SUPERLASERS FOR THE REAL WORLD

Laser Induced Damage

A WAY FOR AN EFFECTIVE AND RELIABLE USE OF A NEW GENERATION HIGH-INTENSITY LASERS

WHITE PAPER

Since the first commissioned lasers, both laser system developers and laser end-users encountered various issues connected to the damage of material exposed to laser radiation. This phenomenon, known as Laser Induced Damage Threshold (LIDT), defines the maximum affordable energy or power, which a particular optical surface or bulk material may withstand without detrimental damage. Therefore, LIDT testing methods have been developed and has been officially recognised by the International Standards Organisation (ISO) in a series of ISO 21254 standards. These standards were established in order to ensure the reliability of results and their portability among different testing facilities.

At first, the testing schemes reflected the need of laser optics manufacturers to understand and manage the quality of their products. However, the rapid development of new generation of high-power laser sources and their applications shifted the market interest in LIDT tests towards machine integrators, whose goal is to implement high quality optical components, which can withstand radiation conditions of new high-power lasers, whilst ensuring the lowest downtime of machines as possible.

INTRODUCTION TO LIDT

Laser damage is related to many variables, which, in general, could be sorted into three classes: laser source properties (wavelength, pulse duration, spatial beam profile, etc.), ambient conditions (temperature, humidity, contamination, etc.) and material characteristics (defects, inclusions, refractive index, etc.). Therefore, unifying the evaluation criteria of LIDT is highly desirable and necessary for any top-class application. It is important to remark, that laser damage is limiting not only the maximum power or energy of the certain laser system, but also how the beam will be handled in the integrated machine and which application will be available for such machine.

LIDT is defined as the highest quantity of laser radiation incident upon the optical component for which the extrapolated probability of damage is zero. Therefore, the LIDT value is obtained by statistical evaluation of the experimental data from measurements on representative samples during the test.

There is a number of precursors, which may lead to laser damage on a particular surface. Some of them can be eliminated, for example proper storage and handling may eliminate contamination or scratches. However, most of the laser damage precursors are inherently connected with the component manufacturing process, laser operation principle or the way of laser system utilization, and demonstrate themselves accordingly. Likewise, different LIDT tests has to be used in order to point out on various precursors. We can demonstrate the approach on a simplified example of a dielectric optical mirror.

A manufacturer of optical thin films and thin-film based components is interested in his product performance, a single value that allows him to compare different coatings and coating processes, and thus the ISO 21254-2 standard procedure called “s-on-1” could be applied. This procedure utilizes extrapolated damage probability from measured data to show the damage threshold fluence in relation to number of pulses per so-called “characteristic damage curve”.

