Work on Coatings

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Motivation:

-> Qualification of optics for ADM-Aeolus mission (ALADIN instrument)
-> Extensive test campaigns (IR, UV, VIS) to identify optics exposed to critical fluence levels

Issues:

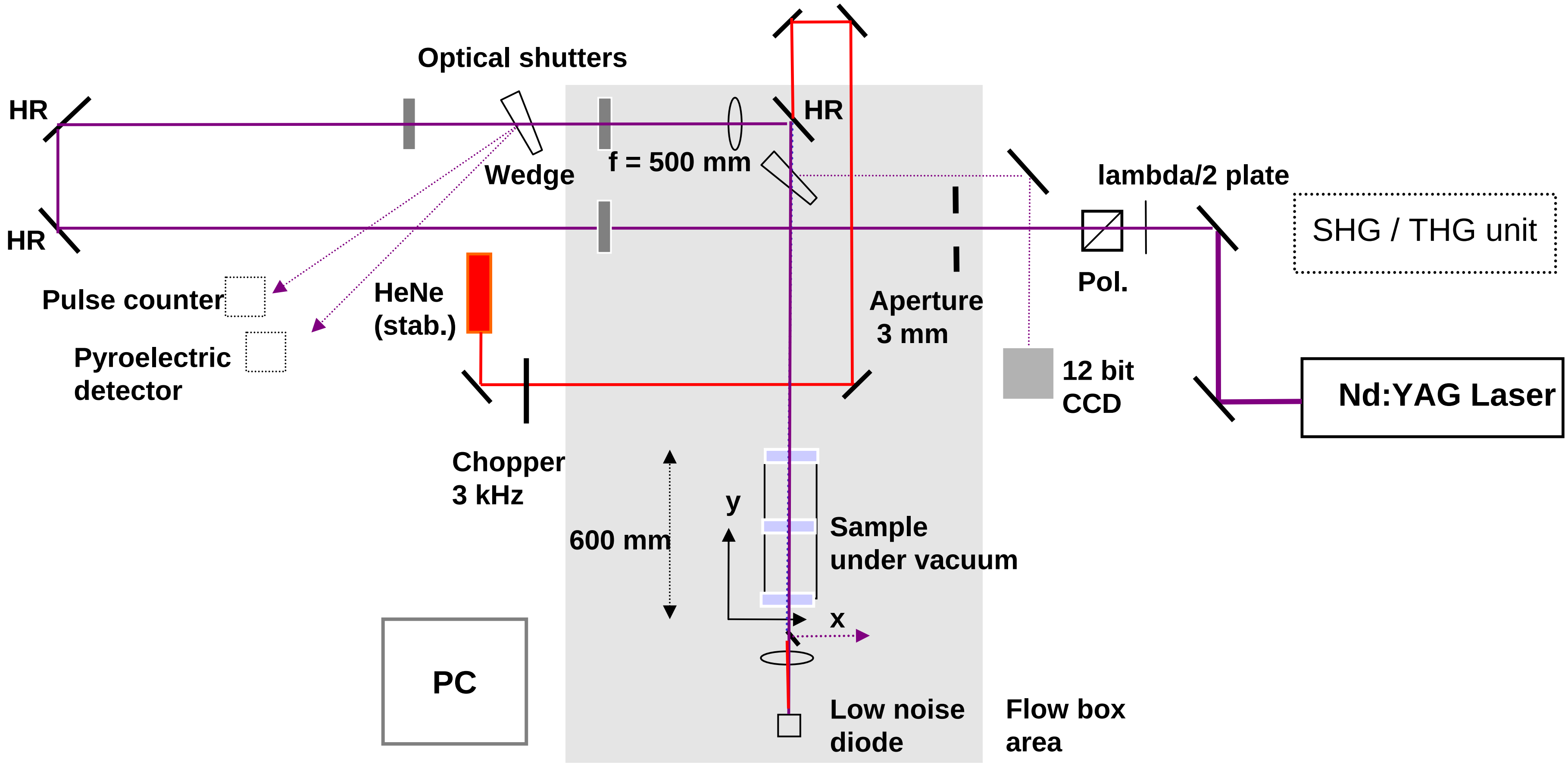
Testing under application-oriented conditions
(high vacuum, dry pump systems, laser parameters comparable to the ALADIN laser system)

