Laser-Induced Damage Tests for Space-borne Lasers

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Risks for optics of ALADIN, the laser in ADM-AEOLUS:

- Laser-induced damage of optics
- Optical aging
- (Contamination)

Laser-induced damage test campaign

Operating in space vacuum, the ALADIN laser will emit 4.6 Billion shots over the duration of the mission.

To address the risks, ESA has set up a laser-induced damage test campaign to address the main issues:

- The intrinsic damage threshold.
- Optical fatigue over the length of the mission.
- (Contamination effects: Contamination builds up over time)

A Laser Risk Reduction Working Group has been set up to assess the risks, advice on the tests and evaluate the experimental data

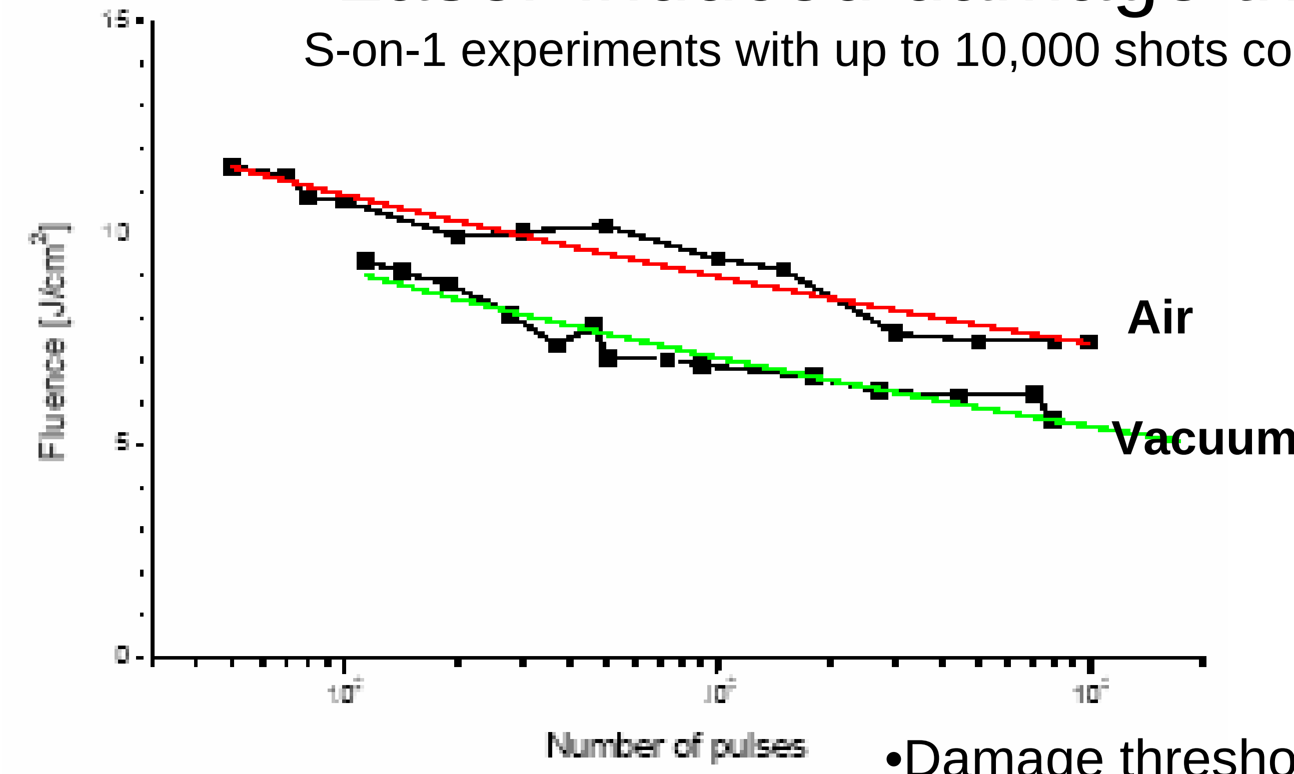
Optical damage: test overview

ALADIN contains more than 70 optical components, of which 20-30 are unique combinations of substrate and coating.

