



Présentation des activités du Laboratoire Hubert Curien

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Laboratoire Hubert Curien, Université J. Monnet, FR

GISDON - Paris 26/06/2012

Outline

- Background – Leitmotiv
- Spatial beam shaping
- Polarization modulation
- Temporal pulse shaping
- Physical insights: Pump-probe

Efficient collaboration of different actors

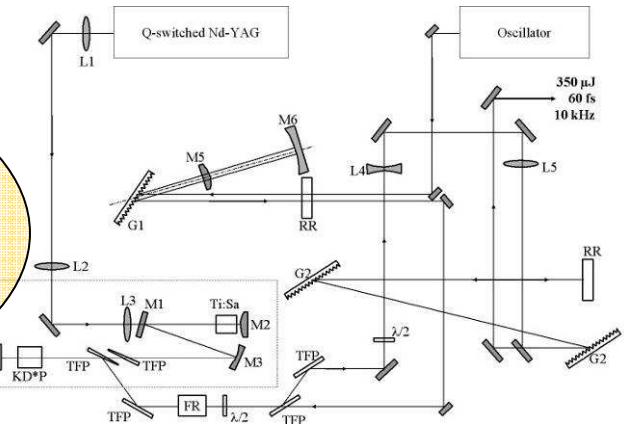


*Lab team
R. Stoian*

Fundamental research

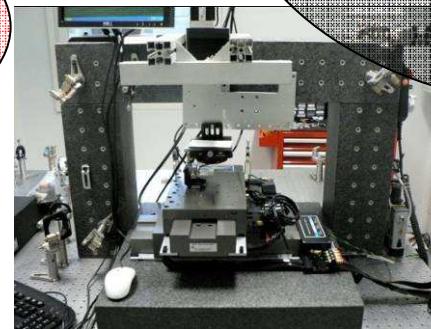


Industry
Impulsion team, H. Soder

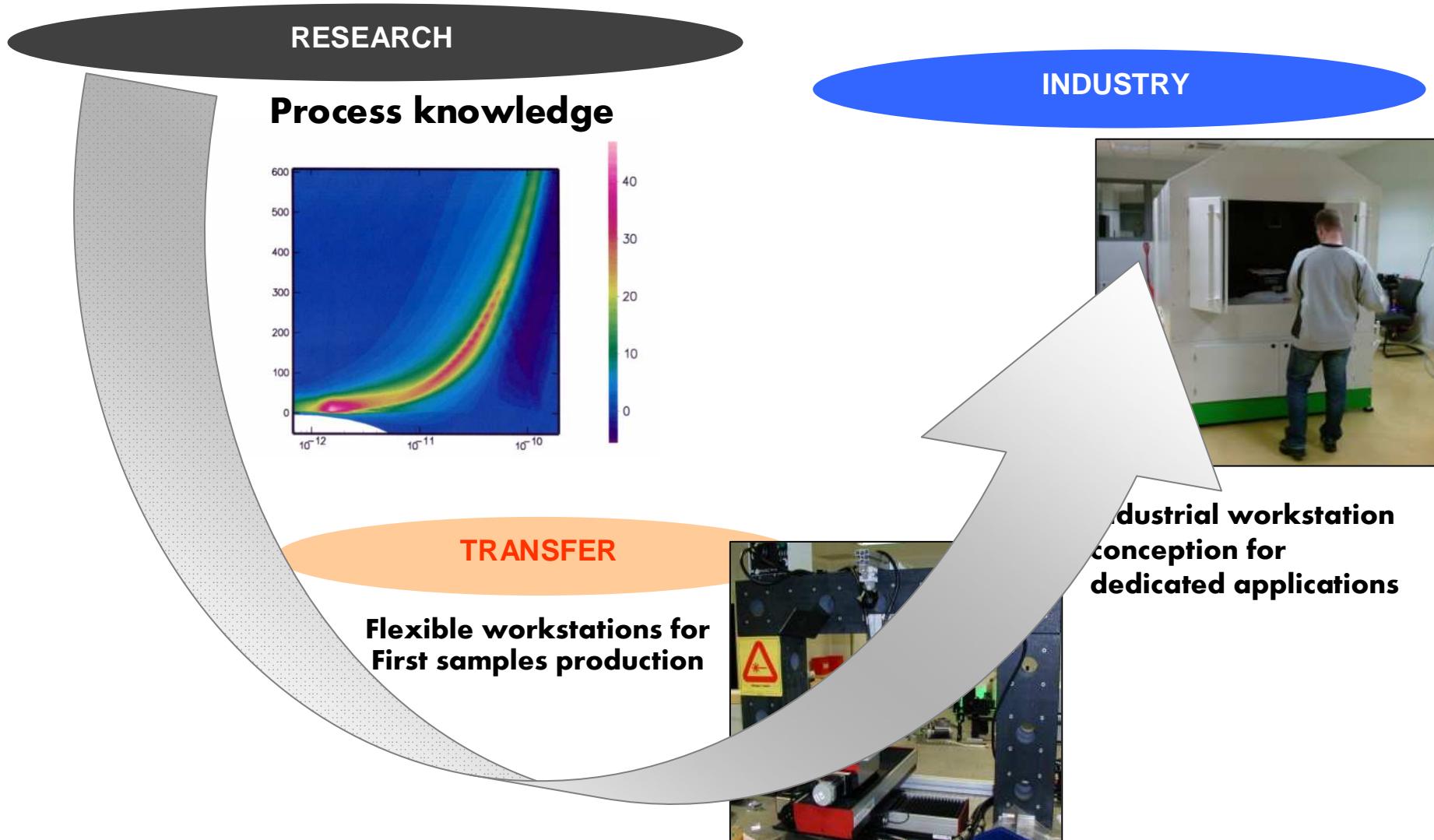


Université Jean Monnet
SAINT-ÉTIENNE

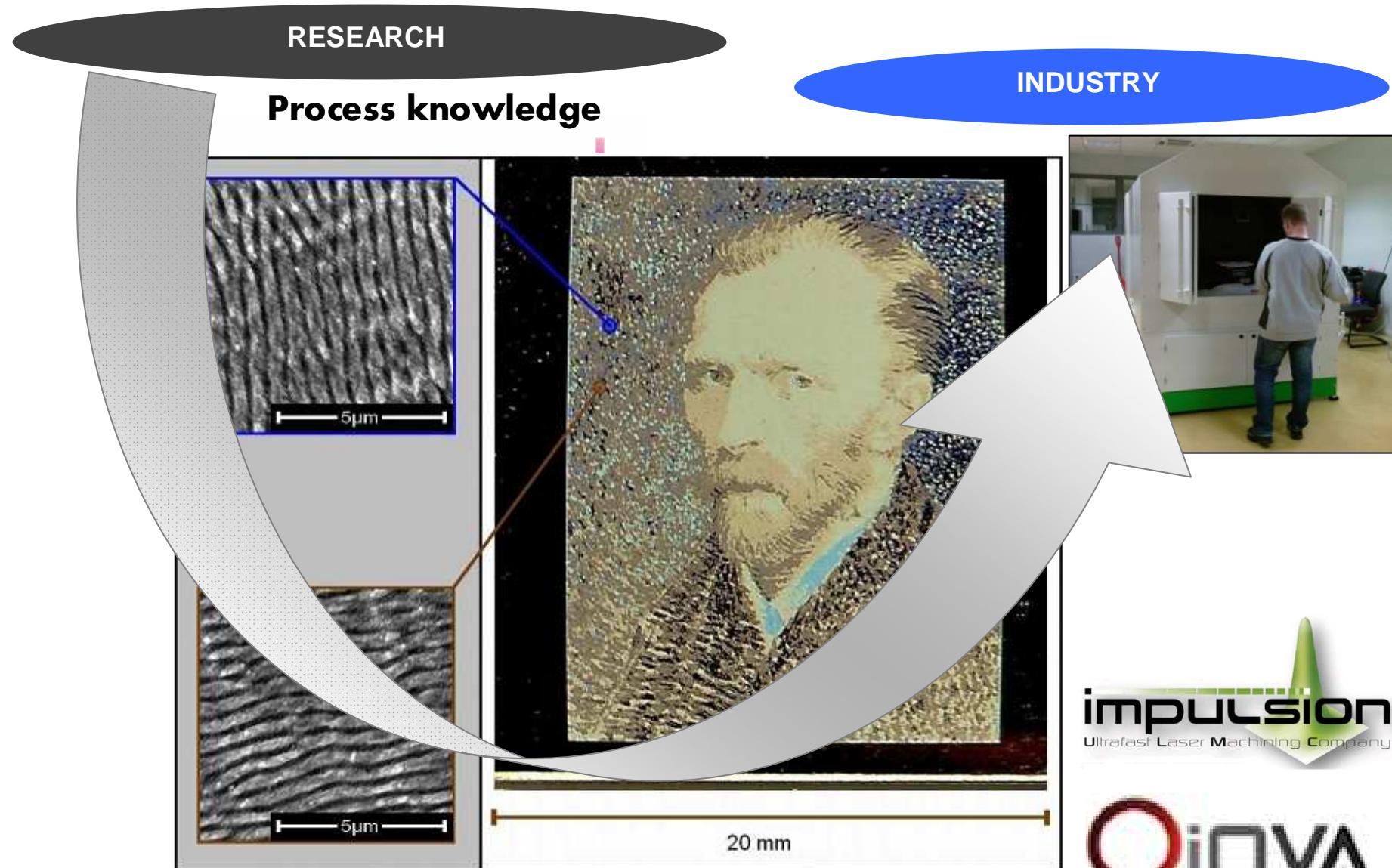
Technology transfer
Femtosecond platform
*PF team
E. Audouard*



The long way for innovation...



The long way for innovation...



Dusser et al. Opt. Express 18, (2010)

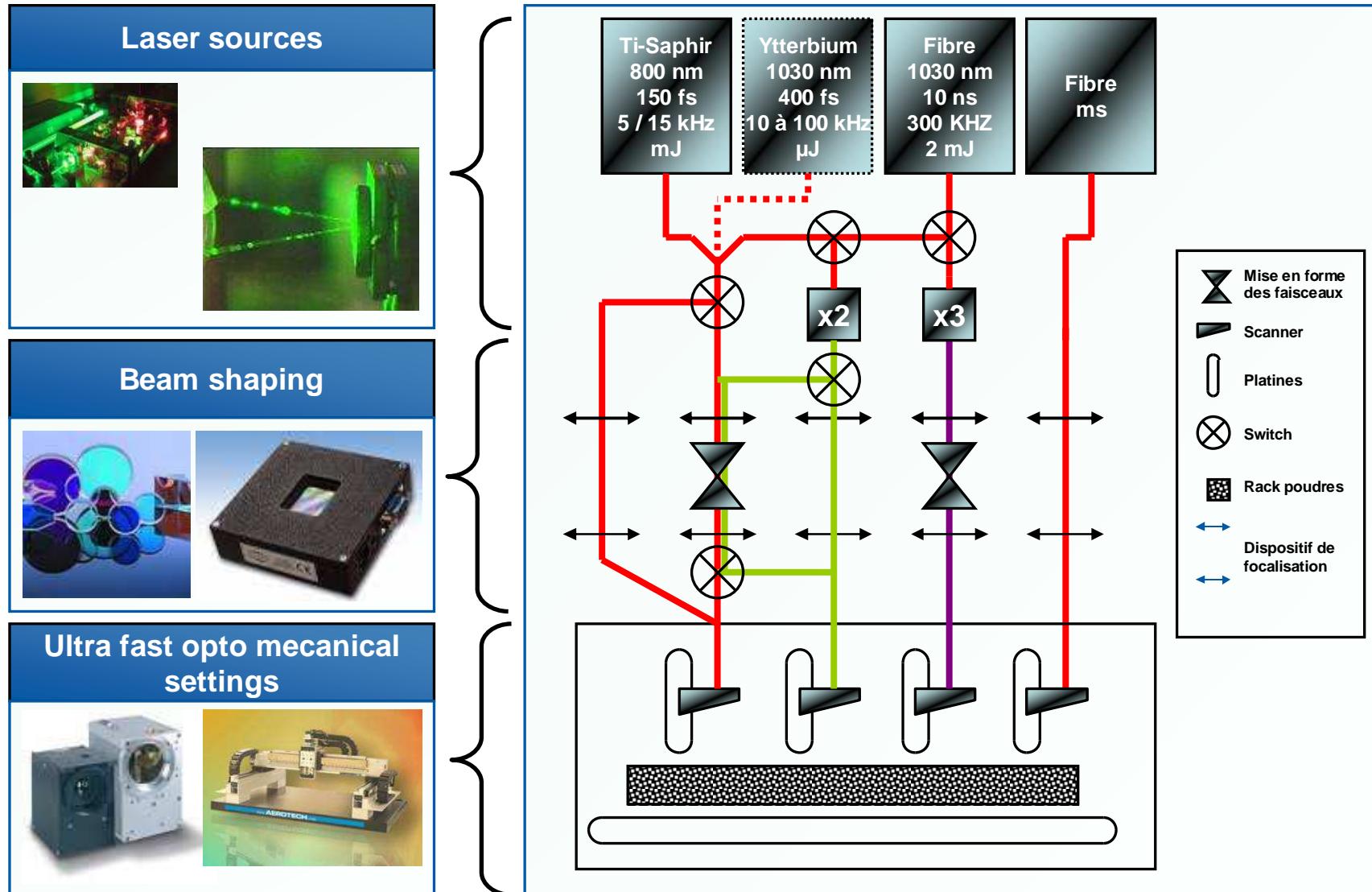


***Need for a strong collaborative work industry/research
Easier if partners are located in the same area***



National project “**Ultrafast Surface Design**”

Unique laser processing equipment for research and Industry



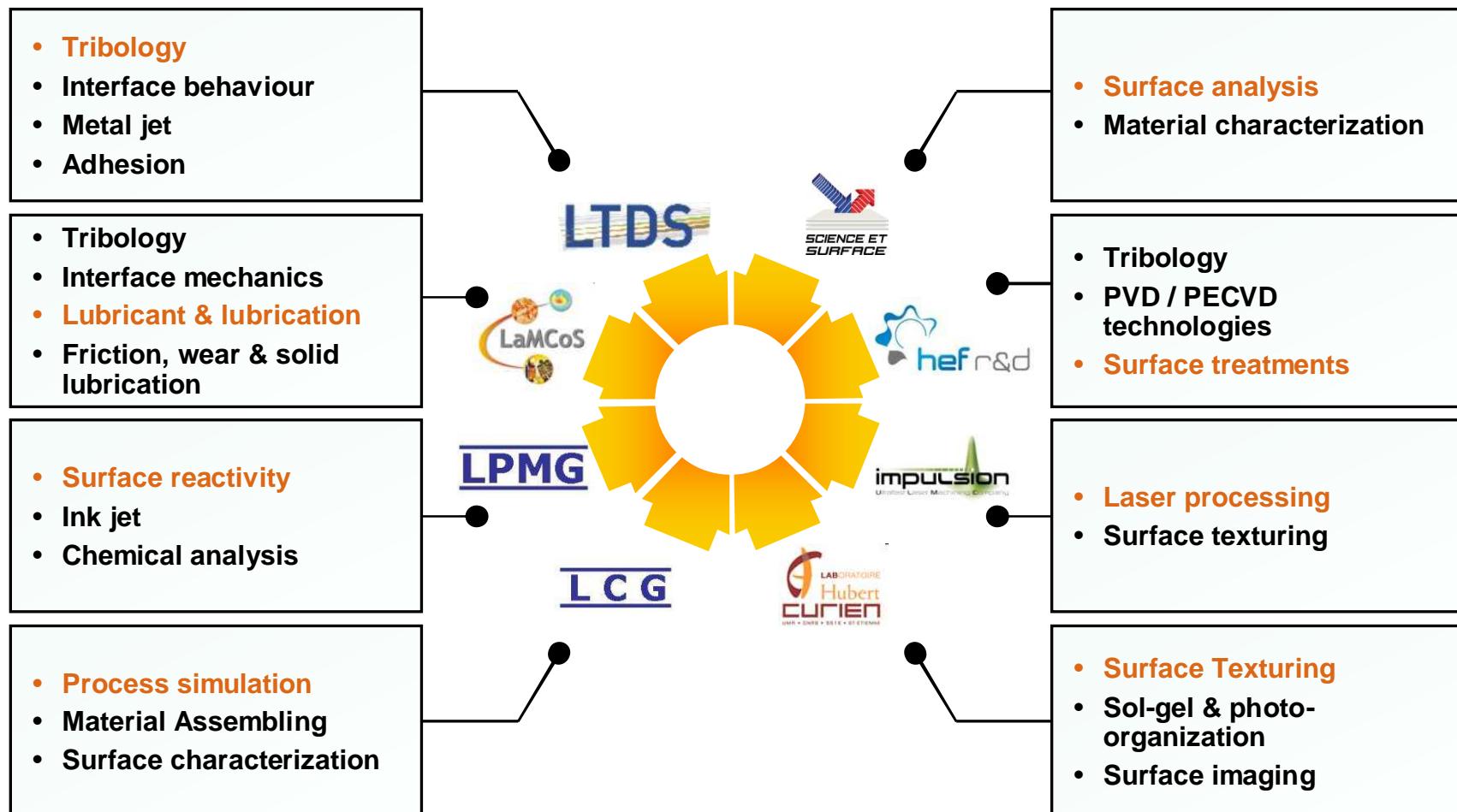
Surface and Interface Science and Engineering

Staff : 300, including 118 PhD and Post-Docs

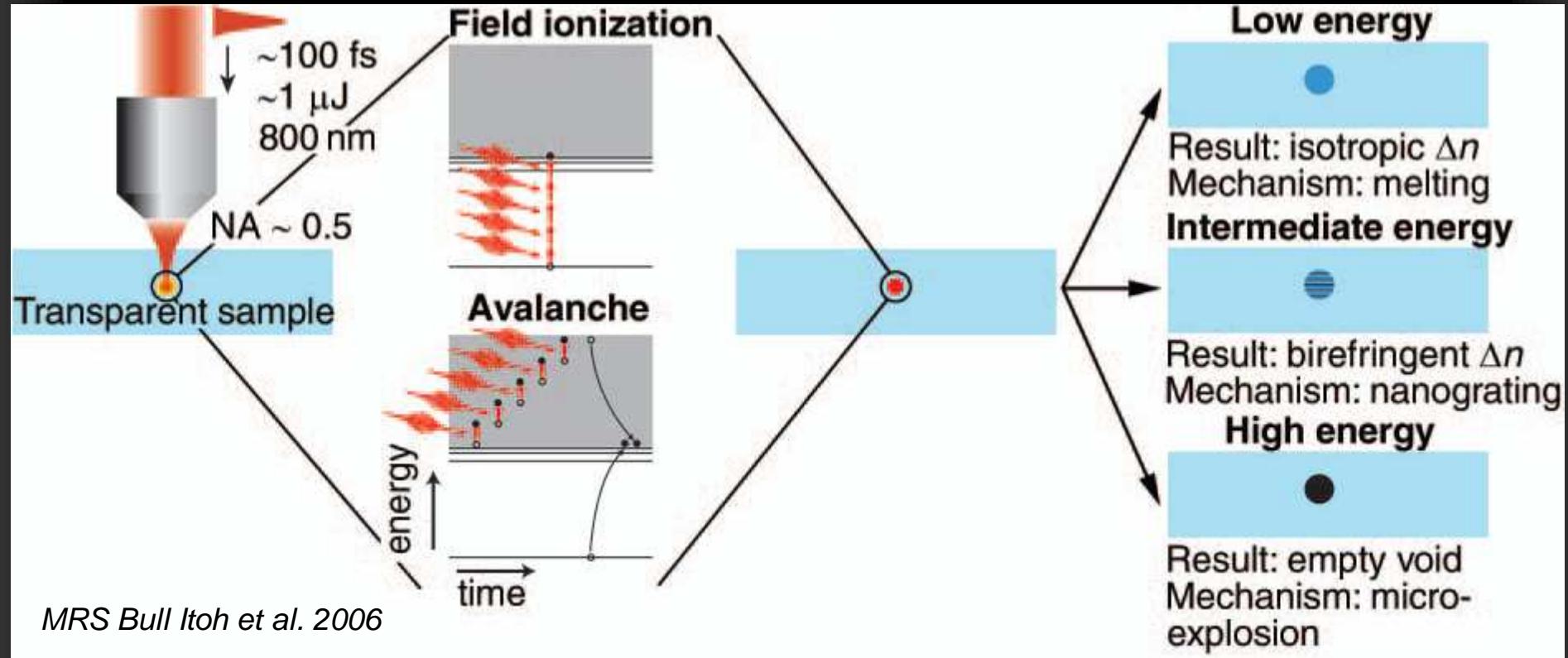


- Partnership with joint knowledge and know-how
- Fundamentals and applied research
- 5 academic labs & 3 companies from Lyon – St-Etienne

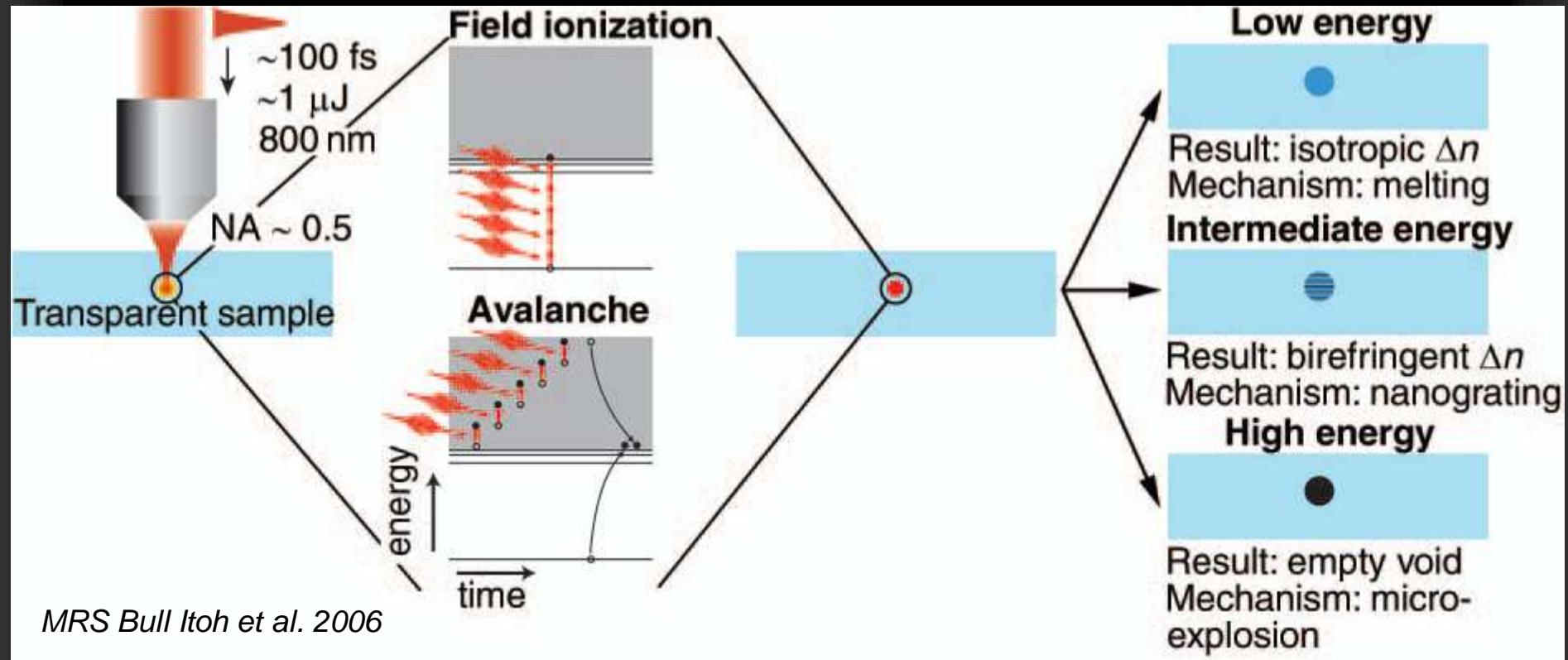




Impulsion fs en volume



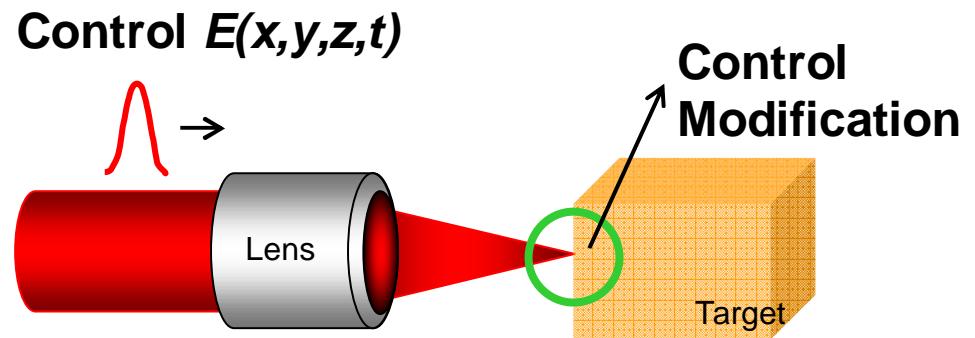
Impulsion fs en volume



Précision (absorption non linéaire)