-> Development of a vacuum laser damage test bench

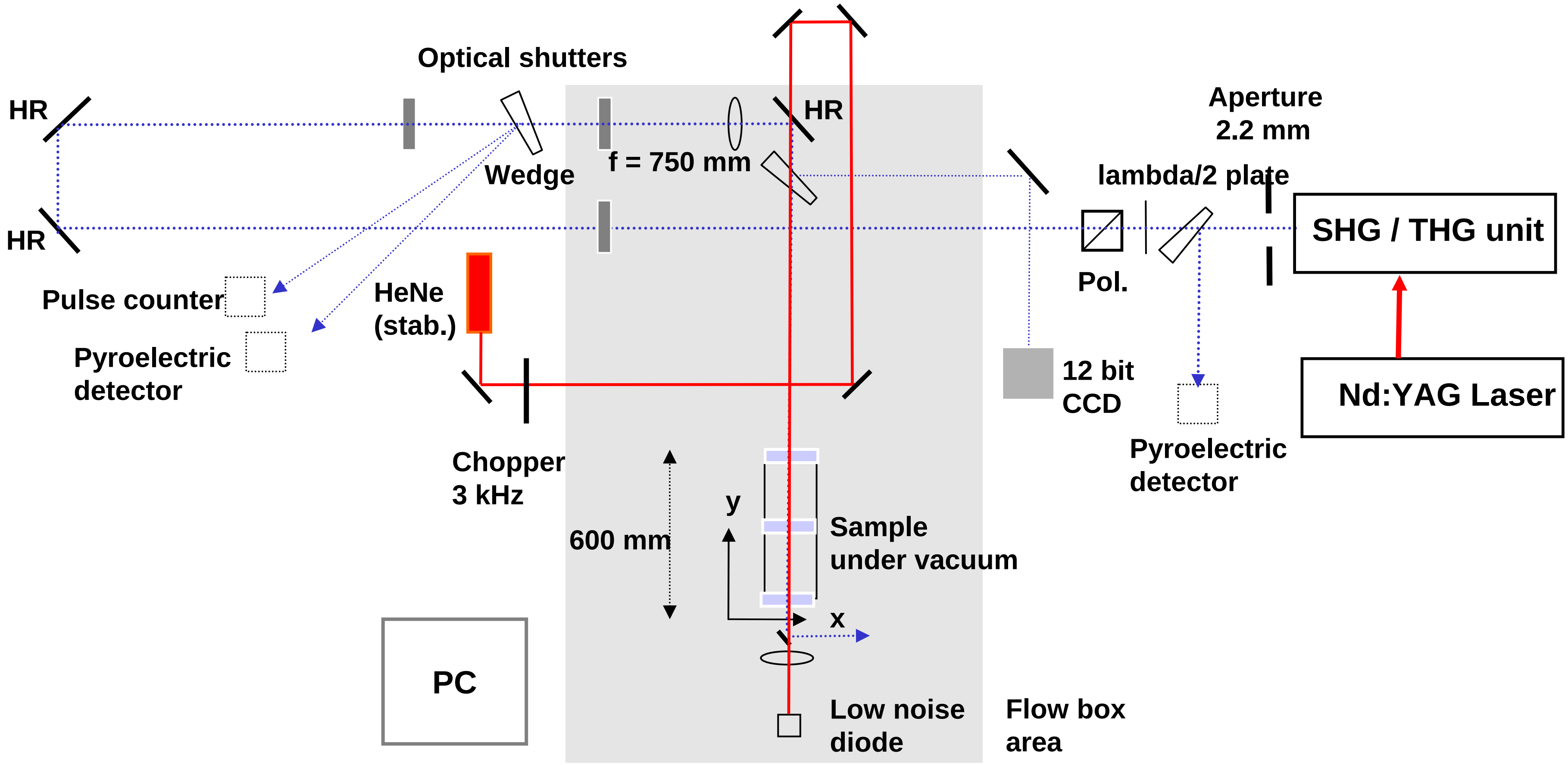
Important aspects:

Scaling of LIDT to Gshot levels from data based up to 10^4 shots/site ?
Vacuum effect on coating performance ?

