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Tribute to Vladimir Chernyak

It gives me great pleasure to write these introductory comments for the special issue honoring Vladimir Chernyak upon his 60th birthday.

Vladimir is a truly remarkable scholar with unusual technical talents and physical insights. The overarching theme characterizing Chernyak's work is developing methods of many-body nonequilibrium statistical mechanics and applying them to treat a diverse set of challenging problems in chemical physics, optics, spectroscopy, networks, algorithms, and optimal control. He had made many novel and creative contributions in broad areas of mathematical physics, chemical physics, field theory, topology, nonequilibrium statistical mechanics, many-body theory, and molecular quantum electrodynamics. His bird's eye view of complex physical systems had allowed him to connect different areas of science and simplify complex dynamical processes at the very fundamental level. He has an unusual ability to break complex problems into their most elementary pieces and come up with novel and general interpretations of experimental observables.

Chernyak belongs to a rare breed of theoreticians who combine thorough formal and analytical skills with the ability to connect to experiments and his work has had a tremendous impact.

Chernyak received his Ph.D. from the USSR Academy of Sciences working on many-body theoretical problems related to optical spectroscopy of surfaces. When working in the USSR Academy of Sciences and National Bureau of Standards he made important contributions to quantum integrable dynamical systems with applications to resonant optics, weak and strong localization of light in disordered systems, and propagation of light in systems with rough boundaries.

I was most fortunate to work with him as a research associate at the University of Rochester from 1993 to 2000 and to continue our collaborations ever since. His penetrating depth and rigor were instrumental for developing the nonlinear response formalism of multidimensional spectroscopy. In addition, he had made profound contributions to fluctuation theorems and statistical mechanisms of nonequilibrium states. He developed a theory for the electrodynamics of confined excitons, which lays the foundation for the systematic and consistent treatment of interatomic forces and retardation in nonlinear optical spectroscopy of molecular nanostructures. His work resulted in a novel microscopic algorithm for computing optical response functions which can treat conjugated-molecules, semiconductors, and molecular and metallic nanostructures within the same framework. It also provides a unified picture for many important effects which are usually introduced phenomenologically such as local fields, cascading, superradiance, polaritons and exciton transport. He further discovered some very profound generalizations of density functional theory to nonequilibrium systems. These are most valuable in the calculations of optical properties of large molecules and materials. Chernyak had rigorously identified the relevant coherence sizes underlying different measurements in femtosecond spectroscopy of photosynthetic antenna complexes. He developed fruitful collaborations at Los Alamos and continued to make highly original contributions in the field of photonic materials. Chernyak has further made important contributions to non-adiabatic dynamics in molecules, including semiclassical density matrix theory of conical intersections and a method computing non-adiabatic couplings via TDDFT. Dendrimeric molecules with branched tree-like structure show unusual transport and optical properties, stemming from their peculiar dimensionality: Together with Sergei Tretiak he had developed an elegant exciton scattering formalism that allows to create optical excitations of conjugated molecules and dendrimers out of small segments properly presenting the coherence. An important consequence of that study was the ability to dissect the electronic excitations of dendrimers into distinct chromophores, despite the delocalized nature of the underlying electronic states. The approach provides a natural framework for the design of supramolecular structures such as artificial light-harvesting antennae with controlled energy funneling pathways, and allows exploring the coherent coupling among different segments.

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Another notable contribution has been the development of a series of algorithms, based on quantum field theory that allow efficient approximate computations for statistical models that reside on irregular lattices/graphs/networks. His topological view of stochastic currents in driven systems had led to building an extension of optimal stochastic control theory, as well as establishing a variety of general and exact relations that fall into a category of fluctuation theorems, e.g., pumping restriction and pumping quantization theorems, including many-particle effects in open networks, providing insights into, e.g., robust performance of molecular motors.

This volume is timely tribute to Chernyak's widely felt impact on science and the many past and ongoing collaborations he has made. We all wish him many more productive and successful years.

Shaul Mukamel
Department of Chemistry, University of California, Irvine, USA
E-mail address: smukamel@uci.edu