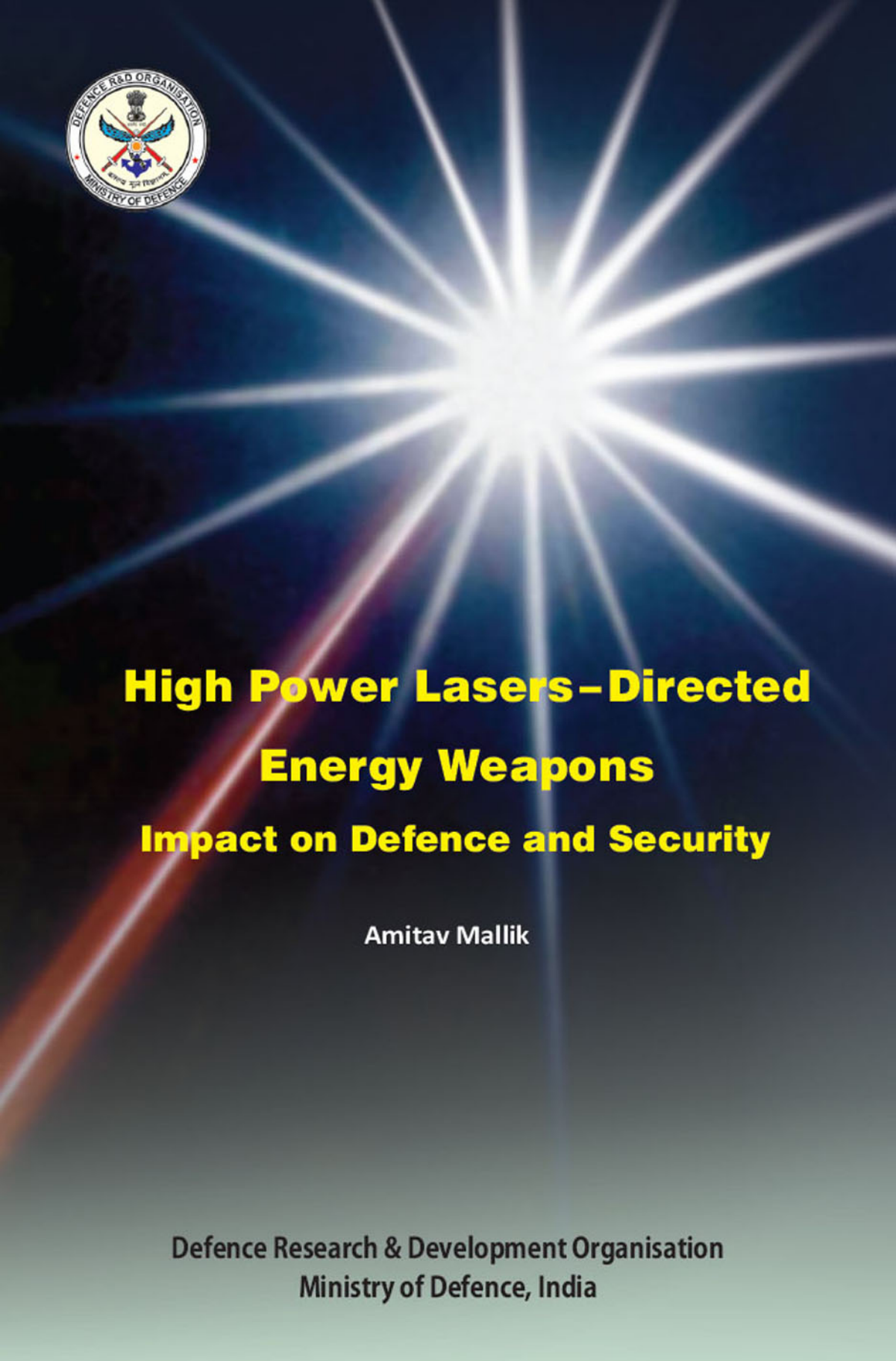

High Power Lasers – Directed Energy Weapons

Impact on Defence and Security

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Defence Research & Development Organisation
Ministry of Defence, India

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Preface

Laser technology has been one of most fascinating discoveries of the 20th century. The laser device is unique in many ways, the most striking aspect being its extraordinary brightness. This has caught the imagination of mankind towards realisation of the ultimate 'death ray' weapon that could outmatch all other weapons. Directed energy weapons (DEW) using high power lasers (HPL) have indeed arrived and are about to make a major impact on the strategies for future wars and on the ways technological deterrence will play an important role in avoiding future wars.

