



CANDLE SRI  
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# The Effect of Ultrashort Pulse Shaping on Regimes of Laser Processing of a Glass

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# Outline

- ❖ Glass Processing
  - ▼ Application of Ultrafast Lasers
  - ▼ Advantages of Using Temporally Shaped Ultrashort Pulses
- ❖ Experimental Techniques for Determination of a Single Pulse Induced Optical Breakdown Threshold (OBT)
- ❖ Double Pulse Irradiation Effect on OBT
- ❖ Dependence on Pulse Duration
- ❖ Summary

# Glass Processing

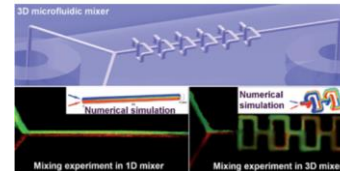
## *Application of Ultrafast Lasers*

Potential applications in photonics, integrated optics, microfluidics among many others.

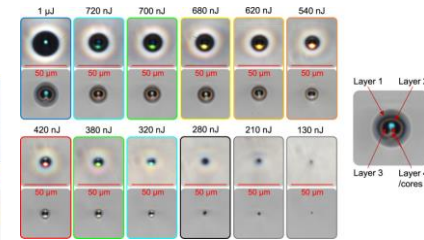
- = Fabrication of diffraction gratings, phase plates, waveguides, etc.
- = Glass drilling and cutting.

### Advantages of Ultrafast Processing

- reduced heat affected zones – improved quality and resolution of fabrication
- multiphoton absorption at a localized area in the volume of a transparent sample – high resolution 2D and 3D writing of micro- and nanostructures



Liao, Y., Song, J., Li, E., et al (2012). doi:10.1039/c2lc21015k



Chen GY, Piantedosi F, Otten D, et al. DOI: 10.1038/s41598-018-28631-3.

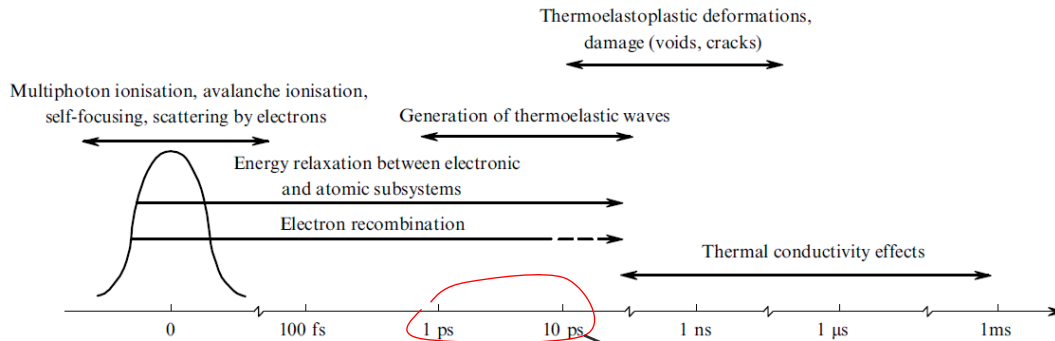
# Glass Processing

## Advantages of Using Temporally Shaped Ultrashort Pulses

The fabrication method also requires further improvement.

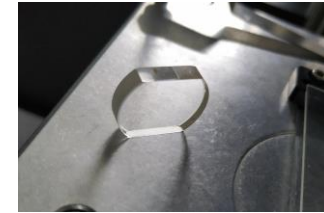
The possibility of effectively controlling the dynamic processes at picosecond and sub-picosecond time scales has triggered interest in temporal shaping methods.

Time scales of different complex processes caused by femtosecond laser irradiation



