Rate Integrated MEMS Gyroscope with sub-Hz Frequency Symmetry and Temperature Robustness

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I. Introduction

Autonomous car navigation relies on the information provided by multiple sensors and external signals to obtain position. GPS/GNSS signal is fundamental for navigation and it can provide accuracies below 1 meter when augmented with inertial sensors (gyroscopes and accelerometers). However, in GPS-denied environments (e.g. urban canyons, tunnels) and in absence of other signals of opportunity, the use of inertial sensors is the only self-contained reliably approach to obtain accurate orientation angle and position at any time.

Gyroscopes that provide this level of accuracy are bulky and have a cost exceeding the automotive industry demands. Off-the-shelf, cost effective MEMS rate gyroscopes require electronic integration of the rate in order to obtain the angle information. In this process errors are also integrated making long term navigation not accurate. Rate integrating gyroscopes, on the other, side are able to mechanically integrate the angle and remove the need for electronic integration thus increasing accuracy. However, the mechanical requirements of the MEMS element are very stringent: high Q factor and high frequency symmetry between the drive and sense mode that is difficult to obtain with the current silicon fabrication technologies.

Here we present dynamically balanced gyroscope with as-fabricated frequency symmetry of less than 1Hz thanks to specifically designed concentrated anchors [1]. A Q factor more than 300K has been experimentally measured and temperature stability of 50mHz over 120C range [2] have been obtained.

II. Device

A dynamically balanced gyroscope has been fabricated using standard SOI process. While in operation, 2 concentric masses oscillate in anti-phase motion for low anchor energy dissipation and robustness against external vibration (Fig. 1). Concentrated springs are specifically designed to provide sub-Hz frequency symmetry and resist package stress (Fig. 2). The masses are free to oscillate in any direction of the XY plane and have the potential to be mechanized as a rate integrating gyroscope thus removing the need for electronic integration of the rate and reducing orientation error.

III. Results

X and Y modes of fabricated resonator have been measured using FPGA-based lock-in amplifier using a Electromechanical Amplitude Modulation technique to remove feed-through current. Dev#2, with a center frequency of 3011Hz and Δf=0.19Hz is shown in Fig.3. Decay time at 0.1Pa has been measured to be 32.5s, corresponding to a Q factor of 331K. Frequency split stability has been measured in a thermal chamber from -30C to 95C showing a variation with temperature of 50mHz (Fig. 4).

References

[1]J. Giner, Y. Zhang, K.Ono et al *IEEE SENSORS*, Orlando, FL, USA, 2016
[2] J.Giner[1], Y.Zhang[1], D. Maeda et al, IEEE MEMS 2017

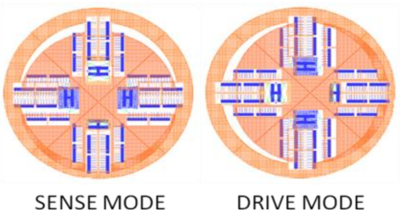

Figure 1: Finite Element analysis simulation showing the two operational drive and sense mode.

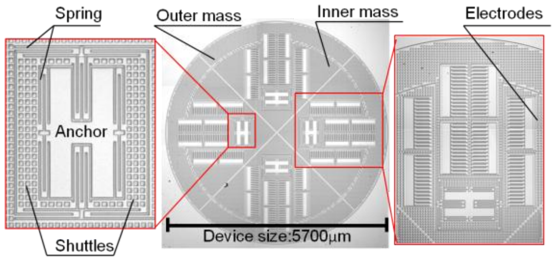

Figure 2: Optical image of the gyroscope and close up of electrodes and spring-shuttle-anchor module.

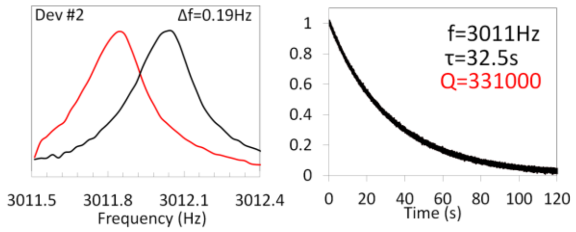

Figure 3: Experimental demonstration of frequency symmetry and decay time at 0. 1Pa.

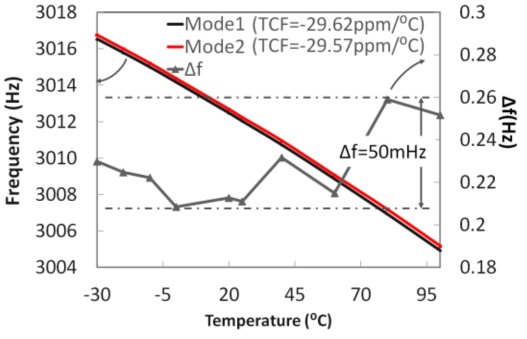

Figure 4: TCF and Δf of Dev #2 in thermal chamber.