Analysis of Laser Damage Threshold and Morphology at the Surface of AR-coated Ceramic Yb:YAG

Mariastefania De Vido[1], Jonathan Phillips[1], Joachim Hein[2], Jörg Kroener[2], Jodie M Smith[1], Klaus Ertel[1], Paul Mason[1], Saumyabrata Banerjee[1], Oleg Cheklov[1], Tom Butcher[1], Stephanie Tomlinson[1], Andy Lintern[1], Justin Greehalgh[1], Waseem Shaikh[1], Steve Hawkes[1], Cristina Hernandez-Gomez[1], John Collier[1]

[1] STFC Rutherford Appleton Laboratory, Didcot UK
[2] Friedrich-Schiller Universität Jena, Jena, Germany

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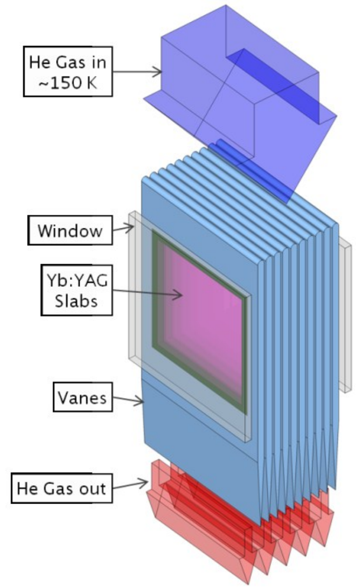
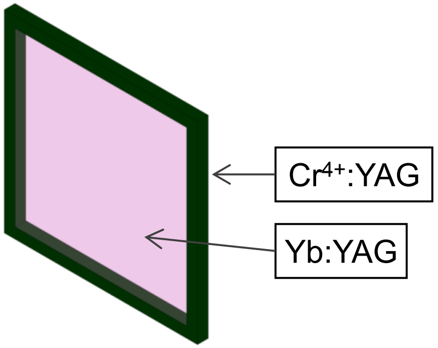
Outline

- Why are we interested in LIDT testing of AR coated ceramic Yb:YAG?
- Description of samples
- Description of experimental setup and methodology
- Experimental results
- Conclusions

DiPOLE Gain Medium

- **AR-coated ceramic Yb:YAG gain medium**
  - ➢ Reasonable gain + lifetime
  - ➢ Good thermo-mechanical properties
  - ➢ Large sizes possible
  - ➢ Compound structures for ASE suppression
- **Operation at cryo temperature**
  - ➢ Reduced reabsorption, higher o-o efficiency
  - ➢ Increased gain cross section
- **Distributed face cooling**
  - ➢ He gas flow
  - ➢ Large depth/volume *and* high surface area





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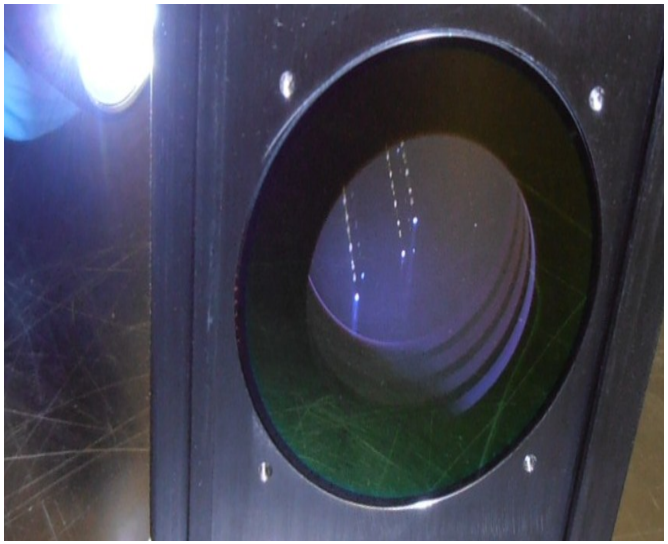
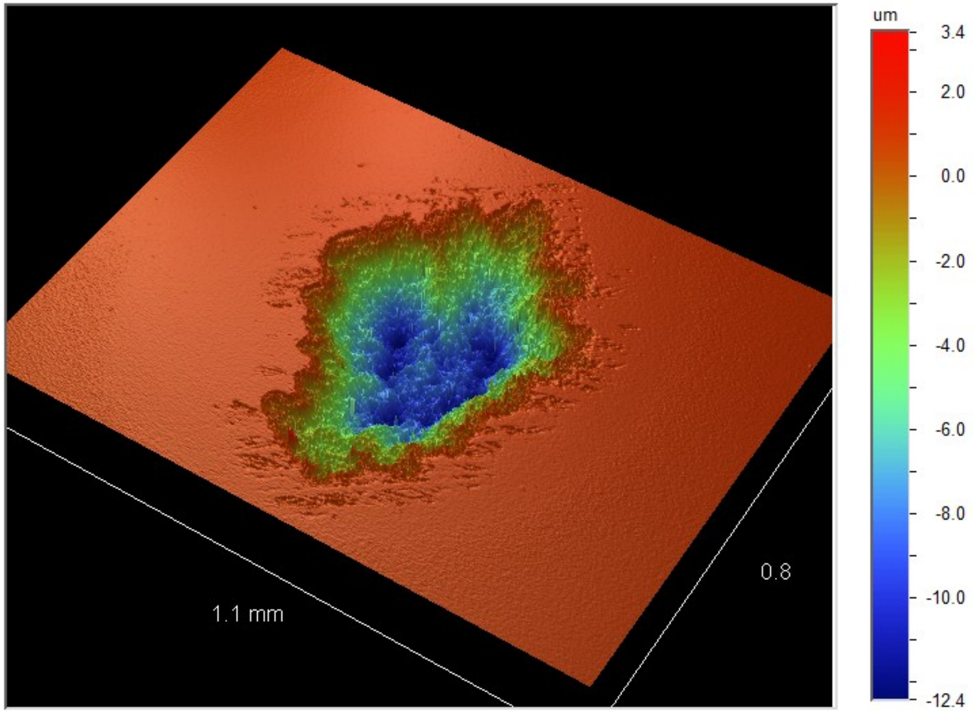
Laser Damage Observed in DiPOLE





