Australian Government
Civil Aviation Safety Authority

ADVISORY CIRCULAR
AC 139.E-03 v1.0

Laser emissions which may endanger the safety of aircraft

File ref: D19/165433

December 2024

Advisory circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Advisory circulars should always be read in conjunction with the relevant regulations.

Audience

This advisory circular (AC) applies to:

- pilots
- aerodrome operators
- operators of laser shows
- air traffic controllers
- aeronautical information service providers.

Purpose

This advisory circular (AC) provides general information and advice on measures to protect pilots of civil aircraft from accidental laser beam strikes, on or in the vicinity of an aerodrome.

This guidance should be used in the planning and control of advertising, entertainment, and similar visual displays using visible laser light.

This AC is unlikely to prevent wilful or malicious laser attacks against aircraft by those intent on causing mischief.

For further information

For further information or to provide feedback on this AC, visit CASA's contact us page.

Unless specified otherwise, all subregulations, regulations, Divisions, Subparts and Parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998 (CASR)*.

Status

This version of the AC is approved by the National Manager, Flight Standards Branch.

Note: Changes made in the current version are not annotated. The document should be read in full.

Table 1. Status

Version	Date	Details
v1.0	December 2024	This AC replaces AC 139-23(0) - Laser Emissions which may Endanger the Safety of Aircraft published April 2007.
(0)	April 2007	This is the first AC to be issued on this subject.

Contents

Acknowledgement of Country

The Civil Aviation Safety Authority (CASA) respectfully acknowledges the Traditional Custodians of the lands on which our offices are located and their continuing connection to land, water and community, and pays respect to Elders past, present and emerging.

Artwork: James Baban.

1 Reference material

1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Table 1: Acronyms

Acronym	Description
AC	advisory circular
AEL	Accessible Emission Limit
CAR	*Civil Aviation Regulations 1988*
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulations 1998*
LCFZ	laser-beam critical flight zone
LFFZ	laser-beam free flight zone
LSFZ	laser-beam sensitive flight zone
MPE	maximum permissible exposure
NFZ	normal flight zone
NOHD	nominal ocular hazard distance
OD	optical density

1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below. Where definitions from the civil aviation legislation have been reproduced for ease of reference, these are identified by 'grey shading'. Should there be a discrepancy between a definition given in this AC and the civil aviation legislation, the definition in the legislation prevails.

Table 2: Definitions

Term	Definition
ED50 (Exposure Dose 50%)	At the ED50 distance, there is roughly a 50-50 chance that a fixed laser beam aimed into an unmoving eye under laboratory conditions will cause the smallest medically detectable change to the retina. Such small changes can heal just as small skin cuts and burns can heal with no adverse effect.
irradiance (E)	The power per unit area expressed in watts per square centimetre (W/cm^2) or watts per square metre (W/m^2). Small values may be expressed as micro watts per square centimetre ($\mu W/cm^2$) or nano watts per square centimetre (nW/cm^2), 10^{-6} and 10^{-9} respectively.
laser	1. An acronym for light amplification by stimulated emission of radiation. 2. A device that produces an intense, coherent, directional beam of optical

Term	Definition
	radiation by stimulating emission of photons by electronic or molecular transition to lower energy levels.
maximum permissible exposure (MPE)	The internationally accepted maximum level of laser radiation to which human beings may be exposed without risk of biological damage to the eye or skin. The light level (irradiance) at the NOHD is at the Maximum Permissible Exposure or MPE. Farther than the NOHD, the irradiance falls below the MPE, and is generally considered safe.
protected flight zones	Airspace specifically designated to mitigate the hazardous effects of laser radiation. These zones are defined as follows: • *Laser-beam critical flight zone (LCFZ)* - airspace in the proximity of an aerodrome but beyond the laser-beam free flight zone (LFFZ) where the irradiance is restricted to a level unlikely to cause glare effects • *Laser-beam free flight zone (LFFZ)* - airspace in the immediate proximity to the aerodrome where the irradiance is restricted to a level unlikely to cause any visual disruption • *Laser-beam sensitive flight zone (LSFZ)* - airspace outside, and not necessarily contiguous with, the LFFZ and LCFZ where the irradiance is restricted to a level unlikely to cause flash-blindness or after-image effects • *Normal flight zone (NFZ)* - airspace not defined as LFFZ, LCFZ or LSFZ but which must be protected from laser radiation capable of causing biological damage to the eye.
nominal ocular hazard distance (NOHD).	The distance along the axis of the laser beam beyond which the appropriate maximum permissible exposure (MPE) is not exceeded (i.e. an indication of the “safe viewing” distance). Beyond the NOHD, laser light directly entering the eye is considered safe. Specifically, at the NOHD distance there is “a negligible probability of damage” according to the laser safety standard ANSI Z136.1.

