MICRO ELECTRO MECHANICAL SYSTEMS
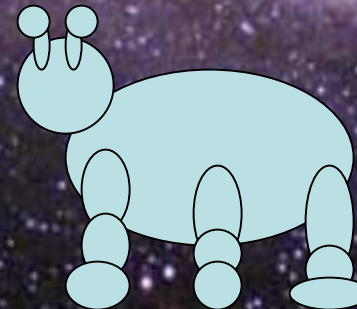
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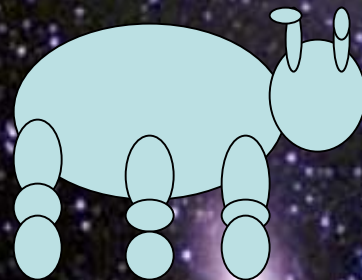INSET intern

WENHUA ZHANG
My mentor

PROFESSOR KIMBURLY TURNER, PHD.

Our advisor and idol
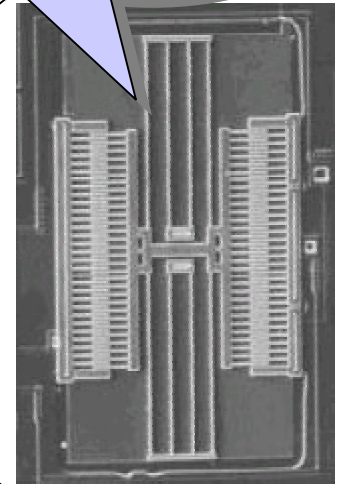
HOW THIS STUFF WORKS
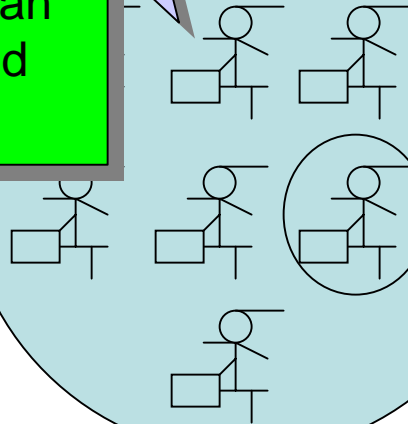
THE "BIGGER" PICTURE

What are these things good for?

One would probably be led to ask what the significance of a MEMS device is; that is, why are we moving from what we had before to what we are making now?

The truth is that MEMS have a lot of advantages including: they take up less space, use less power, and for many applications are cheaper than their macroscopic counterparts.

MEMS oscillators can be applied for such applications as high "Q" frequency filters. Because of the physical dimensions of MEMS devices and the properties associated with those dimensions, MEMS open new doors to things that were never before possible until now.

For applied purposes, all oscillators operate on a phenomena known as resonance…

To envision resonance, one can think of a swing. When the swing is lifted and released it speeds towards where it would normally rest—at the bottom; however, when it reaches that point it has retained energy from it's acceleration. This energy (in the form of momentum) causes the swing to continue it's path upward until that momentum is dissipated by the force of gravity pulling down on the swing; however, now energy is stored in the form of potential energy. At this point the swing begins to accelerate again towards the ground due to gravity…this cycle continues and the frequency at which the swing oscillates (goes from one point through a cycle and back) is known as the resonance frequency…

Now imagine if you were to try to apply a force to this object at either peak of the oscillation at the same frequency as the oscillation…pretty easy, huh? But what if you tried to apply a force at any other frequency? You may get the swing swinging for a brief period of time, but eventually your applied force would come out of sync with the momentum and you would be working against the natural momentum of the swing--it would stop.

