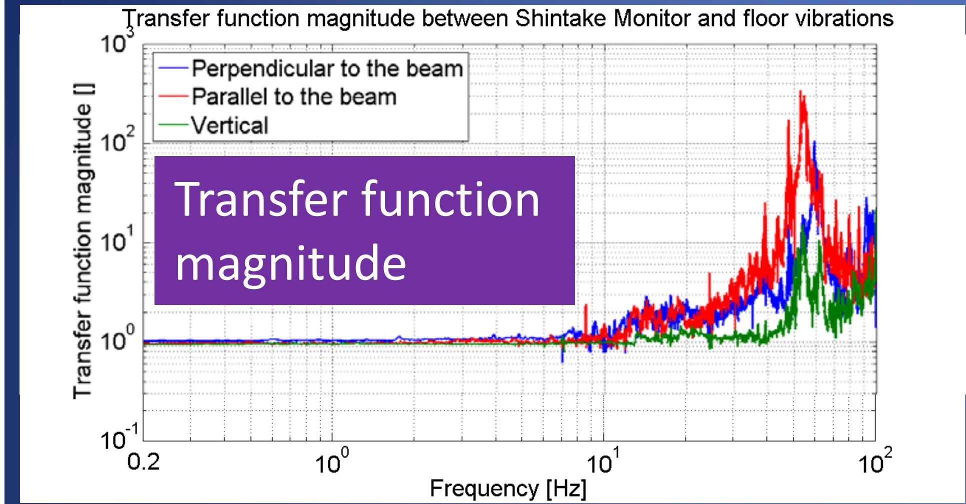


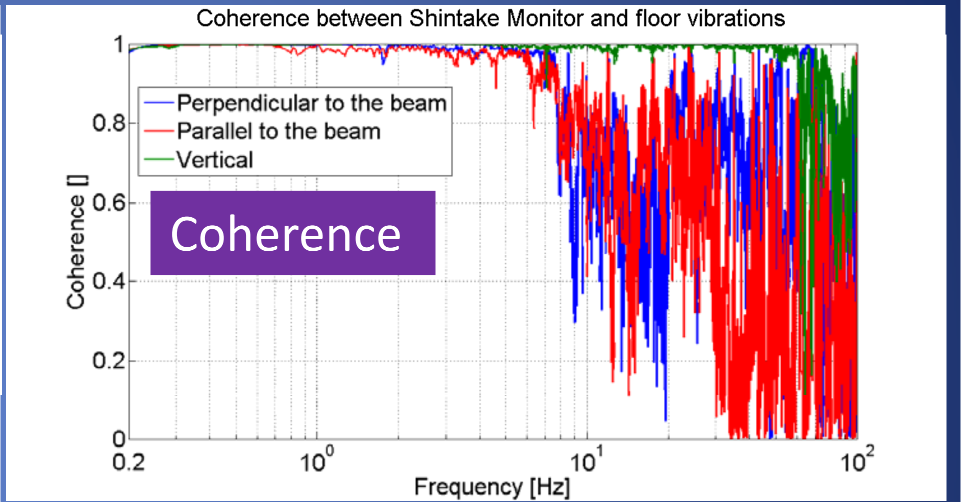
Shintake monitor vertical table

- ✓ Vibration measurements done on the top the vertical table
- ✓ The electron beam passes through the center of the table
- ✓ Since the laser interferometer optics is constructed on the whole area of the vertical table, vibrations are not overestimated