- Recurring damage at ~2.5 J/cm^2
- In high-pressure cold He flow
- Localised, not growing fast
- Only Yb:YAG affected, not windows

LIDT Testing

- Tests performed at Friedrich-Schiller-Universität Jena
- 1 on 1 LIDT test following ISO11254-4

Objectives:

Assess influence of sample fabrication on LIDT

Polishing technique

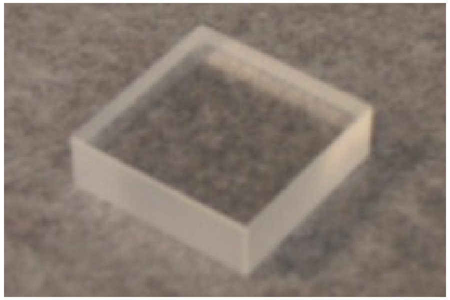
Coating technique

Assess influence of environmental parameters on LIDT

Temperature

Atmosphere vs vacuum pressure

Sample Fabrication Parameters



- 0.7% Yb doped ceramic YAG
- Dimensions: 24 mm x 24 mm x 7 mm
- AR coated by means of:
    - Ion Assisted Deposition
    - Ion Beam Sputtering

Sample	Polishing Technique	RMS roughness after polishing	Coating
Sample 1	Normal	<0.2 nm	IAD
Sample 2	Normal	<0.2 nm	IBS
Sample 3	Super Polishing	0.1 nm	IAD
Sample 4	Super Polishing	0.1 nm	IBS
Sample 5	Ion Beam Polishing	<0.33 nm	IAD
Sample 6	Ion Beam Polishing	<0.33 nm	IBS
Sample 7	Magneto-rheological Finishing	<0.46 nm	IAD
Sample 8	Magneto-rheological Finishing	<0.46 nm	IBS

Low roughness substrate

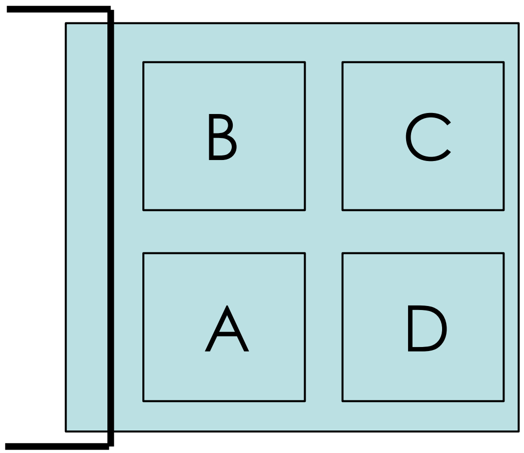
Higher roughness substrate

Environmental Parameters

Four runs at different environmental conditions:

Run	Temperature (K)	Pressure (mbar)
A	300	1000
B	300	$1 * 10^{-6}$
C	150	$1 * 10^{-6}$
D	115	$1 * 10^{-6}$

For each run: 11 energy levels, 10 shots per energy level



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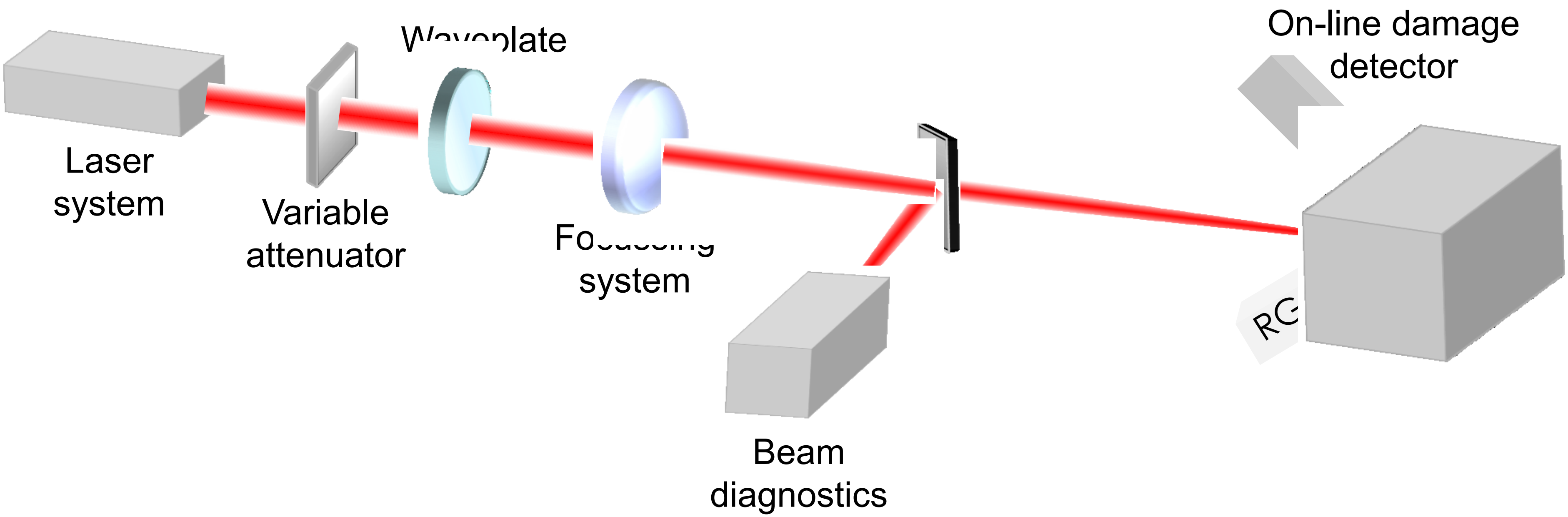
Test Station



Damage diagnostics:

- CCD microscope: identification of damage. Sensitivity increased by scattering signal of green cw beam collinear to the main beam.
- Residual gas analyser: detection of particles blown away from the surface.
- Microscopic examination of testing sites after irradiation.

