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Scanning mirrors as tunning device in oscillator systems.

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Abstract. *Abstract. MEMS (micro electrical mechanical systems) scanning mirrors has been largely used in many kinds of optical systems like laser printers, optical bar code readers, 3D digitalizers, fingerprint readers. Its function is to move a laser beam over a pattern. The scanning mirror system has three components: The mirror, the oscillator and the laser control. The mirror is driven by the oscillator at its resonance frequency so the mirror can reach its highest optical amplitude. The problem in oscillator`s design is to find and keep the exact resonance frequency of the mirror. The use of MEMS scanning mirror as tunning element in its own oscillator circuit allow the development of a fine control system that can handle little changes on fabrication process and work environment like temperature and humidity changes. This result in a system that can work at its ideal optical angle amplitude and oscillation frequency (resonance frequency) This work presents an overview about theory of oscillators and resonant scanners mirrors and explain how the scanner device can be used as tunning element.*
(single space line, size 10)
Keywords: Scanning mirror, Laser Beam, Electro-mechanical device, oscillator circuit, tunning element

1. Introduction

Optical microscanners have many applications like barcode readers, laser printers, displays, projectors, confocal microscopies, high-resolution inspection systems and instrumentation (Wu, 1997 , Urbach, Fisli and Starkweather, 1982, Miyajima, Asaoka, Isokawa, Ogata, Aoki, Imai, Fujimori, Katashiro and Matsumoto, 2003). The driving mechanisms commonly used in microscanners include electrostatic, piezoelectric, electromagnetic and thermal transducers (Petersen, 1980, Ferreira and Moehlecke, 1999, Asada, Takeuchi, Vagnov, Belov, Hout, and Sluchak, 2000).

The double-rotor structure is presented in Fig.1(Oliveira and Ferreira, 2003). It is composed by two square bases (rotors) connected to a fixed rectangular frame by two torsion bars. A third bar connects the two bases. One of them, devoted to the actuation, has the coil while the other carries the mirror.

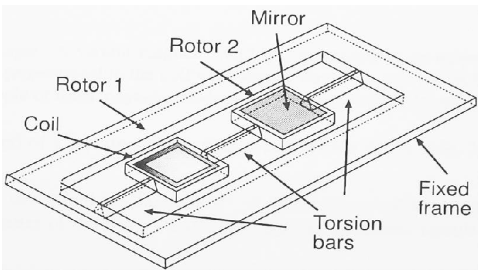

Figure 1. Double rotor scanner.

The devices uses electromagnetic induction as driving mechanism (Ferreira, Pourlborz, Ashar, Khan-Malek, 1998). The main advantage of this mechanism, when compared with galvanometric actuated devices, is the absence of the fatigue problem in the metal tracks that supply the current to the moving coil.

Figure 2 shows the principle of electromagnetic induction actuation (Barbaroto, Ferreira, Doi, 2002). A variable magnetic field B2 (stator), generated by an external magnetic circuit, induces a voltage across the scanner coil and a current, proportional to the coil's resistance, flow in it. The interaction between the induced current and a DC magnetic field B1, generated by a couple of permanent magnets, produces a torque that rotates the structure along her axis. When a sinusoidal signal is applied to the stator, the AC current in the coil causes it to oscillate.

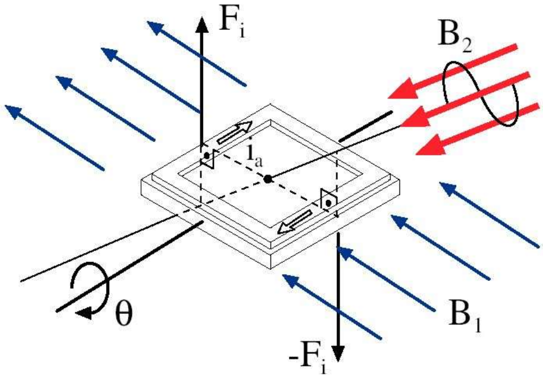

Figure 2. Rotor Coil under the permanent magnetic field (B1) and the variable magnetic field (B2)

The microscanner and its driving circuit (Oliveira and Ferreira, 2003) can schematically described by the electromechanical equivalent system in Fig 3:

