Near field interactions in nanoscale science

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All bodies are surrounded by fluctuating electromagnetic fields due to thermal and quantum fluctuations of the charge and current density at the surface of the bodies. Immediately outside the bodies, this electromagnetic field exists partly in the form of propagating electromagnetic waves and partly in the form of evanescent waves that decay exponentially with distance away from the body's surface. These fluctuating electromagnetic modes are responsible for a great variety of near-field phenomena such as the Van der Waals force, the Casimir force, near-field heat transfer, and friction forces.

As devices evolve from micro- to nanoscale mechanical structures, these forces become relatively stronger, and their effect cannot be ignored any further. To improve the understanding of these near-field interactions and to quantify their influence is extremely important for a diversity of seemingly different fields, such as nanomechanics, quantum computing with trapped ions, measurements of gravitational forces at the nanometer scale, and detection of single spins for magnetic resonance force microscopy. Researchers working to develop nanomechanical devices can mitigate adhesion caused by Van der Waals and Casimir forces by designing relatively stiff structures, but this leads to compromise in the range of motion or in the voltages required for actuation. Noncontact friction, namely, friction between objects in close proximity but not in physical contact, can originate from these fluctuating fields, and it is of great practical importance to understand dissipation in nanoscale devices. Radiative heat transfer at the nanoscale, augmented by the contribution of evanescent modes, is connected with the development of near-field scanning thermal microscopy, a new quantitative tool for metrology at the nanoscale. The extreme near-field regime – separations less than approximately 10 nm – is extremely difficult to access experimentally, mostly due to the difficulties associated with nanofabrication and with the emergence of nonlocal and nonlinear effects.

This presentation will describe the recent scientific advances regarding near-field interactions in nanoscience, the challenges and needs, and the potential benefits of using hard X-ray experiments to study these interactions.