Ersch. in: Nature Photonics ; 7 (2013), 12. - S. 934-935

http://dx.doi.org/10.1038/nphoton.2013.281

Inelastic scattering puts in question recent claims of Anderson localization of light

Maret *et al.* reply: The interplay between nonlinear effects and Anderson localization in disordered optical fibres[1] has recently attracted great interest, and it is important in the action of random lasers in which closed multiple scattering loops have enhanced intensity[2]. As optical nonlinearities in TiO_2 can give valuable information on the nature of light transport in strongly scattering powders, we studied these effects in an extended experimental and theoretical investigation (to be published). Now, Scheffold and Wiersma have put forward that such effects may question the interpretation of the results of our recent experiments in terms of Anderson localization[3,4].

As noted by Scheffold and Wiersma, our measurements of the time-dependent transmission profiles[4] eliminate the influence of absorption. This technique thus reveals the signatures of Anderson localization more clearly than integrated transmission data[3]. The relevant signals appear at different timescales, which is also true for the nonlinear contributions in our study to be published. Based on the arguments put forth by Scheffold and Wiersma, one would expect that no saturation of the profile would be observed when a band-pass filter for the incoming wavelength is inserted. However, such an experiment (Fig. 1) clearly shows saturation of the profile width, similar to that reported in ref. 4, irrespective of the detected frequency.

In addition, we emphasize that the dependence of the localization length on kl^* was determined in two separate ways in ref. 4. Besides the variation of the samples and the packing fractions mentioned by Scheffold and Wiersma, we also investigated the change in the scattering strength induced by varying the incident wavelength. Our data presented in two different studies[3,4], exhibit a remarkable scaling with the turbidity measured by kl^* — exactly as expected for three-dimensional Anderson localization.

Even if, in an extraordinary coincidence, the change in nonlinear effects mentioned by Scheffold and Wiersma scaled exactly as kl^*, an alternative method of changing kl^* would not give the same quantitative results, whereas we have observed that it does[4]. Also, the determination of the localization length in two experiments that are conceptually very different[3,4] gives the same results (within errors) as a function of kl^*.

Although in different experiments[3,4], the input power density varied by more than four orders of magnitude, the features in the time-dependent integrated transmission varied by less than a factor of five at long times, showing that the nonlinear contributions are weak. Moreover, the nonlinear scenario invoked by Scheffold and Wiersma to explain the narrowing of the observed profiles would not cause saturation at long times, rather they would only reduce the rate of increase, which has not been observed. In that case, the relative contributions should be strongly dependent on the incident intensity, which again has not been observed.

In conclusion, elastically scattered light does show a plateauing width in our experiments, and the observation of a plateau clearly scales with kl^*, as determined by two independent means. Small nonlinear contributions via phonon-assisted processes do exist and provide density of states inside the electronic bandgap of TiO_2, which can qualitatively account for the observed frequency shifts given the intensity enhancement in the localized modes. Both integrated time-dependent transmission and transmission profiles are quantitatively accounted for by the self-consistent Vollhardt–Wölfle theory of Anderson localization of photons in the presence of realistic nonlinear effects, boundaries and other sample parameters[5] matched to the experiment (see Fig. 1). Thus, although small nonlinear effects may eventually be present, they do not invalidate the experimental observation of the Anderson localization transition with light.

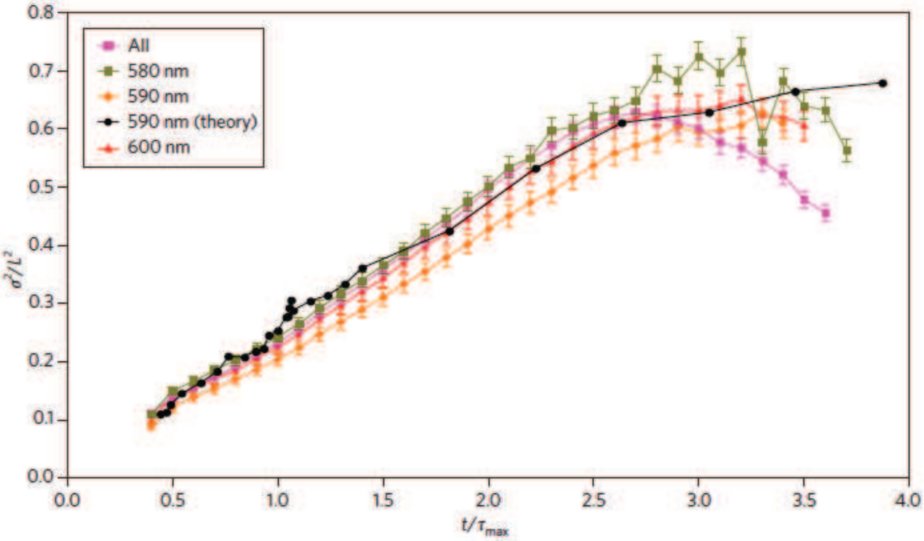

Figure 1 | Time dependence of the mean square width σ^2 normalized to sample thickness L for pressed powder of a strongly scattering sample (R700, see ref. 4, kl^* = 2.7(3), L = 0.86 mm, absorption time = 0.9(1) ns) at incident laser wavelength 590 nm and different band-pass filters between the sample and the detector. The legend shows the centre filter wavelengths; the filter width was 10 nm. Coloured lines represent experimentally measured data, whereas the black line indicates curve predicted by theory for the same sample parameters as those used in the experiment.

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