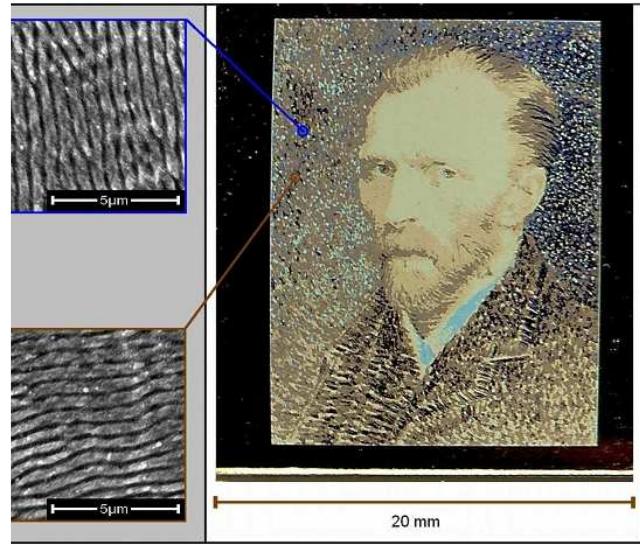
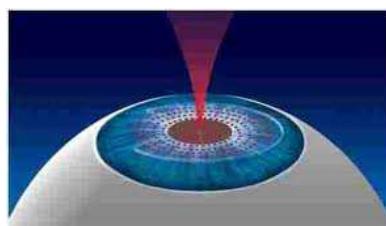
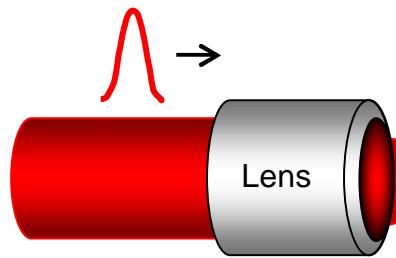
- Usinage dans la masse
- Seuil de modification: \searrow limite diffraction
- Effets thermiques restreints ($\text{fs} \ll \text{ns}$)
- Nanostructuration 'ripples' (laser)

Leitmotiv



Leitmotiv

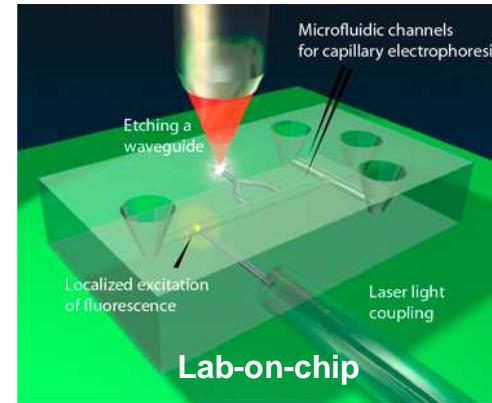
Control $E(x,y,z,t)$



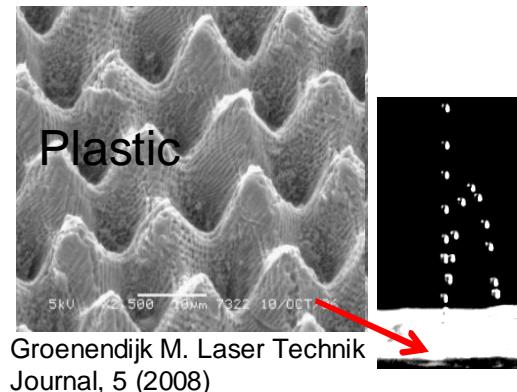
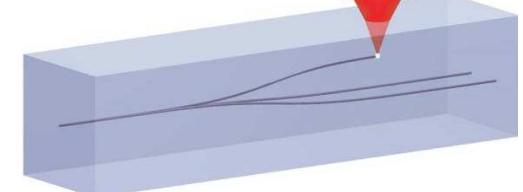
Dusser et al. Opt. Express (2010)

Control
Modification

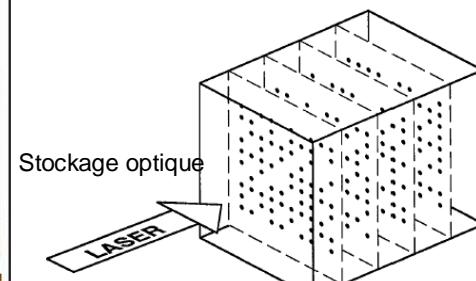
Target



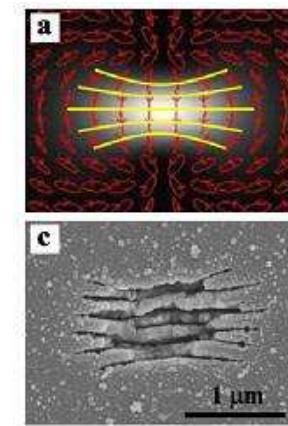
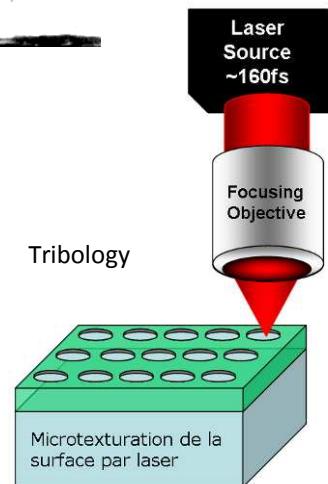
Nolte et al. App. Phys. A 77 (2003)



Groenendijk M. Laser Technik Journal, 5 (2008)

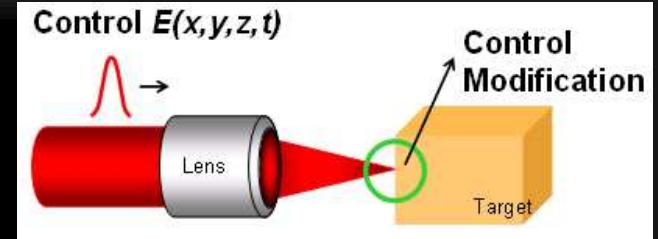


Glezer et al. Opt. Lett. Vol.21 (1996)



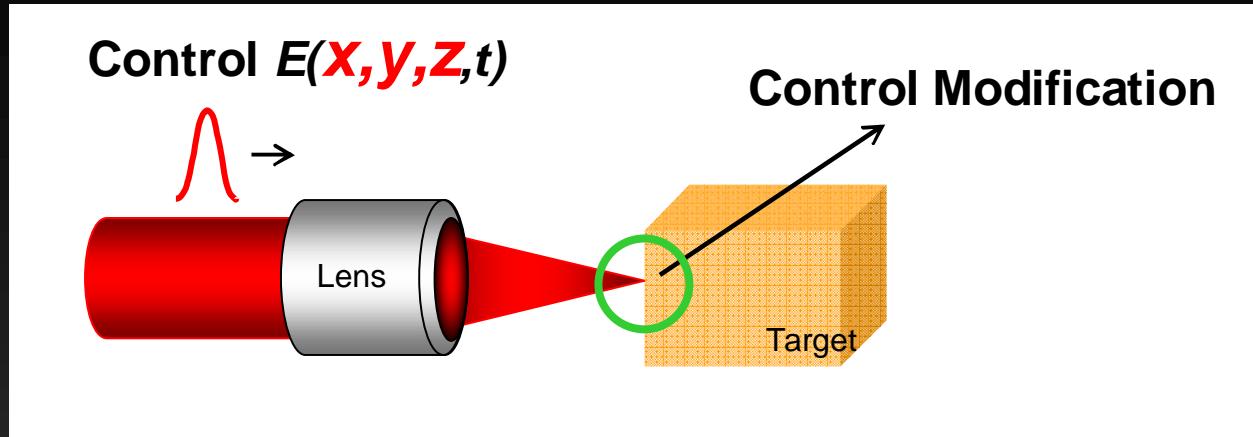
Hnatovsky et al.
Phys. Rev. Lett. 106 (2011)

Outline

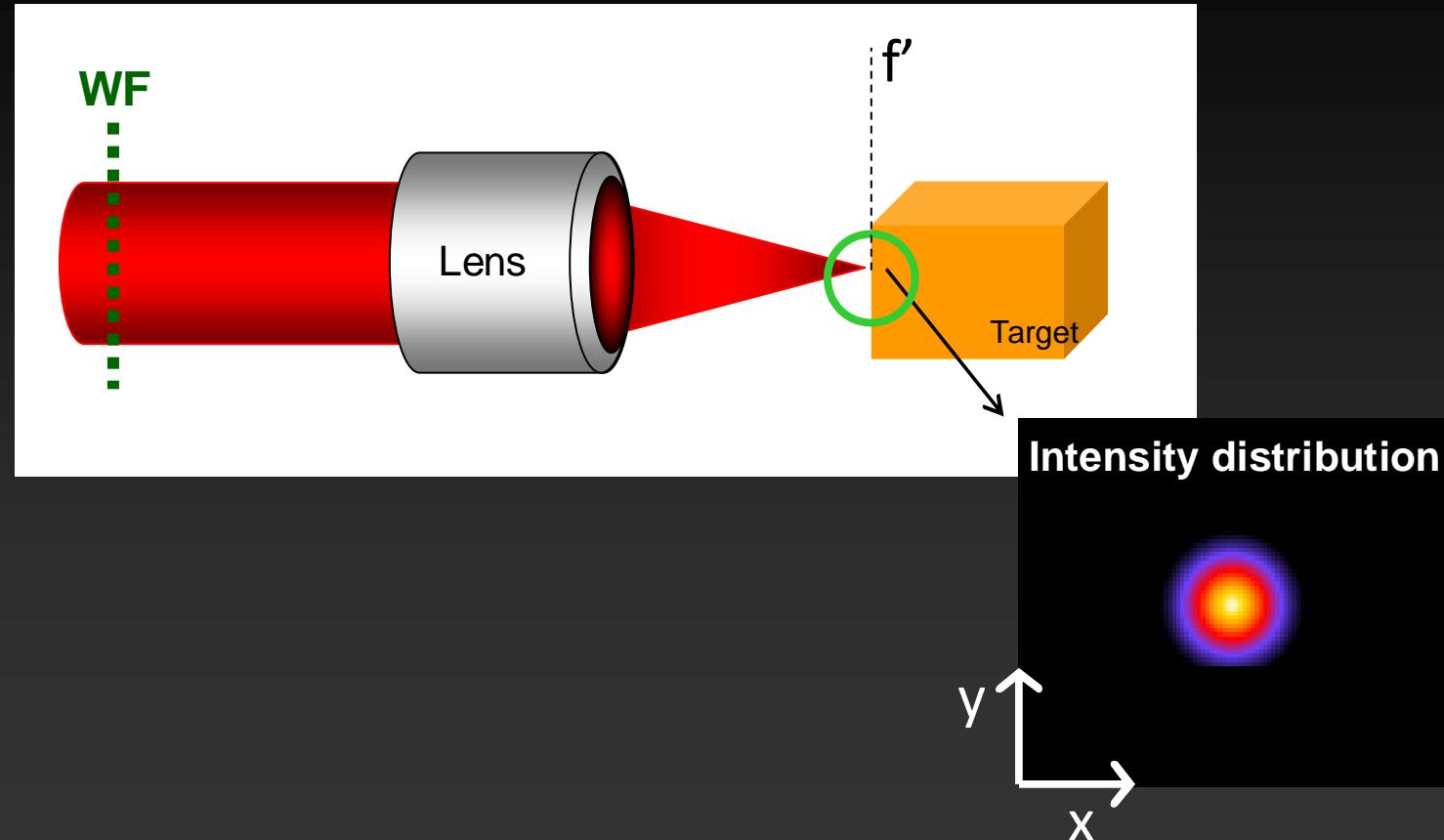


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- **Spatial beam shaping**
- Polarization modulation
- Temporal pulse shaping
- Physical insights: Pump-probe

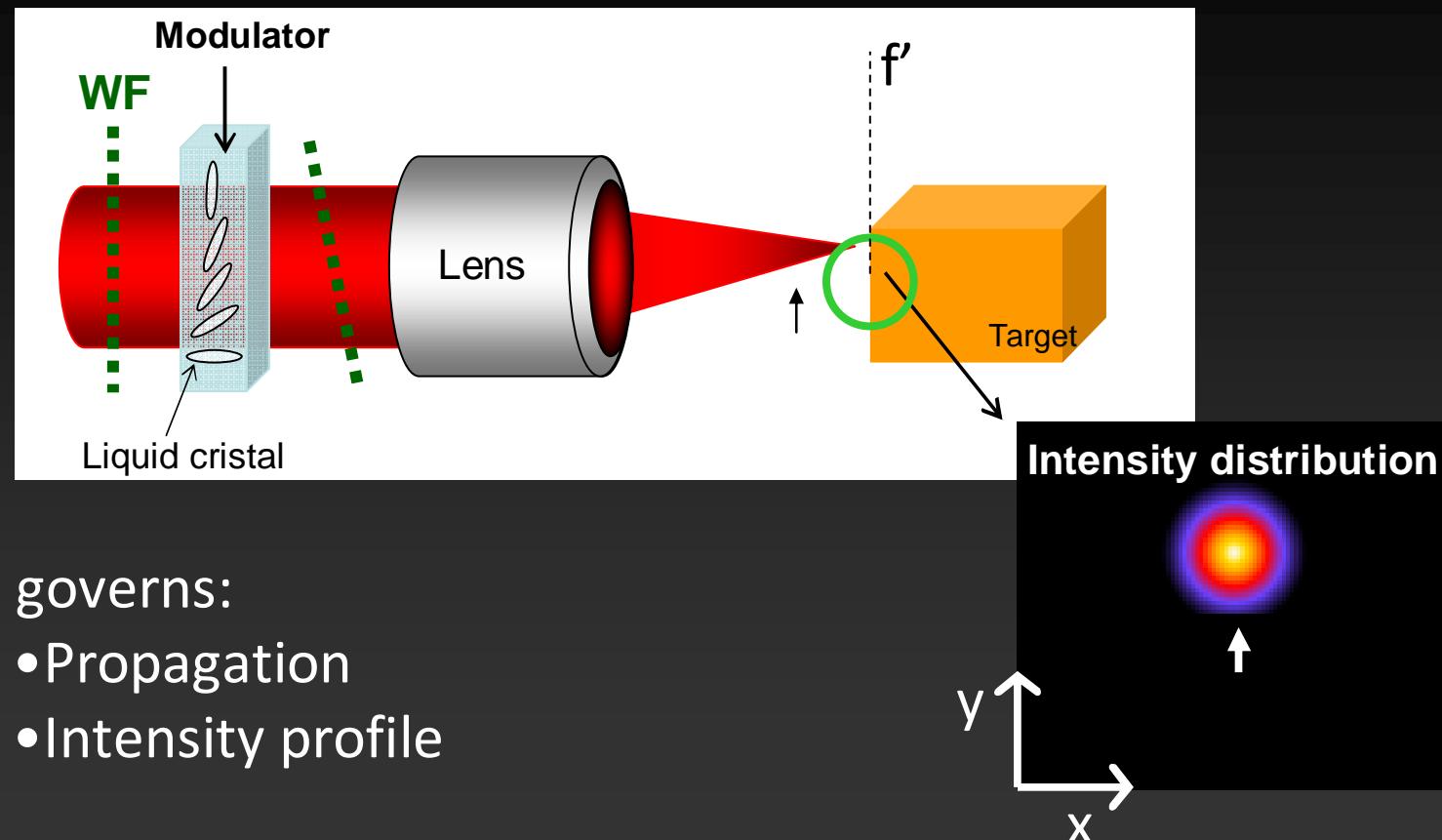
- Leitmotiv



- Spatial beam shaping – Wavefront modulation



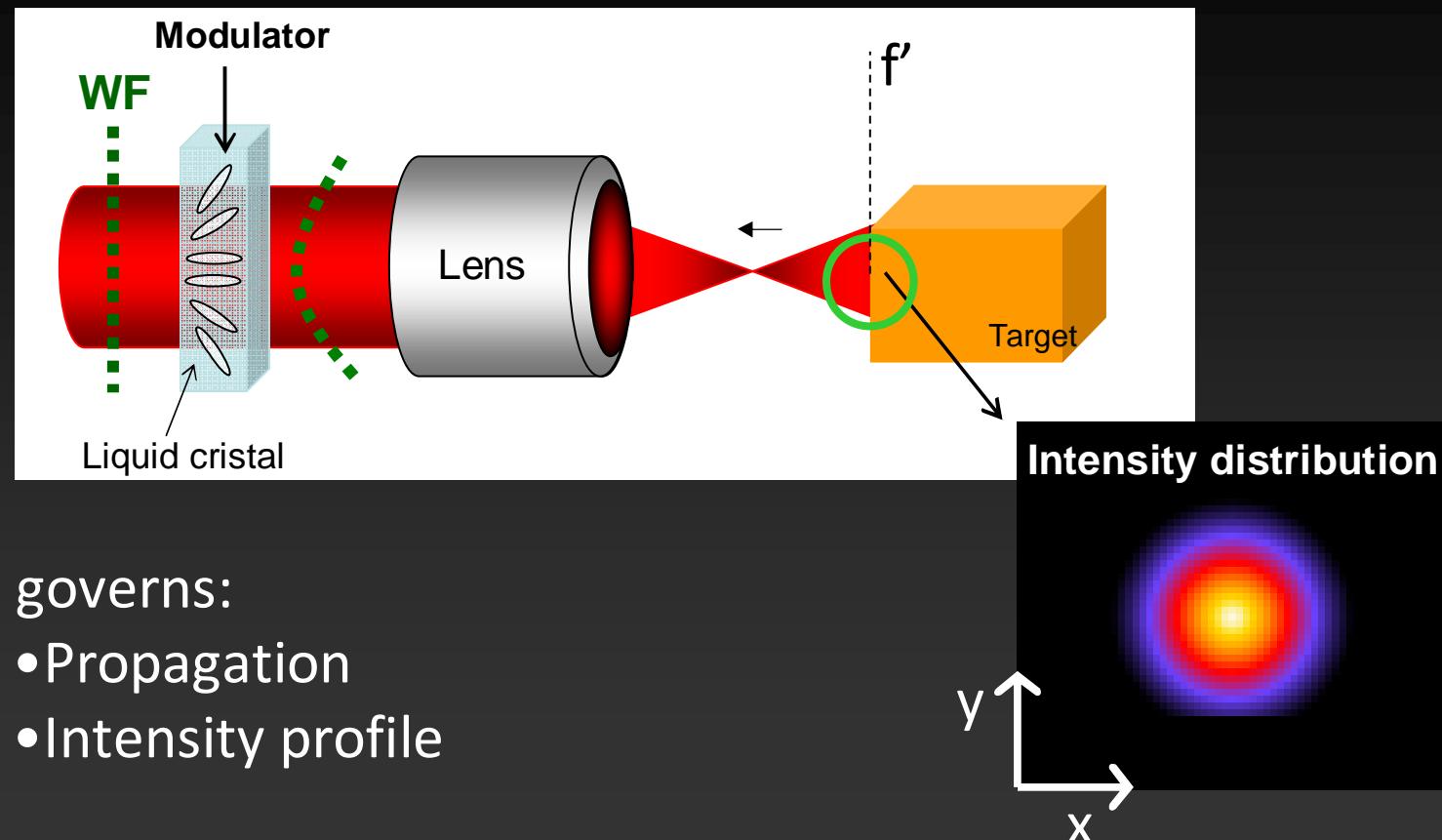
- Spatial beam shaping – Wavefront modulation



WF governs:

- Propagation
- Intensity profile

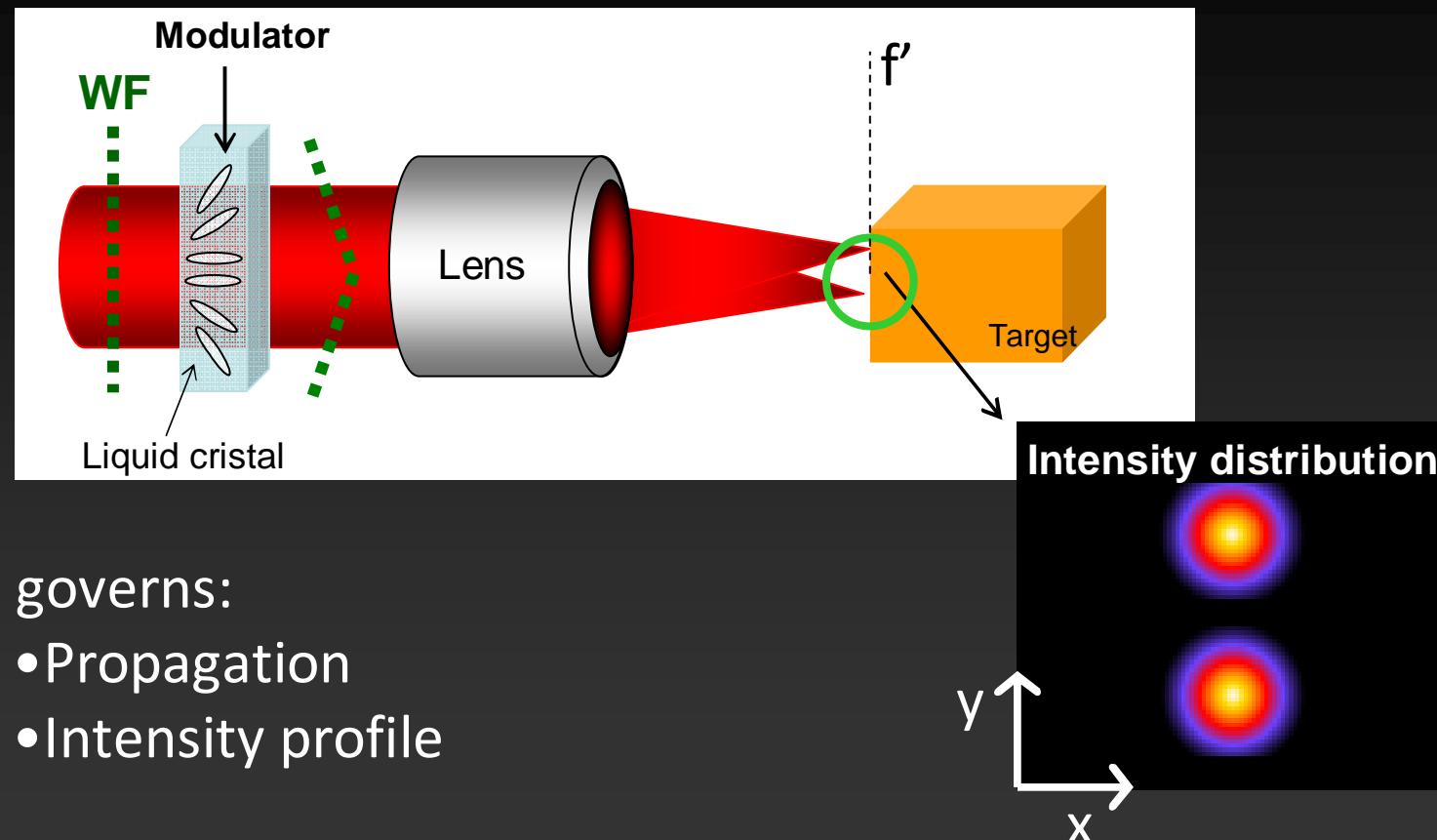
- Spatial beam shaping – Wavefront modulation



