INTERNATIONAL STANDARD

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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 des faisceaux laser — Polarisation

Reference number
ISO 12005:1999(E)

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 12005 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 9, *Electro-optical systems.*

Annex A of this International Standard is for information only.

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Introduction

This International Standard defines a relatively quick and simple method, requiring minimum equipment, for determining the state of polarization of a laser beam.

This method is suitable for most of the current needs with well-polarized laser beams. However, if more completeness in the determination of the polarization status is needed, the use of a more sophisticated analysing device is necessary. Although not in the scope of this International Standard, 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 International Standard defines a method for determining the polarization status and, whenever possible, the degree of polarization of the beam from a 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 International Standard also defines the method for determining the direction of the plane of vibration in the case of linearly polarized (totally or partially) laser beams. Unless otherwise stated, it is assumed that the laser radiation is quasi-monochromatic and sufficiently stable for the purpose of the measurement.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 11145:1994, *Optics and optical instrument — Lasers and laser-related equipment — Vocabulary and symbols*.

IEC 61040:1990, *Power and energy measuring detectors — Instruments and equipment for laser radiation*.

CIE 59:1984, *Definitions and Nomenclature, Instrument Polarization.*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 11145, IEC 61040 and CIE 59 and the following apply.

3.1
polarization
restriction of electromagnetic wave motion to certain directions

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

3.2
state of polarization
classification of polarization as linear, random, circular, elliptical or unpolarized

3.3
direction of vibration
direction of the electric field vector of an electromagnetic wave

3.4
plane of vibration
plane containing the electric field vector and the direction of propagation of the electromagnetic radiation

3.5
ellipticity
b/a
⟨elliptically polarized radiation⟩ ratio of the minor semiaxis b of the ellipse to the major semiaxis a of the ellipse

NOTE The 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).

3.6
ellipticity angle
ε
angle whose tangent is the ellipticity

NOTE The ellipticity angle is constrained to $-45° \leqslant \varepsilon \leqslant +45°$. When $\varepsilon = \pm 45°$ the polarization is circular, and when $\varepsilon = 0°$ the polarization is linear (see annex A).

3.7
azimuth
Φ
angle between the major axis of the instantaneous ellipse and a reference axis perpendicular to the direction of propagation

NOTE See annex A.

3.8
linear polarizer
optical device whose output is linearly polarized, without regard to the state and degree of polarization of the incident radiation

3.9
extinction ratio
⟨linear polarizer⟩ measure of the quality of the linear polarizer

NOTE If perfectly linearly polarized radiation is incident on a polarizer, then the extinction ratio of the polarizer is given by:

$$\text{extinction ratio} = \frac{\tau_{\text{min}}}{\tau_{\text{max}}} = \frac{\rho_{\text{min}}}{\rho_{\text{max}}}$$

where

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

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

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

3.10
quarter-wave plate
optical device which resolves an incident totally polarized beam of radiation into two orthogonally polarized components and introduces a 90° phase shift between them

3.11
Stokes parameters
set of four real quantities which completely describe the polarization state of monochromatic or quasi-monochromatic radiation

NOTE The parameters are, collectively, known as the Stokes vector, a 4×1 vector (see annex A for a complete description and formulae for Stokes parameters).

4 Test method for state of polarization

4.1 Principle of measurement

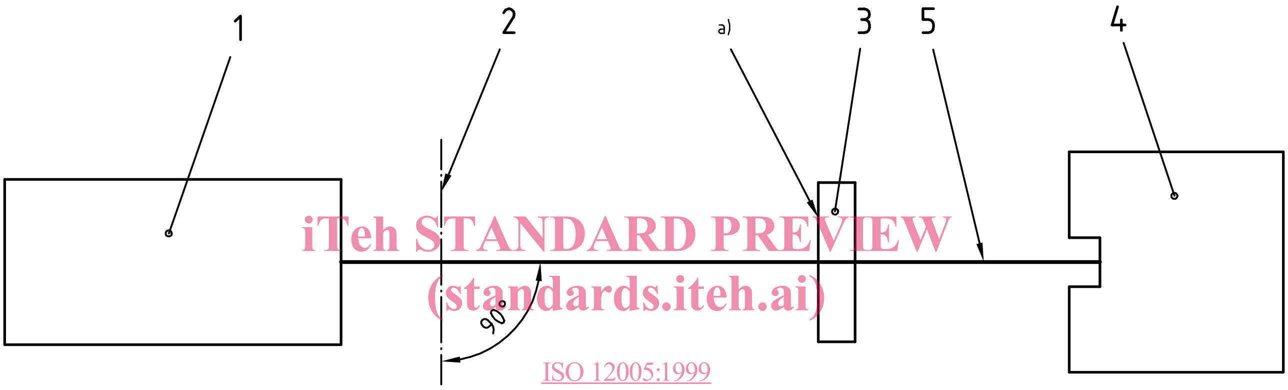
The first test for laser beam polarization determines whether the beam is linearly polarized. This involves recording the maximum and minimum levels of the transmitted radiation while the angular orientation of the linear polarizer is varied. See Figure 1.

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. See Figure 2.

