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Comparative study of laser materials LID at cryogenic temperatures

Lead Beneficiary:

VILNIAUS UNIVERSITETAS - VULRC

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Deliverable Nature	
R = Report, P = Prototype, D = Demonstrator, O = Other	R
Dissemination Level	
PU = Public PP = Restricted to other programme participants (incl. the Commission Services) RE = Restricted to a group specified by the consortium (incl. the Commission Services) CO = Confidential, only for members of the consortium (incl. the Commission Services)	PP

A. Abstract / Executive Summary

Laser induced damage thresholds (LIDT) on new laser glasses as well as on anti-reflection coated sapphire, what is often used in lasers for conductive cooling or as mechanically stable windows, were measured. It was found that even pure materials show a very high stability against high energy laser pulses, this is reduced if they are coated. High reflective coatings show very high damage thresholds if they are irradiated from the air side, but this will change if the irradiation direction is reversed and the laser pulse arrive from the material side at the coating. Damage thresholds of laser materials doped with Ytterbium were compared with undoped samples in order to reveal the effect of the additional absorption of the dopant. Measurements were performed at room temperature as well as with cryogenic cooling under vacuum conditions to have an estimate for the impact of the environment on LIDT.

B. Deliverable Report

1 Introduction

LIDT Tests of new laser materials at room temperature and cryogenic temperatures are needed, since laser applications demand the operation of diode pumped short pulse lasers at these temperatures in order to increase their efficiency. High reflective (HR) and high transmissive (HT) coatings typically have a dramatic effect on the laser induced damage thresholds. Therefore, it is required to study, how pure materials as well as coated materials behave. Since the Ytterbium energy level system is a quasi-three level system, the laser beam with a wavelength inside the amplifying band width is partially absorbed. In order to gain knowledge how doping concentrations have to be included into the design of solid state lasers concerning LIDT, comparative measurements had to be performed. Additionally, sapphire as a window material and a very good thermal conductive optic at low temperatures need to be included in the tests. This would complete the set of materials and coatings combinations for laser applications.

2 Objectives

The comparison of LIDT measured at room temperature and cryogenically cooled should reveal the influence of temperature on the damage threshold. Moreover the influence of doping on LIDT of laser materials has to be investigated. The measurement of AR-coatings on sapphire are needed, since the material is typically part of the laser design. HR coatings for ‘active mirror’ configurations are another part of the investigation. The comparison of coating techniques should reveal the best production process for ‘hard’ laser optics.

3 Work performed / results / description

All reported damage tests were made with an Yb:YAG laser at 1030 nm. The pulse width was 3 ns. The beam diameter in the focus that amounts to about 200 µm was measured for every pulse to calculate the fluences very precisely. Here all measurements are 1-on-1 tests, where the decision about the damage was made twofold: online collected stray light data as well as manual observation with a microscope after irradiation was combined.

3.1 Investigation of the doping concentration on LIDT

In figure 1 the damage probability measured on an undoped sample. This is to be compared to the measurement shown in figure 2, what reveals between them no difference larger than the error bars of the measurement. Since these measurements are only examples of many more that were performed the important conclusion that the doping does not play a role in the damage behavior is therefore possible with reasonable certainty.

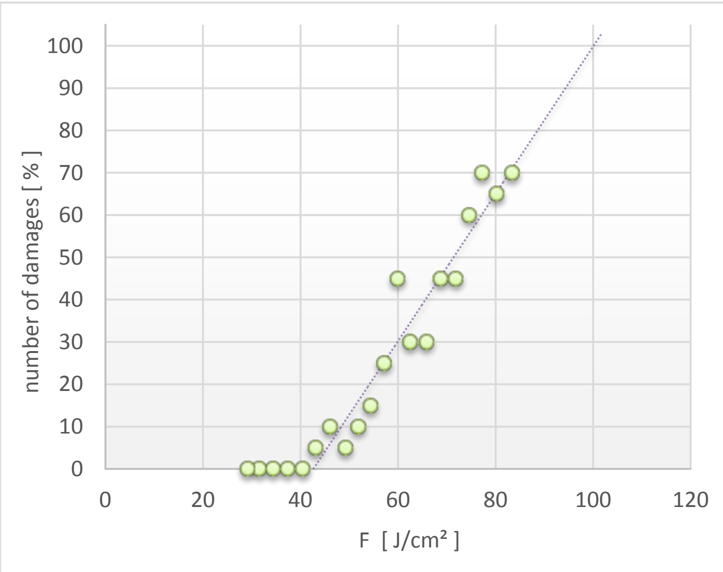

Figure 1: LIDT for an undoped sample. The material was a Lithium-aluminosilicate glass.

3.2 Comparison of LIDT measured at cryogenic temperatures with room temperatures

Many further measurements were done at room temperature as well as cryogenic temperatures like the one reported earlier in deliverable 16 of the work package 33. Likewise no significant difference dependent on the temperature was observed, except for Yb:YAG ceramics (see 3.3), where a small tendency to higher LIDT with lower temperatures could be seen. But these differences are much smaller than variations from several production runs.

