

4. Conclusions

The search for a universal criterion that captures all the nuances of non-classical correlations is an object of ongoing intensive discussion [46, 47]. The presented results contribute to this debate by providing an illustration of the differences between various measures of quantum correlations, such as the correlation function based on intensity fluctuations \mathcal{C} , entanglement and discord. We calculated the covariance matrix of two arbitrary output modes of the light elastically scattered by a disordered material for different states of the input mode, and analysed their correlation properties. Surprisingly, the results show that if the input is a thermal state then any two output modes will be (Gaussian) discorded, a signature of the quantum character of light. Moreover, it turns out that coherent states are the *only* Gaussian input that do not produce quantum correlations, as measured by any of the quantities considered here.

It is known that the propagation of light through a scattering medium is modified by quantum interference when the input state is entangled [48], but the effects of quantum discord on light propagation are still a largely unexplored subject. Quantum discord appears naturally from the multiple scattering of thermal light, even for large photon numbers. Such macroscopic effects can potentially be exploited to develop novel imaging techniques, and the very idea that some form of quantum correlation can spontaneously be generated from a thermal input via a process as common as multiple scattering can have profound implications in both quantum and bio-imaging. Since the amount of expected quantum discord grows when the number of scattering channels is small, these effects will play a role especially in the case of strongly scattering materials, where the dimensionless conductance g is small [3]. In particular we expect it to have an effect for systems that show Anderson localization.

Finally, when light undergoes multiple scattering, even very weak nonlinearities can have a dramatic effect [49]. Thus diffusion through a nonlinear system will produce a very rich landscape of possible output states, opening the possibility to generate multimode entanglement from classical input light.

Acknowledgments

We are grateful to M. Paternostro, D. Browne, and M. Williamson for insightful discussions. JA acknowledges support by EPSRC (EP/M009165/1). JB acknowledges support from the Leverhulme Trust's Philip Leverhulme Prize. IS acknowledges support from EPSRC (EP/L015331/1) through the Centre of Doctoral Training in Metamaterials (XM²).