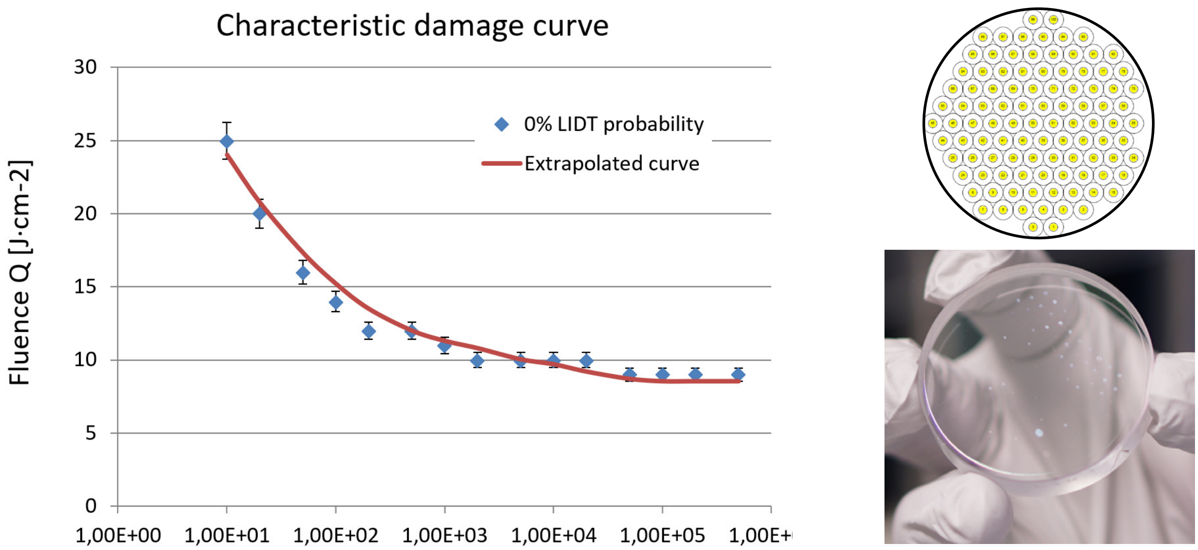

FIGURE 1: CHARACTERISTIC DAMAGE CURVE ACCORDING TO ISO 21254-2, TEST SITES DISTRIBUTION AND TESTED SAMPLE

FIGURE 1 depicts a typical result of such test, which describes LIDT dependence on the number of pulses. The test gives a value, which may be related to the intrinsic damage threshold of the surface and can be used as a performance criterion for choosing the most suitable coating material and production technology. Note, that only a fraction of a tested site surface is exposed to the laser beam. ISO 21254 standard specifies required distance in multiples of a beam diameter among exposed sites to prevent the interference of results with debris ejected from damage craters. This means, that the s-on-1 test has a fairly low probability to activate sparse damage precursors.

On the other hand, an integrator, with the intention to use the above mentioned mirror in a particular laser machine, would require to certify such component for installed laser. In this case, the standardized procedure according to ISO 21254-3 may be used in order to assure laser energy handling capability. In contrast to the previous testing method (ISO 21254-2), the ISO 21254-3 method will not provide a particular damage threshold value but the expose maximum feasible surface area to a specific fluence and number of pulses. Therefore, there is a high probability that the test will activate any single present defect on the examined surface. If no damage is observed during the test, it indicates with high level of confidence that the component is safe to operate at given conditions.

PROBLEM

Nowadays, laser optics manufacturers produce nearly all their components in serial production batches, not particularly considering the specific end-usage e. g. new laser system design or specific laser application. Although such approach brings cost-effective components, it also often results in certain performance and reliability issues. Moreover, the immense industrial demand for high- intensity short and ultrashort lasers and their efficient applications drives forward the development of laser components and optics. Consequently, there is a market demand for laser components and optics with a higher LIDT.

The previously described “s on 1” method will expose only few % of the surface to the critical fluence, therefore, most of the damage precursors remains unrevealed. Meaning that for the fluence spread over a larger surface, the laser damage can occur at much lower LIDT values as depicted in **FIGURE 2**.

Consequently, it is necessary to design such LIDT testing which will be relevant to the new radiation conditions (higher pulse energy and larger spot size) to comply with the new generation of lasers and their applications.