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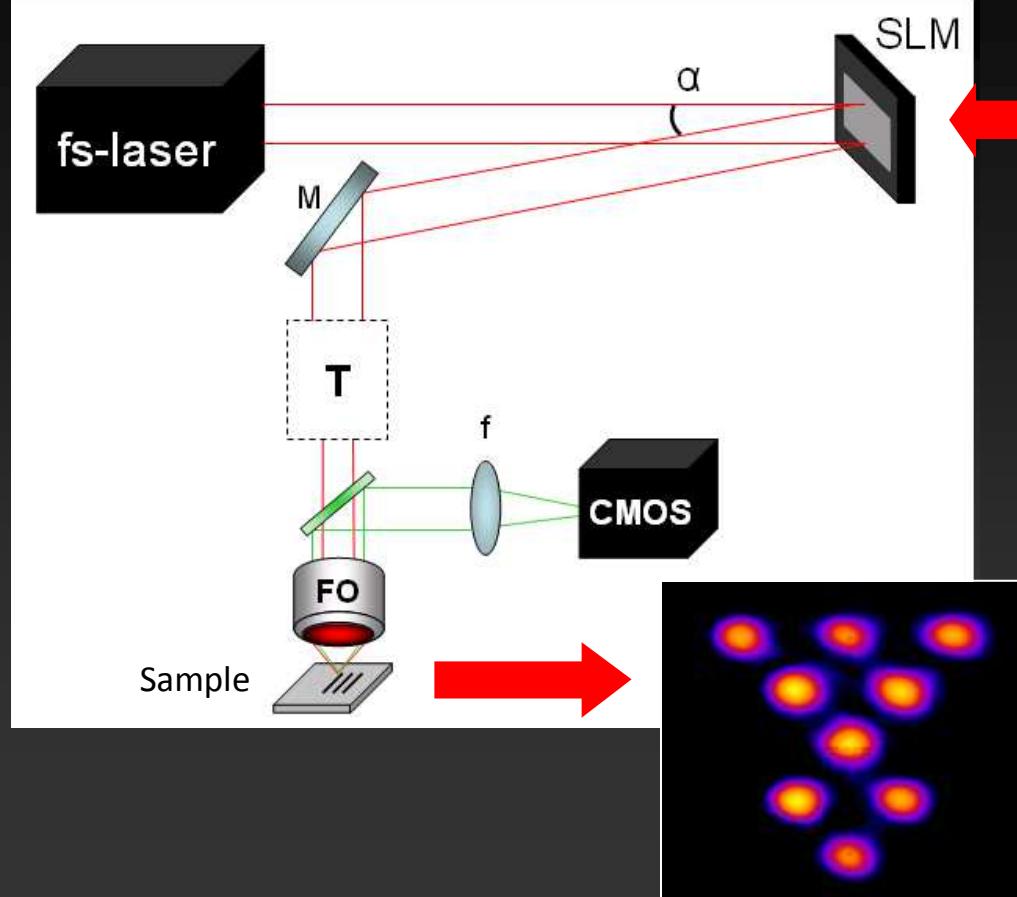
- Spatial beam shaping – Wavefront modulation



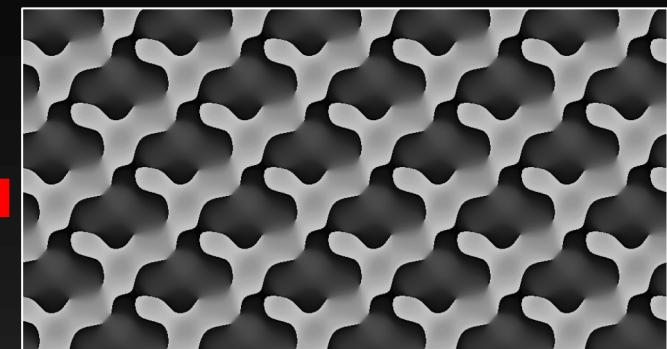
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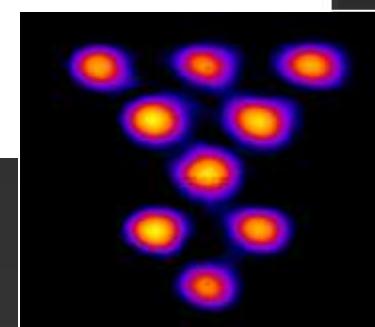
Experimental Set-up



Phase modulation



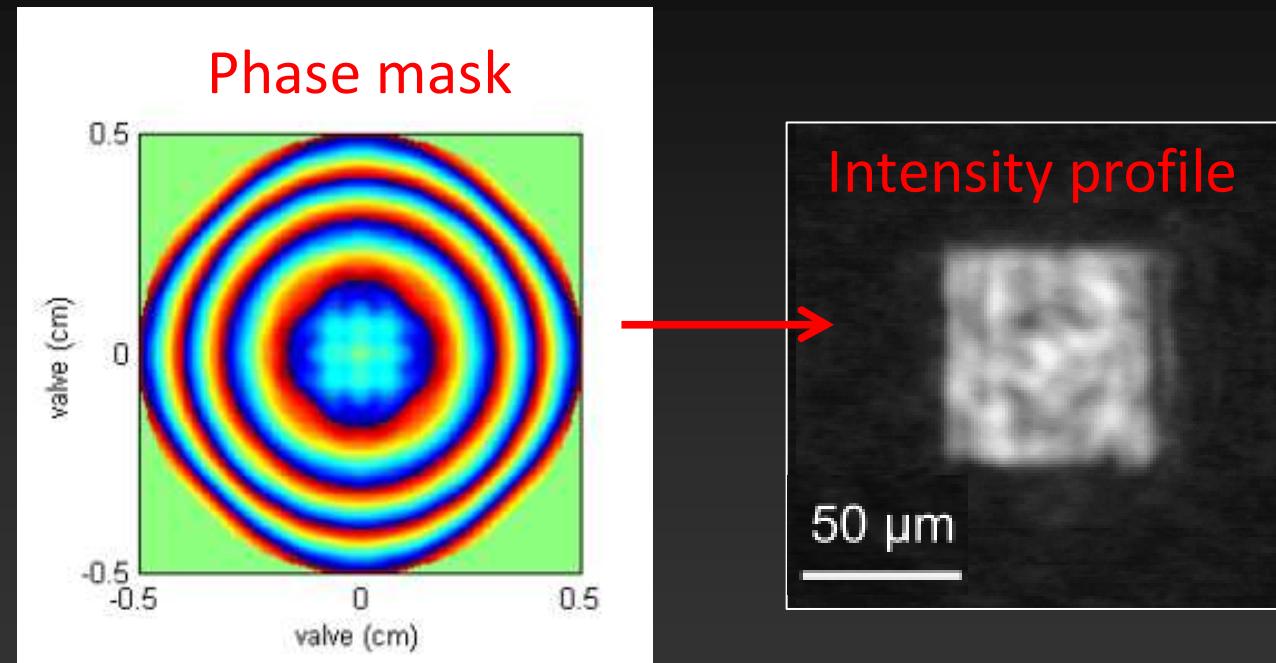
Shaped Illumination



- Spatial beam shaping – Wavefront modulation

IFTA algorithm (Iterative Fourier Transform Algorithm)

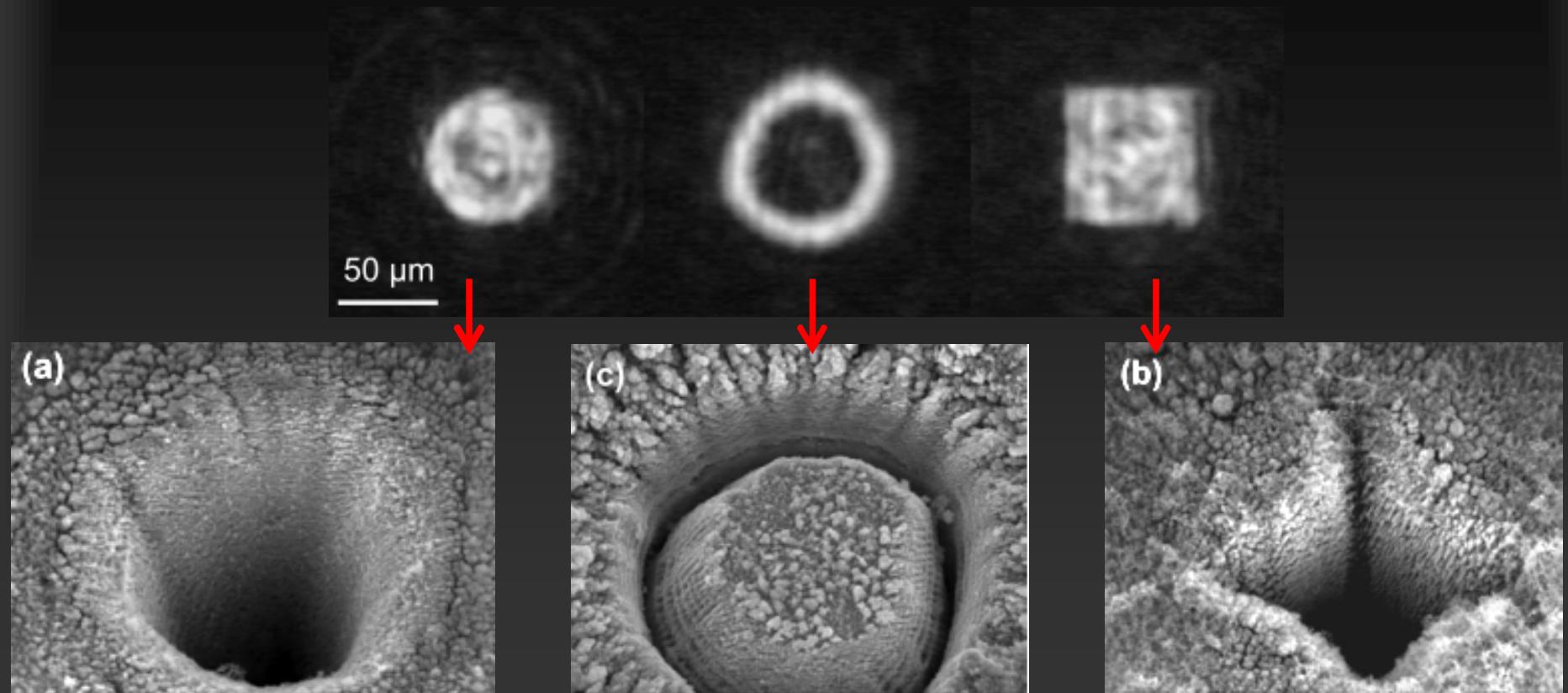
- Phase mask for arbitrary intensity profile



- Spatial beam shaping – Wavefront modulation

IFTA algorithm (Iterative Fourier Transform Algorithm)

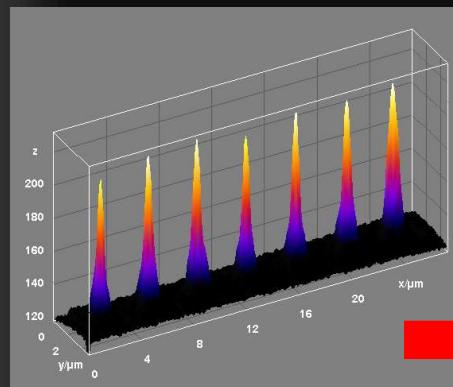
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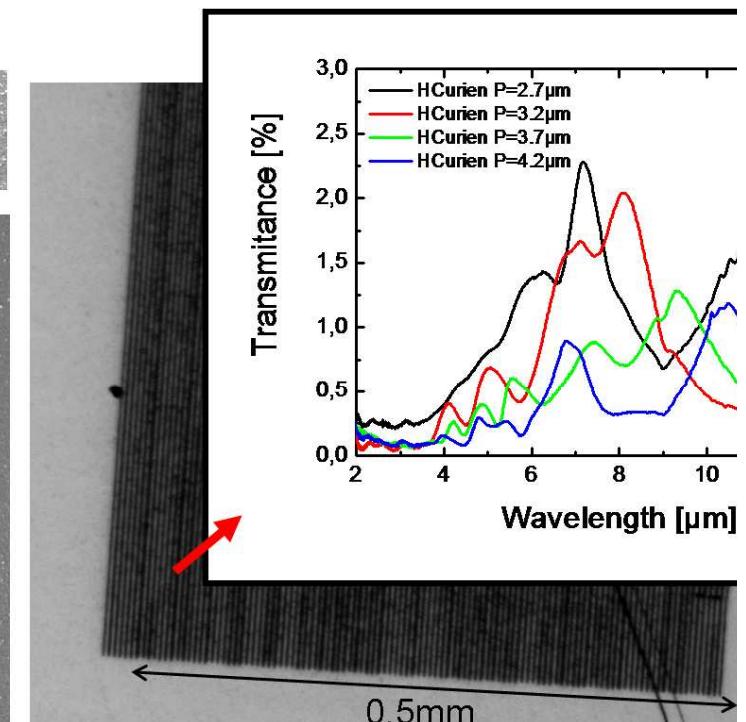
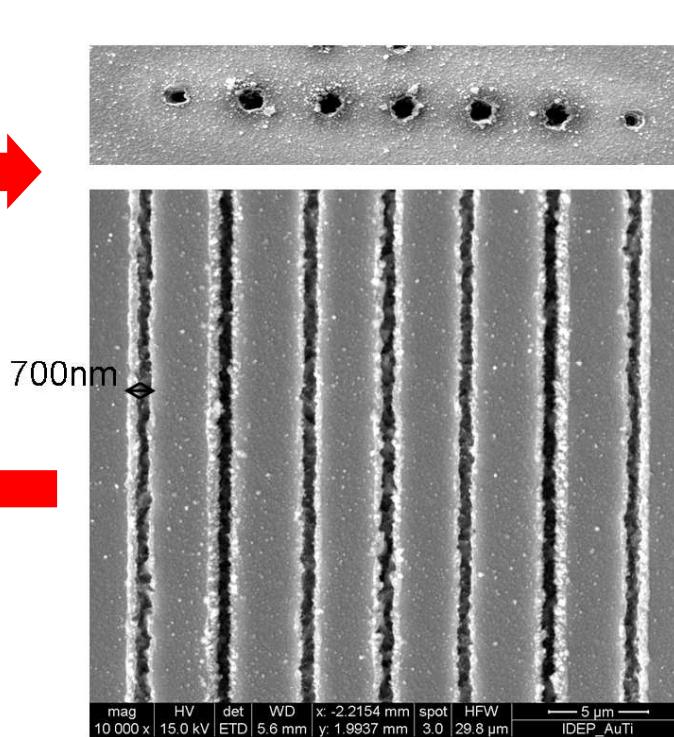
- Spatial beam shaping – Wavefront modulation

IFTA algorithm (Iterative Fourier Transform Algorithm)

- Phase mask for arbitrary intensity profile



Surface function
(plasmonic)

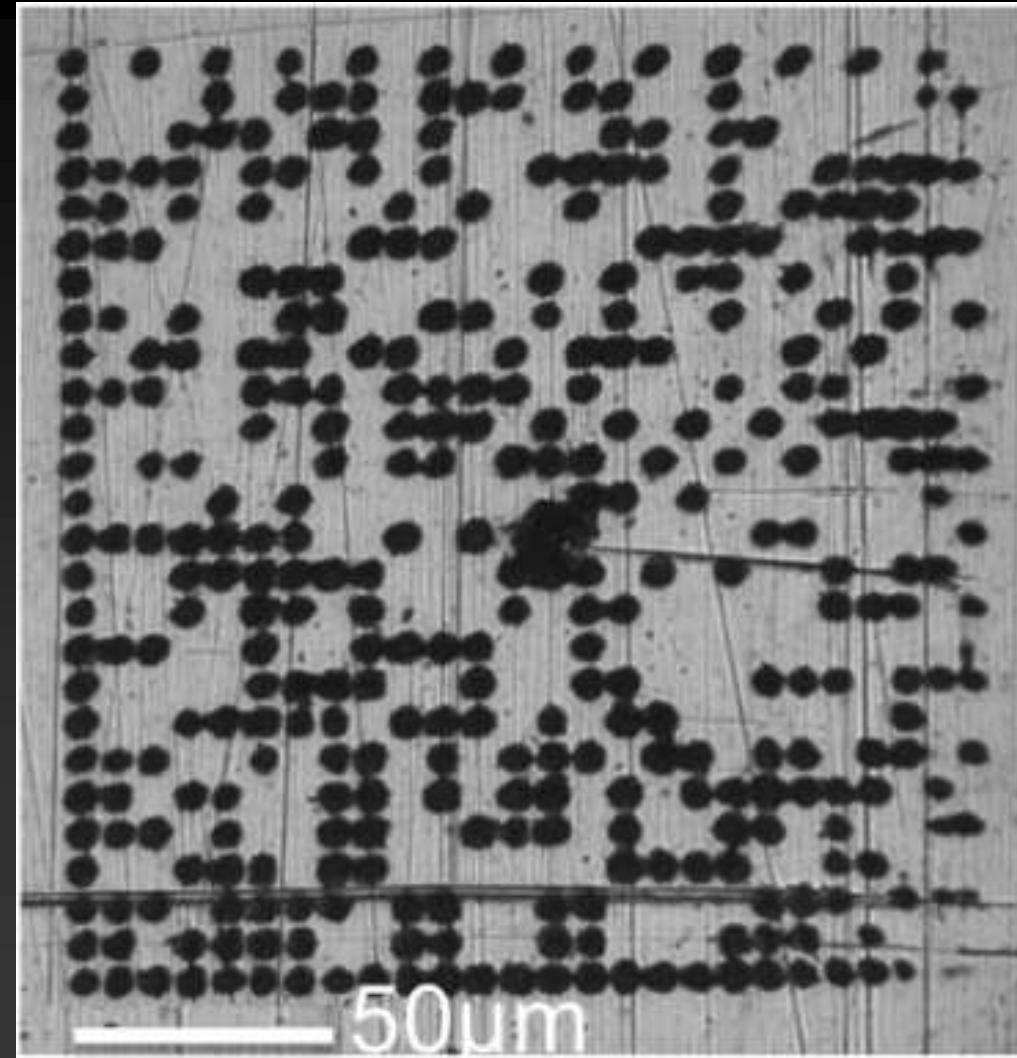


- Spatial beam shaping – Wavefront modulation

IFTA algorithm

Single static exposure
~700 spots 
Stainless steel

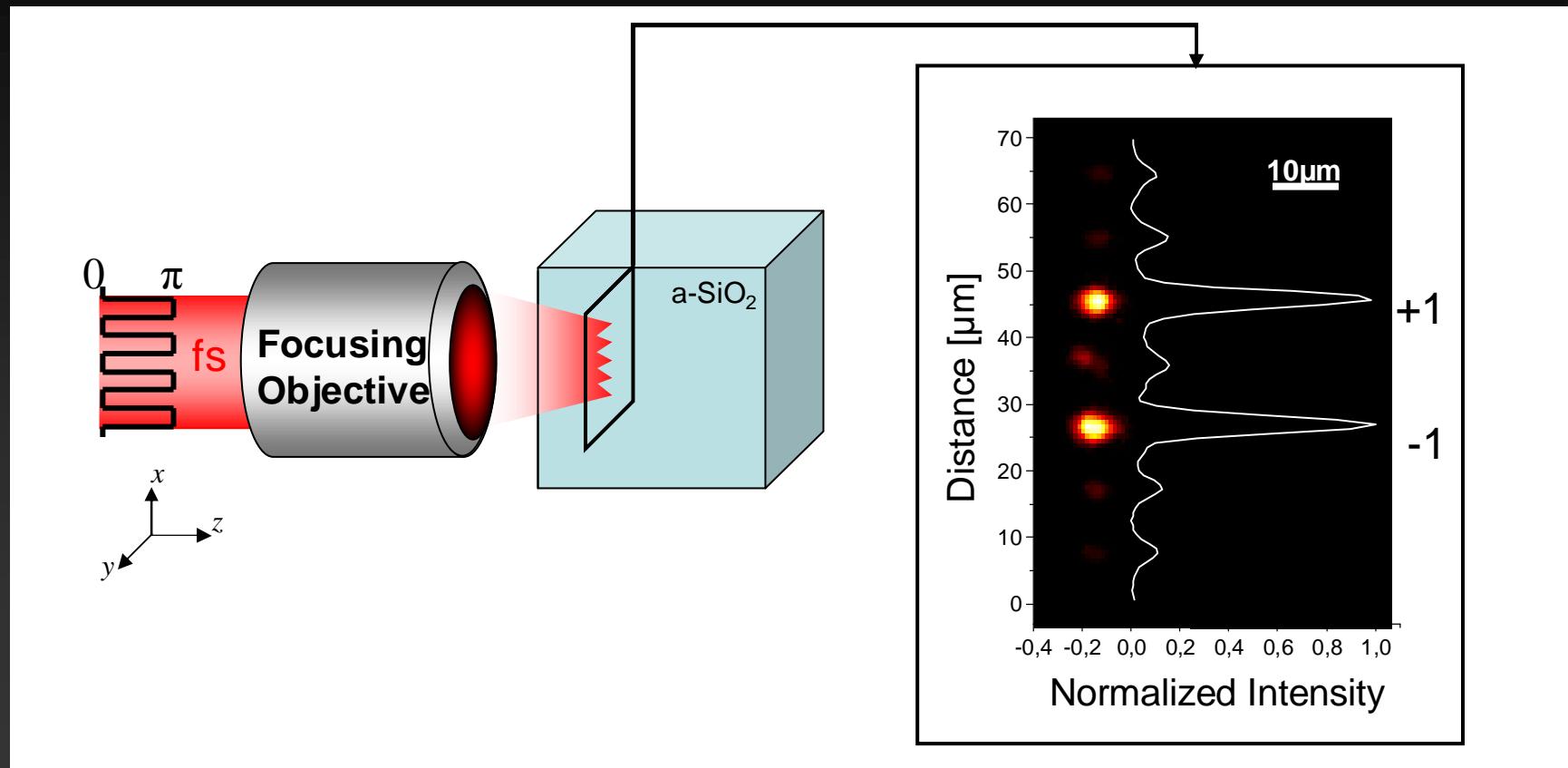
 Surface function
(data marking)



- Spatial beam shaping – Wavefront modulation

IFTA algorithm (Iterative Fourier Transform Algorithm)

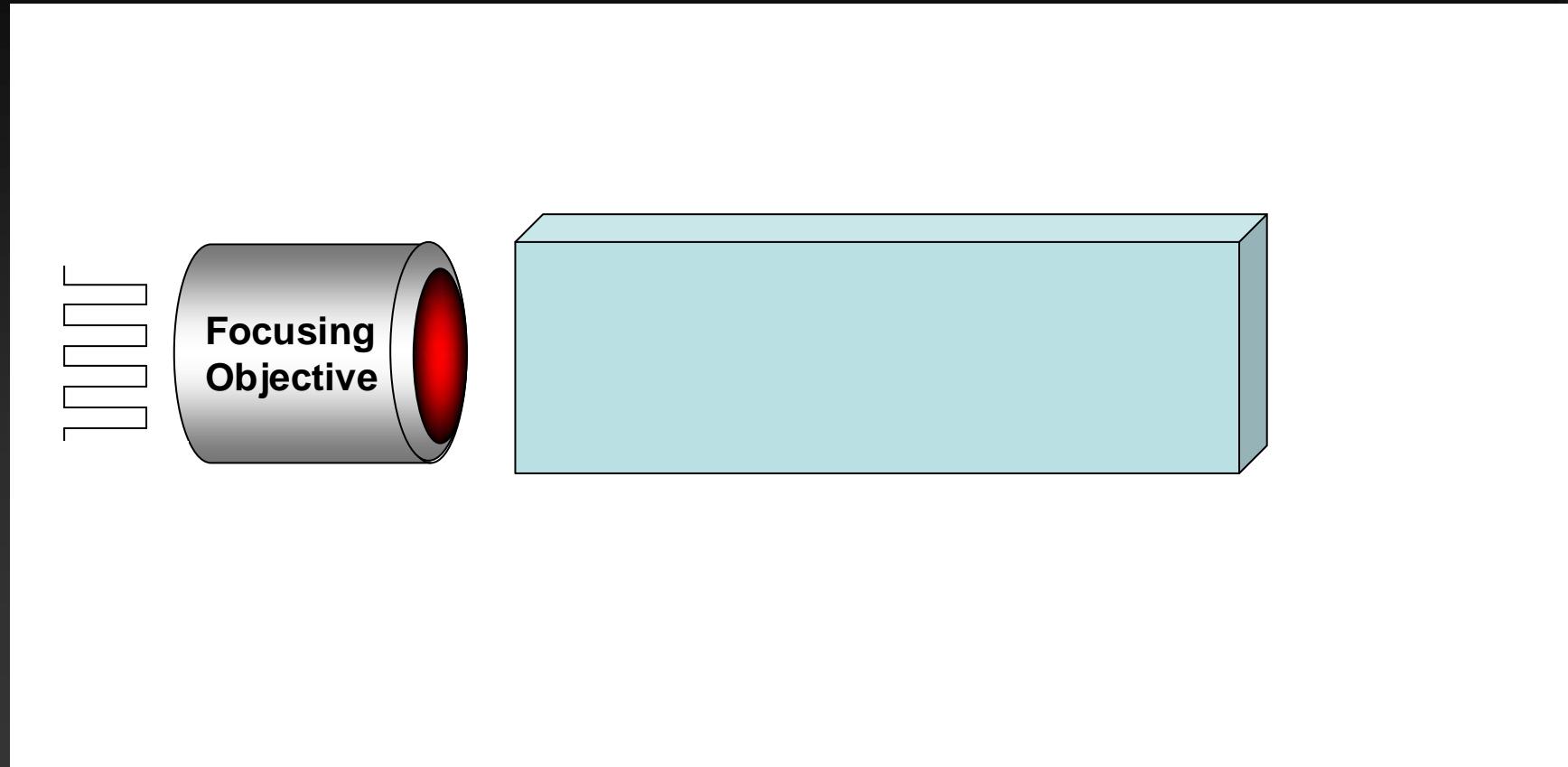
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- Spatial beam shaping – Wavefront modulation

