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Lasers and laser-related equipment — Test methods for laser beam parameters — Polarization

Lasers et équipements associés aux lasers — Méthodes d'essai des paramètres du faisceau laser — Polarisation

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Contents

Page

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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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,* Subcommittee SC 9, *Laser and electro-optical systems,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 123, *Lasers and photonics*, in accordance with the agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 12005:2003), which has been technically revised.

The main changes are as follows:

— Description errors in 4.5 (Analysis of the results) were corrected.

— Definitions of the “degree of polarization” and the “degree of linear polarization” were made clear.

— Definition of extinction ratio was changed.

— Previous 3.3 (direction of polarization), 3.4 (plane of polarization), and 3.5 (ellipticity) were deleted, because these terms are confusing due to the different definitions, and they are not necessarily required for this document. Previous 3.11 (Stokes parameters) was deleted and moved to Annex A, because they are not used in the measurement and analysis.

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

This document deals with a method for determining the polarization state of a laser beam.

This document is applicable for well-polarized laser beams, including those emitted by lasers with a high divergence angle. However, if more completeness in the determination of the polarization status is required, the use of a more sophisticated analysing device is necessary. Although not within the scope of this document, the principle of operation of such devices is given in Annex A, together with a description of the Stokes parameters which are needed in that case.

Lasers and laser-related equipment — Test methods for laser beam parameters — Polarization

1 Scope

This document specifies a method, which is a relatively quick and simple method with minimum equipment, for determining the polarization status and, whenever possible, the degree of polarization of the beam from a continuous wave (cw) laser. It can also be applied to repetitively pulsed lasers, if their electric field vector orientation does not change from pulse to pulse.

This document also specifies the method for determining the direction of the electric-field vector oscillation in the case of (completely or partially) linearly polarized laser beams. It is assumed that the laser radiation is quasimonochromatic and sufficiently stable for the purpose of the measurement. This document is applicable to radiation that has uniform polarization over its cross-sectional area.

The knowledge of the polarization status can be very important for some applications of lasers with a high divergence angle, for instance when the beam of such a laser shall be coupled with polarization dependent devices (e.g. polarization maintaining fibres). This document is applicable not only for a narrow and almost collimated laser beam but also for highly divergent beams as well as for beams with large apertures.

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 11145, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols*

ISO 11554, *Optics and photonics — Lasers and laser-related equipment — Test methods for laser beam power, energy and temporal characteristics*

CIE 059-1984, *Definitions and Nomenclature, Instrument Polarization*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11145, CIE 059-1984 and the following 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/

3.1
polarization
restriction of oscillations of the electric field vector to certain directions

Note 1 to entry: This is a fundamental phenomenon which can be explained by the concept that electromagnetic radiation is a transverse wave motion, i.e. the oscillations are at right angles to the direction of propagation. It is customary to consider these oscillations as being those of the electric field vector.

3.2
state of polarization
classification of *polarization* (3.1) as linear, circular, elliptical or unpolarized

3.3
ellipticity angle
ε
<elliptically polarized radiation> angle whose tangent is the signed ratio of the minor semiaxis b to the major semiaxis a of the *polarization* (3.1) ellipse where its positive or negative sign designating the right-handed or left-handed elliptical *polarization* (3.1), respectively; i.e. $\tan \varepsilon = \pm b/a$

Note 1 to entry: The polarization ellipse is described by the motion of the terminal point of the electric field vector in a transverse plane to the direction of radiation propagation (see Annex A).

Note 2 to entry: The ellipticity angle is constrained to $-45° \le \varepsilon \le +45°$. When $\varepsilon = \pm 45°$ the polarization is circular and when $\varepsilon = 0°$ the polarization is linear (see Annex A).

3.4
azimuth
Φ
angle between the major semiaxis of the *polarization* (3.1) ellipse and a reference axis perpendicular to the direction of propagation

Note 1 to entry: The azimuth is constrained to $-90° \le \Phi \le +90°$ (see Annex A).