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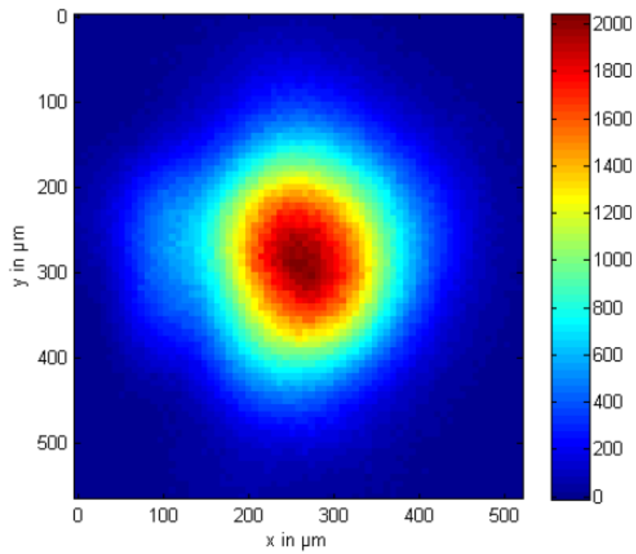
Laser Parameters

Wavelength	1030 nm
Pulse duration	3 ns
Energy per shot	Up to 100 mJ, controlled using a variable attenuator
Polarisation	Parallel
Focal spot size (1/e)	~250 μm



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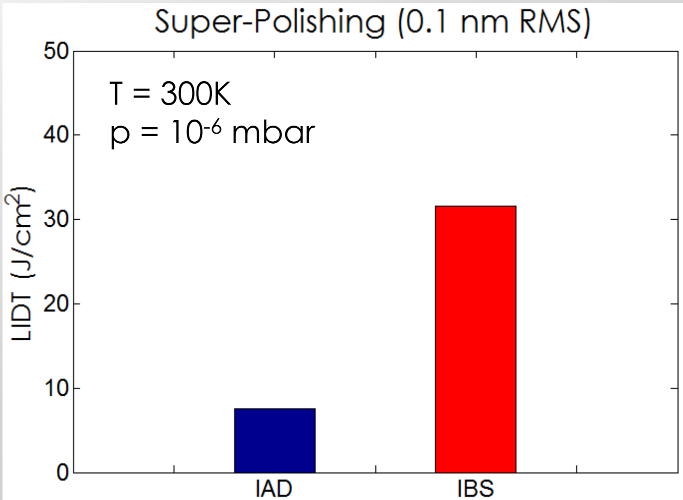
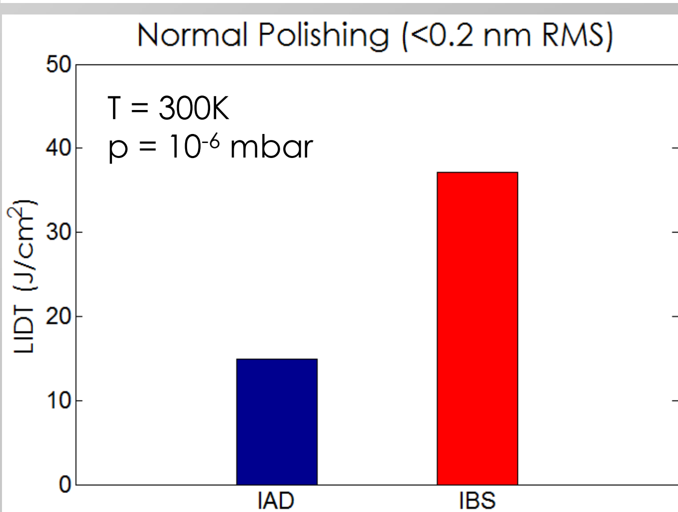
Data Analysis

- Roughness
  - high
  - low
- Coating
  - IAD
  - IBS
- Environmental conditions (pressure and temperature)