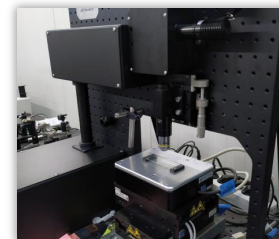
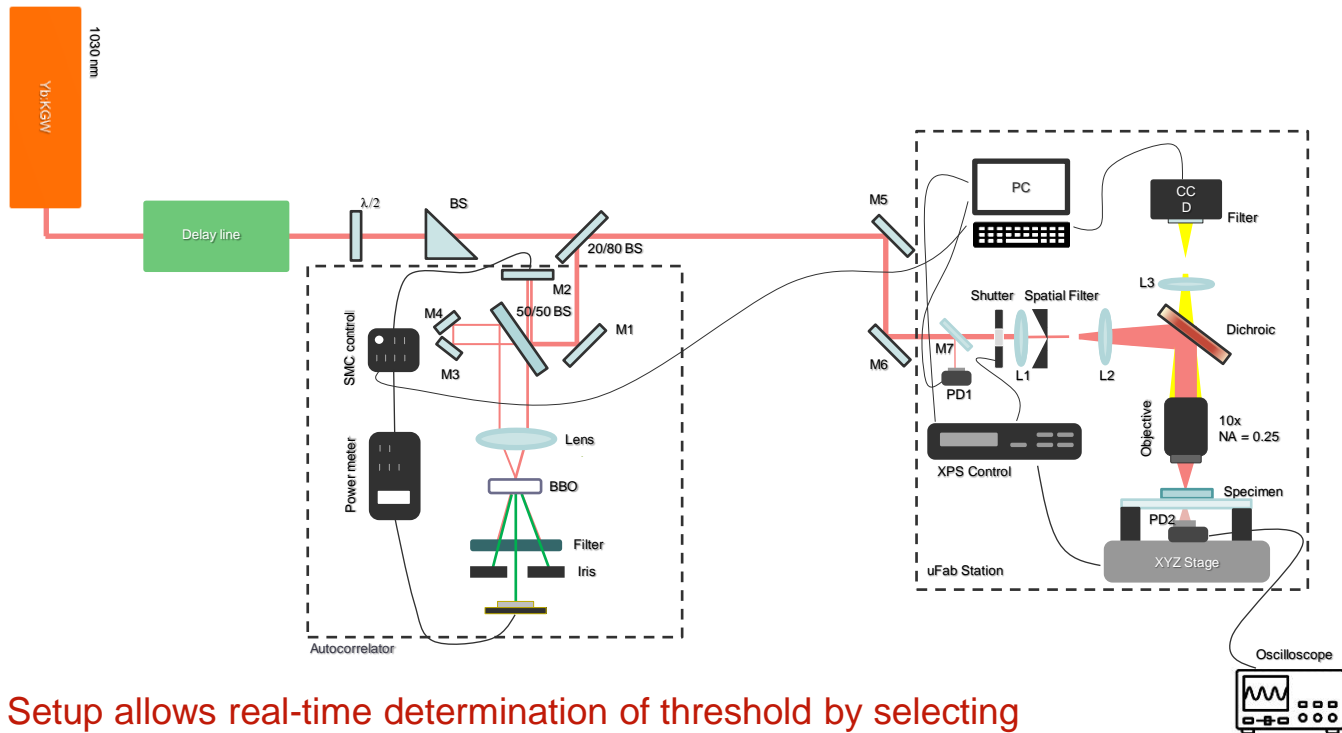
Bulgakova, N. M., Stoian, R., & Rosenfeld, A. (2010). doi:10.1070/qe2010v040n11abeh014445

The modification threshold.. variation depending on fabrication parameters



N-BK7 – universal optical glasses widely used in optical manufacturing, optoelectronics, microwave technologies, integrated optics, etc.

# Experimental Setup and Techniques



## Features of uFab workstation

Travel Range	100 x 100 mm (XY), 25 mm (Z)
Scanning Speed	up to 300 mm/s (XY), up to 5 mm/s (Z)
XYZ positioning accuracy	±50 nm

## Laser Parameters

Pulse Duration	from 500 fs to 10 ps
Repetition Rate	from 1 Hz to 100 kHz
Pulse Energy	up to 1.8 mJ (1030 nm)
Wavelengths	1030 nm, 515 nm

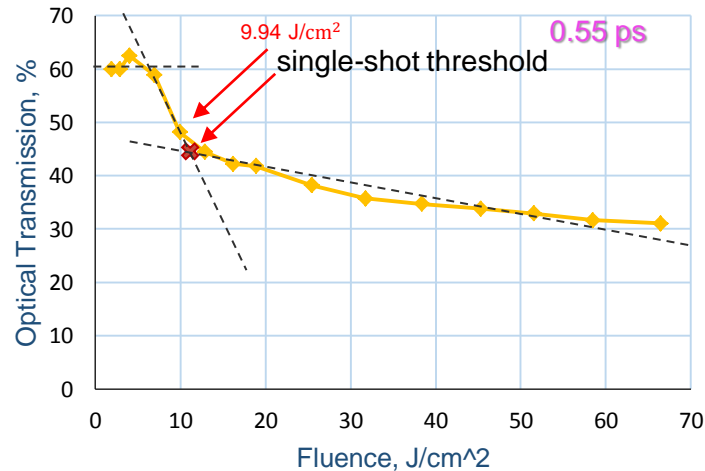
Setup allows real-time determination of threshold by selecting appropriate laser modulation, and scanning parameters.

