Influence of Core Diameter and Coating Material on Nanoscond Laser-Induced Damage Threshold of Optical Multimode Fibers

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Introduction

- Optical multimode fibers are applied in materials processing, defense, aviation technology, medicine and space
- High-power laser applications are of increasing interest

Approach

- Comparison of laser-induced damage thresholds (LIDT) of the surface of fibers with different core diameters
- Determination of LIDT values of the surfaces of fluorine-doped SiO_2 (preform cladding material) and standard fiber coating materials

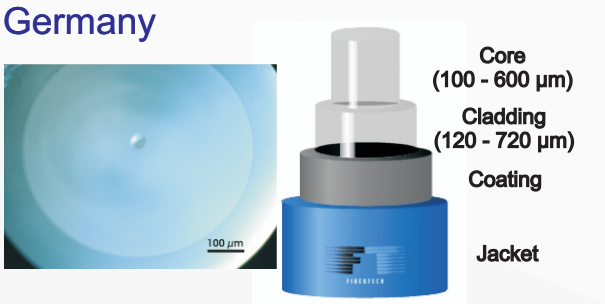
Experimental

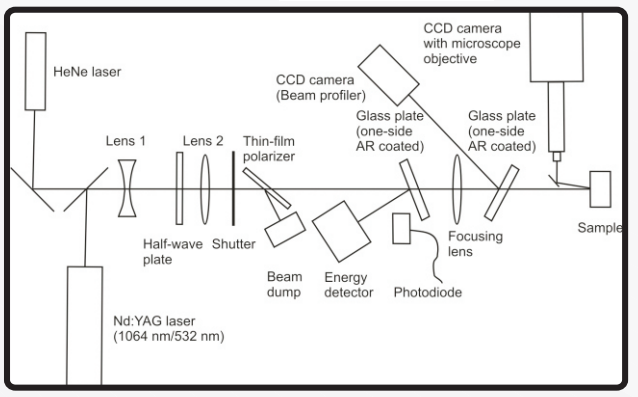
Samples:

- Fiber samples (All-silica, FiberTech, length 50 mm) with varying core diameters and constant core/cladding ratio, FiberTech polish
- Cylindrical specimen (diameter 9 mm, length 23 mm) cut from preform cladding material (~4 % fluorine-doped SiO_2, F320 HQ, Heraeus), FiberTech polish
- SiO_2 samples (1" square, 1 mm thick) covered with different coating materials

Laser:

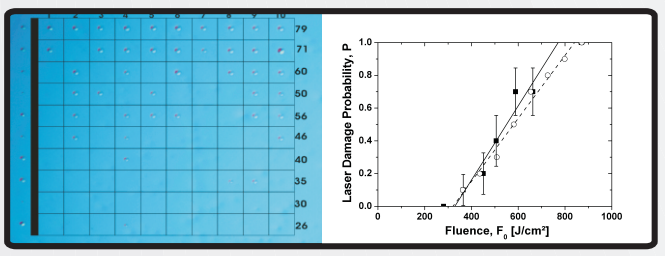
- 1064 nm: 12 ns, $2w_0$=49 µm, 27 mJ, 10 Hz
- 532 nm: 8.5 ns, $2w_0$=30 µm, 12 mJ, 10 Hz





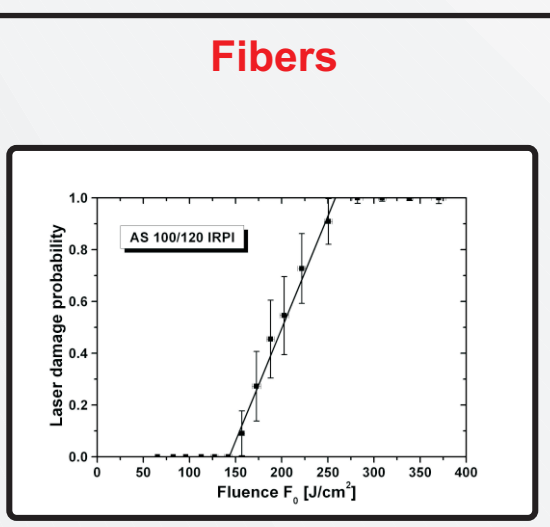
Results

In principle LIDT measurements were performed according to the standard ISO 11254-1/2, Part 1: 1-on-1 test [1], Part 2: S-on-1 test [2] Additionally, for fiber samples a R-on-1 test was applied and their congruence was verified on a SiO_2 preform sample [3].



Left figure: R-on-1 (to the left of the bold line) vs. ISO-standard
Right figure: Damage probability P vs. maximum laser fluence F_0 for 1064 nm [3]

Fibers



Laser damage probability P vs. maximum laser Fluence F_0, fiber AS 100-120 IRPI at 1064 nm wavelength

Damage threshold fluences F_{th} for fibers with different core diameters, 532 nm and 1064 nm

Fiber Type	Core Ø [µm]	F_{th} [J/cm²] 532 nm	F_{th} [J/cm²] 1064 nm
AS 100-120 IRPI	100	135	145
AS 200-240 IRPI	200	180	265
AS 400-480 IRSN	400	210	340
AS 600-720 IRSN	600	200	570

- LIDT values increase with increasing core diameter probably due to different frozen glass structures generated by the fiber pulling process [3]
- Reproducibility of LIDT values within 10% for 1064 nm wavelength [3]

Fluorine-doped SiO_2 preform

	F_{th} [J/cm²] 1-on-1	F_{th} [J/cm²] 10-on-1
532 nm	160	130
1064 nm	440	205

Damage threshold fluences F_{th}, 532 nm and 1064 nm

- LIDT values at 1064 nm are comparable to the results of undoped SiO_2 preforms [4]
- LIDT values at 532 nm are higher than the values of undoped SiO_2 preforms [4]
- Finally, the fluorine-doped part of the fiber (cladding) is not the crucial part for damage

Coatings

Sample	F_{th} [J/cm²] 1-on-1	F_{th} [J/cm²] 10-on-1
Silicone	25	17
Polyimid	8	<4
Single Layer-Acrylat	33	28
Fluorine-doped Acrylate I	29	24
Fluorine-doped Acrylate II	40	38
Primary Coating I	44	34
Primary Coating II	53	49
Secondary Coating	30	10

Damage threshold fluences F_{th} at 532 nm, 1-on-1 and 10-on-1

Conclusions

- Determination of LIDT values of fibers with different core diameters, fluorine-doped preforms and fiber coating materials on dielectric substrates
- Fiber LIDT values decrease with fiber diameter (glass structure effect)
- Cladding material (fluorine-doped) exhibits roughly the same LIDT values as the core material
- Fiber coating materials offer LIDT values about one order of magnitude lower than core and cladding, i.e. the optical multimode fiber itself
- Multi-pulse behavior of coating materials might be critical

References

[1] ISO 11254-1:2000, Laser and Laser-Related Equipment - Determination of Laser-Induced Damage Threshold of Optical Surfaces - Part 1 : 1-on-1 Test

[2] ISO 11254-2:1999, Laser and Laser-Related Equipment - Determination of Laser-Induced Damage Threshold of Optical Surfaces - Part 2 : S-on-1 Test

[3] G. Mann et al., *Breakdown limits of optical multimode fibers for the application of nanosecond laser pulses at 532 nm and 1064 nm wavelength*, Appl. Surf. Sci. 255 (2009) 5519

[4] G. Mann et al., *Nanosecond laser-induced surface damage of optical multimode fibers and their preforms*, Appl. Phys. A 92 (2008) 853

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