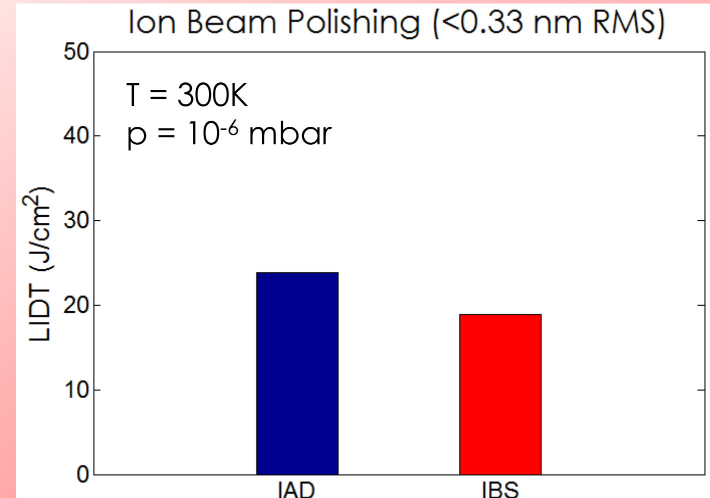
Impact of substrate roughness on LIDT

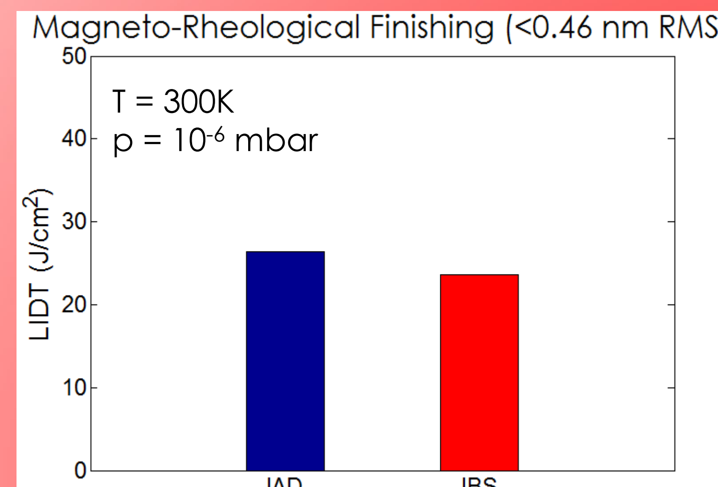
LOW ROUGHNESS



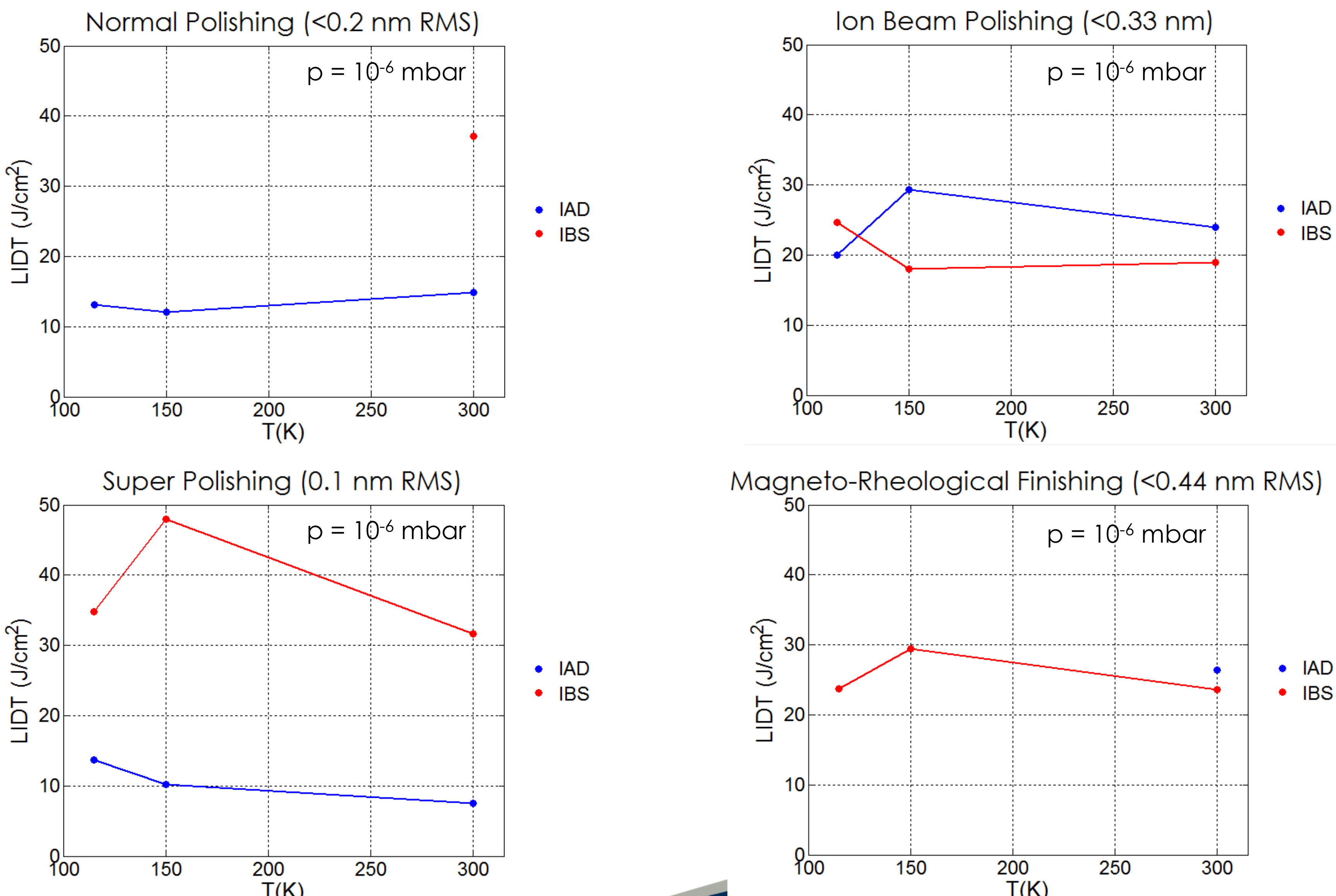


HIGH ROUGHNESS





Impact of temperature on LIDT



