Strengths

1. Evaluation of the order parameter dynamics in a disordered superconducting system.

2. Detailed investigation of the interplay between order parameter relaxation and emergence of inhomogeneities.

3. Thorough characterization of the emerging inhomogeneities

Weaknesses

1. Discussion of the clean case can be improved, see requested changes
2. Details of the computation should be specified.
3. Some of the figures are too small, see requested changes

Report

In this manuscript authors study the quench dynamics of a superconducting in real space by solving the time-dependent Bogoljubov-de Gennes equations. In contrast to the homogeneous case they find the emergence of inhomogeneities on a longer time scale which induces an exponential decay of the (averaged) order parameter oscillations.

This is an interesting paper which presents a thorough analysis of the dynamics on short and longer time scales and provides a detailed discussion of the emerging inhomogeneities, also as a function of disorder.

I believe that this paper is of significant relevance for the community and will stimulate further work in this direction. I therefore recommend publication of the manuscript in SciPost after the authors have considered the requested changes.

Our response:

We thank the Referee for their time and effort reviewing our manuscript and for their positive assessment of our work.

Requested changes

- What induces the emergence of the inhomogeneities in the clean system and what determined the corresponding time scale? There should be some "seed" which leads to the development of the inhomogeneous structures which can be either due to uncertainties in the preparation of the initial state and (or) due to the finite time step in the Runge-Kutta integration. I recommend that authors elaborate a bit more on this point. In this context authors should also specifiy the accuracy of the initial iteration and the magnitude of the time step.

Our response:

Both the unavoidable numerical error in the initial state which is obtained from the self-consistent solution of the BdG equation, and the finite time step in Runge-Kutta integration that will also induces instabilities, contribute to the seed for the inhomogeneities when we quench the system. At longer time, according to Ref. [Europhysics Letters 85, no. 2 (2009): 20004.], the parametric instabilities will induce the observed patterns. In the clean limit, the corresponding time scale depends on how sudden the system changes, which means how fast we quench the system. In the disordered case, the amplitude of the instability or the disorder determines the corresponding time scale.

The value of the finite time step for 200x200 is dt = 0.1/\Delta_0 for temperature quench and dt = 0.01/\Delta_f for coupling constant quench. For other smaller system sizes, we use a smaller time step dt=0.01/\Delta_0. We checked dt = 0.1/\Delta_0 and dt = 0.01/\Delta_0 with the BCS approaches, and found that the results are the same in the time scale that we can study.
The numerical error for the initial input is 10^{-16}, which is the maximum numerical accuracy of our calculation.

We have discussed more about this point and specified the initial iteration and the magnitude of the time step in the updated manuscript in section II at page 4.

- Please enlarge Figs. 1,3,5

Our response:
Thanks for the suggestion. We have enlarged Figs. 1,3,5 in the updated manuscript.

- I would guess that most readers (including myself) associate with "quench" a reduction of the interaction parameter. While authors specify on page 4 that they consider a temperature quench (and they also state that quenches in the interaction lead to quantitatively similar results) it would nevertheless be clearer if from the beginning (including the abstract) the term "temperature quench" would be used.

Our response:
We thank the referee for the suggestion. However, we studied both temperature and coupling constant quench protocols, and different lattice structures, and found quantitatively similar results. We expect that the pattern formation is robust to different quench dynamics protocols. Therefore, we think the use of temperature quench might be too limited and potentially confusing. We prefer to keep using “quench” in certain cases if it refers to features that occur for both quenches.