D u a l R & D

towards a Wide Bandwidth and high sensitivity
Dual Acoustic GW Detector

At the end of the 3 year long R&D project:

guidelines for the detailed design of a dual detector with optimal sensitivity and very wide bandwidth

INFN

Gravitational wave astronomy

requires significant improvement of detector sensitivities

To fully exploit the potentialities of resonant detectors and
to make them complementary to advanced interferometers
a totally **new** approach is needed

dual resonator gw detector

covers the high frequency (1-7kHz) gw spectrum with high sensitivity

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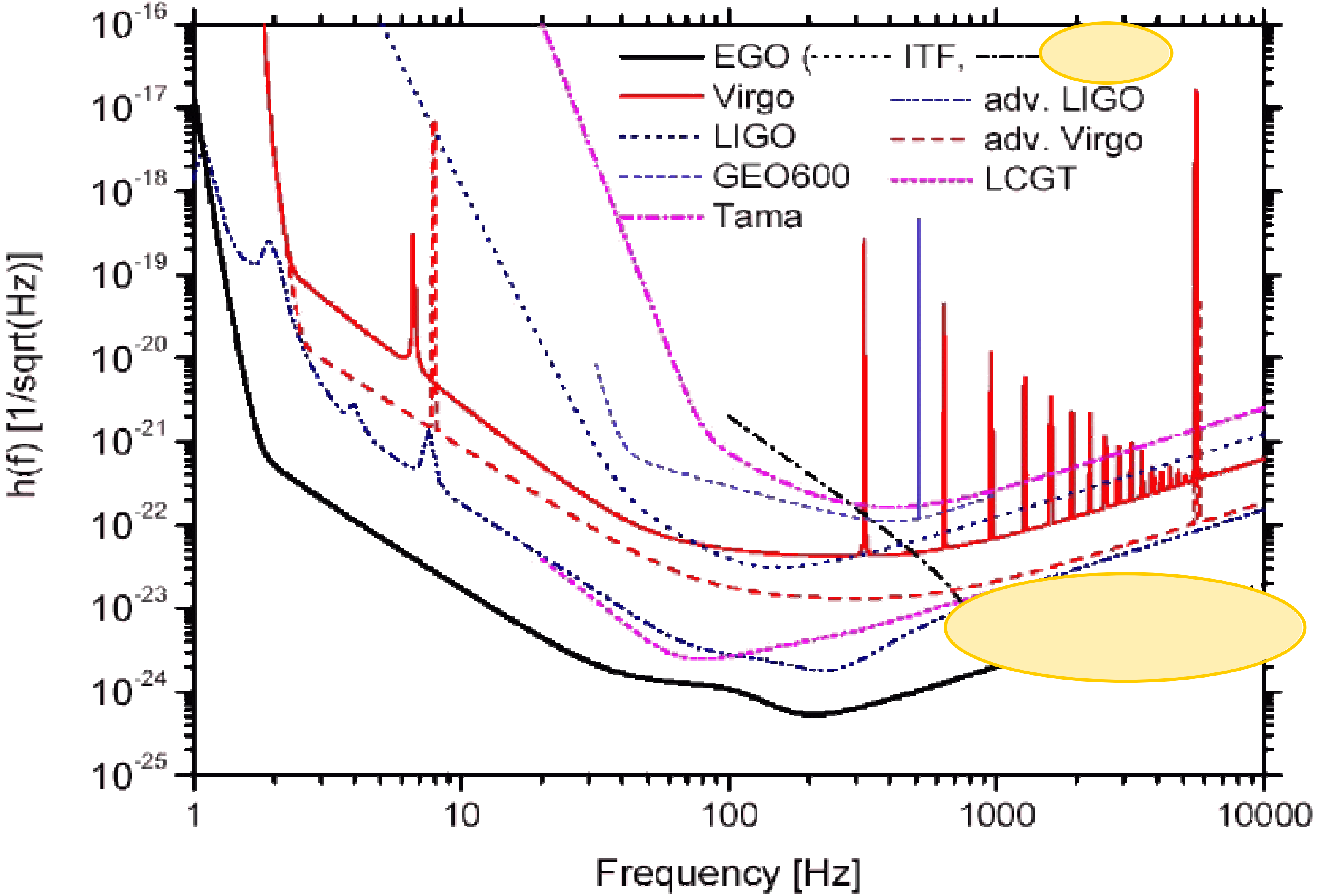
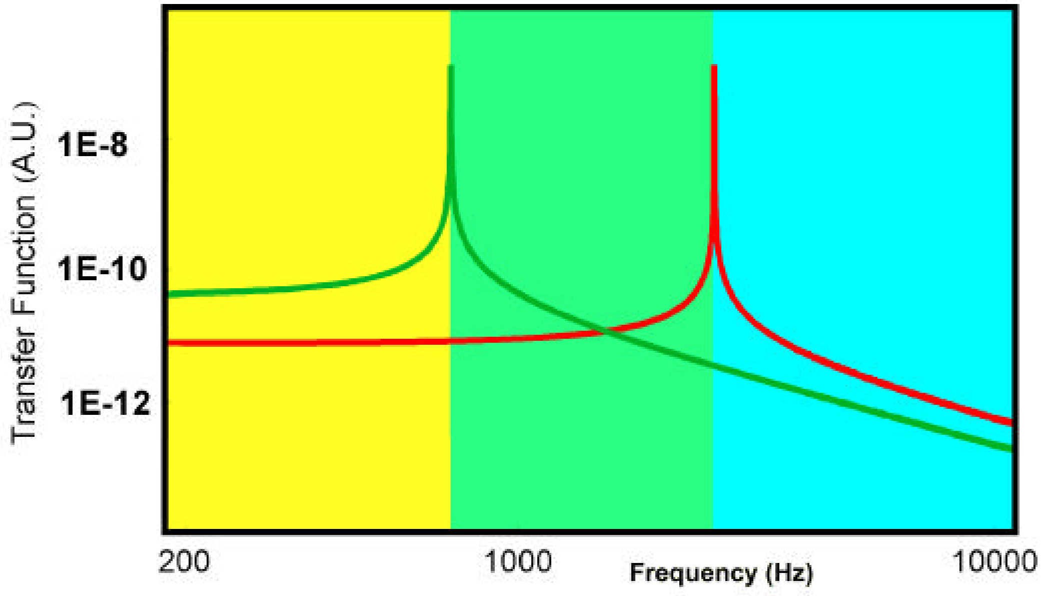
Ultimate sensitivity of the EGO* observatory