1.3 References

Legislation

Legislation is available on the Federal Register of Legislation website https://www.legislation.gov.au/

Table 3: Legislation references

Document	Title
CAR 1988	Part 9, Division 9, 94 Dangerous Lights.
Part 139 (Aerodromes) Manual of Standards 2019	Section 9.143 Other lighting on the aerodrome

International Civil Aviation Organization documents

International Civil Aviation Organization (ICAO) documents are available for purchase from http://store1.icao.int/

Many ICAO documents are also available for reading, but not purchase or downloading, from the ICAO eLibrary (https://elibrary.icao.int/home).

Table 4: ICAO references

Document	Title
ICAO Annex 14 Volume I	Aerodrome Design and Operations
ICAO Doc 9815	Manual on Laser Emitters and Flight Safety

Other

Table 5: Other references

Document	Title
FAA AC 70-1B	Outdoor Laser Operations
AS/NZS 2211.1	Laser safety
AS/NZS IEC 60825-3	Safety of laser products – Part 3: Guidance for laser displays and shows
SAE ARP5293A	Safety Considerations for Lasers Projected in the Navigable Airspace

2 Introduction

2.1 Hazards associated with laser emissions

While sufficient light is required to undertake visual activities, excessive light levels can adversely affect vision to the point of making it ineffective. In aviation, a pilot may experience high light levels when flying towards the sun or when looking at very bright artificial light sources such as searchlights. The use of lasers has caused a significant increase in aviation-related vision problems associated with high-intensity lights.

Lasers can produce a beam of light of such intensity that permanent damage to human tissue, in particular the retina of the eye, can be caused instantaneously, even at distances of over 10 km. At lower intensities, laser beams can seriously affect visual performance without causing physical damage to the eyes.

Visual effects can range in severity from glare, such as oncoming headlights or inability to see outside the aircraft while illuminated, to temporary flash blindness. Temporary flash blindness can cause an afterimage that may persist from several seconds to several minutes. Other effects of laser illumination can include loss of dark adaptation, disorientation, and eye pain. Additionally, exposure to strong laser light could result in eye injury.

Lasers and high-intensity lights, like sky trackers, pose a serious risk to pilots that can result in difficulties flying and impaired vision. It takes only a fraction of a second to cause flashblindness or ocular damage, even if the aircraft is travelling quite quickly.

2.2 Mitigating the risk of laser emissions

Protection of pilots against accidental laser beam strike has become a serious factor in aviation safety with the advent of the laser light display for entertainment or commercial purposes. To protect the safety of aviation in the vicinity of aerodromes, heliports and certain other areas, such as low-level visual flight rules (VFR) corridors, it is necessary to protect the affected airspace against hazardous laser beams. For non-visible laser beams, the nominal ocular hazard distance (NOHD) value is the sole consideration. For visible laser beams, in addition to the NOHD, visual disruption must also be considered.

Laser emitters operated by authorities in a manner compatible with flight safety are excluded from these restrictions. Typical examples of lasers used to support aviation include some cloud base or visibility measurement equipment, some bird harassing devices, and some aircraft docking guidance systems. Aerodrome authorities are to ensure that these lasers have the beam aimed in such a direction, and/or that the times of operation are controlled, to ensure no hazard is posed to aircraft operations.

In all navigable air space, the irradiance level of any laser beam, visible or invisible, is expected to be less than or equal to the maximum permissible exposure (MPE) unless such emission has been notified to the authority and permission obtained.

2.3 Protected areas

Protected flight zones are established in order to mitigate the risk of operating laser emitters in the vicinity of aerodromes.

The dimensions indicated for the various zones are given as guidance, however the ICAO Manual on Laser Emitters and Flight Safety (Doc 9815) advises that they have been found to provide for the safe operation of aircraft in the vicinity of aerodromes.

The increased use of lasers for light displays for entertainment and other commercial purposes requires protection of flight crews of civil aircraft from accidental illumination from such displays.

