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Ultrafast phenomena characterisation using time-resolved digital holography

Dr. Balys Momgaudis

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CONTENT

- Introduction
- Motivation
- Methodology
- Capabilities
- Applications
- Prospects

Prelude

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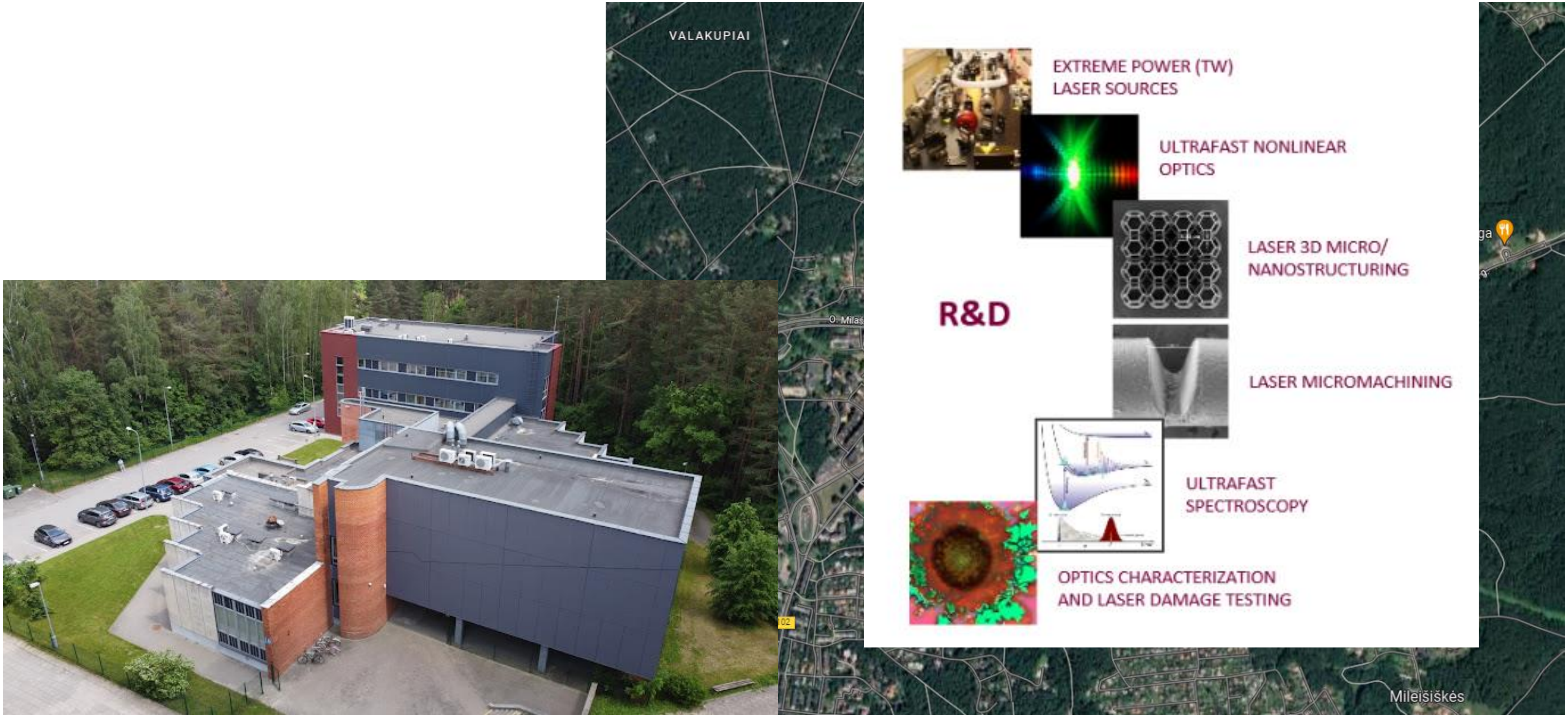

Motivation

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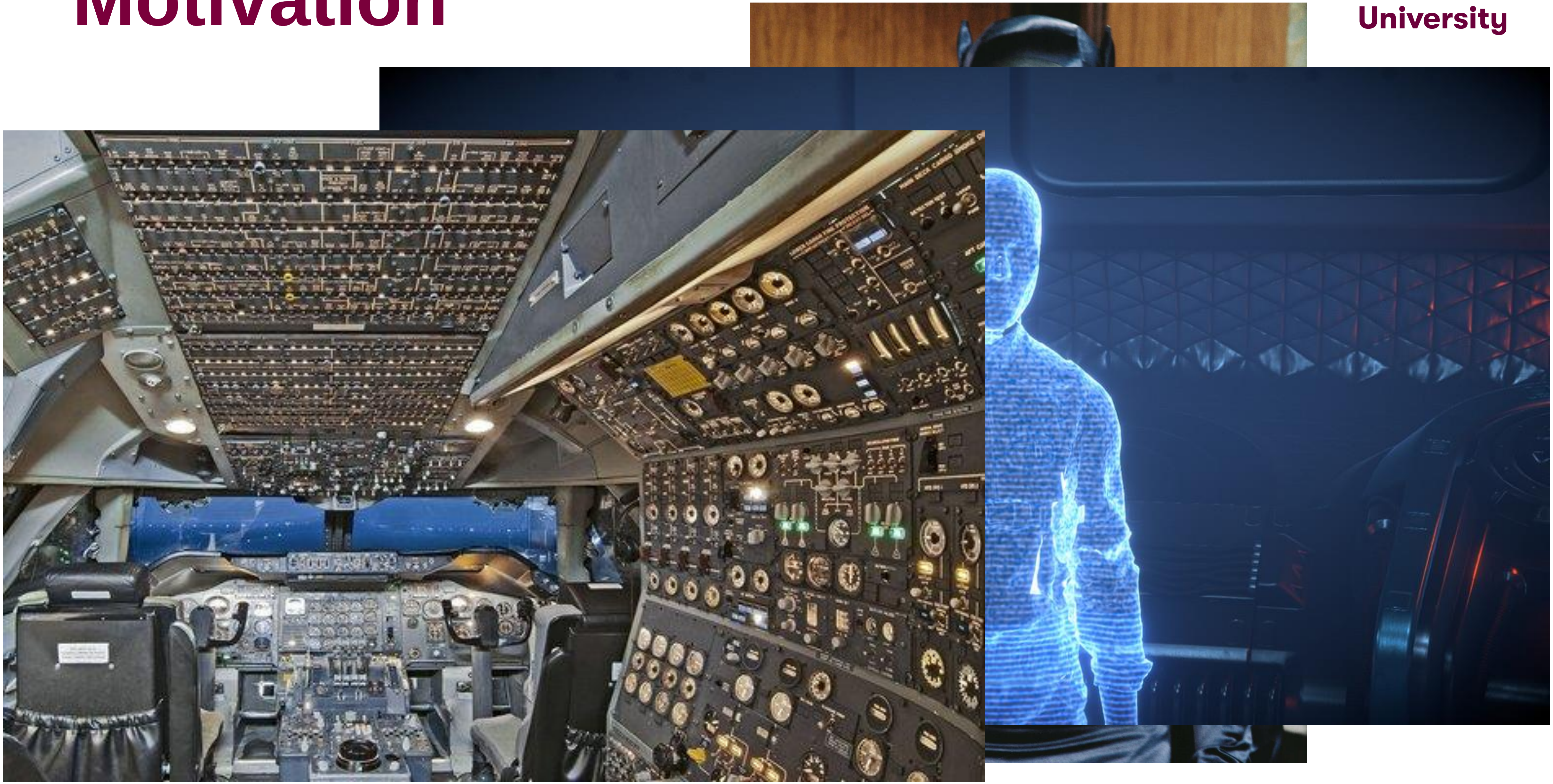
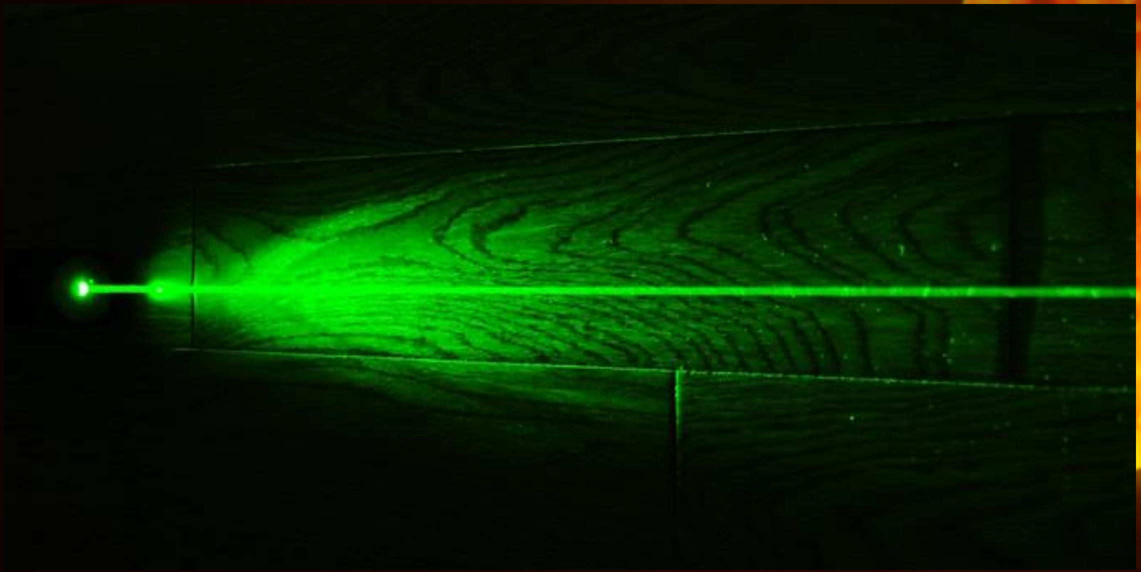


Methodology: Pump-probe

- What is the rate of CCD camera?
- How fast is ultrafast?



