

# On-line monitoring in laser cleaning

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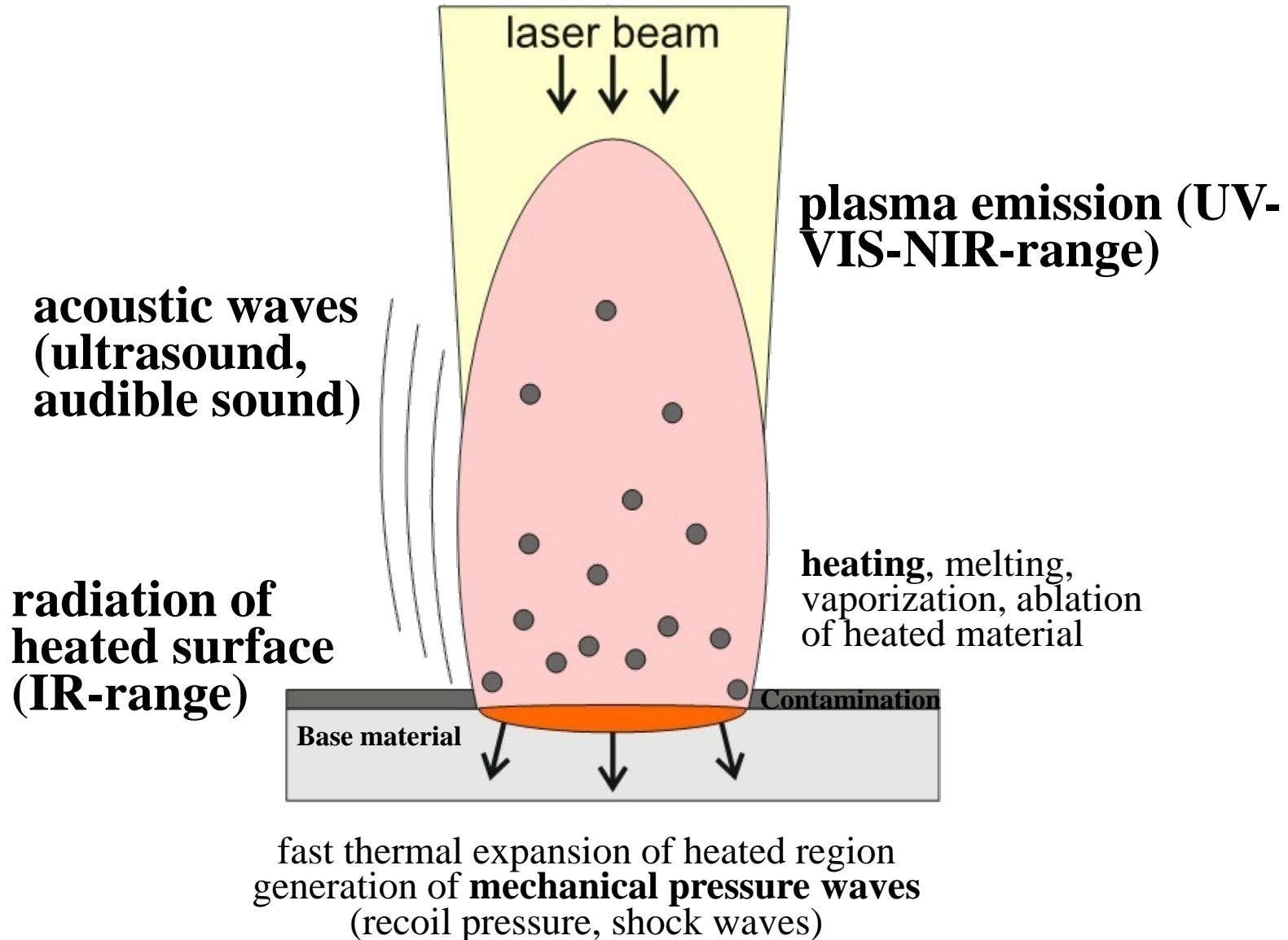


# Outline

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- Physics phenomena at laser cleaning
- Traditional LIBS for laser cleaning control
- Adapted LIBS for multipulse laser cleaning
- Example of laser cleaning with spectroscopic control in multipulse regime
- Conclusion