IFTA algorithm (Iterative Fourier Transform Algorithm)

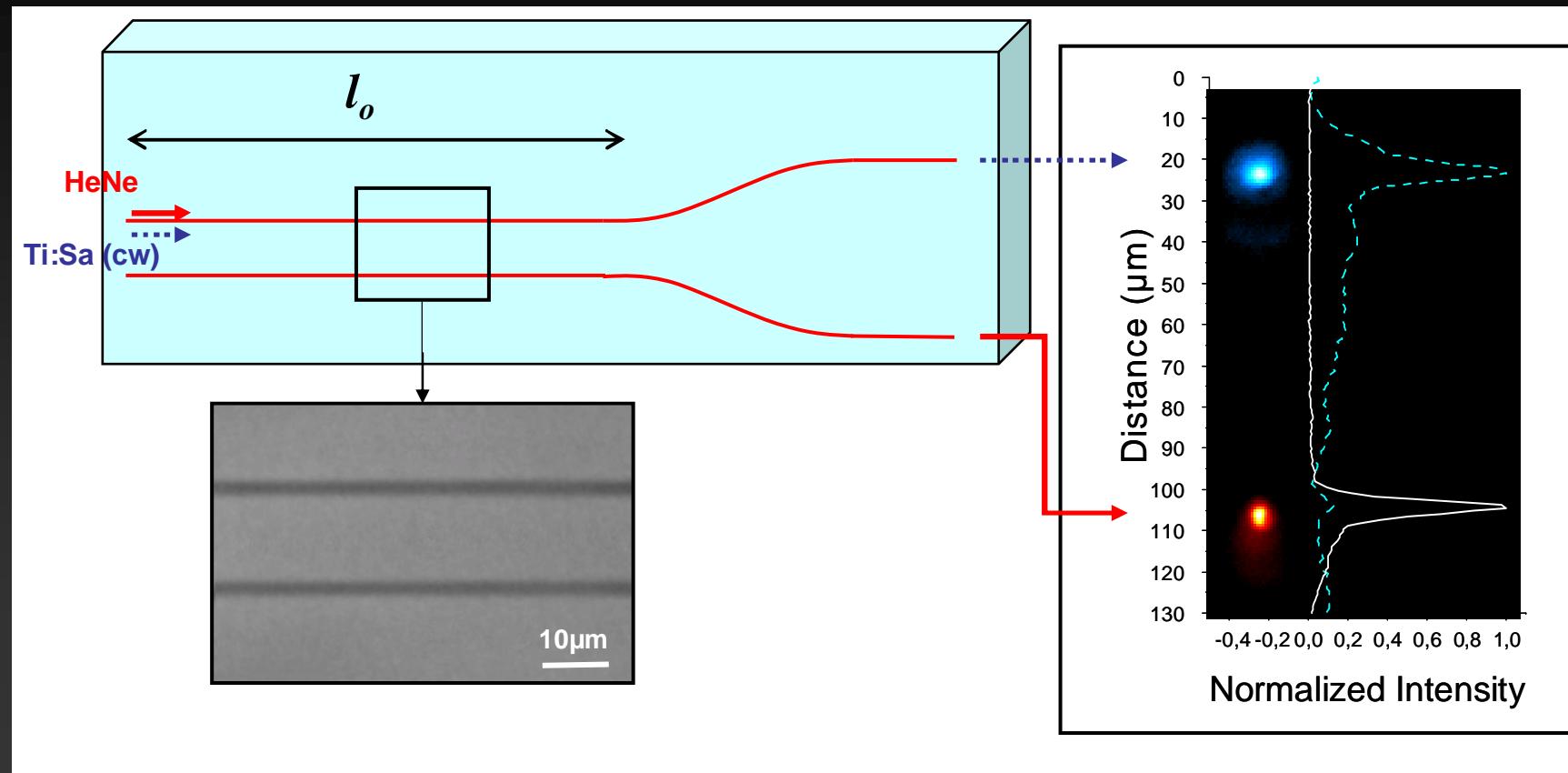
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- Spatial beam shaping – Wavefront modulation

IFTA algorithm (Iterative Fourier Transform Algorithm)

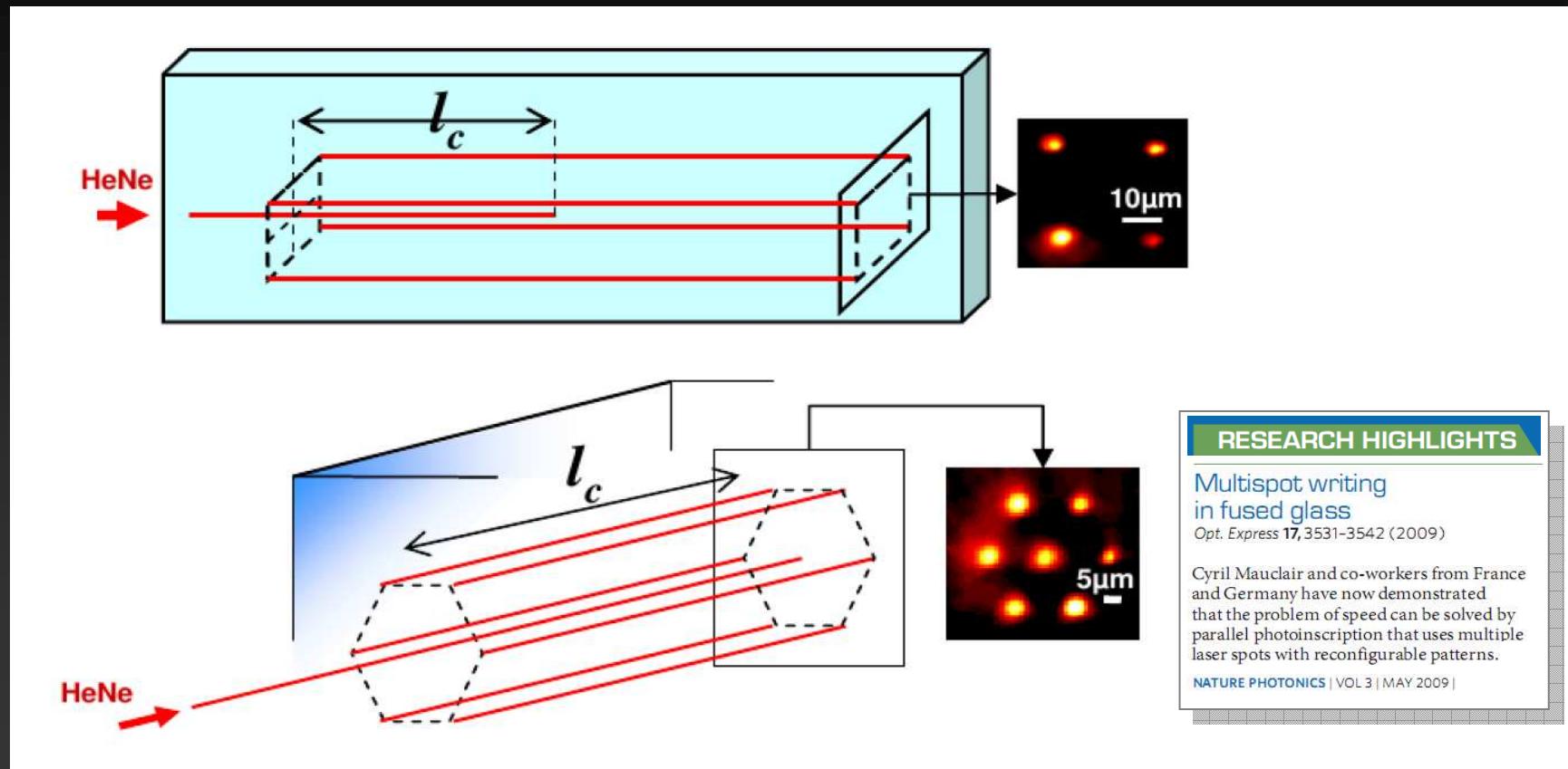
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IFTA algorithm (Iterative Fourier Transform Algorithm)

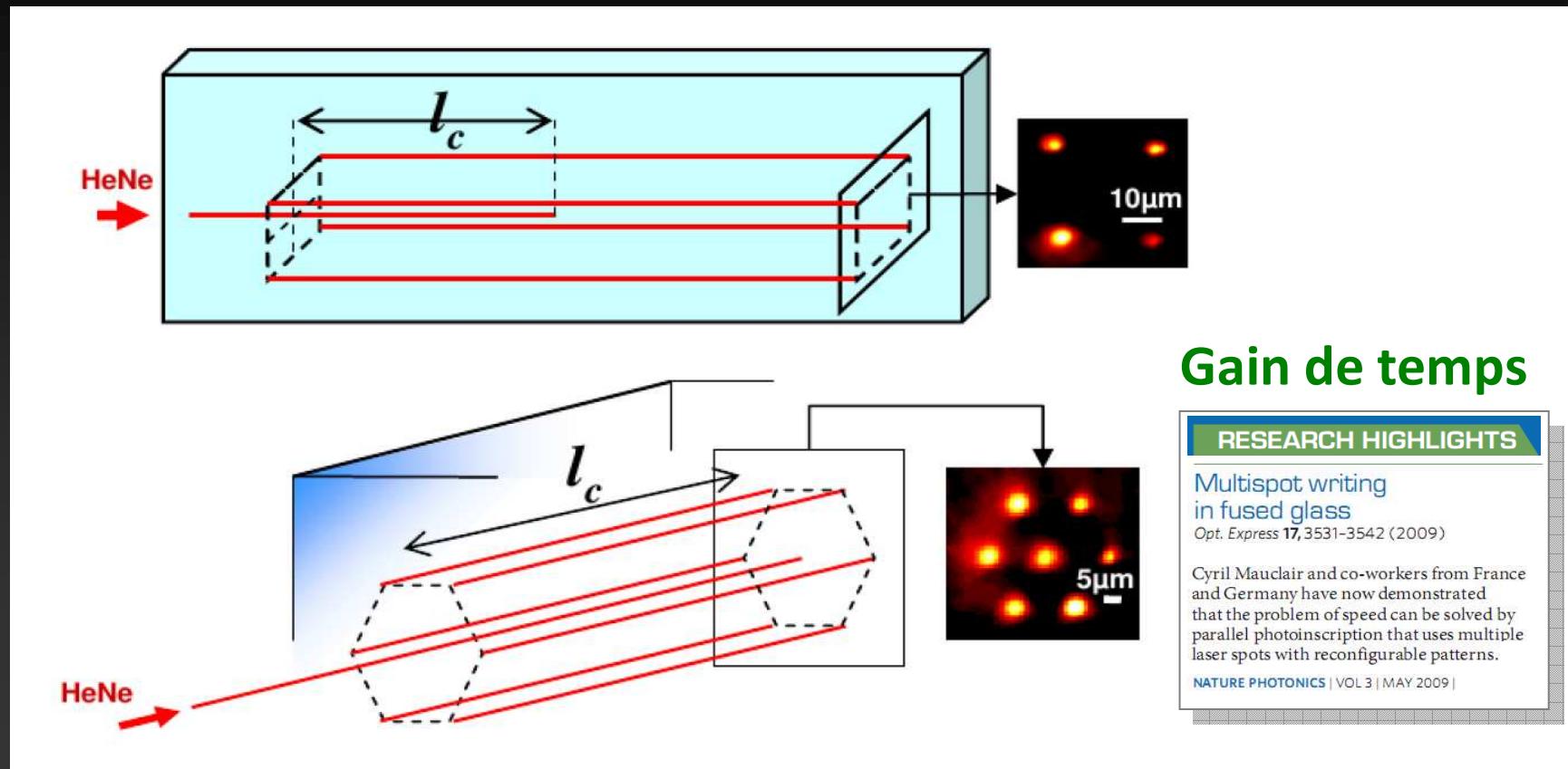
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- Spatial beam shaping – Wavefront modulation

IFTA algorithm (Iterative Fourier Transform Algorithm)

- Phase mask for arbitrary intensity profile

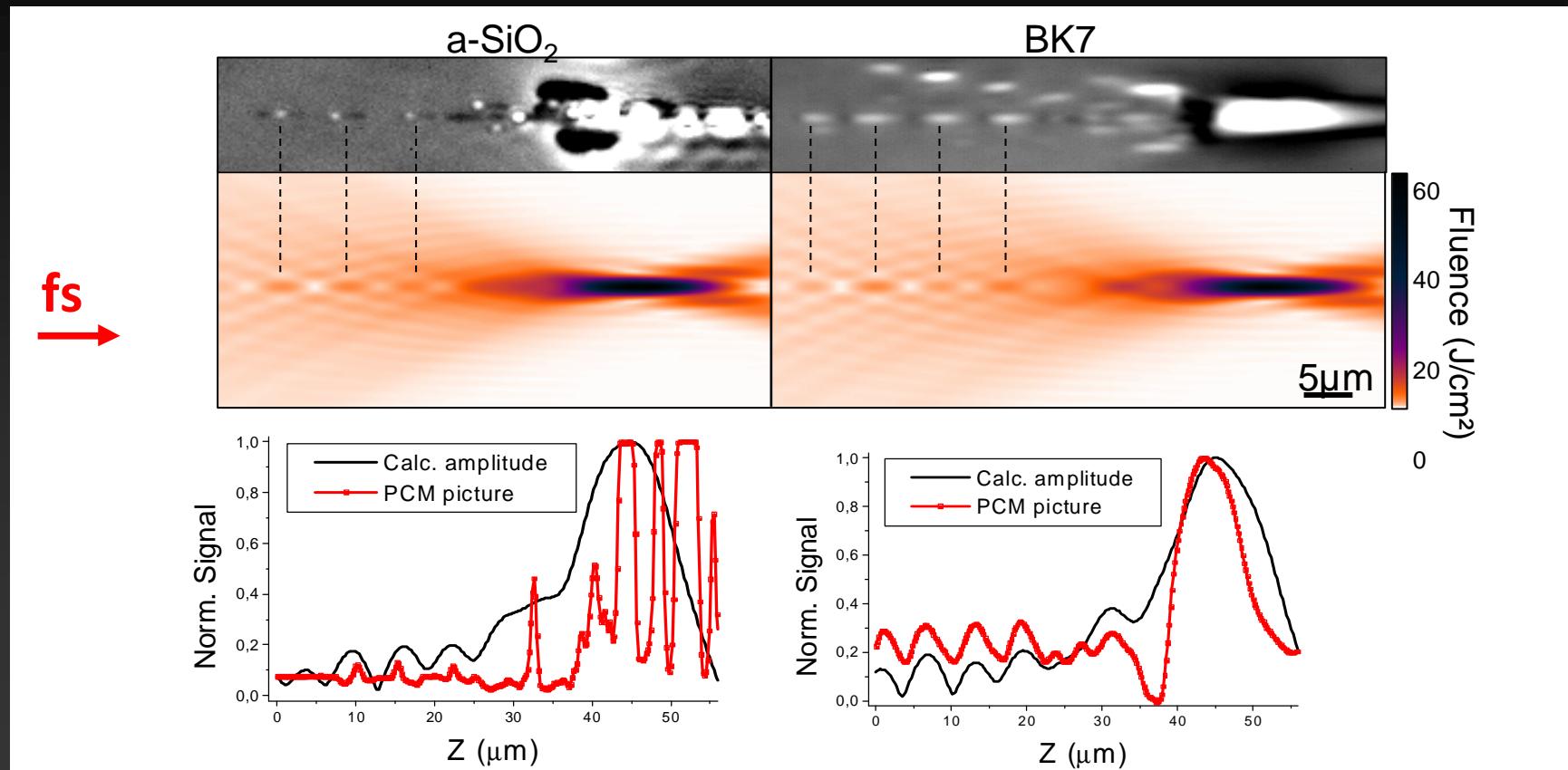


Mauclair et al. Opt. Express 2009

- Spatial beam shaping – Intensity modulation

IFTA algorithm (Iterative Fourier Transform Algorithm)

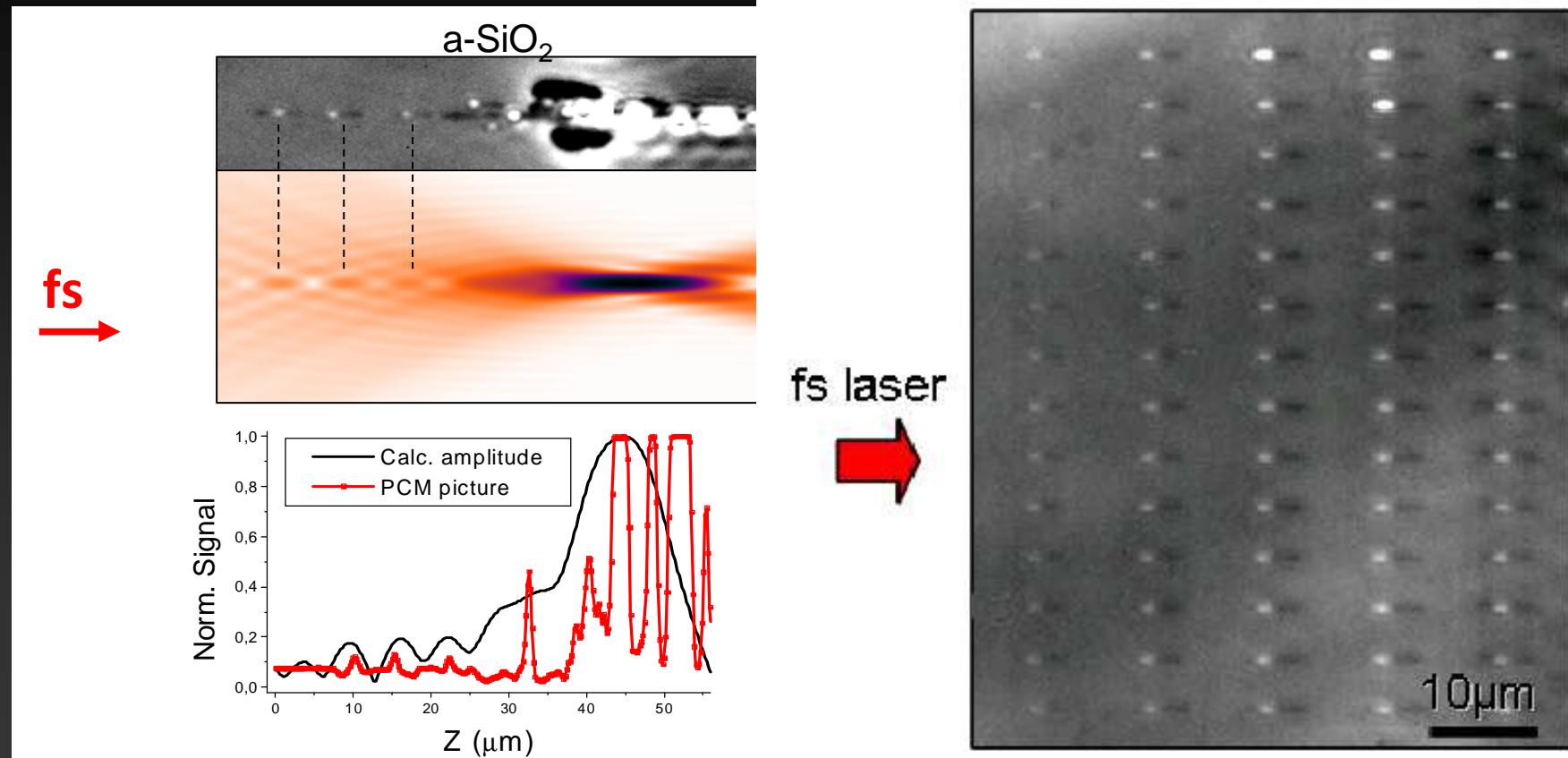
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- Spatial beam shaping – Intensity modulation

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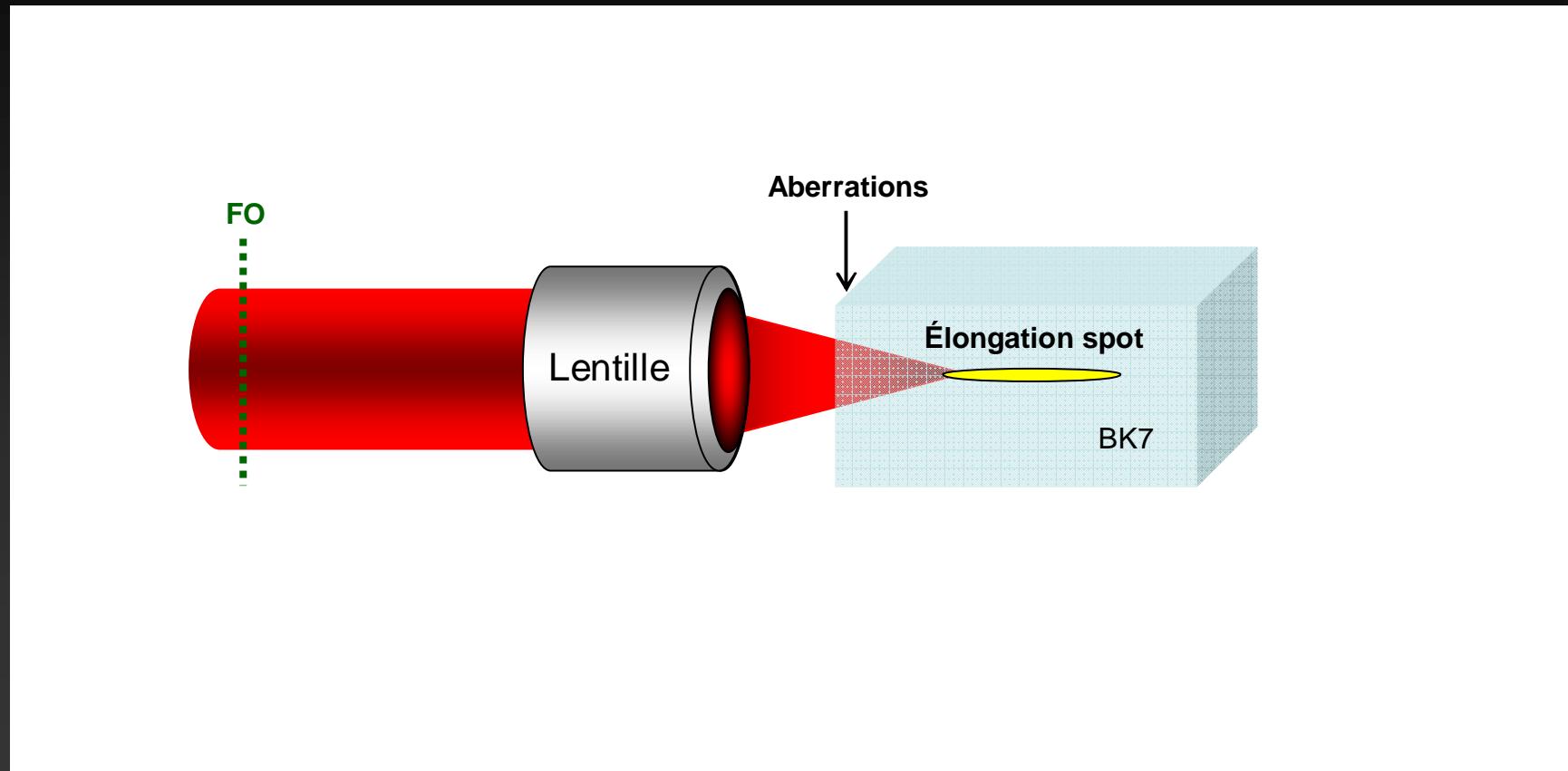
- Phase mask for arbitrary intensity profile