All unique coatings are tested
•Fluences up to 25J/cm^2
•355nm, 532nm, and 1064nm in addition to 808nm
•Dichroics, Polarisers, AR, HR and Partial reflectors
•Incidence angles of 0º, 11 º, 30º, 45º, 56º, 90º

Laser-induced damage threshold

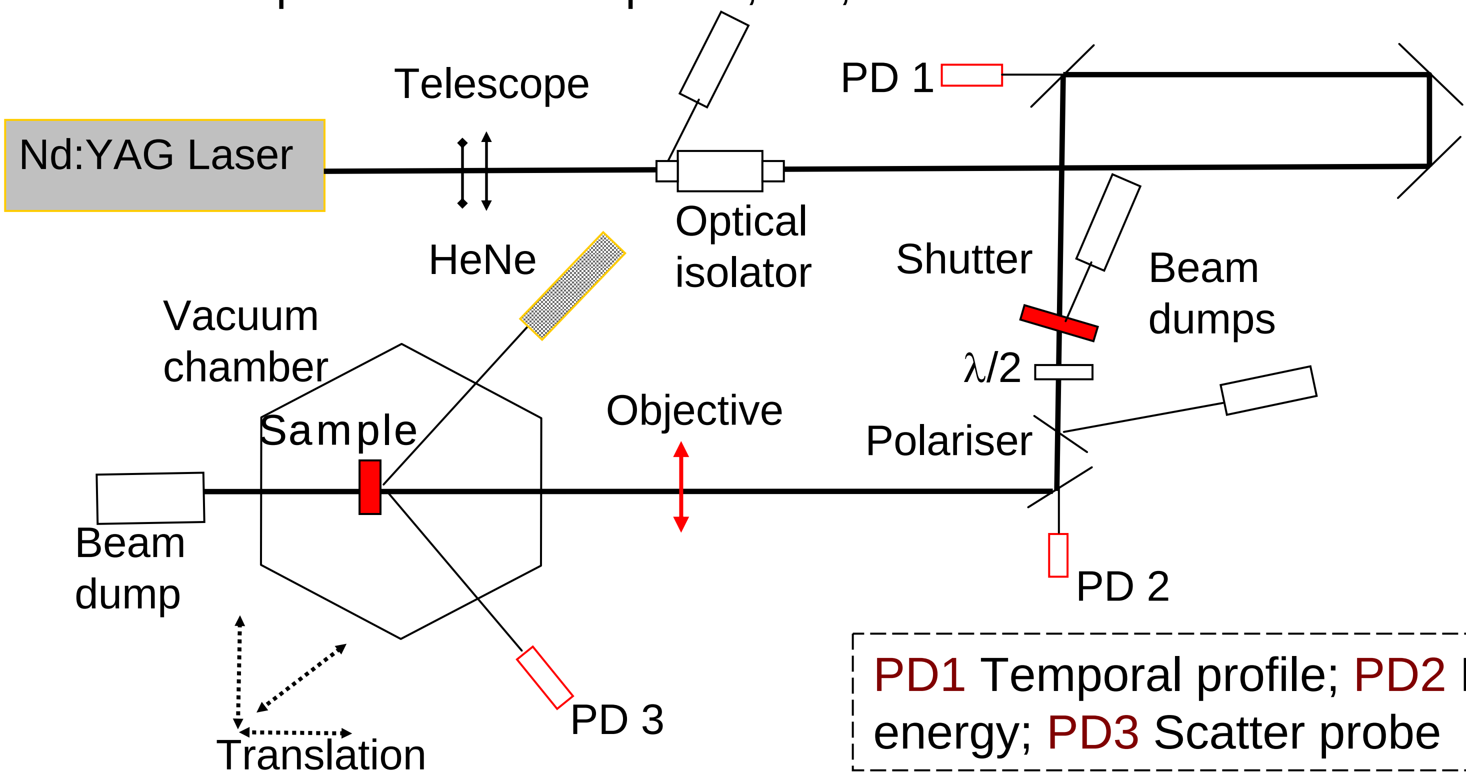
S-on-1 experiments with up to 10,000 shots conducted at DLR



- Damage threshold is lower in vacuum than in air.
- Extrapolation of the damage threshold up to 5billion shots can only be done with difficulty.