Directed energy weapons using HPL are a new generation of weapons that travel at the speed of light with unprecedented accuracy. This has opened up very interesting applications hitherto not possible with conventional technologies. Worldwide R&D in HPL–DEW has demonstrated many successful tests to establish the technology with its promising potential for the future of defence and security.

The aim of this monograph is to present an overview of this fascinating technology in all its dimensions in simple language, so that this serves as an easy reference for the highly complex subject that combines several disciplines to bring the science fiction like concepts into real-life applications. The other focus of the monograph is to present an analysis of the strategic impact of HPL–DEW in the context of strategic missile defence and space security that may significantly affect the perceptions of deterrence in the world power balance equations.

The narrative is divided into seven chapters; the first four chapters giving an introduction to the subject and the HPL–DEW technology, and the fifth chapter discussing defence applications. The last two chapters present the strategic implication and a quick recap of HPL–DEW technology including Indian perspective.

Much of the matter in this monograph is from the author's own notes and his long experience in HPL technology. This monograph is not intended as a reference textbook but is oriented to add to the understanding of HPL–DEW as a weapon and bring out its impact on defence and security.

August 2012 Amitav Mallik

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My special thanks go to my friend and associate Dr BS Patel, for agreeing to review the manuscript and give valuable suggestions.

I write this monograph with many warm memories of all my colleagues and friends in the high power laser technology field, without whom the success achieved a decade ago at Laser Science and Technology Centre, Delhi would not have been possible.

Amitav Mallik

List of Acronyms

ABL	airborne laser
ABM	anti-ballistic missile defence
ADS	active denial system
AEL	accessible emission limits
ALL	Airborne Laser Laboratory
ALPS	auto-laser pointing system
ALTB	airborne laser testbed
AOS	adaptive optical system
ARL	Air Force Research Laboratory
A-SAT	anti-satellite
ATDC	advanced technology concept demonstrator
ATL	airborne tactical laser
ATP/FC	acquisition, tracking, pointing and fire control
AWACS	airborne warning and control system
BILL	Beacon illuminator
BMD	ballistic missile defence
BMDO	Ballistic Missile Defence Organisation
BMDS	ballistic missile defence system
BMS	battle management system
C-CLAW	close combat laser weapon
CCD	charged couple device
CD	combustion driven
CL	chemical laser
CNC	computer numerical control
COIL	chemical oxygen iodine laser
CTA	caesium titanyl arsenate
CW	continuous wave

DAE	Department of Atomic Energy
DARPA	Defense Advance Research Project Agency
DEW	directed energy weapons
DF	deuterium fluoride
DFG	difference frequency generation
DIRCM	directional infrared countermeasure
DOD	Department of Defense
DPSSL	diode-pumped solid state laser
DRDO	Defence Research and Development Organisation
DScC	Defence Science Centre
DST	Department of Science and Technology
EDFA	erbium-doped fibre laser
EMP	electromagnetic pulse
EOCM	electro-optics countermeasure
ERL	energy recovery linac
FALCON	fission activated laser concept
FDA	Food and Drug Administration
FEL	free electron laser
FOV	field-of-view
FWHM	full width at half-maximum
GDL	gas dynamic laser
GSGG	gadolinium scandium gallium garnet
HAZ	heat affected zone
HCL	heat capacity laser
HCSSL	heat capacity solid state laser
HEL	high energy laser
HELEX	high energy laser experimentale
HELLFIRE	helicopter-launched fire and forget
HELSTF	high energy laser system test facility
HPFL	high power fibre laser
HPL	high power laser
HPM	high power microwaves
HYLTE	hypersonic low temperature
HYWN	hypersonic wedge nozzle
IAF	Indian Air Force
ICBM	intercontinental ballistic missile

ICT	information and communication technology
IDF	Israel Defense Force
IR	infrared
IRCM	infrared countermeasure
ISRO	Indian Space Research Organisation
JHPSSL	joint high power solid state laser
KTP	potassium titanyl phosphate
LAMP	large advanced mirror programme
LASER	light amplification by stimulated emission of radiation
LASTEC	Laser Science and Technology Centre
LATEX	Laser Associe'A une Tourelle Experimentale
LDS	laser dazzle sight
LED	light emitting diode
LGB	laser guided bomb
LIDAR	light detection and ranging
LIPC	laser induced plasma channel
LLLGB	low level laser guided bomb
LLNL	Lawrence Livermore National Laboratory
LODE	large optics demonstration experiment
LODR	laser orbital debris removal
LOS	line-of-sight
LPB	laser power beaming
LRAD	long range acoustic device
LRF	laser rangefinder
LTB	lithium tri-borate
MAD	mutually assured destruction
MANPAD	man-portable air-defence systems
MARTI	missile alternative range target instrument
MDA	Missile Defense Agency
MIRACL	mid-IR advanced chemical laser
MIRV	multiple independent re-entry vehicle
MPE	maximum permissible exposure
MTCR	Missile Technology Control Regime
MTHEL	mobile THEL
MTV	mobile test vehicle
NACL	navy ARPA chemical laser

