ABSTRACT

Ultra-fast x-ray matter interaction

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Free electron x-ray lasers will soon produce extremely high-intensity, ultra-short pulses of coherent, monochromatic radiation in the 1-30 keV energy range. The realization of these sources will open the door to detailed research in new areas of radiation-matter interaction. The interactions are expected to have both desirable and undesirable effects. Even in an unfocused beam of an x-ray free electron laser, the interaction may damage the optical components necessary for studying and controlling the output. When focused, the x-ray laser pulses will be capable of producing high temperature multiply ionized dense plasmas. This will enable the creation and study of novel states of matter, such as "warm dense matter," in a controlled manner never before possible. Ultrafast pulses can also be used to image single nm-sized objects such as biomolecules if the pulses are shorter than the time for x-ray damage to alter the structures.

Theoretical methods that are being developed to predict and understand the physics of short pulse x-ray material interaction are described. The basic physical phenomena are presented, beginning with the absorption of x rays and followed by the transport and cascade of photo- and secondary electrons, the coupling of electron energy to atoms and ions, and the bulk thermal and hydrodynamic effects. Computer modeling techniques, including Monte-Carlo, molecular dynamics, and continuum dynamics methods are described. We discuss theoretical analysis of the damage mechanisms for x-ray optical components, and present guidelines for the maximum dose to various materials and implications for the design of optical components. Finally, we summarize results of recent experiments on ultrafast radiation-matter interaction using the FLASH short wavelength free electron laser in Hamburg.

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