- Spatial beam shaping – Wavefront modulation

Pre correction of aberration

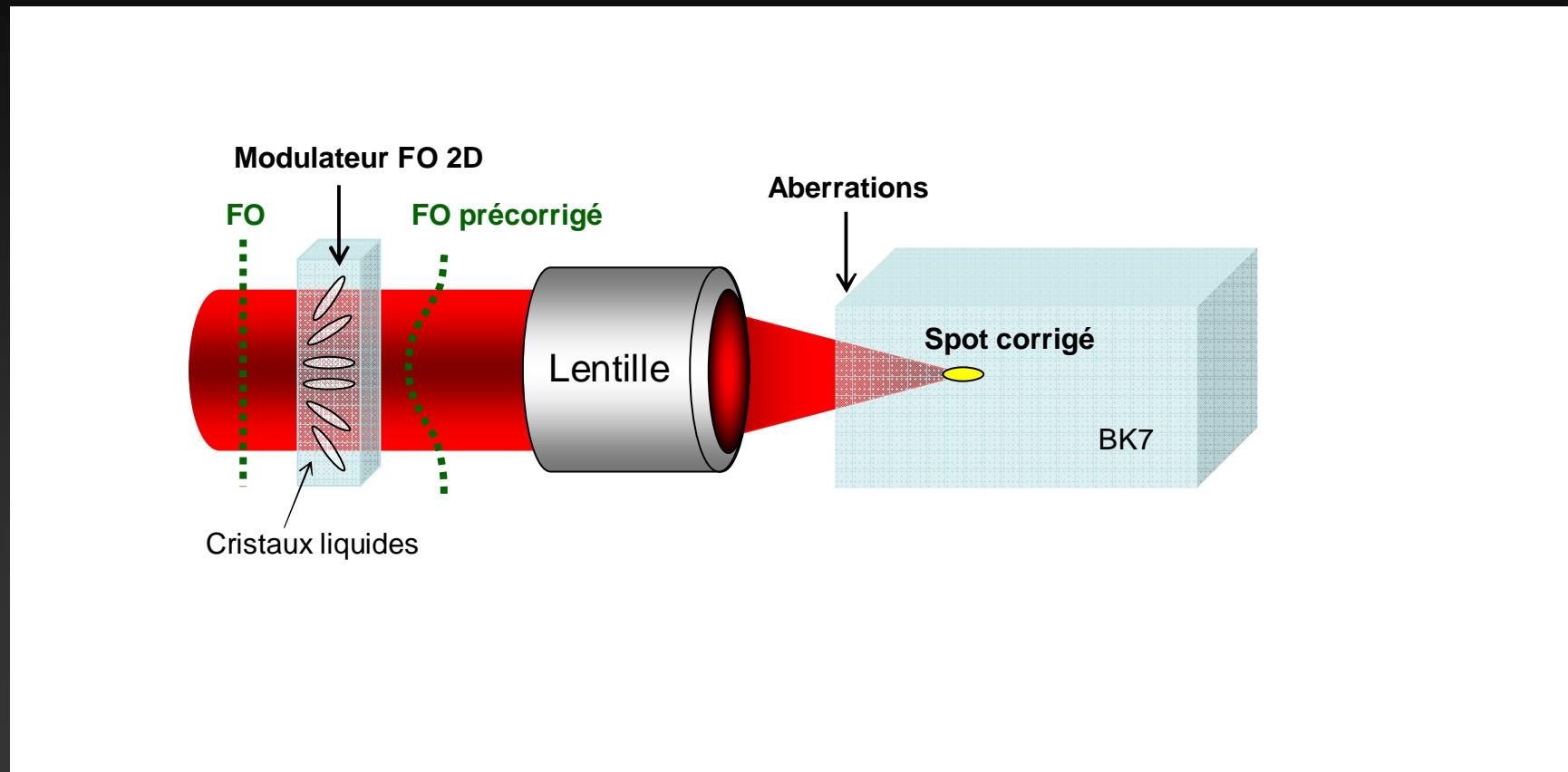
- Phase mask depending on depth



- Spatial beam shaping – Wavefront modulation

Pre correction of aberration

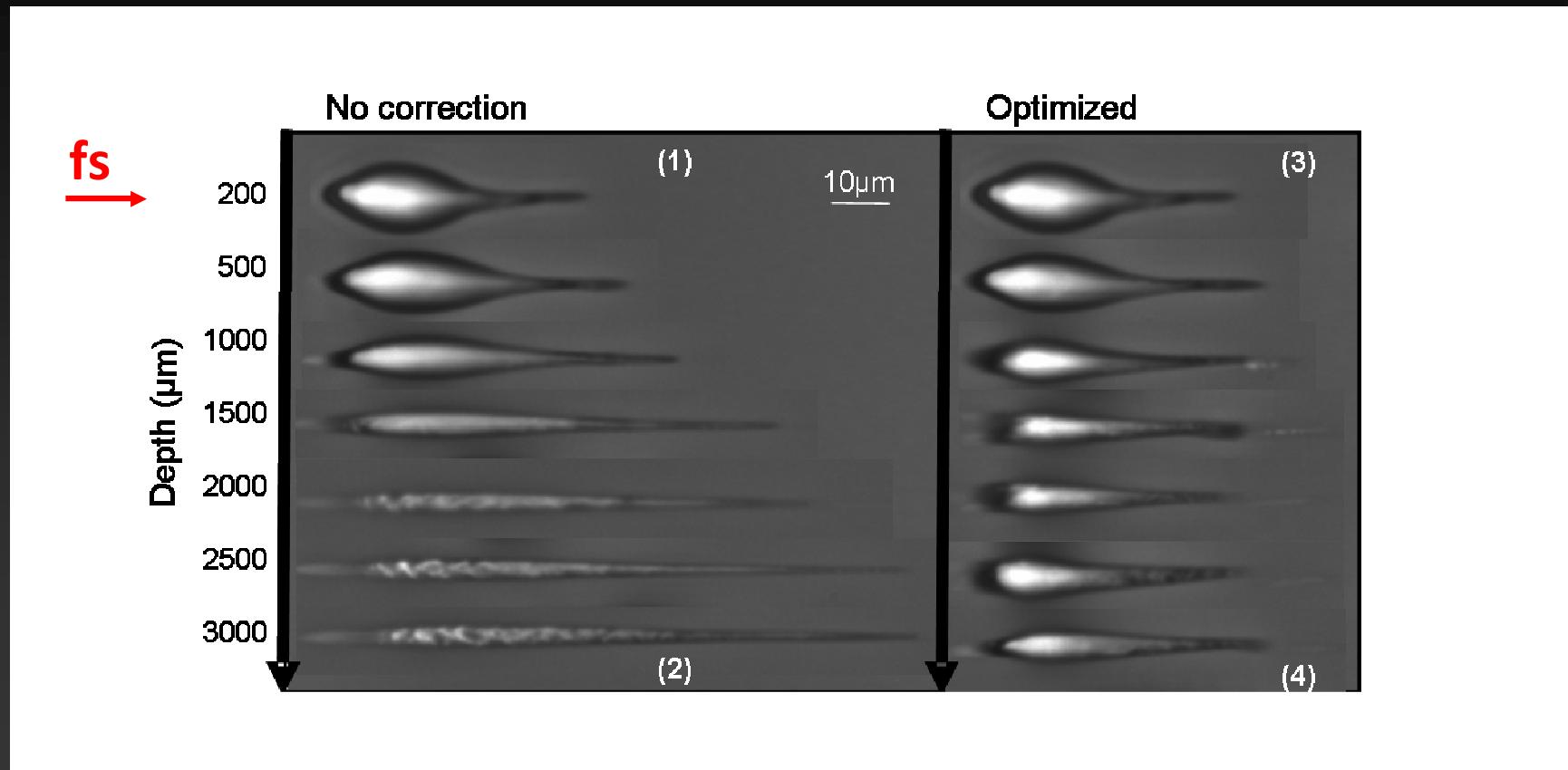
- Phase mask depending on depth



- Spatial beam shaping – Wavefront modulation

Pre correction of aberration

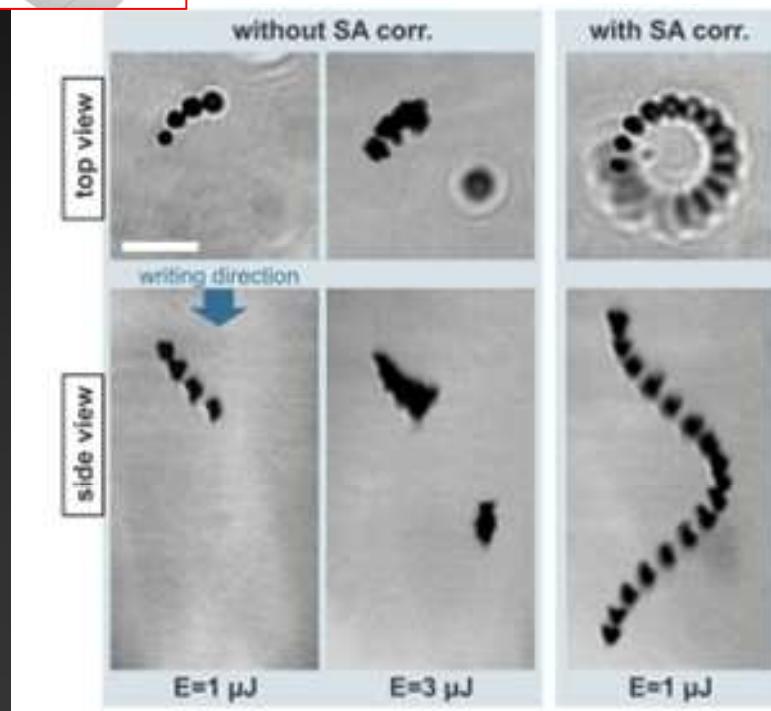
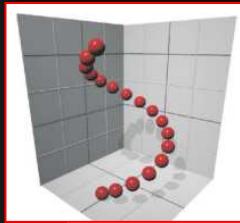
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- Spatial beam shaping – Wavefront modulation

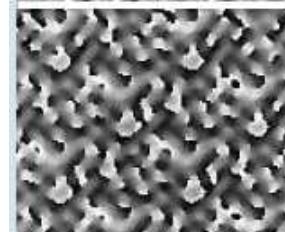
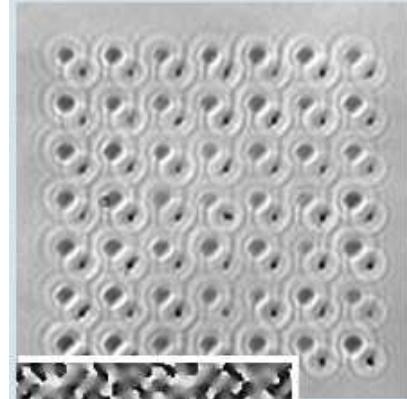
Pre correction of aberration - **STATE of the ART**

- Phase mask depending on depth

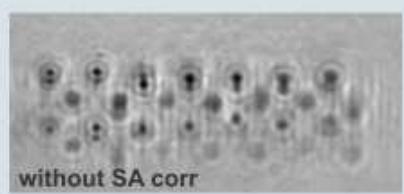
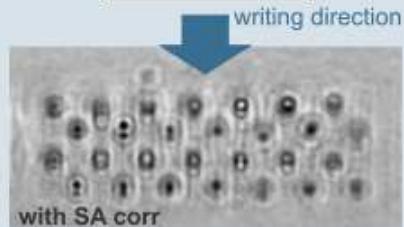


3D parallel fabrication

top view,
lithium niobate

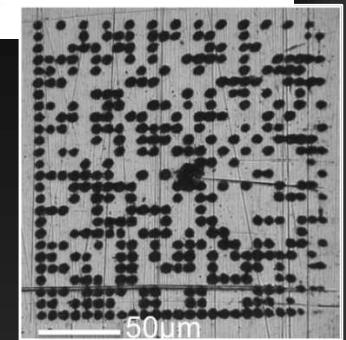
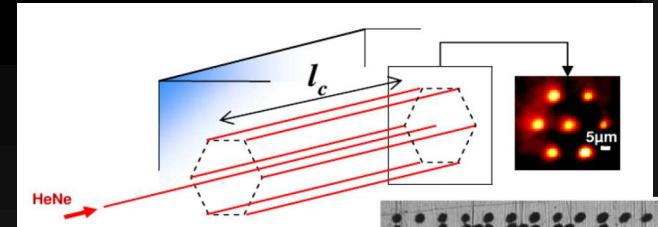
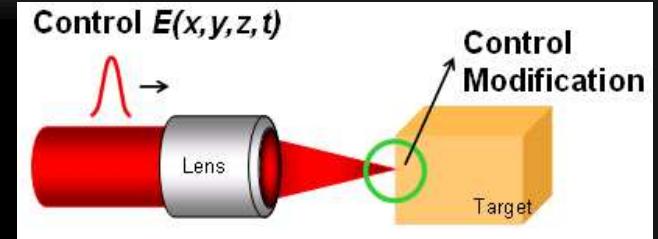


side view,
fused silica



Outline

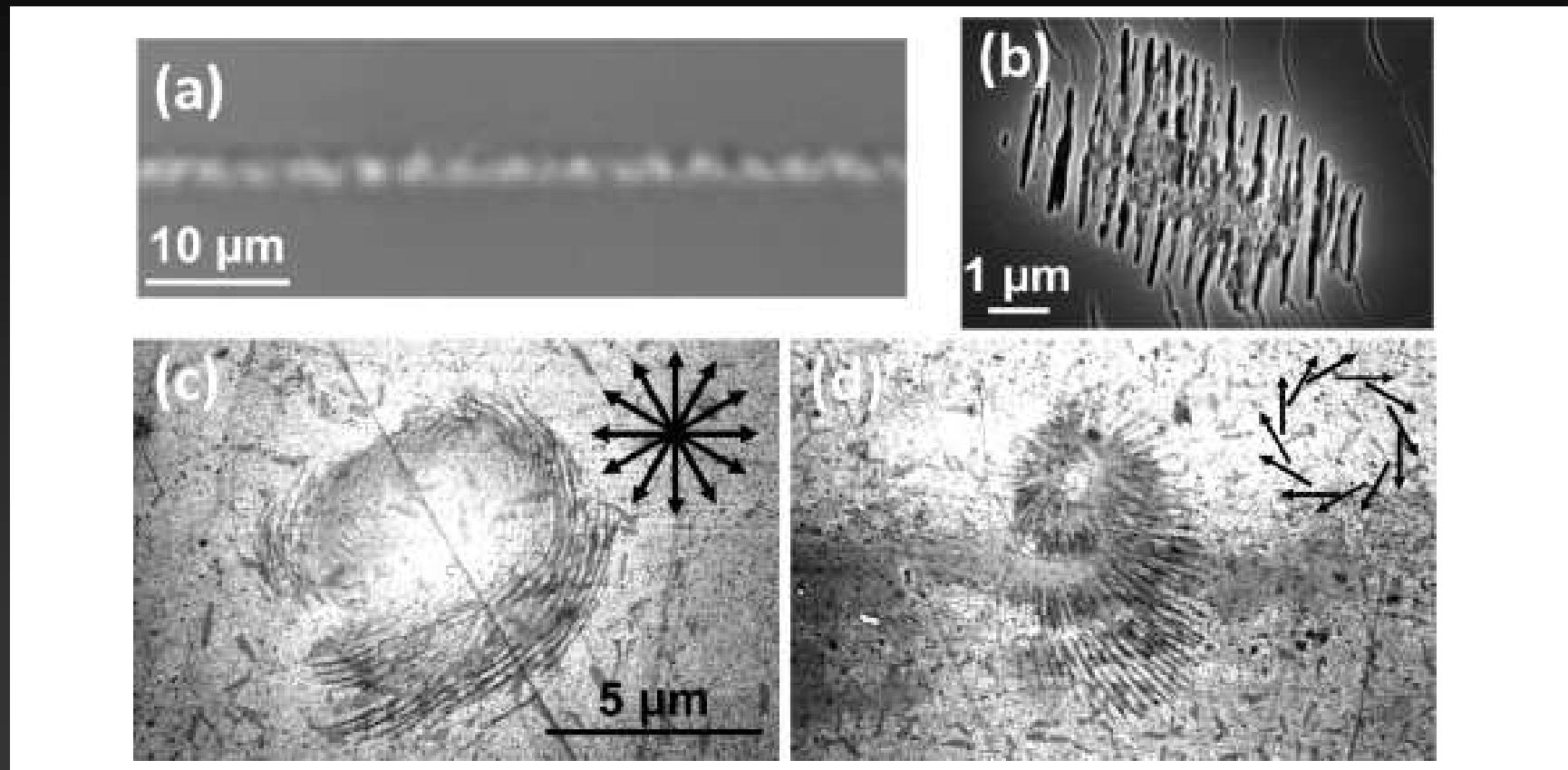
- Background – Leitmotiv
- Spatial beam shaping
- **Polarization modulation**
- Temporal pulse shaping
- Physical insights: Pump-probe



- Spatial beam shaping – **Polarization** modulation

Control of nanostructuration in the bulk

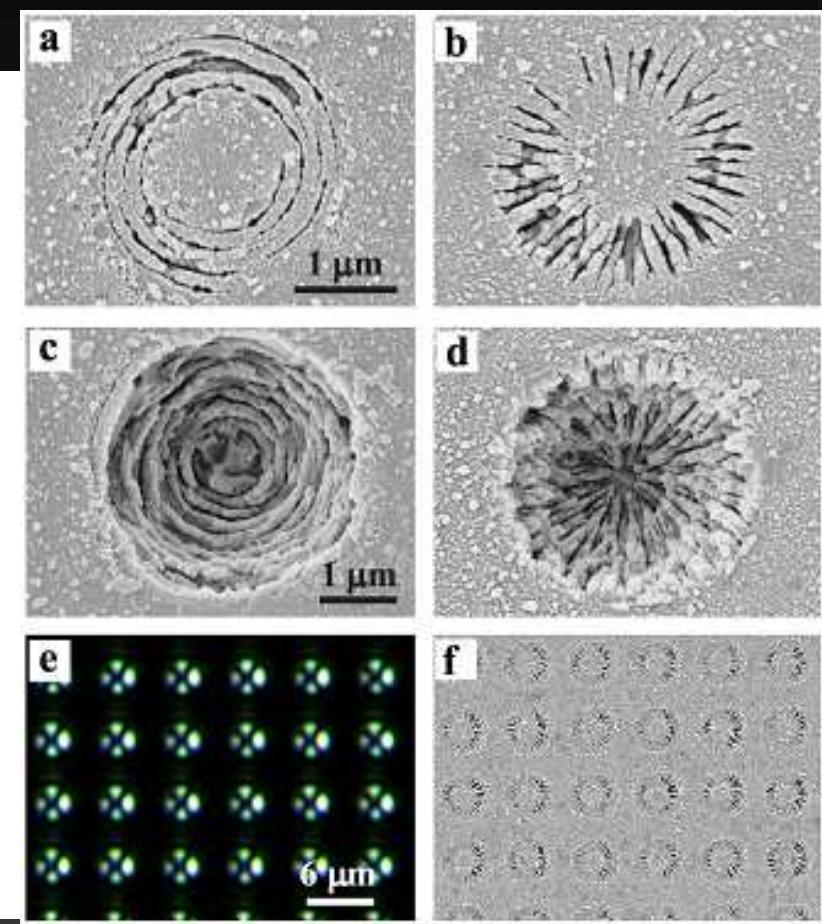
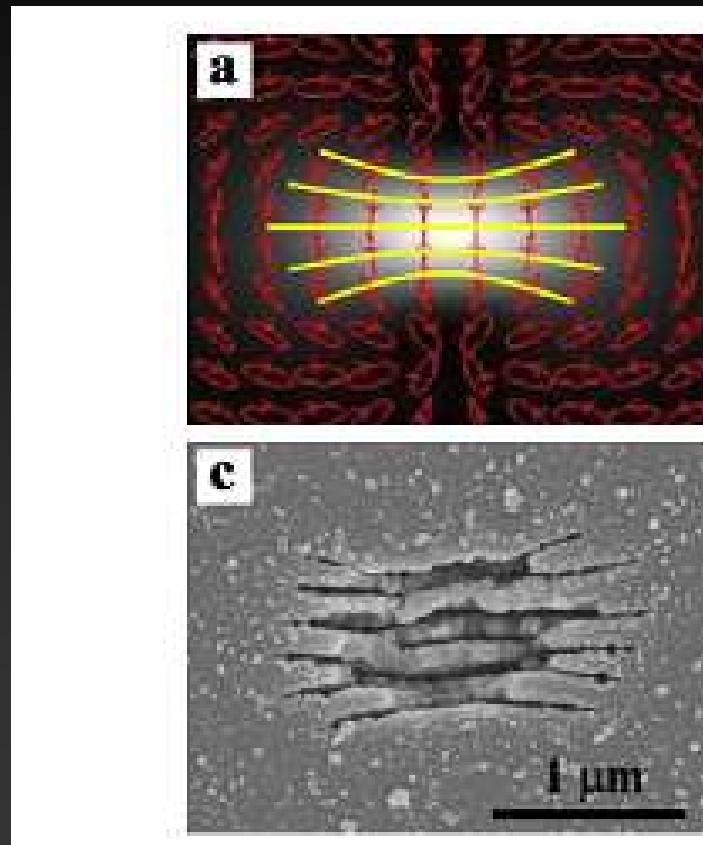
- Ripples orientation



- Spatial beam shaping – **Polarization** modulation

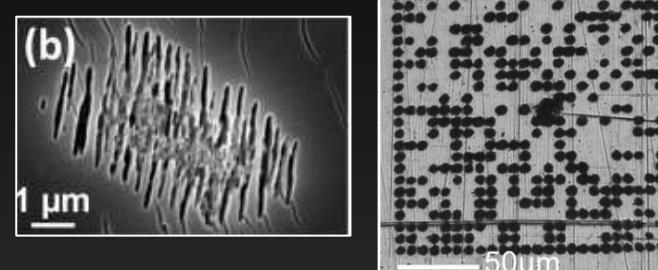
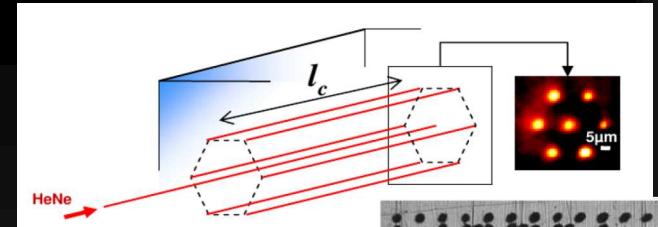
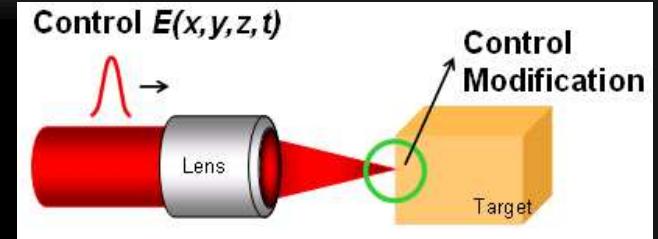
Control of nanostructuration in the bulk