3.5
linear polarizer
optical device whose output is linearly polarized, without regard to the status and *degree of polarization* (3.9) of the incident radiation

3.6
extinction ratio
r_e
<linear polarizer> measure of the quality of the *linear polarizer* (3.5)

Note 1 to entry: If perfectly linearly polarized radiation is incident on a polarizer, then the extinction ratio of the polarizer is given by

$$r_e = \frac{\tau_{max}}{\tau_{min}} \text{ or } \frac{\rho_{max}}{\rho_{min}} \quad (1)$$

where

τ_{max} (ρ_{max}) is the maximum transmittance (reflectance)

τ_{min} (ρ_{min}) is the minimum transmittance (reflectance)

of radiant power (energy) through (from) the linear polarizer.

Note 2 to entry: The extinction ratio is often described in the following form:

$$r_e = \frac{\tau_{max}}{\tau_{min}}:1 \text{ or } \frac{\rho_{max}}{\rho_{min}}:1 \quad (2)$$

3.7
r_p
polarization ratio
<laser beam> measure of the *degree of linear polarization* (3.10) for completely or partially polarized laser beams

$$r_p = \frac{P_{max}}{P_{min}} \text{ or } \frac{Q_{max}}{Q_{min}} \tag{3}$$

where, P_{max} (Q_{max}) and P_{min} (Q_{min}) are the maximum radiant power (energy) and minimum radiant power (energy) passing a *linear polarizer* (3.5), when varying the angle of the rotatable polarizer

Note 1 to entry: The measured beam powers P_{max} and P_{min} and measured beam energies Q_{max} and Q_{min} are specified in 4.4.2.

3.8
quarter-wave plate
optical device which resolves a completely polarized incident beam of radiation into two orthogonally polarized components and introduces a 90° phase shift between them

3.9
degree of polarization
p
ratio of the beam power (or energy) of the completely polarized component to the total beam power (or energy)

3.10
degree of linear polarization
p_L
ratio of the difference to the sum of beam powers P (energies Q) in the direction ξ of maximum transmission and the direction η of minimum transmission through the *linear polarizer* (3.5)

$$p_L = \frac{P_{max} - P_{min}}{P_{max} + P_{min}} \text{ or } \frac{Q_{max} - Q_{min}}{Q_{max} + Q_{min}} \tag{4}$$

Note 1 to entry: The measured beam powers P_{max} and P_{min} and measured beam energies Q_{max} and Q_{min} are specified in 4.4.2.

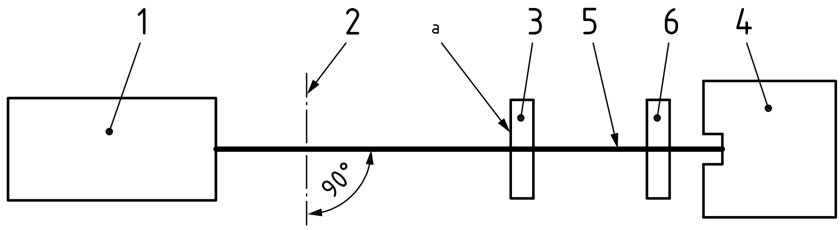
4 Test method for state of polarization

4.1 Principle of measurement

The first test for laser beam polarization determines whether the beam is linearly polarized. This involves recording the maximum and minimum levels of the transmitted radiation while the angular orientation of the linear polarizer is varied, as shown in Figure 1.

If the beam is not linearly polarized (according to the criteria given in 4.5), it is tested for elliptical or circular polarization. For this test the beam is measured after transmission by both a quarter-wave plate and a linear polarizer, as shown in Figure 2.

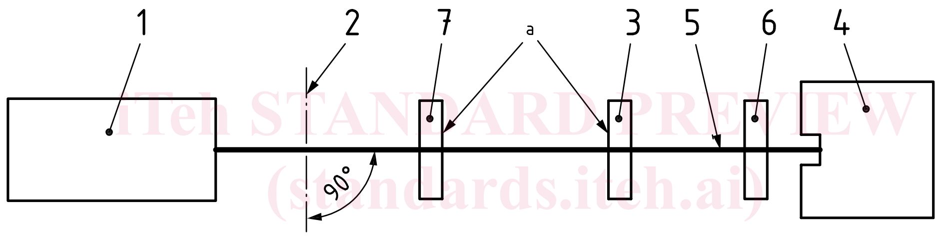
If the beam is not in either of these states, it is only partially polarized or unpolarized.