Nd:YAG	neodymium-doped yttrium aluminium garnet
Nd:YLF	neodymium-doped lithium yttrium fluoride
NMD	National Missile Defense
NRL	Naval Research Laboratory
OPC	optical phase conjugation
OPO	optical parametric oscillator
OTV	orbital space vehicle
PCM	phase conjugate mirror
PDFFA	praseodymium-doped fluoride fibre amplifier
PDRR	programme definition and risk reduction
PEP	pulsed energy projectile
PGM	precision-guided munition
PGMM	precision-guided mortar munition
PLA	People's Liberation Army
PRC	People's Republic of China
PRS	pressure recovery system
PTS	pointer tracker system
RAM-D	rocket, artillery and mortar defence
RFNC	Russian Federal Nuclear Center
RLG	ring laser gyro
RMA	Revolution in Military Affairs
R_2P_2	rapid retargeting and precision pointing
RPL	reactor pumped laser
RPV	remotely piloted vehicle
RTA	rubidium titanyl arsenate
RTP	rubidium titanyl phosphate
SADAG	sequential discharge acoustic generator
SASE	self amplified spontaneous emmission
SBL	space-based laser
SBL-IFX	space-based laser integrated flight experiment
SDI	strategic defense initiative
SDIO	Strategic Defense Initiative Office
SHG	second harmonic generation
SFG	sum frequency generation
SLAC	Stanford Linear Accelerator Center
SLBD	sea lite beam director

SLR	satellite laser ranging
S/N Ratio	signal/noise ratio
SOG	singlet oxygen generator
SPICE	space pointing integrated control experiment
SRS	stimulated Raman scattering
SSDC	space and strategic defense command
SSHCL	solid state heat capacity laser
SSL	solid state laser
SSRL	Standford Synchrotron Radiation Laboratory
TEA	transversely excited atmosphere
THEL	tactical high energy laser
TILL	track illuminator
TOW	tube-launched, optically-tracked, wire command data link
UAV	unmanned aerial vehicle
UCLA	University of California, Los Angeles
YLR	ytterbium fibre laser
WMD	weapon of mass destruction

Chapter 1

Directed Energy Weapons: An Introduction

1.1 DIRECTED ENERGY WEAPONS FOR DEFENCE AND SECURITY

The progress of science and technology has been closely linked to man's pursuit of electromagnetic spectrum towards higher frequencies as this has opened up new application potentials and enabled new capabilities for defence and security. After the early days use of radio frequency for communication, radar and microwaves have opened up new avenues related to defence applications. Today, the decisive impact of technology on war and peace is much more pronounced than ever before. As we commence the 21st century, the perceptions of military might and defence preparedness are changing significantly as compared to the last century which was dominated by cold war.

The cold war era was dominated by nuclear weapons and missile technology. More recently, satellite surveillance, information communication technologies (ICT), and precision strike capabilities have transformed the strategic doctrines for defence and security around the world. Thus, 21st century is likely to be influenced by technologies that can either complement these capabilities or create new capabilities that can out-match the winner technologies of the 20th century.

While information technology and space technology are proving to be major enablers for modern network centric warfare, another new technology emerging clearly as critical for 21st century is directed energy weapons (DEW). Sustained R&D over past three to four decades and successful tests after overcoming many hurdles and problems, have led the technology to a state of maturity that is likely to enable deployment of new generation beam weapon systems. While high power lasers (HPL) and high power microwaves (HPM) have emerged as the two main options for the DEW technology, HPL technology has progressed rapidly and has a clear advantage for long-range military applications. Directed energy weapons are revolutionary in nature and thus have the potential to significantly influence the international power balance in the 21st century.

Electromagnetic energy is known to travel at the speed of light to reach long distances in a split second, and this aspect has always fascinated human mind over the ages. One of the first uses of such energy against enemy was the use of mirrors by Greek warriors to reflect sun rays into the eyes of the enemy to blind them before attacking them.

One is of course familiar with the mythological tales of the third eye of 'Lord Shiva' (Indian deity) that could send a scorching beam of light to burn and destroy the evil. All such perceptions and early adaptations of the use of visible light energy were indeed precursors to DEW. Ever since the discovery of laser (light amplification by stimulated emission of radiation) in 1960, the real world has come very close to the science fiction images of bright light beams as the new generation weapon. HPL–DEW, today is recognised as unique speed of light energy beam weapons using high power lasers that can be precisely aimed to target over long strategic distances. Other DEW options include HPM and particle beams, but they are yet to mature to the level of HPL, which is ready for direct use as a weapon system in modern warfare.

