Nanosecond Laser Damage Resistance of Differently Prepared Semi-finished Parts of Optical Multimode Fibers

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Introduction

- Optical multimode fibers are applied in fields like automotive, defense, aviation, medicine and biotechnology
- High power applications (fiber lasers, laser light cabel) are of increasing interest
- Besides geometrical parameters and absorption behavior of fibers the laser damage threshold is a major aspect

Problem

Laser-induced damage threshold (LIDT) can limit the performance of complex optical systems with respect to beam quality and transmissible power

Question:

Does the pulling process (pulling temperature, cooling rate, mechanical stress) and the polishing of fiber end faces influence the LIDT?

Experimental

Specimens:

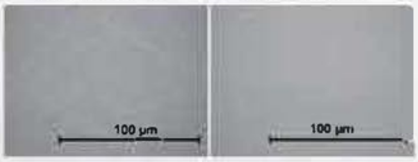
- Material: SiO_2 glass (F300, Heraeus)
- Multimode fiber preform
- Cylindrical samples: 20 mm diameter and 10 mm thick
- Transformation temperature (F300): 1070 °C

Surface preparation:

According to sequences "A" and "B"

Surface Preparation Steps	"A"	"B"
Grinding with abrasive grains with grain diameters down to ≈15 µm	×	×
Polishing with Ce_2O_3 suspension with Ce_2O_3 grain diameters of 3 µm		×
Polishing with diamond suspension with diamond grain diameters of 3 µm	×	×
Polishing with diamond suspension with diamond grain diameters of 1 µm	×	×
Polishing with diamond suspension with diamond grain diameters of 0.25 µm	×	×

Preparation "A" Preparation "B"



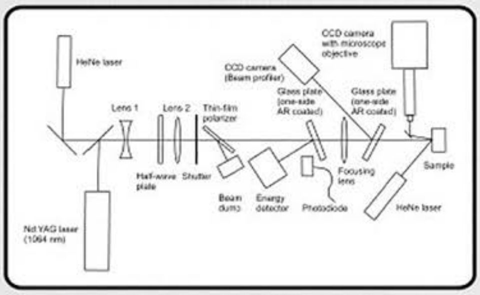
Thermal treatment:

- Tempered at 1100 °C, 1300 °C and 1500 °C for 15 min.
- Cooling rates: 10 K/min (oven) and 10^5 K/min (quenched in air)

Laser setup:

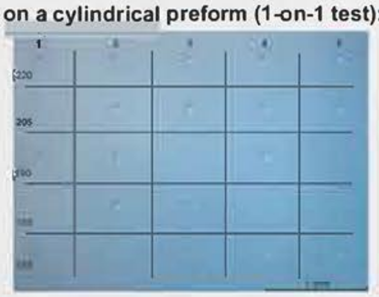
- Nd:YAG laser
- 1064 nm, 12 mJ, 10 Hz
- Gaussian beam profile
- 2w = 50±2 µm
- M^2=1.6
- Precision of absolute LIDT value: 25%
- Maximum laser fluence: $F_0 = \frac{2E_0}{\pi w^2}$
  E_0 (pulse energy)

Experimental setup:



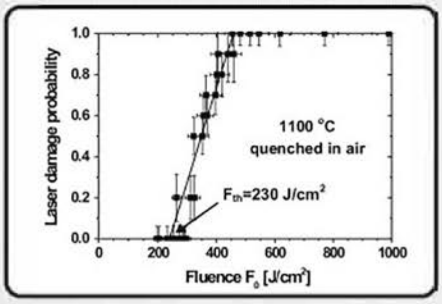
According to standard ISO 11254-1/2:
Part 1: 1-on-1 Test / Part 2: S-on-1 Test

Array of laser induced damage sites on a cylindrical preform (1-on-1 test):



top: consecutive numbers of damage sites
left: relative laser power

Interpretation of data:



Damage probability vs. maximum laser fluence

Results

Maximum temperature [°C]	Surface preparation	F_{th} cooling rate 10 Kmin⁻¹ [J/cm²]	F_{th} cooling rate 10^5 Kmin⁻¹ [J/cm²]
20	B	220	
1100	B	250	230
1300	B	250	350
1500	B	320	250
1500	A	150	-

Damage threshold fluences F_{th} for cylindrical preforms with different thermal history and varying surface preparation (1-on-1)

Maximum temperature [°C]	Surface preparation	F_{th} 1-on-1 [J/cm²]	F_{th} 100-on-1 [J/cm²]
20	B	220	220
1100	B	230	210
1300	B	350	270
1500	B	250	230

Damage threshold fluences F_{th} for cylindrical preforms with different thermal history Comparison between (1-on-1) and (100-on-1) laser treatment

Conclusions

- LIDT values between 150 J/cm² and 350 J/cm² (1064 nm, 15 ns, unseeded)
- An insufficient polishing procedure decreases the damage resistance significantly
- A thermal pre-treatment enhances the damage threshold
- A multi pulse impact results in lower thresholds compared to the single pulse illumination (incubation effect)

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