A Challenge to Multi-leg Hubbard Ladders: from Directly-Extended to Cluster Multi-chain Schemes

Masahiko Machida[1,3], Ryo Igarashi[1,3], Atsushi Yamamoto[1,3], Masahiko Okumura[2,3], Susumu Yamada[1,3]

[1] CCSE, Japan Atomic Energy Research Institute, 6-9-3 Higashi-Ueno, Taito-ku, Tokyo 110-0015, Japan

[2] CCMP, RIKEN, Wako, Saitama 351–0198, Japan

[3] JST-CREST, 5, Sanbancho, Chiyoda-ku, Tokyo, 102-0075, Japan

The original DMRG method is one of the most powerful numerical tools to explore the ground-state in 1-D lattice model. Indeed, there have been a number of successful reports on 1-D lattice models. However, the original DMRG is not an all-round player. Especially, the extension to 2-D models has been not so successful. Some literatures claim that substantial improvements are required to face 2-D models.

In this paper, we propose a practical scheme to treat 2-D lattice models. The basic idea is to examine multiple-leg ladder models instead of 2-D lattice ones. One of the reason is that two-leg systems are known to be rather different from 1-D and the ladder systems may fully capture nature of 2-D models.

First, we show that multiple-leg ladder models can be basically reduced to multi-band 1-D models. Then, since the quantum degree of freedom per site increases, the exact diagonalization part in DMRG should be parallelized. We briefly explain our parallelization scheme Yamada and report how many-legs we can calculate in the Hubbard ladder models. We propose two schemes, one of which is the directly-extended version and another is site-clustering multi-chain one. The advantage of the former scheme is high accuracy. We demonstrate some successful examples obtained by using the scheme. In contrast, we claim that the latter scheme is quite powerful in extending the number of legs. By clustering two sites into a single site, we approach more than 10-leg Hubbard ladder with the multi-chain scheme. We present some reasonable results obtained by the combined scheme.

References

[1] S. Yamada, M. Okumura, and M. Machida, J. Phys. Soc. Jpn. **78**, 094004 (2009).