Contribution ID: **44** Type: **Oral Presentation**

Wavelet Tensor Network States for Quantum Fields

Over the last few decades, significant progress has been made in the development of variational tensor network states (TNS) used to solve quantum field theories (QFTs). This is especially true in 1+1 dimensions, where one can take the continuum limit of matrix product states (MPS) to model both non-relativistic and relativistic fields. In this work, we instead employ a discrete approach to model quantum fields, decomposing the fields in the infinite basis of Daubechies wavelet scaling functions. This then allows us to exploit the full machinery of discrete MPS on continuous theories, which is not yet accessible by (relativistic) continuous MPS.

We study the Lieb-Liniger model of interacting non-relativistic bosons in 1+1 dimensions in the thermodynamic limit, utilizing two different orders of Daubechies wavelets. Importantly, at these orders the wavelets have continuous first derivatives. We calculate the ground state using the variational uniform MPS (VUMPS) algorithm. To gain better control, we then construct a refinement of this ansatz via an optimized isometry on the physical Hilbert space. Our wavelet approach could later be applied to a larger class of QFTs, such as relativistic fields or QFTs in higher dimensions. Also interesting is the connection between our model and wavelet MERA, which also uses Daubechies wavelets but cannot yet be applied to interacting theories.

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Session Classification: B - Contributed Talk