Holography

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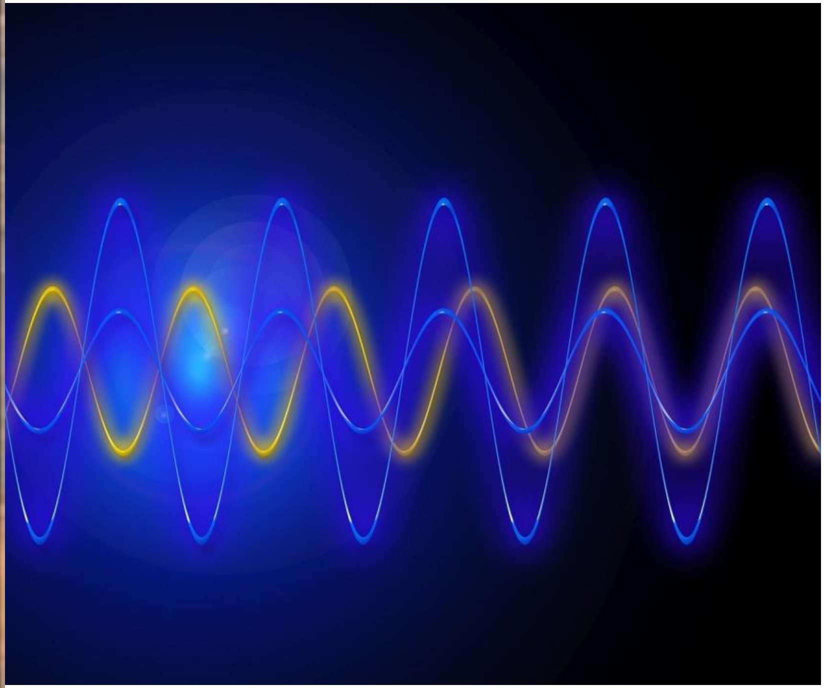
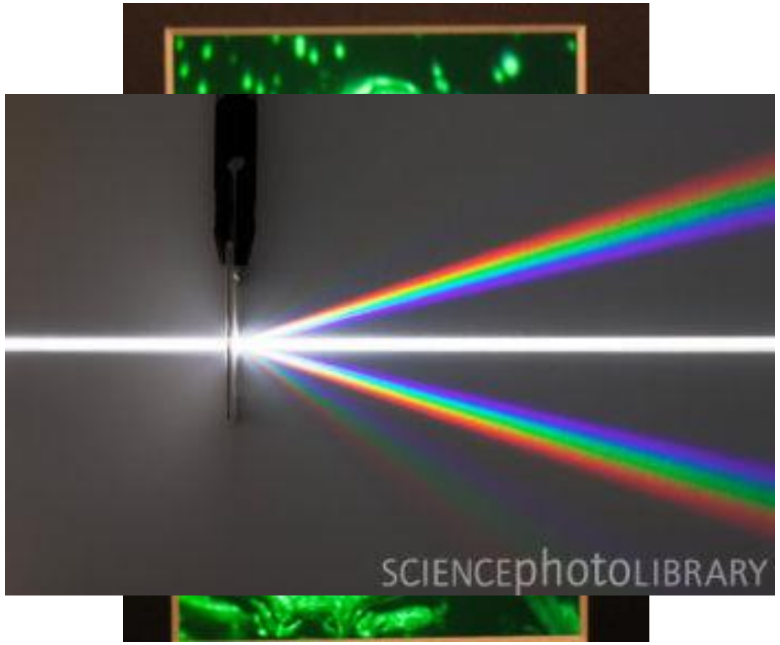


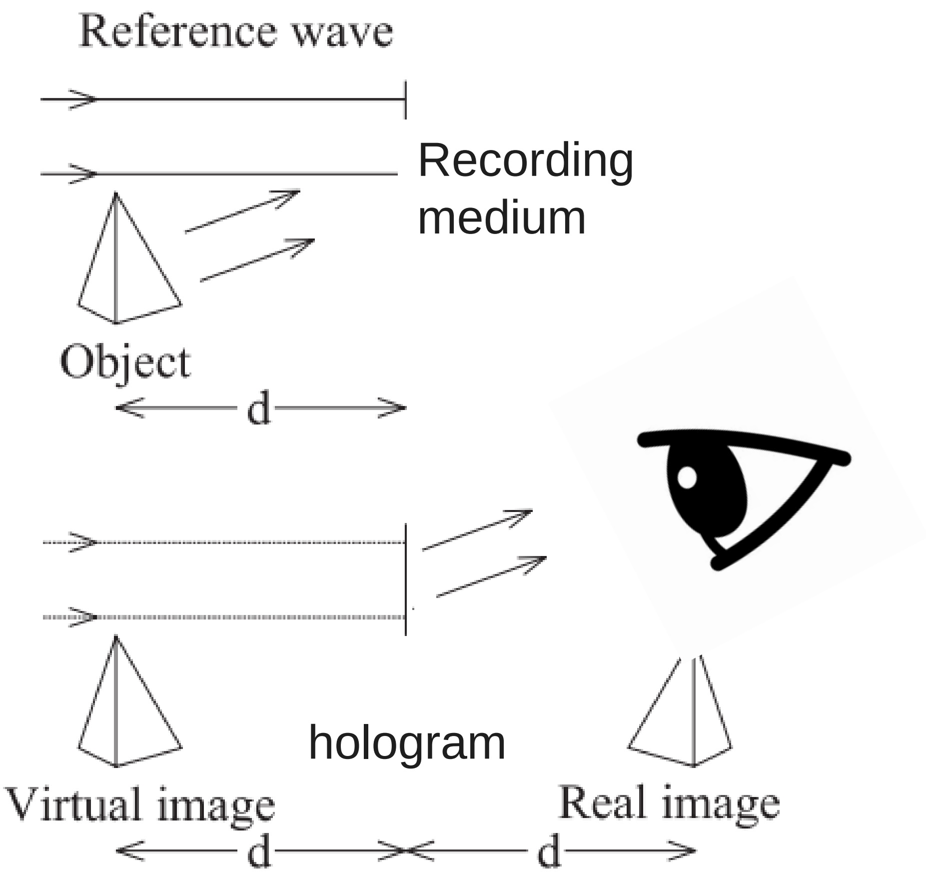
Holography

$h = \beta I$

$I = |O + R|^2 = (O + R)(O + R)^{*} = o^2 + r^2 + RO^{*} + OR^{*}$

$Rh = R\beta(O+R)(O + R)^{*} = \beta(R(o^2+r^2) + R^2O^{*} + r^2O)$





Schnars, Ulf, and Werner PO Jüptner. (2002): R85.

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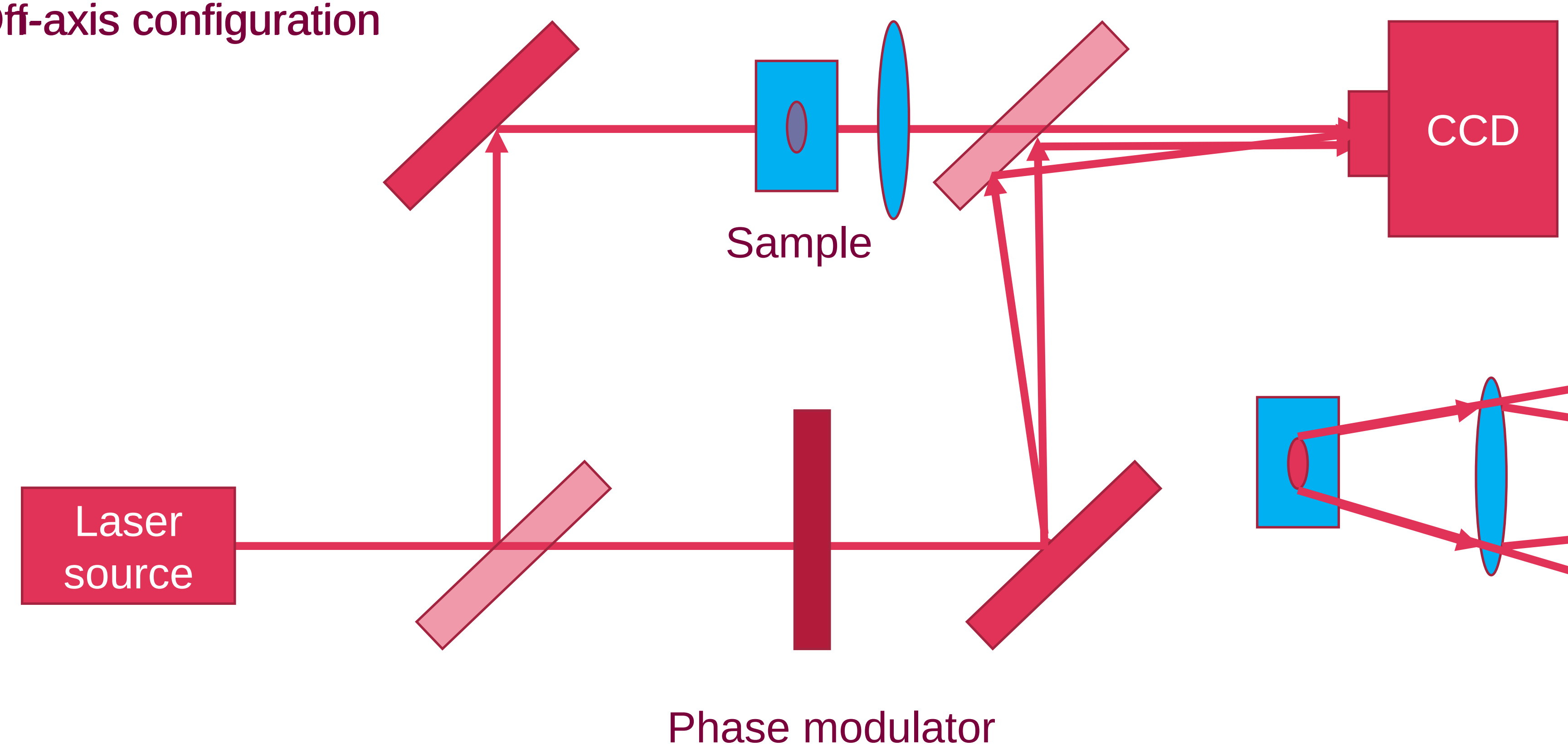
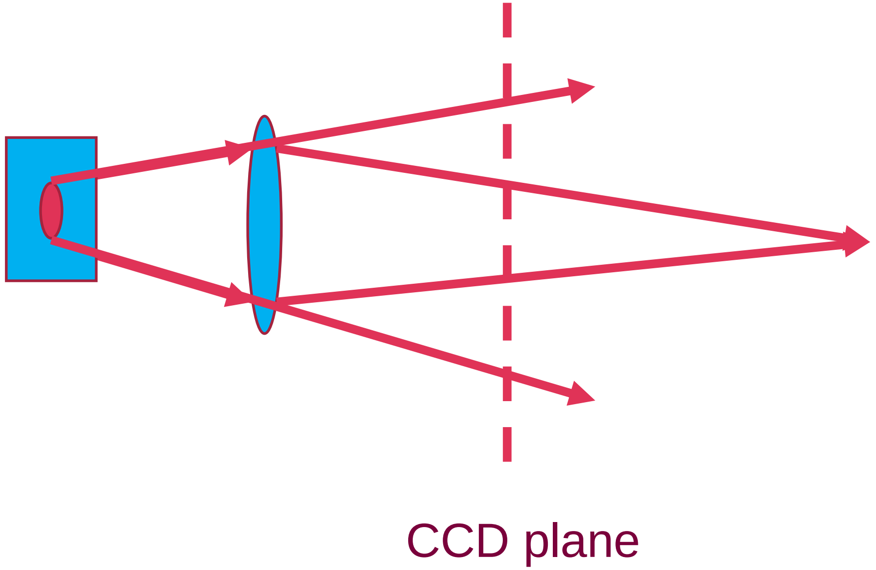
Digital holography setups