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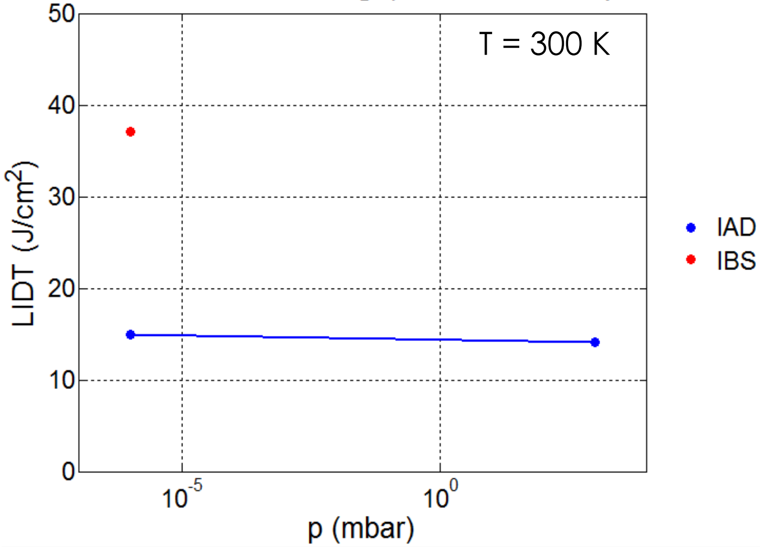
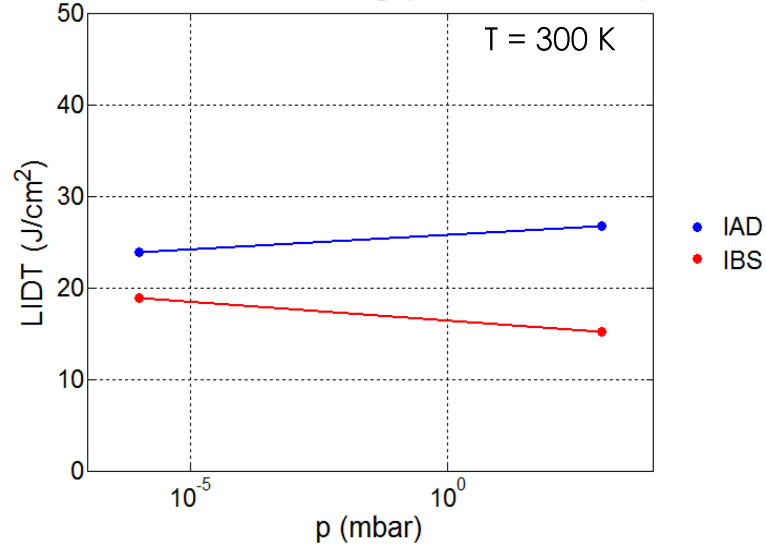
Impact of pressure on LIDT

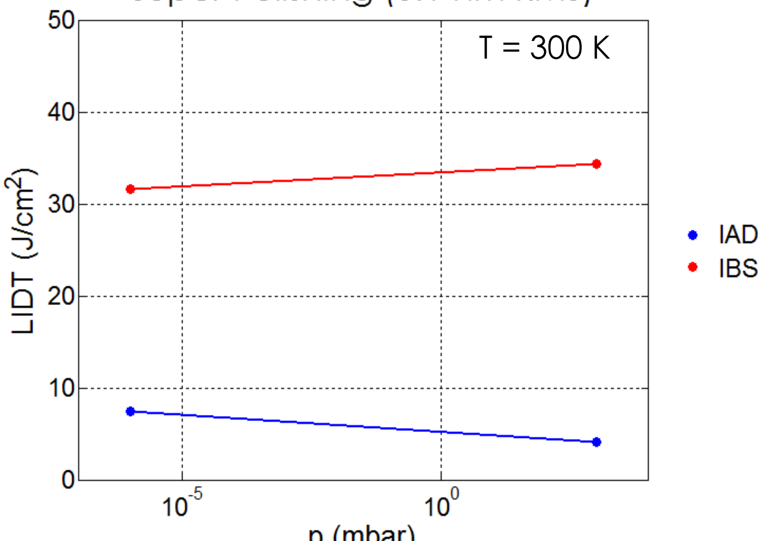
Normal Polishing (<0.2 nm RMS)



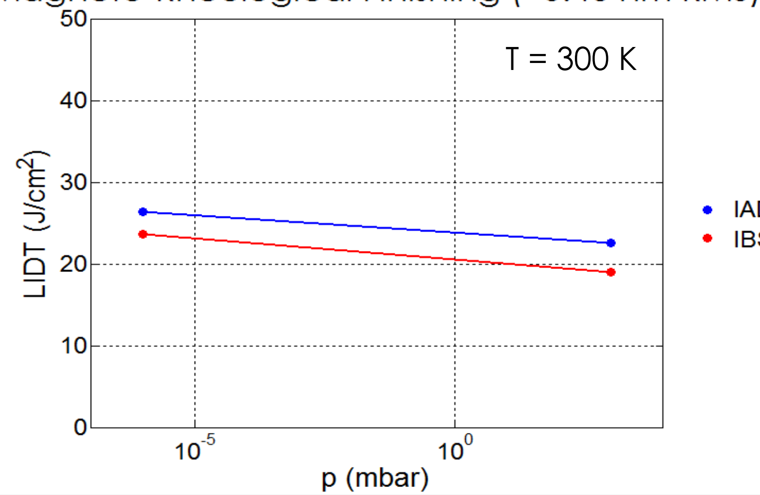
Ion Beam Polishing (<0.33 nm RMS)



