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A theoretical model of the "transverse optical magnetism" phenomenon

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In recent scattering experiments [1,2], high-intensity, short-duration, electromagnetic pulses were scattered off dielectric liquids such as water and carbon tetrachloride. The observed pattern of the scattered light led the authors to propose a theory, based on single-particle, classical electromagnetic scattering, that there was magnetic dipole radiation generated. They called this phenomenon "transverse optical magnetism". This explanation has been challenged in the literature since strong magnetic interactions can be assumed to be negligible in classical electromagnetic scattering. Additionally, the fact that this effect is observed in a variety of liquids, including the highly symmetric CCl_4 (that lacks an electric dipole and quadrupole moment) leads one to look for alternative explanations for the observations.

We have recently demonstrated that a dense ensemble of two-level atoms driven by an electromagnetic field can be modelled by an effective single quantum system that has a time-varying decoherence rate [3]. Our effective single particle model provides a way in which computational time can be reduced, and also a model in which the underlying physical processes involved in the system's evolution are much easier to understand. We use this model to provide an elegant theoretical explanation for "transverse optical magnetism". We show that the radiation pattern suggestive of magnetic dipole scattering occurs naturally when the inter-particle interactions caused due to spontaneous emission from individual atoms are taken into account in 3-dimensions. Our effective single particle model's predictions match very well with experimental data.

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[2] S. C. Rand, W.M. Fisher, and S. L. Oliveira, J. Opt. Soc. Am B, 25:1106, 2008.

[3] C. S. DiLoreto and C. Rangan, Phys. Rev. A 97: 013812, 2018.

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