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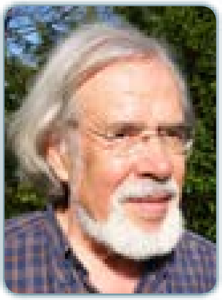

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Embedding the photon with its relativistic mass as a particle into the electromagnetic wave explains the Gouy phase shift as an energetic effect

A new aspect concerning the relationship between a photon and electromagnetic wave has been developed by considering the question why the energy and the mass density of an electromagnetic wave described by $m=E/c^2$ are propagating in the same direction. For instance, in optical resonators, the energy density usually propagates along curved lines. However, according to Newton's first law the mass density should propagate along a straight line if no force is exerted it. In order to solve this problem, which represents a contradiction between fundamental physical laws, the assumption has been made that a transverse force is exerted on the mass density and in consequence on the mass of the photons forcing them to follow the propagating energy density. This force has been computed by considering the infinitesimal change of the normalized Poynting vector with respect to an infinitesimal propagation step. Integration of the negative value of this force along the curvature of the phase front shows that the photon is moving within a transverse potential. This potential allows describing the transverse quantum mechanical motion of the photon by the use of a Schrodinger equation which is identical with the Schrodinger equation describing the motion of the electron, except that the mass of the electron is replaced by the relativistic mass of the photon. In this way, it could for the first time be shown that the Schrödinger equation is also describing the motion of a particle which has no rest mass. The eigensolutions $\chi nm(x,y,z)$ of this Schrodinger equation allow to compute the probability density $|\chi nm(x,y,z)|^2$ of the photons propagating with an electromagnetic wave. The obtained results have been verified for the case of the plane, the spherical, and the Gaussian wave. In case of a Gaussian wave it could be shown that the probability density $|\chi nm(x,y,z)|^2\ )|^2$ of the photon computed in this way is in full agreement with the normalized local intensity provided by paraxial wave optics for a Gaussian mode of order n,m. Also, the Guoy phase shift could be computed by the use of this particle picture in full agreement with the result obtained by the use of wave optics. Moreover, this particle picture allows explaining the Guoy phase shift, which so far has only been considered as a phase shift without any further physical meaning, as an energetic effect. It could be shown that due to the Gouy effect the axial energy of the photon is reduced with the consequence that the total energy of the photon turns out to be the sum of this reduced axial energy and the energy of the transverse quantum mechanical motion of the photon as obtained as energy eigen solution of the Schrodinger equation.

Biography

Konrad Altmann has completed his PhD in Physics from the Ludwig-Maximilian University of Munich, Germany, at 1975. The issue of his thesis was the quantum mechanical description of molecular spectra. For this work, he obtained the marking "with excellence". From 1976 to 1991 he was with the industrial company Messerschmitt-Bolkow-Blohm and developed a computer program for the description of a gas dynamic CO2 laser. From 1991 to 1993 he was with the German Aerospace and developed computer programs and published papers concerning laser beam propagation in the atmosphere. In 1993 he founded the company LAS-CAD GmbH with the purpose to integrate different simulation tools, necessary for the analysis of the multi-physics interaction in solid-state lasers, into the commercial program LASCAD. This program provides the laser engineer with the ability of a quantitative understanding of the complicated effects in laser systems. He has over 25 years of progressively responsible experience in computational physics especially in the field of optics. He wrote more than 40 scientific publications in molecular physics, propagation engineering and laser technology and applied for 38 patents of which 15 have been granted. He also wrote programs for the simulation of laser beam propagation in the atmosphere. In 2014 he was becoming Adjunct Professor of the National Engineering Center for DPSSL of the Chinese Academy of Science.

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