Measurements between Shintake and the floor

Vibratory behavior of the mechanical support

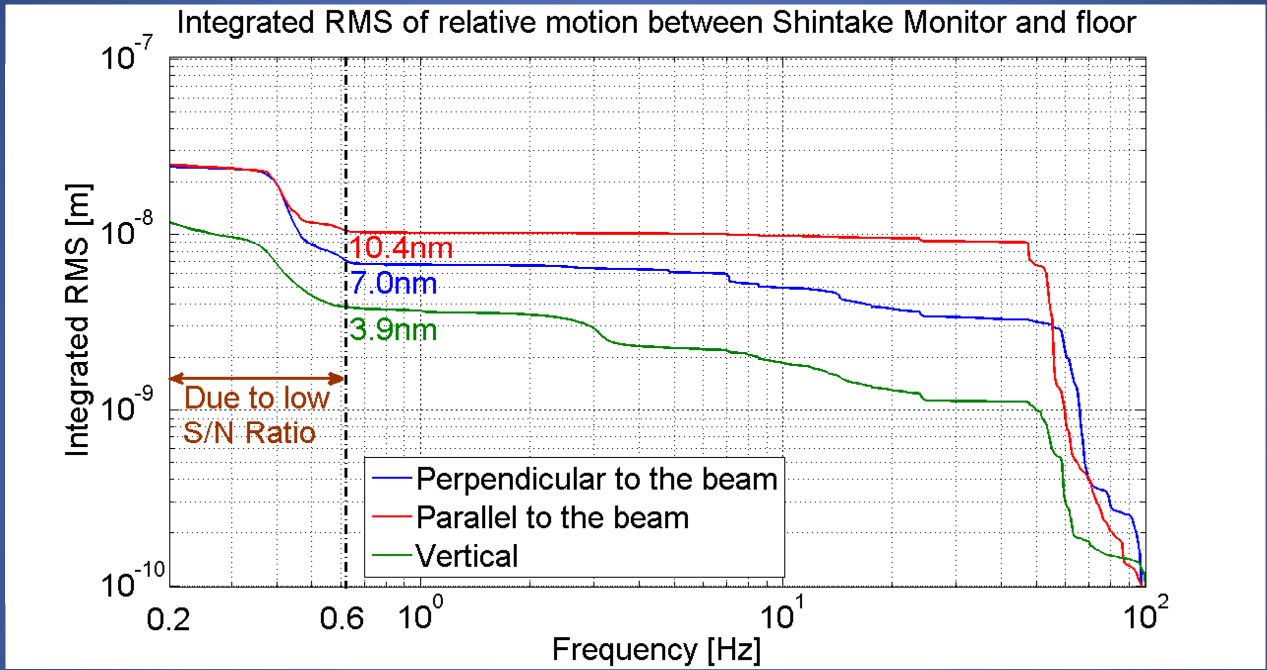




- ✓ Totally flat below 10Hz
- ✓ Resonance around 50Hz
- ✓ Very flat up to 40Hz in vertical direction
- ✓ In horizontal directions: equal to one below 10Hz and decrease above
- ✓ In vertical direction: equal to one up to 60Hz

