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Initial value problem in the case of multivalued dispersion equations

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Dispersion equations and relations are the key subjects of linear theories involving waves and collective excitations. However, in some systems, dispersion equations contain multivalued functions and their solutions are ambiguous. To resolve such uncertainty we suggest analyzing the initial value problem that gives the unambiguous solution.
As an example, we considered the excitation of the Dirac plasmons in graphene on a polar substrate and analyzed a strong coupling between plasmons in graphene and surface optical phonons of the substrate. Due to square-root singularity in graphene polarizability [1], the dispersion equation for this system contains branch points on the plane of complex frequency, ω. The use of the initial value problem gives a unique solution and clarifies the physical picture of coupled oscillations. Particularly, we found that lower plasmon-phonon mode, which in terms of dispersion can have a good quality factor, is almost absent in excitation spectra. The main physical reason for the mode collapse is the suppression of space-time-dependent electric fields near $\omega = v_F k$, where v_F is the Fermi velocity and k is the plasmon wavenumber [2]. The evidence of the collapse can be seen in the relevant experiments [3, 4].

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