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Simulating XY spin systems with coupled laser networks

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Coupled lasers are useful for both applied and fundamental research. It has been shown that a very large arrays of >1000 lasers with nearest-neighbour coupling rapidly dissipates into long range phase ordering, identical to the ground state of a corresponding XY spin Hamiltonian. Finding the ground state can be mapped to solve optimization problems that are NP hard. Topological defects arise as a result of spontaneous symmetry breaking, when a system undergoes a phase transition from a complex disordered phase state to an ordered phase state, known as Kibble Zurek Mechanism (KZM). Because of topological protection they become trapped in the system, therefore limits the coherence of the system and its ability to approach a fully ordered state. Revealing and controlling these topological defects has been an important area of research in various fields such as cosmology, spin systems, cold atoms and optics. We investigated dissipative topological defects in a one-dimensional ring network of coupled lasers and show how their formation is related to the Kibble-Zurek (KZ) mechanism. These defects may be topologically protected, depending on the size and geometry of the system, preventing it from reaching a perfect ordered state. We experimentally found that the probability of topological defects increases with the system size, and also strongly depends on various laser parameters such as pump and coupling strengths. We confirmed that the formation of topological defects is governed by two competing time scales, namely phase locking time and synchronization time of the lasers amplitude fluctuations. More specifically, when the phase locking time is smaller than the synchronization time, the probability for topological defects formation is zero. Whereas, when the phase locking time exceeds the synchronization time, the probability for topological defects formation is finite.

Speaker Biography

Vishwa Pal joined Indian Institute of Technology Ropar, India, as an assistant professor of Physics in May 2018. He received his PhD in 2014 from School of Physical Sciences, Jawaharlal Nehru University, New Delhi, India. He has done part of his PhD at CNRS Laboratories Aime Cotton, Orsay, France. During his PhD program, he investigated semiconductor laser systems. After PhD, he received a 3-years PBC fellowship for outstanding postdoctoral researcher by the Council for Higher Education of Israel. In 2018, he joined CREOL, the College of Optics and Photonics, Florida, USA, as a research scientist and worked on synthesizing non-diffracting optical beams in free space by exploiting space-time correlations. In 2018, he also received Marie Sklodowska-Curie Actions Individual Fellowship by European Commission.

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