Spontaneous emission from active dielectric microstructures

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Variable coherence in determining the scattering parameters of diffuse media using laser speckle

K. J. Webb, M. A. Webster, J. D. McClinton, and A. M. Weiner

We demonstrate the application of variable coherence to the determination of scattering parameters of a diffuse medium and the potential for imaging spatially-dependent scatter. A key concept in this work is the ability to produce a coherent/fractional beam by frequency modulating a collimated laser beam (with a center wavelength of 532 nm) at a rate much lower than the integration time of the detector. This allows for a rapid measurement and the adoption of beam coherence in the stage of scatter, which we show is related to obtaining the necessary sensitivity.

The spatial intensity statistics are described by the contrast ratio, which we have previously shown to be used in extract material parameters using light of beam coherence by varying the material thickness [1]. The requirement and commercially viable with acrylates (with the scattering due to ~50 nm TSP powders separated in the acrylate background as the diffuse medium in a transmission geometry. The marked contrast ratio dependence upon the source linewidth was seen, with the marks shown in Fig. 1. The theoretical fits were obtained using an approximate linear statistics for the difference ratio.

To demonstrate the applicability of the specific contrast ratio to a scattering medium, we have performed a number of experiments to collect imaging-type data [2]. The data shows a statistically varying contrast ratio which can be used to measure spatial phases through interference images. In the images of Fig. 2, the difference of contrast ratio between the interference and homogeneous transmittances. Lighter phases correspond to neoprene rubber, while dark regions correspond to the beam attenuation of scattering (measured by a wood batten, not shown). While image shows one colour of better contrast ratio due to the beam attenuation due to scattering caused by a white acrylic photopolymer. The localization of the interference is shown for the 532 nm linewidth used in Fig. 2a, and its contrast ratio that determines the electric field in terms of the transverse current. For materials with gain the wave equation can be derived from the solution to the homogeneous wave equation and the adjacent wave equation.

As an example we show in Fig. 1, in polar coordinates, the distribution of spontaneous emission going into radiation modes from an active optical fiber. The distribution is shown for the center of the fiber core and at the side of the fiber core, respectively. The optical fiber has the core reflective index 1.45, cladding reflective index 1.43, core radius 2 μm. The emission wavelength is 1550 nm. The emission rate Γ_{s} is for dipole with orientation along the fiber axis, Γ_{e} is the sum of emission rates for dipoles with orientation perpendicular to the fiber axis, and Γ_{n} is the sum of these two emission rates.

The presentation will include an analysis of the effects of gain on the radiation pattern and the rate of radiation into the guided modes for active optical fibers.

References

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Spontaneous emission from active dielectric microstructures.

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Spontaneous emission is one of the key issues that determine the noise properties of photonic devices and the pump power threshold of lasers. The spontaneous emission in dielectric microstructures (cross-coupled, photonic crystals, optical waveguides, etc.) can be more efficiently controlled and engineered due to the dependence of the emission rate on the orientation and polarization of the moments in the structure [1,2]. This paper addresses the methods of quantifying chromophores of dielectric media which enable calculation of the local rate of spontaneous emission in active microstructures.

For positive structures the spontaneous emission may be controlled by expanding the radiation field in negative orthogonal modes normal to one of the two, and using the Fermi Golden Rule. The example was found in [1] for calculating the positive dependence of spontaneous emission in passive photonic crystals. However, for active materials the results are more complex due to the distribution of observable emissions in terms of the field evolutions and current density. The total rate of spontaneous emission is given by

\[ \Gamma_{s} = k_{B}T \ln \left( \frac{1}{|\sigma_{0}^{2} \rho_{0}^{2} |} \right) \]

where \( \sigma = i |\sigma_{0}^{2} \rho_{0}^{2} | \) is the classical transverse Green's tensor that determines the electric field in terms of the transverse current. For materials with gain the wave equation can be derived from the solution to the homogeneous wave equation and the adjacent wave equation.

As an example we show in Fig. 1, in polar coordinates, the distribution of spontaneous emission going into radiation modes from an active optical fiber. The distribution is shown for the center of the fiber core and at the side of the fiber core, respectively. The optical fiber has the core reflective index 1.45, cladding reflective index 1.43, core radius 2 μm. The emission wavelength is 1550 nm. The emission rate Γ_{s} is for dipole with orientation along the fiber axis, Γ_{e} is the sum of emission rates for dipoles with orientation perpendicular to the fiber axis, and Γ_{n} is the sum of these two emission rates.

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References