Dissipation and Wavepacket Collision in Carbon Nanotube Waveguides

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Abstract

Carbon nanotubes (CNTs) superior mechanical, electrical and thermal properties make them attractive components in Nano mechanical devices. Their large aspect ratio and low density makes them ideal candidates for high frequency resonators in numerous applications including wireless communication, and mass and chemical sensors. One reason why CNTs have been slow to be put to use in these applications is because of their poor quality factor (ratio of energy stored to dissipated per cycle). Recent studies on standing flexural waves in short CNTs has revealed that the accumulation of energy into the gateway modes triggers the anomalous intrinsic dissipation during which 90% of the energy is dissipated in mere 10 ps. This suggests that if one can regulate the energy accumulation in gateway modes then one can tune the damping of CNT resonators, opening application for thermal switching or mechanical signal processing.

In this study we used classical molecular dynamics to simulate long carbon nanotubes to determine if there is an experimentally observable manifestation of anomalous dissipation in large scale systems. Both standing and traveling waves were studied and the active gateway modes were identified. It was found that these delocalized waves dissipate in a highly non-linear way, and exhibit Mpemba-like effect in which the resonators take less time to dissipate if they start with more energy. In the second part of this work the attenuation of traveling flexural wave packets was studied—including the collisions between wavepackets. Surprisingly, these wavepackets showed markedly different dissipation behavior form extended waves with the same wavelength as amplitude. Moreover, the wavepacket collisions were seen to be sensitive to the direction of collision hinting to temperature gradient dependence to the thermal conductivity.

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