When Is Spiral Straight?

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Diffusion occurs for many types of particles or energy transfer in scattering media. Accurate measurement of diffusion is needed to probe the properties of associated media and predict processes.1

Nondestructive characterization of diffusion is often done through surface measurements, in which the particle or energy for transport is launched into the medium, and the measured diffuse remission is compared against a model-predicted value. There are rigorous models of photon diffusion associated with various shapes of applicator-tissue interface;2 however, direct numerical implementation of these analytic entities is daunting. For this reason, alternative numerical approaches, such as the finite element method, are frequently used.

For photon diffusion in noninvasive biological imaging applications, arguably the simplest geometry approximated is that of an infinite planar volume of tissue interfaced with an infinite planar applicator—such as a “semi-infinite” geometry. In practice, however, one commonly encounters configurations that could be idealized by either a concave geometry, wherein the photon probes the regime inner to a cylindrical tissue-applicator interface, or a convex geometry, wherein the photon probes the regime outside a cylindrical tissue-applicator interface.

We introduced novel analytical treatment of steady-state photon diffusion in concave and convex geometries.3 Our approach, validated by experiments,4 accurately quantified photon remission along the azimuthal and longitudinal directions with respect to a photon-launching position in idealized concave and convex geometries. In the concave geometry, photon remission along the azimuthal (or longitudinal) direction is found to be greater (or smaller) than that along a straight line on a semi-infinite interface, given the same line-of-sight source-detector distance.

The trends in the convex geometry are opposite. These findings project naturally to the existence of a set of spiral paths on a concave or convex interface, along which photon remission is modeled by the simplest form of describing remission along a straight line on a semi-infinite interface versus the same line-of-sight source-detector distance.5 Such interesting phenomenon as a spiral/straight equivalence pattern of diffuse photon remission, as shown in the figure, might exist in other regimes, and it may provoke simple sensing strategies to accurately probe the associated medium with challenging geometries.6

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References

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