TECHNICAL SPECIFICATION

ISO/TS 22247

First edition
2022-04

Optics and photonics — Effective numerical aperture of laser lenses — Definition and verification procedure

Optique et photonique — Ouverture numérique efficace des lentilles laser — Définition et procédure de vérification

Reference number
ISO/TS 22247:2022(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172, *Optics and Photonics*, Subcomittee SC 9, *Laser and electro-optical systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Lenses are used in the field of laser beam forming, typically for collimation of divergent radiation or for focusing collimated radiation to obtain very small spots. A distinction is made between rotational symmetric lenses on one hand and cylindrical lenses, which provide optical power only in one direction, on the other hand.

Two crucial quality characteristics can be defined for such lenses: the trivial demand that the lenses should not clip the laser beam during propagation and the more sophisticated requirement, that they should not significantly increase the beam propagation factor of a traversing beam.

If the divergence angle of the beam before or after the lens is large, the geometric form of the surfaces of the lens needs to be carefully designed to an aspherical or acylindrical form to fulfill the second requirement. The desired form of the surfaces depends on the intended use of the lens and the wavelength of the laser radiation.

In fabrication and application of such lenses the following problems may arise, even in combination:

— in fabrication of the lens the optimum surface form has not been reproduced;

— the lens is applied to a laser beam with a different wavelength than the design wavelength.

Non-well designed or non-well produced lenses or lenses applied to beams with wavelength for which the lens has not been designed may still be useful as long as the involved divergence angles are small enough.

To account for this, an effective numerical aperture is defined here as the sine of half of the maximum divergence angle a laser beam may have before the lens, when it collimates the beam, or after the lens, when it focuses the beam, to ensure that the aberrations introduced by the lens to the beam at the given wavelength is acceptable.

This definition is in close relationship to ISO 11146-1, which is important in the field of laser beam characterization. It provides the decisive parameter in the field of laser beam forming. Furthermore, it is related to a fairly simple verification procedure, which can be applied by manufacturers of laser lenses as well as users with acceptable effort.

Optics and photonics — Effective numerical aperture of laser lenses — Definition and verification procedure

1 Scope

This document covers terms, definitions, and a verification procedure to characterize the ability of laser lenses to collimate divergent laser beams and to focus collimated laser to small spot sizes. The aim of this document is to give users reliable information on the applicability of laser lenses in the field of beam forming.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11146-1, *Lasers and laser-related equipment — Test methods for laser beam widths, divergence angles and beam propagation ratios — Part 1: Stigmatic and simple astigmatic beams*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

NOTE Within this document, the terms power density and energy density are used in units of areal densities. According to the common understanding in the fields of optics, photonics and laser technology, the term power density is generally perceived in unit of areal density. In this document, the term energy density also follows this specification. In text books, this power density is also denoted as irradiance and this energy density as fluence.

3.1
beam diameter
$d_u(z)$
<encircled power (energy)> diameter of a circular aperture in a plane perpendicular to the beam axis that contains u % of the total beam power (energy)

Note 1 to entry: For clarity, the term “beam diameter” is always used in combination with the symbol and its appropriate subscript: d_u or d_σ.

[SOURCE: ISO 11145:2018, 3.3.1]

3.2
beam diameter
$d_\sigma(z)$
<second moment of power (energy) density distribution function> diameter defined by using the second moment of the power (energy) density distribution function

$$d_\sigma(z) = 2\sqrt{2}\sigma(z)$$

