

CMP Seminar
Michigan State University

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***Force detection and frequency fluctuations in carbon nanotube
mechanical resonators***

Carbon nanotubes allow studying a broad range of phenomena, from many-electron transport in one-dimensional systems to nonlinear dynamics and fluctuations of bending modes. They also provide unique tools for mass and charge measurements with unprecedented sensitivity [1,2]. Another important new application is force measurement. I will present our recent force sensing experiments in which our nanotube mechanical resonators display quality factors as high as 5 million, and experience a force noise as low as 10^{-21} N Hz^{-1/2} [4]. This force noise has a thermal origin and is associated with the Brownian motion of the nanotube at a temperature of 0.04 K. To detect the low amplitude vibrations of the nanotube in the Brownian motion regime at such a low temperature, we employed an ultrasensitive method based on correlated electrical noise measurements, in combination with parametric down-conversion.

The nanotube dynamics is also affected by non-thermal fluctuations. They lead to a broadening of the resonant response beyond the decay-rate value. We developed a simple technique to extract the decay rate that does not involve complicated ring-down measurements [5]. It relies on the interplay of periodic driving and frequency fluctuations in the displacement spectrum of the nanotube resonator. We find that the intrinsic quality factors of nanotube resonators may even surpass the values we measure.

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- [2] G. A. Steele, et al., *Science* **325**, 1103 (2009). B. Lassagne, et al., *Science* **325**, 1107 (2009).
- [3] J. Moser, J. Güttinger, A. Eichler, M. J. Esplandiu, D. E. Liu, M. I. Dykman, and A. Bachtold, *Nature Nanotech.* **8**, 493 (2013).
- [4] J. Moser, A. Eichler, J. Güttinger, M. I. Dykman, and A. Bachtold, *Nature Nanotech.* **9**, 1007 (2014).
- [5] Y. Zhang, J. Moser, J. Güttinger, A. Bachtold, and M. I. Dykman, *Phys. Rev. Lett.* **113**, 255502 (2014).

Thursday, February 5, 2015
10:00 a.m.
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Prof. Norman Birge - Host