Off-axis configuration





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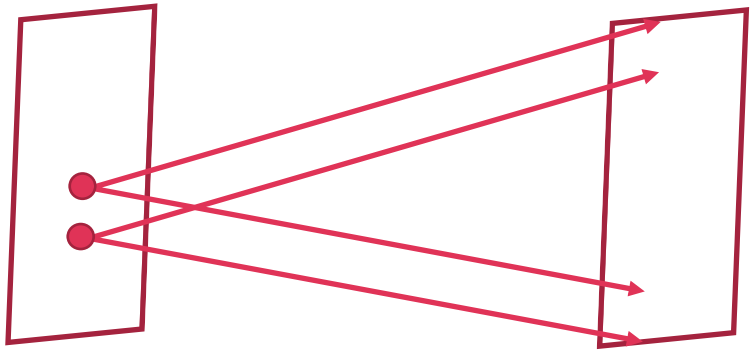
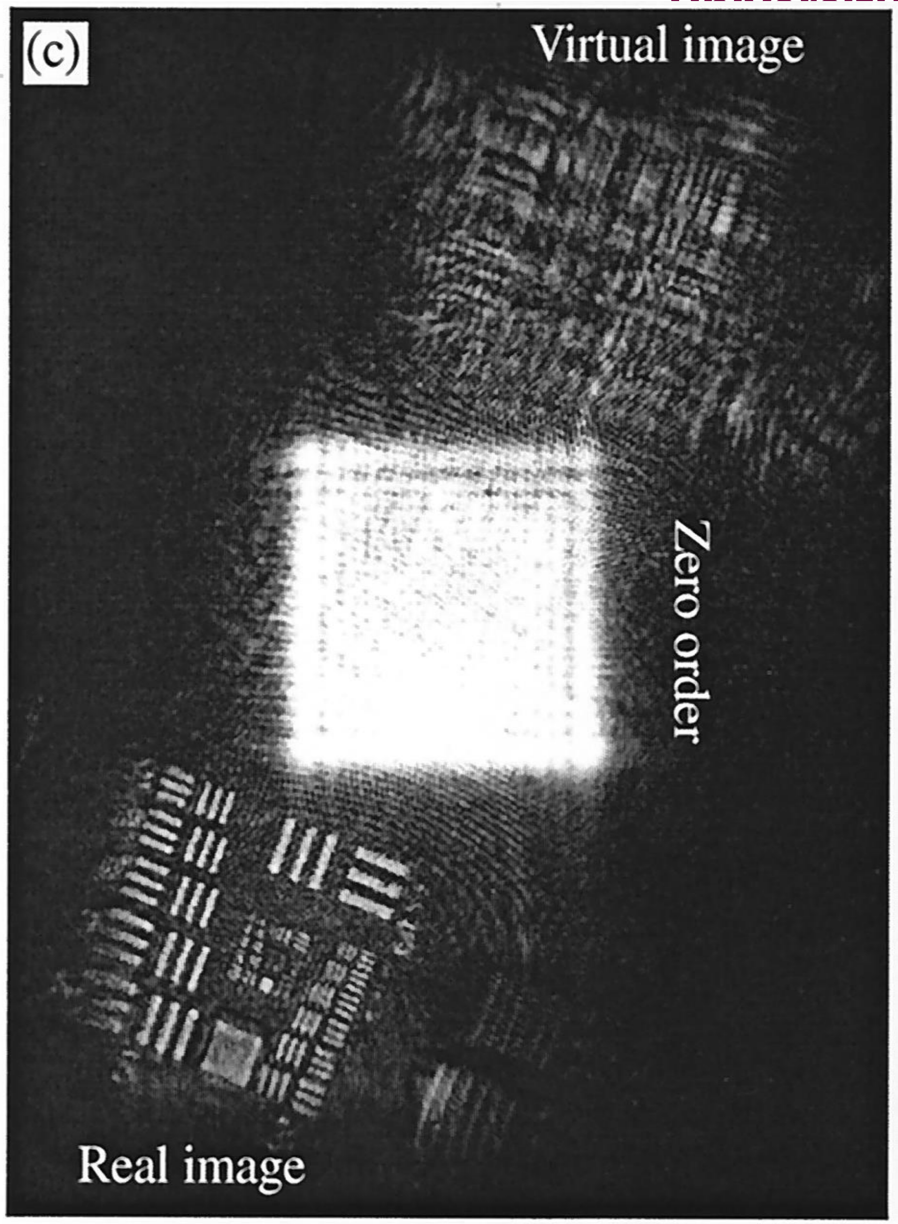
Digital reconstruction

$$\Gamma(\xi, \eta) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h(x, y) R(x, y) g(\xi, \eta, x, y) \, \mathrm{d}x \, \mathrm{d}y$$



$g(\xi, \eta,$



$$\Gamma(\xi, \eta) = \Im^{-1}\{\Im(h \cdot R) \cdot \Im(g)\}.$$

Pros and cons

Pro	Con
Quantitative phase	Phase unwrapping
Numerical focusing	Speckle noise
Noncontact	interpretation
Price	
Real-time	
Digital	

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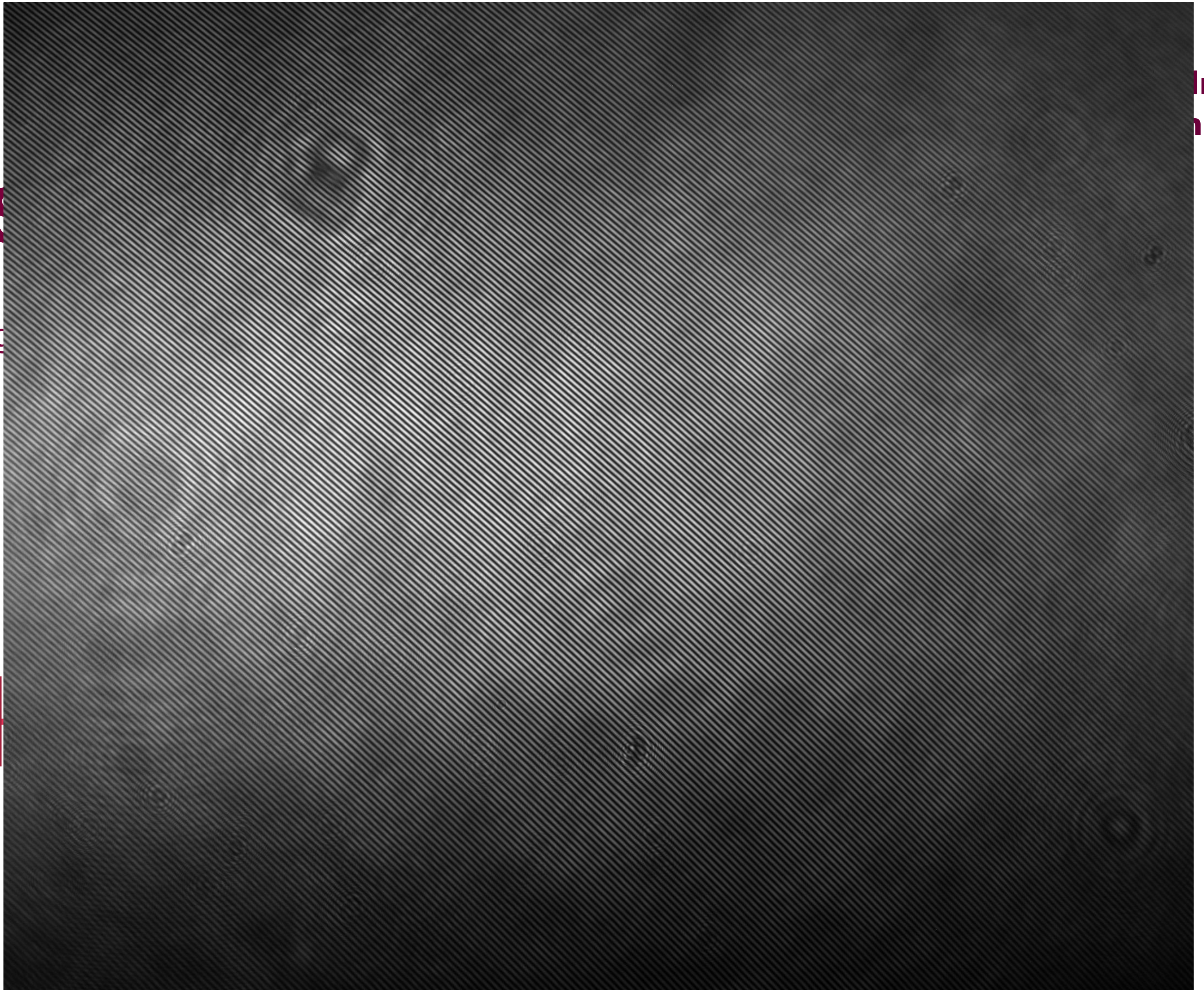
Off-axis config



Laser source

10-30 fs

Material response to laser excitation

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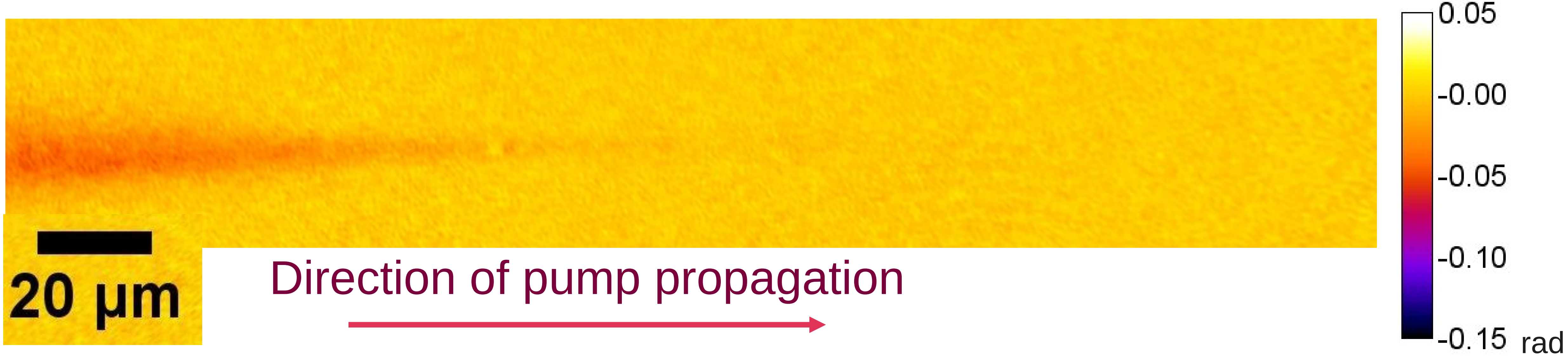

Optical path: L=n*l

- Light Intensity
- Free electron plasma
- Bound states
- Density
- Phase change
- Absorption
- Temperature
- Strain
- Object size