Introduction



Laser damage test bench: IR optical setup

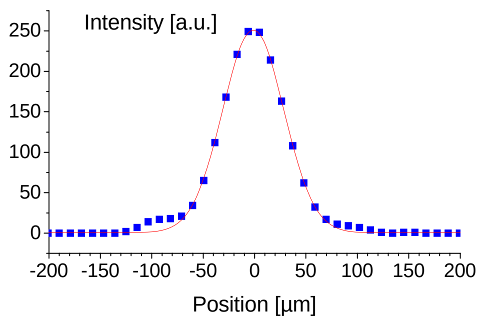


Laser damage test bench: UV optical setup

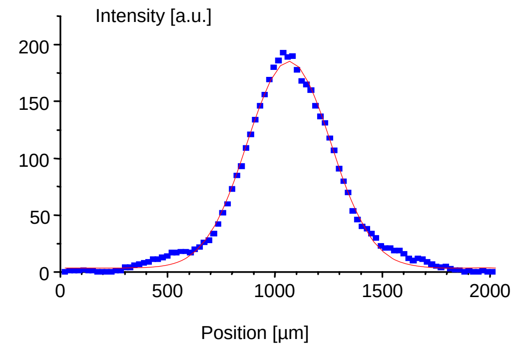
wavelength	1064 nm
repetition rate	**100 Hz**
pulse energy	**400 mJ**
pulse duration (FWHM)	**3.5 ns**
pointing stability (long term)	< 20 µrad/h
beam quality	**M^2 < 1.5**
linewidth	**< 250 MHz**

repetition rate	< 0.001 %
pulse to pulse energy stability	< 1.3 %
pulse to pulse spatial profile stability	< 3.3 %
pulse to pulse temporal profile stability	< 5 %
pulse to pulse pointing stability	< 10 µrad

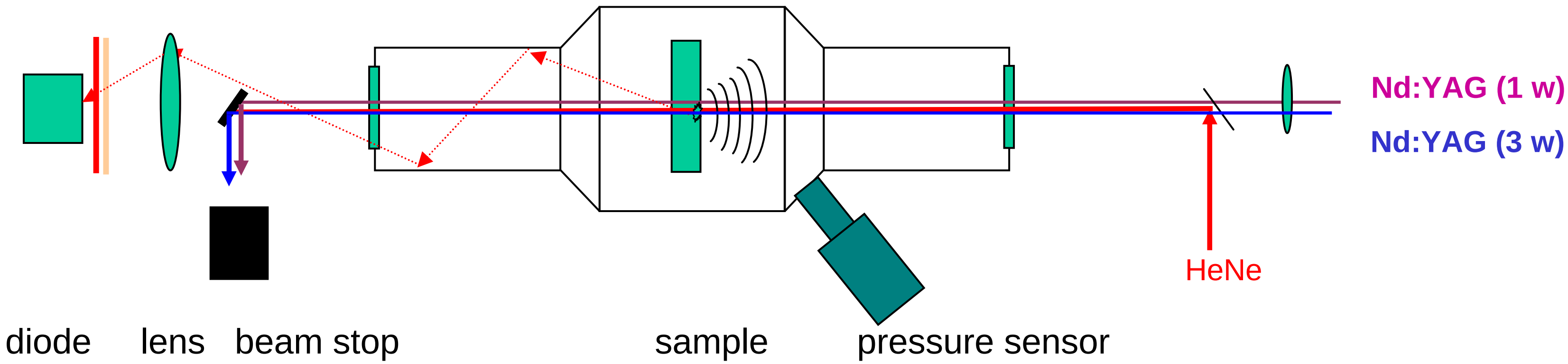
wavelength	355 nm
pulse energy (IR pump energy 300 mJ)	70 mJ
pulse duration (FWHM)	**3 ns**
pulse to pulse energy stability (IR pump energy 200 mJ)	< 3 %
pulse energy stability long term (40 min) (IR pump energy 200 mJ)	< 3 %
pulse to pulse spatial profile stability	< 3 %
spatial profile stability long term (40 min)	< 2 %
pulse to pulse pointing stability (horizontal / vertical direction)	< 25 µrad
pointing stability long term (40 min) (horizontal / vertical direction)	< 25 µrad

