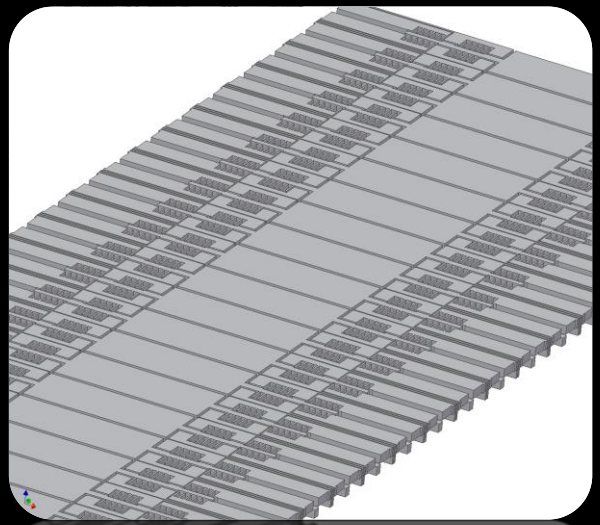
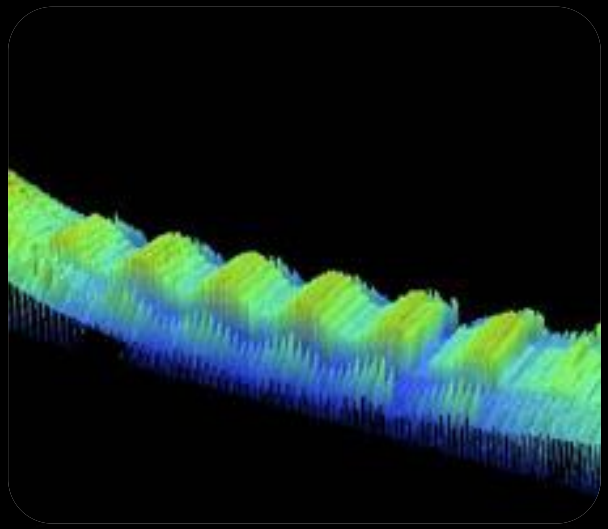
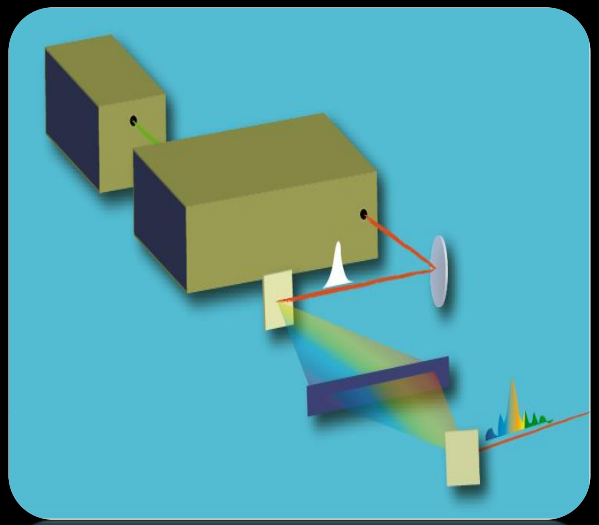
PuShME: Spectral phase and amplitude modulation from DUV to IR with a reflective MEMS pulse shaper

Luigi Bonacina

GAP Biophotonics – University of Geneva







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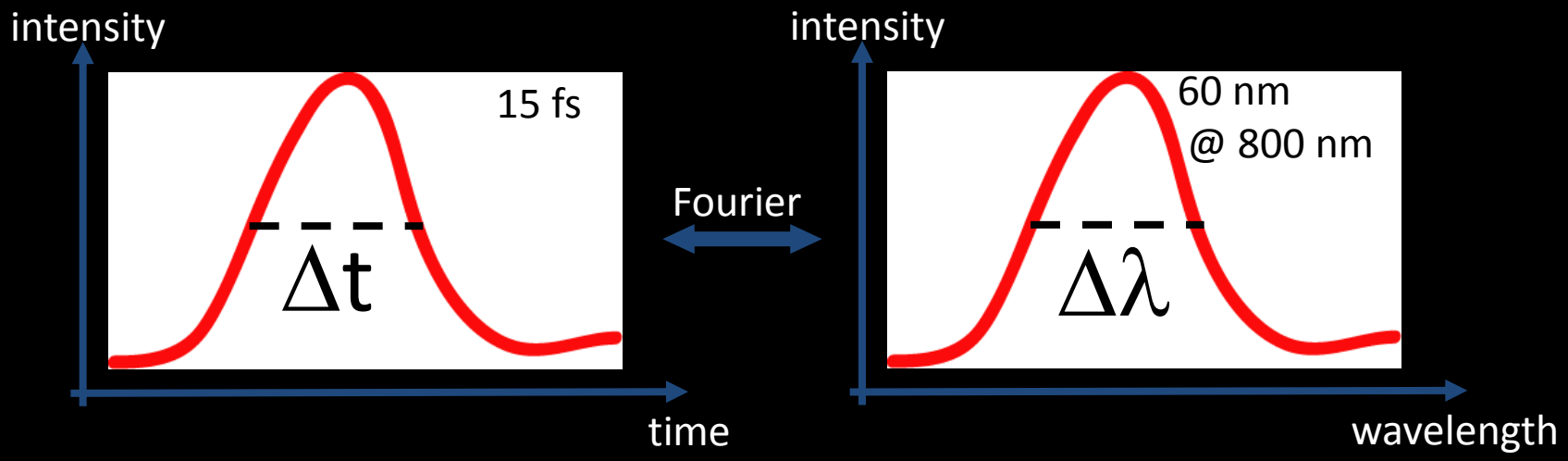
2nd Photonic Instruments Workshop

