ラダー格子上の量子ハードコア粒子系のエンタングルメント・スペクトル

PS-B23　物材機構　田村亮

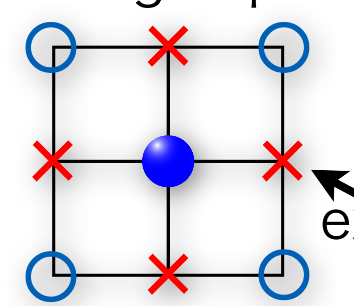
Hard-core quantum system

$$H = \sum_i h_i^\dagger(z) h_i(z) \qquad h_i(z) = [\sigma_i^- - \sqrt{z}(1 - n_i)]\mathcal{P}_{\langle i \rangle}$$

$\mathcal{P}_{\langle i \rangle} = \prod_{j \in G_i} (1 - n_j)$: projection operator to all sites adjacent to site i to be empty

set of sites adjacent to site i

e.g. square lattice



The model corresponds to Rydberg lattice gas systems for $|V| \gg |\Omega|, |\Delta|$:

$$H_{\mathrm{Rydberg}} = \Omega \sum_i \sigma_i^x + \Delta \sum_i n_i + V \sum_{i,j} \frac{n_i n_j}{|\boldsymbol{r}_i - \boldsymbol{r}_j|^6}$$

L. Lesanovsky, Phys. Rev. Lett. **106**, 025301 (2011).
L. Lesanovsky and H. Katsura, Phys. Rev. A **86**, 041601(R) (2012).

Shu Tanaka, Ryo Tamura, and Hosho Katsura, Phys. Rev. A **86**, 032326 (2012).

ラダー格子上の量子ハードコア粒子系のエンタングルメント・スペクトル

PS-B23　物材機構　田村亮

Exact ground state

$$|z\rangle = \frac{1}{\sqrt{\Xi(z)}} \prod_i \exp(\sqrt{z}\sigma_i^+ \mathcal{P}_{\langle i \rangle})|\Downarrow\rangle$$

We can obtain the ground state of quantum system
by weighted superposition of allowed classical states
with hard-core exclusion as well as PEPS(the RK model).

D. S. Rokhsar and S. A. Kivelson, Phys. Rev. Lett. **61**, 2376 (1988).

$$|\Psi(z)\rangle = \sqrt{\Xi(z)}|z\rangle \qquad |\Psi(z)\rangle = \sum_{\mathcal{C}} z^{n_{\mathcal{C}}/2}|\mathcal{C}\rangle$$

$|\mathcal{C}\rangle$: classical configuration of particle with hard-core exclusion

$\Xi(z) = \langle\Psi(z)|\Psi(z)\rangle = \sum_{\mathcal{C}} z^{n_{\mathcal{C}}}$: normalization constant (partition function of the classical lattice gas model)

Shu Tanaka, Ryo Tamura, and Hosho Katsura, Phys. Rev. A **86**, 032326 (2012).

