BOOK REVIEWS

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Light: The Physics of Photons. Ole Keller. 482 pp. CRC Press, Boca Raton, Fl. 2014. Price: $79.96 (hardcover). ISBN 978-1-4398-4043-6. (Chandrasekhar Roychoudhuri, Reviewer.)

Everything you wanted to know about the modern photon by way of mathematical formalisms is available in **Light: The Physics of Photons**, by Ole Keller. It is a remarkably comprehensive look at the photon (a propagating electromagnetic wave packet) from all possible theoretical angles developed to date, which includes classical electromagnetism, quantum electrodynamics, and also special and general relativity. It should be a delightful book for theoretically inclined advanced students and scientists specializing in optical science. The large list of references is a valuable resource for critical thinkers as it includes many publications by the founding fathers.

At the outset, Keller astutely underscores that an observable phenomenon like "photon" cannot be explained by "what it is," but its description should evolve iteratively through an *indefinite number of observations of "photon-matter" interaction phenomena*. This is congruent with Bohr's pragmatic advice that "no elementary quantum phenomenon is a phenomenon until it is a registered (observed) phenomenon." To this, we need to add that a deeper understanding of the *ontological reality* can also be accessed iteratively provided we keep insisting on visualizing the invisible interaction processes that give rise to the measurable data. After all, human evolution has been proceeding successfully through innovations of tools and technologies by human engineers over many thousands of years. Their continued successes derive from persistent attempts to emulate nature's allowed processes in different permutations and combinations through trial and error until the desired innovation works, irrespective of their limited understanding of the final theories behind the phenomena under consideration. We still cannot provide the final description of photon phenomena, but engineers have already ushered in the Knowledge Age by inventing the working Global Internet System. They have figured out how to generate, manipulate, propagate and detect observable photon phenomena. If we do not consciously frame our questions to seek the interaction processes behind the ontological reality, the relevant answers will not become apparent to us. Framing the questions determines the answers. Even current QM formalisms yield more such realities when scrutinized through enquiring questions relevant to the interaction processes.

It is pleasantly surprising that Keller systematically avoids the most common phrases abundantly used in the context of "photon" physics: (i) Indivisible Quanta, (ii) Indivisible Photon and (iii) Wave-Particle Duality. All stable elementary particles, with zero or non-zero rest mass, break up into other particles, or share partial energy, when arranged to collide with other appropriate particles. To me, "duality" implies lack of our precise knowledge about something, not a new final knowledge.

He presents diverse mathematical approaches to EM wave packets (photons) as excited states (modes) of the vacuum. This postulate should be obvious to us from the fact that once generated out of an excited atomic or molecular dipole (or an antenna), the wave packet perpetually travels at the same constant velocity $c = (\varepsilon_0\mu_0)^{-1/2}$ across the entire galaxy, from one end to the other, without any further support from the emitter. This galactic vacuum possesses many different physical properties, including ε_0 and μ_0. Although Keller is not explicitly critical of the prevailing theoretical definition of the photon as an excited mode of the vacuum, he should be given credit for consistently underscoring the classic problem behind the quantum-mechanical definition of a photon: localization of a photon appears to be unresolved. This *localization problem* may not be of concern to most theoretical physicists given the prevailing cultural paradigm of physics. However, I interpret this as an implied pressure on the next generation of physicists to resolve this localization problem.

In Ch. 27 Keller underscores that "All quantum physical phenomena are maximally closed." Thus, if a photon emitted by a source is later registered by a detector, it is not meaningful "to try to find out what might have happened to the photon on its travel from source to detector." Fortunately, science and engineering of classical optics have been thriving for centuries, including the recent developments in nano-photonics and plasmonic photonics, on the basis of *propagating* classical EM wave packets with quantitative predictions for field distributions in any region between source and detector (using the Huygens-Fresnel diffraction integral and Maxwell's wave equation) without the need for invoking Einstein's or Dirac's indivisible photon. Interestingly, in Ch. 4 Keller attempts to accommodate Huygens' postulate of wave propagation through secondary wavelets by commenting: "Thus, in a sense the wave picture of Huygens is not that far from the corpuscular model of light." However, Huygens' postulate explains the diffractive spreading of light waves in excruciating details through the well-validated Huygens-Fresnel (HF) diffraction integral. Emitted photon wave packets from any extended source propagate by evolving through complex near-field patterns to the asymptotically expanding steady far-field patterns. This persistent diffractive spreading of EM wave packets is hardly obvious from the model of relativistic indivisible photons, in the absence of any other interacting force fields, which then delivers complex spatial energy distributions on their way to the far-field (on a detector array). The HF integral does not require us to accept any further ad hoc postulates to understand diffraction phenomenon (superposition of secondary wavelets on detectors). These successes, of course, must imply that the semi-classical approach to light-matter interaction processes is a better model than the "indivisible photon," as has been advocated by Willis Lamb and E. T. Jaynes, to name a few.