Extended laser-induced damage tests (I)

S-on-1 experiments with up to 1,000,000 shots conducted at ESTEC



PD1 Temporal profile; PD2 Pulse energy; PD3 Scatter probe

Sites: >80; Fluence: 1-30J/cm2; Spot diameter 900μm; Pulse duration 8ns; Repetition rate: 50Hz; Pressure: 10^{-5}mbar.

Details of the laser system

- Injection seeded Nd:YAG (Continuum powerlite 9000)
- Pulse energy **700mJ @ 1064 nm**, rep. rate **50 Hz**
- Top-hat profile, spatial variation < 15%
- Pulse duration **8ns**
- Endurance (flash lamps): 60 M shots / 14 days

>> realistic conditions for endurance tests for ALADIN

>> large beam size (1mm), avoiding size effects on damage threshold

Safety features for night & weekend operation

Computer controlled laser operation, laser shutdown upon:

- hang-up of safety system (within 5 sec)
- power drop >20% (10 sec)
- hang-up of test control computer (1 min)
- lab intrusion (10 sec, in addition to immediate shutter)

Damage recognition

Three independent sensors:

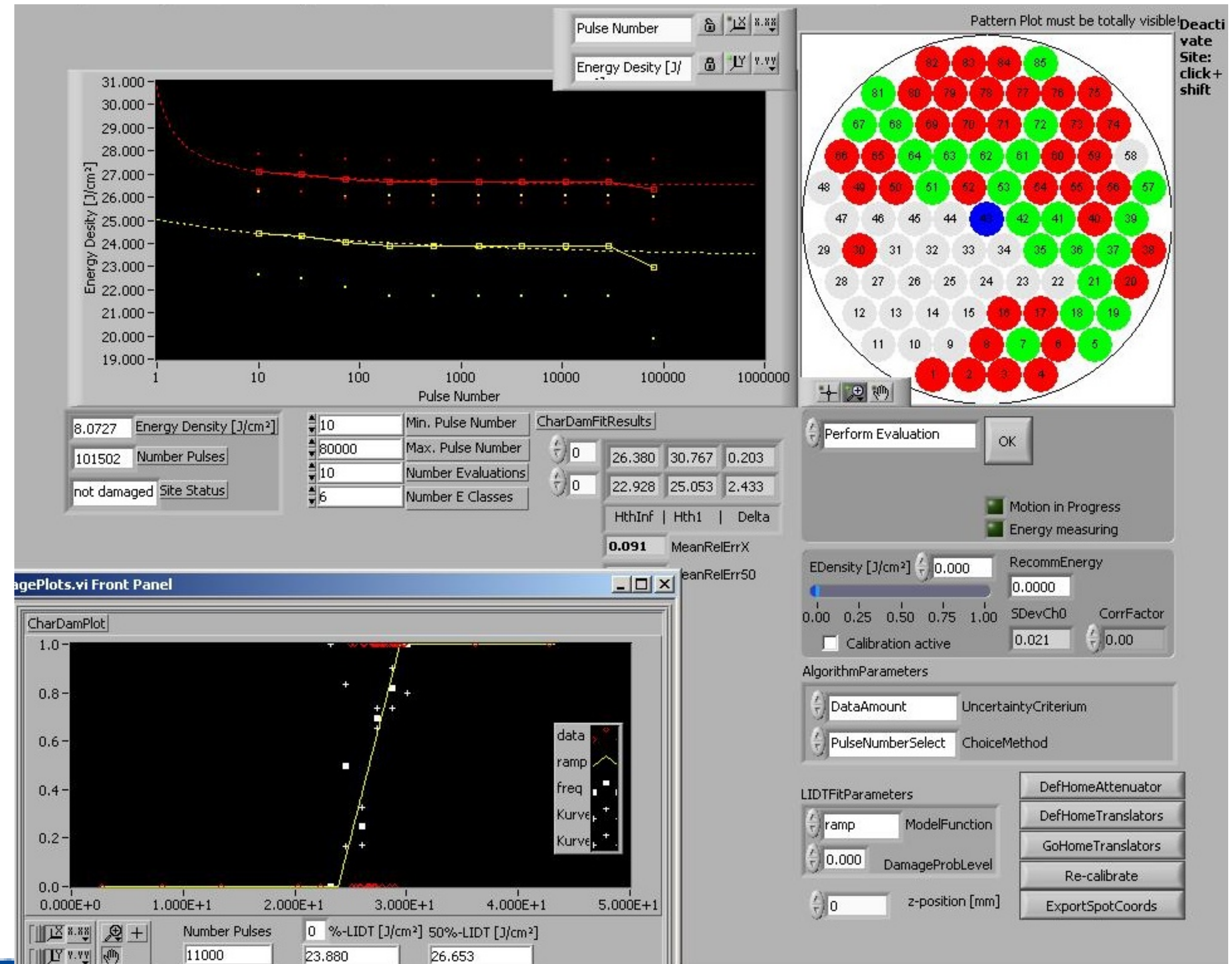
- HeNe-scatter probe (45º incidence angle), chopped with lock-in amplifier
- pressure sensor
- Video monitoring of transmitted beam

