On unitarity of the particle-hole dispersive optical model

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The particle-hole (p-h) dispersive optical model (PHDOM) was developed recently to describe simultaneously the main relaxation modes of high-energy (p-h)-type excitations in medium-heavy mass spherical nuclei. These modes include the p-h strength distribution (Landau damping), coupling to the single-particle (s-p) continuum and to many-quasiparticle configurations (the spreading effect). The model, formulated with the use of the Fermi-system Green functions, is, actually, an extension of the continuum-RPA version to the description (phenomenological and in average over the energy) of the spreading effect. This effect is considered in terms of the specific p-h interaction (polarization operator, or p-h self-energy term) responsible for the spreading effect. After energy averaging, the strength of this interaction is properly parameterized to satisfy a statistical assumption concerned with independent spreading of different p-h states. This allows one to get in a closed form the expression for the PHDOM basic quantity – the "free" p-h Green function (p-h response function, or p-h propagator). Being the direct extension of the discrete-RPA p-h propagator, this expression contains the imaginary and real parts of the strength of the energy-averaged p-h self-energy term. The imaginary part determines the real one via the proper dispersive relationship, which follows from the spectral expansion of the 2p-2h Green function (2p-2h configurations are the doorway-states for the spreading effect). The "free" p-h propagator corresponds to the model of non-interacting independently damping quasiparticles. Within the PHDOM, the s-p continuum is taken into account with the use of an approximate spectral expansion for the Green function of the Schrodinger equation involving the imaginary and (dispersive) real additions to the mean field. The imaginary part of the combined s-p potential is relatively small (as compared with the imaginary part of the potential used for the optical-model description of nucleon-nucleus scattering) due to a (destructive) interference between the spreading effect on particles and holes.

The methods used within the PHDOM for the description of the spreading effect lead to weak violations of the model unitarity. The sources of unitarity violations are an energy dependence of the energy-averaged p-h self-energy term, and also the above-mentioned approximate spectral expansion of the optical-model Green function. Unitarity violation within the s-p optical model due to the mean-field energy dependence is discussed in Ref. [1]. The signatures of unitarity violations within the PHDOM are the appearance of: (i) nonzero values (markedly larger than uncertainties of numerical calculations) of the spurious strength function, corresponding to the unit external field; (ii) small negative values of the strength function of the isoscalar giant monopole resonance (ISGMR) at the energies much larger than the ISGMR energy. The last effect leads to an underestimation of the total ISGMR strength.

In this work [2], we investigate weak unitarity violations within the particle-hole dispersive optical model and propose a method for unitarity restoration by modifying the optical model green functions following the method of Ref. [1]. The method is illustrated by consideration of the isoscalar monopole excitations in the ^{208}Pb nucleus. In particular, we study the energy-averaged isoscalar monopole double transition density and strength functions in a wide excitation-energy interval that includes the isoscalar giant monopole resonance (ISGMR) and its overtone (ISGMR2).

In Fig. 1, the relative strength functions, $y_i^R(\omega)$, calculated within the PHDOM-UV for the ISGMR is given in a comparison with the respective quantities obtained within the PHDOM initial version. These results can be considered as an evidence of weak violation of model unitarity. Nevertheless, restoration of model unitarity allows one, in particular, to eliminate negative values of the ISGMR relative strength function.

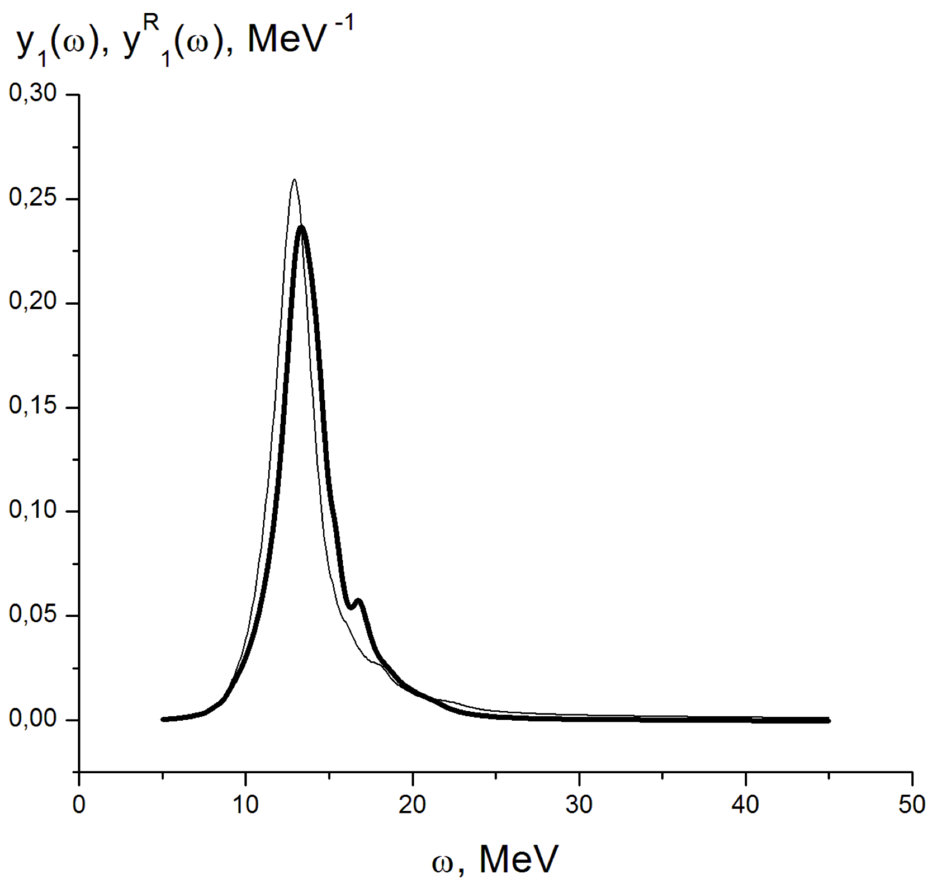

FIG. 1. The relative energy-weighted strength functions calculated for the ISGMR in ^{208}Pb within the initial $\boldsymbol{y_1}(\omega)$ (thick line) and unitary $\boldsymbol{y_i^R(\omega)}$ (thin line) versions of the PHDOM.

[1] S. Shlomo, V.M. Kolomietz, and H. Dejbakhsh, Phys. Rev. C **55**, 1972 (1997).

[2] M.L. Gorelick, S. Shlomo, B.A. Tulupov, and M.H. Urin, to be published.