

Preface

Directed energy weapons are nothing new to mankind; historically the origination of such weapons began centuries ago when the famous Greek mathematician, physicist, engineer, inventor, and astronomer; Archimedes of Syracuse used different mirrors to collect sunbeams and focused them on the Roman fleet in order to destroy enemy ships with fire. This is known as the Archimedes Heat Ray. Archimedes may have used mirrors acting collectively as a parabolic reflector to burn ships attacking Syracuse. The device was used to focus sunlight onto approaching ships, causing them to catch fire. Of course the myth or reality of the Archimedes Heat Ray still is questionable, but with the help of a group of students from Massachusetts Institute of Technology certain experiments were carried out with 127 one-foot (30 cm) square mirror tiles in October of 2005 that were focused on a mockup wooden ship at a range of about 100 feet (30 m). The flames broke out on a patch of the ship, but only after the sky had been cloudless and the ship had remained stationary for around 10 min. It was concluded the device was a feasible weapon under these conditions.

The battles of tomorrow will be fought with different weapons that have more lethal effects and faster delivery systems. One of mankind's greatest achievements in the twentieth century is the ability to destroy the entire human race several times over. At this time of intensive arms more money is invested in the next generation of weapons. It is in the best interest of every citizen to be aware and able to make an informed judgment on the best possible direction for the arms race. Offensive or defensive weapons are a cruel reality that nevertheless must be addressed.

The scientific work during the 1950s that led to the invention of the laser was followed closely by work in military research institutes and organizations all over the world and this opened a new door to the Archimedes Heat Ray. Lasers have found many military applications, not as new weapons, but rather as the supporting technology to enhance the performance of other weapons such as laser-guided bombs and so on. Our fascination and appreciation of modern weaponry is at an all-time high. It was not until the 1970s that the possibility of laser weapons again

captured the imagination of military planners. High-energy and other directed energy weapons finally became a reality, and the possibility of using them in the battlefields of tomorrow has been investigated vigorously ever since.

The development of laser weaponry and other directed energy weapons technology conjures up the Heat Ray of Archimedes and Flash Gordon-like images of vaporizing enemies, demolishing buildings, and burning through metal. In this book introduces such weaponry to readers of different technical backgrounds as well as to introduce a certain technical approach to such research and to help better understanding of such weapons utilizing various technical and research resources.

The next 10 years will see the emergence of high-energy lasers as an operational capability in US service. These weapons will have the unique capability to attack targets at the speed of light and are likely to impair the effectiveness of many weapon types significantly, especially ballistic weapons. Constrained by propagation physics, these weapons will not provide all-weather capabilities, and will perform best in clear sky—dry air conditions.

The book in its laser technology section talks about the interaction between high-power laser beams and matters whereas other aspects of directed energy weapons, such as particle and high-power radar beams as a weapons of tomorrow can be found in the literature provided by other authors. Laser-beam interactions with materials, treat, from a physicist's point of view, the wide variety of processes that lasers can induce in materials. Physical phenomena ranging from optics to shock waves are discussed. The approach that is taken emphasizes the fundamental ideas both from a newcomer's or research worker's point of view to provide important background for material science, mathematics, optics, and the like, or a most critical up-to-date review of the field.

A directed energy weapon (DEW) such as a high-energy laser emits energy in an aimed direction without the means of a projectile. It transfers energy to a target for a desired effect. Some such weapons are real or in development; others are at present only in science fiction.

The energy can come in various forms:

- Electromagnetic radiation (typically lasers or masers)
- Particles with mass (particle beam weapons)
- Sound (sonic weaponry)
- Fire (flamethrowers)
- High-power laser weapons

Some lethal directed energy weapons are under active research and development, but most examples appear in science fiction, nonfunctional toys, film props, or animation.

In science fiction, these weapons are sometimes known as death rays or ray-guns and are usually portrayed as projecting energy at a person or object to kill or destroy. Many modern examples of science fiction have more specific names for directed energy weapons, due to research advances.

For those readers who need to dive deep into the technologies behind such research a short course in various topics of mathematics and physics has been offered in the appendices in order for them to brush up on these topics and be able to understand different solutions and mathematical modeling that are offered for the solution, for example, of the heat diffusion equation for different boundary and initial conditions. In the case of application of lasers as weapons, the book has attempted to serve both scientists interested in the physical phenomena of laser effects and engineers interested in practical applications of laser effects in industry. Thus, several sections are devoted to reviewing and dealing with the solution of the diffusion equation utilizing the aid of integral transform techniques. Among the several different approaches to solve the boundary value problems for heat conduction; the integral transform technique offers the most straightforward and elegant solution, provided that the transforms, the inversions, and the kernels are readily available.

Some appendices at the end of the book are devoted to systematic mathematics and physics of the heat conduction solution and its boundary value problems. As a result of the transforms, the inversions, complex variables, and their examples are presented and the kernels are tabulated, and the Laplace and Fourier transforms are also introduced. The appendix on introduction to ordinary and partial differentials is also presented to help the reader understand the solution techniques used to solve the heat conduction problem for various boundary values. Appendices on optics and the electromagnetic field also help better understanding of the behavior of the physics and mathematics of these weapons.

Note: In most of the appendices of different topics either the references mentioned at the end of each appendix have been used and quoted directly or indirectly or it is up to each reader to refer to them separately for more knowledge and information. I have also decided to shift these appendices around by eliminating some of their content that I believe is no longer necessary, as well as converting some content into part of the main chapters of different subjects of Volume II here and finally keeping the rest as appendices as originally planned.

Those left as an appendix of their own for those readers needing some refresher and review on the topics that are presented by these appendices are:

Appendix A: Short Course in Taylor Series

Appendix B: Short Course in Vector Analysis

Appendix C: Short Course in Ordinary and Partial Differential Equations

Appendix D: Short Course in Complex Variables

Appendix E: Short Course in Fourier and Laplace Transforms

Appendix F: Short Course in Electromagnetics

Appendix G: Short Course in Optics

Appendix H: Short Course in Heat Conduction Equation

Appendix I: Data and Plots of Thermal Parameters of Different Materials

Appendix H: Acronyms and Definitions

In this book, I have also taken under consideration to show the solutions and present the heat conduction complex problem and those boundary values that are very much related to problems of high- power laser interaction with materials. Most cases have looked at one-dimensional heat conduction with semi-infinite slab configuration with a heat resource as part of heat conduction equations making dealing with it a more difficult and complex problem. Wherever was needed the best possible references were given for further investigations by readers interested in doing their own research beyond what is given here.

Albuquerque, NM

Bahman Zohuri

Directed Energy Weapons

Physics of High Energy Lasers (HEL)

Zohuri, B.

2016, XX, 816 p. 171 illus., 39 illus. in color., Hardcover

ISBN: 978-3-319-31288-0