Measurements between Shintake and the floor

Integrated RMS of relative motion

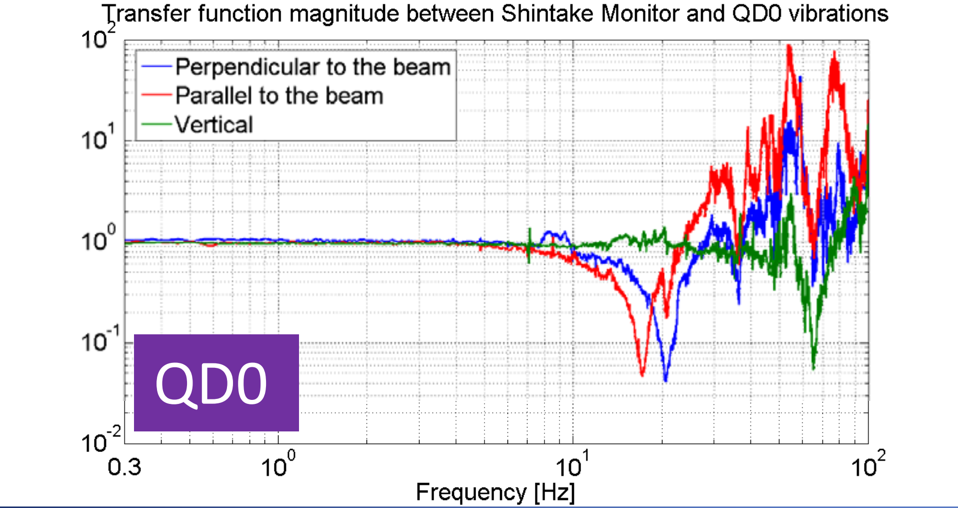


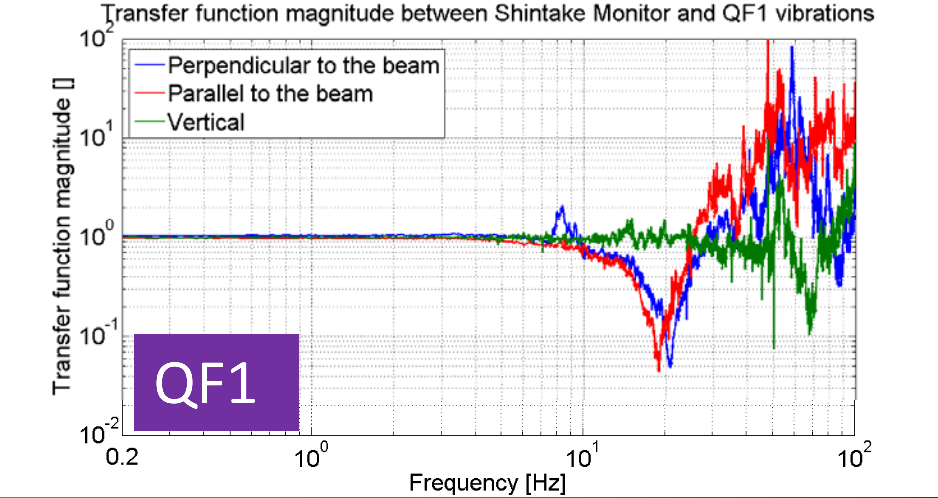
- ✓ Almost flat below 10Hz
- ✓ Large around 50Hz due to the resonance
- ✓ Increase below 0.5Hz due to the low S/N Ratio and not to motion

➔ **Shintake Monitor supports of Shintake team validated on site**

Measurements between Shintake and [QD0; QF1]

Transfer function magnitude

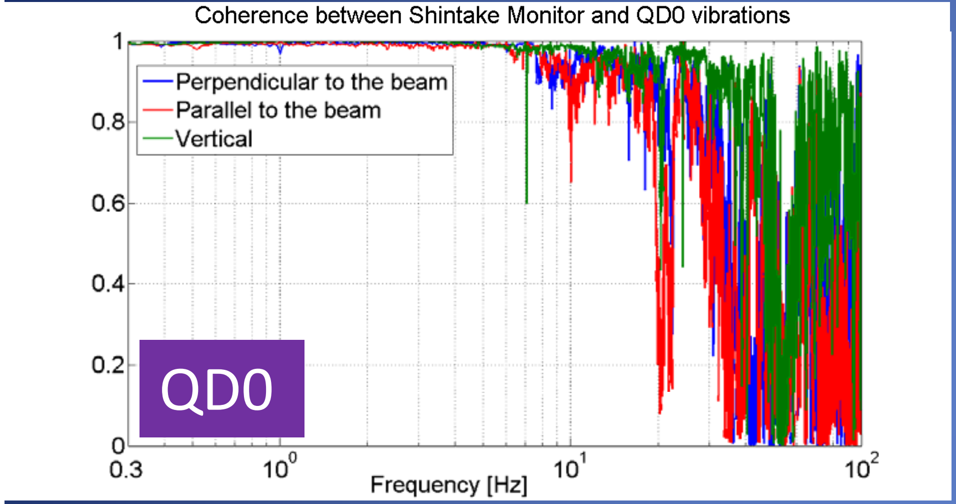


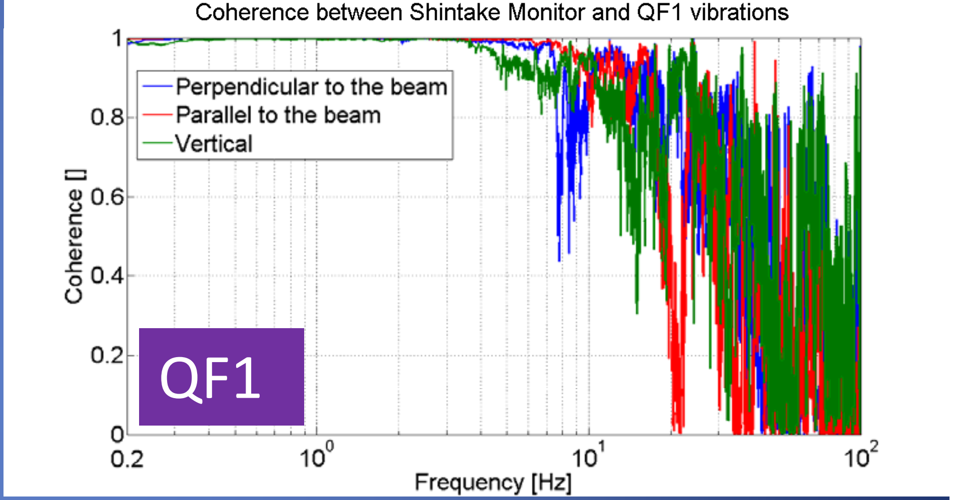


- ✓ Almost the same for QD0 and QF1
- ✓ Totally flat below 10 Hz
- ✓ Decrease around 20Hz in horizontal directions and around 70Hz in vertical direction because of final doublet resonance
- ✓ Increase around 50Hz in horizontal directions because of Shintake table resonance and above 50Hz because of final doublet antiresonance

