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Design and Simulations of Two Degree of Freedom Torsional Ring Gyroscope using COMSOL Multiphysics

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ABSTRACT: This Paper reports a FEM simulation of two degree of freedom torsional ring gyroscope and its Eigen frequency analysis using COMSOL multiphysics tool. Here, we used two rings in which outer ring is free to move in the drive direction (x-axis) while the inner ring is free to oscillate in sense direction (y-axis). For simulation, the outer ring is attached to the one end of the rectangular torsional beam of 51 × 6 × 8 µm, while another end is fixed at anchor points. Similarly the inner ring is attached to the outer ring with the help of rectangular torsional beam of 5 × 21 × 8 µm. The complete structure is meshed and appropriate boundary conditions are applied to calculate the eigen frequency in the drive and sense directions. The Eigen frequency in drive direction is found 21.762 KHz while in the sense direction 21.767 KHz.

KEYWORDS: FEM, COMSOL Multiphysics, Eigen Frequency

I. Introduction

In conventional comb finger structure gyroscopes, a small capacitance is generated in drive and sense direction along with the high actuation voltage. This problem can be overcome by using torsional ring gyroscope that provides a large drive and sense capacitance at small actuation voltage and increasing to its sensitivity to angular rate as reported [1]. This structure is ease to fabricate and we use one of the cost effective technique UV-LIGA to fabricate this type of structure by using nickel as a structural layer because of its robustness.

II. Theory

For resonance frequency analysis of torsional gyroscope; spring constant for both beam in drive and sense direction must be known. So the torsional spring constants in equation of motion are defined as [2]:

$$K_{xd} = \frac{2SG}{L_{xd}}, \qquad (1)$$

$$K_{ys} = \frac{2SG}{L_{ys}} \qquad (2)$$

Where G is the shear modulus and *S* is the cross-sectional coefficient.The shear module G is defined as:

$$G = \frac{E}{2\,(1+\nu)} \qquad (3)$$

Where E is the young's modulus and ν is the Poisson ratio. The cross sectional coefficient *S* for rectangular cross section is defined as:

$$S = \left(\frac{w}{2}\right)^3 \frac{t}{2}\left\{\frac{16}{3} - 3.36\,\frac{w}{t}\left(1 - \frac{w^4}{12t^4}\right)\right\} \qquad (4)$$

Where w is the width and t is the thickness of each beam.

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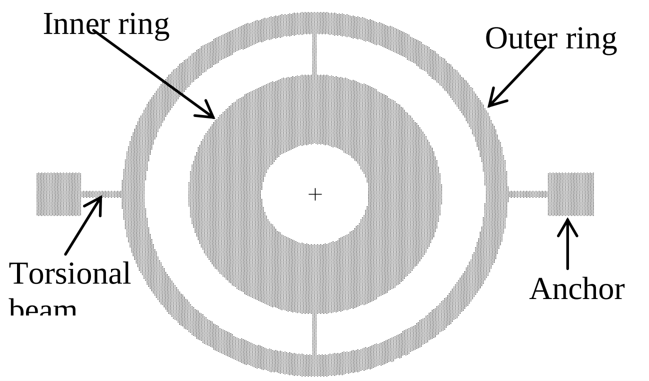

Fig.1 Schematic of two degree of freedom ring gyroscope

The conceptual schematic of two degree of freedom ring gyroscope is shown in figure 1. The structure is based on two interconnected rings: drive ring and sense ring. One end of the anchor is connected to the drive ring through two torsional beams along the x-axis and another end is fixed. The drive ring is free to move only about the x-axis (drive direction). The sense ring (inner ring) is attached to the drive ring through two torsional beams which is free to oscillate about the y-axis (sense direction).

III. SIMULATION & RESULTS

For simulations, outer ring is chosen as width of 25 µm and thickness of 8 µm while the inner ring is selected as of 81 µm width and 8 µm thicknesses. Nickel is used as key structural layer because of its robustness. Two anchors are connected to the outer ring with the help of drive rectangular torsion beam. For the boundary condition, these two anchors are fixed and the Eigen frequency analysis is done in the solid mechanics physics of COMSOL. The Eigen frequency in drive direction should be matched with the resonance frequency in the sense direction for good sensitivity

Table1. Resonance frequency and corresponding displacement values

	Frequency (KHz)	Displacement (µm)
Drive mode	21.762	2.69×10^6
Sense mode	21.767	6.24×10^6
Out of plane mode	31.507	2.02×10^6

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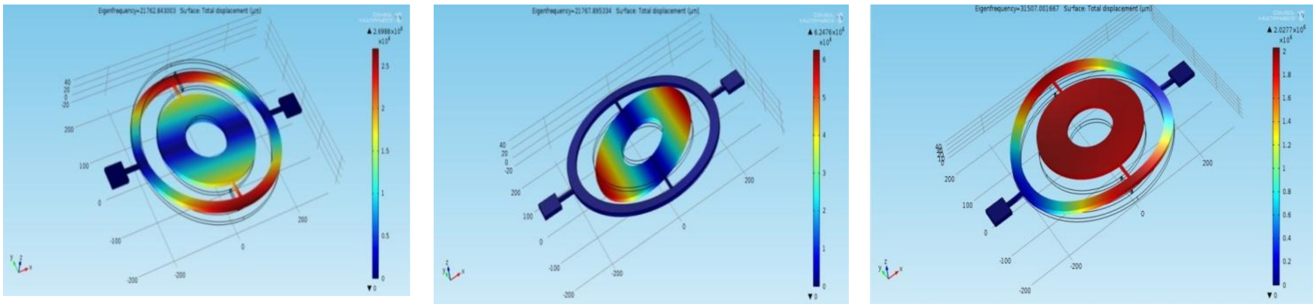

Fig.2 COMSOL simulations of 2-DOF torsional ring gyroscope structure. (**a)** Drive oscillator resonance frequency at about 21.762 KHz. (**b)** Sense oscillator resonance frequency at about 21.767 KHz. (**c)** The undesired linear out-of-plane mode at about 31.508 KHz.

Here, we observed drive mode resonance frequency about 21.762 KHz while the sense mode of about 21.767 KHz. The corresponding displacement for each resonance frequency is shown in table 1.

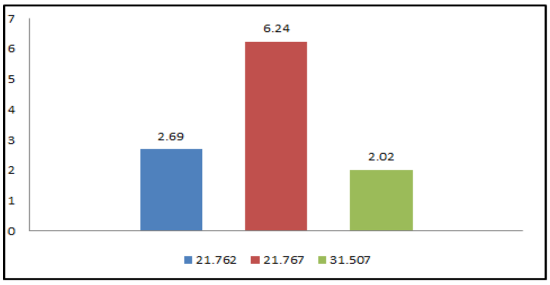

Fig.3 Bar graph of Eigen frequency and displacement for drive mode, sense mode, and out of plane mode

The bar graph provides the information about the displacement corresponding to the resonance frequencies in drive, sense and out of plane (z-axis) mode.

IV. CONCLUSION

Eigen frequency and analysis of two degree of freedom torsional ring gyroscope is presented in this paper using comsol multiphysics tool. The Theory of torsional spring constant is discussed. For Simulation two rings of different dimensions are taken which are made of Ni and optimised to the thickness of 8 µm. The appropriate boundary conditions are applied and calculated the drive mode and sense mode frequencies and observed frequencies are 21.762 KHz and 21.767 KHz in drive and sense mode respectively.

V. ACKNOWLEDGEMENT

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