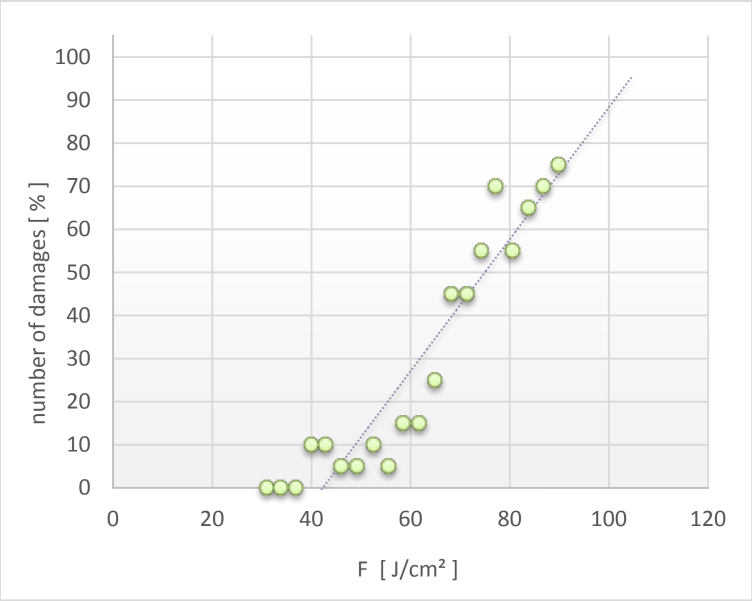

Figure 2: LIDT for an 0.5%Yb-doped Lithium-aluminosilicate glass.

3.3 LIDT measurements on AR-coated Yb:YAG

In figure 3 the damage probability is plotted for an Yb:YAG ceramics sample. It shows the result of the highest damage threshold of 40 J/cm² in that case. Here different coatings were compared. They differed by up to a factor of two. At low temperature slightly higher LIDT values compared to room temperature were observed.
This shows that Yb:YAG is a very promising material for diode pumped lasers, since it does not only allow high damage thresholds on the pure material but also with proper AR-coatings.

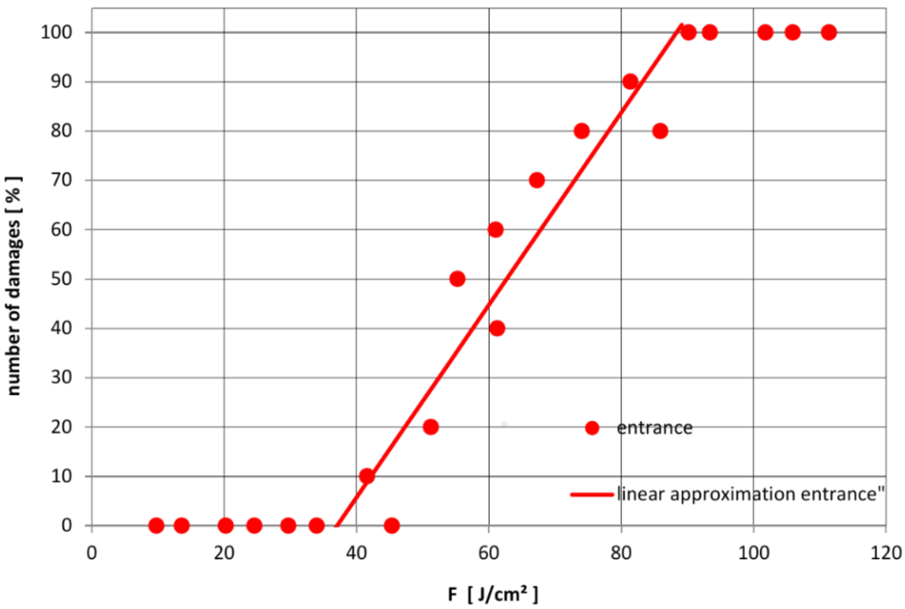

Figure 3: LIDT measurement on AR-coated Yb:YAG ceramics.

3.4 LIDT measurements for active mirror designs

Laser glass samples that are intended to be used in an active mirror design were measured in a configuration with the illumination by the test laser from the air side compared with the measurement with illumination from the glass side. This comparison should show what influence the substrate to the damage behavior has.

Figure 4 shows the air-side measurement, whereas in figure 5 the glass-side measurement is depicted. Even the same coating is tested and damages always occur on the coating a huge difference is observable. In the first case a damage threshold of almost 80 J/cm³ was measured, whereas in the second case the threshold is about a factor of four lower.

This is a hint that higher intensities caused by interference of counter propagating waves are probably the reason for lowered damage thresholds.