Two evaluation procedures:

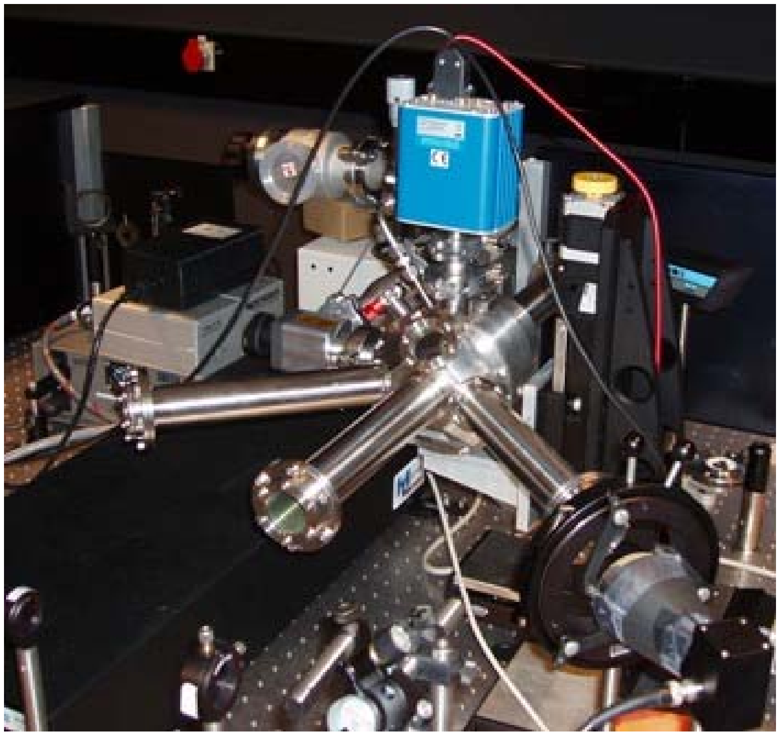
- Real-time thresholds for automatic interruption of irradiation after damage
- Off-line for manual determination of scatter/pressure rise onset