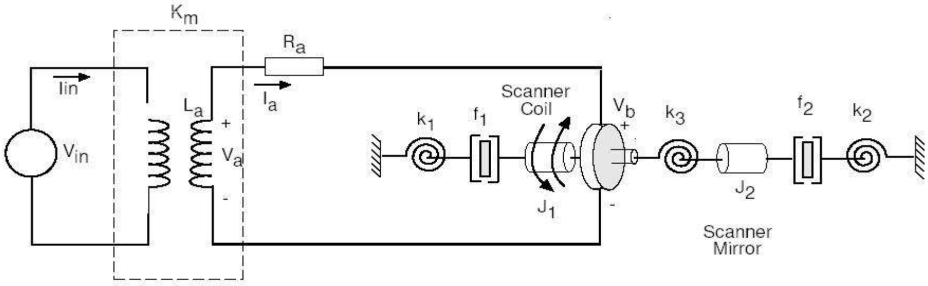

Figure 3. Electromechanical equivalent system of double rotor scanner.

The double rotor scanner motion could be modeled by a system of differential equations that relates the scan angle of the two rotors, θ_1 (coil) and θ_2 (mirror), with the physical dimensions of the device, materials used and packaging.

Supposing a torque Tm(t) applied to the rotor 1 and the two bases connected by the torsion bar 3, the system of differential equations is:

$$\begin{aligned} J_1.\ddot{\theta}_1(t)+f_1.\dot{\theta}_1(t)+k'_1.\theta_1(t)+k_3.\theta_2(t)=T_m(t) \\ J_2.\ddot{\theta}_2(t)+f_2.\dot{\theta}_2(t)+k'_2.\theta_2(t)+k_3.\theta_1(t)=0 \end{aligned} \quad (1)$$

where

J_1 and J_2 are the rotor inertia moment
f_1 and f_2 are the viscous damping
k_1 , k_2 and k_3 are the torsional stiffness of the torsion bars
$k'_1 = k_3 + k_1$
$k'_2 = k_3 + k_2$

The highest optical angle can be achieved at the system resonance frequency and the main design problem is to do the coil to oscillate at this frequency. A simple method is to make a fixed frequency oscillator to drive the scanner. But this is not the best method because the resonance frequency changes a few with some variables like fabrication process and operation temperature. So the problem is solved using a feedback system. This can be done by Electrical or Optical feedback.

In Electrical feedback we can “sense” the resonance frequency measuring the impedance change in the stator coil. At this frequency the system has better efficiency so the current decrease raising the impedance. In Optical feedback the sensing is done by a PSD that “sees” the laser beam so we can actually read the optical amplitude to know if the system is in resonance.

In this paper we present the differences between the two methods and what's the best to make a oscillator tunned by the microscanner.

2. Materials and Methods

All oscillator circuit has a frequency precision. When we design a oscillator to operate at some fixed frequency, it will operate with some tolerance because all tunning element has its own that can change with temperature, humidity, etc. Good tuner elements has the tolerance measured in "ppm" (parts per million) like quarts crystals that has a typical tolerance of 20 ppm at 25 degrees Celsius. A 1Mhz oscillator build with crystal will operate between 0.99998Mhz and 1.00002Mhz.

This tolerance depends of a physical property of the tunning element called Quality Factor ("Q") that means how much the signal will be amplified at resonance frequency and attenuated at other one.

To make a choice between Electrical or Optical feedback we need to analyze the quality factor of the scanner reading the electrical response of the stator and the PSD response when applying a frequency range to the scanner.

The data was gathered using the setup as Fig.4:

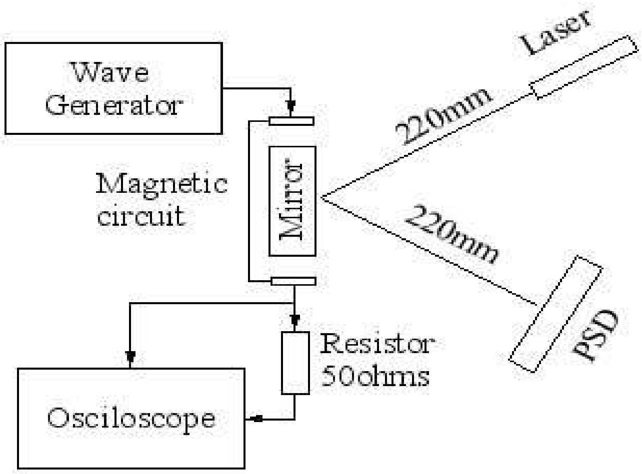

Fig4. The setup data acquisition.