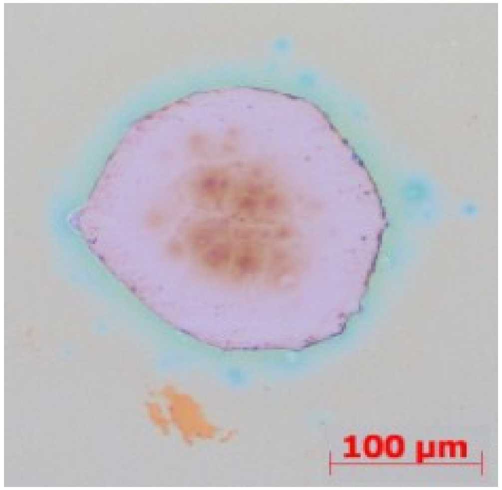
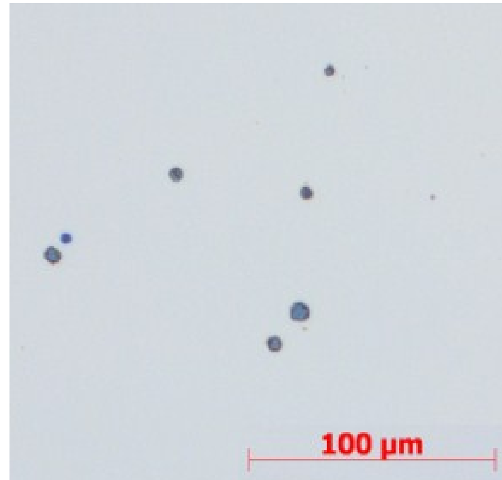
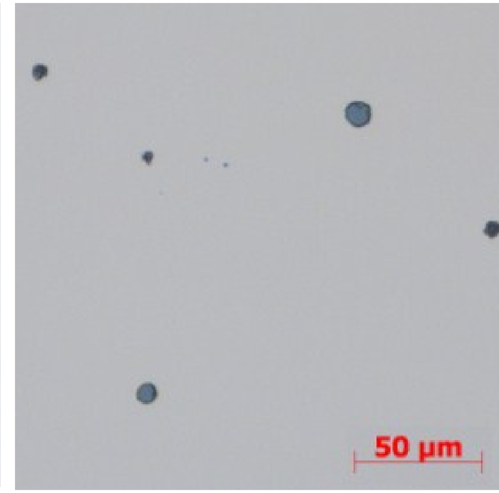
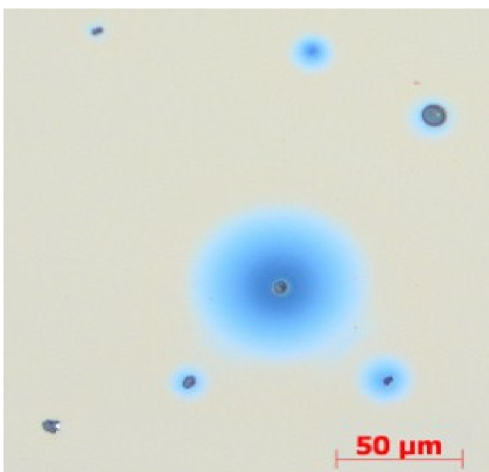
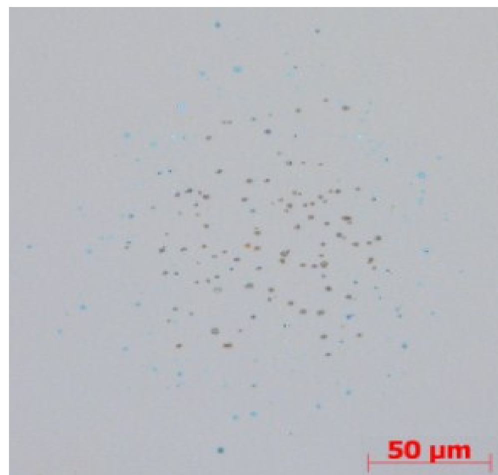
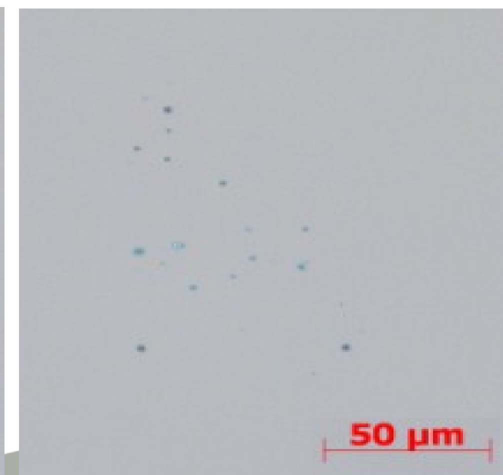
Super Polishing (0.1 nm RMS)



Magneto-Rheological Finishing (<0.46 nm RMS)



Impact of T on damage morphology

Normal polishing	T = 300K p = 10^{-6} mbar	T = 150K p = 10^{-6} mbar	T = 115K p = 10^{-6} mbar
IAD coating			
IBS coating			