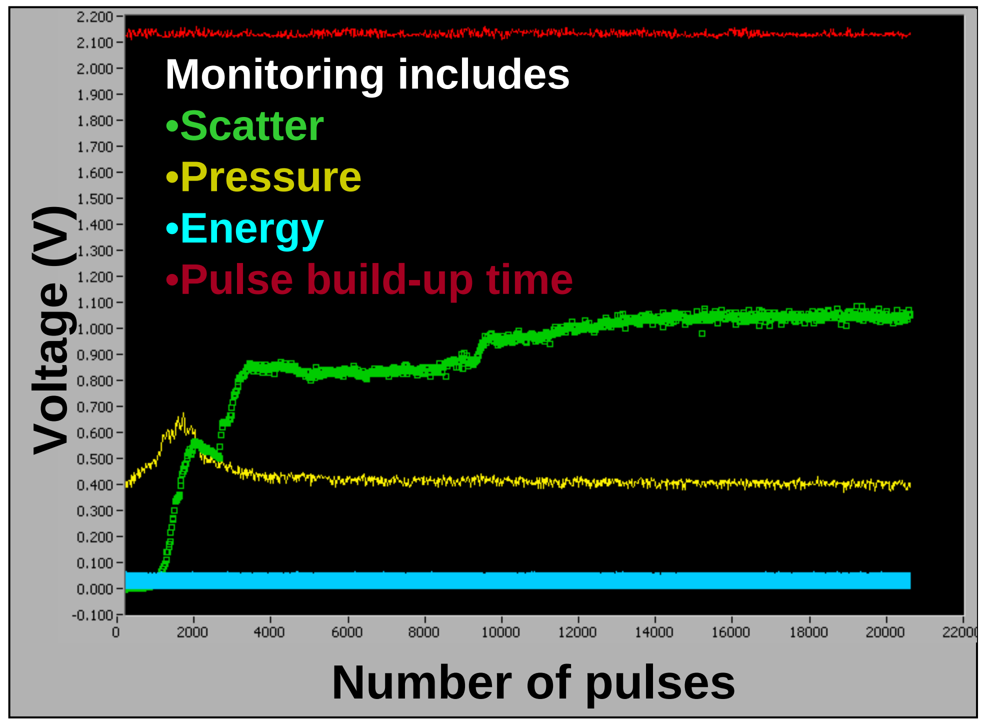
Panel of test control software

(from LZ Hannover, adapted)