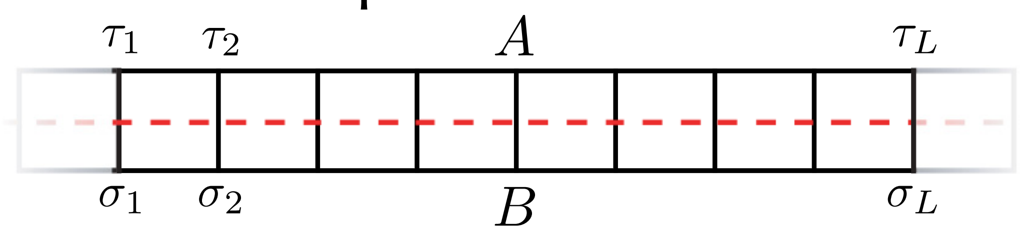
ラダー格子上の量子ハードコア粒子系のエンタングルメント・スペクトル

PS-B23　物材機構　田村亮

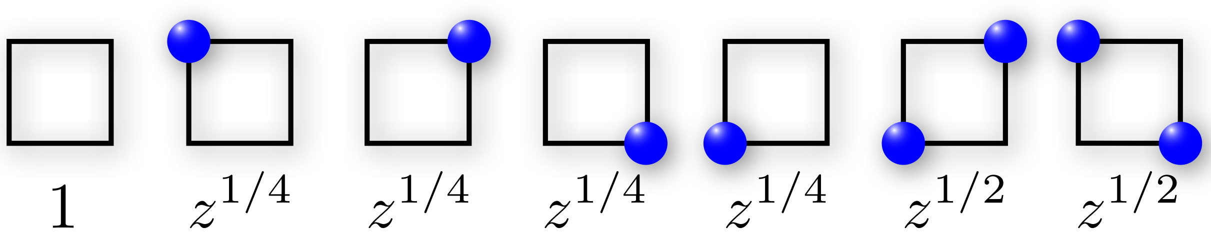
Two-leg ladder system

$$|\Psi(z)\rangle = \sum_{\tau}\sum_{\sigma}[T(z)]_{\tau,\sigma}|\tau\rangle \otimes |\sigma\rangle$$

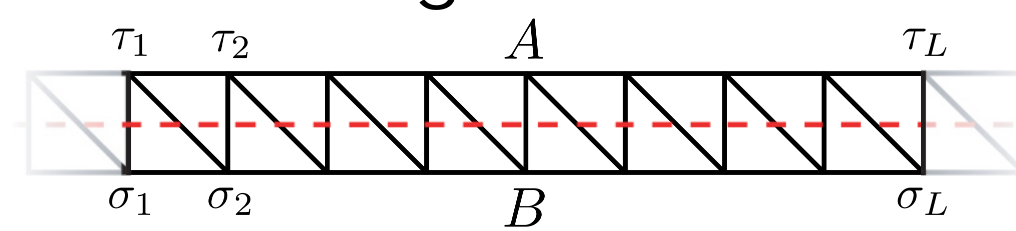
Square ladder



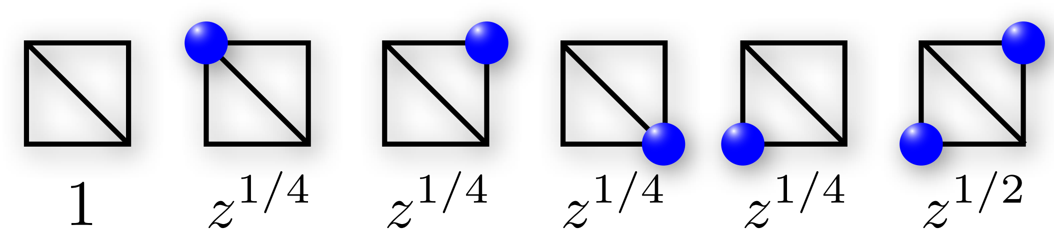
$$[T(z)]_{\tau,\sigma} = \prod_{i=1}^{L} z^{(\sigma_i+\tau_i)/2}(1-\sigma_i\tau_i)(1-\sigma_i\sigma_{i+1}) \times (1-\tau_i\tau_{i+1})$$



Triangular ladder



$$[T(z)]_{\tau,\sigma} = \prod_{i=1}^{L} z^{(\sigma_i+\tau_i)/2}(1-\sigma_i\tau_i)(1-\sigma_i\sigma_{i+1}) \times (1-\tau_i\tau_{i+1})(1-\tau_i\sigma_{i+1})$$



We can identify $T(z)$ as the transfer matrix of two-dimensional lattice gas with hard-core exclusion.

