Sagnac Interferometry for the Determination of Rotations in Seismology

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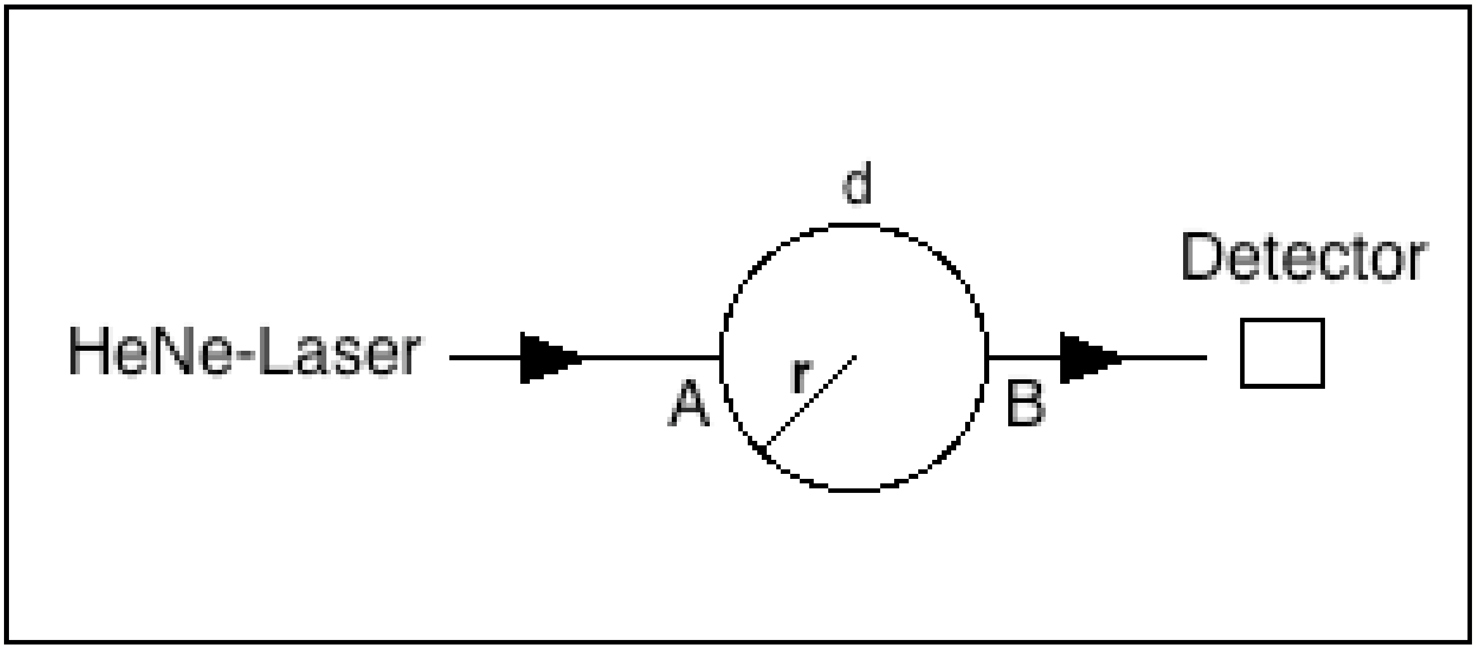
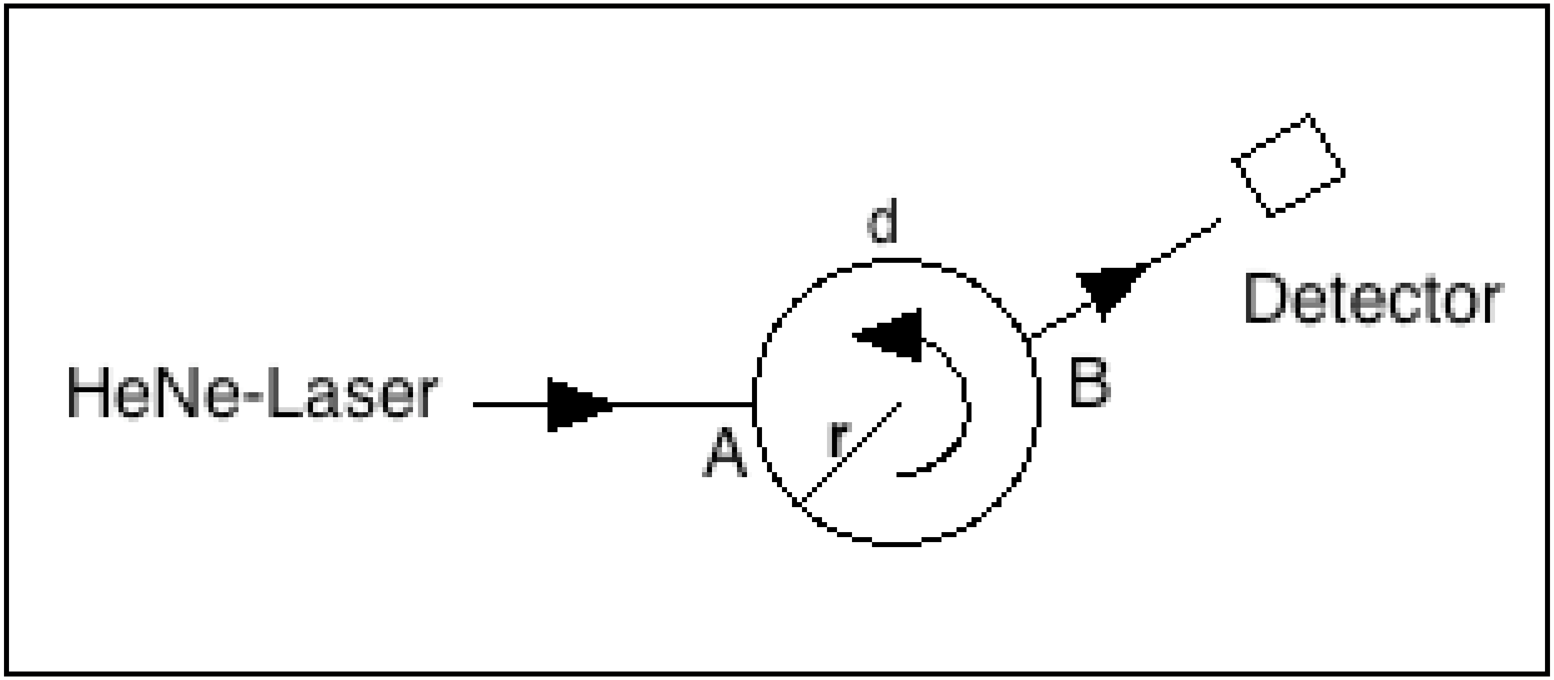
Sagnac Interferometer Concept



