

# Matrix product states—properties and extensions

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I will discuss recent studies of the asymptotic critical properties of matrix-product states (MPSs) [1]. Variationally optimized MPSs for the transverse-field Ising model on finite and infinite chains were obtained using  $D \times D$  matrices with small  $D \in \{2 - 10\}$ . For finite chain length  $N$ , there are energy minimums for symmetric as well as symmetry-broken states. These energies cross each other at a field value  $h_c(N, D)$ ; thus the transition is first-order. A continuous transition develops as  $N \rightarrow \infty$ . The asymptotic critical behavior is then always of mean-field type (the magnetization exponent  $\beta = 1/2$ ), but a window of field strengths where true Ising scaling holds ( $\beta = 1/8$ ) emerges with increasing  $D$ . Asymptotic mean-field behavior was also demonstrated for infinite-size 2D tensor-product states (iPEPS) with small tensors. The behaviors should be generic at symmetry-breaking transitions. I will also discuss recent work on using MPSs and certain generalizations in non-standard ways to obtain ground states as well as excitations [2].

## References

- [1] C. Liu, L. Wang, A. W. Sandvik, Y.-C. Su, and Y.-J. Kao, Symmetry breaking and criticality in tensor-product states, *Phys. Rev. B* **82**, 060410 (2010).
- [2] C. Liu and A. W. Sandvik (in progress).