Nano-Optics and Nanophotonics

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Dressed Photons to Revolutionize Modern Physics

Exploring Longitudinal Electromagnetic Waves and Off-Shell Quantum Fields

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Preface

Dressed photon (DP) is a quantum field that mediates the interaction between nanometer-sized particles (NPs). It localizes at an NP and its size is much smaller than the wavelength of a propagating light (a free photon). That is, DP is not an entity directly observed by conventional methods in optics and it should not be confused with a special type of linear evanescent light field, because, through previous research on *optical near field*, it has been found that DP is generated by nonlinear field interactions between matter and incident light field, for which quantum off-shell momentum field plays an important role. DP has unique features that are complimentary to those of the free photon (on-shell field), and a variety of novel phenomena originate from DP. Since they are analogous to some physical, chemical, and biological phenomena, we conjecture that those similarities are the manifestation of underlying mathematical universality represented by nonlinear off-shell field interactions.

By the authors' previous publications, the results of experimental studies and their application to innovative technologies have been reviewed. Although some theories were also introduced, they were prototypes built by modifying conventional on-shell scientific theories. Even though this introduction seemed to be successful in analyzing some experimental results, the problem was that these theories did not deal with the concept of "field interaction" mentioned above in a satisfactory fashion.

However, in the last few years, theoretical studies on off-shell science have rapidly progressed to solve this problem. Based on this progress, this book reviews the theories of DP creation and relevant phenomena. The first half of this book introduces the results of experimental studies, application technologies, prototype theories, and their problems: Chap. 1 presents fifteen novel phenomena originating from DP and reviews the history of DP studies. Chapter 2 demonstrates application technologies based on unique features of DP. These technologies are complimentary to those of the conventional ones. Chapter 3 reviews the experimental grounds of the unique phenomena of DP energy transfer. Numerical simulation is also reviewed that was carried out by prototype methods modifying on-shell scientific approaches, and their problems are pointed out. Chapter 4 describes numerical simulation based on a quantum walk model that was developed to solve these problems.

The second half of this book deals with the recent theoretical progress on off-shell field study focusing on DP dynamics. In the first half of this Preface, we have emphasized the important role played by nonlinear field interactions between matter and light fields in DP dynamics. As Einstein's theories of special and general relativity clearly show, light field as free electromagnetic one is closely related to what we call "physical space-time". From such a viewpoint, "matter and light field" interactions may be formally regarded as "matter and physical space-time" interactions just like matter and gravitational field interactions. As we know, the notions of space and time were originally introduced into a given physical system under consideration as purely mathematical quantities called coordinates. Although the above-mentioned Einstein's theory had revolutionized the situation, we can safely say that the present status of "physical space-time" is not complete, as is typically shown by the presence of cosmological term $\Lambda g_{\mu\nu}$ in Einstein's field equation. Occasionally as has been ridiculed by the term *Einstein's mollusk*, metric tensor $g_{\mu\nu}$ itself is not a physical quantity.

The most important aspect of our accomplishment we are going to explain in the second half is that we have succeeded in formulating a complete theory on "physical space-time" which covers not only timelike but also spacelike components of it by utilizing Greenberg-Robinson theorem in the axiomatic quantum field theory. Presumably, we can say that the problems of the unification of four forces, dark energy, and dark matter stand as big three enigmas in the contemporary theoretical physics. We believe that the reason why we cannot understand dark energy and matter is because we do not have a relevant theory on "physical space-time".

The second half starts from Chap. 5, which gives introductory remarks on the following Chaps. 6–10. Since the knowledge on Hamiltonian structure of the classical physics plays a quite important role in formulating our notion of "physical space-time", Chap. 6 is reserved for the explanation of it. In Chap. 7, we discuss several cutting-edge topics including dark energy, which are related to the spacelike part of "physical space-time". By combining the notions of conformal gravity and of the timelike part of "physical space-time", we are going to solve the mystery of dark matter in Chap. 8. The noticeable advantage of our new form of conformal gravity is the fact that it naturally bears the characteristics of spin-network as well as an entropy field different from the one in thermodynamics.

Based on the important outcomes explained in Chaps. 7 and 8, we will discuss novel cosmology in Chap. 9, and in the final Chap. 10, we will touch on a certain aspect of hierarchy problem in elementary particle physics relating to the unification of four forces, together with a couple of intriguing implications noticed on the relation between our novel cosmology and remarkable predictions of superstring theory made by Witten and Maldacena.

The first half was mainly written by M. O., the first author. The second half was mainly by H. S. However, they completed the manuscript in close cooperation with one another. The authors hope that this article will stimulate readers to gain an interest in off-shell science and to expand the routes available for reaching new studies of modern science.

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