WHAT WE ARE DOING

One could actually think of this comb drive oscillator as analogous to the swing with a few minor differences. First, our drive is not powered by gravity, but instead the oscillation is caused an electrostatic force due to fringe forces at the end of the fingers. Second, the energy which causes the comb to return to it's former position (the down swing) is not stored in the form of gravitational potential, but instead in the form of spring potential
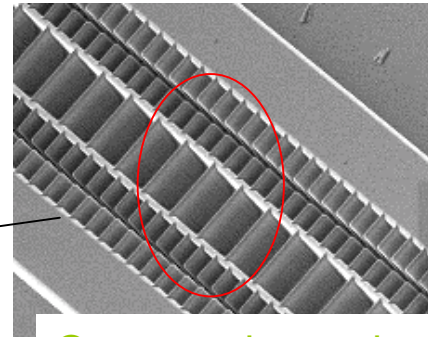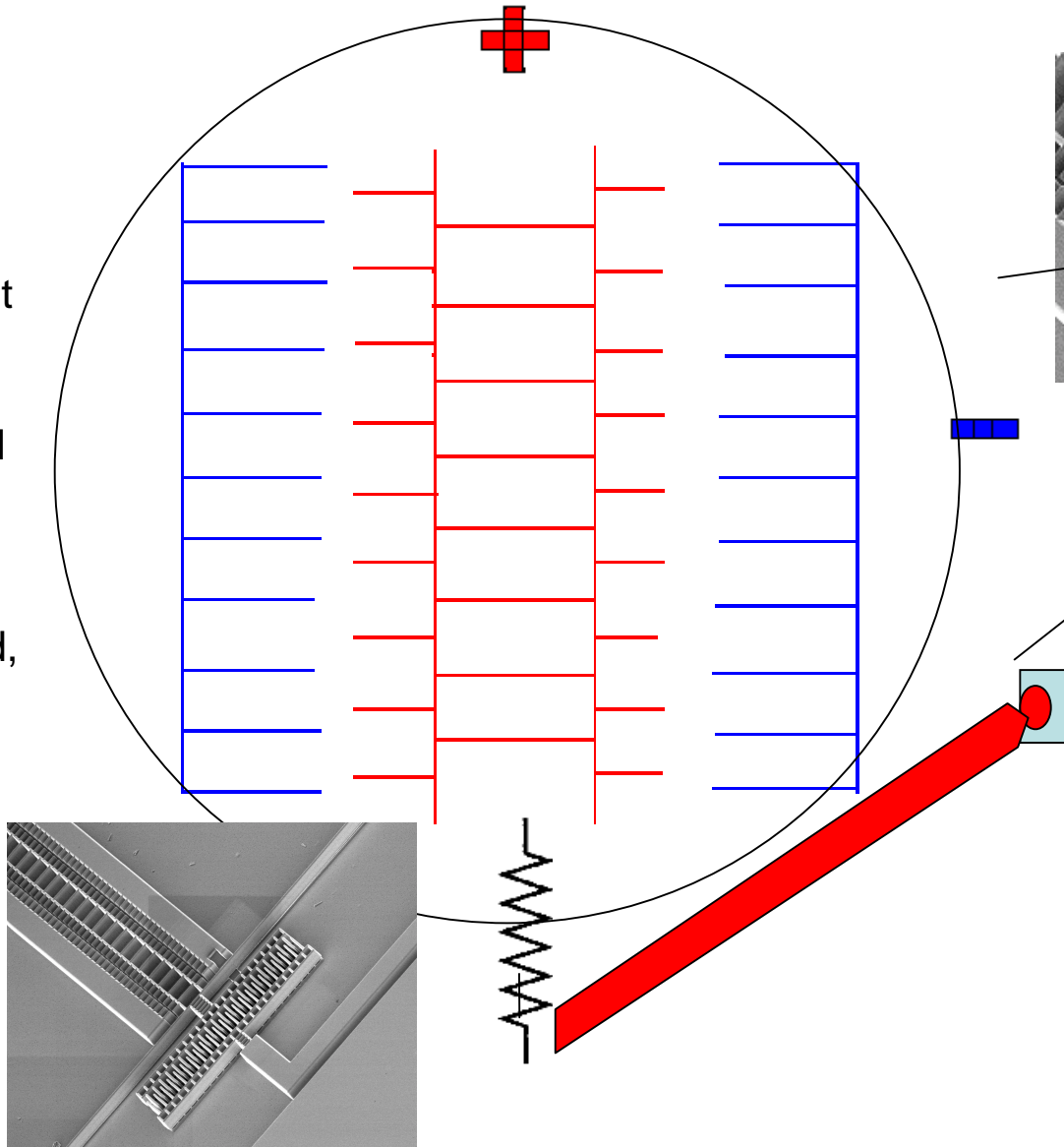
Our experimental set up consists of an oscillator subjected to an electrostatic force which excites the device into vibrating at resonance. These oscillations are measured by a laser that looks at our device and can tell us the displacement, velocity, and other pertinent information.
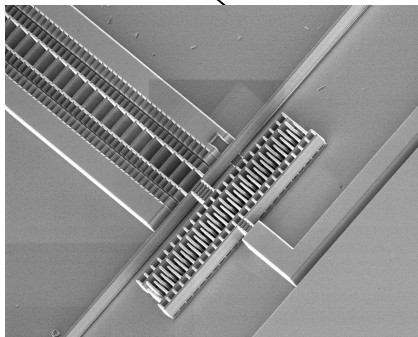
Frequency squared vs. Temp
$y = -371843x + 6E+08$