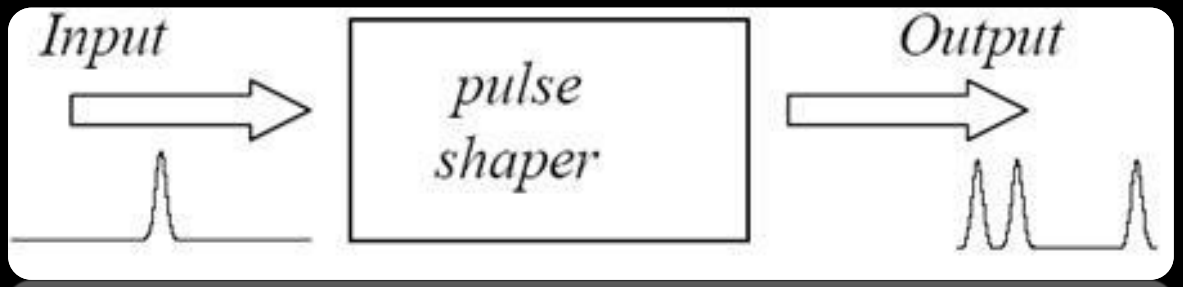
Technopark Zürich

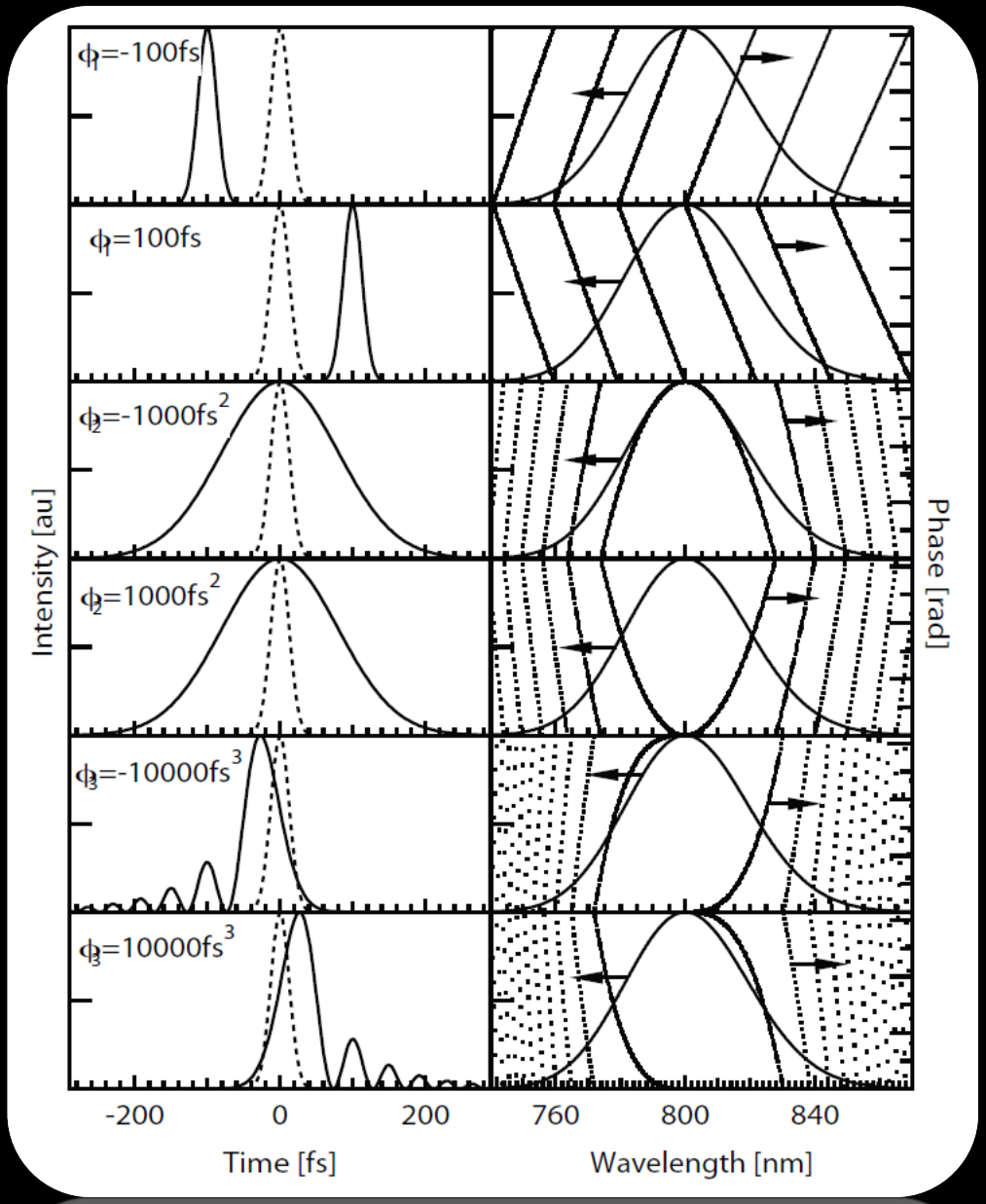
- Ultrashort pulse *temporal* shaping
- Current shaping techniques
- PuShME: a MEMS-based all reflective shaper
- Application exemples

