Electric Field Quench in AdS/CFT†

K. Hashimoto,[*1,*2] S. Kinoshita,[*3] K. Murata,[*4] and T. Oka[*5]

In this paper, we analyze response of the strongly coupled gauge theory against an electric field quench, by using the AdS/CFT correspondence. The system is $\mathcal{N}=2$ supersymmetric QCD with $\mathcal{N}=4$ super Yang-Mills as a gluon sector, and has a confining spectrum for the meson sector (while the gluon sector is always deconfined). We turn on the electric field in a time-dependent manner, and find that the system develops to a deconfinement phase of mesons.

We study time-dependent behavior of various observables such as electric current carried by the quarks and the quark condensate. We define the thermalization time scale and the deconfinement time in terms of the gravity dual side: the thermalization is with the Hawking temperature, and the deconfinement is with the strong redshift.

Among our findings, the most interesting is the fact that the deconfinement transition of the mesons occurs even with a small electric field once it is applied time-dependently. In the static electric field, there exists a critical value of the electric field beyond which the electric current flows and the system is deconfined. In our time-dependent quench, if the quench is made sufficiently fast, even with a final electric field which is smaller than the critical value, the system goes to a deconfinement phase — there appears a strong red shift region in the gravity dual.

In the dual gravity picture, this phenomena can be understood as the D-brane version of the weakly turbulent AdS instability. The wave packet on the D-brane is getting sharp as time increases and, eventually, collapses into the naked singularity. Accordingly, we also found a curious behavior of the deconfinement time — the time scale when a strong redshift region appears on the D7-brane. The deconfinement time takes only discrete values.

Furthermore, the potential implication of the present study of nonequilibrium dynamics in QCD to strongly correlated electron system is suggestive. Then, it is tempting to speculate that the formation of naked singularity explained in the previous section is an indication of the "meson Mott transition", i.e., the QCD version of the exciton Mott transition. We plot a schematic phase diagram obtained by this analogy in Fig. 1 with three regions (i), (ii), and (iii).

(i) Confinement phase with coherent oscillation. When the field is weak, the system is always in the confinement phase. However, when the ramp speed is fast (small ΔV), the field induces a coherent oscillation of vacuum polarization due to meson excitation.

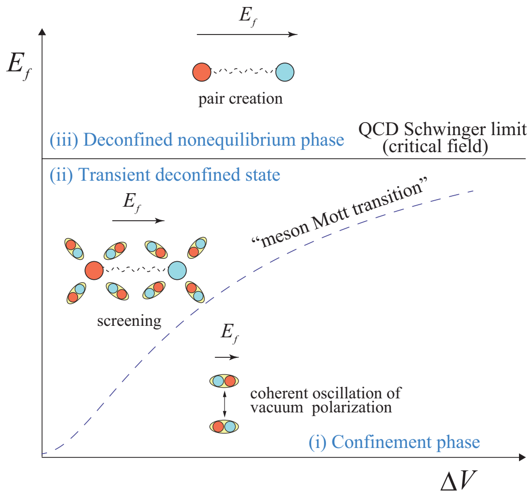

Fig. 1. Schematic "dynamical phase diagram" of states realized in the present study by a static electric field E_f following an initial ramp (parametrized by the time parameter ΔV). See text for details.

(ii) Transient deconfined phase ("meson Mott transition"). This is the speculated "meson Mott transition" regime. When the meson amplitude becomes large, the confinement force becomes relatively weak due to screening. The quarks become liberated and deconfinement takes place in the meson (quark) sector.

(iii) Deconfined nonequilibrium phase above QCD Schwinger limit. When the electric field is stronger than the confining strength (= QCD Schwinger limit), the confinement phase becomes unstable against direct pair creation of quark and antiquarks.[1)]. This state is a static nonequilibrium phase with finite current.

In summary, by studying the dynamics of supersymmetric QCD in strong electric fields, we observed many interesting, and universal nonequilibrium physics. Our finding implies similarities between possible formation mechanism of quark gluon plasma in heavy ion collision experiments to laser induced phase transitions in condensed matter, which helps us understand the physics more deeply.

References

1) K. Hashimoto and T. Oka, JHEP **1310**, 116 (2013) [arXiv:1307.7423].

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*1 RIKEN Nishina Center
*2 Department of Physics, Osaka University
*3 Osaka City University Advanced Mathematical Institute
*4 Keio University
*5 Department of Applied Physics, University of Tokyo