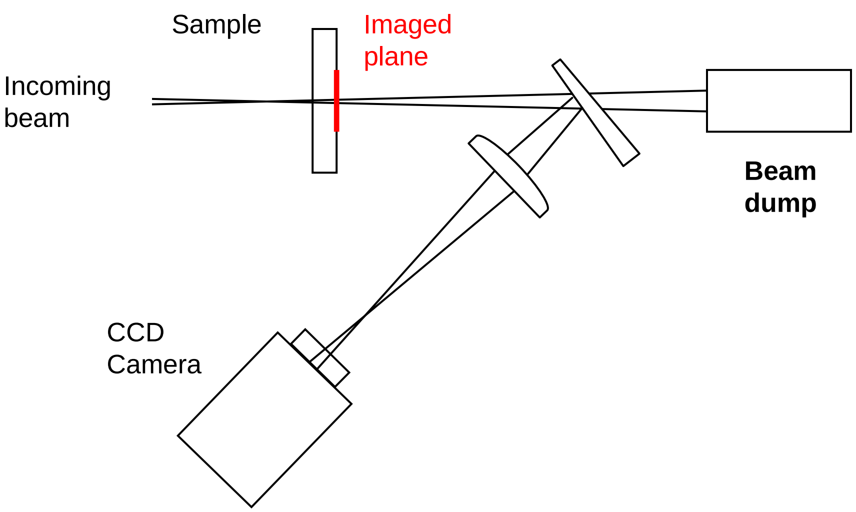


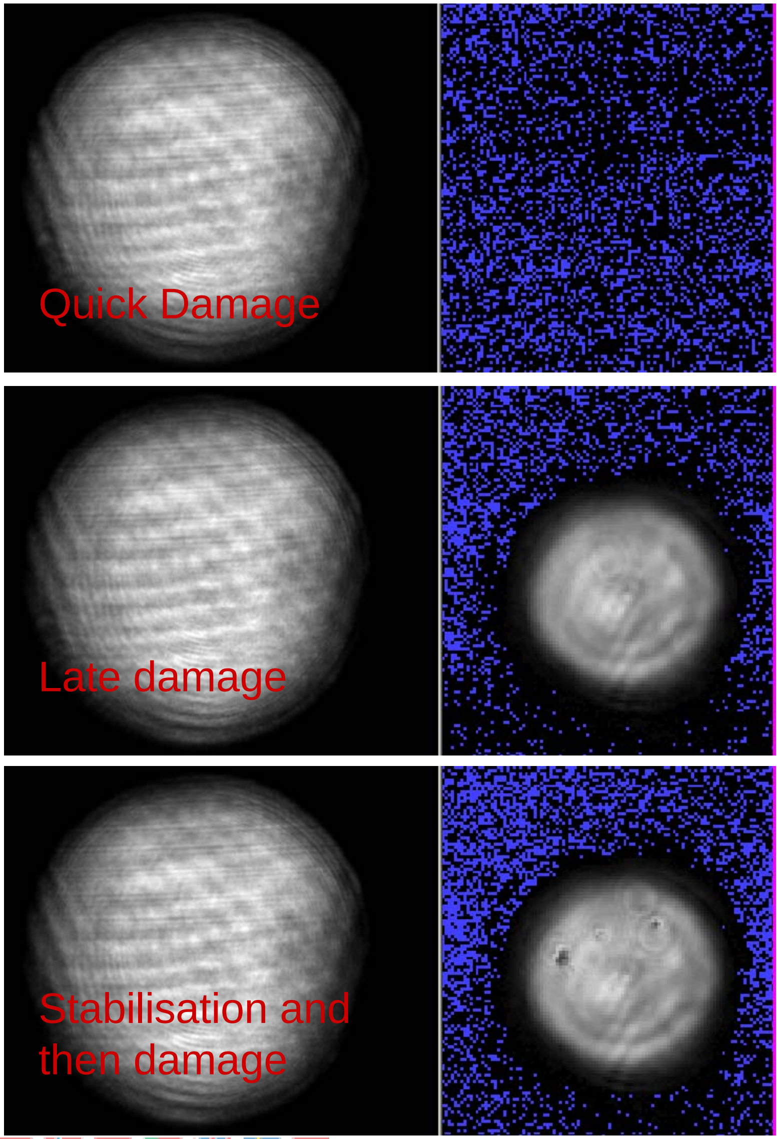
Extended laser-induced damage tests (II)





Damage behaviour (I)

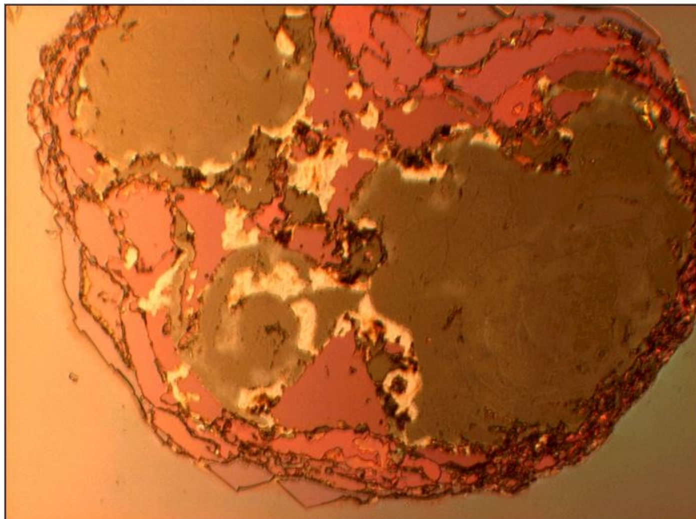




Beam profile and surface damage is monitored by imaging the front surface onto a CCD.

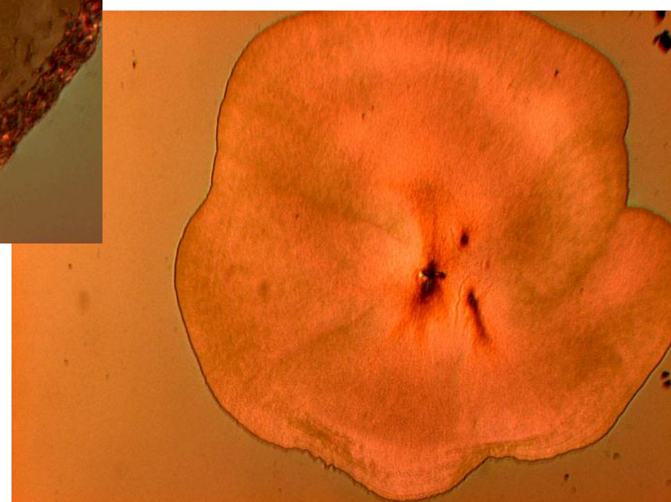
Damage behaviour (II)