Parameters

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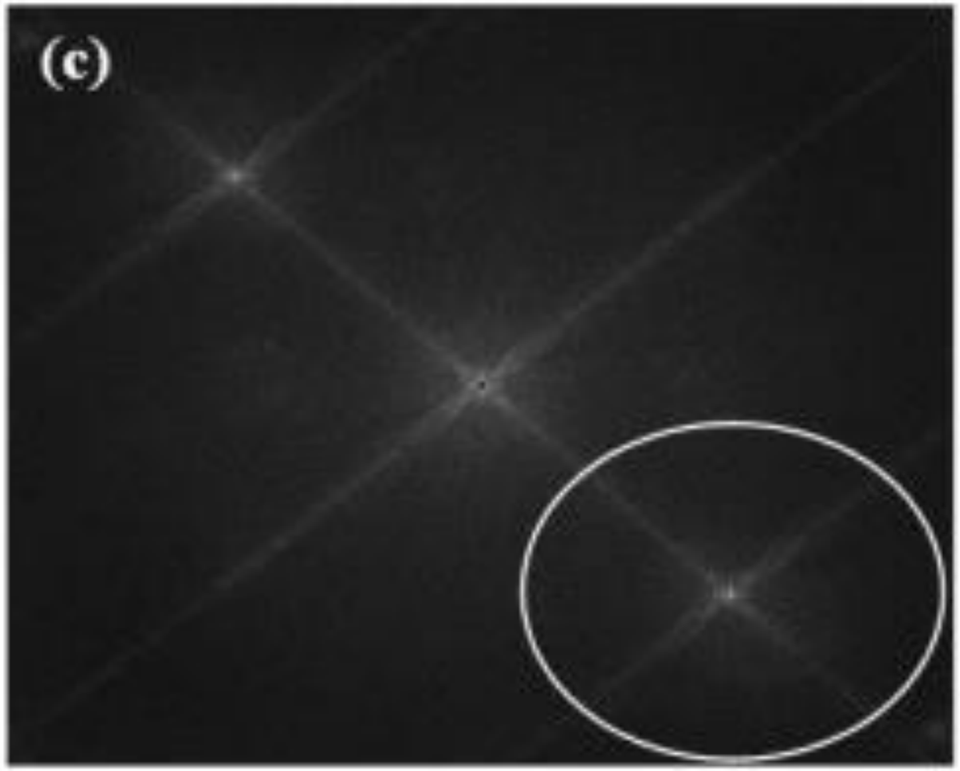
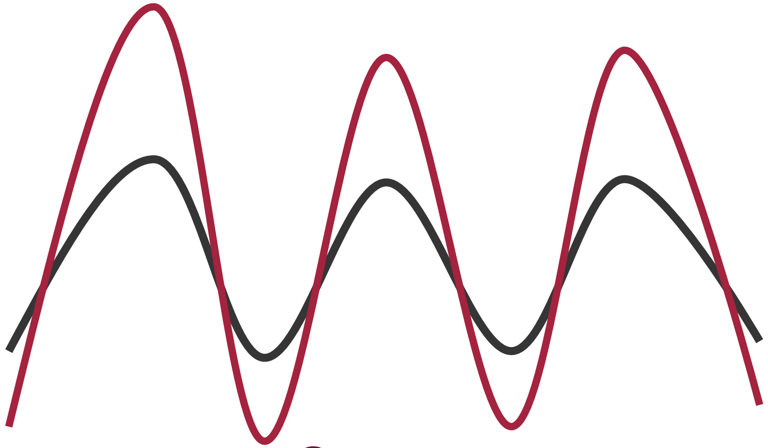
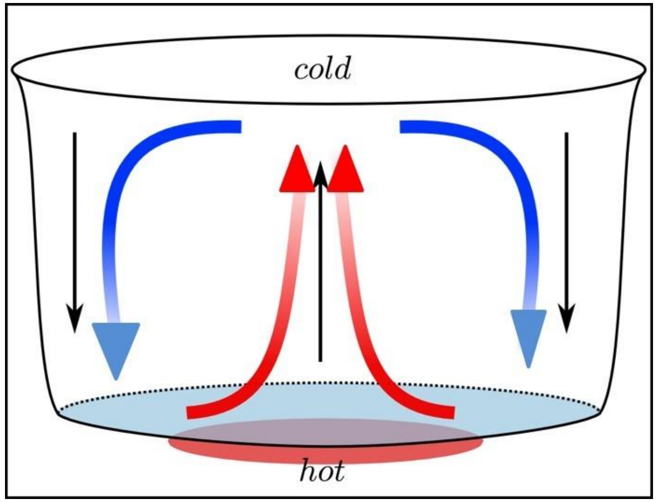
- Ter
- Ter
jitter and resolution)
- Spa
- Tra
- Sin)



Filtering in Fourier plane



Contrast



Convection

Nonlinear refractive index evaluation

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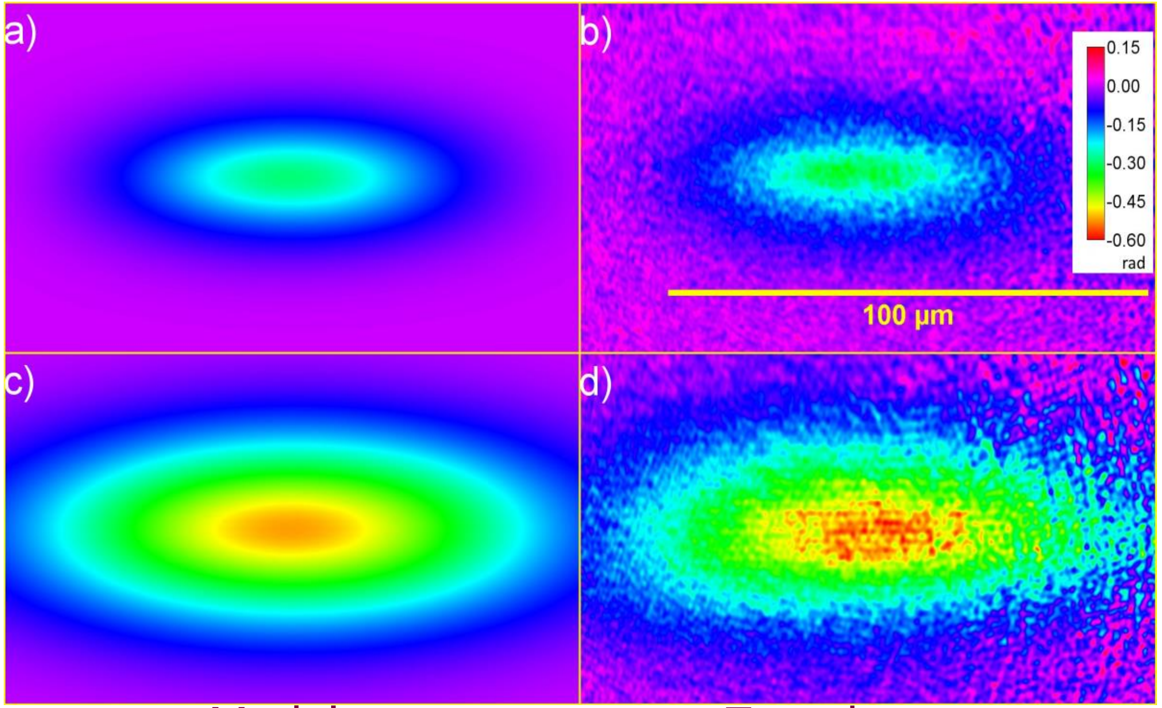
$$\frac{\partial E_1}{\partial z} = \frac{i}{2k_1}\left(\frac{\partial^2 E_1}{\partial x^2} + \frac{\partial^2 E_1}{\partial y^2}\right) + iC_1|E_1|^2E_1 + \frac{1}{u_{01}}\frac{\partial E_1}{\partial t}$$

$$\frac{\partial E_2}{\partial z} = \frac{i}{2k_2}\left(\frac{\partial^2 E_2}{\partial x^2} + \frac{\partial^2 E_2}{\partial y^2}\right) + iC_2|E_1|^2E_2 - \frac{1}{u_{02}}\frac{\partial E_2}{\partial t} + \frac{g_{02}}{2}\frac{\partial^2 E_2}{\partial t^2}$$

