

ACCELERATED LIFETIME TESTING OF OPTICAL MATERIALS UNDER HIGH-REPETITION UV LASER IRRADIATION

Martynas Keršys¹, Andrius Melninkaitis¹

¹Vilnius University, Faculty of Physics, Laser Research Center, Vilnius, Lithuania
martynas.kersys@ff.stud.vu.lt

High-power ultraviolet (UV) laser systems are widely used in industrial micromachining, lithography, and scientific instrumentation. However, the long-term stability of these systems is fundamentally limited by the durability of their optical components [1]. Under high-repetition-rate irradiation, cumulative energy deposition can induce gradual functional degradation well below the single-pulse laser-induced damage threshold (LIDT), making optical fatigue a limiting factor for component lifetime.

This study presents an accelerated lifetime testing (ALT) approach for evaluating optical fatigue in BK7 glass, UV-grade fused silica, and a high-reflectivity (HR) dielectric mirror under 355 nm picosecond irradiation. Samples were irradiated using a ~ 10 ps UV laser light, while transmission and reflectance were monitored *in situ* at multiple fluence levels and beam diameters. Transmission kinetics were analyzed using stretched-exponential model to extract characteristic lifetimes - time it took for the characteristic to drop to a certain level (e.g., t_{90} , t_{95}).

The results show that lifetime extrapolation is possible, however it strongly depends on irradiation regime. Moderate fluence levels yield consistent scaling behavior, whereas excessively high fluence induces rapid nonlinear response and increased statistical scatter, limiting ALT predictability. The findings highlight the importance of regime selection and mechanism stability when applying accelerated lifetime methodologies to UV optical components.

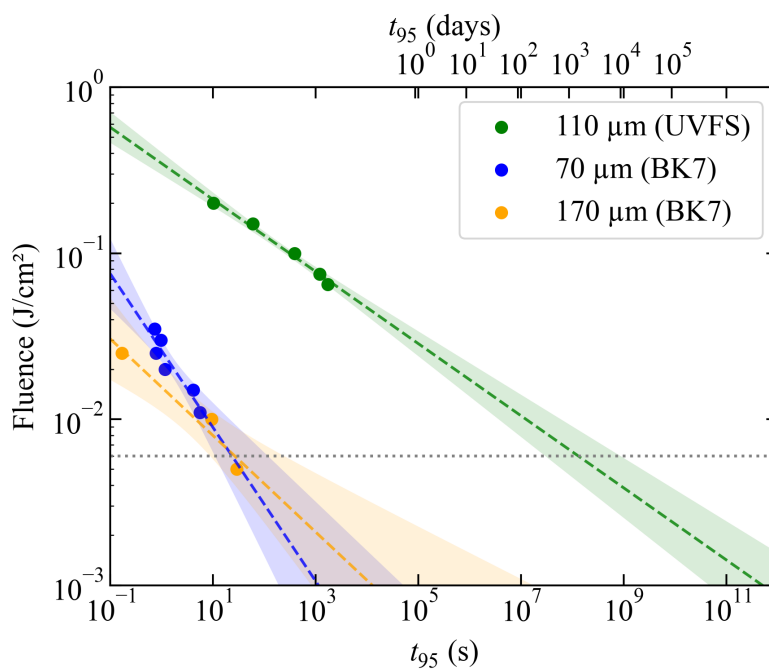


Fig. 1. Log-log dependence of fluence on characteristic (transmission) lifetime t_{95} for UVFS (with 110 μm beam diameter at $1/e^2$) and BK7 (with 70 μm and 170 μm beam diameters) under 355 nm picosecond irradiation. Points represent experimental values extracted from stretched-exponential fits; dashed lines show power-law scaling, and shaded areas indicate fit uncertainty. The dotted line marks a representative operating fluence that can be reached in the used EKSPLA Atlantic 80-IR-GR-40-UV30-VP pulsed laser.