Ultrabosonic and subbosonic behaviors in photoexcited one-dimensional Mott insulators

K. Iwano[1*], T. Yamaguchi[1], and H. Okamoto[2]

[1]*Institute of Materials Structure Science, KEK, Tsukuba 305-0801, Japan*
[2]*University of Tokyo, Chiba 277-8561, Japan*
*E-mail: kaoru.iwano@kek.jp

The physics of optically excited states in one-dimensional (1D) Mott insulators has attracted much attention in recent decades. The lowest optical excitations are described as a pair consisting of a doublon (D) and a holon (H), which are doubly occupied and empty sites of electrons, respectively, in a background of singly occupied sites corresponding to the Mott insulator. When the intersite Coulombic attraction (V) works substantially between a doublon and a holon, the pair forms a bound state, while it remains an unbound pair for sufficiently weak V, still having finite mutual correlation avoiding the occupancy on the same site. So far, most of the interests have been in a single pair of DH. In this study, we report a unique behavior particularly found for multi DH pairs [1].

First, we find that, in a situation with vanishing V, the pairs obey a particle statistics that **exceeds** that of ordinary bosons. This feature appears most directly in the enhancement factor (b) of the matrix element for the pair photocreation. Namely, the usual boson factor $\sqrt{n}$ is expected for the transition from n pairs to (n+1) pairs. In contrast, our numerical analysis indicates the factors of $\sqrt{3}$ and $\sqrt{6}$ for n=2, and 3, respectively, with high accuracy. Second, when V is increased from zero, this factor is gradually suppressed and drops even below the usual boson factor. These *ultrabosonic* and *subbosonic* behaviors are shown for the case of n=2, in Fig. 1. Lastly, when V exceeds a certain value around two, the factor jumps to the value of the usual boson factor. Judging from the size (N) dependency, this jump is a transition, which coincides with that of the DH bound state formation.

These unique behaviors are deeply related to the spatially extended nature of unbound DH pairs. Namely, when we add another pair to already excited pairs, there arises phase coherency if the pairs have the same wave number with respect to the relative motion. We interpret that such coherency contributes to the of the enhancement of b. Another interpretation from a different viewpoint is explained in the case of two DH pairs. A simple hypothetical case assumes four independent bosons, in which one D (H) is converted to two D's (H's). In this case, the b^2 value is estimated at $(\sqrt{2})^2 = 4$ and we consider this number the maximum number. Meanwhile, the minimum number is given by the two strongly bound DH pairs, which is two as b^2. The effective number of particles is two in the latter case. The present result for unbound DH pairs, b^2 =3, is the midpoint of these numbers, which suggests that the effective particle number is intermediate.

References:
[1] K. Iwnao et al., Phys. Rev. B. 102, 245114 (2020)

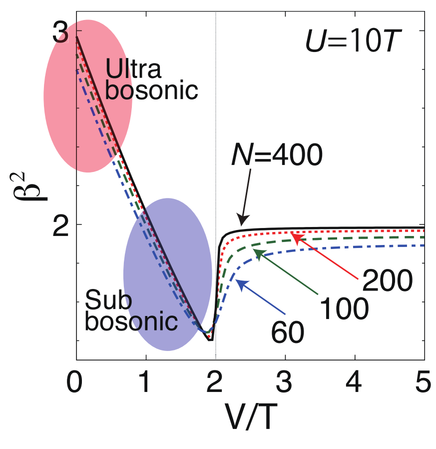

Figure 1: V/T-dependency of the enhancement factor b at U=10T. Here, U, V and T are the on-site and nearest-neighbor (n. n.) Coulombic repulsions, and n. n. transfer energy, respectively. N is the system size.

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