Frequency squared (Hz^2) vs. Temperature (K)

- Series1
- Linear (Series1)
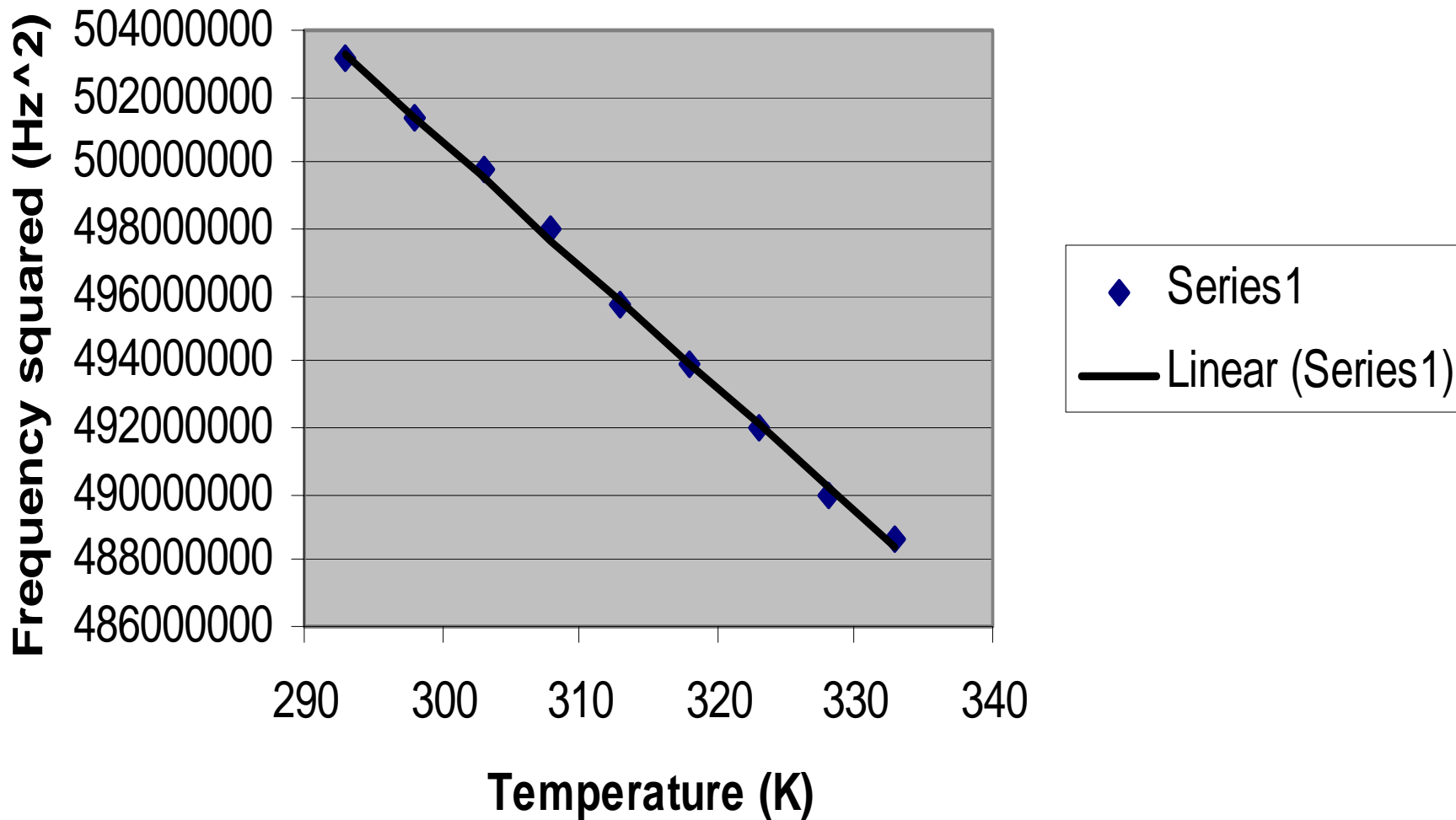
The more applicable part of the experiment that we are conducting is temperature response testing; that is, we are subjecting the device to a variety of different temperatures to see how the response varies. The significance of the temperature response has to do with an applied oscillator: for our purposes we will say that we have a high "Q" MEMS oscillator filter designed to filter out all frequencies other than 60 kHz—the resonance frequency that the device will normally oscillate at. This device, however, was fabricated to operate at this frequency at 22 degrees Celsius. So what would happen if it were taken out to the desert where there is suddenly a drastic temperature increase? Would it still work?...