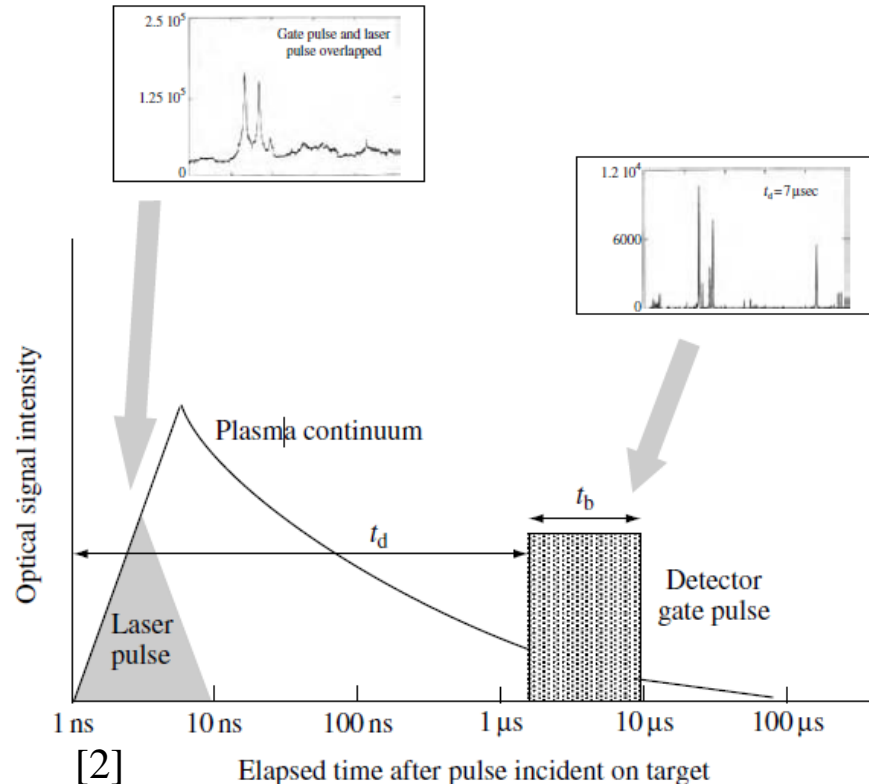
# Physical phenomena at Laser Cleaning





# LIBS for Online Control of Laser Cleaning

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Application of traditional LIBS – online control processes with lasers operating at low repetition rate of pulses.

- Cleaning of cultural heritage.



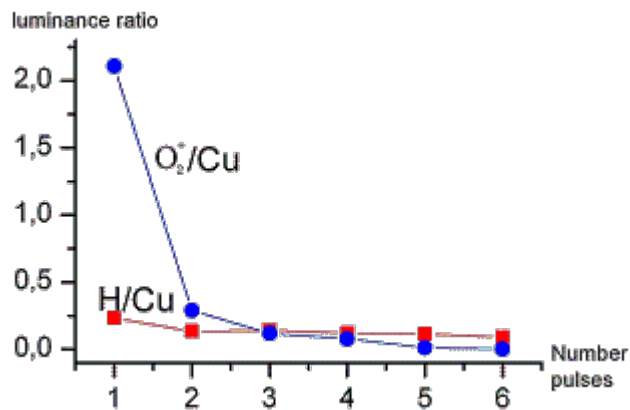
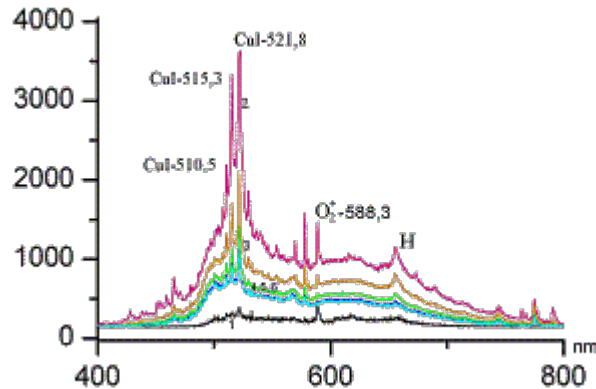
Laser restoration (cleaning) of  
M.I. Lichacheva's treasure  
(exhibit in Hermitage,  
St.Petersburg)

