**Evidence for Quantized Displacement in Macroscopic Nanomechanical Oscillators**

**Authors: Alexei Gaidarzhy, Guiti Zolfagharkhani, Robert L. Badzey, and Pritiraj Mohanty**

**Recommended and Commentary by Al Migliori, Los Alamos National Labs**

http://arxiv.org/PS_cache/cond-mat/pdf/0503/0503260.pdf

The harmonic oscillator is a good generalized model for mechanical, optical, electrical or microwave resonators that are often the important system to be measured in an experiment. Attempting to understand these oscillators as they approach quantum limits in a measurement system brings in a host of fascinating and very current physics. Basically, the quantum limit occurs when the amount of thermal energy exchanged during a measurement (zKT where z is the ratio of the time the measurement takes to the dissipation-controlled decay time) is less than one quantum of energy. As this limit is reached, and in this particular carefully-constructed measurement system under discussion small enough that uncertainty-principle effects and quantum decoherence come into play—this nano-harmonic oscillator--, the "coordinate" of the oscillator is not a conserved quantity, while the "momentum" is. Thus "precise" measurement of the coordinate changes the momentum, forever making future coordinate measurements random. But "careful" precise measurement of momentum cannot change the momentum because it is a conserved quantity. Therefore, future measurements of momentum are not randomized. Momentum is a quantum non-demolition variable for the experimental setup of this PRL (QND) and is substantially different in behavior from its conjugate, position. Basically, a QND variable is conserved by the Hamiltonian—and is, therefore specific to the particular system under study [ref 8 of this PRL].

The detailed study of quantum-measurement-limit harmonic oscillators and QND variables is, therefore, increasingly important as we push both size in nanosystems, and signal/noise in, say, massive gravitational wave detectors further and further. Clean studies and clear theoretical analysis of such systems are a current fairly hot topic because so much controversy remains, and so little data exists. In this PRL, in a clever geometrical arrangement, the authors achieve several "firsts" relevant to understanding of the quantum-limit harmonic oscillator, and, consequently, the real fundamental limits to the noise of a repetitive set of measurements on a harmonic-oscillator detector of some sort, and QND. These firsts include a) the highest nanomechanical resonance frequency measured yet--of central importance because as the energy quantum increases, it is easier to keep the system in the quantum limit. Another first b) is that the authors make reasonable arguments that their resonator can be observed in both the classical limit and in the quantum limit by changing T and B, perhaps relevant to the convergence to Zurek's "pointer states"[ref 6 of the PRL], the classical evolution of the high-energy harmonic oscillator.

The system in this PRL is driven magnetically via Lorentz force in a conducting element attached to the resonator, in fields below 8T. Both driving current and magnetic field can be varied to measure the functional response expected in the classical and quantum limits, but more importantly, can continuously change key energy scales so that predicted trends can be verified. As expected, the system behaves classically in the classical limit, but in the quantum limit, surprising responses occur, including non-monotonic dependence of the amplitude on the magnetic field, with the possibility of watching the system transform from an initial condition that could be a superposition of states. Unfortunately, the signal/noise is still 3 orders of magnitude too low to see the thermal Johnson noise, and its end point at the correlation limit, but this is pioneering work and its further development can contribute to measurements of systems with small (10^9) numbers of particles. Because of the signal/noise issue as well as some other issues, this paper has encountered some skepticism, see for instance arXiv.org/quant-ph/050318. I nevertheless recommend this paper because this type of experiment is sure to be pursued further vigorously and will yield interesting new physics.