Measurements between Shintake and [QD0; QF1]

Coherence





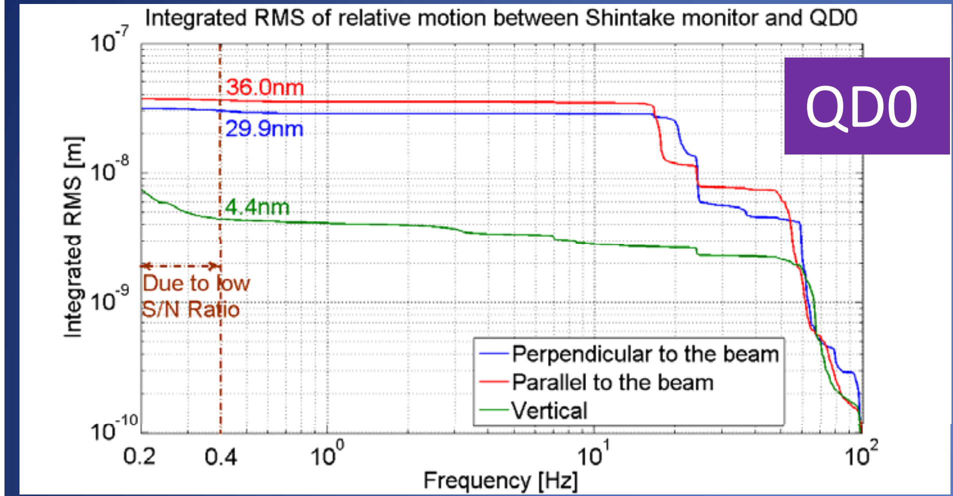
- ✓ Equal to one below 10 Hz in all directions
- ✓ Small decrease above 30Hz and big decrease above 50Hz in vertical direction

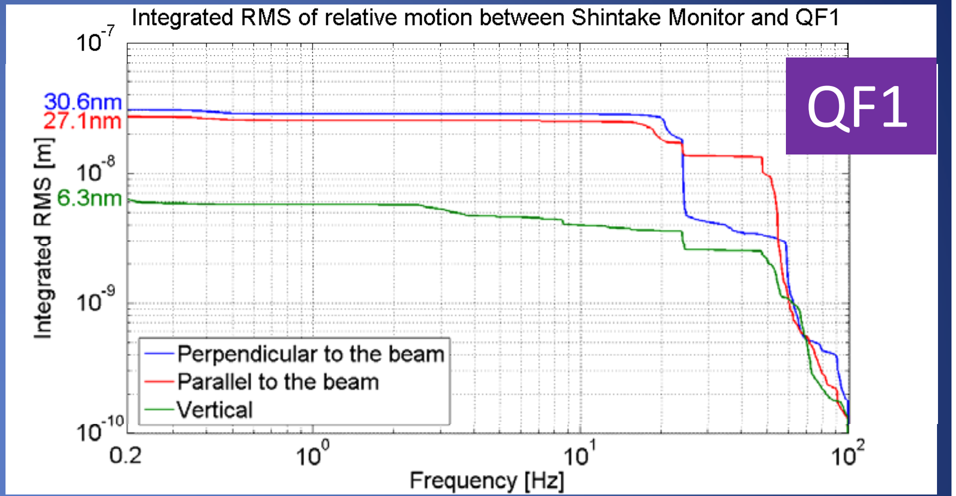
- ✓ Equal to one below 10 Hz in horizontal directions
- ✓ Small decrease above 4Hz and big decrease above 10Hz in vertical direction

Difference due to the longer distance from the IP

Measurements between Shintake and [QD0; QF1]