*observatory proposed by the european gw community to the EU Design Study call 2004

Dual detector: the concept

measurement of differential deformations of two nested bodies, resonating at different frequencies and both sensitive to the gw signal



Intermediate frequency range:

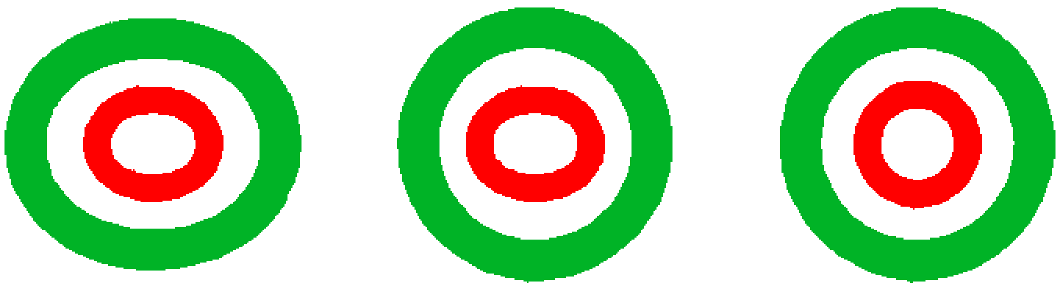
- the outer resonator is driven above resonance,
- the inner resonator is driven below resonance

? phase difference of π

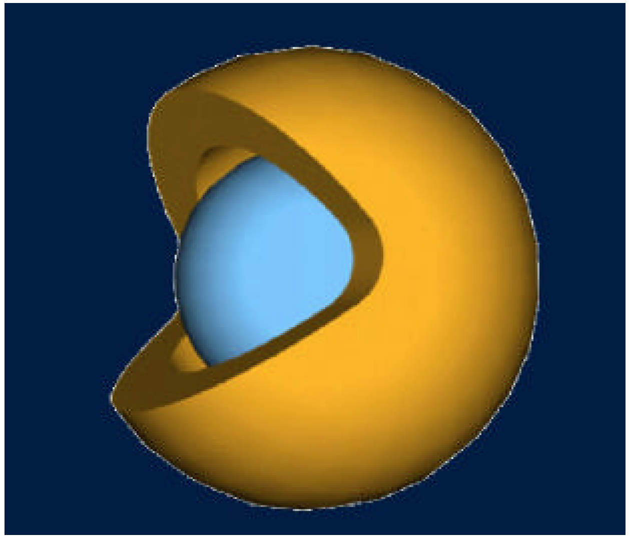
In the differential measurement:

? the signals sum up

? the readout back action noise subtracts

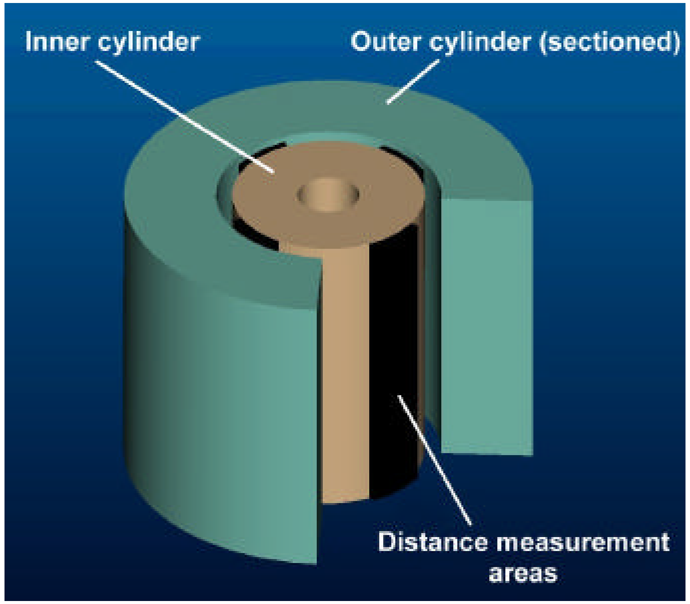


Dual: Two possible configurations



Dual sphere PRL 87 (2001) 031101

antenna pattern: isotropic



Dual cylinder PRD 68 (2003) 102004

antenna pattern:

identical to that of 2 interferometers at 45 degrees with respect to each other

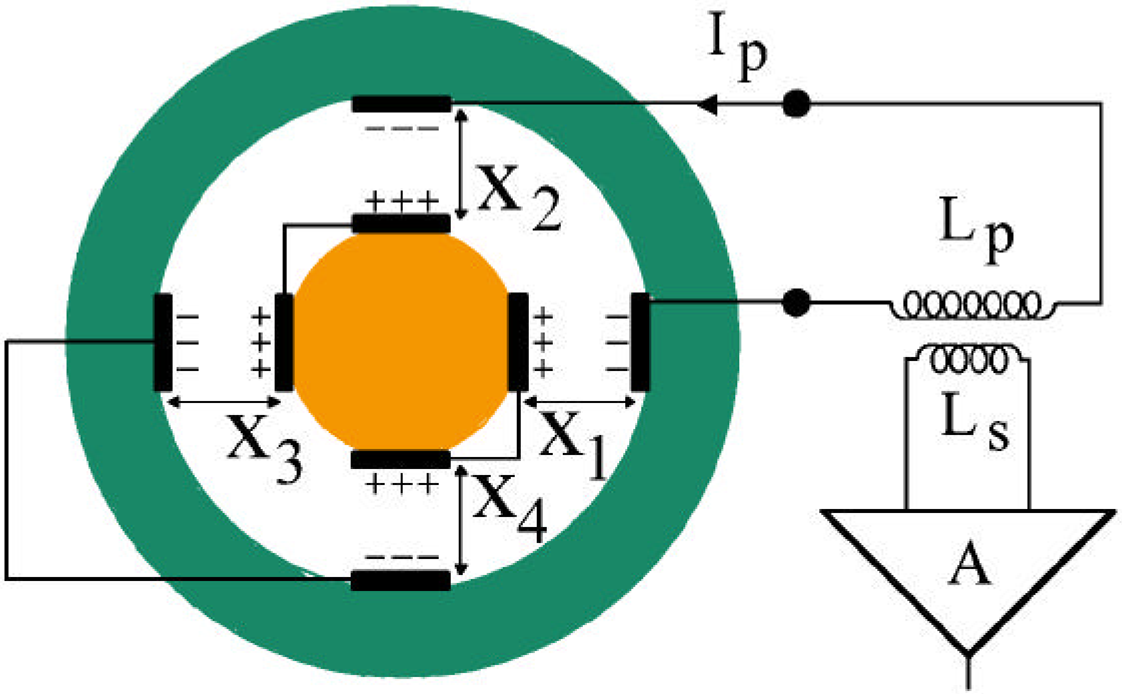
Dual: a new concept of readout

• Average the deformation of the resonant masses over a wide area:

➡ reject high frequency resonant modes which do not carry any gravitational signal but contribute to thermal noise

• Geometrically selective readout that rejects the non-quadrupolar modes

➡ bandwidth free from acoustic modes not sensitive to gw.



