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Lasers and laser-related equipment — Test methods for laser-induced damage threshold —

Part 1:
Definitions and general principles

Lasers et équipements associés aux lasers — Méthodes d'essai du seuil d'endommagement provoqué par laser —

Partie 1: Définitions et principes de base

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Foreword

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This second edition cancels and replaces the first edition (ISO 21254-1:2011) which has been technically revised.

The main changes are as follows:

— functional damage criteria and functional damage threshold (F-LIDT) are introduced;

— new units of laser irradiation level are introduced;

— two new test protocols are introduced:

  — extension to R(S)-on-1 test;

  — extension to the raster scan test;

— integration of a new section "General usage notes" in Annex A;

— discussion on accuracy of measurement units is extended.

A list of all parts in the ISO 21254 series can be found on the ISO website.

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Introduction

Optical components are irreversibly damaged above the so-called laser-induced damage threshold (otherwise referred to as LIDT or damage threshold): which is the maximum laser irradiation level at which it is expected that there is zero probability of damage. Below the single-shot damage threshold, a delayed damage event might also develop over time as a consequence of repetitive laser irradiation, the so-called fatigue effect. Alternatively, repeated exposure with increasing laser irradiation can cause an increase in the damage threshold; the so-called conditioning effect. For the vast majority of use cases, the damage tends to develop on optical surfaces. Only on specific occasions will it occur within the bulk. Thus, if not requested or declared otherwise, the laser-induced damage threshold is tested and reported for the entrance surface of the optical component. For optics with high transmittance, damage may first develop at the exit surface or in the bulk without observing a damage of the entrance surface due to radiation field enhancement effects: self-focusing, diffraction or interference with back-reflected radiation. Back surface damage might also feature lower damage thresholds than the entrance surface as a consequence of poor optical quality. In such cases a functional damage threshold testing can be conducted for the exit surface. However, focusing conditions and the functional damage criterion need to be documented in the test report. Environmental contamination by airborne particles, volatile organic compounds, vacuum exposure, and technological imperfections such as nodular defects of coatings, polishing scratches, Beilby layer, sub-surface damage as well as bulk inclusions, dislocations, or inhomogeneities of any other type are also known to affect the performance of an optical component.

Due to a variety of possible failure mechanisms [6-64], the experimentally estimated “damage threshold” is an aggregated feature of optics handling, environmental conditions, material and surface preparation techniques as well as laser-related exposure parameters such as wavelength, spot size, repetition rate, and pulse duration. As a consequence, there is no single procedure, that could universally satisfy all the testing needs for all the types of optical components available. Instead, different damage testing strategies evolved to address particular needs for testing. Various parts of this document are concerned with the determination of irreversible damage of the optical surfaces and the bulk of an optical component under the influence of laser exposure. This document is dedicated to the fundamentals and general principles of the measurement of laser-induced damage thresholds. Based on the apparatus outlined in ISO 21254-1, measurement protocols for damage testing (1-on-1, S-on-1, R(S)-on-1, and Raster scan) are described in ISO 21254-2, and acceptance testing is described in ISO 21254-3. Recommendations and associated risks pertinent to distinct test procedures will be discussed in more detail in Annex A.

The “classical” 1-on-1 test is a damage threshold measurement procedure that uses one pulse of laser irradiation on each unexposed test site of the specimen. In contrast, the “classical” S-on-1 measurement program is based on a series of pulses with a constant laser irradiation level applied to each unexposed site of the specimen. Testing with multiple laser pulses is closer to the operational conditions in the field, however, the experimental effort necessary for S-on-1 tests is also significantly higher. The ISO 21254-series also introduce new alternatives – concept of “functional” damage threshold and new testing protocols such as R(S)-on-1 and Raster scan. In an R(S)-on-1 test, the same test site is irradiated with sequences of (S) pulses while gradually increasing the irradiation level between particular irradiations until the damage is observed. As a further extension of this measurement concept, the Raster scan technique is designed to irradiate a significant fraction of the test sample area with spatially overlapping laser pulses. ISO 21254-3 describes the acceptance testing for a certain laser irradiation level of optical surfaces, leaving samples that pass the test undamaged. ISO/TR 21254-4, which considers damage detection methods and the inspection of tested surfaces, is a Technical Report which complements this document.