Condensed Matter/ Biophysics Seminar

A multiscale approach to the physics of ion-beam cancer therapy

Prof. Eugene Surdutiovich
Oakland University, Rochester, MI

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The scientific interest in obtaining a deeper understanding of radiation damage is motivated by the development of ion-beam cancer therapy and other application of ions interacting with biological targets. A number of important scientific questions, especially related to DNA damage assessment on the molecular level, have not yet been resolved. Therefore, this field has attracted much attention from the scientific community, atomic and molecular physics in particular. Among these studies is the multiscale approach to the assessment of radiation damage induced by irradiation with ions. It is aimed at a phenomenon-based quantitative understanding of the scenario from the incidence of an energetic ion on tissue to the cell death. This method combines many spatial, temporal, and energy scales, and is therefore a truly multiscale approach.

The multiscale approach raises questions about the nature of the effects that take place and lead to survival curves and the calculation of relative biological effectiveness and other macroscopic quantities. The main issues addressed by the multiscale approach are ion stopping in the medium, the production and transport of secondary electrons produced as a result of ionization and excitation of the medium, the interaction of secondary particles with biological molecules, the most important being DNA, the analysis of induced damage, and the evaluation of the probabilities of subsequent cell survival or sterilization.

The milestones in the development of the multiscale approach were the calculations of the Bragg peak, the estimation of DSB yield by secondary electrons, assessment of the complex DNA damage, and the obtaining of survival curves. A special investigation was devoted to DNA damage as a result of thermo-mechanical effects caused by ions. These effects can be described as a dynamical change in temperature and pressure in the medium, due to ions passage, causing forces that may rupture bonds in DNA molecules. The understanding of such a possibility evolved from the estimates of the temperature increase in the medium as a result of ion propagation to the analysis of thermal and pressure spikes in liquid water and further to the analysis of the shockwave in the medium and its effect on biomolecules.

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