Melting and cracking

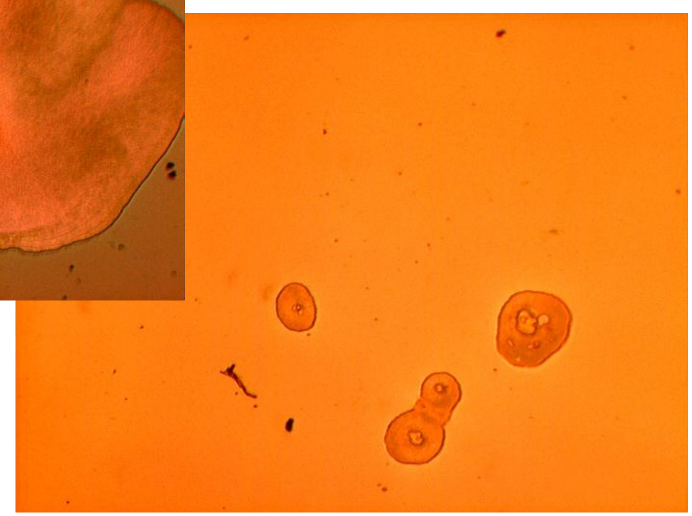


1 mm

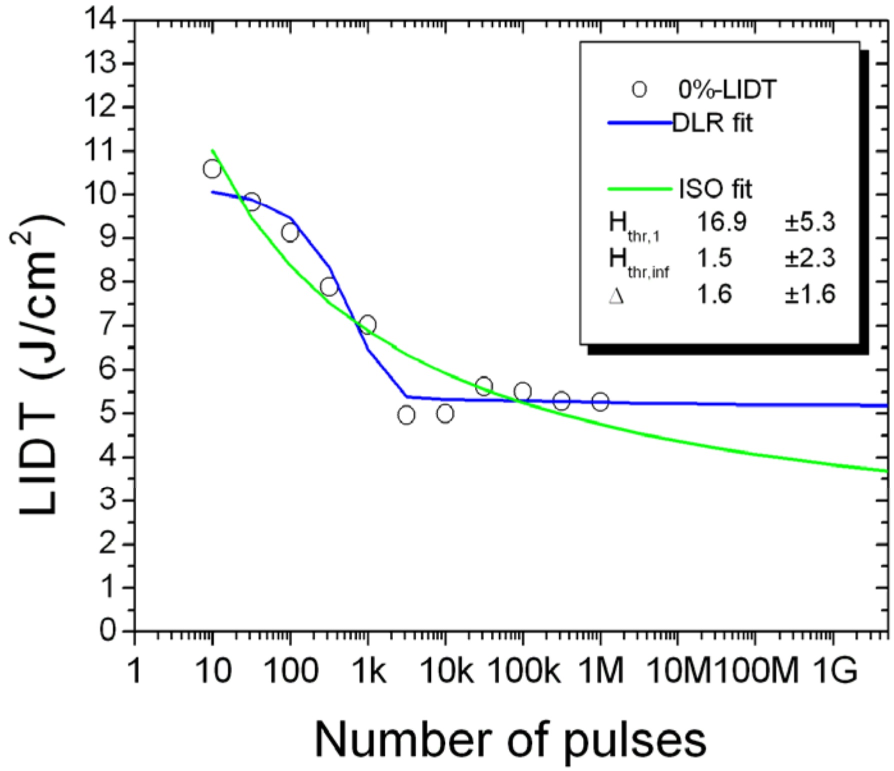
Superficial melting



Small damage



Extended laser-induced damage tests (III)



$$H_{thr}(N) = H_{thr,\infty} + \frac{H_{thr,1} - H_{thr,\infty}}{1 + \frac{1}{\Delta}\log_{10}(N)}$$

Extended laser-induced damage tests are also performed at higher repetition rates:
- 3kHz at 1064nm at LZH,
- 900Hz at 355nm at LLG

