The invention of the first laser in 1960 has been followed by a successive series of shorter-wavelength lasers. The shortest wavelength coherent radiation realized so far is about 4.5 nano-m, in the x-ray region. After developing the excimer, free electron, and soft x-ray lasers, scientists have now become interested in producing coherent gamma-rays. This has been considered to be one of the two dozen most important problems in physics and astrophysics today (Physics Today, May 1990, p.9). The key to developing a gamma-ray laser lies in an interdisciplinary approach and involves the knowledge of various branches of physics and engineering.

The thesis basically consists of two parts. Chapters 2 to 6 summarize the current work on the development and applications of the x-ray and gamma-ray lasers. Chapters 7 and 8 deal with our original work on the interaction of charges and dipoles with gamma-ray lasers.

In chapter 2 we first briefly review the steps taken for the development of soft x-ray lasers. We then discuss
the ideas for the further development of shorter-wavelength x-ray emission. At the end of this chapter, we mention a few proposed applications of x-ray lasers.

In chapters 3, 4, and 5 we concentrate on the development of gamma-ray lasers. At present their feasibilities are predicted either through nuclear transitions (Chapters 3 and 4) or through electron and positron beams (Chapter 5). It is a general feeling, that atomic transitions may not lead to the generation of coherent radiation in gamma-ray region, and nuclear transitions seem more promising.

Chapter 3 deals with the basic features of gamma-ray lasers based on nuclear transitions. Section 3.1 discusses their essential requirements, viz. the inversion density and cross-section for stimulated emission, and bandwidths of the involved energy levels. In section 3.2 we discuss the different transition possibilities and systematically explain the problems appearing with the nuclear transitions.

In chapter 4, we review all major proposals given by different authors for developing a gamma-ray laser based
on nuclear transitions. First we briefly discuss the possible approaches for achieving population inversion in a nuclear excited state. At present, the two-step pumping mechanism seems to be the best, which is presented in section 4.1. In the first of these steps, the population is to be stored in an isomeric state. The second step is to transfer this stored population to another level that can lead to lasing. This step can be performed either through optical pumping or through the electronic excitations, which are discussed in sections 4.2 and 4.3, respectively. In section 4.4, we review the steps for the search of appropriate material suitable for gamma-ray lasing. It is expected that for developing such a device one has to first isolate sufficiently pure isomeric nuclei of the appropriate candidate. Section 4.5 deals with the nuclear isomer separation problems. It also lists the up-to-date experiments performed by different groups. After discussing the population inversion in an upper laser level in sections 4.1 to 4.5, the nuclear superradiance is discussed in section 4.6. This process is supposed to be a viable lasing process in the case of gamma-ray lasers.

Chapter 5 reviews the gamma-ray laser proposals based either on electron or electron and positron beams. In
analogy to the development of free electron lasers, section 5.1 deals with the possibility of coherent gamma-rays through an inverse Compton effect in an interfering geometry of two laser beams. Section 5.2 reviews the proposals given on the basis of electron and positron beams, viz. the induced annihilation of para-positronium atoms and the relativistic electron-positron gamma-ray laser. At the end of this chapter, in section 5.3, we mention few other ideas based on electron beams.

It is a human propensity to speculate the possible applications of an under-developed instrument. Similarly, in the case of gamma-ray lasers, people have started to foresee the possible applications. Chapter 6 gives a comprehensive collection of their applications in science and industry.

Chapter 7 deals with the problem of interaction of an electron with a gamma-ray laser beam. Although it is a model calculation of the problem, it yields very interesting results. Subsection 7.2.1 classically reviews the charge particle dynamics in the electromagnetic field of a plane wave. Under the dipole approximation, the radiation field generated by the laser may be treated as a
plane wave if its wavelength is larger than the charge particle mean free path. Subsection 7.2.2 describes, quantum mechanically, the behaviour of an atomic electron inside the laser field. It also describes the experimental investigations of this behaviour. In sections 7.3 and 7.4 we present a model calculation of our own for the interaction of an electron with a gamma-ray laser beam. Our results indicate interesting physics in the form of either reflection or transmission or trapping of the electron for large times. However, our approach is based on a model calculation and the complete solution to the problem requires the introduction of some other effects. As discussed in section 7.5, the conclusion part of this chapter, our results are not expected to be washed out in a more realistic calculation.

In chapter 8, we present a short generalized treatment for the interaction of an electric dipole with a plane electromagnetic wave gamma-ray laser beam of a finite diameter. It is found that the dipole may either be unaffected or can rotate without affecting its translational motion or may rotate with either accelerated or decelerated motion.