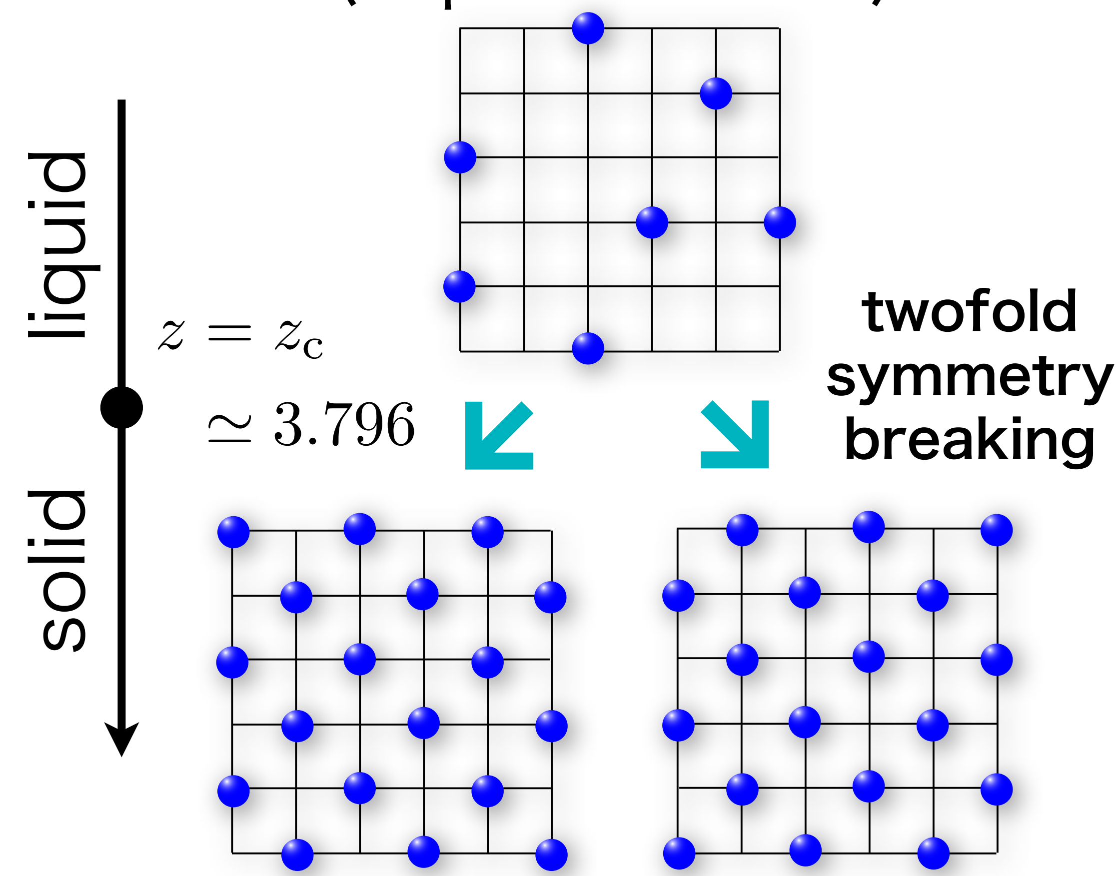
Shu Tanaka, Ryo Tamura, and Hosho Katsura, Phys. Rev. A **86**, 032326 (2012).

ラダー格子上の量子ハードコア粒子系のエンタングルメント・スペクトル

PS-B23　物材機構　田村亮

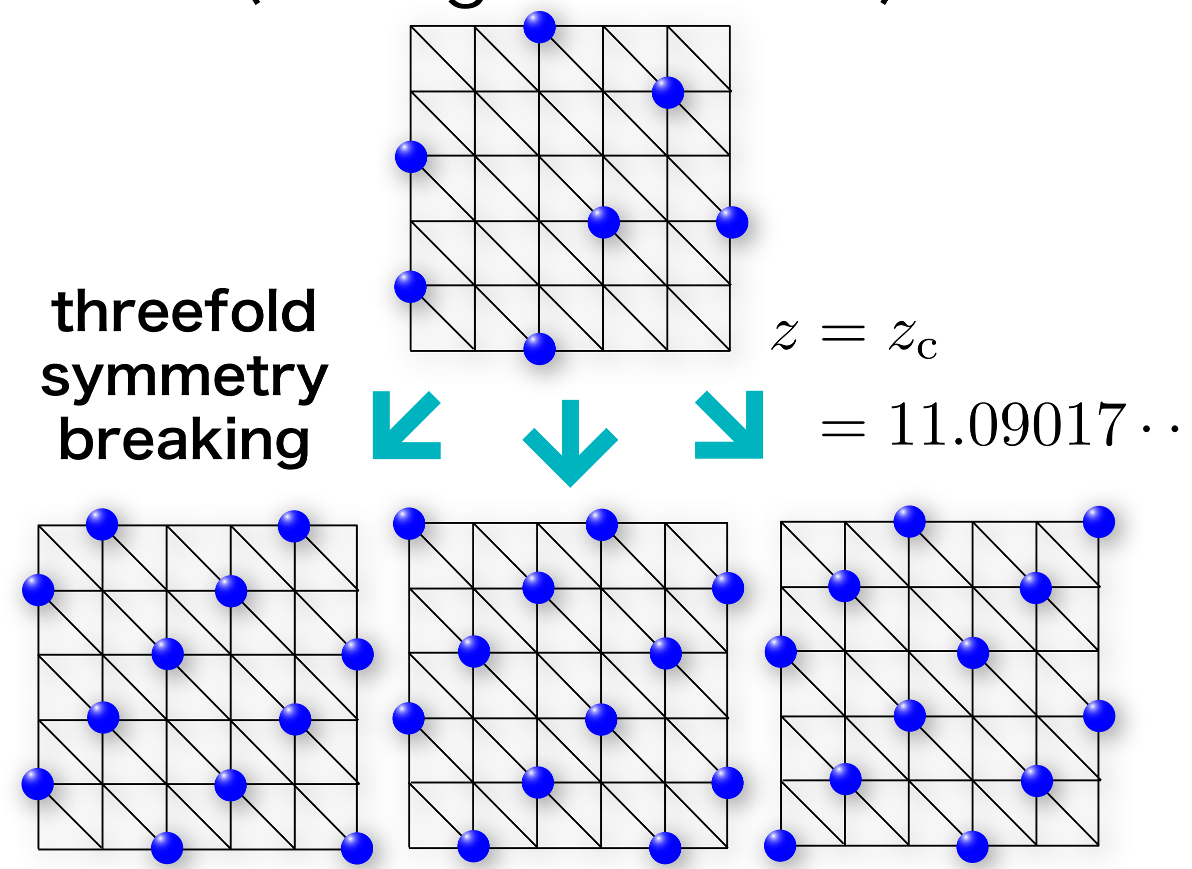
Corresponding two-dimensional classical lattice gas