Key

1 laser
2 reference axis
3 linear polarizer (rotatable)
4 detector
5 laser beam
6 attenuator (optional)
[a] Rotation 180°.

Figure 1 — Schematic arrangement for the test for linear polarization



Key

1 laser
2 reference axis
3 linear polarizer (rotatable)
4 detector
5 laser beam
6 attenuator (optional)
7 quarter-wave plate (rotatable)
[a] Rotation 180°.

Figure 2 — Schematic arrangement for the test for elliptical or circular polarization

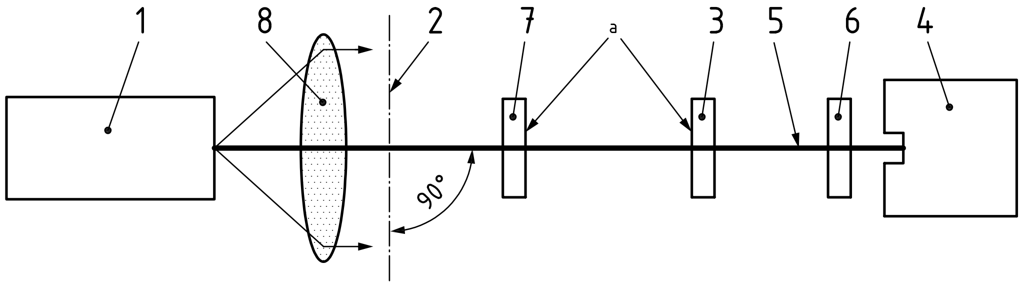
4.2 Equipment arrangement

4.2.1 General

The experimental set-up is shown in Figures 1 and 2.

4.2.2 Special arrangement for the testing of beams with large divergence angles

A highly divergent beam will not be transmitted through all the components of the test arrangements given above. In this case, a collimating assembly shall be inserted between the laser and the first component (reference axis) (see Figure 3). This assembly is made of collecting optics (such as a lens or a group of lenses), optionally followed by a telescope, achieving a reduction of the beam diameter to a value compatible with the rest of the arrangement.



Key

1 laser
2 reference axis
3 linear polarizer (rotatable)
4 detector
5 laser beam
6 attenuator (optional)
7 quarter-wave plate (rotatable)
8 collimating optics
[a] Rotation 180°.

Figure 3 — Schematic arrangement for the testing of lasers with highly divergent beams

4.2.3 Special arrangement for the testing of beams with large apertures

Care shall be taken that the detecting system captures the whole beam. If this is not possible, for example for beams with large apertures, the measurement shall be performed using smaller non-overlapping sub-apertures. The uniformity of the polarization can be confirmed by the measurement at plural sub-apertures.

NOTE Measurement of spatially non-uniform polarization is out of the scope of this document. However, spatially non-uniform but locally uniform polarization can be measured using the above-mentioned smaller non-overlapping sub-apertures. Also, a CCD or CMOS camera will help to detect spatially non-uniform polarization states.

4.3 Components

4.3.1 Radiation detector

The provisions of ISO 11554 shall apply to the measurement configuration including the radiation detector, and the measurement of laser beam power (energy). Note that only relative measurements are necessary for the polarization analysis. Furthermore, the following points shall be noted.

a) It shall be confirmed, from manufacturer's data or by measurement, that the output quantity of the detector (e.g. the voltage) is linearly dependent on the input quantity (laser power). Any wavelength dependency, nonlinearity or non-uniformity of the detector and the accompanying electronic circuit shall be minimized or corrected by use of a calibration procedure.

b) Care shall be taken to ascertain the damage thresholds (for irradiance, radiant exposure, power and energy) of the detector surface and of all the optical elements located between the laser and the detector (e.g. polarizer, attenuator) so that it is not exceeded by the incident laser beam.