3 Laser hazards

3.1 General

Lasers in and of themselves are a hazard beyond their impact on aviation. CASA does not directly regulate laser show proponents or operators under normal conditions as they are beyond the scope of the civil aviation safety regulations, however, under regulation 94 of the *Civil Aviation Regulations 1988* (CAR), lights that are determined to be dangerous to the safety of aircraft can be subject to regulatory restrictions imposed by CASA. These measures can include directing the lights to be extinguished, screened or prohibited in the future.

Laser or light show proponents should ensure they are familiar with and comply with any Federal, State or Territory requirements, including Work, Health and Safety (WHS) legislation. These requirements could relate to the protection of the public (including pilots), and even employees, from the potential harmful effects of laser emissions.

3.2 Laser hazard evaluation

The purpose of a laser hazard evaluation is to minimize the potential for injury to personnel from a laser emitter. As part of this evaluation, the accessible emission limit (AEL), laser classification, nominal ocular hazard distance (NOHD) and optical density (OD) required for personnel protection are determined. In addition, engineering and administrative control measures should be considered.

The AEL is defined as the maximum accessible emission power or energy permitted within a particular class. The class 1 AEL is the value to which laser output parameters are compared. The class 1 AEL is calculated by multiplying the maximum permissible exposure (MPE) by the area of the limiting aperture.

The MPE is a function of wavelength, exposure time and the nature of exposure (intrabeam, diffuse reflection, eye or skin). MPE values are determined from biological studies and are published in regional, national[1] and international[2] laser safety standards.

MPE values are expressed in terms of irradiance or radiant exposure and are given in W/cm2 or J/cm2 (also W/m2 or J/m2). They represent the maximum levels to which a person can safely be exposed without incurring biological damage. However, sub-damage threshold effects may be significant at exposure levels below the MPE.

The NOHD is the maximum range at which the power or energy entering the limiting aperture can exceed the class 1 AEL. This value expresses the minimum safe distance from which a person can directly view a laser source without a biological damage hazard. Guidance on calculating NOHD and visual interference distance equations can be found at LaserPointerSafety.com.

3.3 Laser classes

Lasers are grouped into 7 classes according to accessible emission limits. It should be noted that modifications can increase the class and subsequent hazard of a laser[3]:

a. Class 1. Lasers are safe under most circumstances and are incapable of damaging the eyes or skin because of either engineered design or inherently low power output.

[1] For example, American National Standards Institute ANSI Z136.1.

[2] For example, International Electrotechnical Commission IEC 60825-1.

[3] Australian Aviation Wildlife Hazard Group (AAWHG) Recommended Practice (RP) 3.2.3(0) - Lasers: Use and General Safety.

b. Class 1M. Lasers emit in the wavelength range 302.5–4000 nm and may be hazardous if optics[4] are used in the beam.

c. Class 2. Lasers emit in the visible wavelength range 400–700 nm and have sufficient power output to cause damage to the eyes if viewed continuously. The ‘blink reflex’ generally affords sufficient eye protection given the low output of these devices. Additional hazard control measures take the form of cautionary signs or labels.

d. Class 2M. Lasers are similar to Class 2 however viewing may be more hazardous if the user employs optics within the beam.

e. Class 3R. Lasers emit in the wavelength range 302.5–1060nm and have the potential to cause damage to the eyes from intra-beam viewing but the risk is lower than for Class 3B lasers. Precautions are required to prevent both direct viewing and viewing with optical instruments.

f. Class 3B. Lasers are more hazardous because of either higher output or operation outside visible wavelengths. In addition, specular reflections may also be hazardous. In general, more stringent controls are needed to prevent exposure.

g. Class 4. Lasers are high power devices capable of producing eye damage even from diffuse reflection. They may cause skin injuries and could also constitute a fire hazard. Examples of class 4 lasers include surgical lasers and those used in the plastic, wood and metal fabrication industries.

Notes:

1. Lasers vary greatly in power output and the hazard potential for eyes and skin can be significant, due to the concentrated amount of energy produced.
2. Laser light shows can be class 2, 2M, 3R, 3B or 4; however, average light shows use class 3B or 4 lasers.

[4] Optics when referred to in Laser Classification, refers to the use of any magnifying viewing instrument. Such instruments includes binoculars, telescopes or magnifying lenses such as those used in telescopic sights on weapons.

