Forecasting of light-matter interaction in liquid crystals with physics-informed neural networks based on the complex Ginzburg-Landau equation

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The Complex Ginzburg-Landau (CGL) equation plays a paramount role in describing the behavior of complex nonlinear physical systems, particularly in the modeling of light-matter interaction in liquid crystal (LC) systems [1]. Namely, the CGL equation is used to model the spatiotemporal complexity of far-from-equilibrium dynamics in liquid crystals [2]. This study presents a novel application of Physics-Informed Neural Networks [3] (PINNs) to the CGL equation, thereby pioneering a model tailored to its structure for an enhanced prediction of state dynamics. The model, being rooted in the CGL equation represented as

$$\partial A_t = \mu A + (1 + ib)\Delta A - (1 + ia)|A|^2 A,$$

effectively forecasts dynamic states over space and time [1]. In the context of our study, we specifically set the parameters b and a to be equal to zero. However, we deviate from the conventional approach where the bifurcation parameter μ adjacent to A is a constant. Instead, we introduce a spatiotemporally variable bifurcation parameter denoted by μ, thereby extending the complexity and applicability of our model. In our work, the CGL equation was integrated into the loss function of the PINN. The prediction of the spatiotemporal dynamics were obtained via a dense network and used to retrieve the bifurcation parameter. Notably, our model accurately predicted the bifurcation parameter, μ, which is essential for system dynamics. This novel use of PINNs offers promising progress towards forecasting and controlling spatiotemporal dynamics of liquid crystals under the complex light-matter interaction governed by the CGL equation.

References

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