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ELECTROMAGNETIC CAVITIES AS ELECTROMECHANICAL TRANSDUCERS: THEORY AND EXPERIMENT

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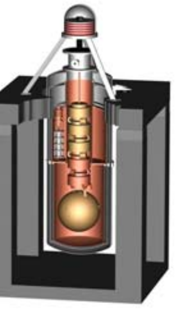
Abstract

e study the dependence of the tunable frequency nge on the gap spacing between the end of the nical insert and the cavity plate in reentrant 1.0 GHz ystron cavities. Fabricated from aluminum, the cavities sted are 80 mm in diameter with the top plate 1-mm ck. Experiments performed on such cavities have own tuning coefficients (change in resonant equency due to variation of the capacitive gap) as high 60.0 MHz/μm, demonstrating the capability of entrant cavities as electromechanical transducers in sonant mass gravitational wave antennas.

Introduction

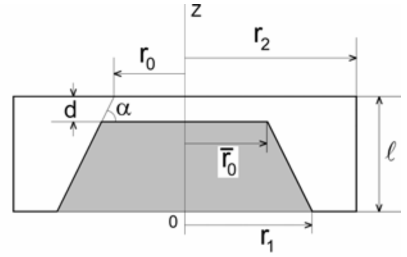
- Theoretical and experimental study on resonance operties of reentrant cavities with conical insert
- The relationship between the resonant frequency and e cavity dimensions with emphasis on how the frequency ries when the top plate is subjected to mechanical formation due to an externally applied force.
- Application: for gravitational wave detection



-Mario Schenberg Detector: is under construction at INPE and the Physics Institute of the University of São Paulo.
-Cryogenic resonant-mass antennas: are the most sensitive device for detecting high frequency gravitational wave signals.
- The antenna (65-cm diameter and 1.15 ton weight) with a 400 Hz bandwidth around 3.2 kHz, will be operating in coincidence with the Dutch Mini-GRAIL and the Italian SFERA antennas

Searching for core collapse in supernova events, eutron stars going to hydrodynamical instability, quakes nd oscillations of neutron stars, excitation of the first uadrupole normal mode of 4-9 solar-mass black holes, nd coalescence of neutron stars and/or black holes stems of 4-9 solar-masses.
The Schenberg detector may probe some "echoes" from e Big Bang – the explosion of the universe creation.

Cavity analysis: A reentrant cavity with a coaxial onical insert as shown below has been modeled as a umped LC circuit leading to the following parameters:



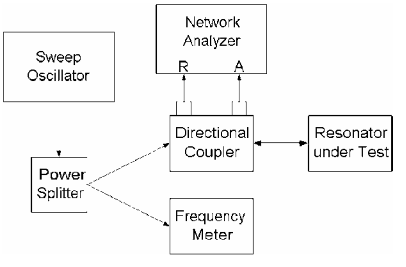
$$\ldots = \frac{\ell}{2\pi}\left(\ln\frac{er_2}{r_1} - \frac{r_0}{r_1 - r_0}\ln\frac{r_1}{r_0}\right), \qquad \frac{C_0}{\varepsilon_0} = \frac{\pi\bar{r}_0^2}{d}, \qquad \frac{C_1}{\varepsilon_0} =$$

$$\ldots\frac{(r_0^2 - \bar{r}_0^2)}{d} + \frac{2\pi}{\alpha}\left(r_0\ln\frac{e\ell_M\sin\alpha}{d} + \frac{d\cot\alpha}{2}\ln\frac{\sqrt{e}\ell_M\sin\alpha}{d}\right)$$

Resonant frequency : $f_0 = 1/2\pi\sqrt{L(C_0 + C_1)}$

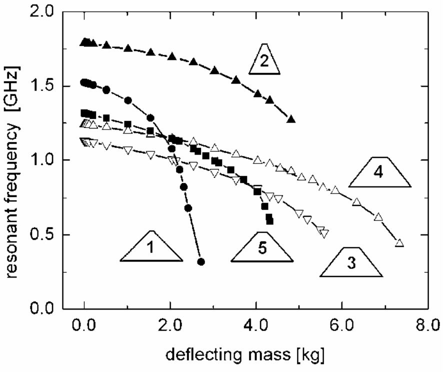
Experiment

The resonance properties of the reentrant cavities with conical insert are experimentally examined by looking at the effect on the resonant frequency of reducing the gap spacing through application of a bending force at the center of the circular top plate with clamped edges. Five coaxial inserts have been tested on a hollow circular cavity of radius 40mm and height 20.0mm. On applying a deflection force (using a set of calibrated weights) we then measured the corresponding downshifted frequencies, which are plotted below. Resonant frequencies are measured by using the reflection-type circuit configuration where the cavity fields are both excited and detected by means of a single electric probe inserted through a 1.0-mm-diameter hole drilled halfway across the cylindrical wall.



Experimental setup to measure resonant frequencies

Reentrant cavity under test

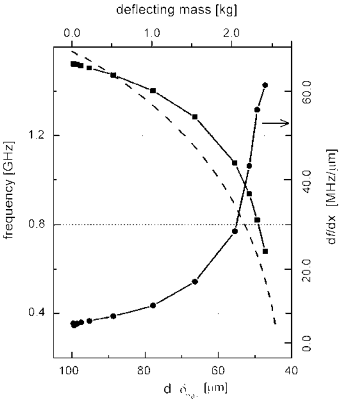


Dependence of measured frequencies for several inserts on the loading weight

Results

Insert #1 having the larger r_1 and the smaller gap d produces the steepest curve. Insert #2, with a smaller r_1, has the effect of flattening the curve relative to curve #1. So the greatest sensitivity of insert #1 is conferred by its large r_1 in conjunction with a small r_o.

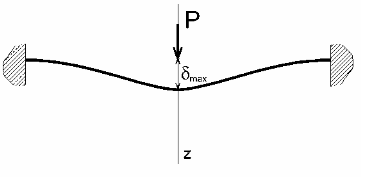
Insert #	d [mm]	r_1 [mm]	r_o [mm
1	0.10	20.0	1.5
2	0.10	10.0	1.5
3	0.30	20.0	5.0
4	0.40	20.0	5.0
5	0.30	20.0	3.0



Resonant frequency and displacement sensitivity df/ for insert #1 expressed in terms of the decreasi dynamical gap $x = d_0 - \delta_{max}$. The dashed line refers calculated frequencies.

The following expression gives the deflections due to pu bending of a clamped circular plate loaded at the center:

$$\delta(r,P) = \frac{Pr^2}{8\pi D}\ln\frac{r}{r_2} + \frac{P}{16\pi D}(r_2^2 - r^2)$$



Deflection of a clamped plate loaded at the center

Conclusion

- Investigation of an 1.0 GHz rentrant cavity as a parametric transducer :
  – Sensitivity to deflections of a 1.0 thick aluminum plate when loaded with weights as light as 10 g;
  — Tuning coefficient (change in resonant frequency due to variation of the capacitive gap): Δf/Δd = 60.0 MHz/μm → converts displacement to electrical units;
  — Examined cavity:1.0-GHz *oversized prototype*
  — Actual cavity : 10.0 GHz - dimensions scaled down by a factor of 10 → thus it is expected to be 100 times more sensitive (Δf/Δd 100 times higher)