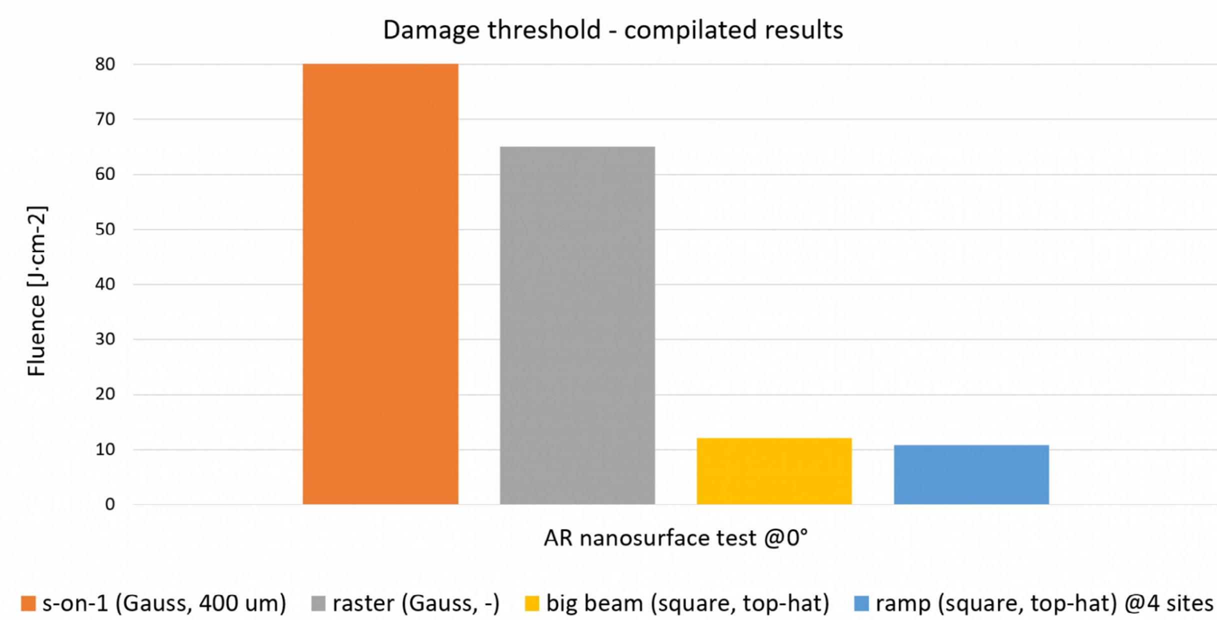

FIGURE 2: LIDT VALUES FOR SAME OPTICS. IN THE CASE OF EXPOSING LARGER AREA OF OPTICS TO LASER RADIATION, LASER DAMAGE WILL OCCUR ON MUCH LOWER VALUE OF FLUENCE

SOLUTION

An ISO standard-compliant LIDT laboratory has been established at HiLASE, targeting testing methods under these new radiation conditions. The LIDT laboratory benefits from advanced laser development at HiLASE, which provides access to the state-of-the-art diode-pumped solid-state laser systems, which offers incomparable energies for experiments. Two systems are mostly used for tests: Bivoj (10 ns, 1030/515/343 nm @10 Hz, flat-top square beam) and Perla (1.7 ps, 1030/515/343 nm @1 kHz, round Gaussian beam). With both lasers providing very high pulse energies, it is possible to measure LIDT using a larger beam size, which greatly increases the measurement accuracy. The testing station, as shown in **FIGURE 3**, is situated in a clean laboratory with controlled humidity, temperature, dust particle concentration, and cleanliness, which adhere to ISO class 6 cleanroom environment.

CERTIFICATE

Certification Body Management System No. 3053
TÜV SÜD Czech s.r.o.

certifies that

Fyzikální ústav AV ČR, v. v. i.
Na Slovance 1999/2
CZ – 182 00 Praha - Libeň
Ident. No.: 68378271

Workplace:
Centrum HiLASE, Za Radnicí 828, 252 41 Dolní Břežany

has established and applies
a Quality Management System for

materials testing on laser induced damage threshold

An audit was performed, Report No. 13.628.879
Proof has been furnished that the requirements according to

ČSN EN ISO 9001:2016

are fulfilled.
The certificate is valid from 23.03.2021 until 22.03.2024
Certificate Registration No. 13.628.373

Prague, 23.03.2021

TÜV SÜD Czech s.r.o. • Novodvorská 994 • 142 21 Prague 4 • Czech Republic • certification@tuv-sud.cz

ZERTIFIKAT ◆ CERTIFICATE ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

LIDT tests at HiLASE are conducted in an experimental chamber with the option of a vacuum (10^{-3} mBar) or non-corrosive atmosphere (up to 2 Bar). A remote-controlled micrometre 2-axis translation stage is used for sample mounting. Online damage detection of the exposed site is realised by an online camera with high magnification that records the test process and pertinent damage event. A laser scanning microscope is used to examine the sample before and after each testing procedure.

