Equilibrium and nonequilibrium atom-surface interactions: Material models and computations

Kurt Busch

AG Theoretische Optik & Photonik, Humboldt Universität zu Berlin, Germany
and
Max-Born-Institut, Germany

Nano-plasmonic and derived systems such as hyperbolic metamaterials promise large and broad-band enhancements of the photonic density of states. In turn, these enhancements strongly modify light-matter interaction, notably near plasmonic surfaces. Specifically, hybrid systems consisting of cold atoms and nano-photonic/nano-plasmonic structures represent a novel class of systems and hold significant application potential for quantum technologies.

However, even for simple systems such as a single atom above a planar surface there is no full consensus regarding theoretical description of atom-surface interactions. A recently developed exactly solvable model [1.2] allows to assess the validity of several often employed approximation schemes, such as the use of the quantum regression theorem or the local thermal equilibrium approximation for equilibrium (e.g. Casimir-Polder forces) and non-equilibrium effects (e.g. quantum friction). Based on the above exactly solvable model system, further analyses [3] demonstrate the importance of the plasmonic material model. Specifically, for atoms near a plasmonic surface, the atoms can spatially resolve the electron scattering processes within the metal and this effectively mandates that nonlocal material models are employed for the description of atom-surface interactions. It turns out that such nonlocal effects enhance atom-surface interactions relative to those associated with local material models so that, e.g., quantum frictional forces are enhanced by several orders of magnitude for experimentally relevant atom-surface distances of the order of a few tens of nanometers.

Finally, these theoretical findings raise the question of how to efficiently compute equilibrium and non-equilibrium effects of atom-surface interactions in complex geometries. In this context, the advantageous properties of the Discontinuous Galerkin Time-Domain (DGTD) [4] suggest to adapt the DGTD approach for computing for atom-surface interactions [5].

[1] F. Intravaia et al., Phys. Rev. Lett. **117**, 100402 (2016).
[2] F. Intravaia et al., Phys. Rev. A **94**, 042114 (2016).
[3] D. Reiche et al., Phys. Rev. A **95**, 155448 (2017).
[4] K. Busch, M. König, J. Niegemann, Laser & Photon. Rev. **5**, 773 (2011).
[6] P. Kristensen et al., in preparation (2017).