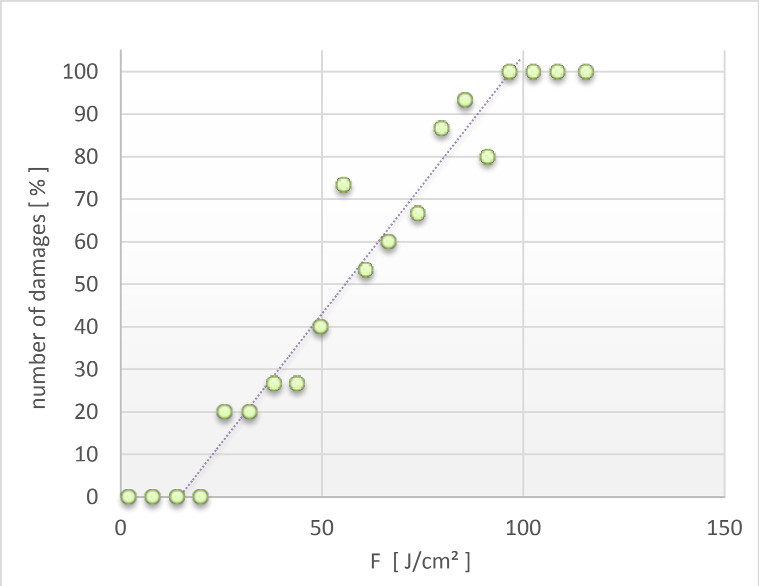

Figure 4: LIDT on an HR-coated sample, where the illumination was from the air side.

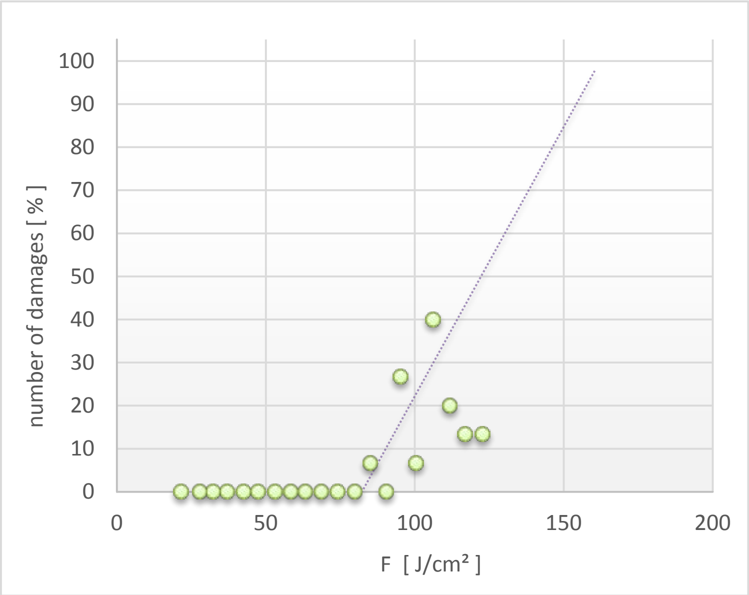

Figure 5: LIDT for the same coating as in figure 4 but with illumination from the glass substrate side.

3.5 LIDT measurements on AR-coated sapphire

The LIDT measurements on AR-coated sapphire is depicted in figure 6. This measurement shows the highest value measured. Compared to Yb:YAG the value is much smaller such that it will be the limiting factor in the laser design. More investigations are needed for the required improvement of these coatings.

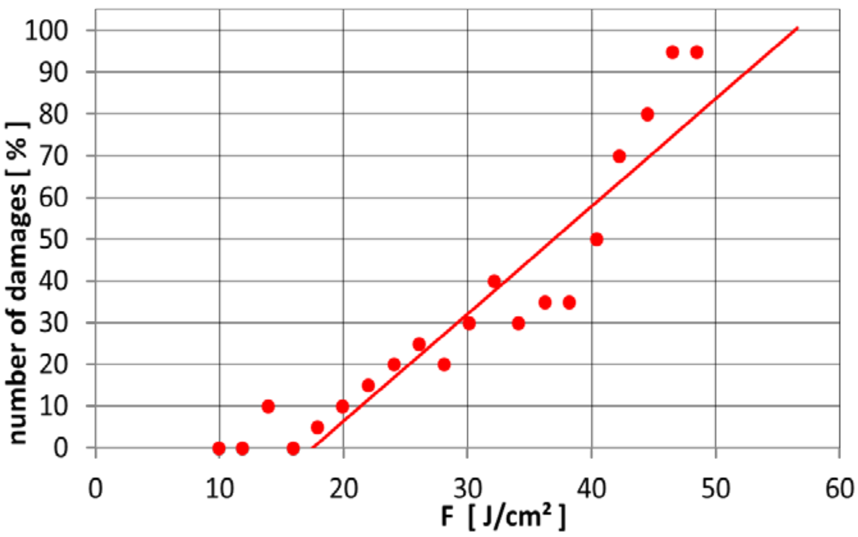

Figure 6: LIDT on AR-coated undoped sapphire

4 Conclusions

The measurements of LIDT on coated samples at different temperatures and vacuum environment have not revealed significant differences. For the higher LIDT values a slight tendency to higher values at lower temperatures could be noticed.
Additionally, no dependence of the LIDT on the doping of samples with the laser active on Ytterbium was found.
For designs with sapphire windows these are actually the bottleneck for the maximum allowed fluence and improvement needed in future.
For active mirror designs much lower damage thresholds have to be taken into account compared to an illumination from the air side, what is assumed to be caused by interference of counter propagating waves in the sample.

5 References/Publications

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