# Single Pulse-Induced Optical Breakdown Threshold

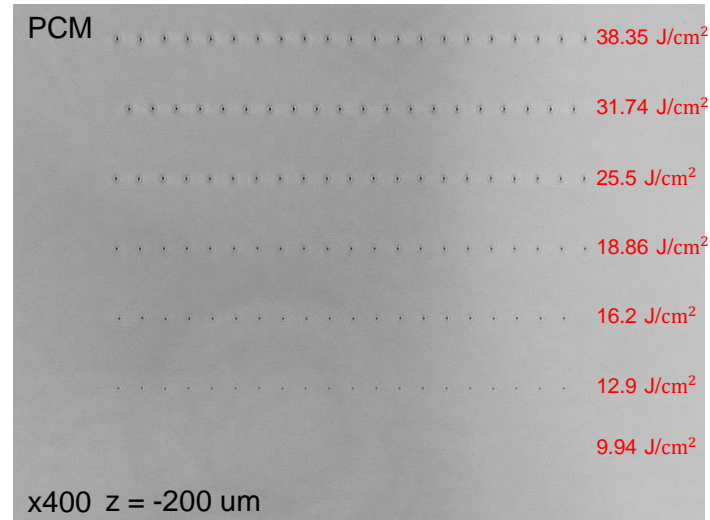
## Experimental Parameters

Wavelength	Pulse Duration	Repetition Rate	Scanning Speed	Spot Size
1030 nm	0.5 – 10 ps	100 Hz	1 mm/s	3 $\mu\text{m}$

## Optical Transmission Change



## Optical Microscopy

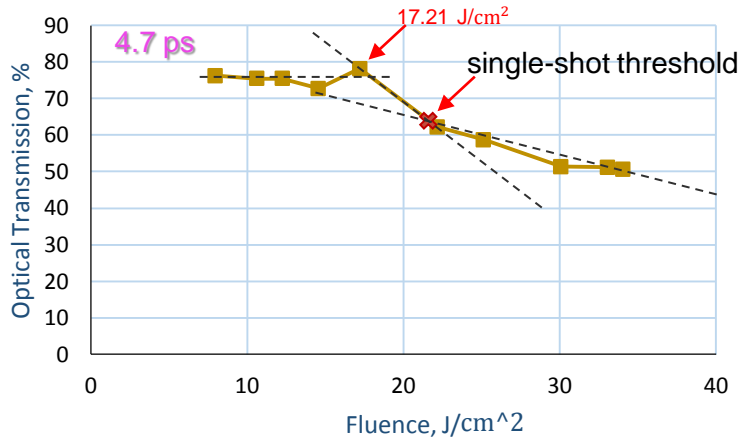


# Single Pulse-Induced Optical Breakdown Threshold

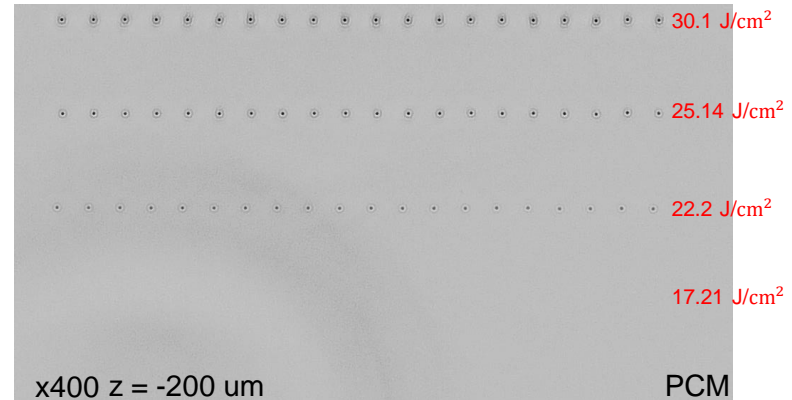
## Experimental Parameters

Wavelength	Pulse Duration	Repetition Rate	Scanning Speed	Spot Size
1030 nm	0.5 – 10 ps	100 Hz	1 mm/s	3 $\mu\text{m}$