# Spectral diagnostics of laser cleaning at low repetition rate of pulses

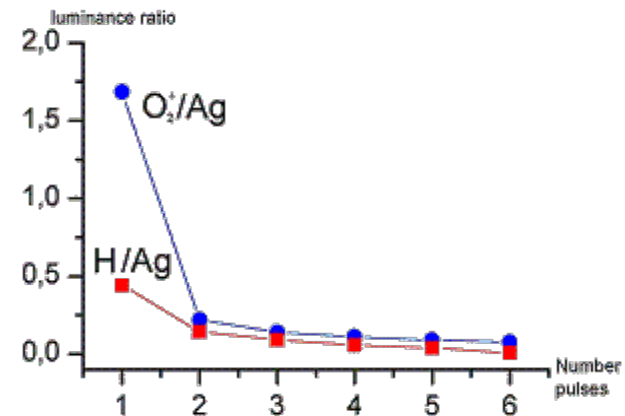
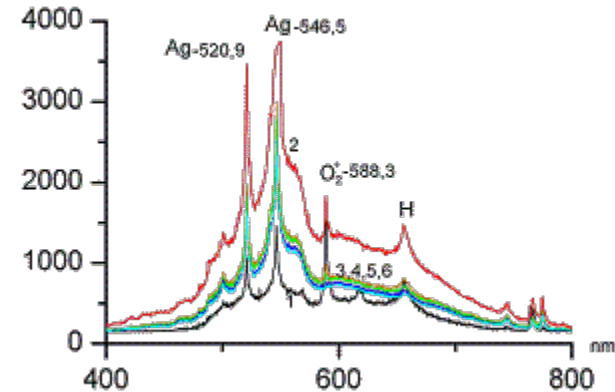
Tools : YAG:Nd laser, 12 ns, 50 mJ, 10 Hz, spectral analyzer: compact spectrometer SPM002 (OFIR)

Objects:

old copper

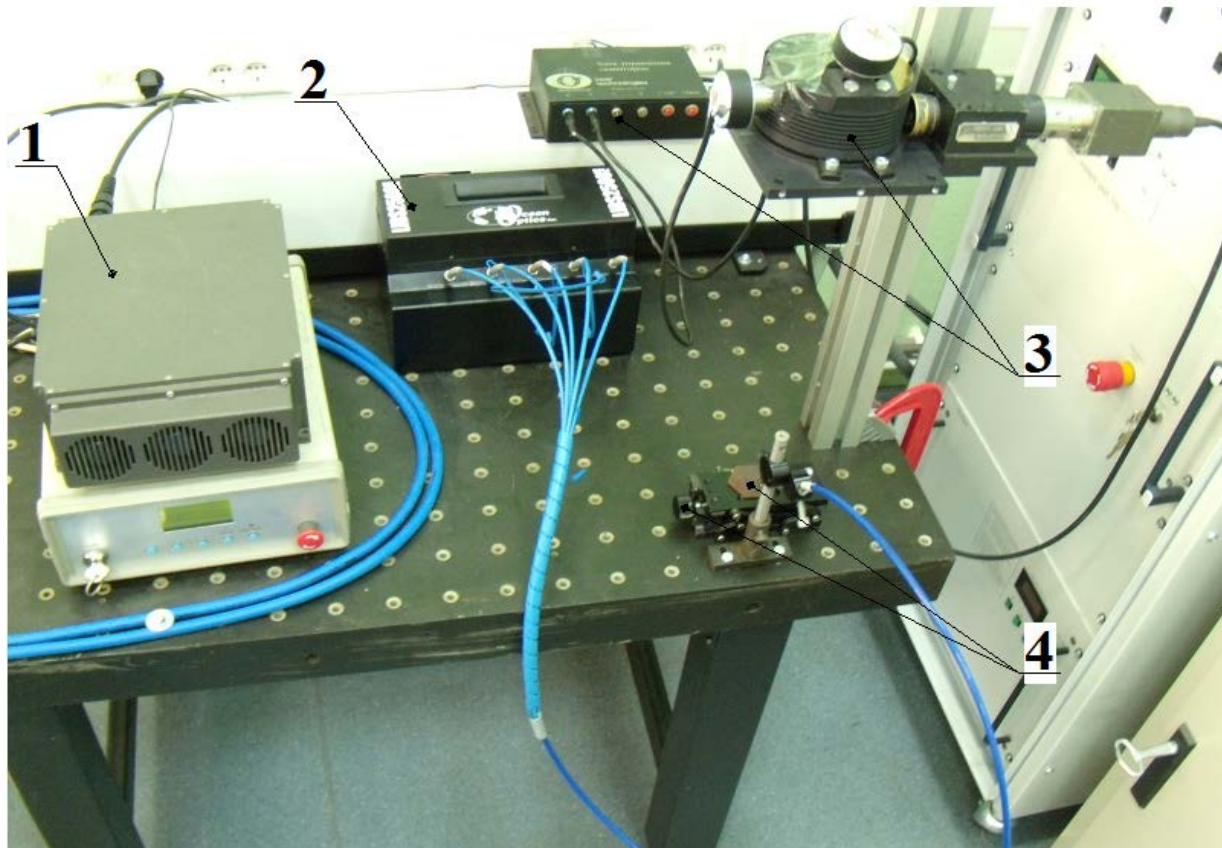


old silver





# Experimental setup for online –control of laser cleaning at high repetition rate



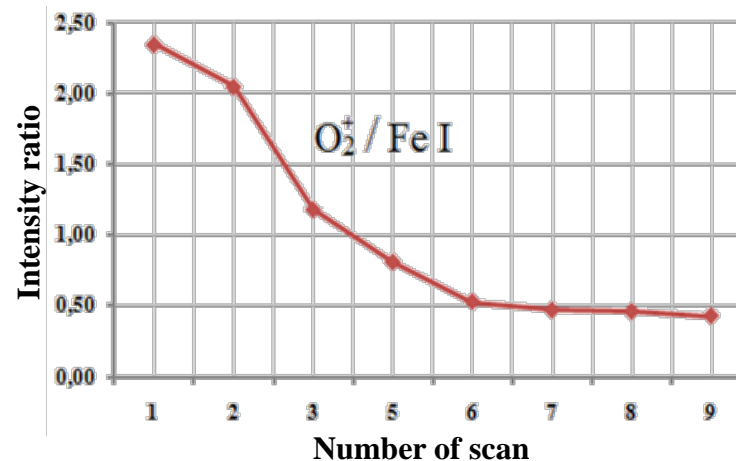
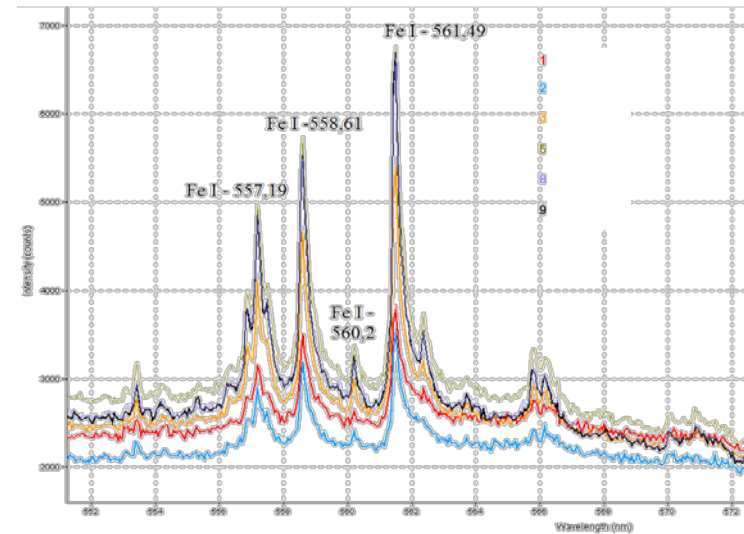
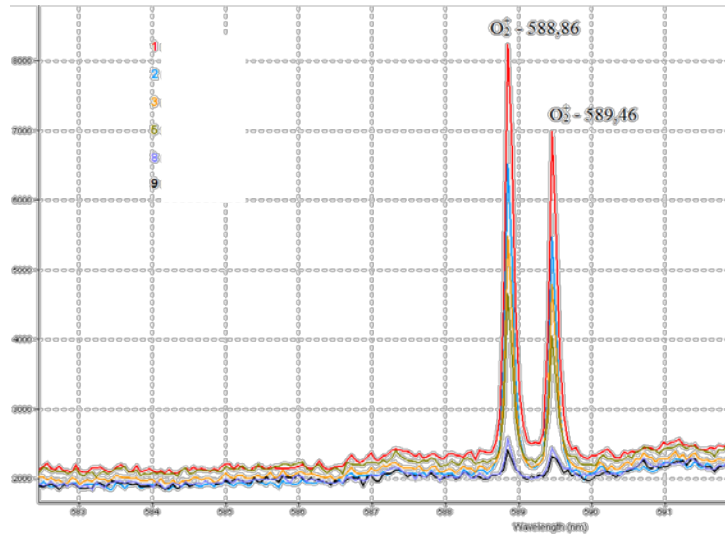
- 1 – pulsed fiber laser ( $P=20\text{W}$ ,  $f=20\text{kHz}$ ,  $E=1\text{mJ}$ ), 2 – fiber spectrometer LIBS 2500 OceanOptics (spectral range 380-890 nm, optical resolution 0,1 nm), 3 – scanning head (0.0002-8 m/s), control unit, 4 – lifting table with a sample, 5 – PC (not illustrated)