- Ripples orientation **STATE** of the ART

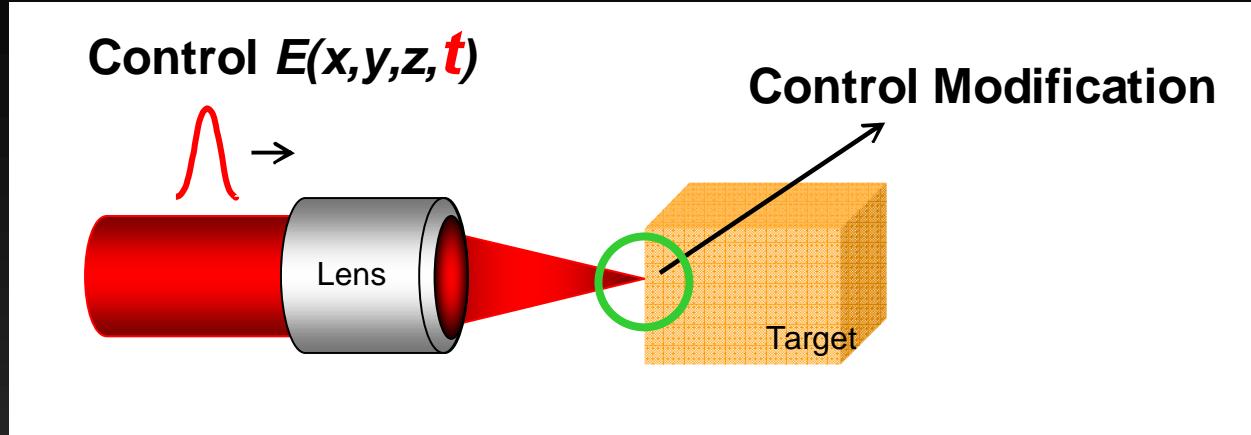


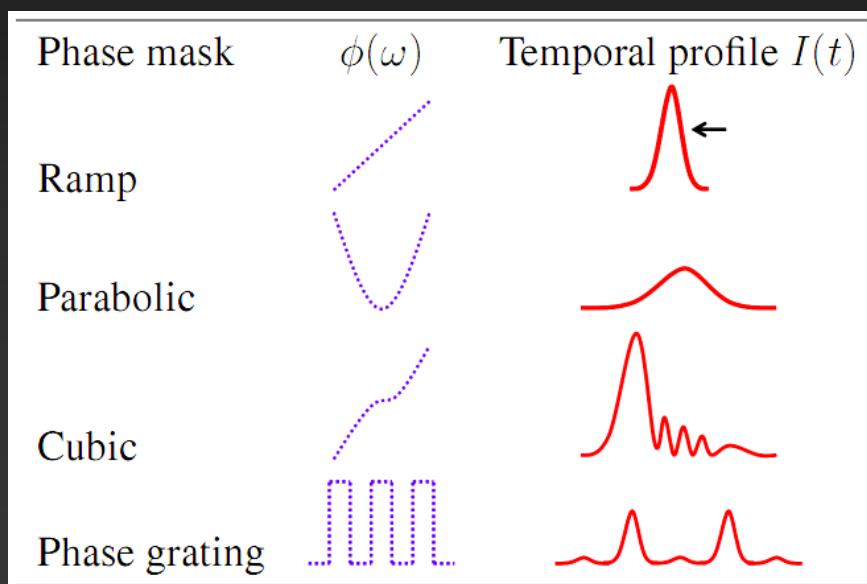
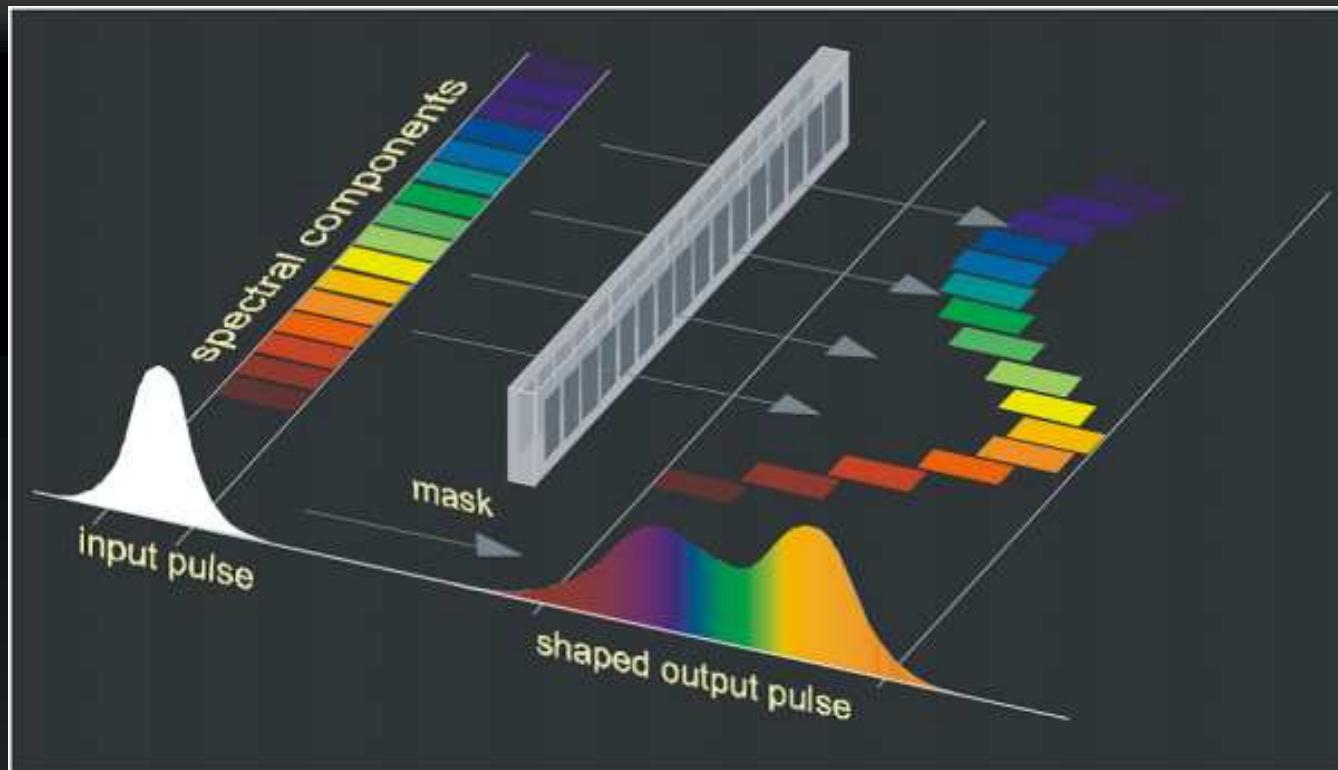
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- Leitmotiv



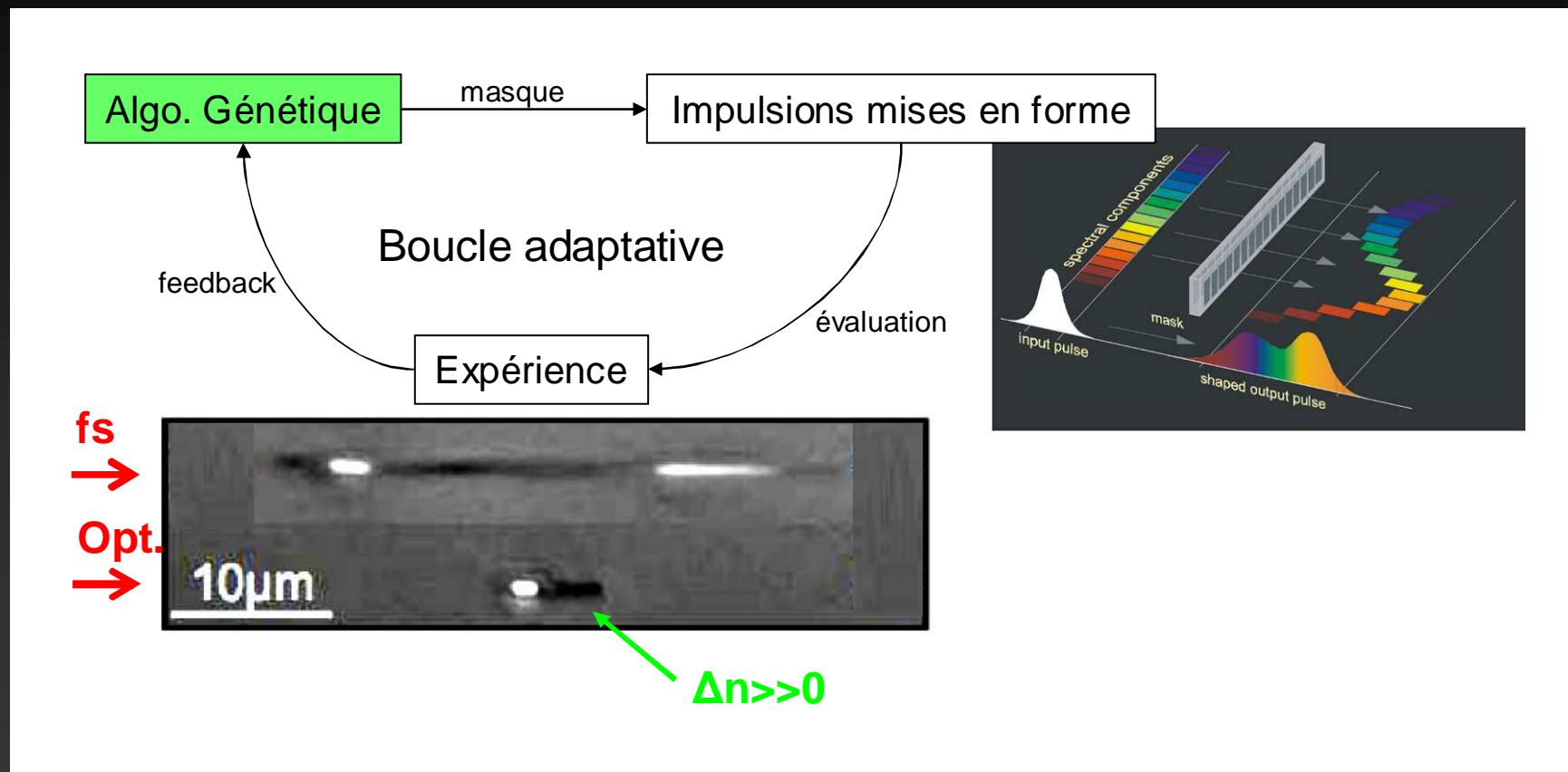


Wollenhaupt et al., Springer Handbook of Lasers and Optics (2007)

- Temporal beam shaping

Control of energy deposition

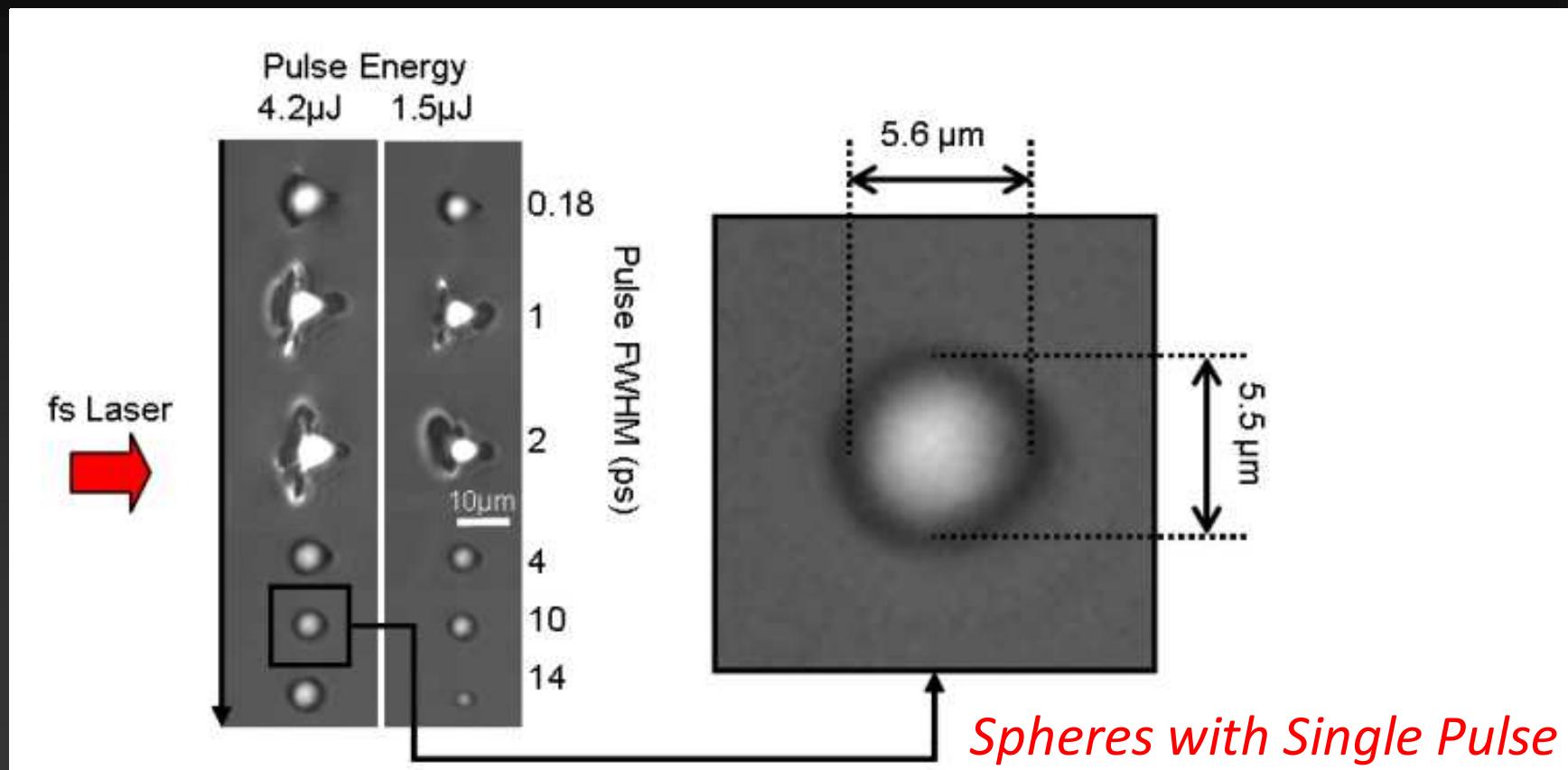
- Modification volume



- Temporal beam shaping

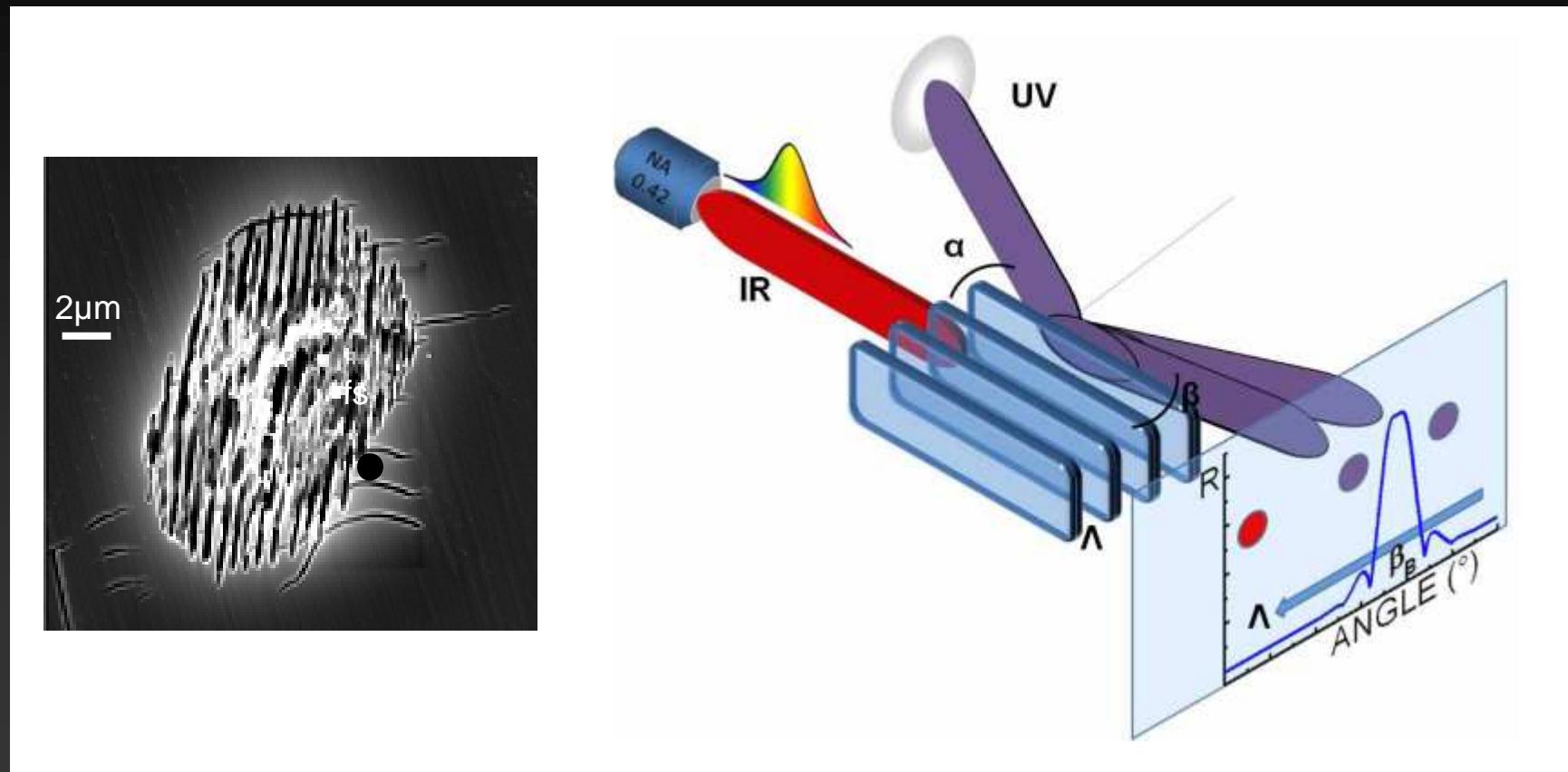
Control of energy deposition

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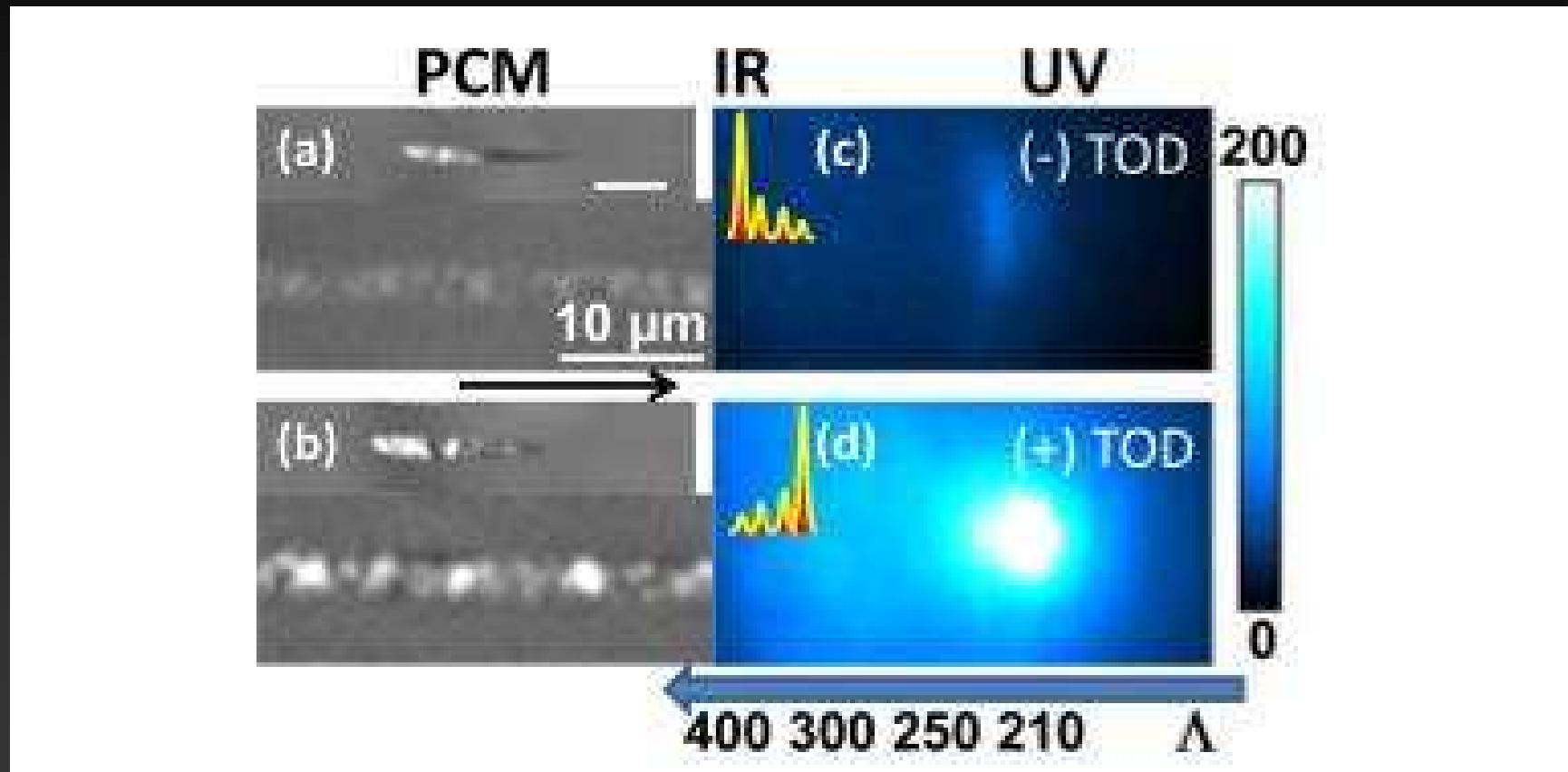
- Temporal beam shaping

Control of nanostructuration in fused silica



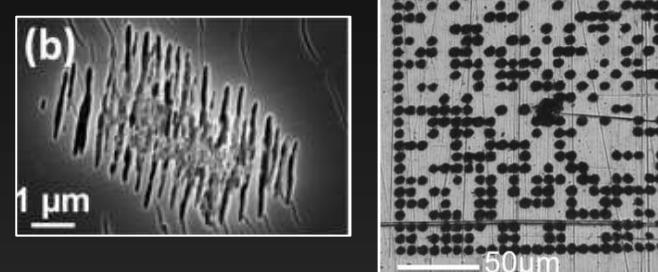
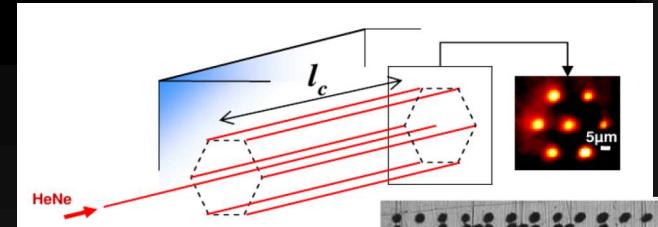
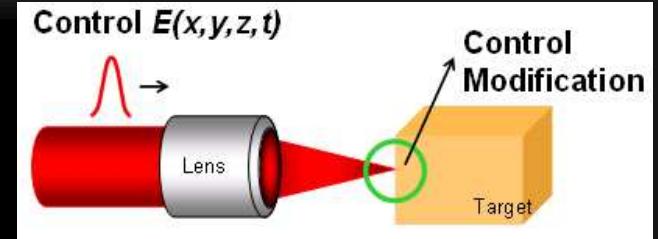
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Control of nanostructuration in fused silica



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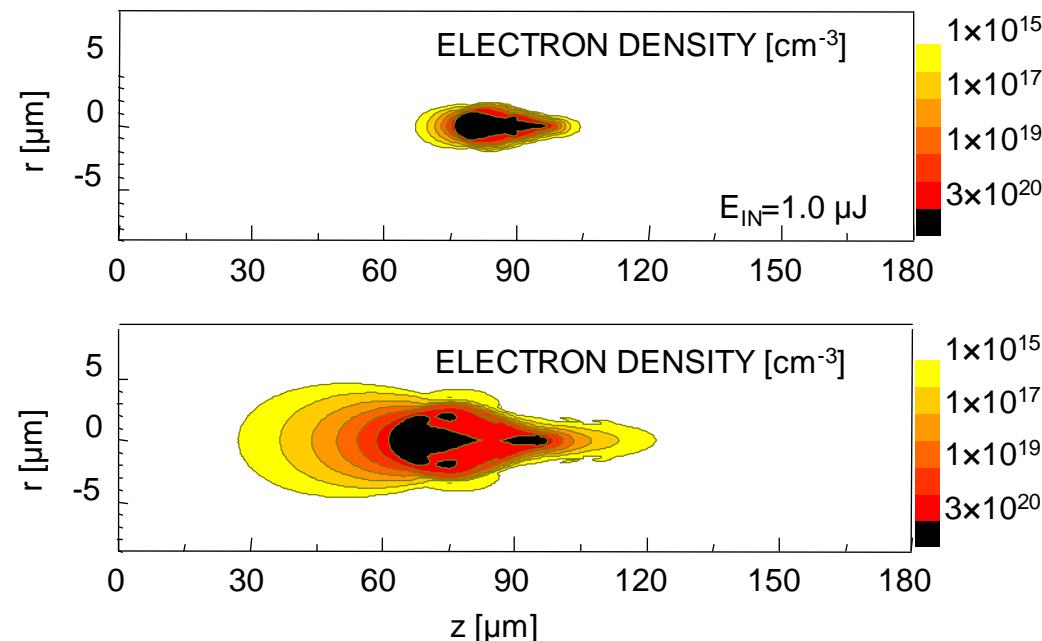


- Physics behind?