## Optical Transmission Change



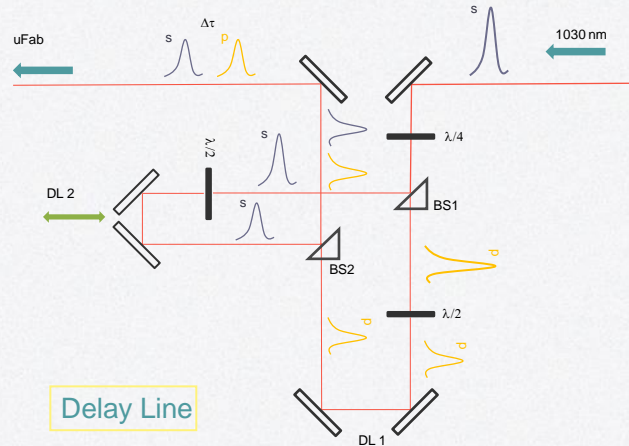
## Optical Microscopy



# Double Pulse Irradiation Effect on the OBT

## *The details of the experiment*

Tunable relative timing: from 0 to 50 ps



### Experimental Details

Delay between pulses: 1 – 21 ps

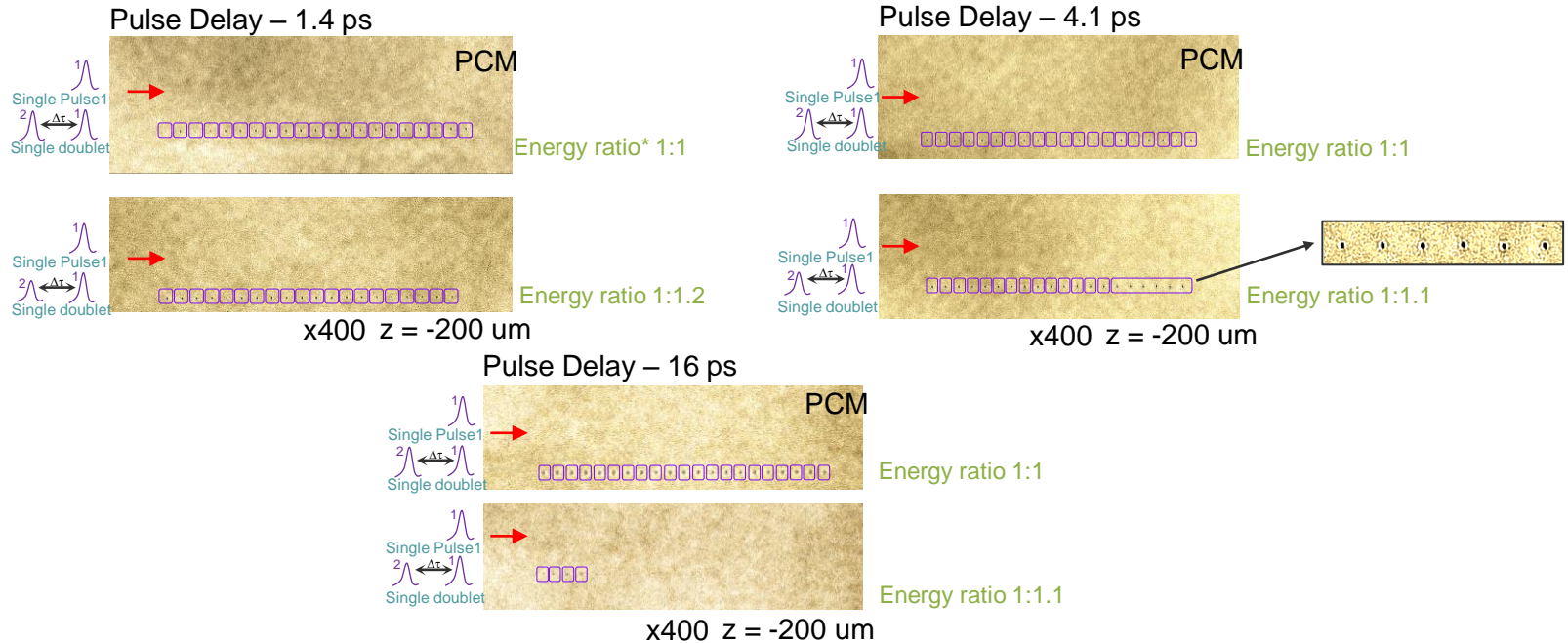
Energy ratio of single doublet: 1:1 to 1:4

In all experiments, the energy of each pulse was below a single pulse-induced optical breakdown threshold.



