Laser Speckles

Epub 4-21-08 ahead of presentation 2008 North American Association for Laser Therapy

Light is not "just light"

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It has become commonplace for manufacturers of non-laser light therapy devices to paraphrase as "light is light" the conclusions drawn in articles by Smith (1991; 2005, commented by Hode, 2005), and Enwemeka (2005; 2006), which were:

1) Lasers are just convenient machines that produce radiation, 2) It is the radiation that produces the photobiological and/or photophysical effects and therapeutic gains, not the machines, and 3) Radiation must be absorbed to produce a chemical or physical change, which results in a biological response.

Whilst these conclusions are, in essence, true, they neglect to account for the unique properties of laser radiation and the effects these properties produce in vivo. In this context, one of the most important properties of laser light is coherence. Coherence means order or synchronicity, and may be described as a property of wave-like states (such as light) that enables it to exhibit interference (laser speckles are caused by this interference). In individual laser speckles, where the intensity is higher than the surrounding environment, the light is partially linearly polarized. The reason for this is that the higher intensity has come about as a result of constructive interference, which occurs only if the interfering waves have the same polarization. Thus, when tissue is illuminated with laser light, volumes of polarized light with high intensity appear randomly in the tissue (regardless of whether the irradiating laser emits polarized or non-polarized light) with an average size of one or a few tenths of a millimeter.

Understanding speckle polarization, intensity, and contrast in scattering media (such as tissue) is essential if we are to understand the effects of photobiomodulation in deep tissue. The polarization and high intensities of individual speckles influence the photon absorption cross section of chromophores, which means that the probability of a photon absorption event to occur, with a subsequent photobiological response, may be significantly increased if a coherent light source is used. Because of the non-coherent nature of radiation from light/IR emitting diodes (LEDs or IREDs) speckling does not occur in the tissue with LED therapy, which may explain why head-to-head comparisons between lasers and LEDs in deep tissue seem to be in favor of lasers, and superpulsed lasers in particular.

References:

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Phys Rev Lett. 2008 Feb 8;100(5):053902. Epub 2008 Feb 8.

Fractality of light's darkness.

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Natural light fields are threaded by lines of darkness. For monochromatic light, the phenomenon is familiar in laser speckle, i.e., the black points that appear in the scattered light. These black points are optical vortices that extend as lines throughout the volume of the field. We establish by numerical simulations, supported by experiments, that these vortex lines have the fractal properties of a Brownian random walk. Approximately 73% of the lines percolate through the optical beam, the remainder forming closed loops. Our statistical results are similar to those of vortices in random discrete lattice models of cosmic strings, implying that the statistics of singularities in random optical fields exhibit universal behavior.

Opt Lett. 2008 Mar 1;33(5):479-81

Singularities in speckled speckle.

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Speckle patterns produced by random optical fields with two (or more) widely different correlation lengths exhibit speckle spots that are themselves highly speckled. Using computer simulations and analytic theory we present results for the point singularities of speckled speckle fields, namely, optical vortices in scalar (one polarization component) fields and C points in vector (two polarization components) fields. In single correlation length fields both types of singularities tend to be more or less uniformly distributed. In contrast, the singularity structure of speckled speckle is anomalous; for some sets of source parameters vortices and C points tend to form widely separated giant clusters, for other parameter sets these singularities tend to form chains that surround large empty regions. The critical point statistics of speckled speckle is also anomalous. In scalar (vector) single correlation length fields phase (azimuthal) extrema are always outnumbered by vortices (C points). In contrast, in speckled speckle fields, phase extrema

can outnumber vortices and azimuthal extrema can outnumber C points by factors that can easily exceed 10(4) for experimentally realistic source parameters.

Phys Rev Lett. 2005 Mar 18;94(10):103902. Epub 2005 Mar 17.

Experimental investigation of local properties and statistics of optical vortices in random wave fields.

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We present the first direct experimental evidence of the local properties of optical vortices in a random laser speckle field. We have observed the Berry anisotropy ellipse describing the anisotropic squeezing of phase lines close to vortex cores and quantitatively verified the Dennis angular momentum rule for its phase. Some statistics associated with vortices, such as density, anisotropy ellipse eccentricity, and its relation to zero crossings of real and imaginary parts of the random field, are also investigated by experiments.