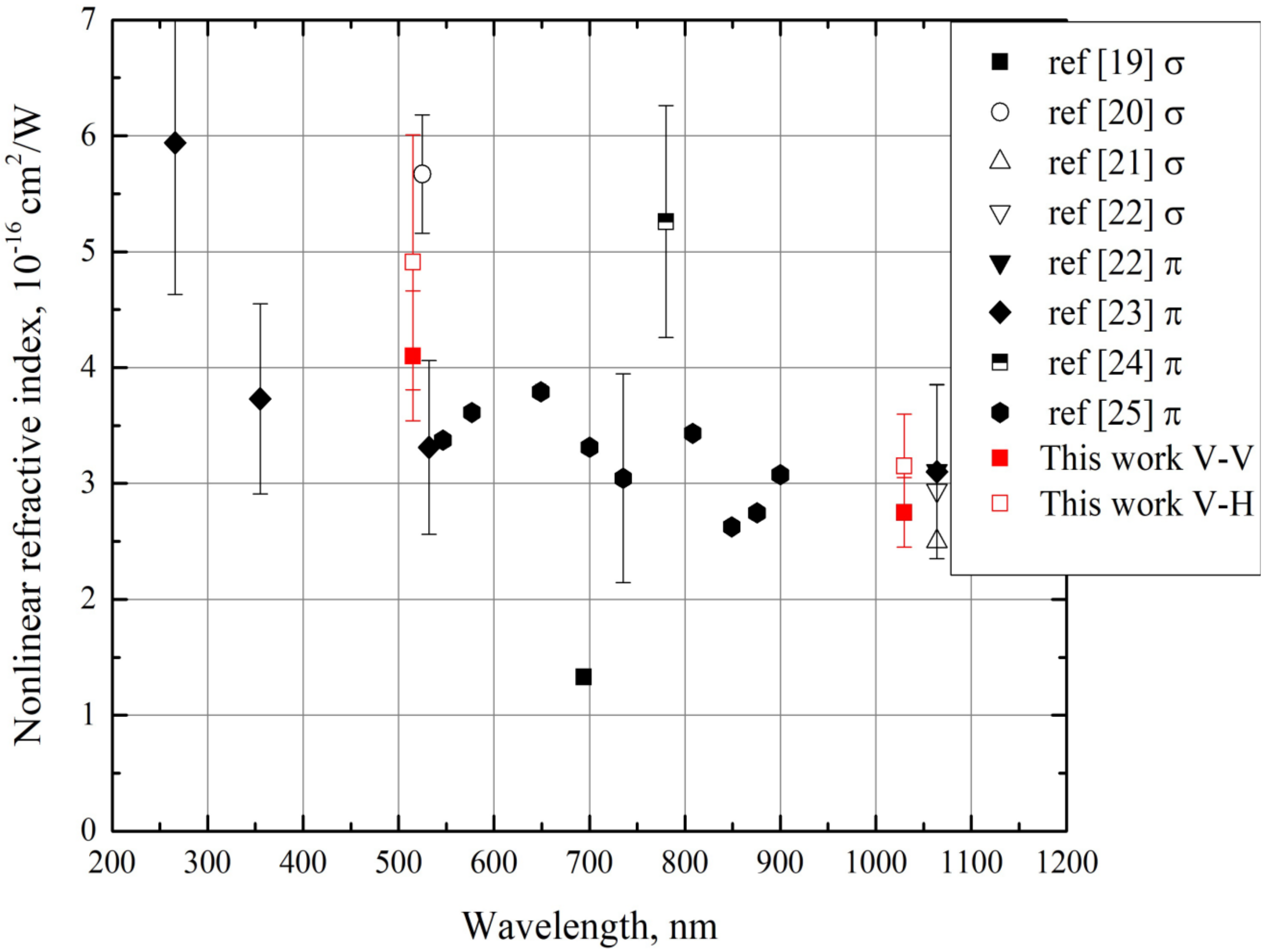
Direction f propagation



Model

Experiment

Phase shift maps in sapphire



Nonlinear refractive index value of sapphire in literature

Fatigue effects Nd:CaF_2

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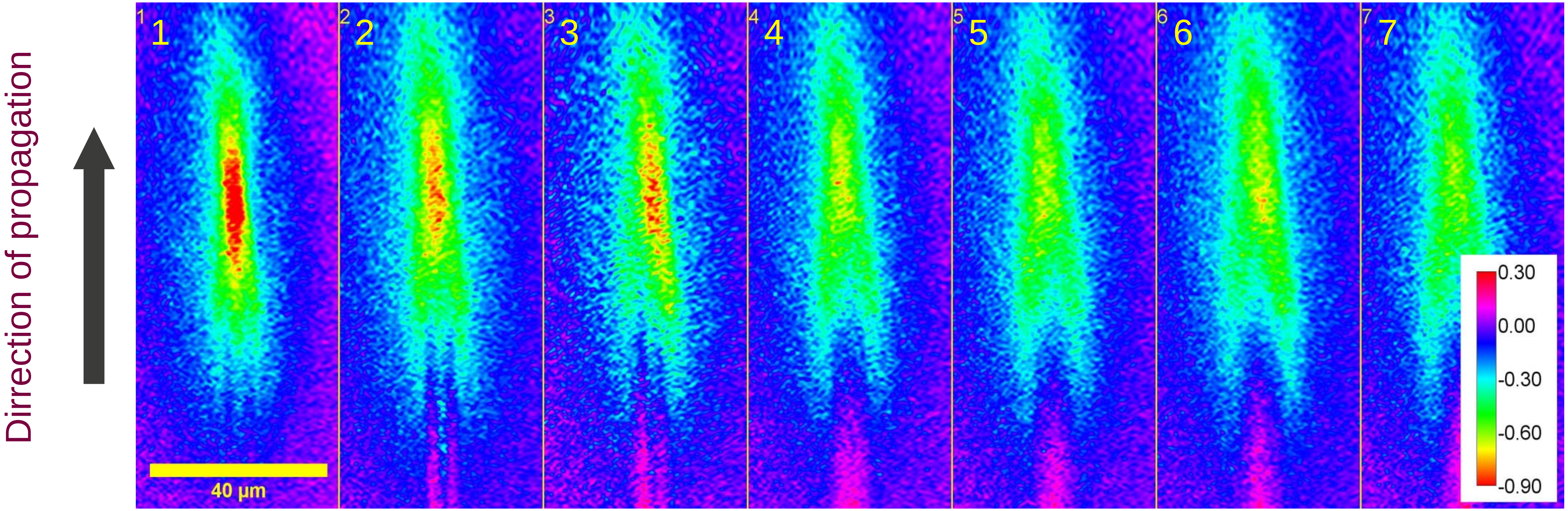

Experimental results in Nd:CaF_2. Phase shift dependance on the number of pulses

Fatigue in bulk media

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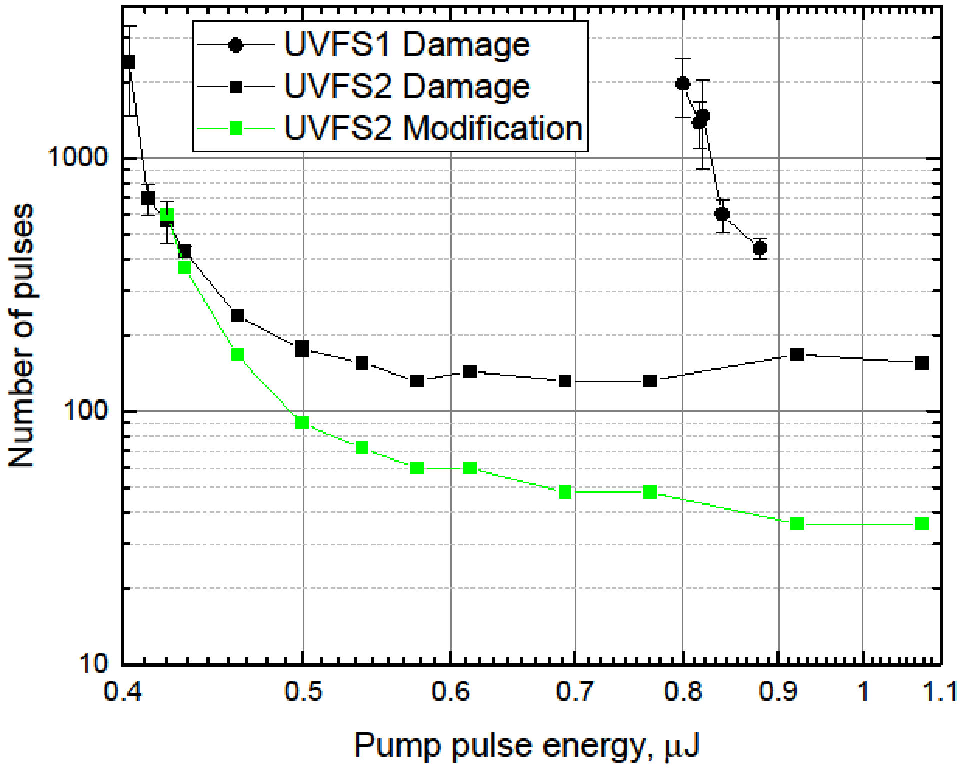
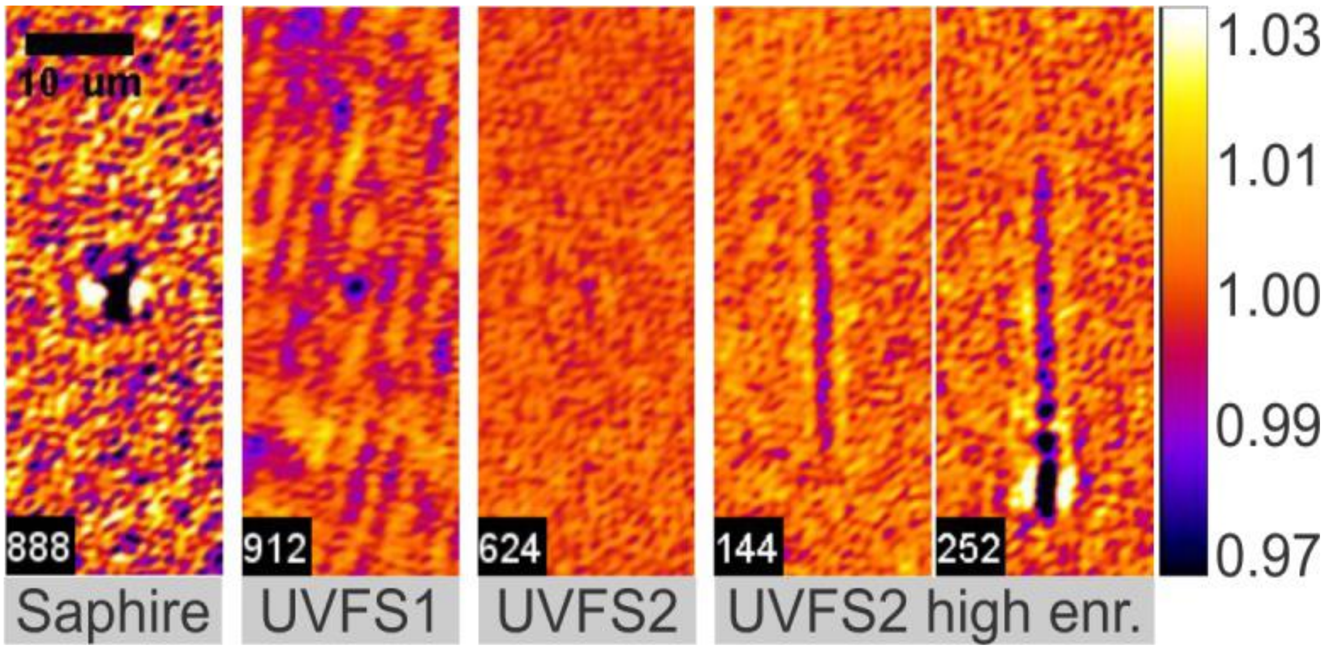