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

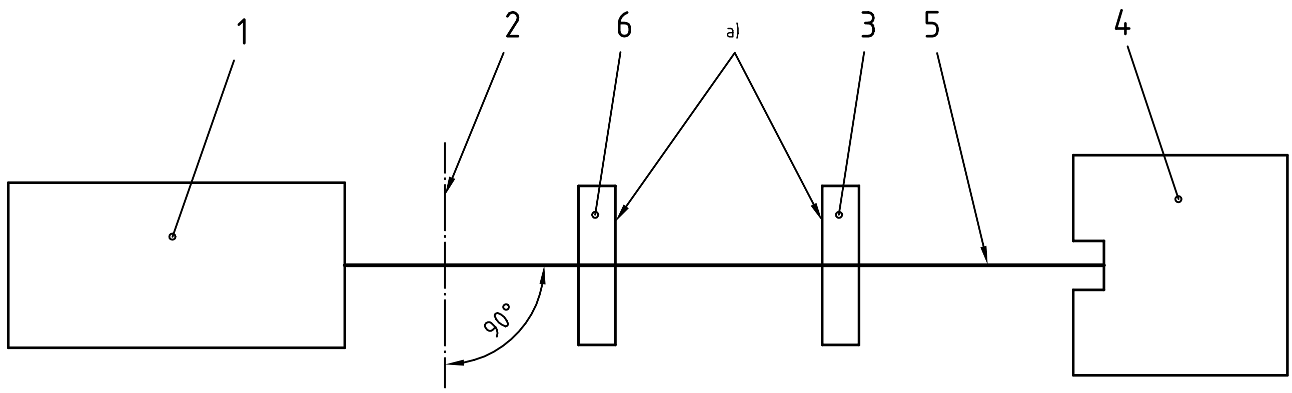
4.2 Equipment arrangement

See Figures 1 and 2 for the experimental set-up.



Key
1 Laser
2 Reference axis
3 Polarizer
4 Detector
5 Laser beam
a) Rotation 180°

Figure 1 — Schematic arrangement of the test for linear polarization



Key

1 Laser
2 Reference axis
3 Polarizer
4 Detector
5 Laser beam
6 Quarter-wave plate
a) Rotation 180°

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

4.3 Components

4.3.1 Radiation detector

The provisions of IEC 61040:1990 apply to the radiation detector; clauses 3 and 4 are particularly important with the exception that only relative measurements are necessary. Furthermore, the following points shall be noted.

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, non-linearity or non-uniformity of the detector and the accompanying electronic circuit shall be minimized or corrected by use of a calibration procedure.

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.

4.3.2 Linear polarizer

The extinction ratio of the linear polarizer shall be less than $[(1/p)-1]/25$, where p is the expected degree of polarization, and at most 0,02. The plane of maximum transmission shall be indicated on the mount.

4.3.3 Quarter-wave plate

The quarter-wave plate is selected for the wavelength to be tested, such as to introduce a $(\lambda/4 \pm \lambda/200)$ optical path difference between the two resolved orthogonal polarized components. The plane of vibration of the fast component (lowest refractive index) shall be indicated on the mount.

4.3.4 Optical attenuator

An attenuator is used to reduce the laser power density.

Optical attenuators shall be used when the laser output-power or power density exceeds the detector's working (linear) range or the damage threshold. Any wavelength dependence, non-linearity or non-uniformity of the optical attenuator shall be minimized or corrected by the use of a calibration procedure.

4.4 Test procedure

4.4.1 General

Set up the experimental apparatus as illustrated in 4.2.

Ensure there is no reflective feedback into the laser by adjusting the angle of the components and their position along the optical path. If attenuating optics are used, test independently to ensure they have no effect on the polarization.

4.4.2 Measurement 1 (see Figure 1)

Define and record the orientation of a reference axis perpendicular to the beam axis.

a) Rotate the polarizer to obtain the maximum and minimum readings at the detector.

b) Record these readings and the angular orientation of the polarizer during the maximum and minimum readings of the detector.

c) Calculate the contrast from the beam powers P (energies Q) in two orthogonal directions:

$$\text{contrast} = \frac{P_x - P_y}{P_x + P_y} \text{ or } \frac{Q_x - Q_y}{Q_x + Q_y}$$

The x and y directions are chosen so that the beam power (energy) is attenuated maximally or minimally, respectively, after transmission through the linear polarizer.

d) Repeat the measurement at least 10 times and calculate the average contrast. If it is less than 0,9 proceed with measurement 2.

4.4.3 Measurement 2 (see Figure 2)

a) Rotate both the quarter-wave plate and the polarizer independently to obtain maximum and minimum readings at the detector. Repeat the procedure to ensure that the absolute maximum and minimum measurements are taken as a function of the angular orientation for both the quarter-wave plate and the polarizer.

b) Record these maximum and minimum readings.

c) Calculate the contrast as defined above for measurement 1 from the measurements obtained.

d) Repeat the measurement at least 10 times and calculate the average contrast.

4.5 Analysis of the results

If the average contrast from the data in measurement 1 is greater than 0,9, then the laser beam is **linearly polarized** and the degree of linear polarization is equal to the contrast. The azimuth is given by the angular orientation of the polarizer during the maximum reading.

If the average contrast from the data in measurement 1 is between 0,1 and 0,9 and the average contrast from measurement 2 is less than 0,1, then the laser beam is **partially linearly polarized.** The degree of linear polarization is equal to the contrast from measurement 1.

If the average contrast from the data in measurement 1 is less than 0,1 and the average contrast from measurement 2 is greater than 0,9, then the laser beam is **circularly polarized**.