Non-Linear Schrödinger Equation

- Calculation of Electronic density

3ps pulse

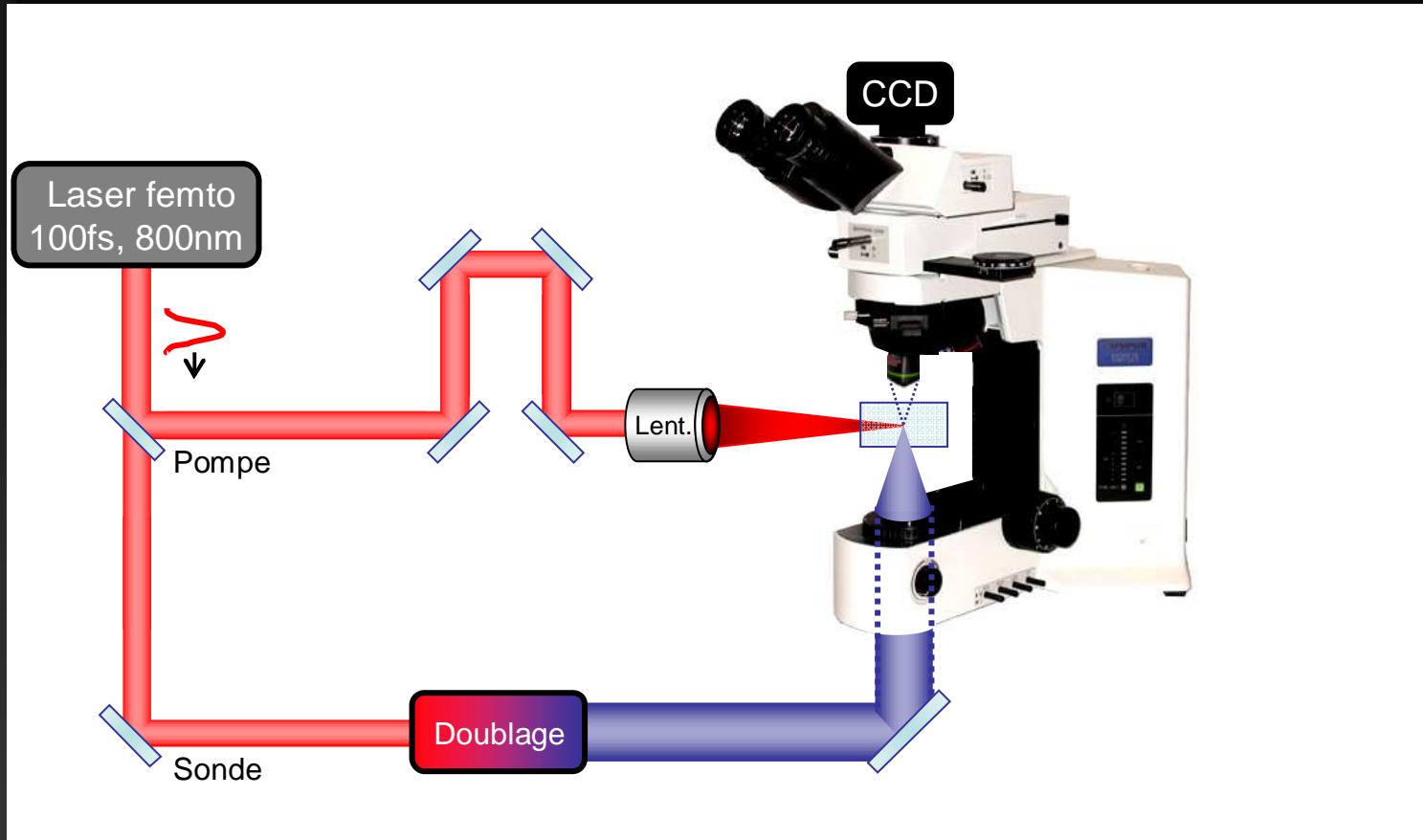


100fs pulse

- Physics behind?

Pump probe set up

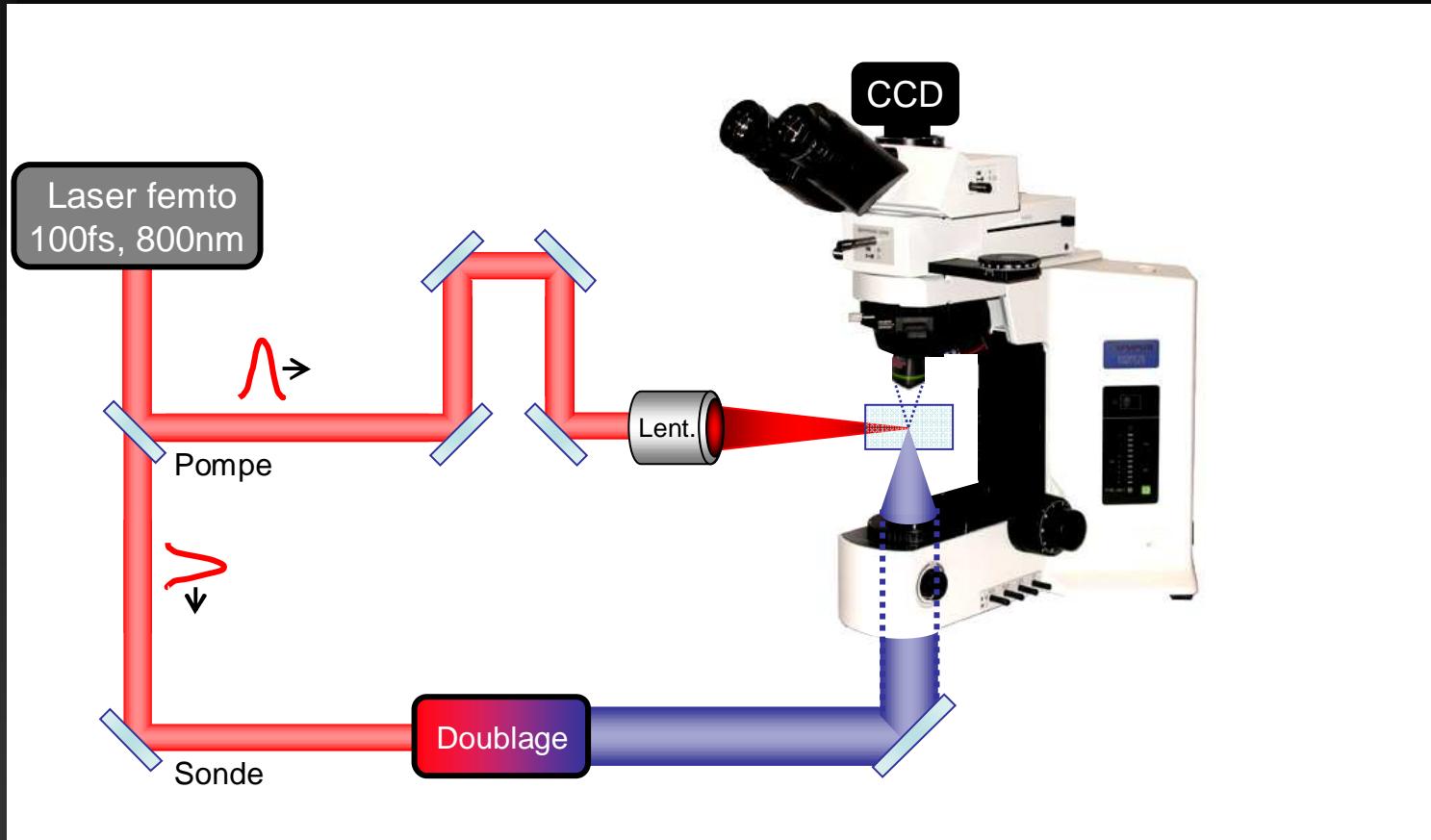
- Pictures of Electronic density



- Physics behind?

Pump probe set up

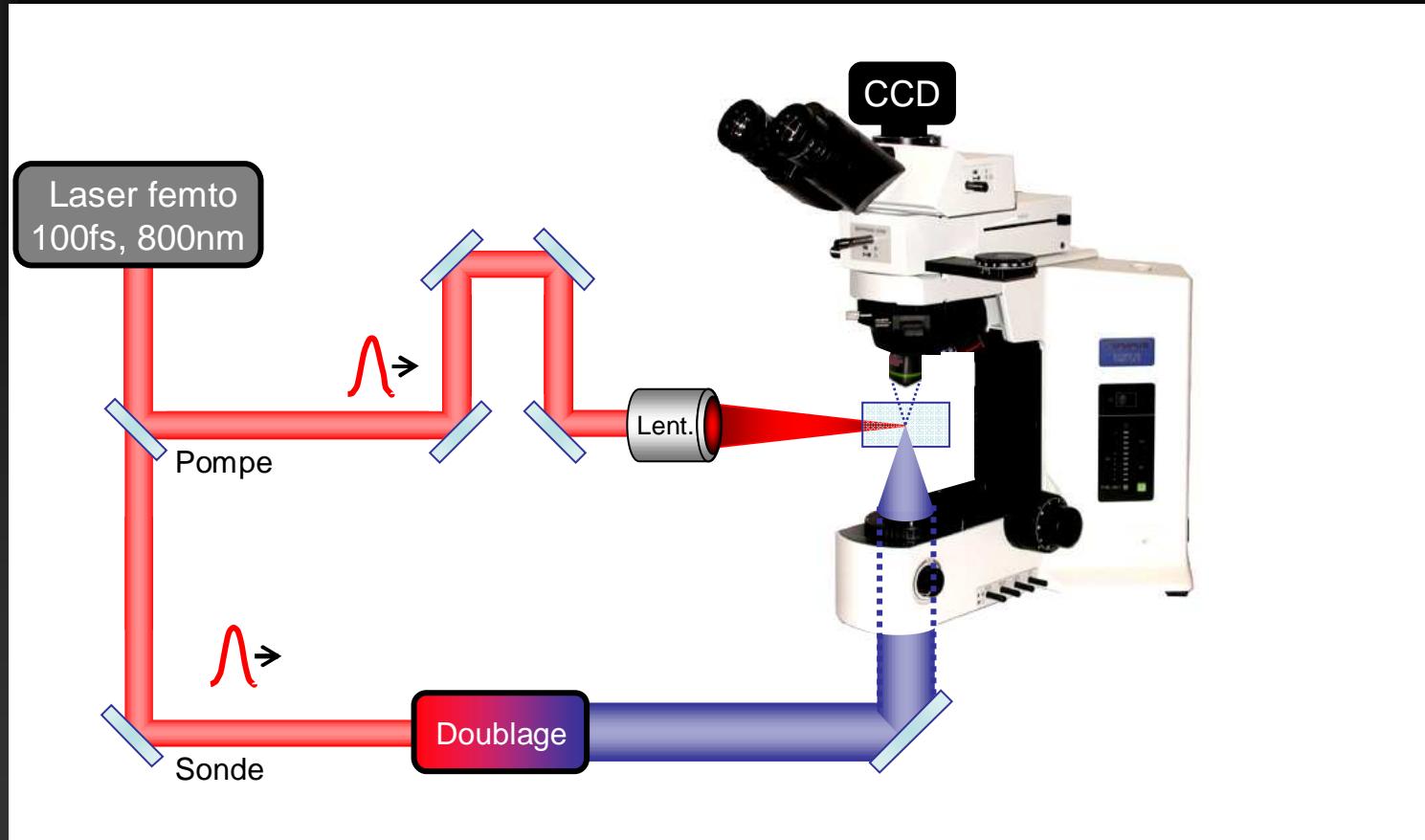
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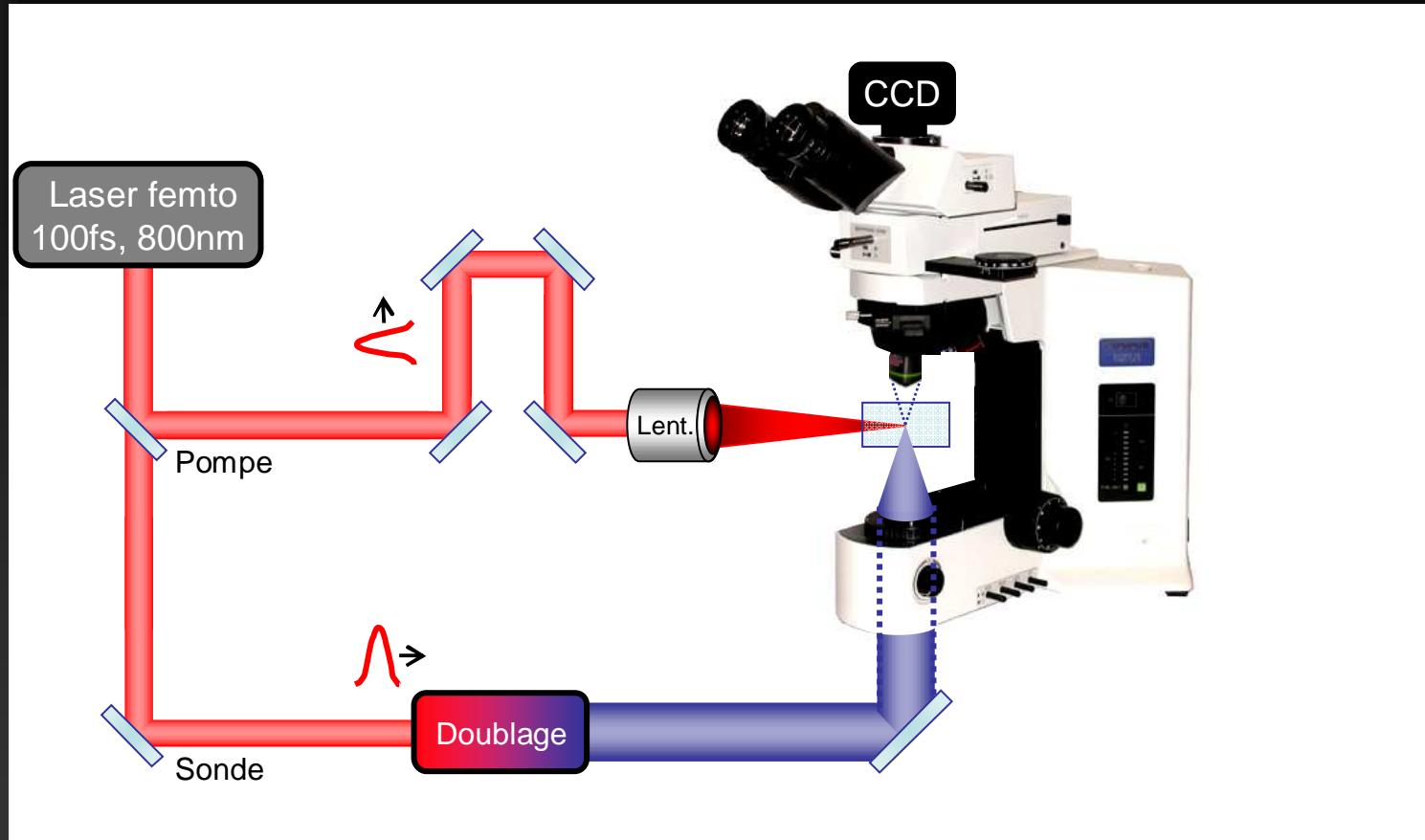
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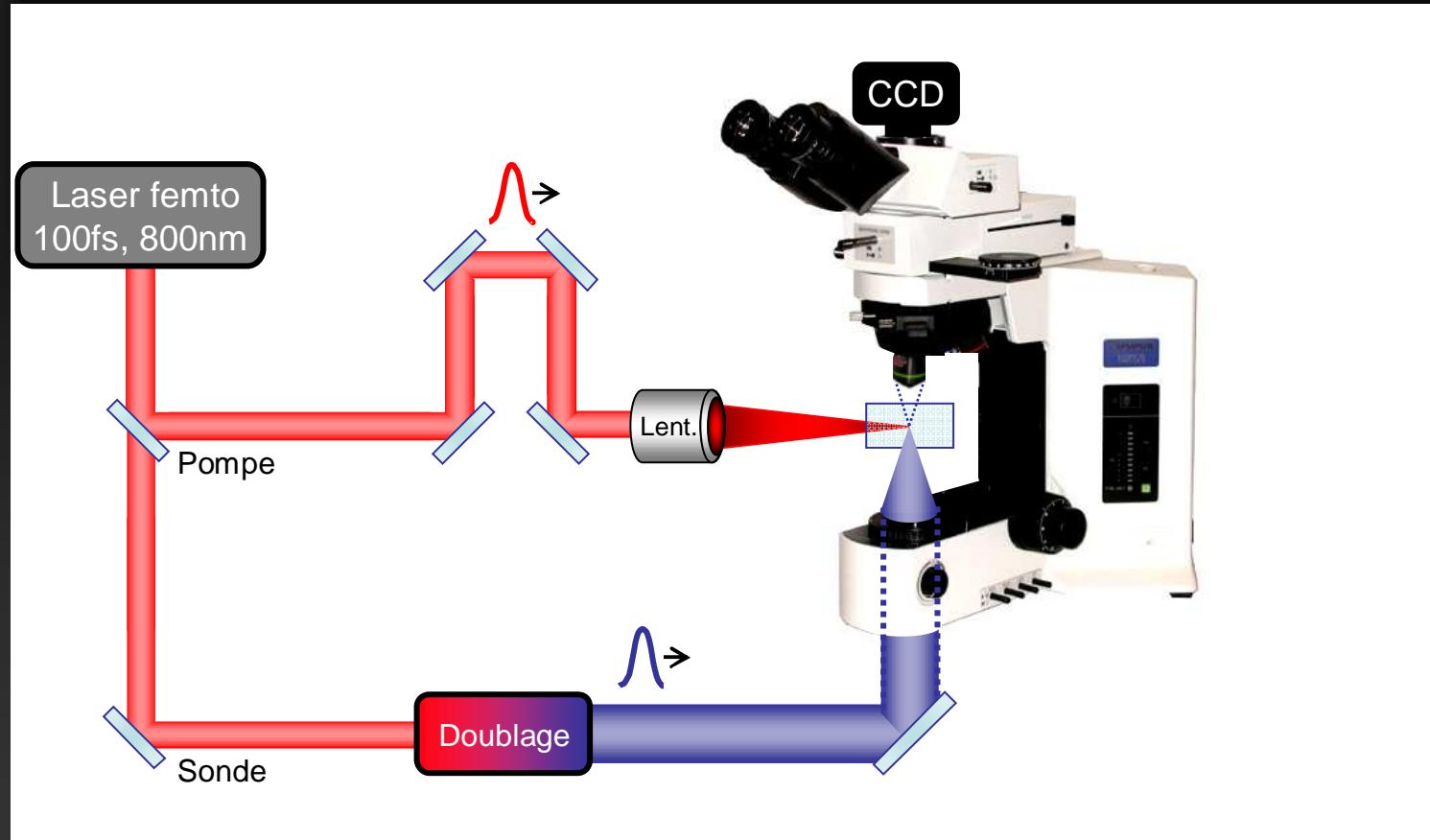
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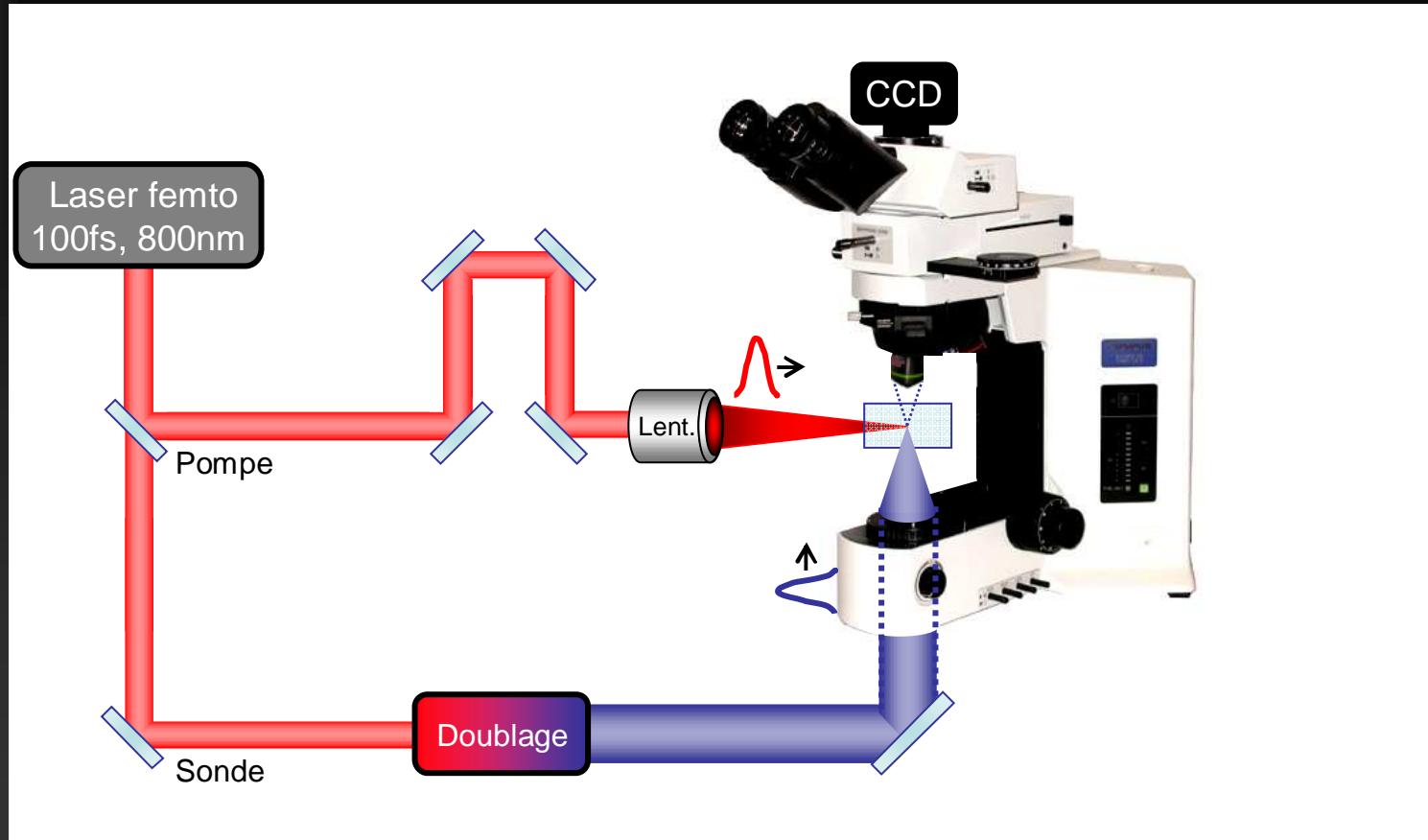
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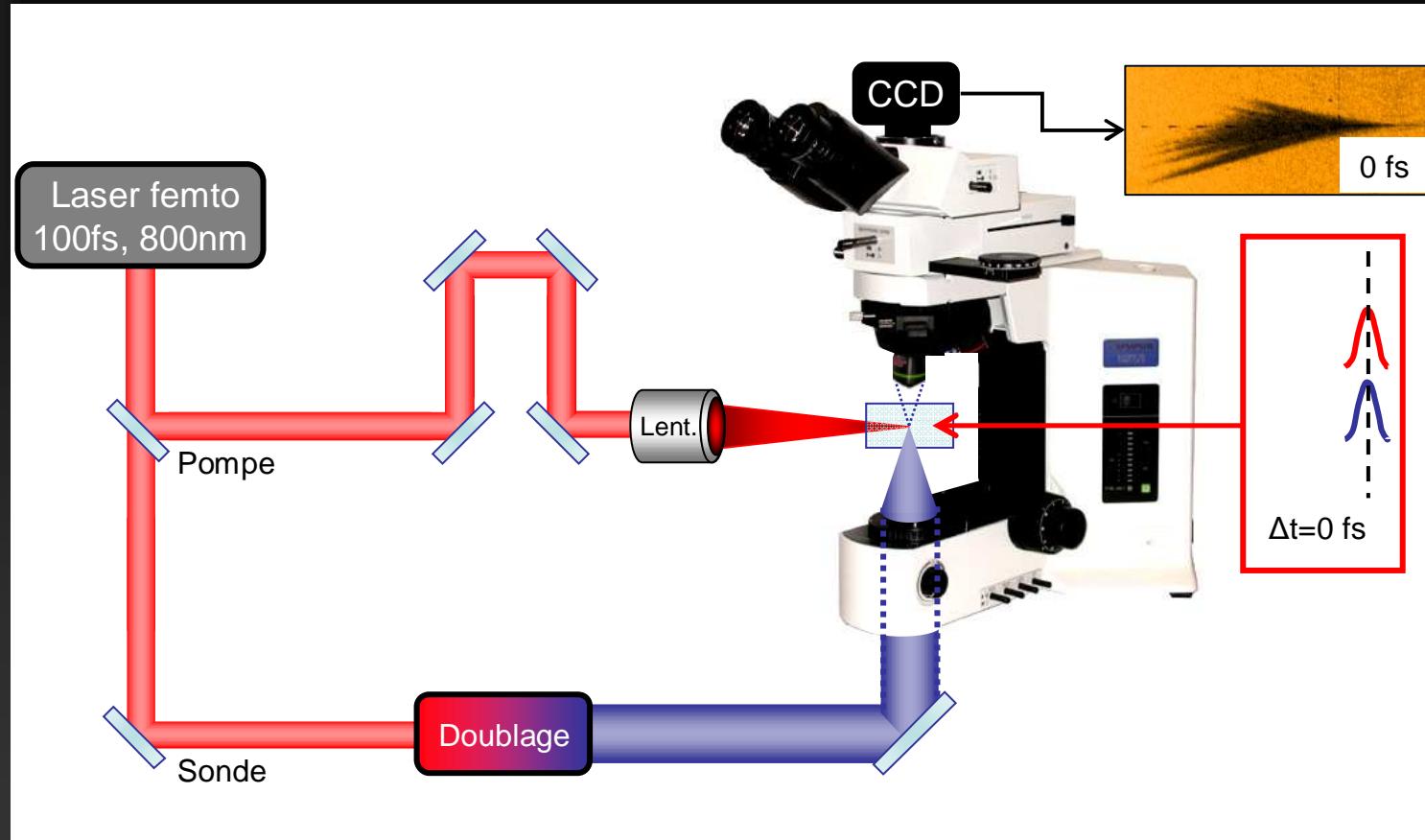
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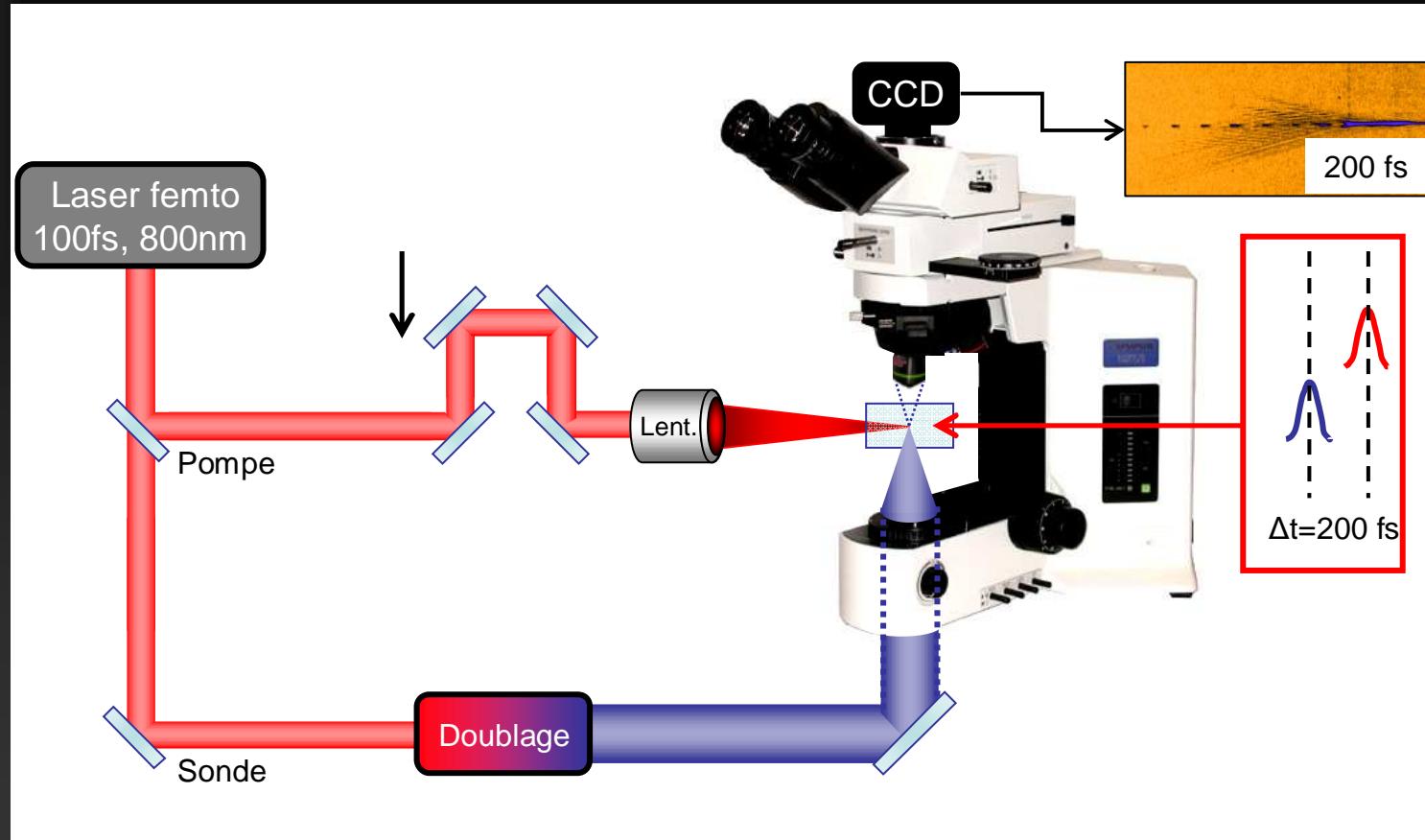
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- Physics behind?