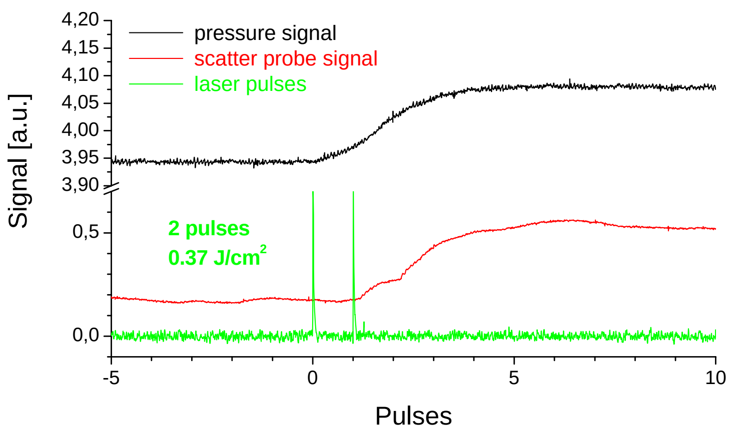


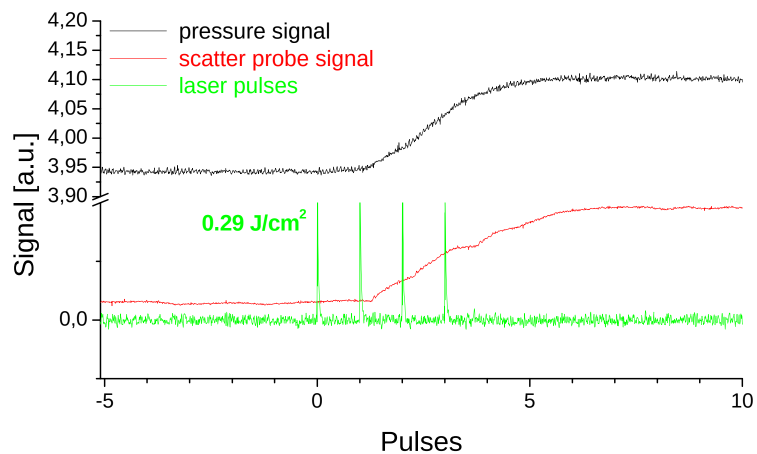
Far field beam profiles
(lhs: IR, rhs: UV)



