Measuring the Virgo-area Tilt Noise with a laser Gyroscope

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Outline

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Sagnac effect

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Motivations

**VIRGO request:** Need of direct measurements of local seismic TILTS \((10^{-8} \text{ rad above } 30 \text{ mHz})\)

**FINAL Task:** Extend the control to the 6 d.o.f. of the position of the IP. Improve the low frequency sensitivity of the GW antenna.
Sagnac effect

$\Delta t_{\text{Sagnac}} = \frac{4A}{c^2} \vec{\Omega} \cdot \vec{n}$

$\Delta f_{\text{Sagnac}} = 4 \frac{A}{P \lambda} \vec{\Omega} \cdot \vec{n}$

Latitude of Cascina, Square 1.35 m x 1.35 m
Horizontal, $\lambda = 632.8$ nm
$\Delta f_{\text{Sagnac}} \sim 107.2$ Hz

Active

No intracavity elements
No Mode competition between CCW & CW
Real vs Ideal

$$\Delta f_s = K_R \left( 1 + K_A \right) \Omega + \Delta f_0 + \Delta f_{bs}$$

- $K_R(\frac{A}{p}, \theta, \phi)$: Geometrical scale factor
- $K_A(\nu_o, (T, P)_{Gas})$: Atomic scale factor
- $\Delta f_0(\nu_o, \Delta l)$: Null shift
- $\Delta f_{bs}$: Backscattering

$$\Delta \nu = \sqrt{f^2 - \Omega_L^2}$$

Ideal performance

$$\frac{d \psi}{dt} = 2 \pi f - \Omega_L \sin \psi$$

lock-in

Given $n$ backscatterers of amplitude $A_n$, located in $z_n$:

$$\Omega_L \propto |\sum_{n} A_n e^{2i k z_n}|$$

Interfering term!
(2008-2010) Prototype setup

Free running --> **Different cavity modes for CW and CCW**

Stabilize Optical Frequency --> No Mode-Splitting but:
The **backscattering phases** strongly change.

Use 2 PZT improve stability
VIRGO Gyrolaser (Square cavity, 1.35 m in side)
July 2010: Installation in the Virgo Central Area

Granite Slab
Steel plate interface
Concrete Monument

“Ty”

“Tx”

Virgo Central Area
Remote control

The perimeter control allows for continuous operation (no mode jumps)

Remote operations have been tested with success

→ Full compatibility with the Virgo SCIENCE MODE
Data acquisition

3 Raw data channels @ 5 kHz
Slow Monitor channels @ 1Hz:

V1:GL_Sagnac_freq_TIME

V1:GL_Sagnac_AC_TIME

V1:GL_Pow_CCW_TIME

V1:GL_Pow_CW_TIME
First results

Tilt “Ty” sensitivity

Coherence Gyroscope-accelerometers

Earthquake NW Balcans 3.9

Earthquake Appennino modenese M 3.2
Conclusions and perspectives
Design, Installation and Operation of the Gyrolaser in the VIRGO area

DAQ and Remote perimeter control implementation

NEXT:
Shift to the vertical configuration
Improve amplitude and freq. stabilization
Backscattering control
Data Filtering

FUTURE: General Relativity Tests (on Earth) with a system of multiple large gyrolasers

Main References:

-- A. Di Virgilio et al., *A laser gyroscope system to detect the Gravitio-Magnetic effect on Earth*, to be published on J. Mod. Phys. D

-- A. Di Virgilio et al., *Performances of ‘G-Pisa’: a middle size gyrolaser*, Class. Quantum Grav. 27, 084033, (2010).


