Extending geometrical optics: A Lagrangian theory for vector waves

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Problem

- Even when ignoring diffraction effects, the equations of geometrical optics (GO) are not entirely accurate.
- In GO, linear vector waves are only described by their position $\mathbf{X}(t)$ and wave vector $\mathbf{K}(t)$, but waves also have polarization.
- Some polarization effects are: mode conversion, polarization precession, and polarization-driven bending of ray trajectories.

Impact

- The theory of GO was extended and reformulated as a first-principle Lagrangian theory [1,2].
- The theory can be applied, as is, to dissipationless linear vector waves, both classical and quantum.
- The new theory includes polarization effects.
- It will provide more accurate ray equations, which potentially will allow the development of improved ray-tracing algorithms.

Accomplishments

The theory can be applied to several systems of interest:

- The theory predicts the polarization-driven divergence of left- and right- polarized EM waves in isotropic media, such as dielectrics and nonmagnetized plasmas [3].
- As a spin-off which was developed in parallel under the NNSA support, the same theory yielded the first point-particle Lagrangian model for the relativistic spin-1/2 electron that includes the Stern-Gerlach spin potential and the spin precession effect [1,4].
- Current work is being done to apply the theory to RF wave ray tracing in tokamaks. This could lead to improved calculations of RF heating and current drive.

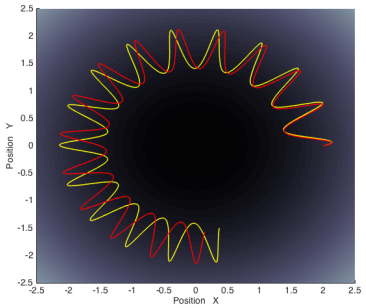

Figure 1: R wave in an axisymmetric plasma; yellow - GO ray trajectories with no polarization effects, red - ray trajectories with polarization effects included.

References

[1] D. E. Ruiz and I. Y. Dodin, Phys. Lett. A **379**, 2337 (2015).
[2] D. E. Ruiz and I. Y. Dodin, Phys. Lett. A **379**, 2623 (2015).
[3] D. E. Ruiz and I. Y. Dodin, Phys. Rev. A **92**, 043805 (2015).
[4] D. E. Ruiz, C. L. Ellison, and I. Y. Dodin, Phys. Rev. A **92**, 062124 (2015).

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