TECHNICAL REPORT

ISO/TR 20811

First edition
2017-08

Optics and photonics — Lasers and laser-related equipment — Laser-induced molecular contamination testing

Qualification des composants optiques laser pour les applications spatiales

Reference number
ISO/TR 20811:2017(E)

© ISO 2017



COPYRIGHT PROTECTED DOCUMENT

© ISO 2017, Published in Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword ..... **iv**
Introduction ..... **v**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Symbols and abbreviated terms **2**
5 Test method **2**
5.1 Test setup 2
5.1.1 Vacuum chamber 2
5.1.2 Laser source and optical beam line 3
5.2 Setup for data acquisition 3
5.2.1 Beam profile monitoring 3
5.2.2 Measurement of pulse energy and determination of transmission 3
5.2.3 Laser-induced fluorescence monitoring 4
5.3 Test preparation 4
5.3.1 Bakeout 4
5.3.2 Pretreatment of optical samples 4
5.3.3 Blank test 4
5.4 LIMC test 5
5.4.1 Test parameters 5
5.4.2 Individual steps for LIMC test 5
5.5 Evaluation of test results 6
Bibliography **10**

© ISO 2017 – All rights reserved

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Electro-optical systems*.

© ISO 2017 – All rights reserved

Introduction

Laser technique is becoming increasingly important for space applications. Complex laser systems are used both for Earth observation and for planetary exploration. For long-term operations, optical components have to satisfy stringent requirements concerning precision and reliability. Before being used in space, all optical components have to be tested extensively. For standardized determination of laser damage threshold, ISO 21254 (all parts) should be applied. For characterization of optics for space applications, corresponding tests should be performed under vacuum conditions. In addition to laser damage issues, laser-induced molecular contamination (LIMC) should be taken into account. LIMC denotes the interaction of laser radiation, especially in case of high fluences and short wavelengths with volatile molecules and the resulting formation of deposits on optical components. LIMC proved to be particularly critical, if the laser system is operated under vacuum conditions and could considerably reduce the functionality of the whole laser system. Molecular contamination is mainly caused by organic materials and silicones, e.g. glues, adhesives, insulating material or circuit boards due to stronger outgassing rates compared to inorganic materials. The outgassing can be reduced but not totally prevented by selection of suitable materials and preconditioning, e.g. bake-out at elevated temperature well above the planned operating temperature. The outgassing behaviour of materials is generally characterized by these parameters: collected volatile condensable material (CVCM), total mass loss (TML), recovered mass loss (RML), volatile condensable material (VCM) and water vapour regained (WVR). Definitions and corresponding measuring specifications for these quantities can be found in ECSS-Standard Q-ST-70-02C, ASTM-E595-07 and ASTM-E1559.

This document outlines the test procedure for investigations of laser-induced molecular contamination in order to compare the growth of laser-induced depositions on optical surfaces for different molecular contamination materials.

© ISO 2017 – All rights reserved

Optics and photonics — Lasers and laser-related equipment — Laser-induced molecular contamination testing

1 Scope

This document describes the setup, test procedure and analysis of measured data for investigation of laser-induced molecular contamination (LIMC) for space and vacuum applications.

LIMC is the formation of depositions on optical surfaces due to interaction of intense light radiation with outgassing molecules especially from organic materials. It is a phenomenon of molecular contamination and it is distinguished from particle contamination, which can occur during manufacturing, assembly, integration or test of the optical components.

Formation of laser-induced depositions can lead to deterioration of the performance of an optical system. Phase distortion, scattering and absorption can be increased by LIMC. LIMC is of particular relevance, if a laser system is operated in vacuum at short wavelength and short pulse duration. In such a case, even small partial pressure of contamination material in the range of 10^{-5} hPa could have strong negative impact on optical performance. It was also shown that the laser-induced damage threshold could be reduced by a factor of 10 and more if laser-induced depositions are involved.

Laser-induced molecular contamination and laser-induced damage are both phenomena, for which the interaction of laser radiation with optical surfaces plays a major role, in case of LIMC with additional molecular contamination. Therefore, this document is treated in relation to ISO 21254 (all parts) which specifies the test methods for the determination of laser-induced damage thresholds.

This method was derived to evaluate qualitatively, whether the material under investigation causes deposits on optical surfaces in a low-pressure environment in the presence of high-energy nanosecond pulsed laser irradiation at a wavelength of 355 nm. Due to the nature of photochemical surface reactions, this result cannot be directly transferred to scenarios where the properties of the irradiation are altered (especially wavelength, repetition rate, pulse duration, etc.). Due to the non-linear growth of the laser-induced contamination and its detection methods, this technique does not provide quantitative means to evaluate the deposit and, therefore, it should be seen as a means to compare materials relatively with respect to their laser-induced contamination behaviour.

Furthermore, it is out of the scope of this method to select representative quantities of contamination materials — representative with respect to the material partial pressure present in the vicinity of the optical surface in a real laser system. This is carefully derived with other methods and is a mandatory parameter to be fixed before applying this method.

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 21254 (all parts), *Lasers and laser-related equipment — Test methods for laser-induced damage threshold*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11145 and ISO 21254 (all parts) and the following apply.

© ISO 2017 – All rights reserved

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

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

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

3.1
laser-induced deposition
material growth on optical surfaces as a result of photochemical or photothermal mechanisms triggered by the interaction of laser radiation with volatile molecules from outgassing process of especially organic materials

3.2
laser-induced fluorescence
light emission from any substance that has been excited to singlet states by absorption of electromagnetic radiation

4 Symbols and abbreviated terms

Symbol	Unit	Term
α	rad	Angle of incidence
d	m	Beam diameter
N_p	—	Number of pulses per site
H_{peak}	J/m^2	Peak energy density
τ	s	Pulse duration
f_p	Hz	Pulse repetition rate
E	J	Pulse energy
p	Pa	Pressure
T_c	K	Contamination temperature
λ	m	Wavelength

5 Test method

5.1 Test setup

5.1.1 Vacuum chamber

A typical setup for tests of anti-reflective optics (angle of incidence: 0°) is shown in Figure 1. The main part is an ultra-high vacuum chamber. It should be ensured that no organic materials are present in this chamber. Especially an oilfree pumping system and metallic sealings instead of plastic o-rings should be used. In particular, the use of silicone-based materials (e.g. pump oils) should be absolutely avoided. In general, silicones have a very low vapour pressure and it is very laborious to get rid of it once the test chamber is contaminated with it. Moreover, silicones are known to produce laser-induced depositions even at ambient or oxygen atmosphere. In contrast to this, for hydrocarbons, the formation of laser-induced depositions is strongly reduced or totally inhibited by oxygen at least in case of UV laser radiation. The vacuum chamber is composed of copper-sealed stainless steel components, e.g. according to ConFlat (CF) standard. The pumping system consists of a turbomolecular pump and an oilfree forepump (e.g. scroll pump). For pressure sensing Pirani, Penning or capacitance manometer should be used. Additionally, a quartz crystal microbalance (QCM) sensor and/or a mass spectrometer can be integrated for determination of outgassing rate and composition of contamination material. By using a mass spectrometer, it is possible to determine the partial pressure of the contamination material in the main chamber, provided that the total pressure is below 10^{-5} hPa. If the total pressure is higher, a differentially pumped mass spectrometer should be used. The mount for the optical sample under test is positioned at the centre of the vacuum chamber. This mount is movable in horizontal

© ISO 2017 – All rights reserved