A 50 ohms resistor was used in series with the magnetic circuit to measure the system current and then the Magnetic circuit (stator) impedance was calculated.

The sine wave signal was made by an Agilent 15Mhz Function Waveform generator at 10Vpp from 66Hz to 85Mhz in 0,5hz steps since the two scanner's resonance frequency are about 70Hz and 77Hz, so we can analyze the scanner behavior around its resonance. The system current was measured over the 50 ohms resistor with a Tektronix TDS 460 at 4ms time resolution. Instead of a PSD, a pattern was used to measure the line printed by the laser beam. Figure 5 shows a setup photo.

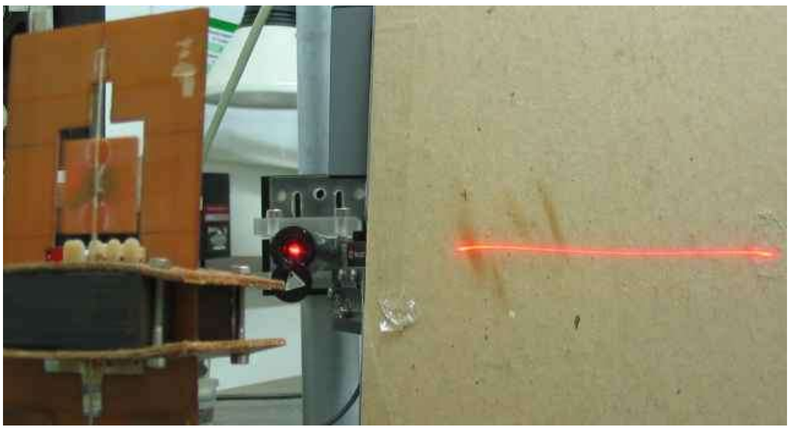

Figure 5. The Scanner, the laser pointer and the pattern.

3. Results

The calculated impedance is showed in fig. 6. The vertical scale starts at 0 to gives a real dimension of impedance variation and consequent quality factor. The printed line length is showed in fig. 7 that represents the PSD response.

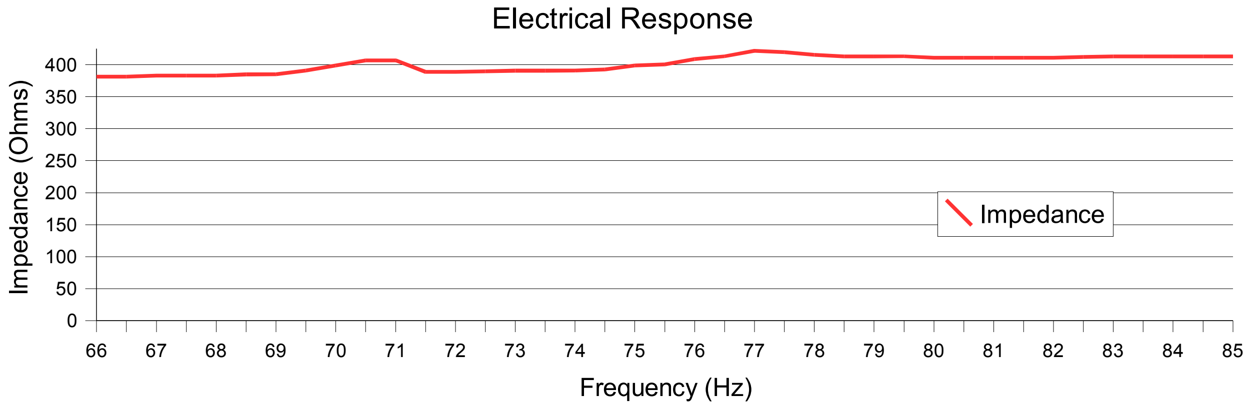

Figure 6: Electrical Response based on current in the 50 ohms resistor.