# Spectral criterion at laser cleaning of metals – oxygen elimination

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Oxygen/ iron relation lines intensity versus number of passes



# Example of the implementation method online monitoring of laser cleaning

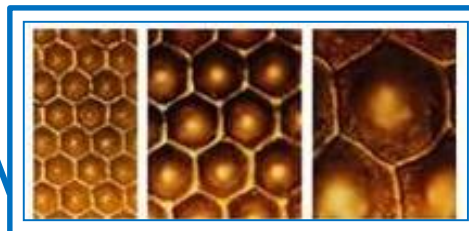
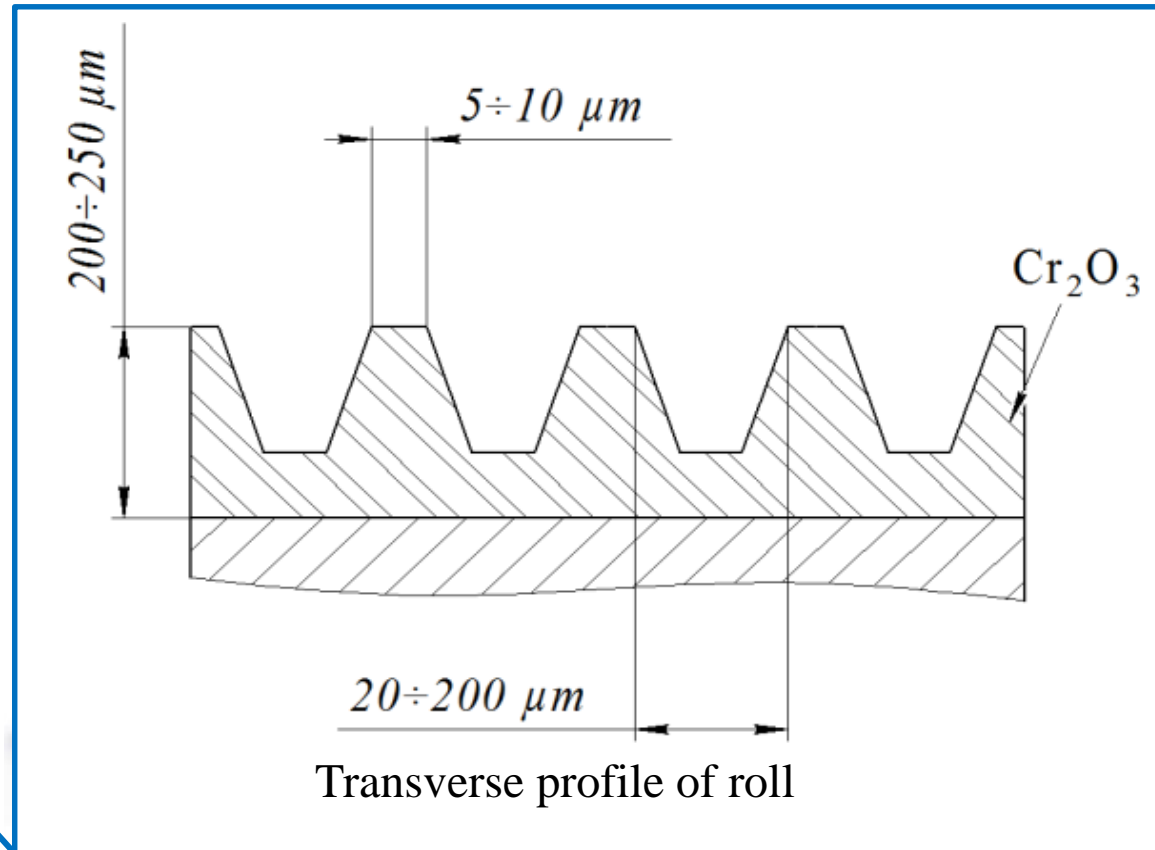