The founding fathers of quantum mechanics correctly recognized that the "measurement problem" is a serious issue in the context of interpretation of quantum mechanics. The "problem" is assumed to be resolved using a mathematical formalism. Keller makes an excellent presentation of this formalism. I believe that there are deeper issues behind the measurement problem that are still unresolved. In reality, it is an *information retrieval problem* out of any phenomenological observations. We need to apply the Keller Model of gathering data from innumerable measurements for a given type of entity through varied phenomenological interactions with other entities. Any observed phenomenon (measured data) is generated as a quantitative change in our instrument. It happens through some physical transformations experienced by our chosen interactants through exchange of energy facilitated by some allowed mutually stimulating force. All forces being of finite range, the interactants must be within the range of each other's mutual physical influence (or physical entanglement) for energy exchange to proceed in a causal manner. Unfortunately, we never have complete information about any individual interactant. We do not even know what electrons and photons are! Hence, the measured data cannot directly give us *complete* information about any one of the desired parameters of the interactants. We are forced to create *interpretative "*information" to fill up the lack of direct information in our measured data. Absence of such real information cannot be solved by mathematical theorems alone. Thus, the measurement problem can be overcome, but only slowly as we keep on observing innumerable observations as per the Keller Model; while iteratively re-examining the foundational postulates to help us visualize the interaction processes.

Let us apply Bohr's philosophy, as espoused by Keller, to superposition effects as a light-matter interaction phenomenon, while incorporating Willis Lamb's semi-classical model. A detector's real resultant dipolar stimulation under the influence of multiple superposed waves must be constructed. If we represent $\chi_n(\nu_{mn})$ as the linear polarizability of the dipole, with ν_n as the quantum resonance frequency and $D_{res.} = h\nu_n$ as the QM transition energy, then: $\langle D_{res.}\rangle = \langle|\psi_{res.}|^2\rangle = \langle|\sum_n \chi_n(\nu_n)E_n(\nu_n)|^2\rangle = \chi^2\ \langle|\sum_n E_n(\nu_n)|^2\rangle = [h\nu_n]_{En.Av.}$. Here, $\psi_{res.}$ is the resultant real physical conjoint dipolar amplitude undulation. The allure of "hidden" parameters arises if $\psi_{res.}$ is kept relegated to the status of a mathematical probability amplitude only. In actual photoelectric experiments, whether one is registering superposition fringe shape or communication data structure, only a large number of ensemble-averaged data validate the relevant phenomenon. So, we should restrain from drawing any phenomenological conclusion out of a single event, following Bohr's teachings. The equation underscores that the "quantum cup" [a term coined in my book *Causal Physics*] of energy $h\nu_n$ is extracted out of all the stimulating wave packets $E_n(\nu_n)$. It does not directly corroborate the "indivisible single photon interference" model. Besides, the QM theory has never demanded a postulate, so that all quantum transition must be triggered by a quantum donor having the exact quantum cup of energy. Note further that if $\chi_n(\nu_n)$ is a constant for a narrow band transition, it can be taken out of the two-step QM recipe math, leaving inside the summation of wave amplitudes, which allows us to carry on the classic mistake as if the wave amplitudes, by themselves, are capable of re-organizing the energy to generate the "interference fringes" without the active participation of the detector! That the wave amplitudes do not interact has been underscored by the father of wave propagation, Huygens, and later endorsed by the father of the quantum concept, Planck, while deriving his radiation law. Had Einstein focused on the dipolar stimulation required for any *bound electron* to be stimulated before it could be released, instead of trying to defy Planck, most likely he would have assigned the "quantumness" to bound "photo electrons" and would have discovered quantum mechanics some 20 years earlier in a form different from those given by Heisenberg and Schrödinger.