That's exactly what we are trying to find out! The graph above is a graph of the frequency squared plotted against the temperature (why it is squared has to do with some derivations and slightly complicated math.) As it turns out, the resonance frequency has a tendency to change, decreasing with an increasing temperature. While there may be other factors coming into play, we believe this trend is a result of a change in the stiffness, that results because of a change in the Young's modulus, that is a result of a change in the atomic interactions due to the extra energy put into the system by the temperature change.

The idea is that if the change is small for a wide range of temperatures, than we really don't have to worry about it. As it turns out, after testing over a range of approximately 50 degrees Celsius, we discovered that the percentage change in Young's modulus per degree Celsius was only in the realm .07%, which corresponds to a total change in frequency over the 50 degree range of about 500 hz…not too shabby.

Future developments will consist of hopefully being able to accurately discover how much of this is a result of actual physical changes in the device (change in the Young's modulus) and how much is attributed to other phenomena.

Temperature Testing Results

It is important to note the relationship between the frequency, stiffness and Young's modulus

$$(d\mathrm{E})/(\mathrm{E}(d\mathrm{T}) \sim (d\mathrm{k})/(d\mathrm{T}) \sim (d\mathrm{f}^2)/(d\mathrm{T})$$

The ratio (multiply by 100 for percent) change in the Young's modulus with respect to temperature for various experiments done is given as follows.

"E" is the theoretical Young's modulus and "T" is the temperature in K

$$(d\mathrm{E})/(\mathrm{E}(d\mathrm{T})$$

My result	Rajashree Baskaran UCSB	John Hopkins University	Y. Isono ??
-7e-4	-2.4e-4	-4e-4	~ -2.4e-4

The significance of this data more of less lies in the fact that a change in the Young's Modulus can roughly be related to a change in the frequency. We can then decide that (with regard to changing temperatures) if the resulting change in frequency is practical for using these devices in real life applications.

Acknowledgements

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- And everyone in my lab for their patience, kindness, and generosity.