Pump probe set up

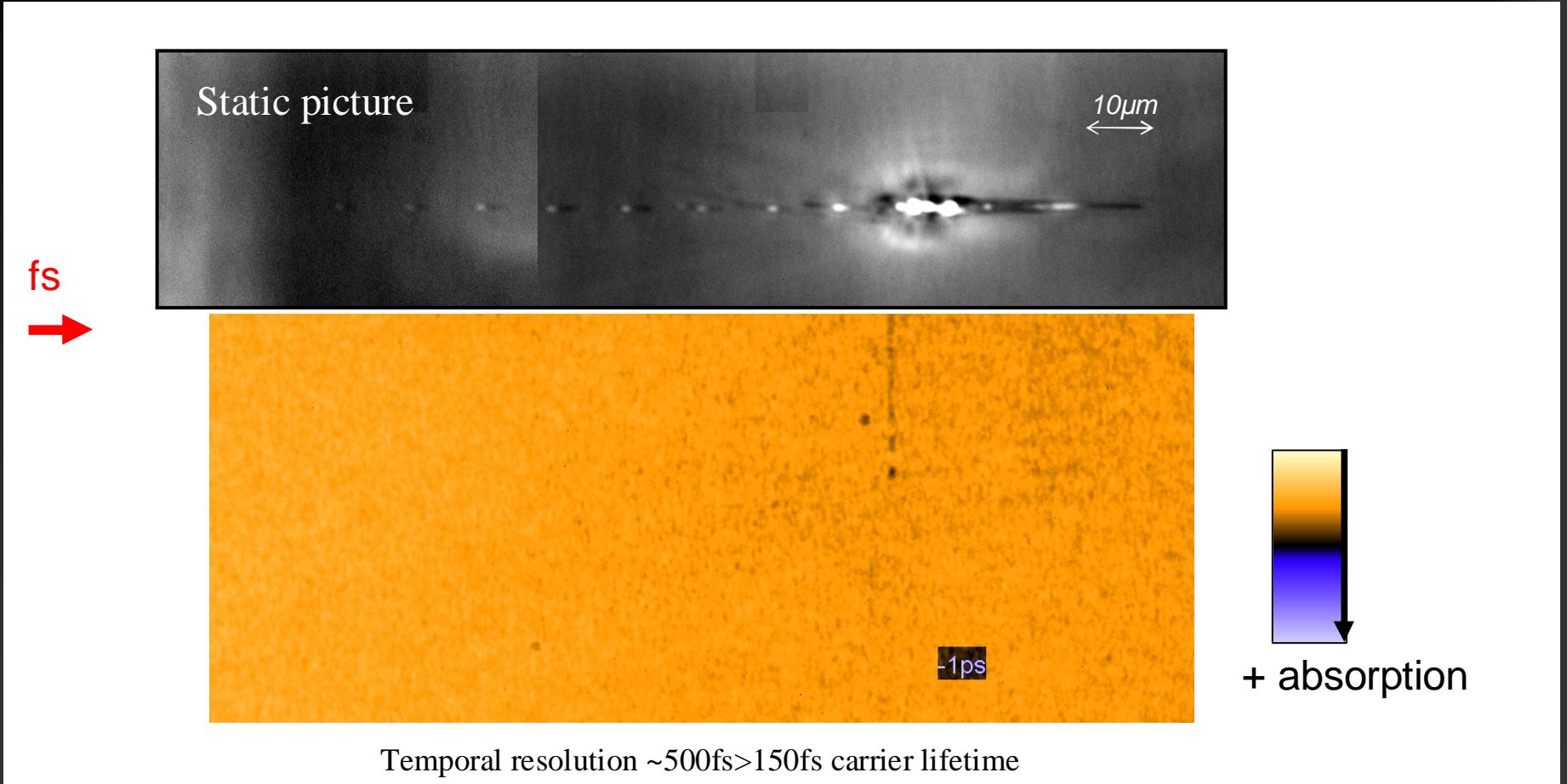
- Pictures of Electronic density



- Physics behind?

Pump probe set up

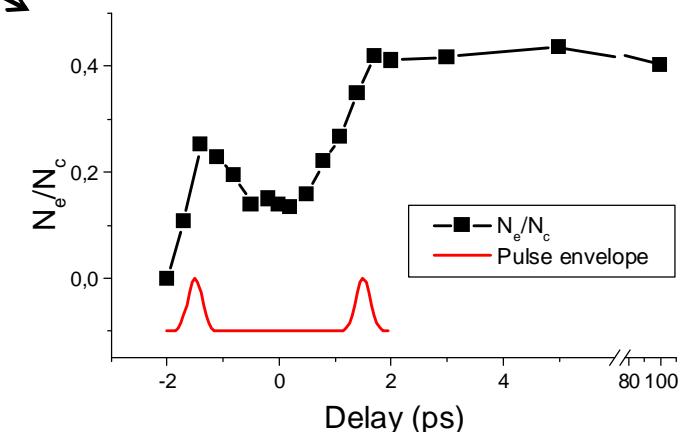
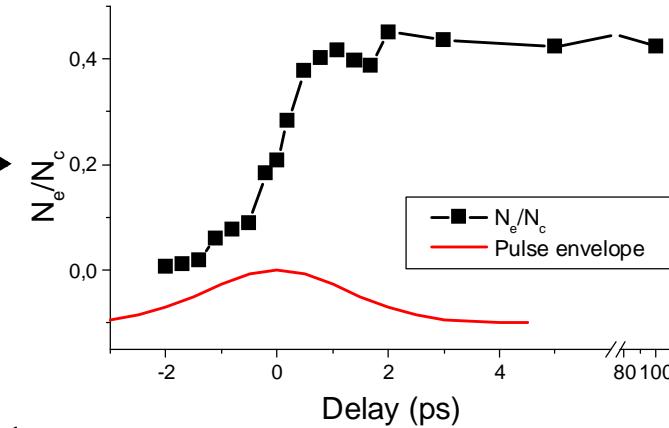
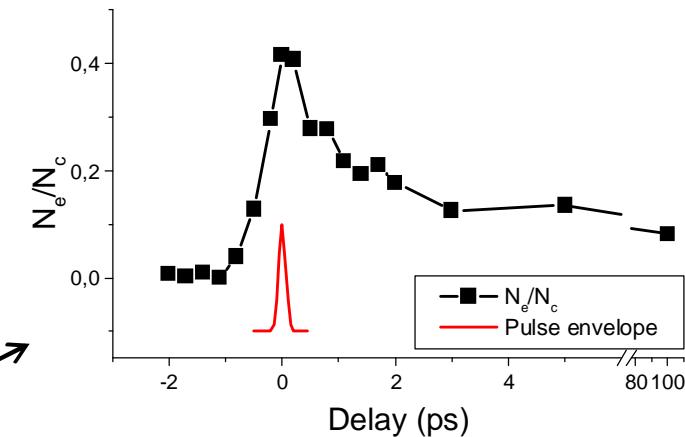
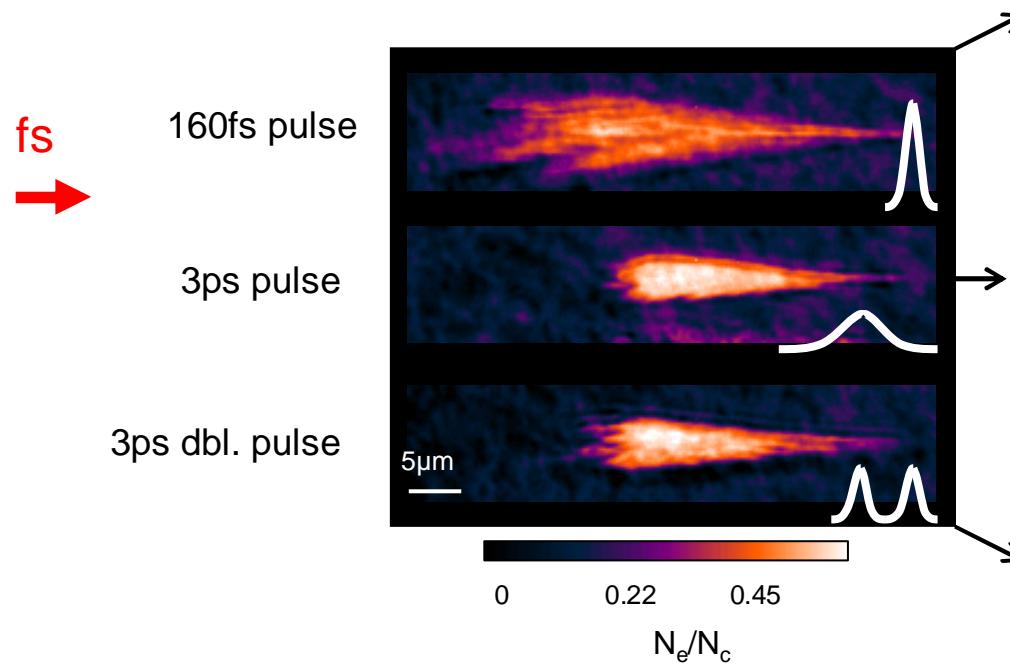
- Pictures of Electronic density



• Physics behind?

Pump probe set up

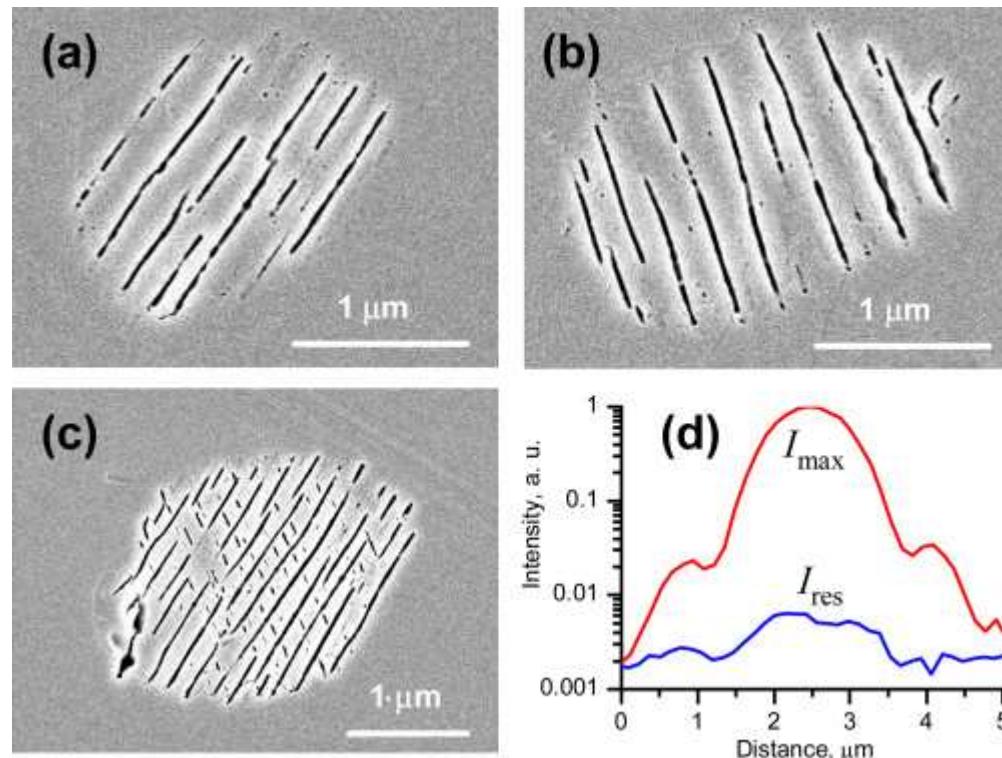
- Pictures of Electronic density
- **Control of energy deposition**



- Post scriptum

Write-rewrite

- Birefringence / Nanostructures in fused silica

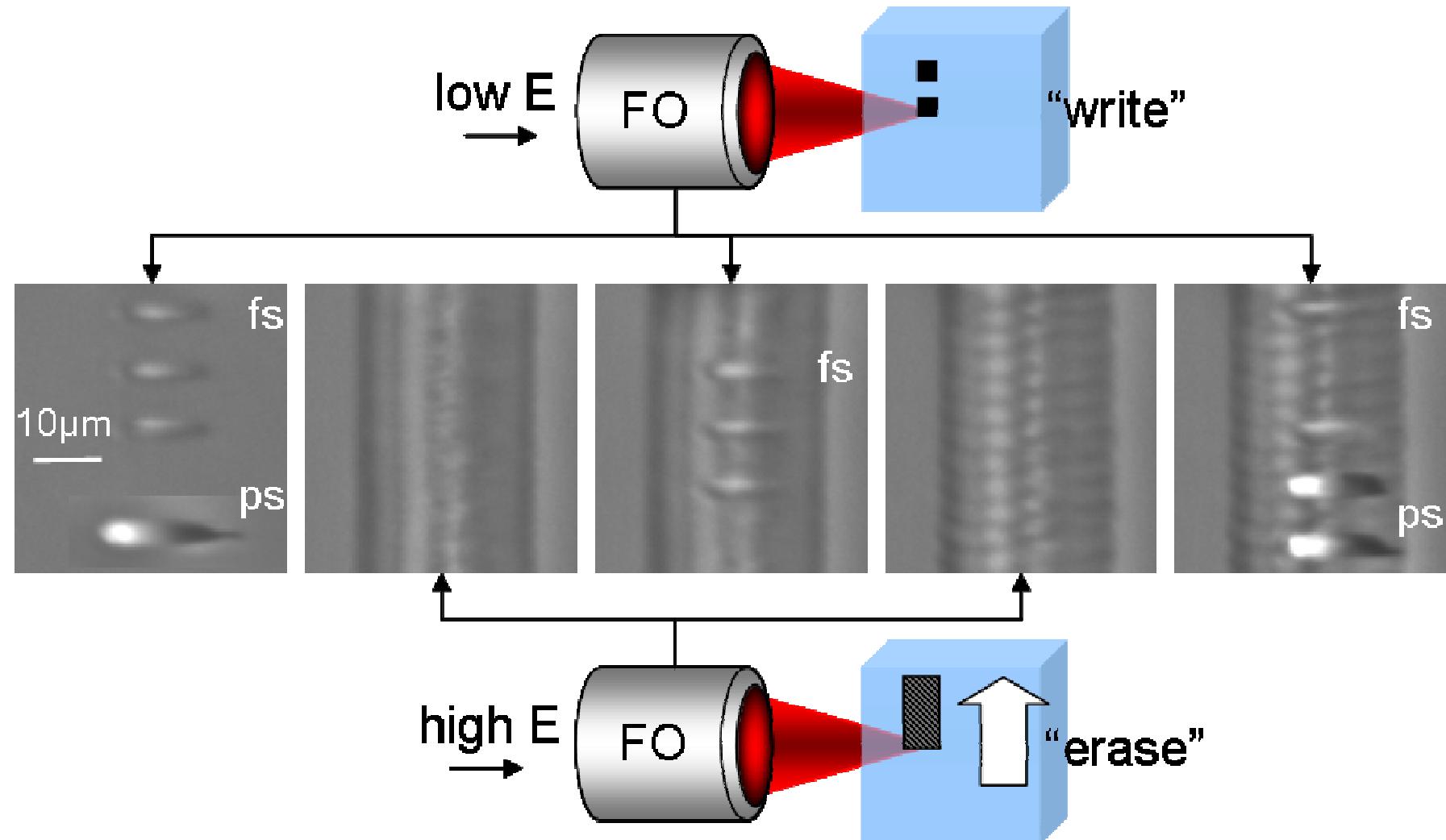


Taylor et al. Opt. Lett. (2207

- Post scriptum

Write-rewrite

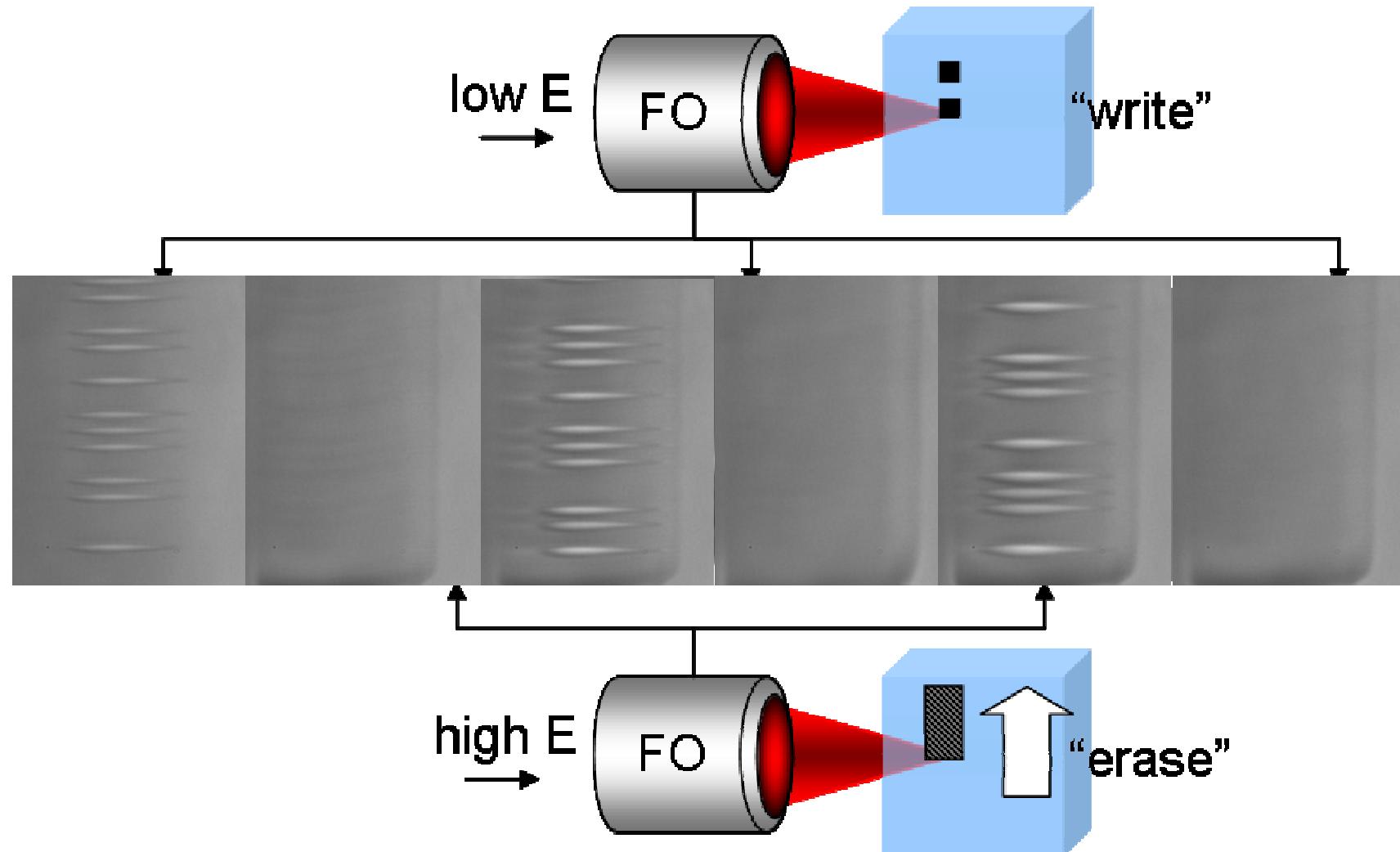
- Our results in BK7



- Post scriptum

Write-rewrite

- Our results in TeO_2



Conclusion

- **Control $E(x,y,z,t)$ → control modification**
- Parallel processing bulk & surface
- Aberration correction → deep writing
- Polarization modulation → nanostructures
- Pulse shaping → localization of energy deposition
- Simulations means (NLSE)
- Pump probe → physical insight, better control of interaction
- Write-Erase