# Cleaning of flexographic rolls.

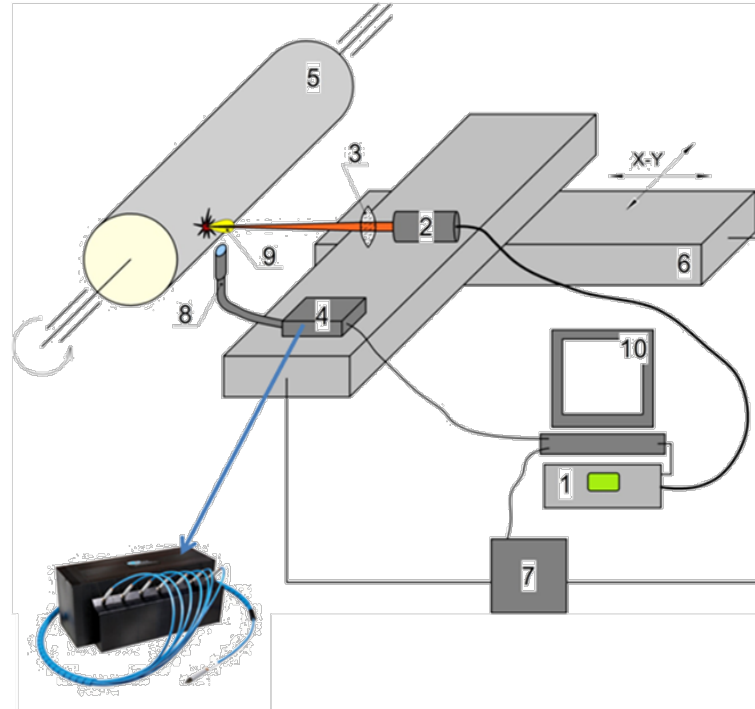
## Statement of the problem

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# Laser cleaning of flexographic roll. Experimental investigations

