Pauli crystal melting in shaken optical traps

The authors consider a system of six non-interacting identical fermions confined in a two-dimensional geometry. Employing four different trapping potentials (harmonic, anisotropic, anharmonic and gaussian trap), they find that the ground state is a Pauli crystal, emerging out of the Pauli exclusion principle.

Subsequently, the fate of the Pauli crystals is investigated upon modulating the trapping frequency for the four different trapping potentials. It is found that the structures persist only in the case of the harmonic trap, whereas in the other cases the patterns fade away during time evolution. An analysis of the Floquet modes reveals that higher excitations and quasienergies are responsible for the blurring of Pauli crystals in the case of the anisotropic, anharmonic and gaussian trap. Great emphasis is put on this analysis in contrast to the energy criterion. The latter predicts that the structures should vanish as long the energy of the system increases. This is however not true in the case of the harmonic trap, where the energy increase is even larger than the respective one for the other trapping potentials.

Finally, the authors conclude that their work sheds light into the dynamical mechanisms of the Pauli crystal melting and could be useful for the creation of more robust Pauli crystals. This work aims to understand the melting process observed in the recent experiment on Pauli crystals and the results are definitely interesting. Moreover, it opens new possibilities for the study of interacting systems and the dynamical formation of patterns.

The authors have to go through however revisions of their manuscript so that several points are clarified. These points are presented in the following list.

1. What do the authors mean by higher-order spatial correlations in the excited states ? Does the higher-order refer to the excited states or to something else ?

2. The degree of anharmonicity in Eqs. (5) and (6) seems to be different. In Eq. (5) only quartic anharmonicity is taken into account, whereas in Eq. (6), which is closer to the experimental setup, higher anharmonicities contribute. Employing the same expression in Eq. (5) as well, without the anisotropy, would allow an even more direct comparison between all the potentials.

3. What confuses me is the observation of the Pauli crystal only in the configuration density. Why this structure is not visible in the one-body reduced density as well ? I would expect that some small density humps would reveal the most probable positions of a single fermion, as shown in the reference Phys. Rev. A **99**, 013605 (2019).

4. I think the presentation would be more smooth if the discussion before Eq. (7) referred to Fig. (2) instead of Fig. (3). Hence the definitions of the angular distributions and the discussion of Fig. (3) would come more natural.

5. The analysis for the six fermions is carried out beyond the Hartree-Fock method by employing 7 single-particle orbitals within the MCTDH-X method. Do the results and the overall phenomenology remain the same by accommodating the six particles into 6 single-particle orbitals ?

6. I think the caption in Table III should state explicitly that this categorization pertains to the case of 6 non-interacting fermions.

7. What is the contribution of the single-particle orbitals in the ground states presented in Fig. 4 ? Is the Pauli crystal structure observed at that level, or one has still to employ the configuration density to see these patterns ?

8. It would be maybe more useful to include the time in ms in Figs. 4, 5 and 6.

9. In Fig. 5 (a), it is shown that the recognition function of all potentials except from the harmonic one, decreases below the threshold identified from the bosonic counterpart of the fermionic system. However, it seems that for the anisotropic potential, there are revivals, and the recognition function increases well above the threshold. Is there some particular reason for that effect ?

10. I think it would be better to group figures 5 (a) and 6 together, and present figure 5 (b) separately. This particular ordering seems to fit better with the discussion in the last paragraph of Section IV A.

11. I think the sentence right after Eq. (A5) is incomplete.

12. There is a missing imaginary unit in Eq. (C1).

13. Do the authors think that this analysis would shed further light to the dynamical formation of star patterns, Faraday waves and fireworks for interacting bosonic particles ?

14. What is the variance of the single shots employed in the manuscript ? Similarly to what has been observed in Phys. Rev. Lett. **118**, 013603 (2017), can this quantity be linked to the fragmentation of the system ?

15. This question goes beyond the scope of this work, but do the authors expect a similar behavior of the dynamical melting process for a different number of fermions, e.g. three as in the experiment. Furthermore, what do the authors think about the few-to-many-body crossover ?

16. This remark also goes beyond the scope of the work. Would the authors expect Pauli crystals to form in a box potential. If so, would the melting mechanism be the same ?