Measuring light diffusion in thin leaky systems

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We developed a new experimental technique that allows to study light diffusion in thin leaky systems, allowing to estimate transport mean free path in samples previously inaccessible.

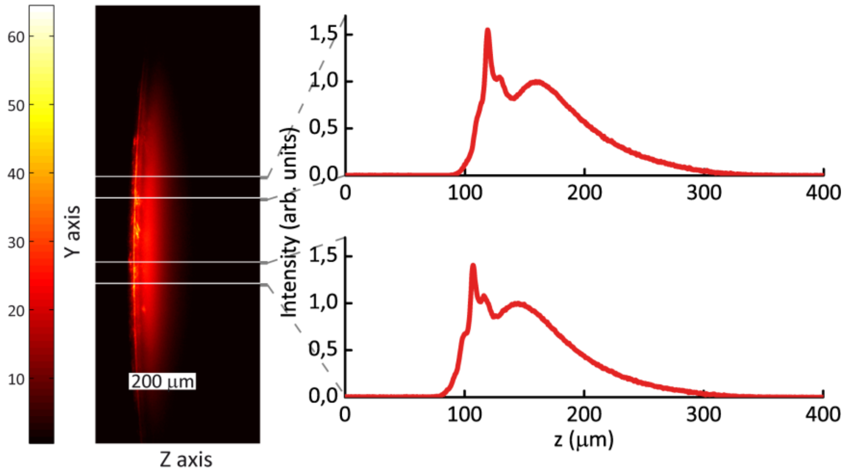
When a pencil of light shines in a white material (a disordered material with no absorption like e.g. a foam), photons entering in different point of the sample follow different paths and their propagation direction is randomized after a few scattering events. The intensity distribution inside the sample may be predicted in the framework of the diffusion approximation[1] that is, disregarding the ondulatory nature of the electromagnetic field to approximate light like intensity packets performing random walk inside the diffusive material. The critical length describing this phenomena is the transport mean free path ℓ, that is the length after which the packet loses the memory of the incoming direction being completely randomized. A few technique (like Enhanced Backscattering Cone[2] and, total transmission measurement[3]) are able to measure this parameter. Here we propose a new approach that is feasible to measure ℓ in thin (nearly 2d) systems in which light injected in plane and has a large probability of exit on the sides of the sample.

A typical sample consists in a drop of water containing dispersed latex beads, enclosed between microscopy coverslips spaced 100 µm. By using a novel strategy to inject the light between coverslips and collecting side emitted photons as a function of the z coordinate (see figure 1), we obtain a measure of how much deep, diffusing light can penetrate inside the sample before being expelled at the lateral side. By fitting [figure 2] this Lateral Leakage Tail (LLT) with results from random walk simulation we are able to estimate the mean free path of the sample.

ℓ measured by fitting LLT on dispersions of micron sized latex beads, and photonic glasses, are in satisfactory agreement with measurements from literature. Our approach opens the way to new applicative (for example biological and lithographic structures) studies on light diffusion and gives a new instrument to address open fundamental questions on light propagation in disordered structures.

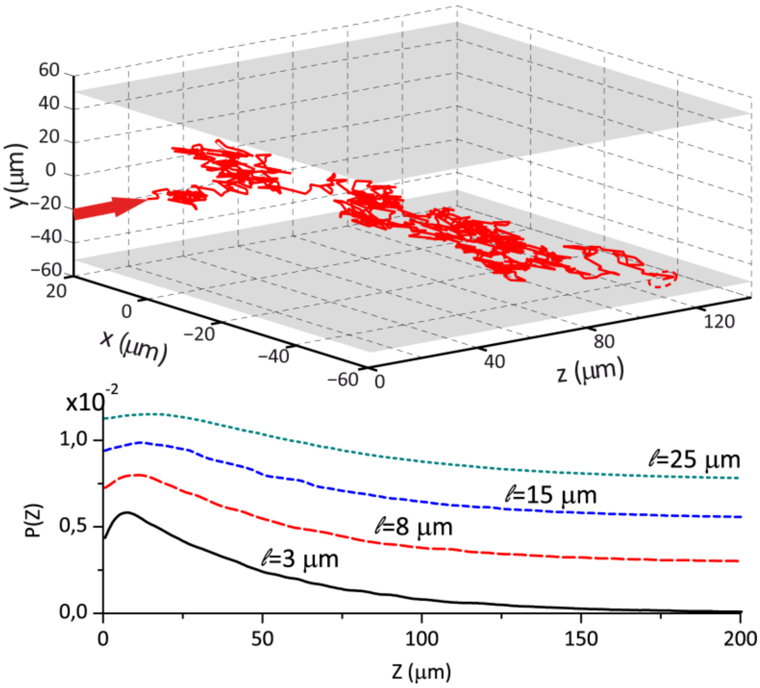
References
[1] Sheng P., Introduction to Wave Scattering, Localization and Mesoscopic Phenomena, Springer; 2nd ed. Edition, Berlin (2010)
[2] Wiersma, D. S., van Albada, Meint P., Lagendijk, Ad , Rev. Sci. Instr., **66** (1995) 5473.
[3] Garcia N., Genack A.Z, Lisyansky A.A., PRB, **46** (1992) 14475.

Figure 1



(On the left) Intensity outgoing from the side of the sample, measured by making an image one of the coverslips enclosing the drop of latex particles on a CCD camera. (On the right), the two graphs represent intensity as a function of z retrieved after integrating on the y direction (the integrated area is the one enclosed by white lines on the figure on the right)

Figure 2



Results from random walk simulations. On the top the trajectory of a single intensity bunch with a random walk step of R=3 µm. On the Bottom P(z) (Probability for a diffusive photon Injected at coordinates (0,0,0) photon to exit laterally from the sample at a length Z) calculated for different values of random walk step size for . Graphs are translated vertically of an arbitrary amount.