Sagnac Interferometer Concept



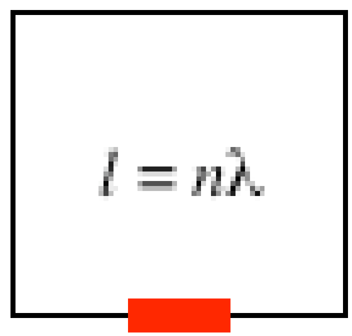
Sagnac Interferometer Concept

passive

Interferometer

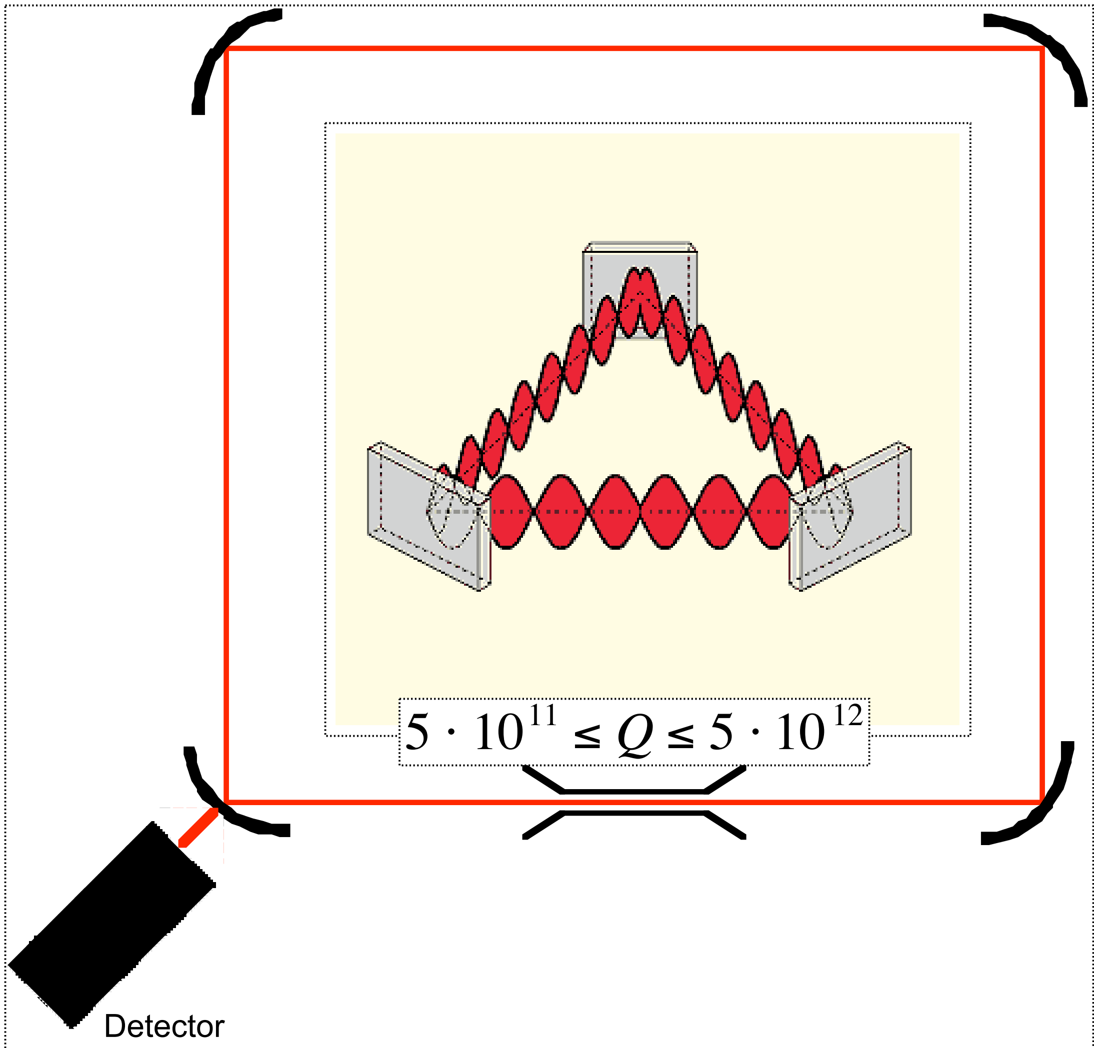
aktive

$$\Delta\varphi = \frac{8\,\pi\,A}{\lambda\,c}\vec{n}\cdot\vec{\Omega}$$



$$\Delta f = \frac{4\,A}{\lambda\,P}\vec{n}\cdot\vec{\Omega}$$

Ring Lasers can be considered as a Standing Wave in Space

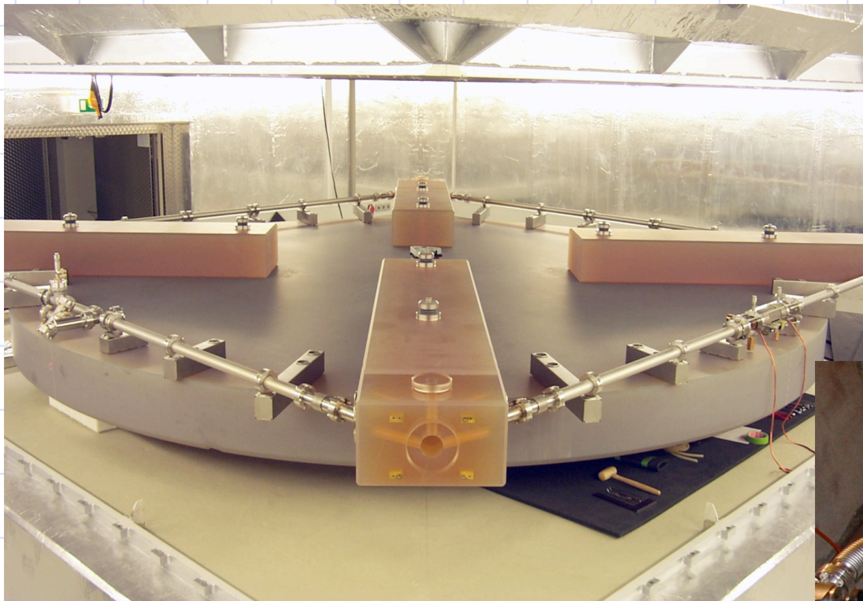


Contributions to the Signal

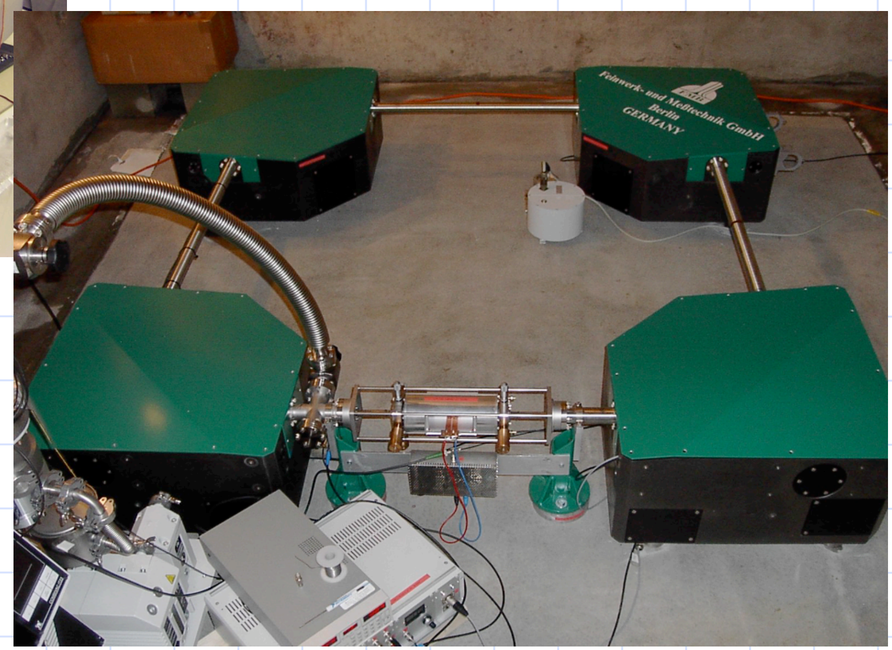
$$\delta f = \frac{4\,A}{\lambda\,P}\,\vec{n}\cdot\vec{\Omega} + f_{Dr}$$

