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# QUANTUM NANO-PLASMONICS

With examples and clear explanation throughout, this step-by-step approach makes the quantum theory of plasmons accessible to readers without a specialized training in theory. A fully analytical formulation offers an opportunity for further development of the research and applications. The theory is focused on the random phase approximation description of plasmons in metallic nanostructures, previously defined for the bulk metal only. Particular attention is paid to the large damping of plasmons in nanostructures, including electron scattering and Lorentz friction losses; a quantum description of the plasmon photovoltaic effect is presented and there is an in-depth analysis of plasmon–polariton kinetics in metallic nano-chains. Suitable for students in the fields of plasmonics, optoelectronics, and photonics and for researchers active in the fields of photovoltaics, optoelectronics, nano-plasmonics, and nano-photonics, the book should also be useful for researchers in soft plasmonics since it includes applications to electro-signalling in neurons.

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# Preface

Plasmonics in metallic nanostructures is a rapidly developing area with various prospective applications in photovoltaics and nano-optoelectronics. The most popular approach to plasmonics is based on the classical Fresnel problem for the propagation of electromagnetic waves with boundary conditions imposed on the Maxwell equations by the presence of metallic components. The typical solution for such a boundary problem uses the dielectric functions of both the dielectric and the metallic materials as prerequisites. The dielectric function of the metallic component is assumed to take the form of the Drude model with the parameters usually adjusted to experimental data extracted from bulk or thin-film measurements. However, this approach is not sufficient for metallic nanostructures because the dielectric functions of bulk metals and thin films differ significantly from that of a metallic nanocomponent. The strong size and shape dependences of plasmon excitations in metallic nanoparticles are caused by quantum-type effects not included in a phenomenological Drude–Lorentz approach and go beyond the classical determination of light scattering and absorption achieved by solving the Maxwell–Fresnel equations. In the present treatise, we demonstrate that the quantum properties of plasmons are of high importance for nanometre-scale metallic components and strongly influence plasmon-assisted phenomena not accounted for by the conventional electrodynamic model. We present the random phase approximation (RPA) theory of plasmons in metallic nanoparticles and detail the development of this theory for nanoplasmonic applications in plasmon-mediated photovoltaics and optoelectronics. This theory may be helpful for improving popular models of plasmonic effects based on the Mie approach and on numerical solutions of the Maxwell equations, e.g., within the COMSOL system. We describe how to upgrade conventional electrodynamic models by including quantum effects suitably due to the nanometre-scale metallic components of various plasmonic systems.

This treatise presents a completely developed, mostly analytical, quantum approach to plasmons in metallic nanostructures that can be directly applied



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to specific situations, such as plasmonics for photovoltaics, plasmon–polaritons in metallic arrays, and plasmons and plasmon–polaritons in ionic soft matter. To ensure completeness we present self-contained descriptions in each chapter, allowing for independent reading of the chapters. Though each chapter uses formalisms developed in the preceding chapters, a short overview of the most important information and derivations is provided in each chapter foreword, repeating and summarizing the previous derivations as necessary. Thus, the reader can begin at any arbitrary point in the book. Furthermore, the analytical formulation of the theory provides the opportunity for immediate further development and applications by readers.

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