2023 Conference on Lasers and Electro-Optics Europe & European Quantum Electronics Conference (CLEO/Europe-EQEC) | 979-8-3503-4599-5/23/$31.00 ©2023 IEEE | DOI: 10.1109/CLEO/EUROPE-EQEC57999.2023.10232580

Probing the Position Resolved Energy Density Inside Photonic Scattering Slabs with Strong Absorption and Anisotropy

Ozan Akdemir[1], Linda Bitenc[2], Innes L. Maxwell[1], Melissa Goodwin[1], Minh Duy Truong[1], Ad Lagendijk[1], Willem L. Vos[1]

1. Complex Photonic Systems (COPS), University of Twente, Enschede, The Netherlands
2. University of Ljubljana, Ljubljana, Slovenia

Understanding the transport of light in photonic scattering media is crucial for many application areas, such as atmospheric and climate sciences [1,2], oceanography [3], biophysics [4,5], powder technology [6], and solid-state lighting [7,8]. In photonic scattering media, such as paint, foam, and tissue, the refractive index varies spatially causing incident waves to be scattered and absorbed [9,10]. While Monte Carlo simulations accurately describe light transport in complex media, they are extremely slow and require high computation power. Fast and accurate analytical methods are needed especially for industrial applications. The P_1 approximation to the radiative transfer equation (RTE) is a commonly utilized analytical method [11]. However, it is known that P_1 fails for samples with both predominant forward scattering and strong absorption, resulting in unphysical negative energy densities. The accuracy of the analytical P_N approximation depends on the order N, the scattering properties of the sample, like albedo, anisotropy, optical thickness, and refractive index contrast of the sample and the surrounding medium [12].

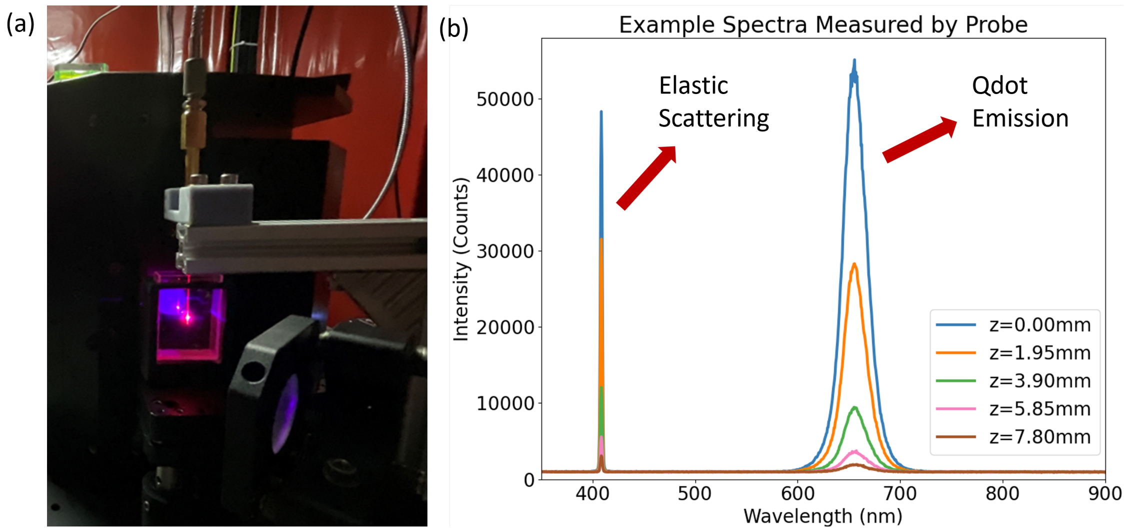

Fig. 1 (a) Photo of the probe used in position resolved intensity measurements inside dyed microsphere suspensions. The probe is a thin capilary holding quantum dots that absorb incoming blue light ($\lambda_0 = 408.5$nm) and emit in red ($\lambda_{em} = 655$nm). (b) An example spectra measured by the probe inside a sample with optical thickness $b = 10$, at different depths. The elastic scattering of the blue light through the probe and the quantum dot emission inside the probe are highlighted.

Here, we report a new experiment to spatially probe the optical energy density inside dyed microsphere suspensions and silicon micropillars. These samples have strong absorption (low albedo) and anisotropic scattering, where the first and third-order P_N approximations are known to fail [12]. We compare the experimental observations to verify theoretical results from P_N approximations and Monte Carlo simulations.

References

[1] D. Stramski, E. Boss, D. Bogucki, K. J. Voss, Prog. Oceanogr. **61**, pp. 27–56, (2004).
[2] T. Nousiainen, K. Kandler, Light scattering by atmospheric mineral dust particles Springer Berlin, Heidelberg, (2015).
[3] N. J. McCormick, Computational Methods in Transport, Springer Berlin, Heidelberg, pp. 151–163, (2006).
[4] W. M. Star, Dosimetry of Laser Radiation in Medicine and Biology **10305**, pp. 147–155, (1989).
[5] A. Kienle, R. Hibst, Phys. Rev. Lett. **97**, pp. 018104, (2006).
[6] T. Burger, J. Kuhn, R. Caps, J. Fricke, Appl. Spectrosc. **51**, pp. 309–317, (1997).
[7] H. Bechtel, P. Schmidt, W. Busselt, B. S. Schreinemacher, Eighth International Conference on Solid State Lighting **7058**, pp. 64–73, (2008).
[8] M. L. Meretska, G. Vissenberg, A. Lagendijk, W. L. IJzerman, W. L. Vos, ACS Photon. **6**, pp. 3070–3075, (2019).
[9] A. Ishimaru, Wave propagation and scattering in random media **I & II**, Academic, New York, (1978).
[10] R. Carminati, J. C. Schotland, Principles of Scattering and Transport of Light, Cambridge University Press, Cambridge, (2021).
[11] S. Rotter, S. Gigan, Rev. Mod. Phys. **89**, pp. 015005, (2017).
[12] O. Akdemir, A. Lagendijk, W. L. Vos, Phys. Rev. A **105**, pp. 033517, (2022)