While the technology today is still far from providing the ultimate death-ray gun in the hands of a foot soldier, DEW as a platform-based weapon system is being pursued by many advanced countries, albeit at varying levels of technology maturity. Invisible infrared (IR) lasers have been in use for IR countermeasures (IRCM) through much of the cold war period. These devices are aimed at blinding or disabling enemy sensors in the visible or IR band to deny enemy the early advantage of accurate observation. More modern versions of IRCM capability include causing dazzle effects to weapon system operators or damaging the guidance sensors onboard on enemy missiles or unmanned air vehicles (UAVs) to render them ineffective. As threats become complex, the need to respond rapidly and accurately with minimum collateral damage will be very essential, and most defence and security planners envisage increasing use of DEW to meet this future challenge across the full spectrum of modern warfare.

The major boost to DEW came in 1983 from the strategic defense initiative (SDI) of the Regan era, when 'Star War' technologies were promoted with the promise of making nuclear weapons obsolete. Billions of dollars have been spent for R&D in DEW, driven by the logic that advanced DEW capability should provide a paradigm shift in the perception of 'strategic deterrence' that need no longer depend so heavily on nuclear-tipped missiles. While HPL technology made impressive progress and remained in the news, significant technological advances were also achieved in the areas of HPM as well as in particle beam technologies [1].

Extensive research into DEW sources and the concurrent advances in beam directing technology have pushed technology envelop to the level where fully configured DEW systems are now being designed and tested for imminent deployment. Advances in material technology, information technology, and space-based capabilities of the 21st century are also providing the right environment for growing demand for DEW systems. The US Air Force project on airborne laser (ABL) is a classic example of how DEW technology is transforming into a formidable weapon system with hitherto unthinkable military capabilities.

Although some of the space-based laser weapon concepts, as espoused by the US President in the SDI–Star War initiative have remained unrealised, the potential of laser-based DEW for tactical air defence, anti-ballistic missile defence, and anti-satellite (A-SAT) applications is now beyond doubt, as proven by several successful HPL tests in the past two decades. While more advanced nations like USA and Russia in this field are already busy solving the final engineering issues for effective deployment of such energy weapons, the technology levels needed for such

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About the Book

High Power Laser (HPL) has emerged as one of the very promising technologies that will have major impact on defence and security in the future. Directed Energy Weapons (DEW) using HPL has already converted the 'Ray-Gun' of science fiction into reality. The DEW with its unique features is clearly the new generation weapon that will transform the concepts of defence and deterrence. HPL–DEW technology is very complex, multi-disciplinary and dual-use in nature. This monograph presents a comprehensive overview of this complex subject that combines the best of optics and electronics to offer unprecedented capabilities. While the role of HPL for missile defence is already well-established, it is the speed of light, instant reach across large distances in outer space that makes HPL–DEW uniquely usable for space war scenario of the future. Impact of this on perceptions of National Security of powerful, space-faring nations is going to be very significant. The 21st century security perceptions will be significantly dominated by space security and missile defence, where HPL will prove very useful. HPL–DEW is thus an ideal choice weapon for space weapon for anti-satellite (A-SAT) capability. Since modern society depends heavily on satellites both for effective functioning as well as for security, protection of one's own satellites is very critical and this comes only with the deterrence derived from one's own A-SAT capability. This goes beyond the missile defence requirements of the future and hence the importance of HPL–DEW needs to be appreciated for the future power balance equations amongst nations.

About the Author

Amitav Mallik has been a research scientist since 1966 and among the first in India to work on lasers. From 1975 to 1985, he was Professor of Electronics at Defence Institute of Advance Studies (DIAT), Pune where he initiated courses on laser technology. In 1996, he became the Director of Defence Science Centre, where he created the new laboratory – Laser Science and Technology Centre (LASTEC) in 1998. Under his leadership, LASTEC achieved many important milestones in high power laser (HPL) technology, thus putting India on the world map of HPL. For his outstanding contribution to laser technology and Defence R&D in the country, Prof Amitav Mallik was awarded the 'Padmashri' in 2002.

Prof Mallik also served as the first ever 'Adviser, Defence Technology' at the Indian Embassy in Washington DC from 1988 to 1994, where he established the initial framework for high-tech cooperation between India and USA. Prof Mallik was also Member, National Security Advisory Board, Govt of India, during 2003–06. He has authored many technical papers and books on technology and security issues.

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