Integrated RMS of relative motion



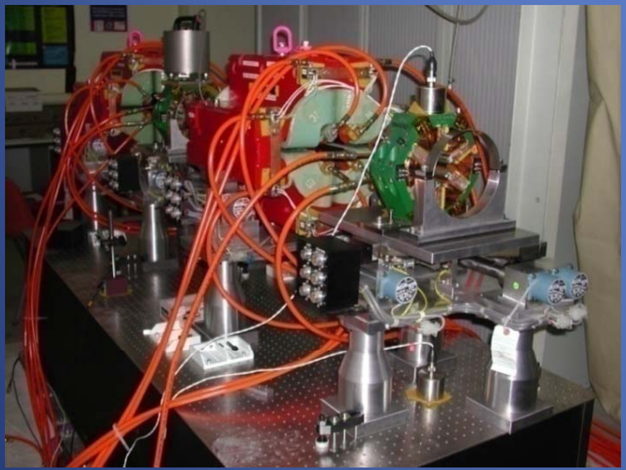


- ✓ Almost the same for QD0 and QF1
- ✓ Very small in vertical direction
- ✓ Quite the same level for the two horizontal directions
- ✓ Increase above 50Hz mainly comes from Shintake Monitor
- ✓ Increase around 20Hz comes from final doublets

➔ **Within tolerances with ground motion as only source of vibrations**

4) Vibration measurements between [QD0; QF1] and the table with flowing cooling water

- ✓ **Stationary study of cooling water vibrations**
  - ➢ **Temporal data analysis**
  - ➢ **3D frequency analysis**
- ✓ **2D frequency analysis**



Set-up done at LAPP at the end of July 2008
(same than the one at ATF2 now)

Introduction

- ✓ **Water flow twice higher than specified (20 l/min instead of 9.3l/min)**
- ✓ **Stationary study of cooling water vibrations**
  - ➢ **Temporal analysis (GURALP: 0.2~50Hz and ENDEVCO: 10~100Hz)**
  - ➢ **3D frequency analysis (ENDEVCO:10~100Hz)**
    - **Window:** Hanning
    - **Frequency resolution:** 2Hz
    - **Time resolution:** 1s (configured size of the multibuffer)
    - **Averaging:** Exponential (2*Tau=1.167s), 5 averages, 66.67% overlap

Stationary checked

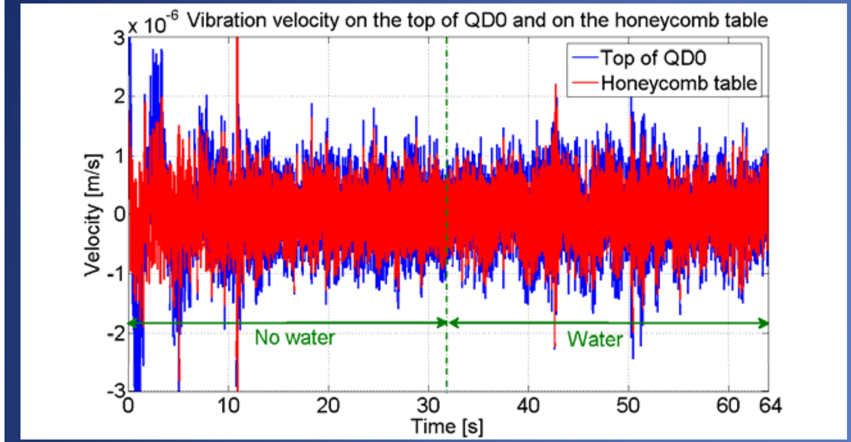
- ✓ **2D frequency analysis (Guralp: 0.2~13Hz and ENDEVCO : 13~100Hz)**
  - ➢ **Frequency resolution: 0.016Hz**
  - ➢ **Window:** Hanning
  - ➢ **Averaging:** Linear, 50 averages, 66.67% overlap

