Measurement of MEMS Mechanical Parameters by Injection Interferometry

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In testing MEMS and MOEMS, one can use the direct observation of the device under a microscope and the functionality test in the intended mode of operation. A new diagnostic tool, also useful since the initial design phases, is presented in this paper. It is based on injection interferometry and provides the actual amplitude of displacement and related parameters, like, e.g., the maximum frequency of operation and the mechanical quality-factor of the structure.

In the following, we present the basic idea and the measurements (vibration amplitude, resonant frequency, Q and hysteresis effects) performed on a MEMS gyro structure with the aid of the injection interferometer.

The injection interferometer has been described in detail in a number of papers [1-3], but, just to recall it briefly, it consists in allowing the retro-reflection from the target under test to be injected back into the laser source. The injection generates an amplitude modulation of the laser power, of the type $P=A\kappa P_0(1+\cos 2ks)$, where A is the attenuation experienced in the back and forth propagation, κ is a factor of the order of unity depending upon laser parameters, and 2ks is the optical phase-shift of the field for propagation to a target distance s.

Key features of the method, especially attractive for testing MEMS are:

- no critical alignment is necessary
- operation on diffusive target surface is ensured (i.e., there is no need for a specular reflection on the target);
- only moving parts do contribute – no need for a very fine spot to be projected on the MEMS details to be tested;
- the photodiode placed on the laser rear mirror is fully adequate for detection (no stray-light filtering is required)
- sub-wavelength sensitivity is easily achieved up to several hundreds kHz.

MEASUREMENTS

We tested a interdigitated-comb gyroscope MEMS in micromachined silicon. The measurement set-up is shown in Fig.1 and includes a single-mode 680-nm laser diode as the source, an objective lens focussing the laser beam in a 100x100 micrometer spot on the gyro moving comb, and an attenuator (not shown in Fig.1) to adjust the amplitude of re-injected field. When the gyro is driven by a sinewave voltage, the moving comb oscillates with an amplitude $\Delta s= s_0 \sin \omega t$ and the signal from the interferometer is $I=I_0\,[1+\cos(2k\, s_0 \sin \omega t)]$, as displayed in Fig.2. From here, the peak displacement is evaluated as $5.5\cdot(\lambda/2)$-fringes, or $s_0=5.5\cdot 340$ nm = 1.87 μm [$s_0=1.98\,\mu$m by taking account of the $\cos\alpha$ tilt-dependence].

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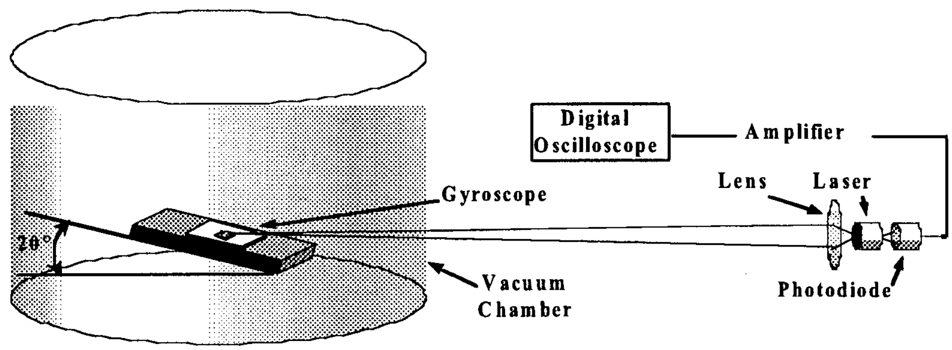
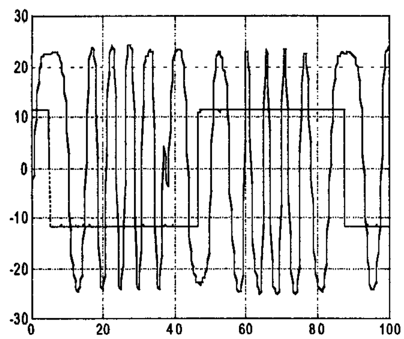
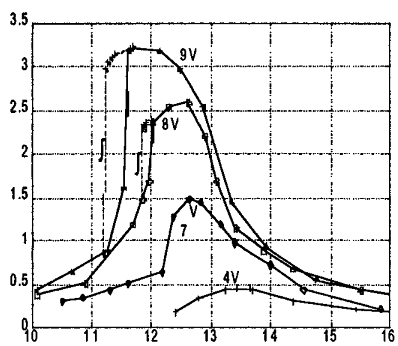


Fig.1 Set-up of the injection interferometer to test the MEMS gyro. The laser is a 20-mW 680 nm laser with monitor photodiode, and a 10-mm focal length objective lens is used to focus the spot on the MEMS at a α=20° tilt angle, through a vacuum chamber with glass walls.



By repeating the frequency response measurement at different voltages and pressures, several performance data on the MEMS are collected, such as: the Q-factor, the hysteresis effects and the incipient creep, as shown in Fig.3.

Fig.2 (see left) Typical interferometric output signal at resonance (f=11.9 kHz). Pressure: 760 mbar



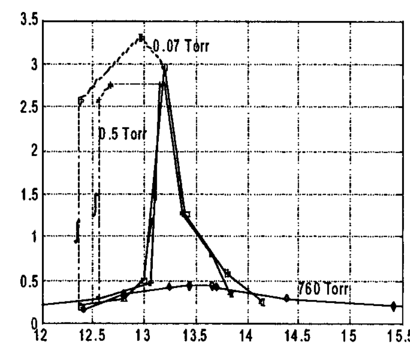


Fig.3 Frequency response (in kHz) of the MEMS gyro at 760 mbar for several drive voltages (left), and for several pressures (right). The typical hysteresis of a 'soft' spring oscillator is found.The Q increases from 4-8 at 760 mbar to 50 at 0.5 torr . Creep is also observed at excessive drive voltage.

REFERENCES

[1] S.Donati, G.Giuliani, S.Merlo: IEEE Journ. Quant. Electr., QE-31 (1995), pp.113-119

[2] S.Merlo, S.Donati: IEEE Journ. Quant. Electr., QE-33 (1997), pp.527-531

[3] V.Annovazzi Lodi, S.Merlo, M.Norgia: Proc. Odimap II, (Pavia, 1999), pp.307-312

[4] V.Annovazzi Lodi, S.Merlo, M.Norgia: IEEE Journ. Mechatronics, (2000), in press.