- Scale Factor
- Rotation Rate
- Orientation
- Nullshift Bias
- Backscatter-Coupling

Ring Lasers come in 2 Flavors



Large, monolithically stable but extremely expensive (long-term stable)



Compound Material mounted on Concrete Foundation (short-term stable)

Current Ring Laser Resolution

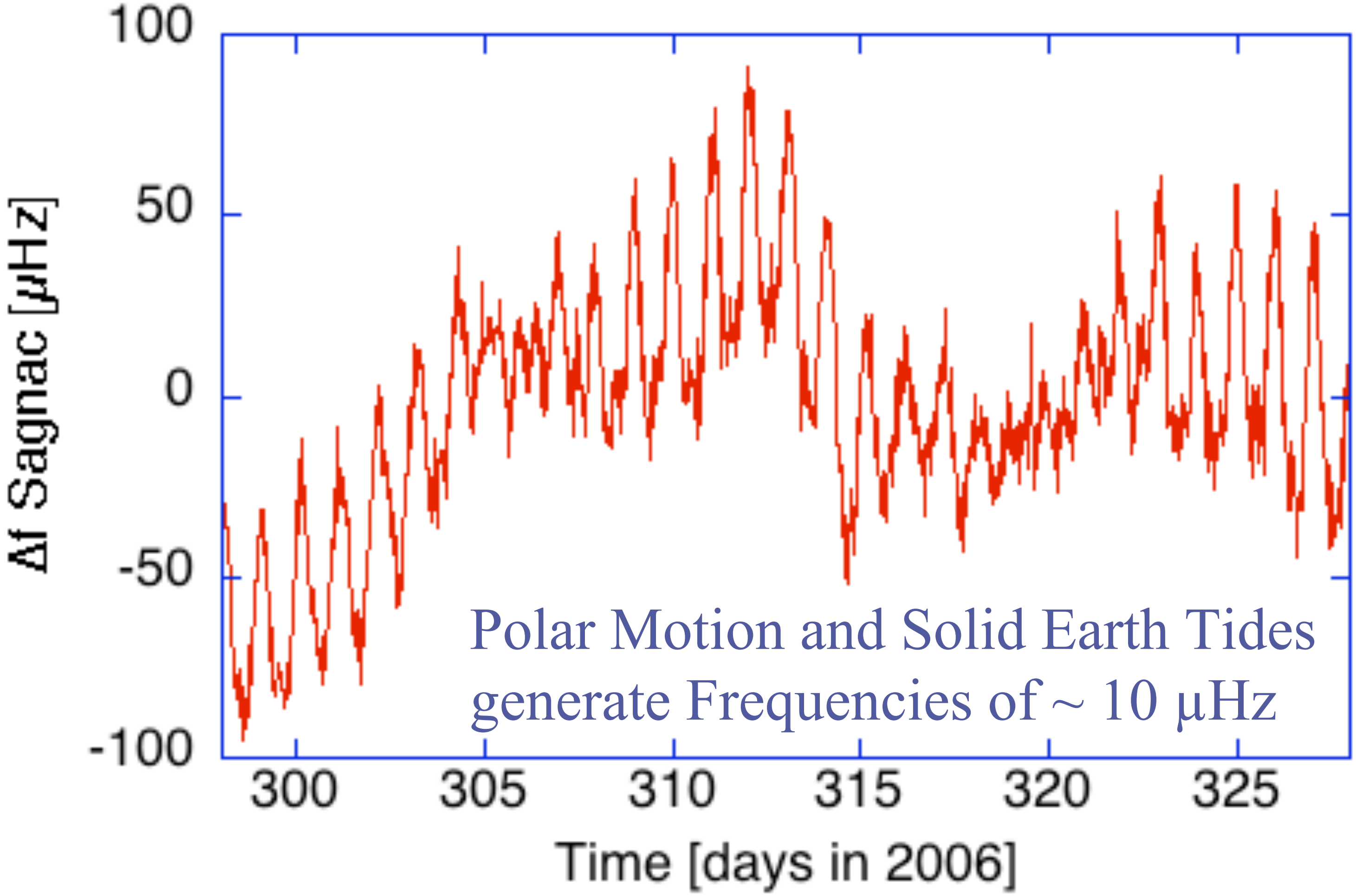
Device	Area [m^2]	τ [μs]	Q	$\delta\Omega$ [rad/s/$\sqrt{Hz}$]
C-II	1	150	4.5 e11	7.2 e-10
GEOsensor	2.56	1200	3.5 e12	4.5 e-11
G	16	1000	3.0 e12	9.0 e-11
UG-1	367	1500	6.0 e12	4.7 e-12

Resolution viewed differently ...