4 Protected flight zones

ICAO has recommended the establishment of protected areas surrounding an aerodrome that protect aircraft from non-aeronautical ground lights. Annex 14 Volume I recommends "To protect the safety of aircraft against the hazardous effects of laser emitters, the following protected zones should be established around aerodromes:

- a laser-beam free flight zone (LFFZ)
- a laser-beam critical flight zone (LCFZ)
- a laser-beam sensitive flight zone (LSFZ)".

Appendix A, Figures 1, 2, and 3 may be used to determine the exposure levels and distances that adequately protect flight operations.

The restrictions on the use of laser beams in the three protected flight zones, LFFZ, LCFZ, and LSFZ, only refer to visible laser beams.

> **Note:** Online charts showing the location of all aerodromes (certified, uncertified, aeroplane landing areas, grass strips, helicopter landing sites etc.) are available through CASA-approved drone safety apps, such as OK2Fly.com.au.

4.1 Laser-beam free flight zone (LFFZ)

The LFFZ is the airspace in the immediate proximity to the aerodrome, up to and including 600 m (2,000 ft) above ground level (AGL), extending 3,700 m (2NM) in all directions measured from the runway centre line, plus a 5,600 m (3 NM) extension, 750m (2 ,500 ft) on each side of the extended runway centre line of each useable runway. Within this zone, the intensity of laser light is restricted to a level that is unlikely to cause any visual disruption. The following conditions are applicable to LFFZ:

a. parallel runways are measured from the runway centre line toward the outermost edges, plus the airspace between runway centrelines
b. within this airspace, the irradiance is not to exceed 50 nW/cm2 unless some form of mitigation is applied. The level of brightness produced is indistinguishable from background ambient light; and
c. to allow laser operations below the arrival path, a 1:40 slope may be applied to the 5,600 m extensions. This slope is calculated from the runway threshold.

4.2 Laser-beam critical flight zone (LCFZ)

The LCFZ is the airspace within 18,500 m (10 NM) of the aerodrome reference point (ARP), from the surface up to and including 3,050 m (10,000 ft) AGL (see Appendix A, Figures 1 to 3). This zone may have to be adjusted to meet air traffic requirements. Within this airspace the irradiance is not to exceed 5 μW/cm2 unless some form of mitigation is applied. Although capable of causing glare effects, this irradiance will not produce a level of brightness sufficient to cause flash-blindness or after-image effects.

4.3 Laser-beam sensitive flight zone (LSFZ)

The extent of this zone should be determined by the operations at the particular aerodrome. The LSFZ need not necessarily be contiguous with the other flight zones.

Within this zone the irradiance should not exceed 100 μW/cm2 unless some form of mitigation is applied. The level of brightness produced may begin to produce flash-blindness or after-image effects of short duration; however, this limit will provide protection from serious effects.

4.4 Normal flight zone (NFZ)

The NFZ is any navigable airspace not defined as LFFZ, LCFZ or LSFZ. The NFZ should be protected from laser radiation capable of causing biological damage to the eye.

The maximum irradiance level (MIL) should be equal to or less than the maximum permissible exposure (MPE).

Appendix A, Figures 1 to 3 define the zones established to protect aircraft in navigable airspace. The dimensions indicated are given as guidance but have been found to protect safety well.

The amount of airspace affected by a laser operation varies with the laser systems output power, which is measured in watts or joules. The following MILs can be used for evaluating laser activities in close proximity to an aerodrome:

a. LFFZ: MIL is equal to or less than 50 nW/cm2
b. LCFZ: MIL is equal to or less than 5 μW/cm2
c. LSFZ: MIL is equal to or less than 100 μW/cm2
d. NFZ: MIL is equal to or less than the MPE for CW or pulsed lasers.

> **Note:** Items a., b. and c. refer to visible laser emissions only.

5 Operational considerations

5.1 Laser shows

Class 3B and 4 laser products should be subject to a risk assessment by the laser show proponent to determine any protective control measures that may be necessary. The risk assessment should take into account the protected flight zones surrounding an aerodrome. Additionally, consideration should be given to appointment of a laser safety officer who has received appropriate training and is knowledgeable in the evaluation and control of laser hazards, including to aviation safety.

Training for laser show proponents, including laser safety officers is available through a number of sources such as the Australian National University and the International Laser Display Association (ILDA).