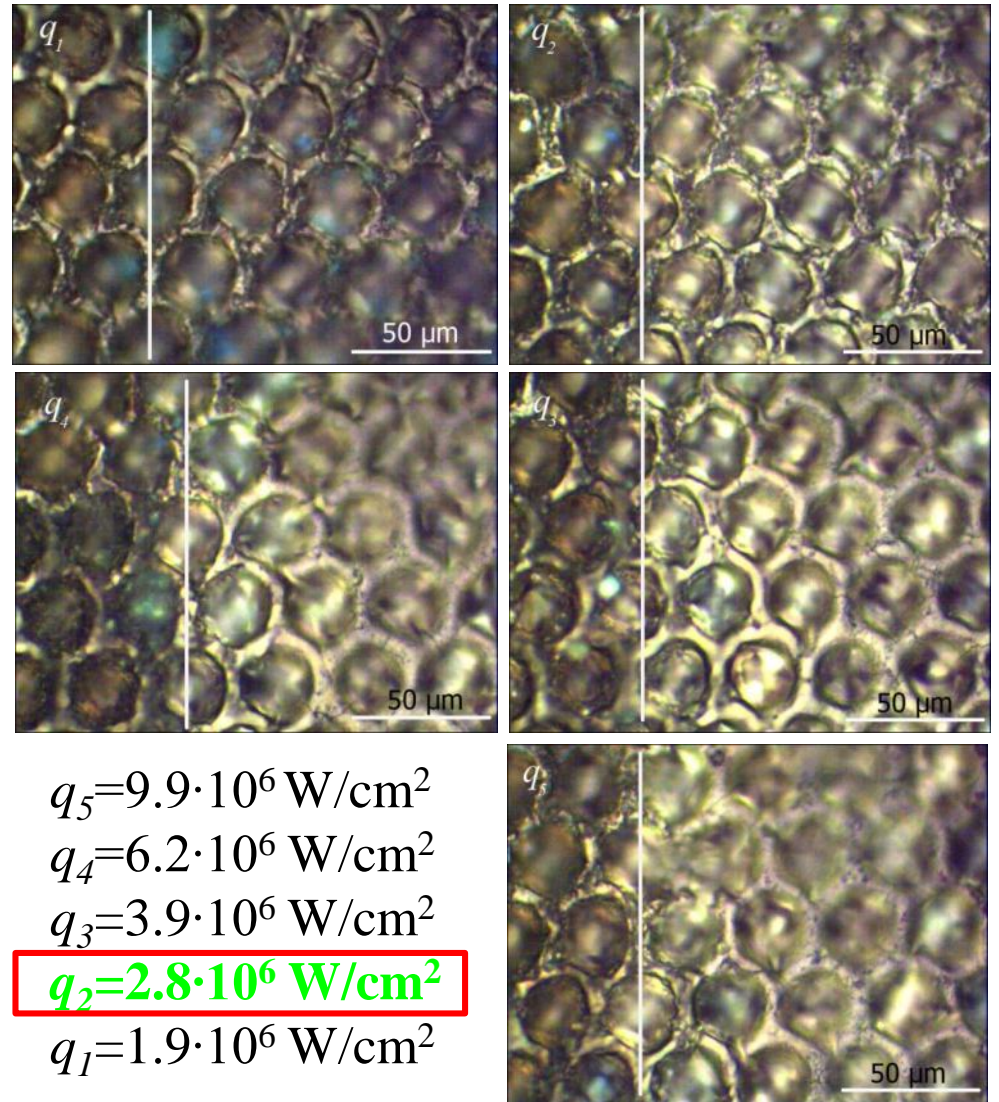
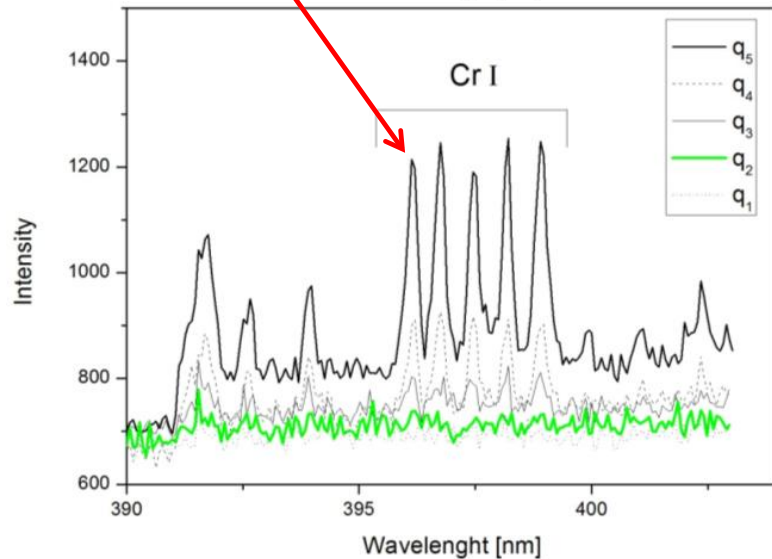
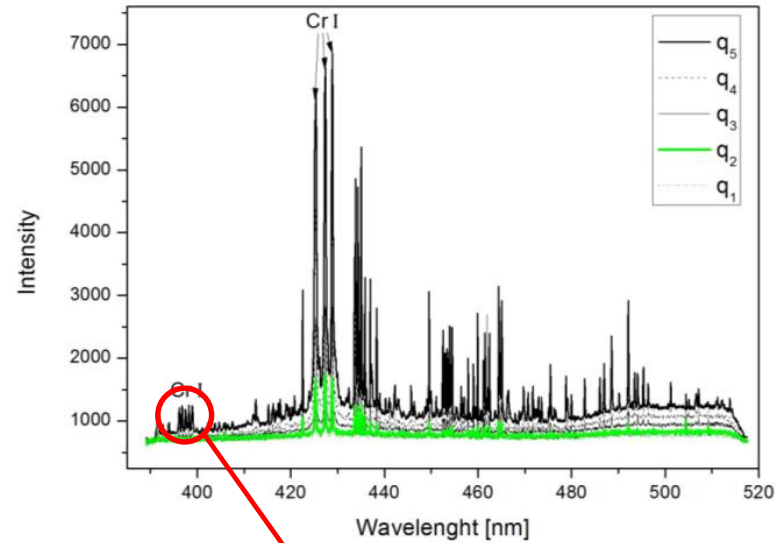


