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3rd International Conference on

Ultraintense Laser Interaction Science

Lisbon, Portugal - October 10-13, 2011

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Book of Abstracts

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Transient electromagnetic waves accompanying propagation of ultra-intense radiation in media

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Propagation of a pulse of energetic particles or electromagnetic radiation (P1) in a medium is accompanied by changes in the matter state (polarization, excitation, ionization, etc.) that may result in a transient macroscopic current pulse (P2). Acting as a source, this current gives rise to a pulse of electromagnetic radiation (P3). P3 usually has a complicated spatiotemporal structure and, in certain conditions, may possess properties valuable for a wide range of applications. The most fascinating features of the phenomenon originate from the fact that the boundaries of medium perturbation by P1 are the shadow-type boundaries and as such can propagate with velocities less than, equal to, or greater than the velocity of light, depending on the interaction geometry. The back and front of P2 follow the perturbation boundaries, forming respectively a subluminal, luminal or superluminal source of P3.

The simplest conditions of P3 generation, involving formation of P2 via anisotropic Compton scattering, were discussed in the literature in early 1960s in the context of nuclear explosions [1]. These pioneering works were soon followed by more detailed studies [2] and receive a new impetus after discovering that some special luminal and superluminal travelling-wave source currents may generate localized waves (focus wave modes, X-shaped waves, etc.) [3] that propagate with unexpectedly slow rate of decay or spreading. Remarkably, nowadays experiments in the area of ultra-intense radiation science are also linked with generation of short transient pulses of currents (beams of charged particles, collective motion in plasma, etc.) produced, intentionally or as by-products, through several mechanisms of matter-radiation interaction [4] and being accompanied by the induced secondary electromagnetic pulse. The latter may play a positive (remote diagnostics of P1 or the medium in the interaction region, assessing the propagation velocity, launching progressive and UWB waves for location and information transmission, and so on) or negative (background/spurious signal, electromagnetic surge, etc.) role.

The presentation introduces a time-domain method for calculating the spatiotemporal structure of the accompanying electromagnetic pulse P3 for line source currents that may have arbitrary shape and propagate with subluminal, luminal or superluminal speed. The method is based on scalarization of the electromagnetic problem (comprising the inhomogeneous Maxwell equations and homogeneous initial conditions), incomplete separation of variables in the resulting scalar wave equation, and solving the obtained 1D Klein-Gordon problem using the ad hoc Riemann-Volterra procedure [5].

Sacrificing generality for the sake of better understanding of its essentials, the method is reported for the two "toy models" that the author considers the most pertinent to the experiments with ultra-high intensity laser beams: the exponentially decaying pulse of line current and the high-frequency modulated line current. Peculiarities of the space-time structure of the induced electromagnetic pulse, such as directionality and localization properties, are analyzed for both cases. P3 induced by modulated line current is further assessed via simplification of the (generally, integral) time-domain formulas, using expansion with respect to a small parameter associated with the inverse dimensionless modulation frequency. Specific phenomena of the frequency transform and beatings are also discussed.

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