5.2 Mitigating laser emissions

There are various strategies available to laser operators to minimise the hazards associated with laser emissions and the risk to aircraft operations:

a. Minimising the angle of elevation of the beams to reduce their impact on airspace.
b. Terminating the laser beams onto adjacent buildings, trees, etc. so the emissions don't penetrate airspace.
c. Using an aircraft spotter to monitor adjacent airspace to suspend or terminate the display in the event of an aircraft entering the area e.g. applications such as FlightRadar24 allow laser show operators to monitor aircraft activity.

5.3 CASA guidance

Guidance material regarding laser displays and the laser power and divergence calculator can be found on CASA's website at: Laser and light shows | Civil Aviation Safety Authority. This calculator is an Excel spreadsheet that provides details of the LSFZ, LCFZ and LFFZ based on laser colour, power and divergence. It also calculates NOHD as an indication of the 'safe viewing distance'.

Note: The version of the spreadsheet downloadable from the CASA website has been simplified and does not include operator details, location of the display, date and time of the display, beam orientation, and risk mitigation details.

5.4 Notifying pilots

The method by which pilots are notified of the presence, and potential hazards, of laser shows is through the publication of a Notice to Airmen (NOTAM). Under Part 175 - Aeronautical information management, laser show proponents are considered aeronautical data originators (ADOs) and the Australian NOTAM Office will provide them with guidance on how to construct and submit NOTAM for publication. For further information about establishing your organisation as an ADO with NOTAM requirements, please contact the Airservices ADO Team on ado@airservicesaustralia.com

For information, the following are examples of NOTAM that have been issued in relation to notified laser displays:

Example 1

Laser testing and alignment outside air traffic control hours of operation within Class G airspace:

GOLD COAST (YBCG)   C358/24

OCULAR HAZARD ASSOCIATED WITH LASER DISPLAY

TESTING AND ALIGNMENT WILL TAKE PLACE

PSN 280958S 1533222E 'COOLANGATTA BEACH'

BRG 080 MAG 3400M FM ARP

BEAMS ORIENTED APRX W AND CONTAINED WI CLASS G AIRSPACE

NOMINAL OCULAR HAZARD DISTANCE (NOHD) 800M

OPR CTC TEL: 04xx xxx xxx OR 04xx xxx xxx

SFC TO 1500FT AMSL

FROM 05 021300 TO 05 021600

Example 2

Laser display in Class C airspace:

MELBOURNE FIR (YMMM)   C1596/24

LASER DISPLAY WILL TAKE PLACE

AT 'location' NEW SOUTH WALES

PSN 334626S 15106448E BRG 330 MAG 10.8NM FM SYDNEY AD (YSSY)

HIGH POWER GREEN LASER ORIENTED VERTICALLY

OCULAR HAZARD IF OVERHEAD LOOKING DIRECTLY INTO BEAM, BUT SAFE WHEN

VIEWED FROM SIDE

OPR CTC TEL: 04xx xxx xxx

SFC TO UNL

FROM 09 230800 TO 09 231200

6 Further information

Further guidance on how to protect flight operations from the hazardous effects of laser emitters is contained in the ICAO publication “Manual on Laser Emitters and Flight Safety (Doc 9815)”.

Appendix A
Laser-beam zones

Figures 1, 2 and 3 below describe the protected flight zones surrounding an aerodrome, including the LFFZ, LCFZ and LSFZ. These diagrams may be used to determine the exposure levels and distances that adequately protect flight operations.