Laser damage test bench: specs and error budget of laser source







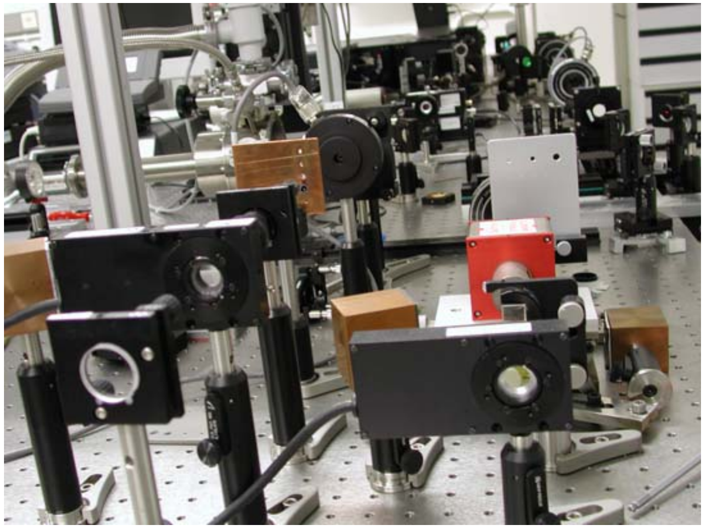
Background pressure: 18 10^{-6} mbar

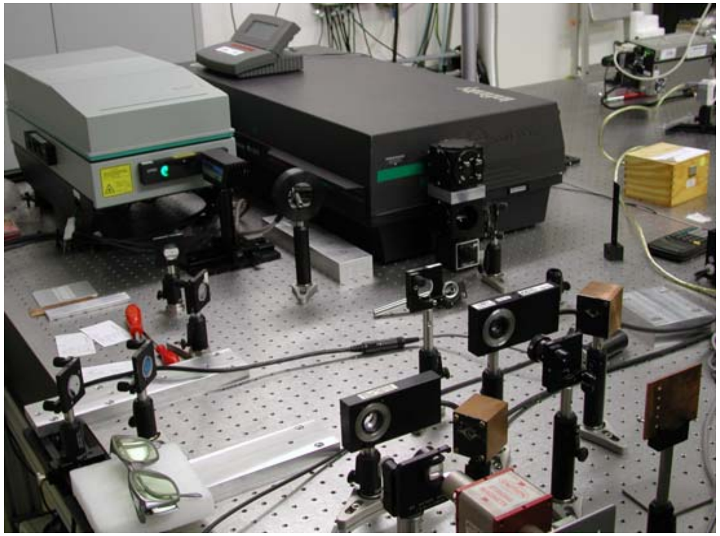
Typical pressure rise: 4…8 10^{-6} mbar

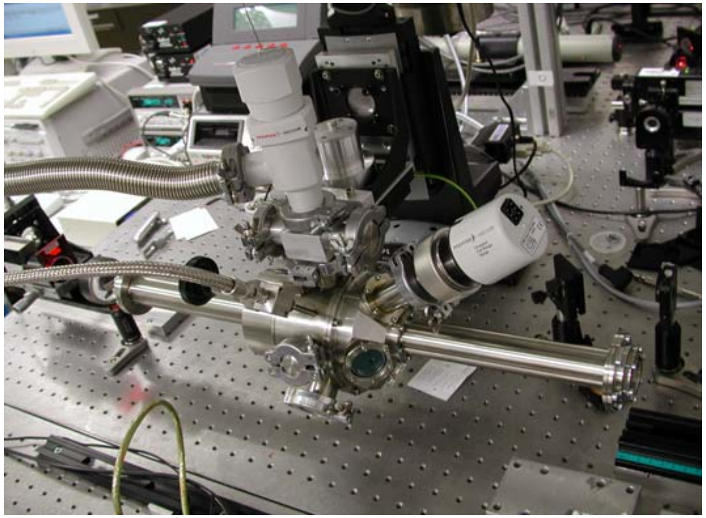
Damage monitoring via scatter probing and transient pressure sensing

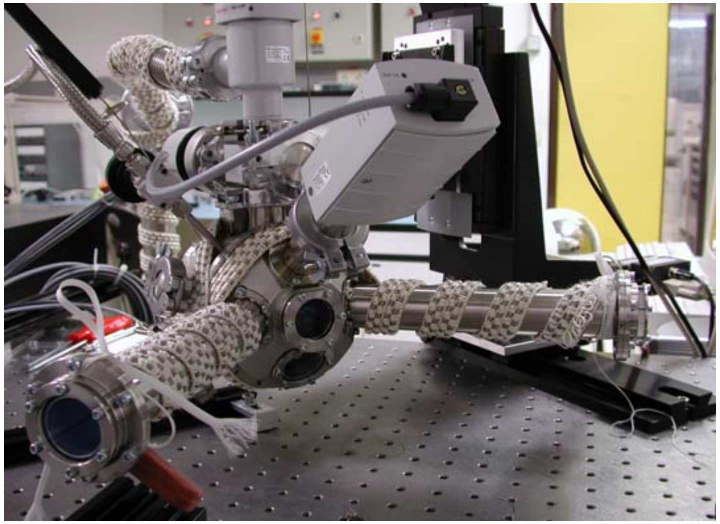
- Test of scattering samples (light trap absorbers)
- Vibration insensitive
- Misalignment (drift) insensitive
- Useful as backup signal
- Fast (up to kHz bandwidth)
- No interference with optical channels
- Sensitive to front and back surface
- No detection of bulk damage!