Optical damage threshold fatigue



Transmission images of optical damage in transparent bulk media

Fatigue in bulk media

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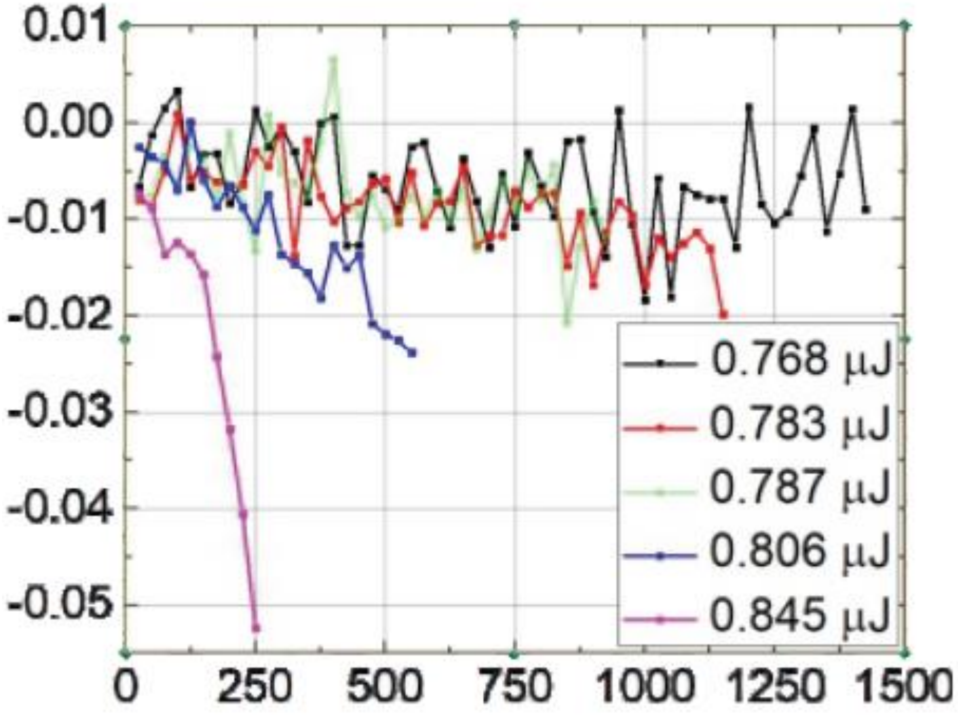
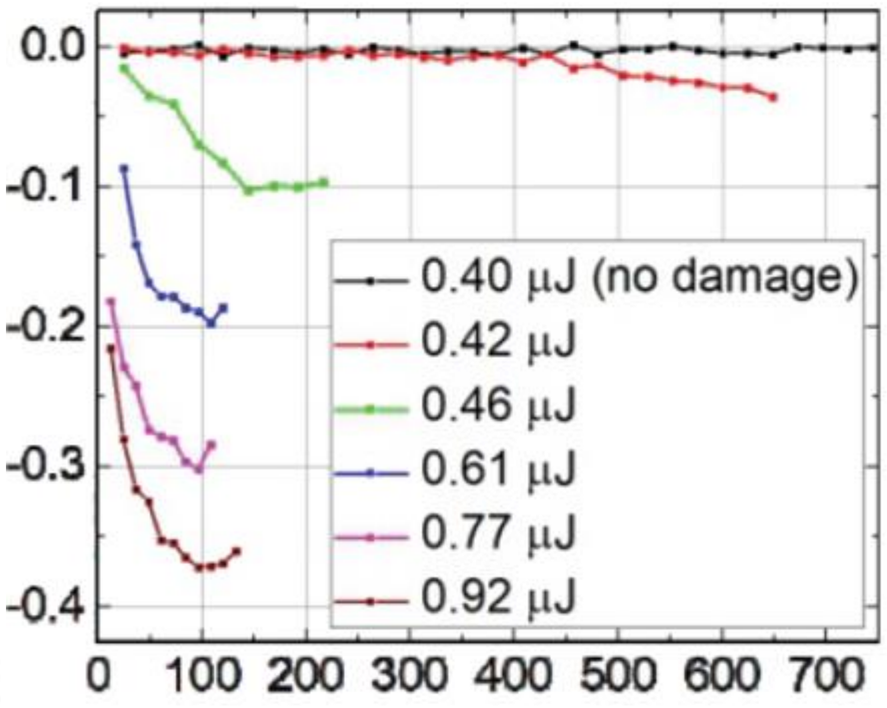
UVFS1 - 0.79µJ



UVFS2 - 0.42µJ



Evolution of self-trapped excitons signal in UVFS samples

Fatigue in bulk media

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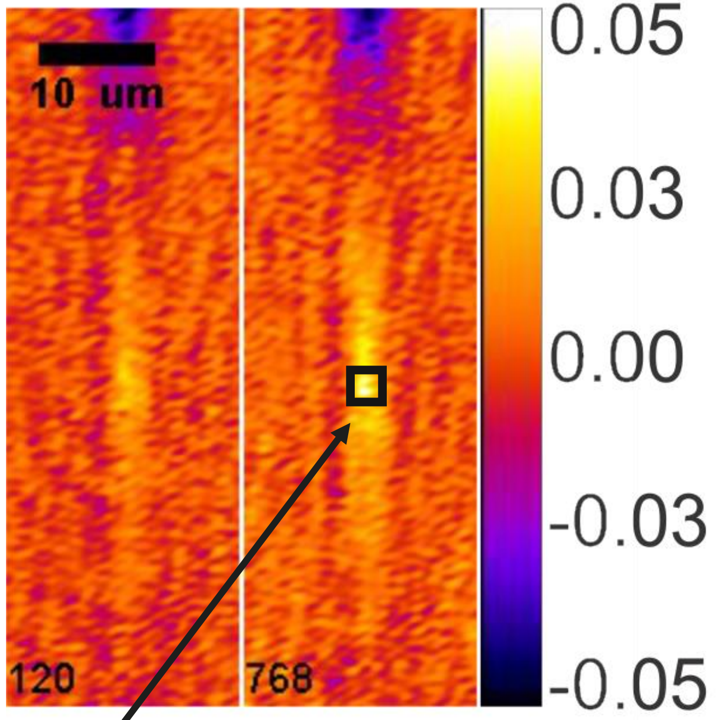
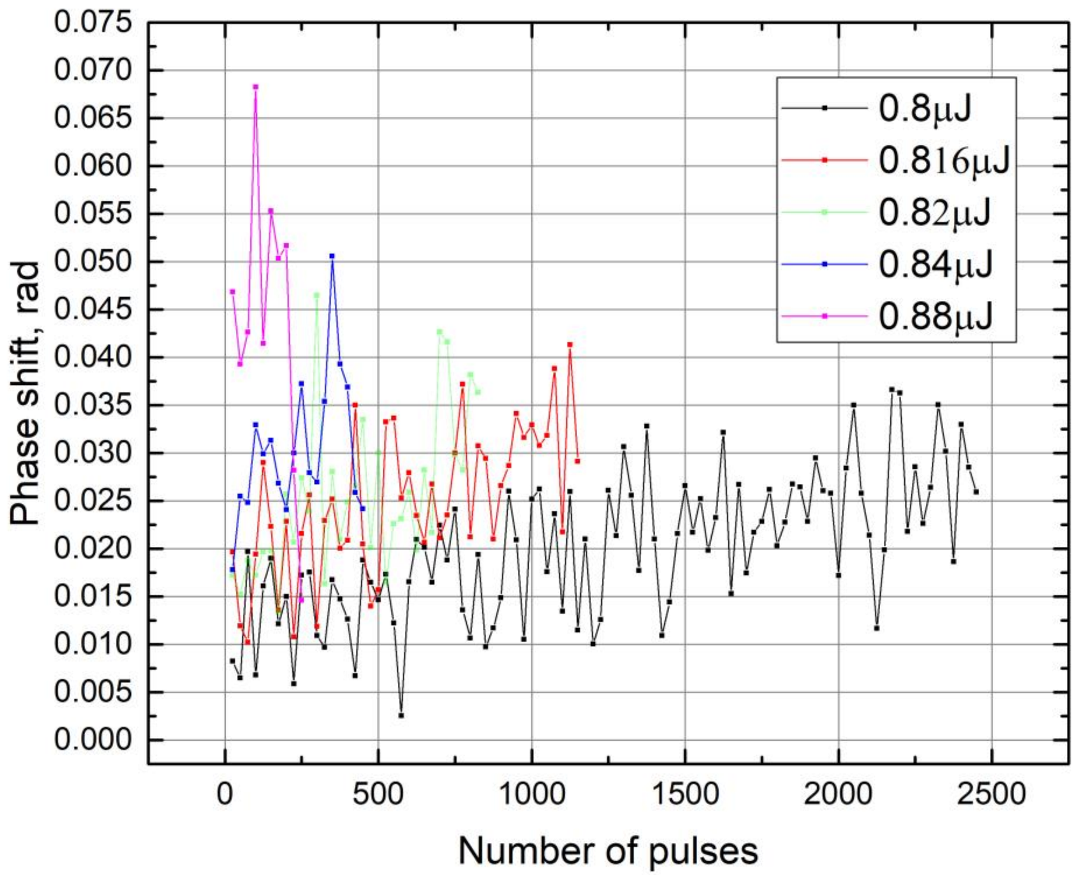
$q = 6 \cdot 10^{19} cm^{-3}$



Area of interest



Electron plasma induced phase shift
dependance on number of excitation pulses

Fatigue in bulk media

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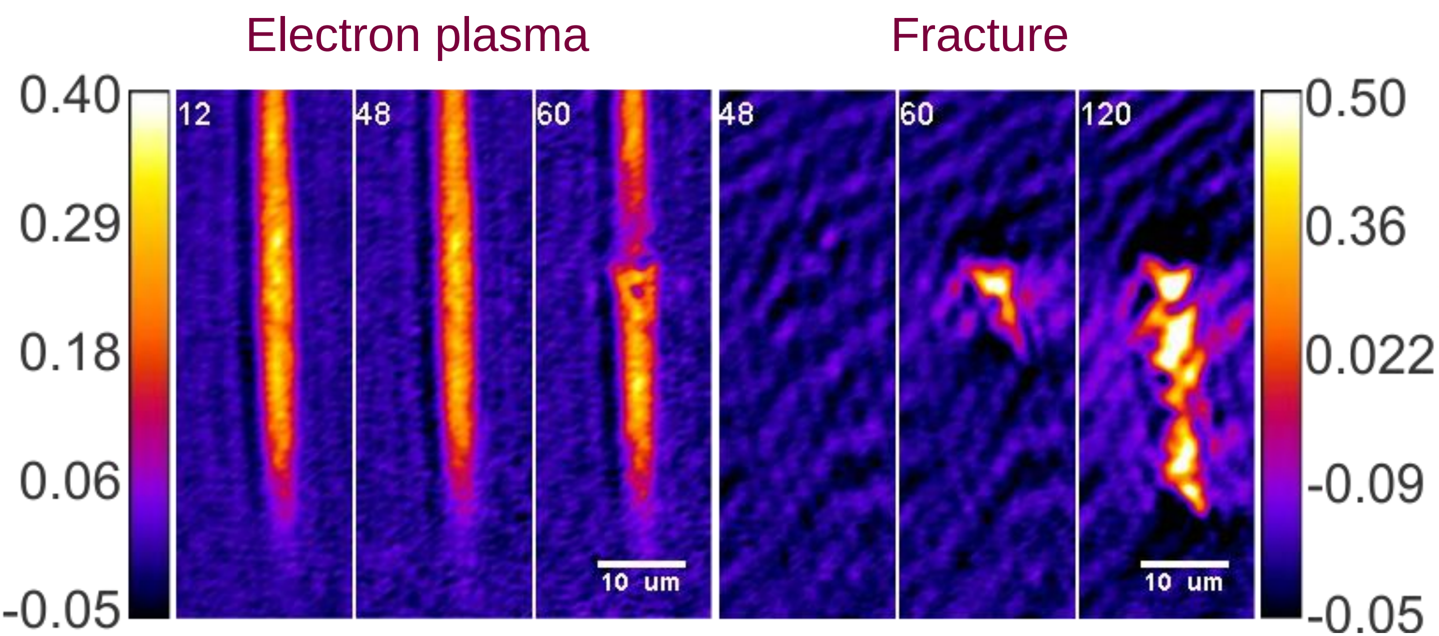
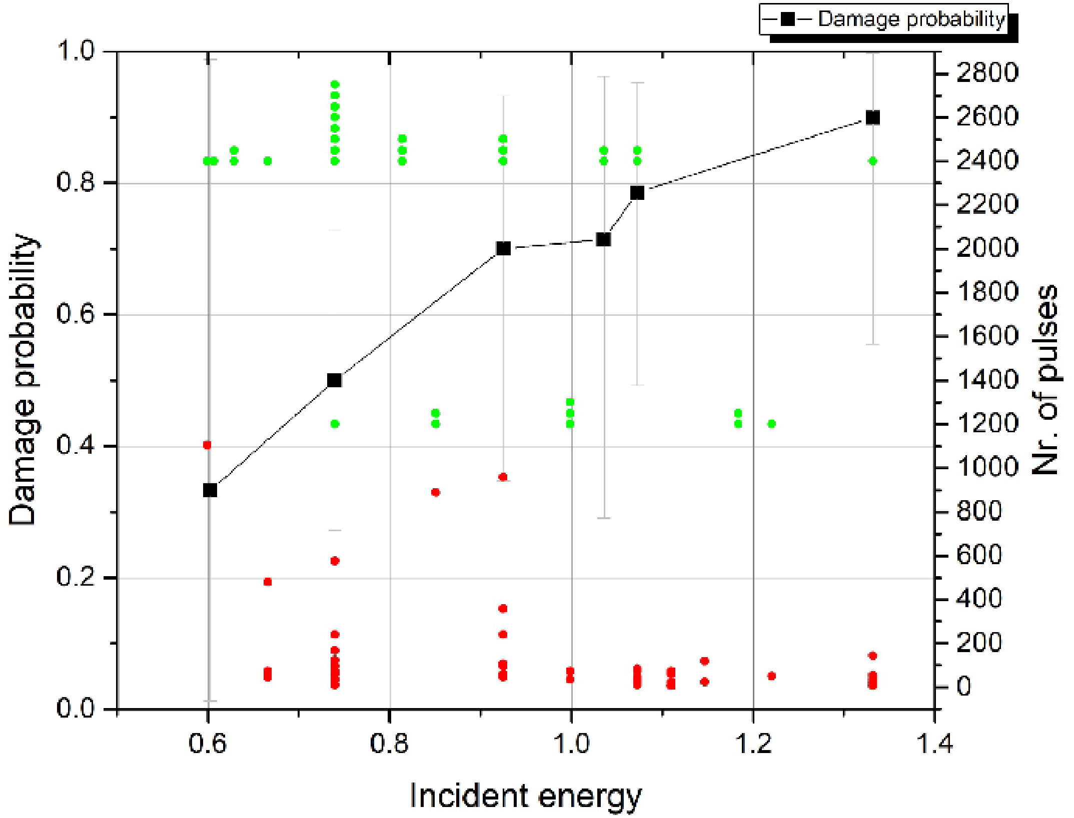