Little is known of optical aging over hundreds of millions of shots

Conclusions on damage behaviour

- Optics qualified for short duration
- High-repetition rate experiments currently being performed
- 1 000 000 – on – 1 test with large beam size and 50 Hz repetition rate helps to validate
  - scaling models for large pulse numbers
  - scaling models for high rep.-rates and small beams

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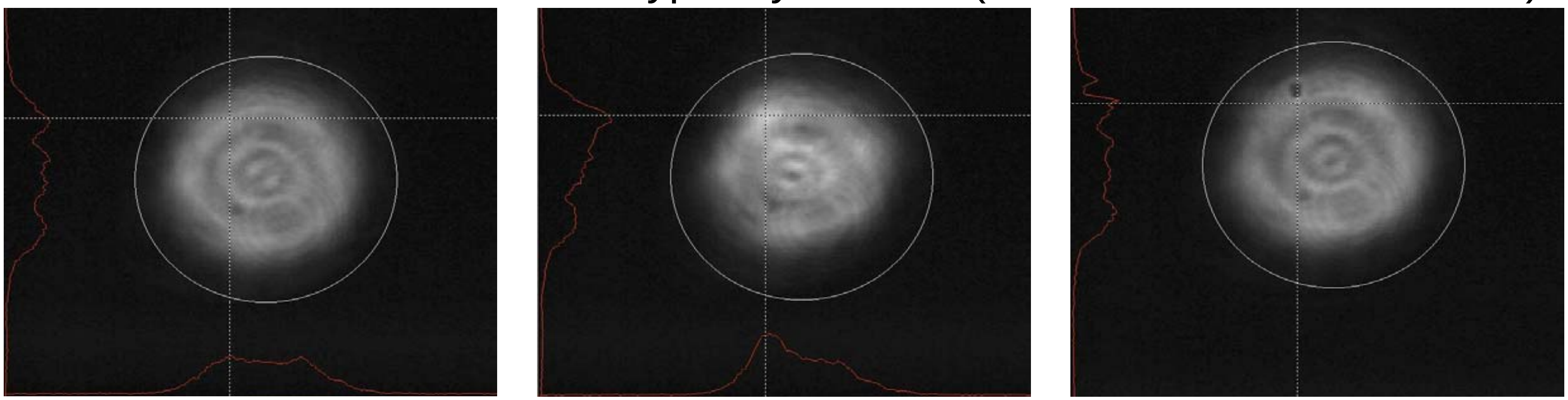
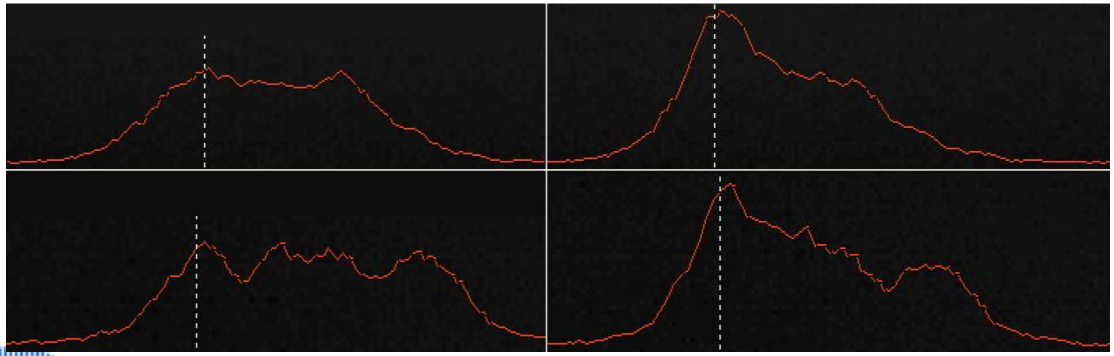
Beam profile fluctuations

- typical stability: 15% RMS
- short intervals (1-2 sec) of increased fluctuations occur irregularly, typically every few minutes; cause(s) are still to be identified, air turbulence is one
- max. local increase of fluence typically 30-50% (worst case 60%, see below)





- original profile
- highest fluctuation (+ 1 sec)
- damage onset (+2 sec)
- profiles through hotspot location