Features of the transient pressure sensing





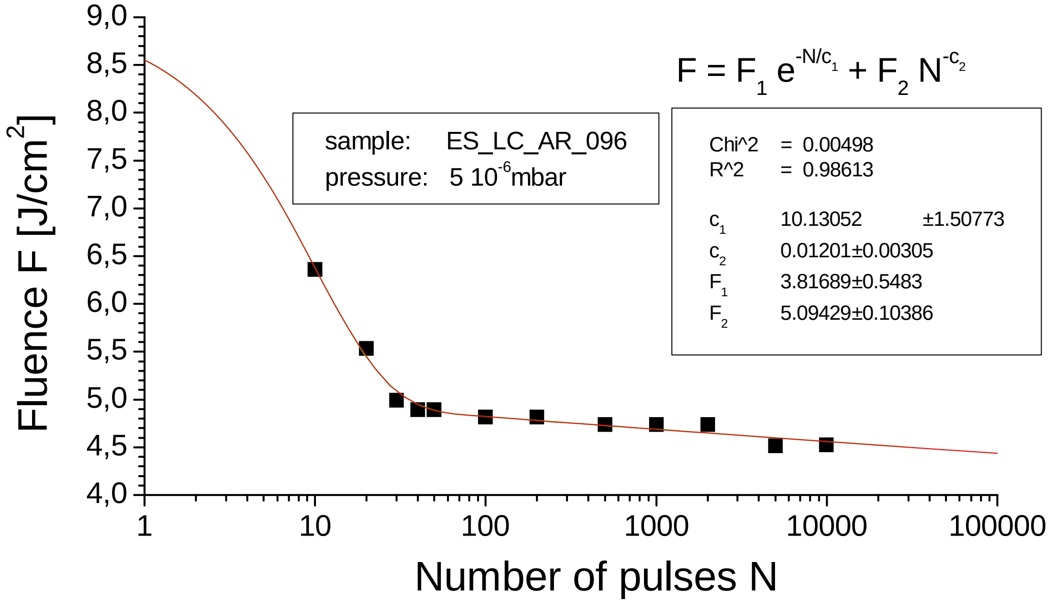




Laser damage test bench: 1w / 3 w beamline / multi-functional vacuum chamber

Data acquisition	up to 800 Hz, multi channel
Automation status	semi- / fully automated
Energy preselection algorithm	binary / random; input & output parameter: pulse energy
Damage detection modes	1. Lock-in based, collinear scatter probing 2. transient pressure sensing, cold cathode sensor
Lifetime testing	up to 50 Mio. Shots (flashlamp lifetime)
Sample positioning	completely inside vacuum
Laser beam analysis	12 bit CCD, 4.4 µm pitch (Spiricon FireWire); online beam profiling; adaptation to sample position
Laser wavelengths	1w & (2w; 3w) separate beam lines
Mode of operation	burst (intermittent) / non-burst operation
Typical vacuum quality	5 10^{-6} mbar, oil-free pump system

Main features of damage test bench

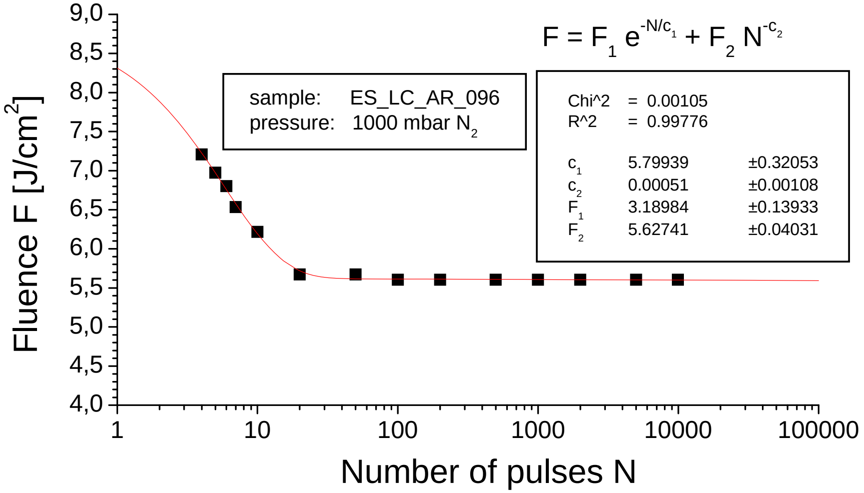


Empirical fitting curve:
$F = F_1 * \exp[-N/c1] + F_2 * N^{-c2}$

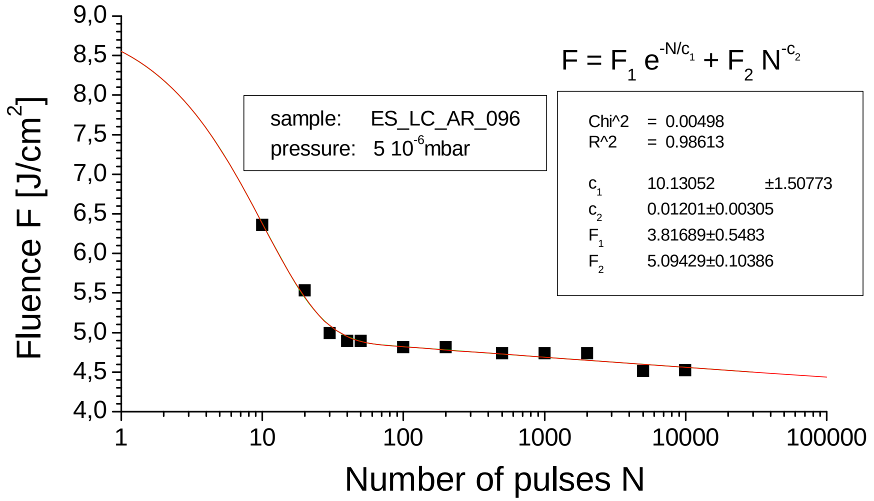
exponentially decaying part $F_1 * \exp[-N/c1]$; slowly decaying part $F_2 * N^{-c2}$

-> valid for all types of samples tested
-> valid for 1064 nm / 355 nm wavelength
-> independent of atmospheric conditions