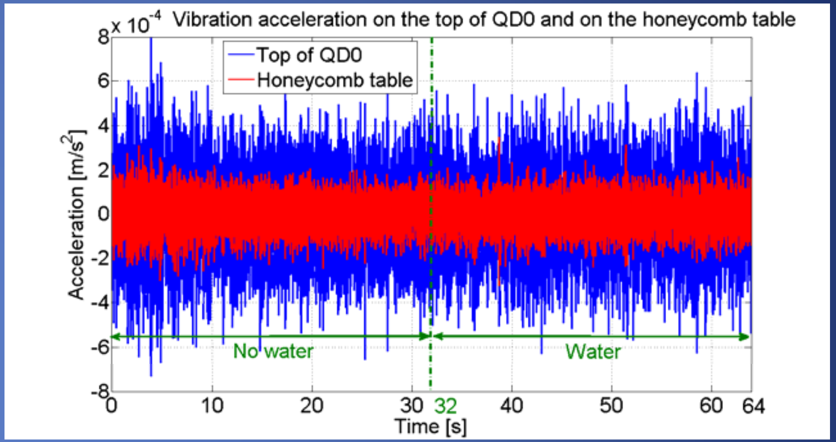
Stationary study of cooling water vibrations

Temporal vibrations of QD0, QF1 and of the table

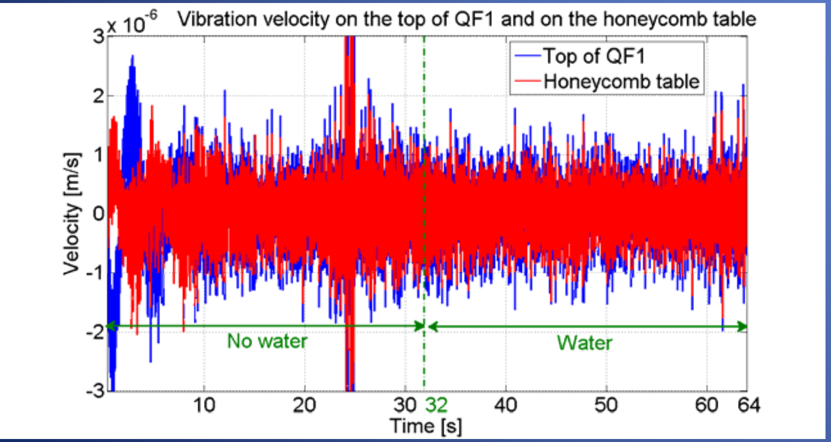
Stationary of ground motion checked to compare with/without water

