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Deep Learning the Digital Twin of Bent Optical Fibre.

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Physical perturbations (bends) in optical fibre cause mode-mixing: energy coupling and interference between the fibre's (otherwise propagation invariant) eigenmodes. This mode-mixing can be described using a complex transmission matrix (TM). The ability to predict the effect of physical bends on the TM can help improve mode division multiplexing, imaging, and endoscopy; furthermore, it enables more efficient wavefront modulation via TM engineering, which has applications in optical machine learning and optical quantum circuit construction. Accurately modelling the effects of bends analytically or numerically is non-trivial due to non-linear interdependence between bends. Convolutional neural networks have been used to create optical digital twins: models which predict the impact of bends on the propagating wavefront. Current optical digital twins simply generate images of the predicted output field given an input field (image) and the bend information. This approach fails to describe the TM directly and relies on extensive training to accurately capture physical trends. We investigate the suitability of a new deep learning approach for optical digital twins: physics-informed neural networks (PINNs). PINNs create a compressed model of physical phenomena within the neural network by explicitly encoding physical relationships into the model's architecture and cost function. We design a PINN to directly predict the TM of a bend fibre while ensuring adherence to the law of conservation of energy. The PINN is compared to a traditional neural network in terms of output prediction accuracy, convergence rate, and number of neurons required.

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