Hard-square model
(Square lattice)



Universality class:
Two-dimensional Ising model

Hard-hexagon model
(Triangular lattice)



Universality class:
Two-dimensional three-state Potts model

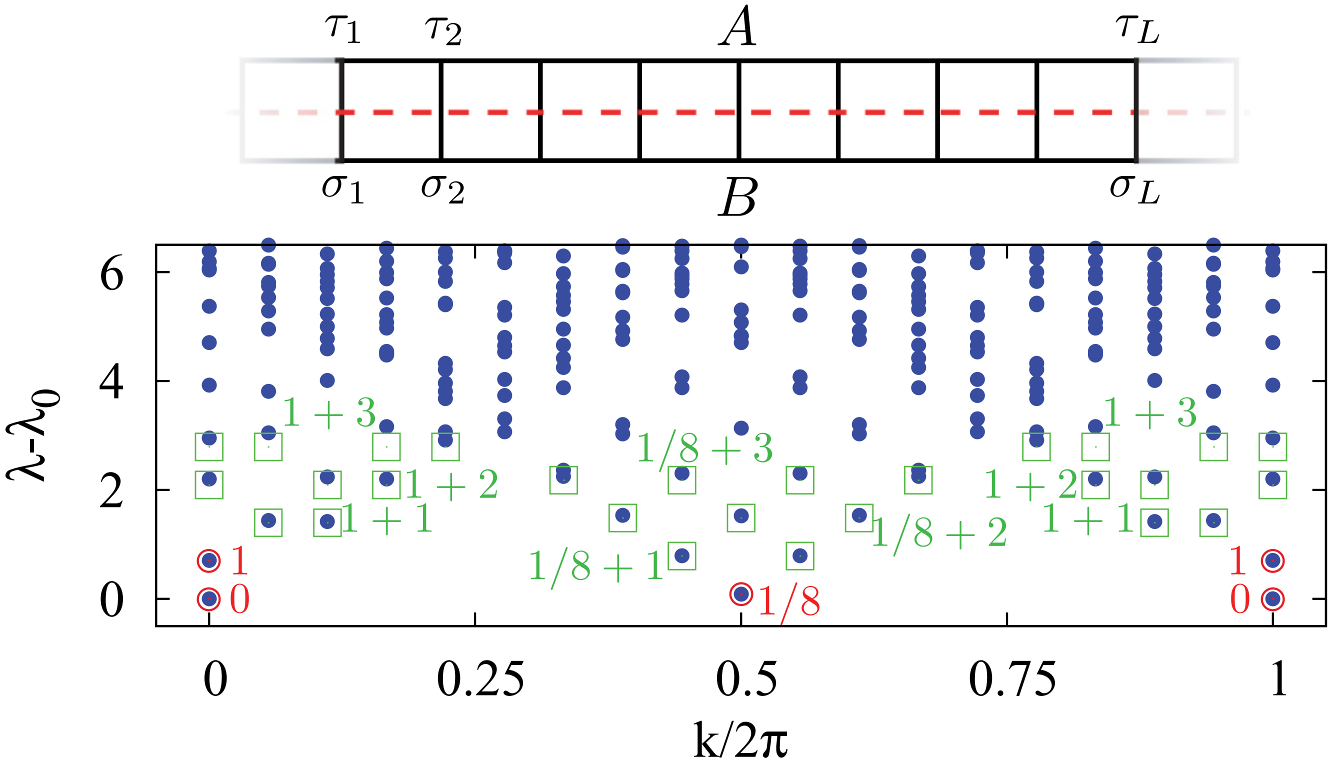
Shu Tanaka, Ryo Tamura, and Hosho Katsura, Phys. Rev. A **86**, 032326 (2012).

