SPACE LASER COMPONENTS RELIABILITY

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Space environment presents unique challenges for operation of optics and optical coatings as part of laser systems. Besides testing components and sub-systems on the component qualification level, the extended testing of complete laser systems like flight modules under acceptance level conditions is an effective way to determine the reliability and long term stability, mitigating the mission risk.

Hence, optics as part of high power space laser systems have to be extensively tested in view of an upcoming mission. The goal is to identify and mitigate production flaws, and to optimize the laser environment, such that a safe operational margin can be maintained over the expected lifetime in orbit.

This talk summarizes the test technology status for qualifying single component laser optics and the lessons learned from these tests. The results are mainly attained from pulsed nanosecond laser radiation from the fundamental wavelength of Nd:YAG lasers and its harmonics. The primary test technology used is the evaluation of the laser-induced damage threshold in a controlled contamination-free environment with the addition of subsequent tests for scaling the test area (raster scan tests) and test time (lifetime tests). Coating technologies that will produce dense, non-porous coatings are recommended as a result of these investigations, as they are resistant to molecular diffusion (e g by water molecules) and consequently do not exhibit spectral shift phenomena (under vacuum exposure) and drop of damage threshold values due to tensile stress effects.

An important outcome for single component testing is the characteristic damage curve, which can be evaluated according to the S-on-1 test procedure detailed in ISO 21254-2 [1]. It allows for the prediction of the LIDT of a sample for large pulse numbers, i. e., for higher pulse numbers than the one applied in the test itself. Hence, it is a means to estimate the lifetime of the optical component. The drawback of this test is the small area coverage. For further operational risk mitigation, which is very stringent for space laser operation, the sample needs to be subjected to a test which is representative in terms of the tested area.

Besides clean environmental tests, the influence of molecular contaminants has to be considered. By injecting small partial pressures of hydrocarbons into the test compartment the performance of laser optics will possibly be deteriorated by the formation of laser-induced deposits, degrading the transmittance or reflectance values. Furthermore, a massive drop in laser-damage threshold can be observed as opposed to the clean environment performance. The growth of such deposits and the occurrence of such damage behavior can be mitigated by oxygen but threshold behavior is still a topic of investigation.

Finally, energetic radiation tests, e. g. via exposure to Co60 gamma radiation or by exposure to energetic proton radiation representatively applied in mission related doses have been performed. These tests have resulted in an increase in bulk absorption for certain nonlinear optical and Q-switching crystals. Higher impurity crystals like phosphates and arsenates seem to be more prone to radiation degradation than borates. Degradation was mainly observed in the VIS and UV spectral range, due to excitation of color centers.

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