Characteristic damage curve: laser fatigue effect

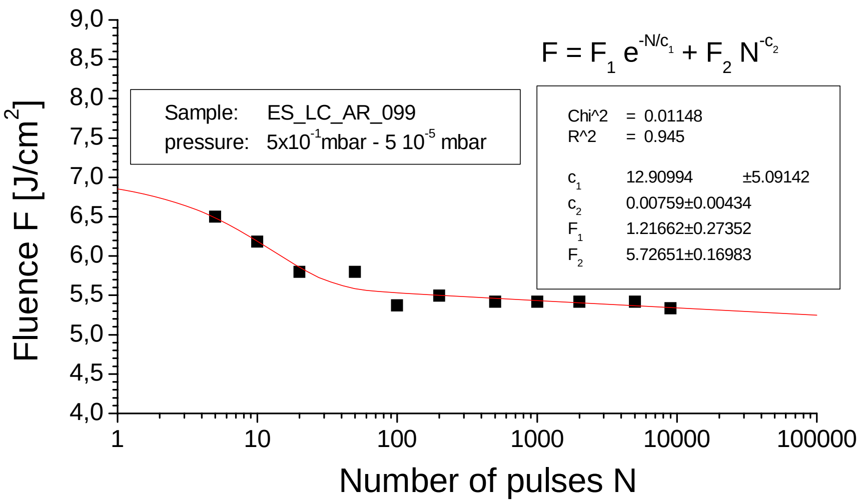


1 bar N_2

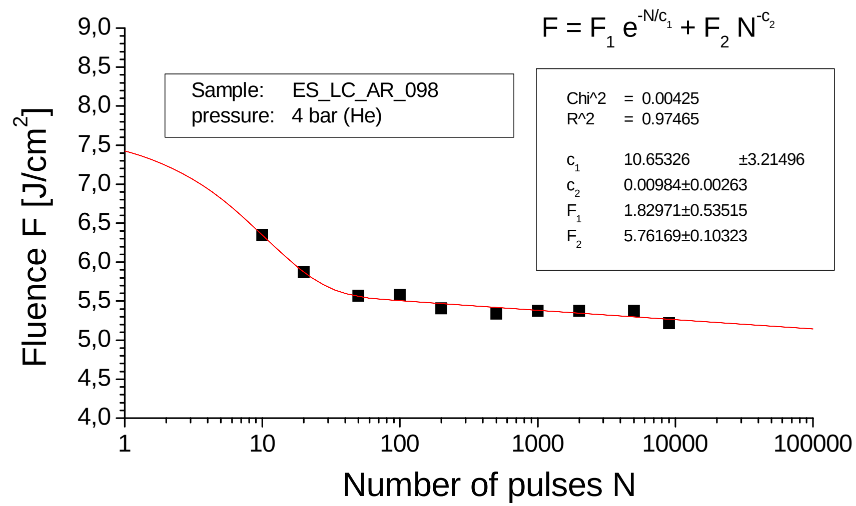


Vacuum

Degradation under vacuum

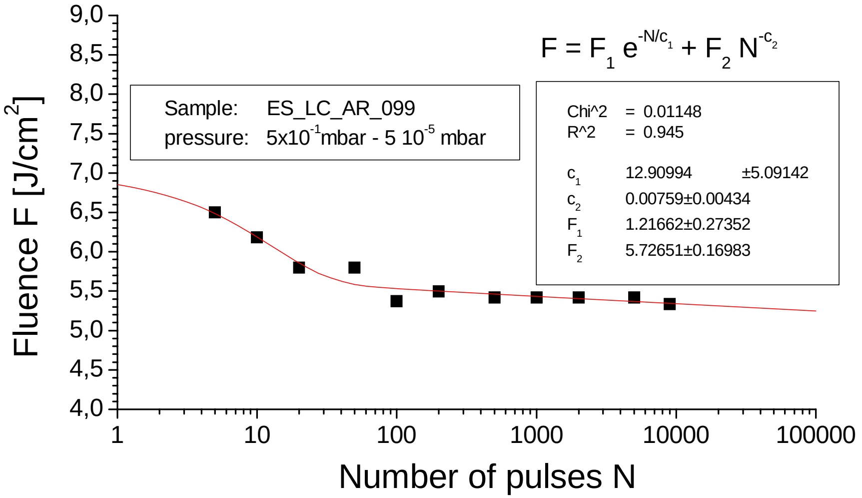


vacuum

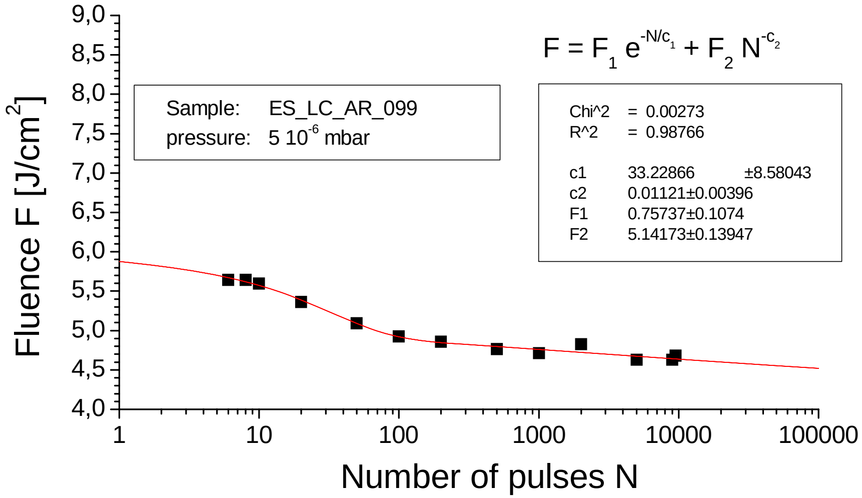


4 bar He

Effect of gas thermal conductivity



Immediate testing



42 h under vacuum

Effect of vacuum residence time

testing of 14 different types of optics, 38 samples overall

Ref. Name; Substrate	Coating type	Test mode	Sample dim´s	$F_{10\,000}$ * [J/cm^2]
Waveplate; crystal quartz	AR	S-on-1	15 x 15 X 0,2 mm	12,4
Piezo mirror, UV grade fused silica	PR	S-on-1	25.4 x 3 mm	12,0
HR mirror; UV grade, fused silica	HR	S-on-1	25.4 X 1,8 mm	18,4
Q-Switch; RTP crystal	AR	S-on-1	9 x 9 X 3 mm	5,8
Polarizer; UV grade, fused silica		S-on-1	25.4 X 3 mm	27,0
MO rod;	AR / HR	S-on-1	12.6 X 3 mm	6,3
Polarizer cube; Fused silica	AR	S-on-1/b	12.7 X 12.7 X 12.7 mm	15,5
Folding mirror; UV grade, fused silica	HR	S-on-1/b	25.4 X 3 mm	10,8
Telescope lens; UV grade, fused silica	AR	S-on-1/b	25.4 X 6.0 mm	23,5
SH; LBO crystal	AR	S-on-1/b	10 x 10 X 2 mm	10,1
TH; LBO crystal	AR	S-on-1/b	10 x 10 X 2 mm	6,6
Dichroic plate; UV grade, fused silica	Dichroic	S-on-1/b	25.4 X 3 mm	19,5
Folding mirror; UV grade, fused silica	HR	S-on-1/b	25.4 X 3 mm	7,4
Light trap	anodized	S-on-1/b	38.1 X 3 mm	0,8

* Stated are „best LIDT values“ for tested types of optics

LIDT-tested ALADIN laser optic components (wavelength 1064 nm)