This is an excellent survey of our theoretical state of understanding of the photon. As Keller advocates, we should continue to study innumerable photon phenomena to keep on enhancing our knowledge about the photon. Even Einstein, the father of photons as "indivisible quanta," alerted us some time before his death: "All the fifty years of conscious brooding have brought me no closer to the answer to the question: What are light quanta? Of course today everybody thinks he knows the answer, but he is deluding himself."

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BOOKS RECEIVED

Advances in Thermodynamics of the van der Waals Fluid. David C. Johnston. 118 pp. IOP Concise Physics, Morgan & Claypool, San Rafael, CA. 2014. Price \$50 (paper) ISBN 978-1-627-05531-4.

Nuclear Medicine: Practical Physics, Artifacts, and Pitfalls. Daniel A. Pryma.197 pp. Oxford University Press, Oxford, UK. 2014. Price \$75 (paper) ISBN 978-0-19-991803-4.

The Quantum Theory of Nonlinear Optics. Peter D. Drummond and Mark Hillery. 182 pp. Cambridge University Press, New York, 2014. Price $80 (hardcover) ISBN 978-1-107-00421-4.

Back-of-the-Envelope Quantum Mechanics: With Extensions to Many-Body Systems and Integrable PDEs. Maxim Olshanii. 166 pp. World Scientific, Singapore. 2014. Price $38 (hardcover) ISBN 978-981-4508-46-9.

General Relativity: Basics and Beyond. Ghanashyam Date. 266 pp. CRC Press, Boca Raton, Fl. 2015. Price $63.96 (hardcover) ISBN 978-1-4665-5271-5.

Rare: The High-Stakes Race to Satisfy Our Need for the Scarcest Metals on Earth. Keith Veronese. 270 pp. Prometheus Books, Amherst, NY. 2015. Price $25 (hardcover) ISBN 978-1-61614-973-4.

Properties of Materials. P. F. Kelly. 427 pp. CRC Press, Boca Raton, Fl. 2015. Price $63.96 (hardcover) ISBN 978-1-4822-0622-7.

Mathematical Structures of the Universe. Michał, Eckstein, Michael Heller, and Sebastian J. Szybka (Eds.) 457 pp. Copernicus Center Press, Kraków, Poland. 2014. Price $69.90 (paper) ISBN 978-83-7886-107-2.

The Art of Insight in Science and Engineering. Sanjoy Mahajan. 405 pp. MIT Press, Cambridge, MA. 20014. Price $30 (paper) ISBN 987-0-262-52654-8.

Radiosensitizers and Radiochemotherapy in the Treatment of Cancer. Shirley Lehnert. 546 pp. CRC Press, Boca Raton, Fl. 2015. Price $127.96 (hardcover) ISBN 978-1-4398-2902-8.

The Physiological Measurement Handbook. John G. Webster (Ed.). 615 pp. CRC Press, Boca Raton, Fl. 2015. Price $119.96 (hardcover) ISBN 978-1-4598-0874-4.

Gravity: Newtonian, Post-Newtonian, Relativistic. Eric Poisson and Clifford M. Will. 794 pp. Cambridge University Press, New York, 2014. Price $85 (hardcover) ISBN 978-1-107-03286-6.

Crystal Growth and Evaluation of Silicon for VLSI and ULSI. Golla Eranna. 428 pp. CRC Press, Boca Raton, Fl. 2015. Price $119.96 (hardcover) ISBN 978-1-4822-3281-3.

Statistical Computing in Nuclear Imaging. Arkadiusz Sitek. 274 pp. CRC Press, Boca Raton, Fl. 2015. Price $95.96 (hardcover) ISBN 978-1-4398-4934-7.

A Laboratory Course in Nanoscience and Nanotechnology. Gérrard Eddy Jai Poinern. 255 pp. CRC Press, Boca Raton, Fl. 2015. Price $55.96 (hardcover) ISBN 978-1-4822-3103-8.

Quantum Mechanics I: The Fundamentals. S. Rajasekar and R. Velusamy. 612 pp. CRC Press, Boca Raton, Fl. 2015. Price $79.96 (hardcover) ISBN 978-1-4822-6337-4.

Quantum Mechanics II: Advanced Topics. S. Rajasekar and R. Velusamy. 312 pp. CRC Press, Boca Raton, Fl. 2015. Price $103.96 (hardcover) ISBN 978-1-4822-6345-9.

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