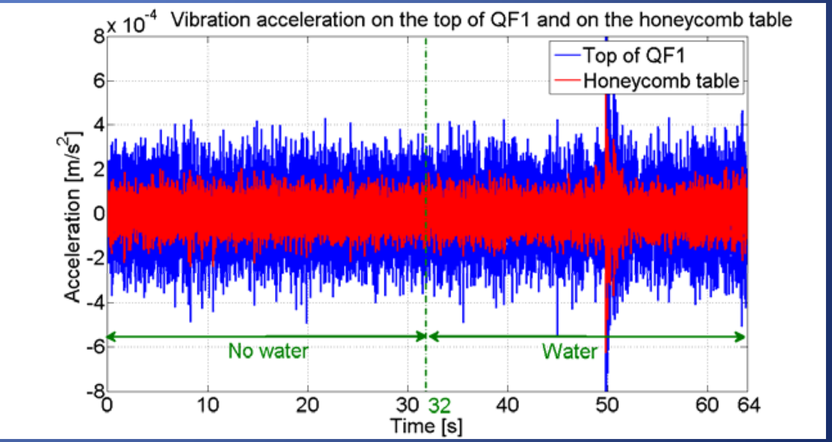
QD0





QF1



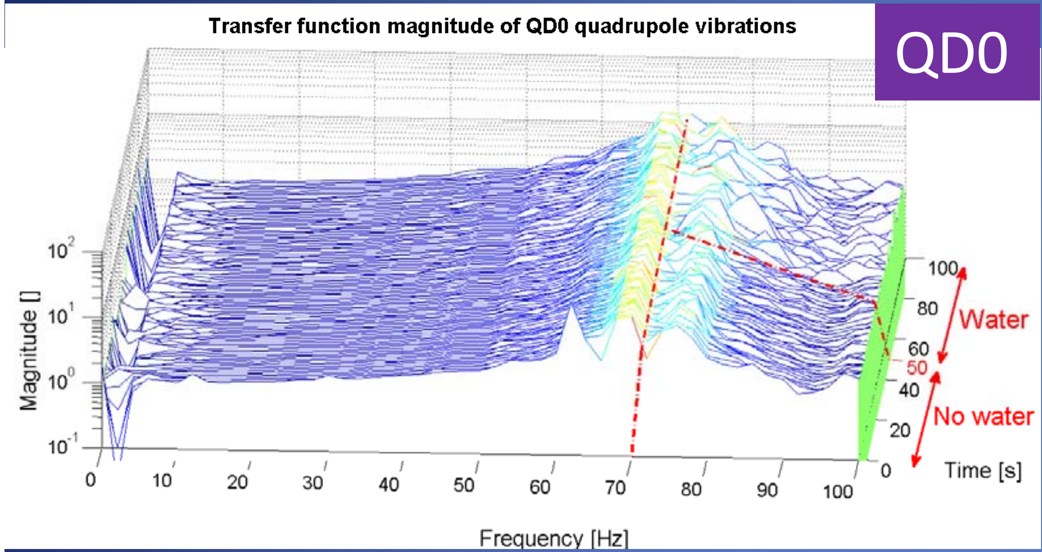


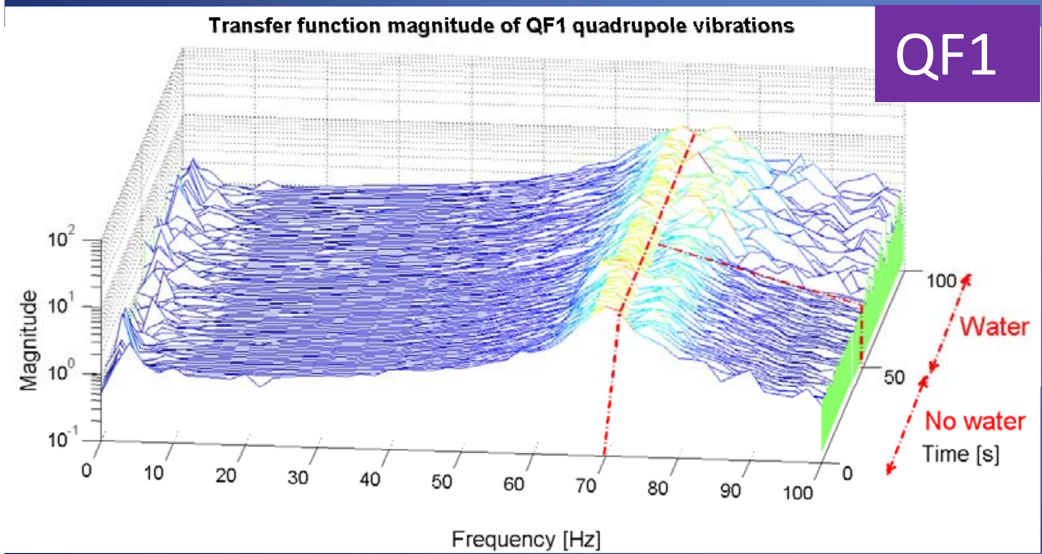
GURALP sensors (0.2Hz – 50Hz) ENDEVCO sensors (10Hz – 100Hz)

- **No vibration increase and no shocks observed with cooling water**

Stationary study of cooling water vibrations

3D transfer function between [QD0; QF1] and the table





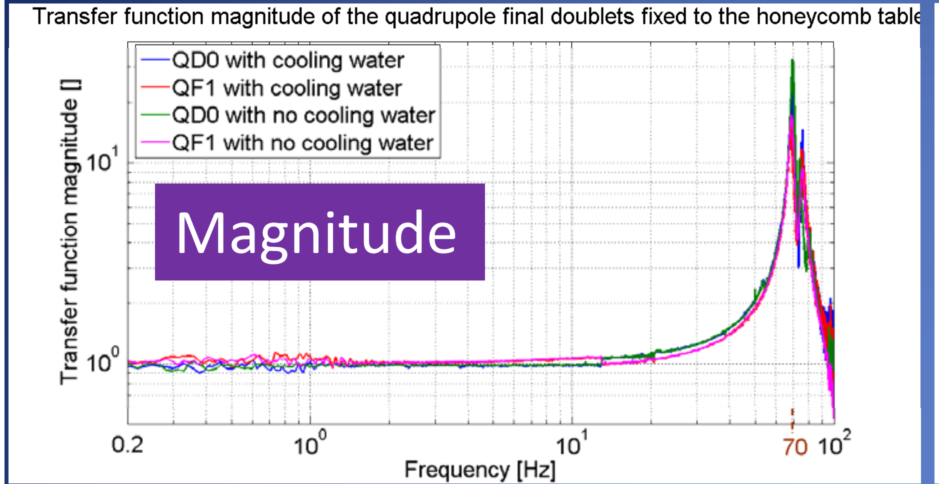
✓ For QD0 and QF1, almost the same vibratory behavior