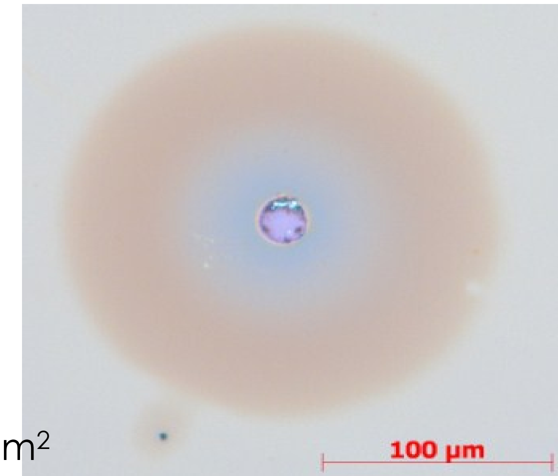
Impact of p on damage morphology

Normal polishing, T = 300K

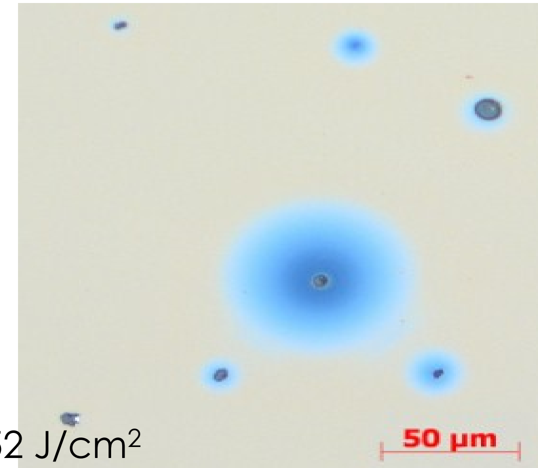
p = 1000 mbar

p = 10^{-6} mbar

IAD coating

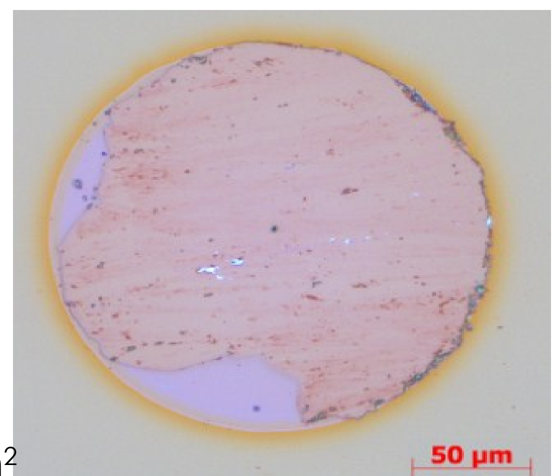


53 J/cm^2

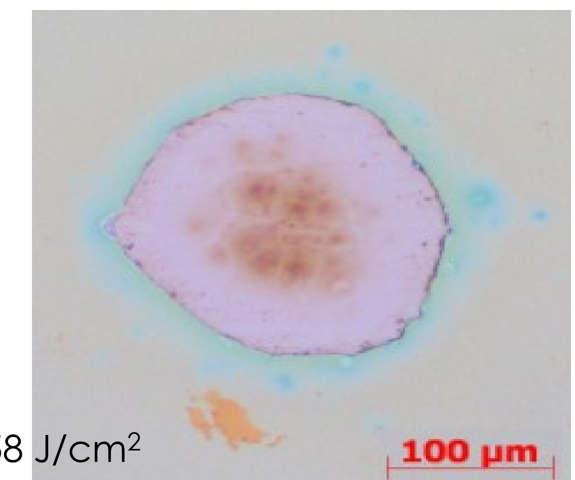


52 J/cm^2

IBS coating



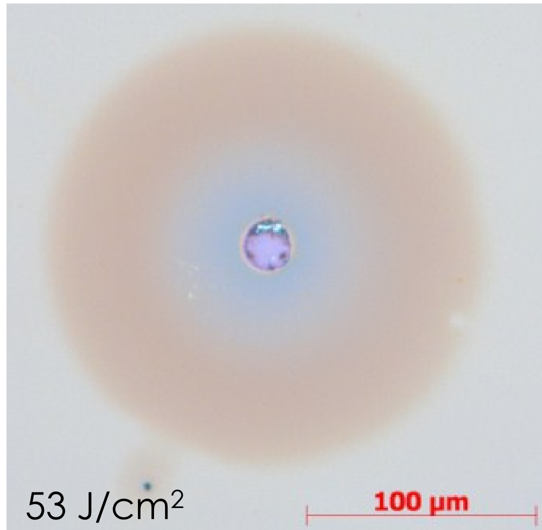
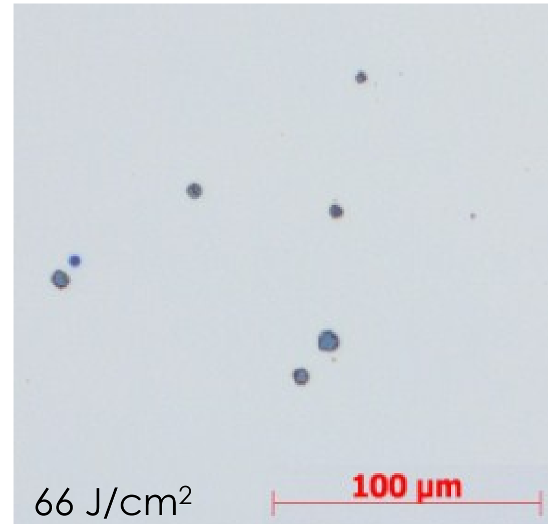
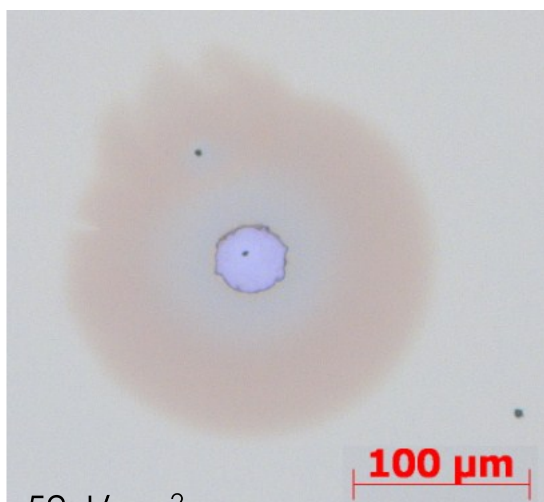
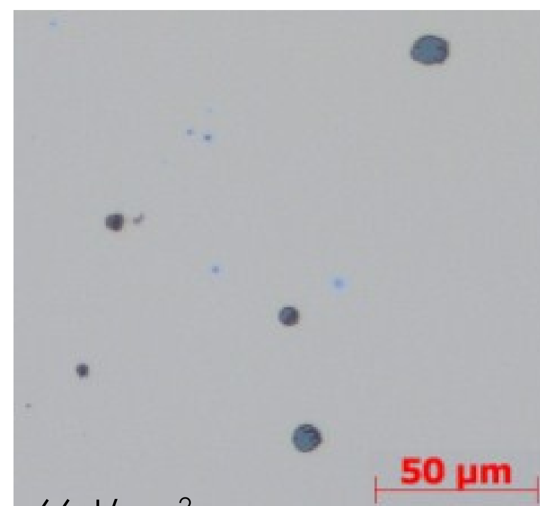
57 J/cm^2