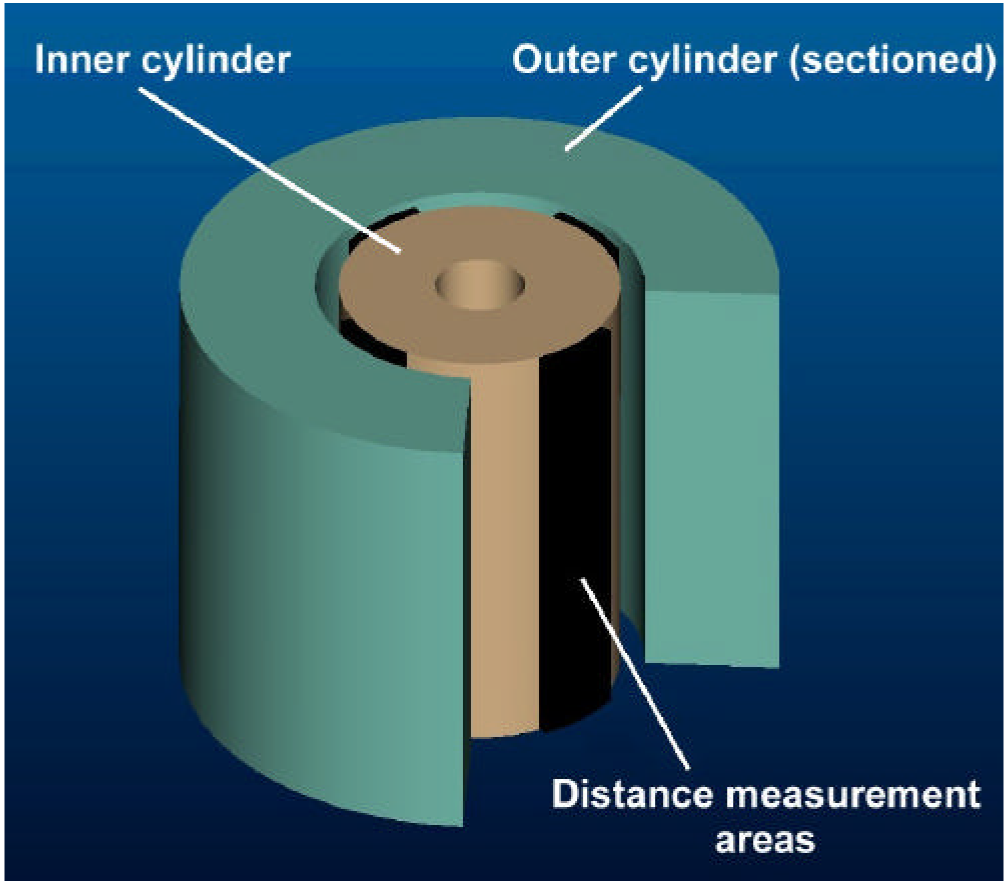
Example:

- capacitive readout -

The detector output is proportional to:

$$X1 + X2 - X3 - X4$$

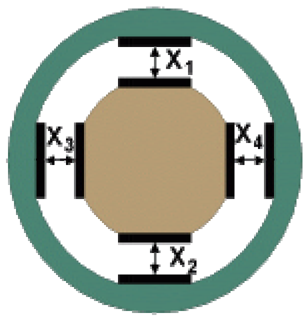
Summary of new concepts and technologies for Dual



- No resonant transducers
  (= frequency selection of the sensitive modes -> narrow band)

measure differential motion of massive cylindrical resonators

- Mode selective readout
  (= geometric selection of the sensitive modes -> broad band)



$$X1 + X2 - X3 - X4$$

- Large area readout

- High cross section materials
  (up to 100 times larger than Al5056 used in bars)

Dual R&D : 3 main research topics

1) Detector design:

- seismic noise control (pre-filtering)
- high frequency (in band) mechanical vibration filtering
- underground operation

2) Readout system

- efficiency in transducing the mechanical signal
- wide readout area and with quadrupolar symmetry
- quantum limited noise figures of readout
- wideband mechanical amplifiers

3) Test mass development

- methods to produce large, high Q masses
- material properties at low T

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Suspension: the prefiltering

<u>Problems</u>:

• large low frequency motion can induce ‘up-conversion phenomena’ (eg. acoustic emission)

• large relative motion between the nested masses can prevent readout functioning

<u>Goals:</u>

• to reduce the seismic noise at the detector input

• to reduce the low frequency relative motion between the nested masses

via active pendulum suspension

Dual R&D

define:

passive isolation
active control
cryogenic-environmant compliant sensors

R&D on readout systems: status

• Requirement: ~ 5×10^{-23} m/√Hz

• Present AURIGA technology: ~ 5×10^{-20} m/√Hz

with:

optomechanical readout - based on Fabry-Perot cavities

capacitive readout - based on SQUID amplifiers

⇓

Foreseen limits of the readout sensitivity: ~ 10^{-22} m/√Hz.

Critical issues:

optomechanical – push cavity finesse to current technological limit together with Watt input laser power

capacitive – push bias electric field to the current technological limit

⇓

Develop non-resonant devices to amplify the differential deformation of the massive bodies.