ラダー格子上の量子ハードコア粒子系のエンタングルメント・スペクトル

PS-B23　物材機構　田村亮

Entanglement spectrum

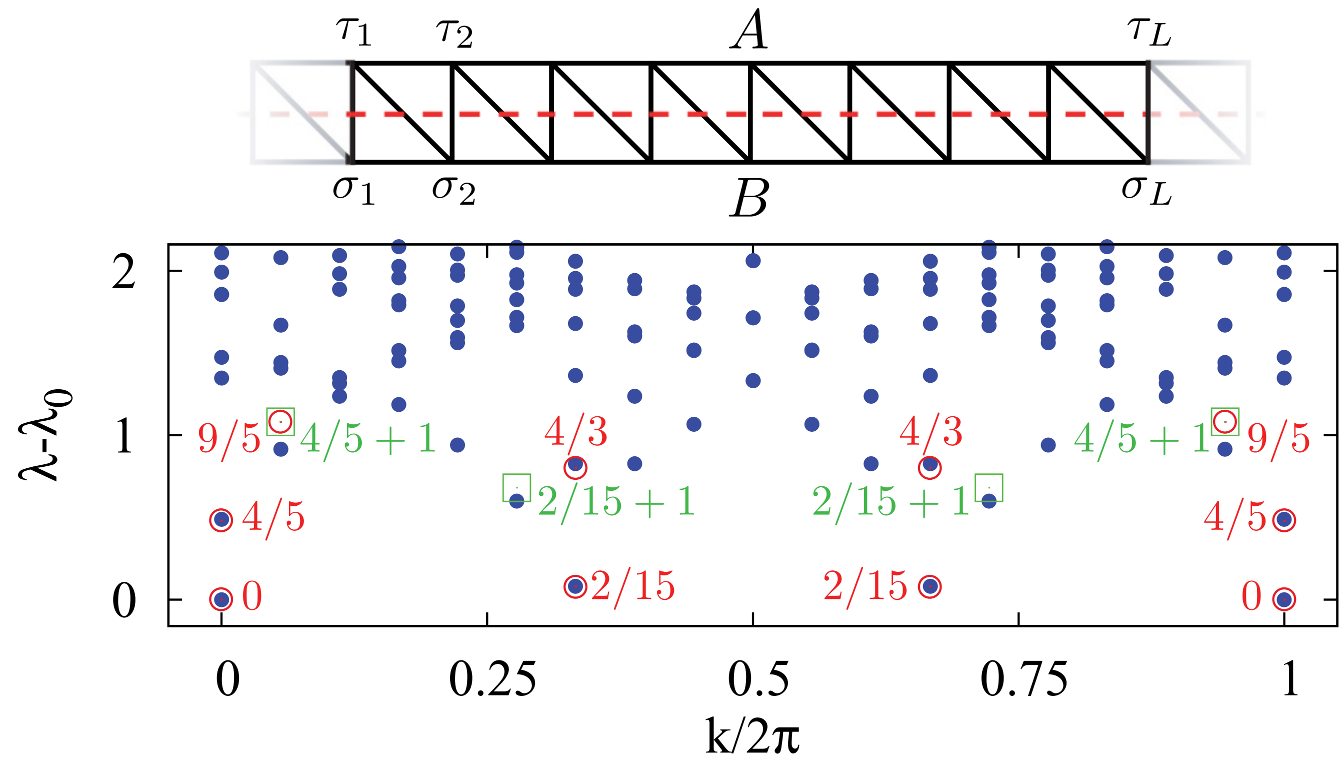
Square ladder



$c = 1/2$

Two-dimensional Ising model

Triangular ladder



$c = 4/5$

Two-dimensional three-state Potts model

Shu Tanaka, Ryo Tamura, and Hosho Katsura, Phys. Rev. A **86**, 032326 (2012).