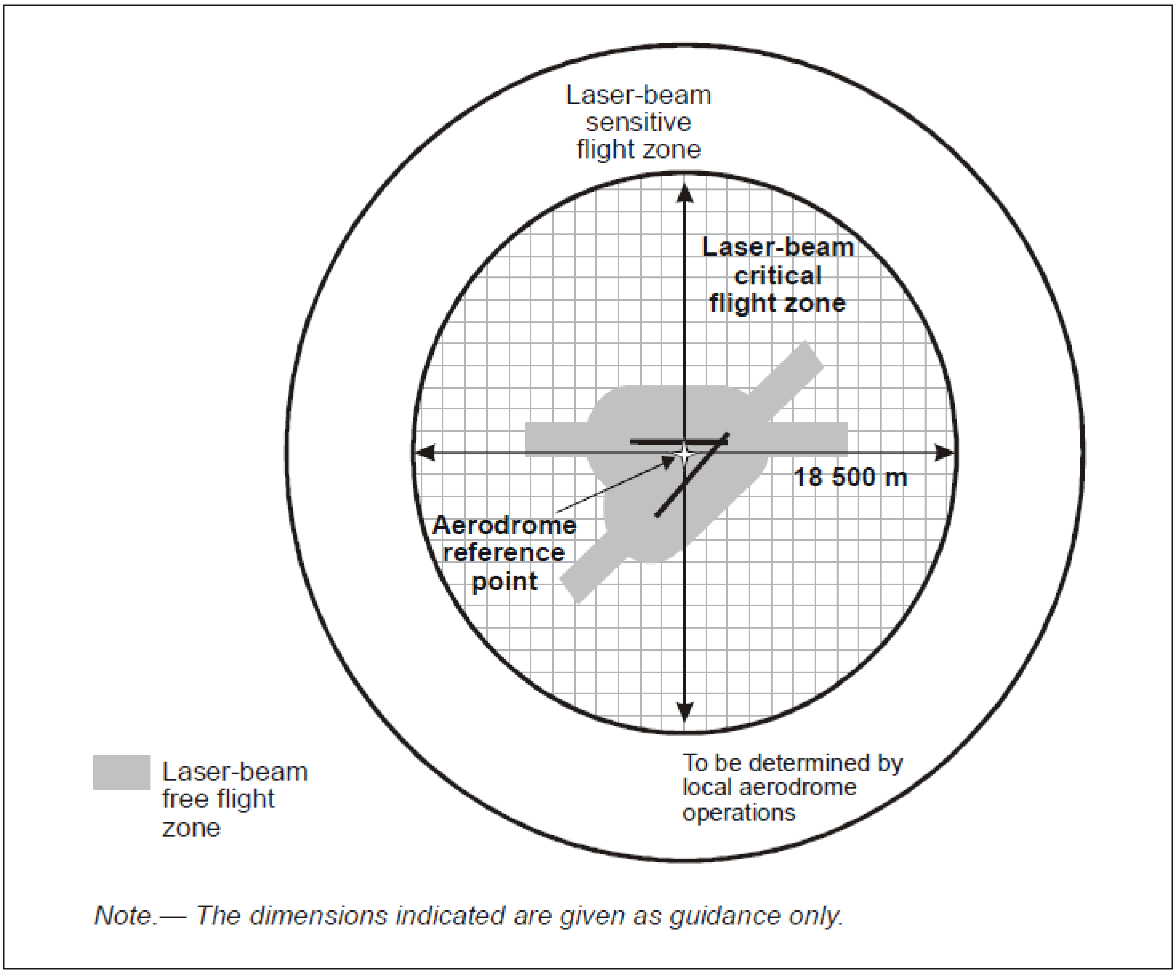

Figure 1: Protected flight zones

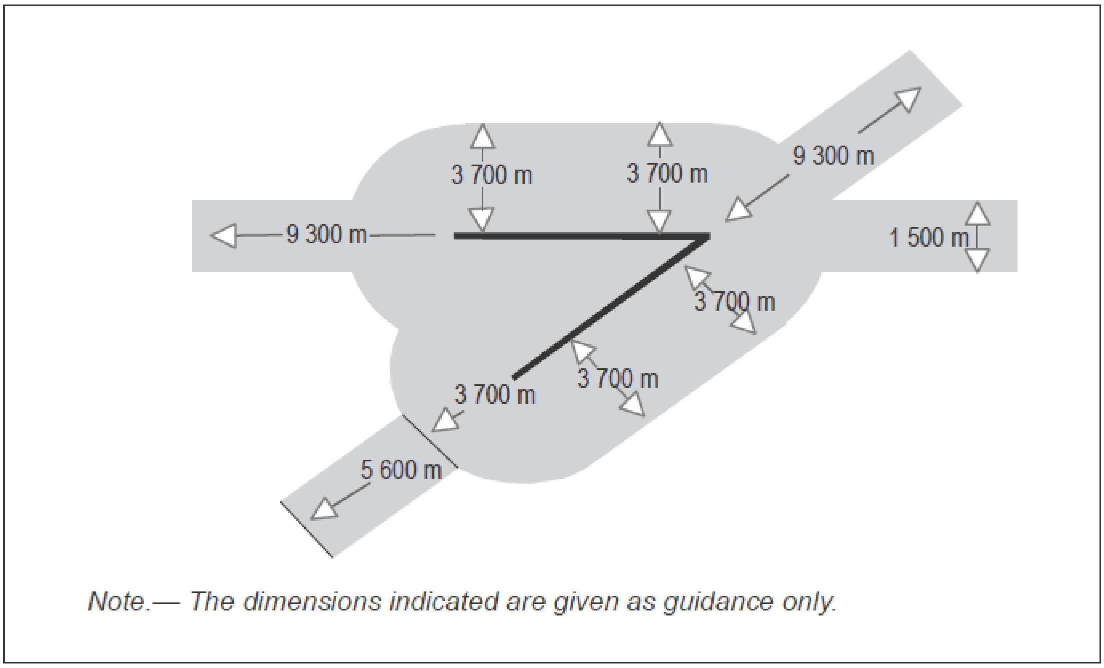

Figure 2: Multiple runway laser-beam free flight zone