58 J/cm^2

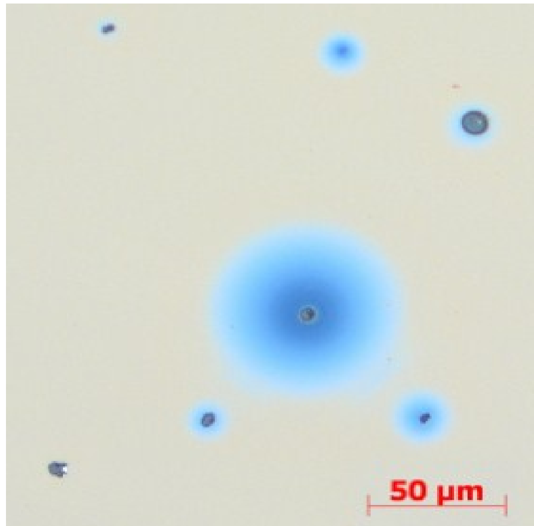
Impact of polishing on morphology

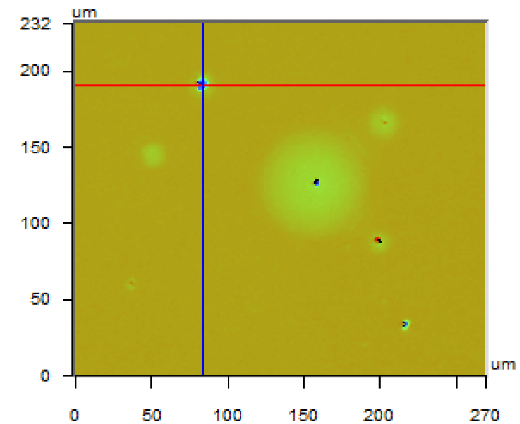
IAD coating, p=10^{-6} mbar

	T = 300K p = 10^{-6} mbar	T = 150K p = 10^{-6} mbar
Normal polishing		
Ion beam polishing		

Damage topography

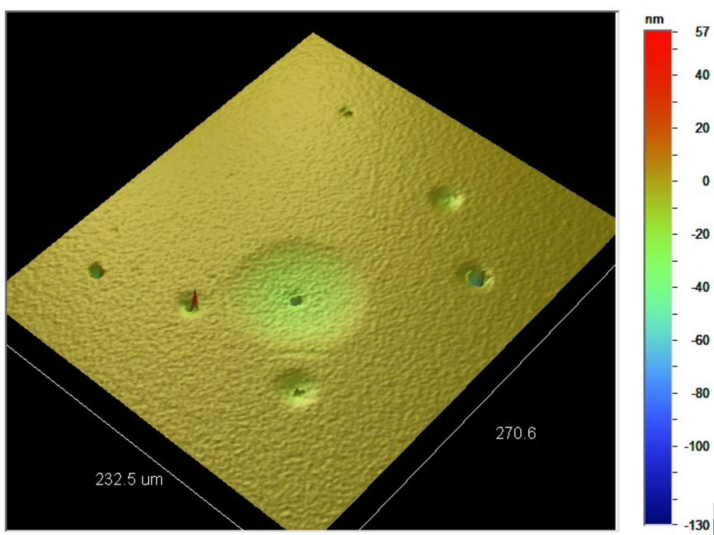
Normal polishing
IAD coating
300K, 10^{-6} mbar



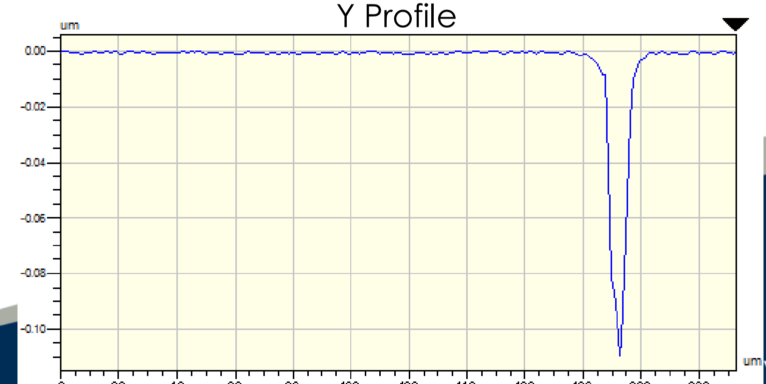


X Profile

3D Profile



Y Profile



Conclusions

- No clear correlation between LIDT and temperature or pressure for both IAD and IBS coated samples and all polishing techniques
- Generally, IBS performs better on low roughness substrates
- Generally, IAD coating performs slightly better than IBS coating for higher roughness substrates
- Both temperature and pressure have an impact on laser induced damage morphology
- Coating technique has an impact on damage morphology, but polishing technique does not
- Disagreement between in-situ observation and off-line testing
- Advanced polishing techniques are no golden bullet

Thank you!