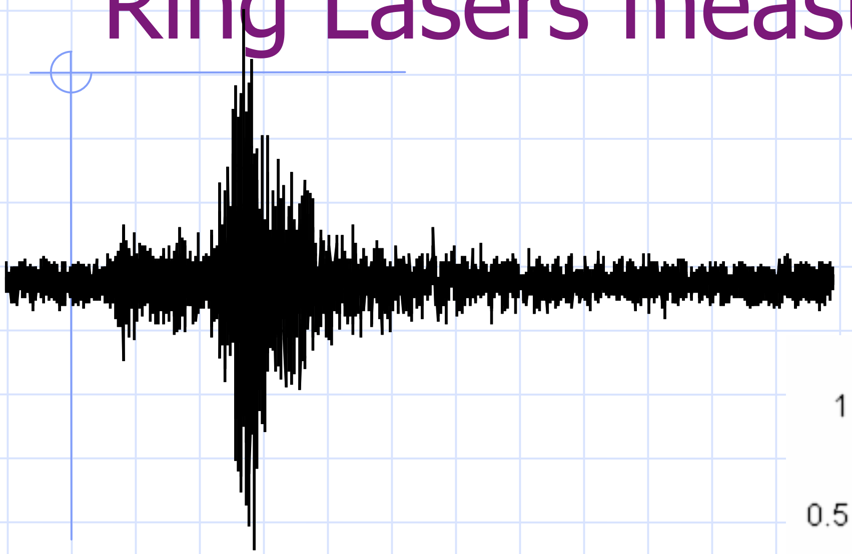
$$\delta\Theta = 9 \cdot 10^{-11} \frac{\text{rad}}{\sqrt{\text{s}}}$$

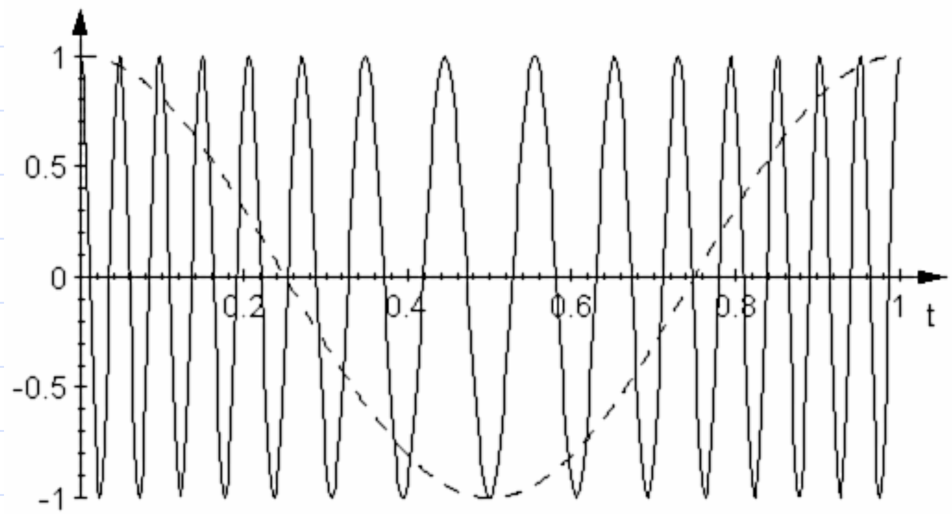
The G Ring Laser can still resolve the angular velocity when it is rotating each second by an angle which is equivalent to the thickness of a hair (~ 50 μm) viewed from a distance of **556 km**.