- 1 – fiber pulsed laser ( $P=20\text{W}$ ,  $\tau=200\text{ns}$ ,  $E_{\text{pulse}}=1\text{mJ}$ ,  $f=20\text{-}100\text{kHz}$ );
- 2 – collimating optics; 3 – focusing lens;
- 4 – spectrometer LIBS-2500 OceanOptics;
- 5 – flexographic roll;
- 6 – x-y stage; 7 – controller box;
- 8 – fiber optics; 9 – plasma plume; 10 – PC.



# Spectral criteria for Laser Cleaning of flexographic rolls

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$$q_5 = 9.9 \cdot 10^6 \text{ W/cm}^2$$

$$q_4 = 6.2 \cdot 10^6 \text{ W/cm}^2$$

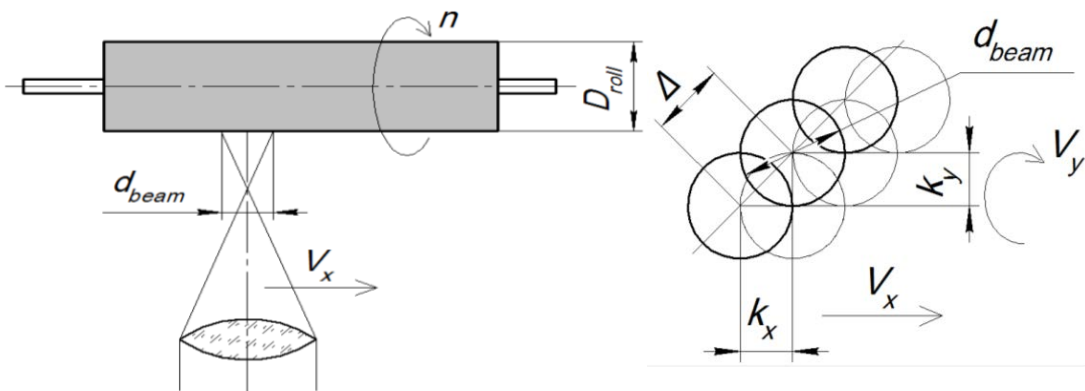
$$q_3 = 3.9 \cdot 10^6 \text{ W/cm}^2$$

$$q_2 = 2.8 \cdot 10^6 \text{ W/cm}^2$$

$$q_1 = 1.9 \cdot 10^6 \text{ W/cm}^2$$

# Technology of laser cleaning of metering rolls

## Scanning of roll surface :



Angular velocity of roll: 
$$n = \left( \sqrt{\Delta^2 - k_x^2} \right) \cdot \frac{60 \cdot f}{\pi \cdot D_{roll}},$$

$f$  – repetition rate of laser pulses,  
 $D_{roll}$  – diameter of roll,  $k_x, k_y$  –  
coefficient of overlap,  $d_{beam}$  –  
diameter of laser beam ( $\Delta \sim d_{beam}$ ,  
 $k_x \sim 2$ ).

## Results of laser cleaning

Before	After
	
	
	

1,2 – UV-paint,  
3 – spirit-based paint





# LaserEcoClean – Result of researches



## Equipment specifications

Length of cleaning roll	to 1360 mm
Diameter of cleaning roll	to 250 mm
Speed of cleaning	1 mm/s
Laser	Fiber pulsed laser (IPG-Photonics $P=20\text{W}$ , $f=20\text{kHz}$ , $E_{pulse}=0,88\text{mJ}$ , $\tau=200\text{ns}$ )

<http://www.laserecoclean.com/>



# Conclusion

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- LIBS can be used for online monitoring of laser cleaning by means lasers operating with low and high pulse repetition rate
- For reliable online monitoring of laser cleaning of metal surfaces is sufficient to choose the ratio of characteristic lines:
  - ❖ the ratio of oxygen line to the line of metal – in cases of cleaning from oxide layer;
  - ❖ and the threshold of the appearance of the secondary lines of the substrate – in cases of cleaning from organic/polymer contamination



# THANK YOU FOR YOUR ATTENTION!

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