Optical damage formation in sapphire

$$q = 1.3 - 2.4 \cdot 10^{20} cm^{-3}$$



Optical damage probability in bulk sapphire as a function of energy when irradiated with multishot femtosecond laser pulses

Evaluation of energy residual following nonlinear interaction

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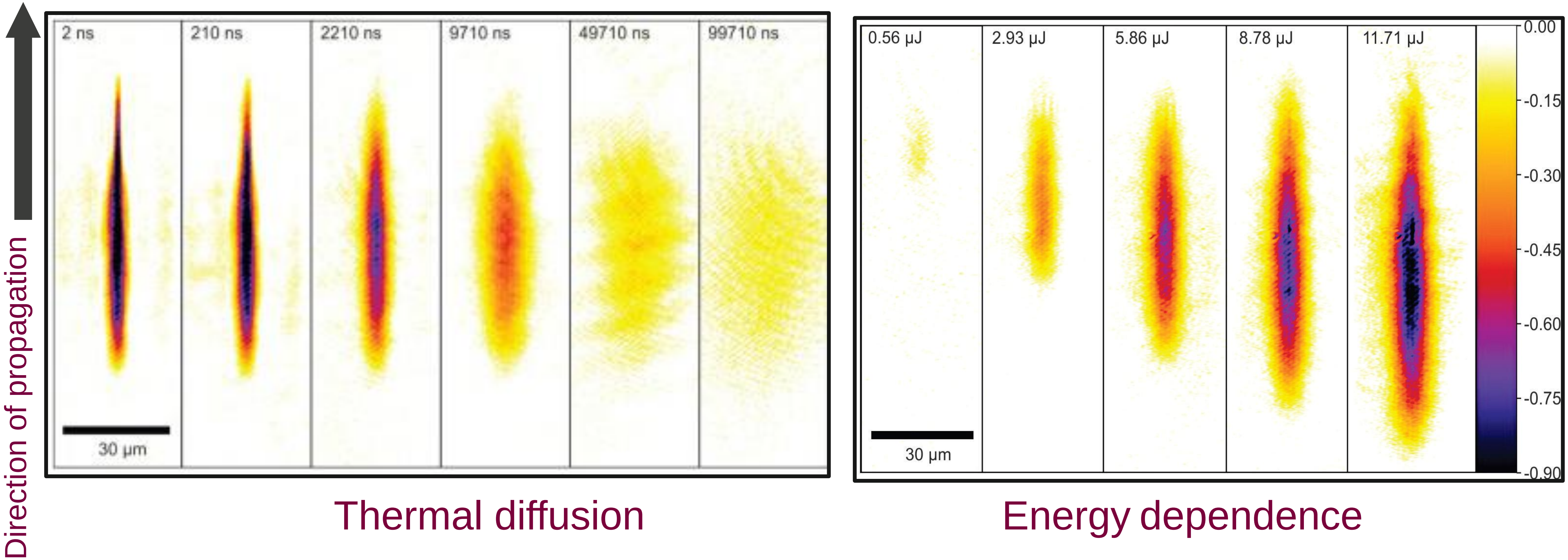

Thermal diffusion

Energy dependence

Phase maps of thermal lens structure in radians

Thermal wave

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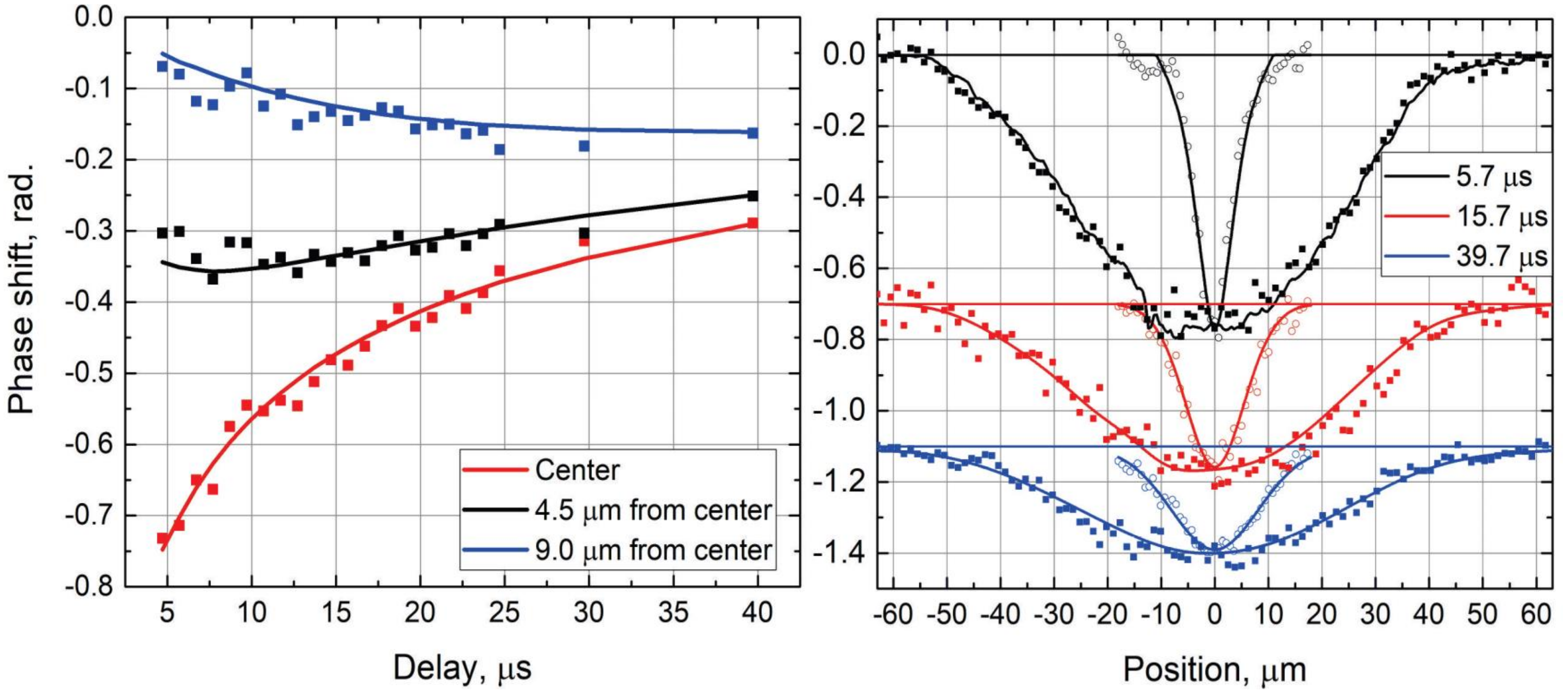
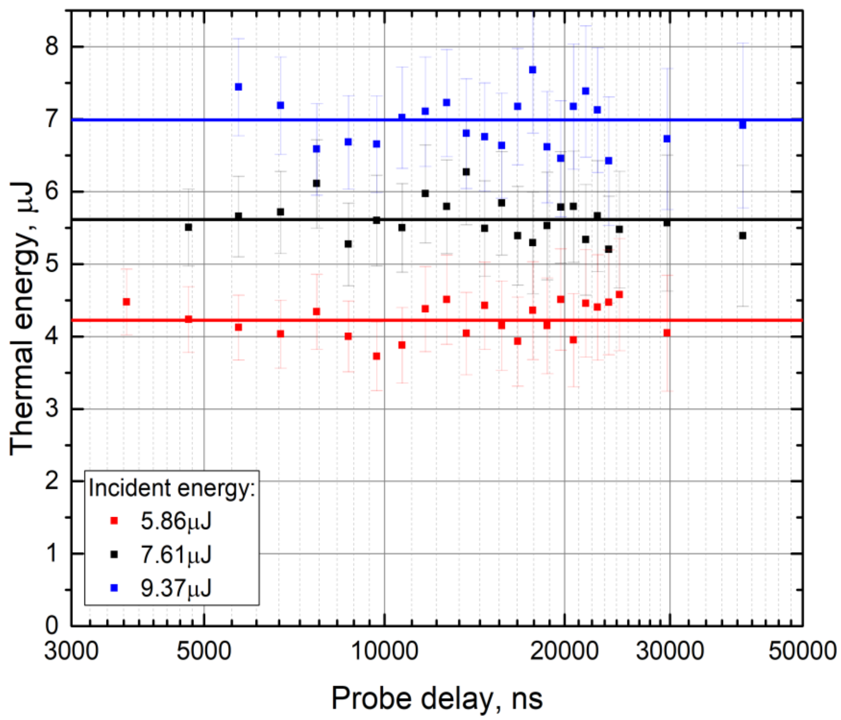
$$\frac{\partial}{\partial x}\left(\lambda_x \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\lambda_y \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(\lambda_z \frac{\partial T}{\partial z}\right) + I(x,y,z,t) = C\frac{\partial T}{\partial t}$$