G Ring Laser Performance



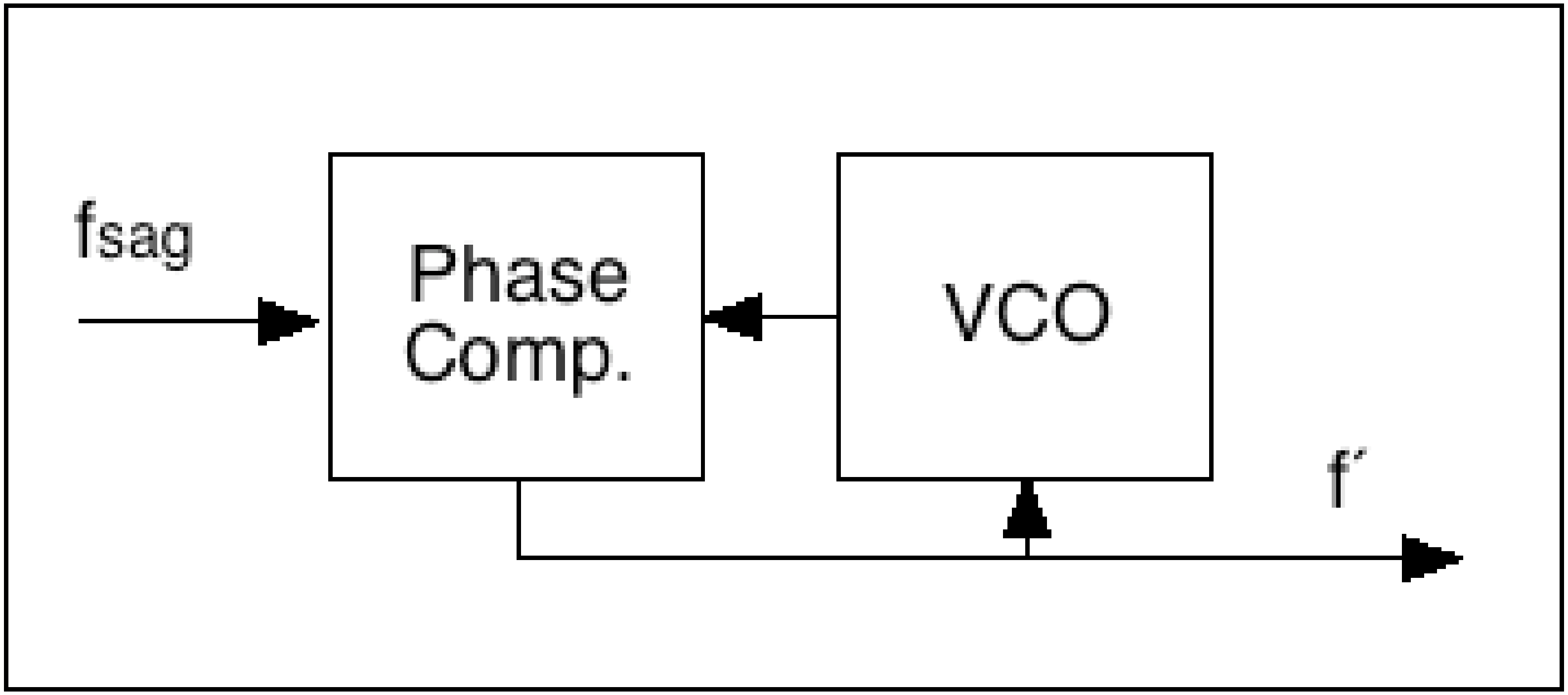
Ring Lasers measure Frequencies



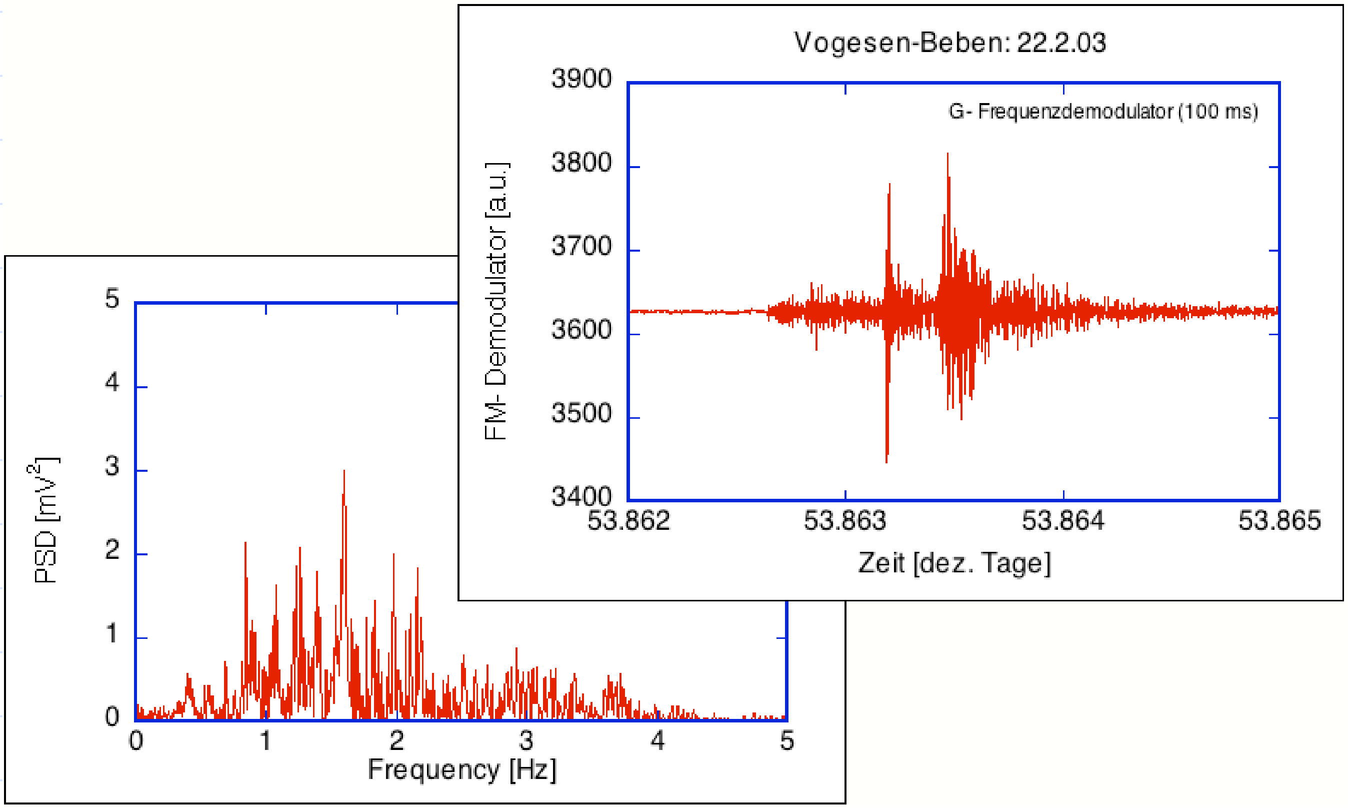


Seismic Signals appear as a Modulation of the Bias-Frequency generated by the Rotation Rate of the Earth