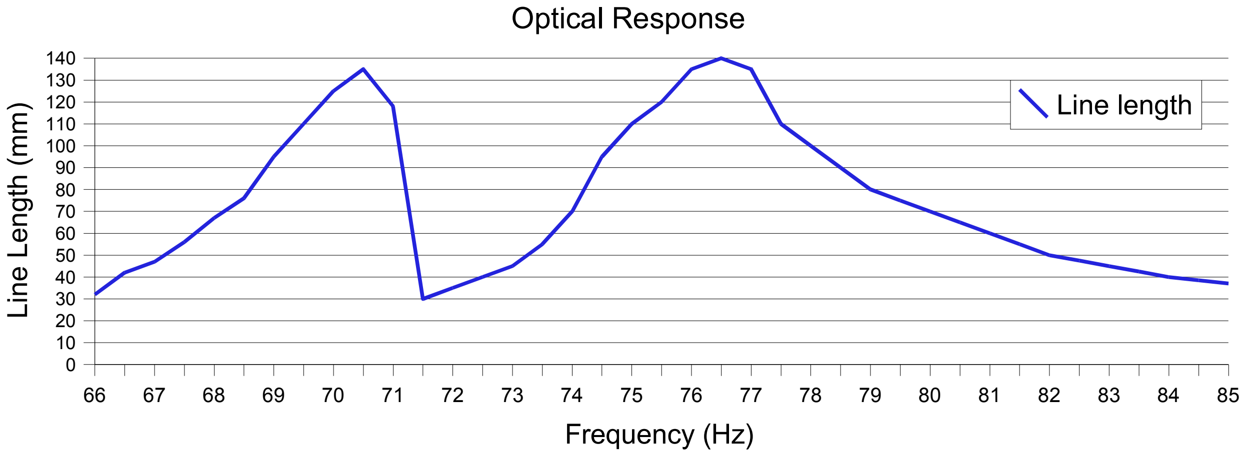

Figure 7: PSD response represented by the printed line length..

4. Conclusion

Analyzing the graphics we can see that Optical Response is much better than Electrical Response because we have a great variation in the printed line length in comparison with the stator impedance in that frequency range. It's more simple and accuracy to make an oscillator with a large input variation source because little steps on frequency (oscillator output) makes great changes on the input and then we can set the resonance frequency accurately.

So to use the microscanners as tunning element of its oscillator we need to feedback from the PSD to get a more stable oscillator. The next step to make complete operational solution is to develop the oscillator with is, in overview, a inversor with auto gain control to excite the microscanner.

5. References

Asada, N., Takeuchi, M., Vagnov, V., Belov, N., Hout, S. I., Sluchak, I., “Silicon micro-optical scanner” Sensors and Actuators A (83), pp. 284–290, 2000.

Barbaroto, P. R., Ferreira, L. O. S., Doi, I., “Micromachined scanner actuated by electromagnetic induction” in Optomechatronic Systems III, Proceedings of SPIE , 4092 , pp. 691–698, SPIE - The International Society for Optical Engineering, (Washinghton, USA), November 2002.

Ferreira, L. O. S., Moehlecke, S., “A silicon micromechanical galvanometric scanner” Sensors and Actuators A 73 ,pp. 252–260, 1999.

Ferreira, L. O. S., Pourlborz, F., Ashar, P., Khan-Malek, C., “Torsional scanning mirrors actuated by electromagnetic induction and acoustic waves” in ICMP98 - International Conference on Microelectronics and Packaging , pp. 155–162, XIII SBMICRO, 1998.

Miyajima, H., Asaoka, N., Isokawa, T., Ogata, M., Aoki, Y., Imai, M., Fujimori, O., Katashiro, M., Matsumoto, K., “A mems electromagnetic optical scanner for a commercial confocal laser scanning microscope” Journal of microelectromechanical systems 12 , pp. 243–251, June 2003.

Oliveira, L. C. M., Ferreira, L. O. S., 2003, “Silicon micromachined double-rotor scanning mirror”, Proceedings of SPIE, Vol. 5264, Dellinghan, WA.

Petersen, K. E., “Silicon torsional scanning mirror” IBM J. Res. Develop. 24 , pp. 631–637, September 1980.

Urbach, J. C., Fisli, T. S., Starkweather, G. K., “Laser scanning for lectronic printing” Proceedings of IEEE 70 , pp. 597–618, 1982.

Wu, M. C., “Micromachining for optical and optoelectronic systems” Proceedings of IEEE 85 (11), pp. 1833–1856, 1997.

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