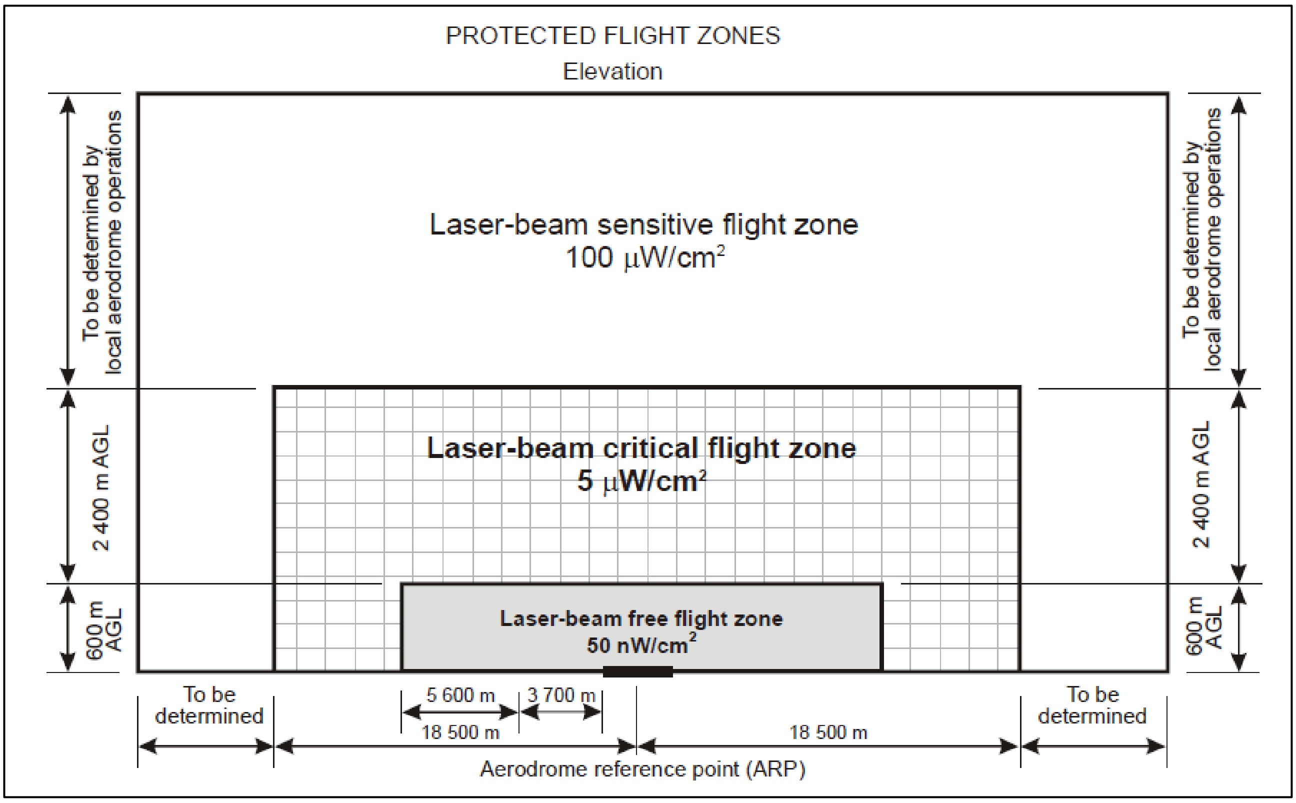

Figure 3: Protected flight zones with indication of maximum irradiance levels for visible laser beams