A Demodulation Technique gives Access to the Seismic Signals

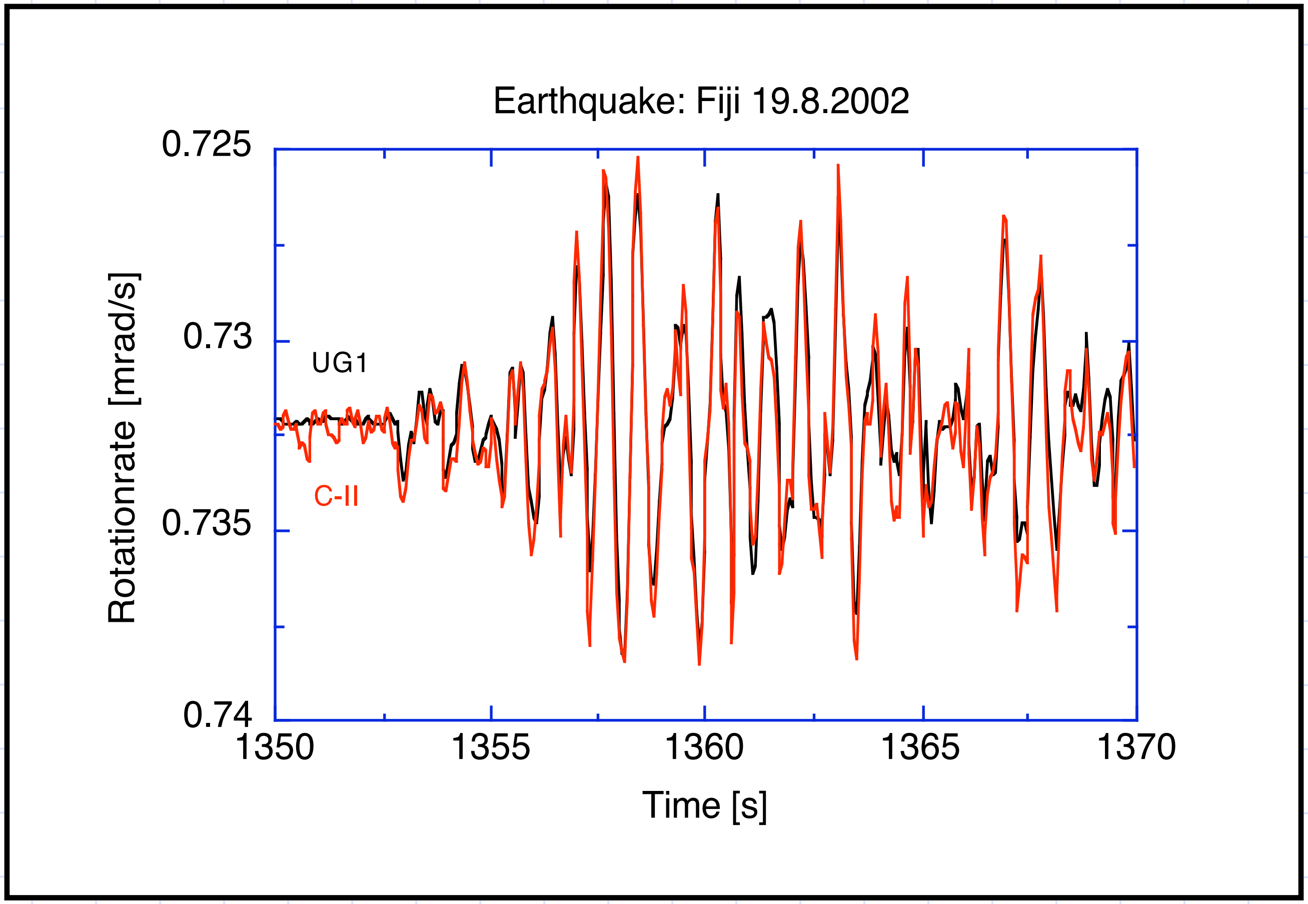


Ring Lasers have no active mechanical Parts (theoretically no bandwidth limit)

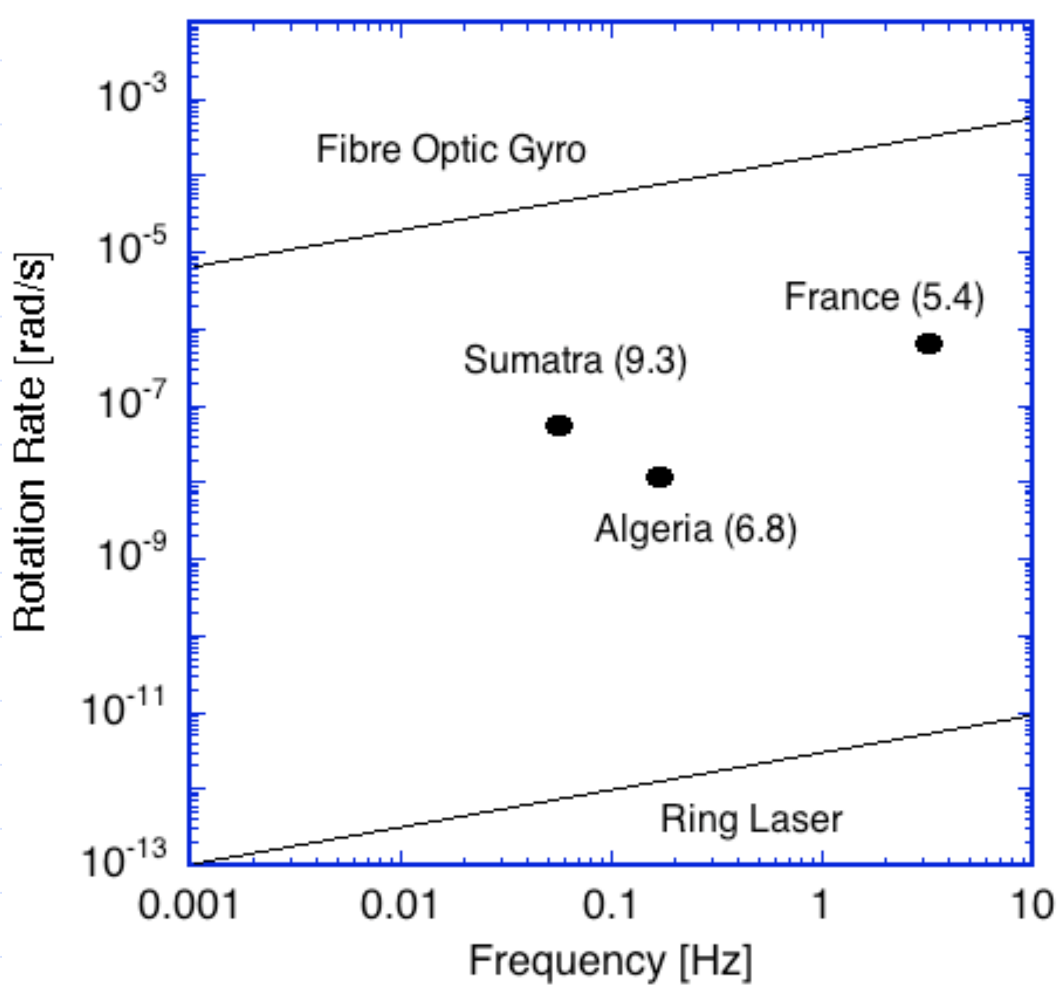


Cut-Off Frequency > 10 Hz

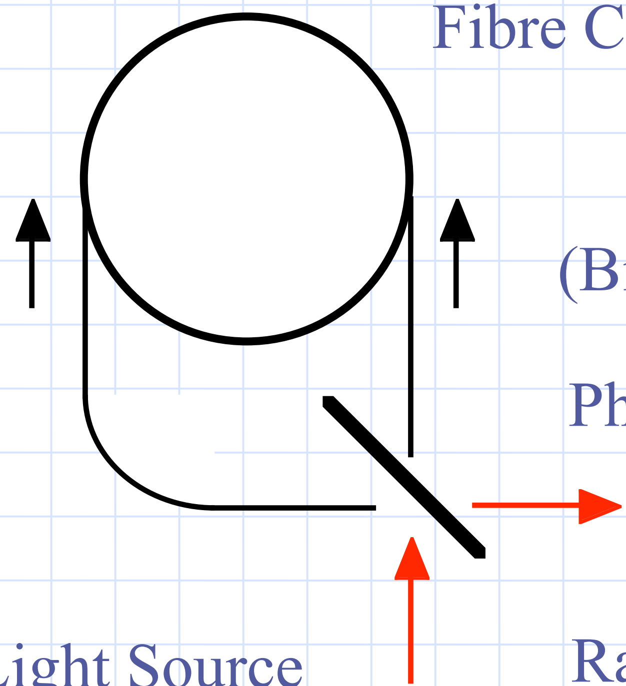
Comparison of 2 different Rings at the same Location (Cashmere)



Seismic Observation Space



Basic Concept of FOG



Fibre Coil (~ 800 m)

(Birefringence causes variable Offsets)

Phase Evaluation

Random Walk Error: ~ 0.01 °/h

Light Source
(modulated)