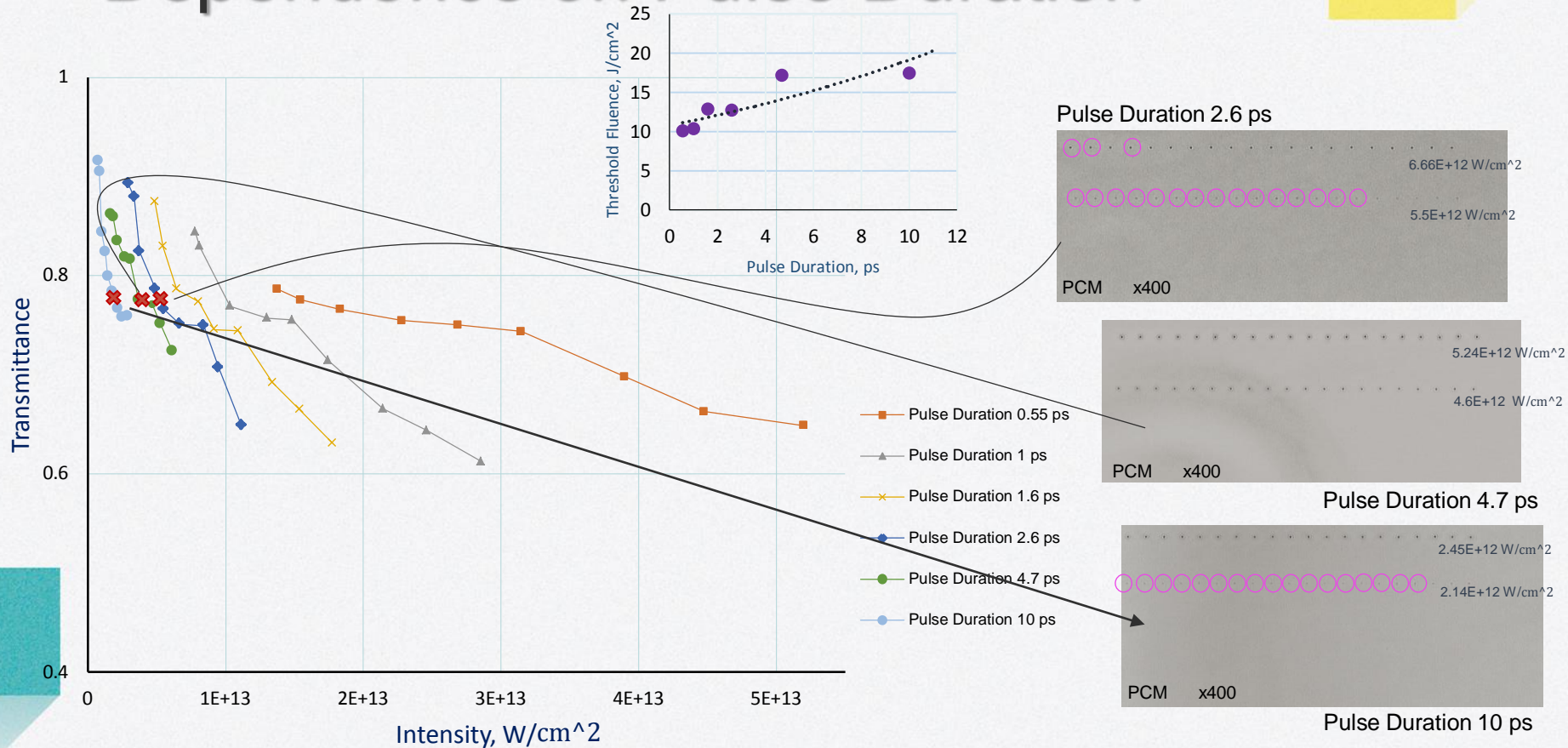
# Double Pulse Irradiation Effect on the OBT Results

Observation of the “pump & pump” effect of single-doublet irradiation



\*Energy Ratio = Variable Energy Pulse: Fixed Energy Pulse

# Dependence on Pulse Duration



# Summary

- ❖ method of real-time determination of single and double pulse induced damage/optical breakdown threshold
- ❖ “pump & pump” effect was observed in tunable-delay single-doublet irradiation experiments
- ❖ double-pulse irradiation with a delay in the chosen range has the potential for practical application to find optimal laser processing regimes
- ❖ this processing technique is a useful tool to understand underlying fundamental physics at appropriate time scales



# Thanks!

# Շնորհակալություն

Do you have any questions?

[maximsargsyan@asls.candle.am](mailto:maximsargsyan@asls.candle.am)

# DELTA uFab Microfabrication Station

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## Features

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Travel Range	100 x 100 mm (XY), 25 mm (Z)
Scanning Speed	up to 300 mm/s (XY), up to 5 mm/s (Z)
XYZ positioning accuracy	±50 nm

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- High-grade optics to achieve nanoscale precision in both 2D and 3D processing
- Software for visualization of the machining process and direct control of sample motion hardware and pulse parameters

