Laser weapon activities in Germany - technology and operational safety aspects

Hans-Albert Eckel
German Aerospace Center (DLR), Institute of Technical Physics, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany Email: hans-albert.eckel@dlr.de

Abstract: The introduction of laser weapons is not only a technical challenge but also requires a detailed consideration of operational safety aspects. The German activities in this field are discussed.
OCIS codes: 140.0140, 290.0290.

1. Introduction

With recent advances in high-energy laser sources, laser weapons can be expected in the battlefield in the near future, of course dependent on the amount of investments. Their laser power will be tens of kilowatts within the next five years, up to above 100 kW for a whole decade [1].
Laser weapons have several main advantages over conventional weaponry. They can be used discreetly; radiation above and below the visible spectrum is invisible and does not generate sound. Lasers travel at light-speed and have near infinite range limited only by beam diffraction, spread, and absorption or scattering by intervening atmospheric contents. Laser weapons potentially eliminate many logistical problems in terms of ammunition supply, as long as there is enough energy available. Depending on several operational factors, laser weapons may be cheaper to operate than conventional weapons in certain scenarios.
On the other hand high energy laser systems developed for outdoor military applications present unique challenges for laser safety and risk analyses. While the technical problems are largely solved, the question of laser safety remains challenging and requires further experimental investigation as well as modeling and simulation.

2. Hazard Analysis

For a complete hazard analysis, all possible contributions must be considered. For a laser weapon, these are the direct laser beam hazard, the target reflection hazard and the hazard due to atmospheric scattering.

While the exposure to the direct laser beam can be easily deduced from the beam parameters and the atmospheric extinction, considerations of target and atmospheric scattering effects are more complicated.

Exposure to the beam reflected by the illuminated target can pose hazards as well. Therefore, accurate models and simulations of reflections are needed to determine the extent of hazardous conditions for laser engagements of targets so that testing or operational use can proceed. Such simulations are based on an engagement scenario, which consists of laser and target properties and the geometry of their interaction. Proper hazard analysis for a material irradiated by a laser relies upon the reflecting properties of the material surface, as these properties determine the magnitude and direction of the reflected laser energy commonly characterized by the bidirectional reflectance distribution function BRDF. However, a high-energy laser heating and possibly melting a material can change the reflecting properties of that material, so these changes must be included in the hazard analysis. Traditional methods for measuring the BRDFs of materials are not practical for measurement of materials with rapidly-changing surface properties [2, 3].

A laser beam that propagates through the atmosphere will be attenuated as it passes through space mainly by scattering effects. The scattered radiation may pose a hazard to observers looking at or alongside the beam. There are two contributions to the scattered radiation that have to be taken into account: Mie (or large particle) scattering occurs where the particle size is greater than the wavelength of the optical radiation, and is normally the dominant contributor to the overall scattered radiation. Rayleigh (or molecular) scattering occurs where particle size is much lower than the wavelength. The scatter hazard is inversely proportional to the visibility. A clear atmosphere may, therefore, be almost no scatter hazard. Special attention has to be given to military operations where the visibility is occasionally limited by natural or artificial fog and all sorts of precipitation [4].

3. German National Programme

The German laser weapon programme is a joint effort of German research institutes and German industry in cooperation with the German Ministry of Defence (MOD). Over the last decade several basic concepts for laser effectors have been developed, numerous system concepts have been evaluated regarding various applications, and possible laser weapon systems have been successfully demonstrated [5, 6].

A major element of the German laser weapon programme is the development of high energy laser sources. The MOD backs different laser concepts: DLR-ITP (DLR – Institute for Technical Physics at Stuttgart) works on the development of thin-disk lasers and has recently started to investigate high brightness diode laser sources, focussing on power scaling and on coherent beam combining concepts. The Fraunhofer IOF (Institute for Applied Optics and Precision Engineering) works on the development of fibre laser sources together with the company Rheinmetall. Both concepts have conceptions for mid and high energy laser sources. The French-German Institute ISL at Saint Louis, France, developed an "eye-safe" laser source (Er^{3+}:YAG, lasing at 1.6 µm), based on the heat capacity concept. Its distinctive feature is the abandonment of cooling during laser emission. The institute deems that upscaling to 100 kW is possible [7].

System-oriented laser weapon activities and demonstrator development are covered by the German industry. In the last decade the two German companies Rheinmetall and MBDA have been putting up various technology demonstrators, both based on fibre laser sources. The main difference in their demonstrators is related to their geometrical beam combining concepts. Rheinmetall: Beam superimposition using spatially distributed telescopes; MBDA: Modular concept using a single telescope with shared aperture. Output power is up to 50 kW for the Rheinmetall Technology Demonstrator and up to 40 kW for the MBDA Modular Weapon Demonstrator [8, 9].

Germany is planning to build up its first naval operational demonstrator. Recently Rheinmetall and MBDA Deutschland have agreed to collaborate in the high-energy laser effectors domain. The two companies intend to construct, integrate and test a laser demonstrator for the German Navy's corvette K130.

4. References

[1] M. Tacke et al., "Mid- to Long-Term Future of Laser Weapons" von Karman Horizon Scan – Laser Weapons, NATO Science and Technology Organization (2016).

[2] J.-F. Daigle et al., "Laser safety evaluation for high-energy laser interaction with solids Optical Engineering", 2017, 56, 026106

[3] J. Speiser et al., "Streuung von Laserstrahlung am Ziel: Experimentelle Ergebnisse und ihre Modellierung", 1. Symposium Lasertechnologie in der Wehrtechnik, 11.-12. Dec. 2018, Meppen

[4] A. Peckhaus et al., "Effect of precipitation on the transmission of high power laser radiation", SPIE Remote Sensing, Paper 11153-7, September 2019, Strasbourg, France

[5] B. Weiß, "Streuung von Laserstrahlung am Ziel: Experimentelle Ergebnisse und ihre Modellierung", 1. Symposium Lasertechnologie in der Wehrtechnik, 11.-12. Dec. 2018, Meppen

[6] J, Boller, "Streuung von Laserstrahlung am Ziel: Experimentelle Ergebnisse und ihre Modellierung", 1. Symposium Lasertechnologie in der Wehrtechnik, 11.-12. Dec. 2018, Meppen

[7] J, Speiser et al., "Gekoppelte Halbleiterlaser als Lasereffektoren", 1. Symposium Lasertechnologie in der Wehrtechnik, 11.-12. Dec. 2018, Meppen

[8] D, Laarmann, "Hochenergielaserwaffen – Sachstand und Ausblick", 1. Symposium Lasertechnologie in der Wehrtechnik, 11.-12. Dec. 2018, Meppen

[9] M, Jung, "Hochleistungslaser für Laserwaffensysteme", 1. Symposium Lasertechnologie in der Wehrtechnik, 11.-12. Dec. 2018, Meppen