Application in Structural Engineering

FOG Applications

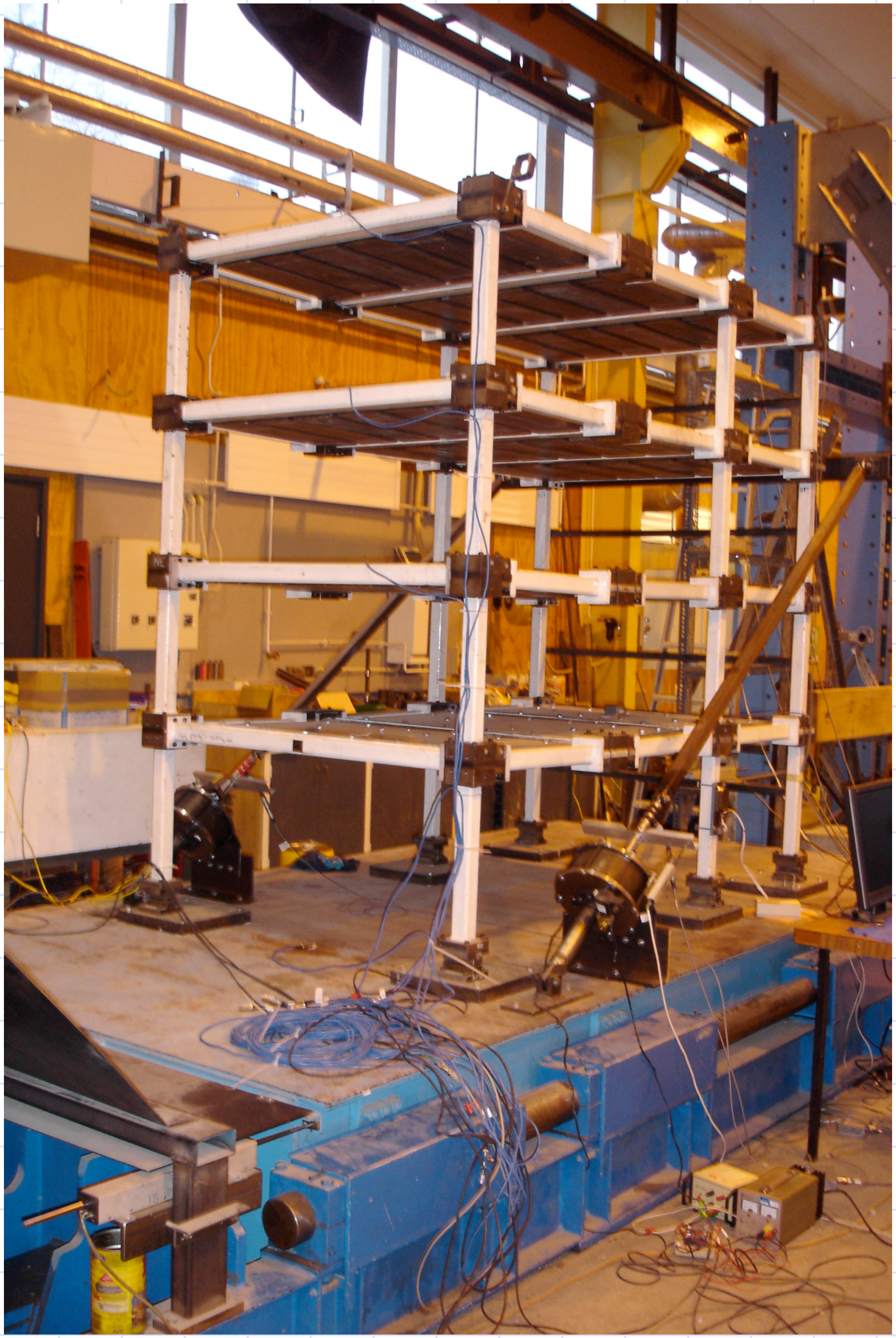
Structure Model on Shake-Table

A view of the structure with the co-located measurement techniques

Transducers and Gyroscope

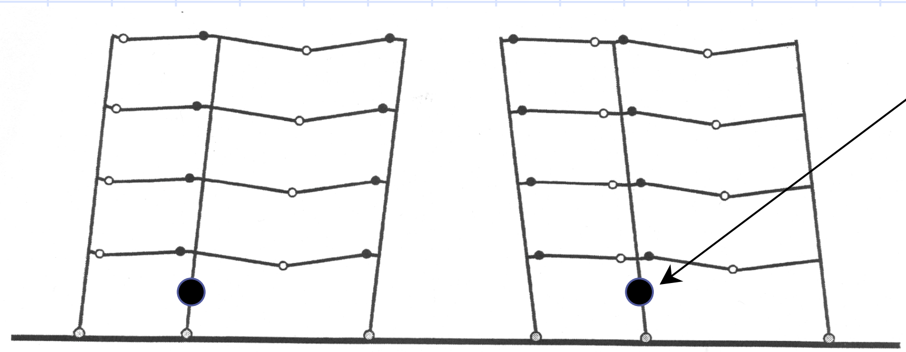
Transducers:
Integration (2 times) on Sensor-differences yields Displacement

Gyro:
Integration (once) and multiplication with height yields Displacement



Gyroscopic Rotational Velocity Measurement

The rocking motion corresponds to a rotation and the gyro picks it up without the necessity of a external reference frame