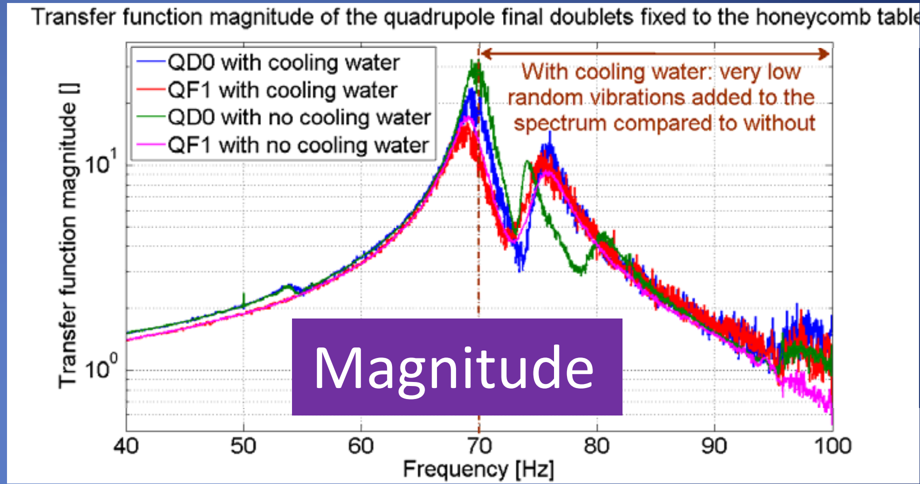
✓ With cooling water, very low random vibrations above 70Hz

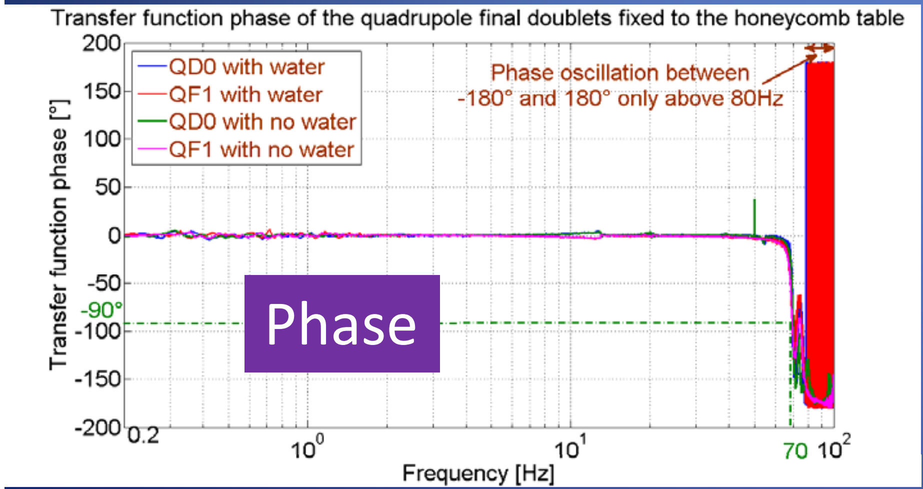
✓ Stationary of these random vibrations

2D Frequency analysis in [O.1; 100] Hz range

Transfer function between [QD0; QF1] and the table







- ✓ QD0 and QF1: Almost the same vibratory behavior with and without cooling water
- ✓ Moreover, flow twice higher than specified

➢ **Quadrupole relative motion due to cooling water << 0.1nm**

5) Conclusion on the tolerance achievement

✓ Flowing water: no impact on [QD0; QF1] relative motion to the floor

✓ With ground motion, relative motion of Shintake to [QD0; QF1]:

	Tolerance	Measurement (between QD0)	Measurement (between QF1)
Vertical	7 nm (for QD0) 20 nm (for QF1)	4.8 nm	6.3 nm
Perpendicular to the beam	~ 500 nm	30.7 nm	30.6 nm
Parallel to the beam	~ 10,000 nm	36.5 nm	27.1 nm

✓ In horizontal directions, vibrations are well below tolerances

✓ In vertical direction, tolerances are stricter but vibrations are still within tolerances

✓ Future prospects: check that vibrations are still within tolerances with higher ground motion