White Paper

VirtualLab Fusion Technologies

— collection of research papers

With this document we would like to provide you with a compact overview of VirtualLab Fusion's theoretical and technological background, in connection with references for a more in-depth study. VirtualLab is a very innovative software product which has experienced major technical developments in recent years. The progress follows our R&D results in physical optics, carried out by an ever increasing team of optical scientists and engineers. You can expect many more new software features and technologies in the near future!

An introduction to field tracing [1] constitutes a good starting point for you to understand some aspects of how VirtualLab performs simulations of complicated optical systems. In short, the goal of field tracing is to solve Maxwell's equations at the system level. This does not necessarily imply rigorous solutions, though: very importantly, it also includes considerations on approximate solutions of Maxwell's equations by geometrical optics arguments. The geometric field tracing concept led to the release of an engine with the same name as an intermediate step on the way to the 2nd generation field tracing engine, released in 2017. Its (current) first version opens the door to a new era of optics simulations in which diffractive and geometric concepts are unified under a single physical-optics theory [2]. This new theory uses mathematical criteria to automatically switch between the geometric and diffractive branches of physical optics. The introduction of the geometric Fourier transform [3] turns out to be the key for identifying the geometric zone of fields and the semi-analytical Fourier transform [4] accelerates computation in the diffractive zone.

The benefits of field tracing start with the source: from spatially partially coherent sources [5], e.g. light-emitting diodes, to temporally coherent femtosecond laser pulses [6]—involving for instance simultaneous spatiotemporal focusing [7]—all can be modeled and investigated.

Due to the variety of the components/devices employed in modern optical systems, it is impossible to find a single modeling technique for all situations. In field tracing, it is wise to split an optical system into regions, and select the appropriate methods for different regions [1]. Then, by matching the boundary values between the regions, they can be interconnected again. Depending on how the regions are connected, the simulation will correspond to either sequential [1] or non-sequential field tracing [8].

This splitting can leave stretches of homogeneous isotropic media in between adjacent regions in the system. Any such stretch is grouped under the umbrella term "free space" (that is, we do not reserve the phrase "free space" exclusively for vacuum or air). A few advanced free-space propagation methods have been developed [9], also covering propagation between non-parallel planes [10]. Very recently, the unification of these approaches has been discovered [2].

And, last but not least, it is of great importance to have efficient modeling techniques for different types of components, so as to be capable of simulating a broad scope of systems with generality and variety. We continuously enrich and broaden our modeling capability; below we list a few of the methods we have developed:

- parabasal thin-element approximation [11]
- propagation through graded-index (GRIN) media [12]
- interaction with etalons and anisotropic media [13]

- stress-induced birefringence [14]
- laser resonator modeling [15]
- with more added steadily!

In addition to those mentioned above, any customized physical-optics-based modeling method can be implemented for your specific case via the fast programming interface available in VirtualLab. Contact support@lighttrans.com for more information and help with the references.

References

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