testing of 8 different types of optics, 22 samples overall

Ref. Name; Substrate	Coating type	Test mode	Sample dim´s	$F_{10\,000}$ * [J/cm^2]
Waveplate; crystal quartz	AR	S-on-1/b	diameter 13 mm	5,6
Lens, Suprasil 1	AR	S-on-1/b	25 x 2 mm	6,5
Beam splitter wedge; Suprasil 1	HR	S-on-1/b	12 X 2 mm	1,7
Beam expander parabola; Suprasil 1	HR 45	S-on-1/b	25 X 2 mm	3,6
Folding mirror; fused silica	HR	S-on-1/b	25.4 X 1,6 mm	2,3
Dichroic plate, fused silica	HR45 @ 355nm	S-on-1/b	25.4 X 3 mm	3,9
Beamsplitter polarizer; fused silica	AR 45	S-on-1/b	25.4 X 3.0 mm	3,5
LBO crystal	AR 1064, 532, 355 nm	S-on-1/b	12 x 12 X 2 mm	4,1

* Stated are „best LIDT values“ for tested types of optics

LIDT-tested ALADIN laser optic components (wavelength 355 nm)

Test bench for LIDT vacuum testing at 355 nm / 532 nm / 1064 nm

Transient pressure sensing technique:

suitable in a vacuum environment for online detection of laser damage

Air – vacuum effect:

small negative fluence offset found under vacuum
indication residence time effects
thermal isolation under vacuum (no thermal conductivity -> no ambient gas)
must be excluded as cause of vacuum degradation.

Laser fatigue effect:

step-like degradation within several pulses
leveling off along a slowly decreasing ramp (> 100 shots applied per site)

Summary

Last not least:

The support by the **European Space Agency**,
Galileo Avionica and Astrium-F
is gratefully acknowledged!

Thank you for your attention!