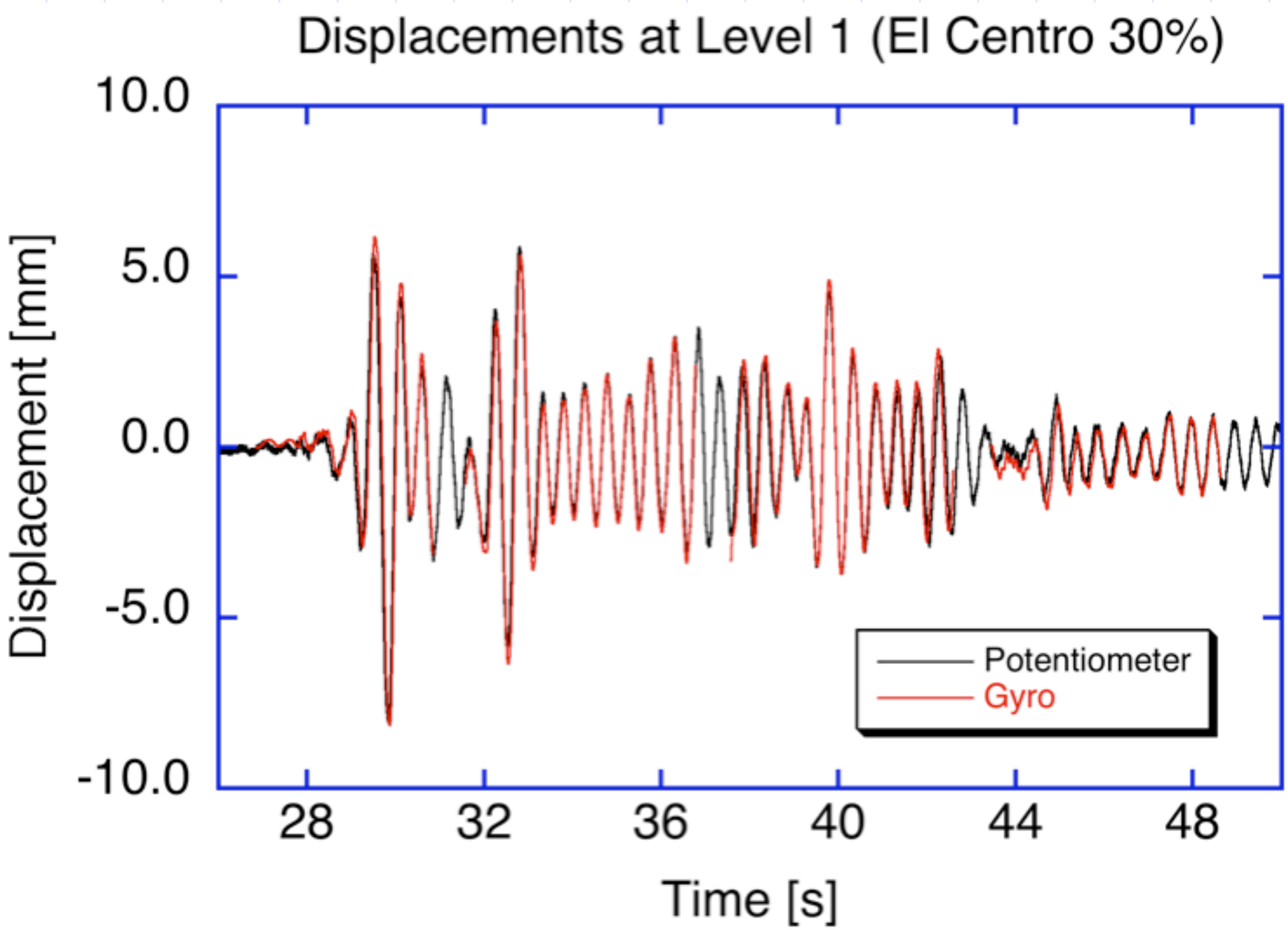
Displacement Transducers

Displacements are measured at the top floor and the mid-heights of the other storeys. There is also a measurement on the table movement

This measurement technique requires a frame of reference:

Structure <--> laboratory floor

Inter-storey drift

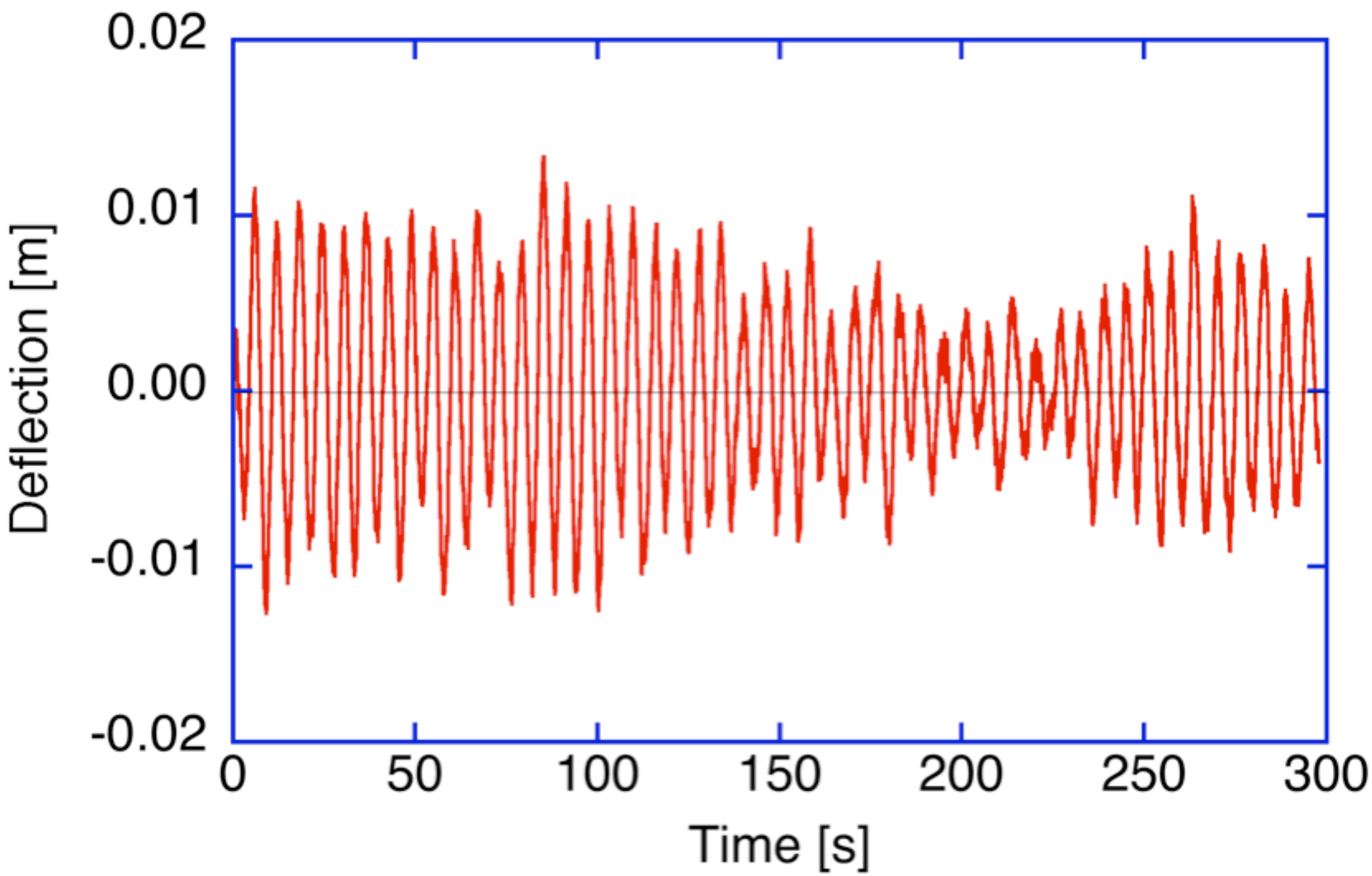


In Situ Measurements

Sky - Tower in Auckland, NZ

Floor 60 - approx. 220 m high

Wind Loading: ~ 36 km/h



Spectrum of Sky-Tower Rocking