Comparison between the experimental results and thermal diffusion model



Evaluated residual energy

Evaluation of residual energy for different pump pulse durations

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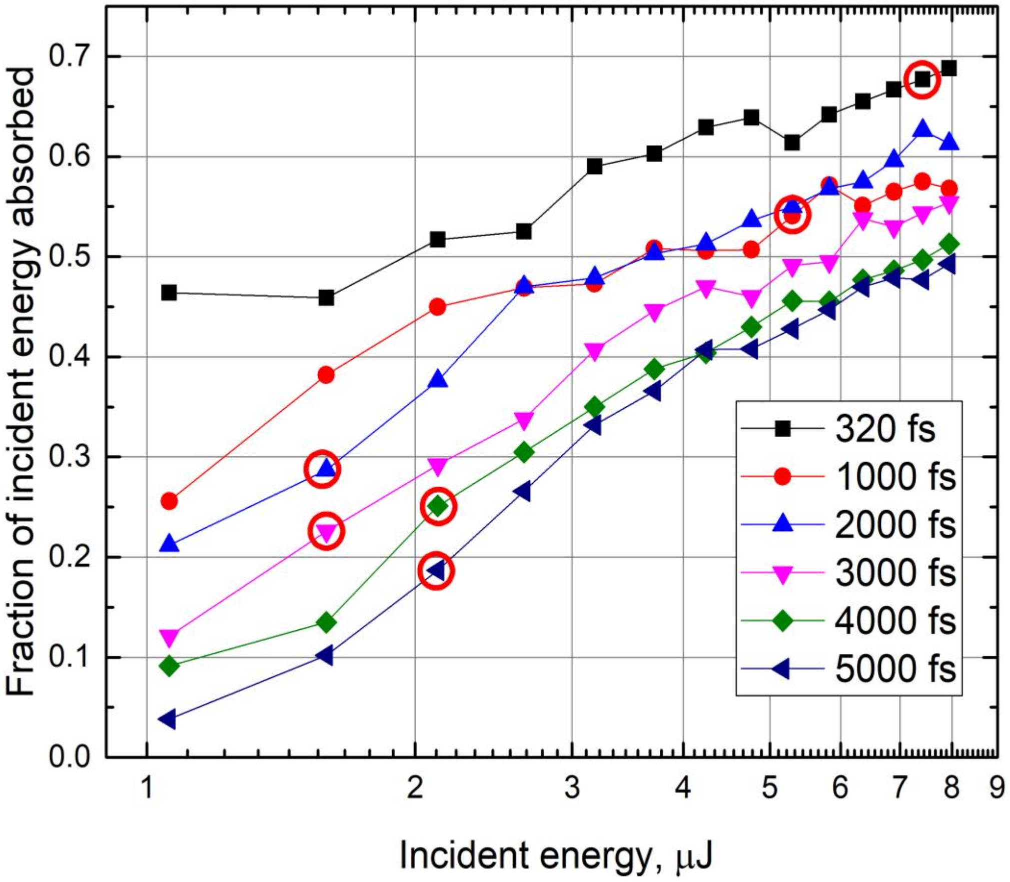
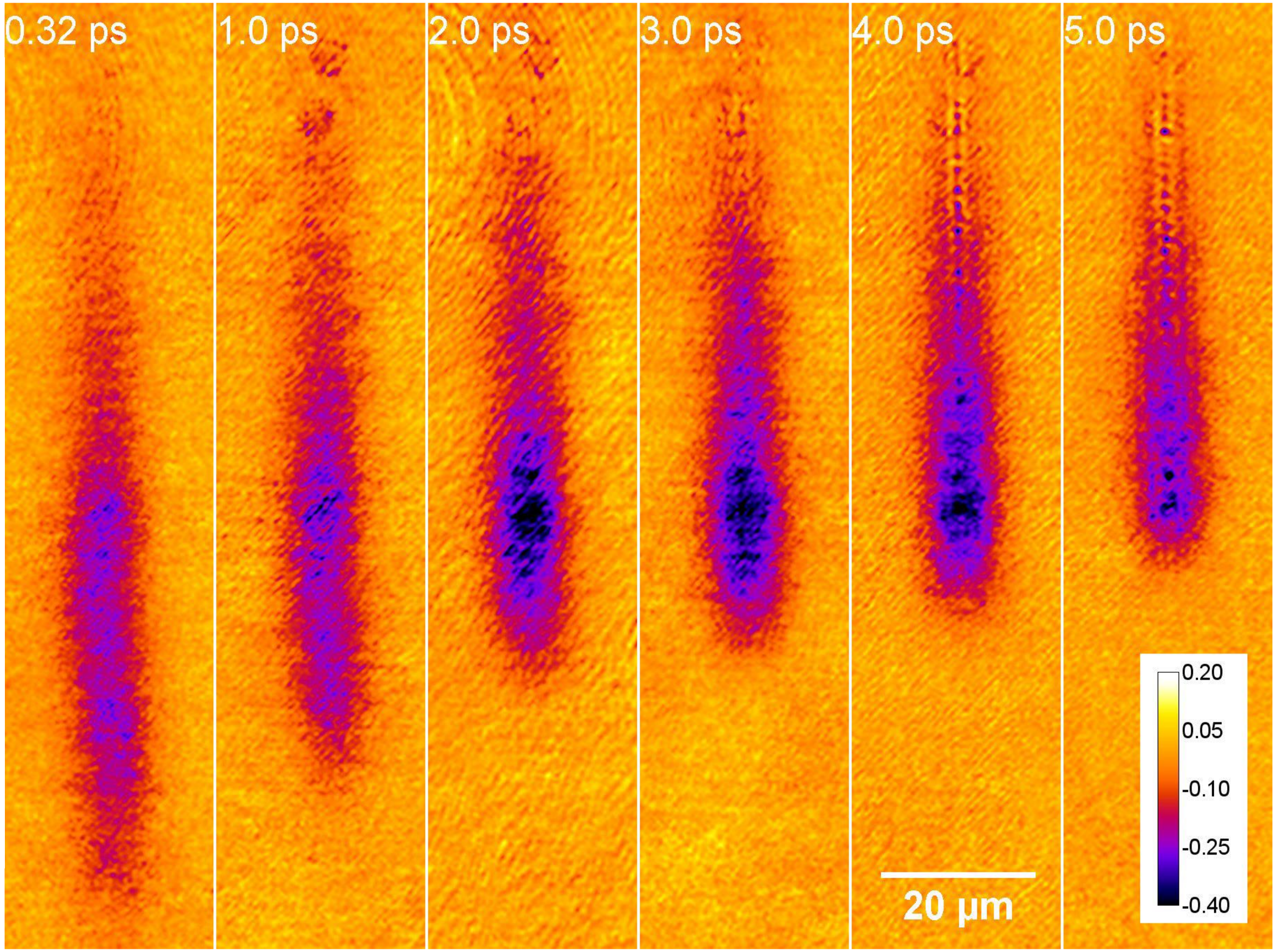


Thermalized energy fraction



Thermal lens created by pulses of same energy but different duration

Prospects

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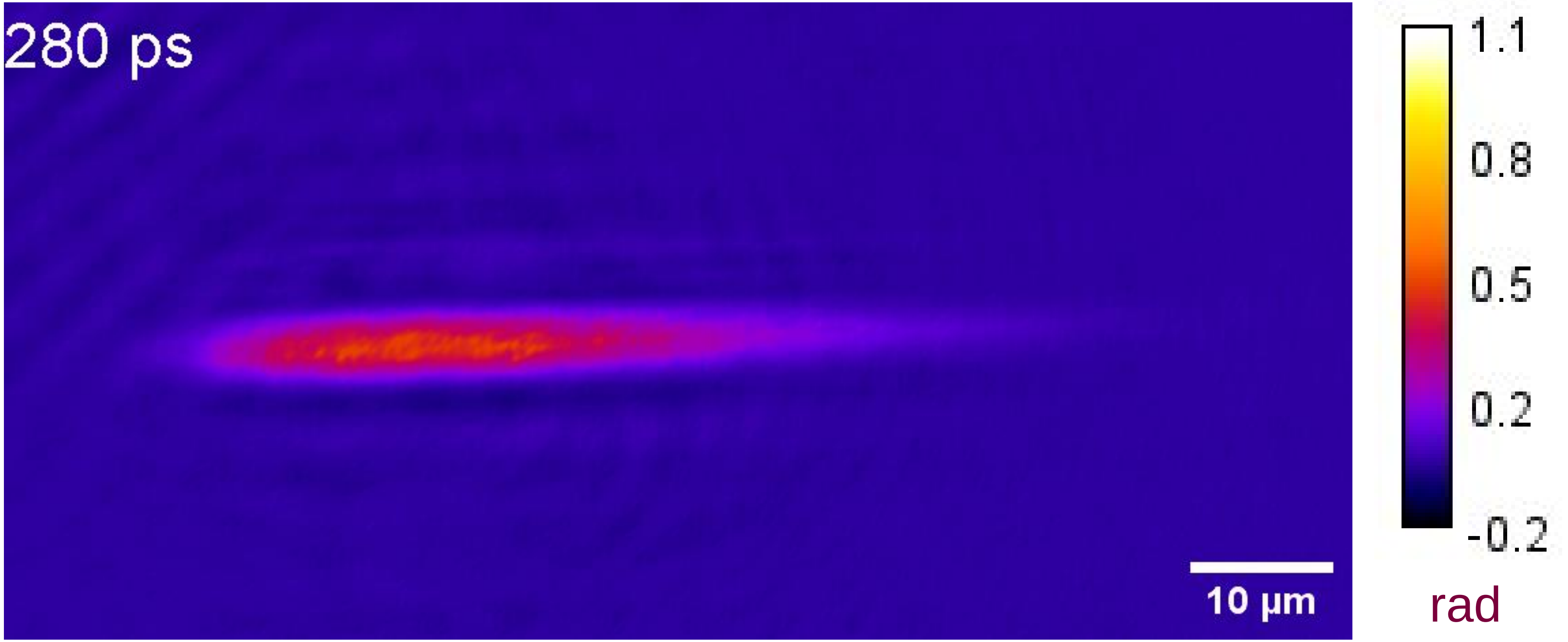
- Nondestructive shockwave amplification
- Ferroelectric domain inversion imaging
- Attosecond holography
- Semiconductors characterization
- Material response to burst excitation



Shockwave
In diamond

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CONTACTS

Balys Momgaudis
+370 633 89423
balys.momgaudis@ff.vu.lt