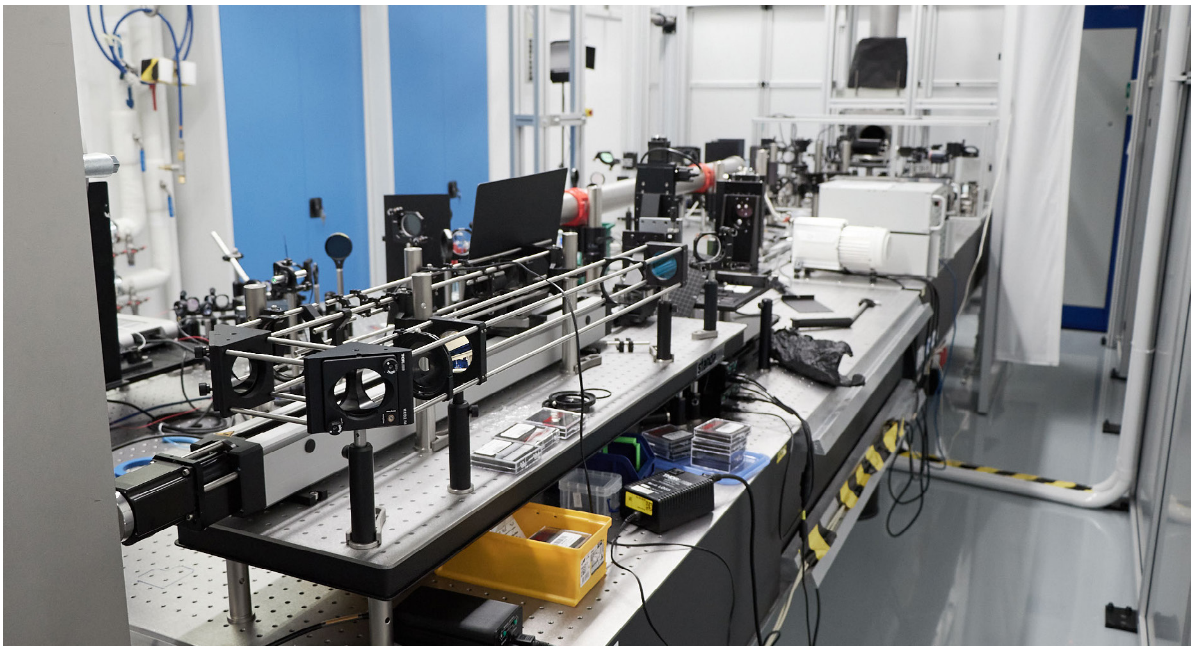

FIGURE 3: HILASE CENTRE LIDT LABORATORY

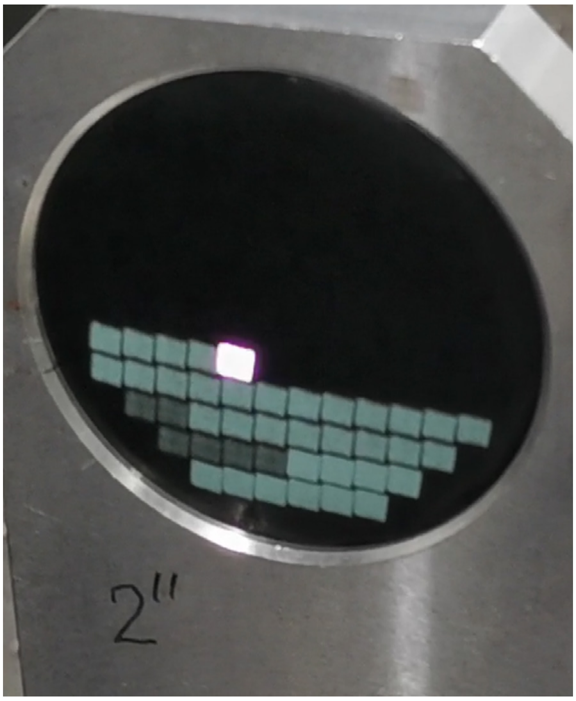

FIGURE 4: ABSORPTIVE COATING FAILING DURING TEST OF LASER ENERGY HANDLING CAPABILITY

FIGURE 4 demonstrates LIDT testing of absorptive coating under the radiation of a large beam, i.e. top-hat square beam (spot size 3 mm) of ns pulses were used for testing.

SUMMARY

Accurate knowledge of LIDT is essential for any demanding application utilizing high-power lasers. As demonstrated in the text above, laser damage is a multi-parameter problem with no universal solution, where each particular case has to be investigated reflecting particular restrains and specifics. However, investing resources into proper and thorough investigation will always pay-off with safety, reliability and effectivity, thus building a strong client customer relationship. HiLASE centre is offering top-class accuracy, deep understanding of the phenomena and the possibility to customize LIDT tests in regards to a particular application. Our unique background and know-how allows us to provide LIDT testing service for any area with maximum confidence.

CLICK HERE TO SPEAK WITH OUR LIDT EXPERTS

STAY IN TOUCH AND BE INFORMED

in hilase-centre · HiLASECentre · HiLASECentre · HiLASECentre

HiLASE Centre · Institute of Physics of the ASCR, v.v.i. · Za Radnici 828, CZ-25241 Dolni Brezany
solutions@hilase.cz · (+420) 314 007 718 / 314 007 710 · **www.hilase.cz**

Czech Academy of Sciences

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research, Development and Education

MINISTRY OF EDUCATION, YOUTH AND SPORTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 739573 (HiLASE CoE)

FZU