Ultrashort laser pulses



- Time-bandwidth product ≥ constant
- @ laser output: all spectral components in phase



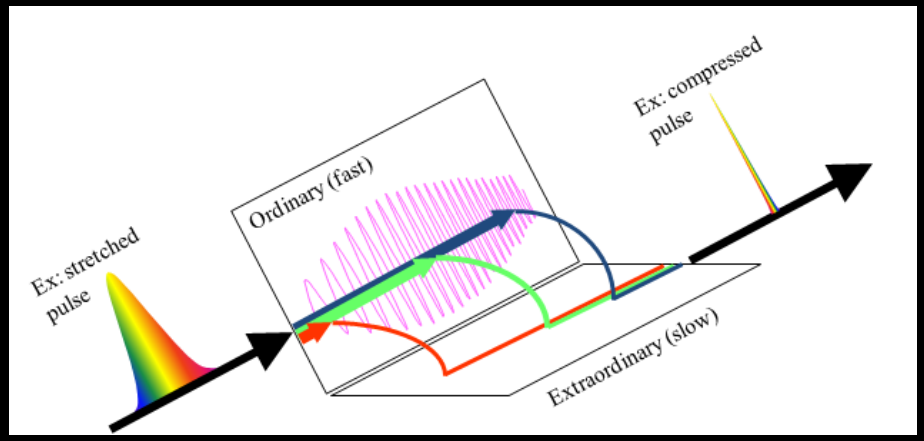


fs pulses are short…

→ shaping is performed in the spectral domain

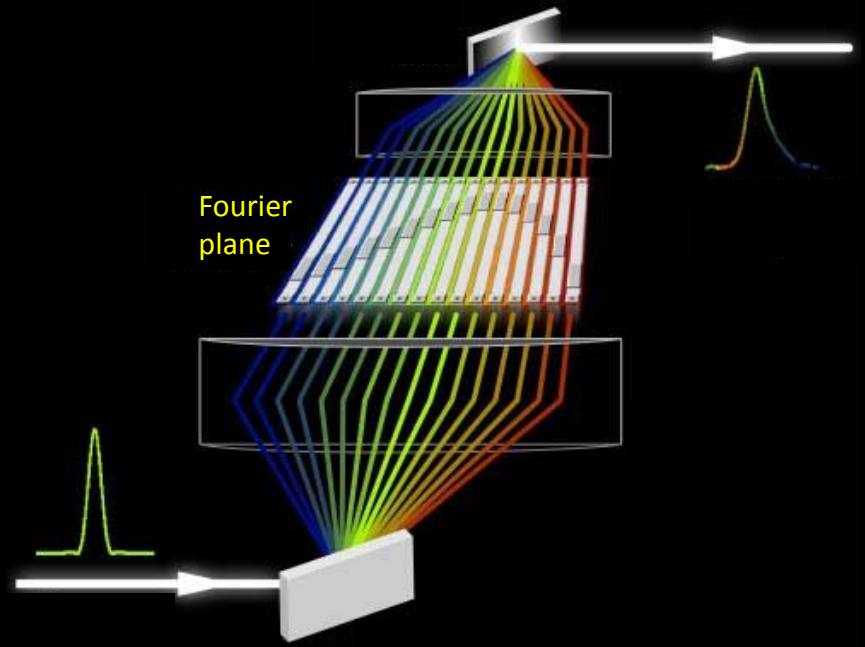
Programmable pulse shapers

- Collinear: acousto-optic dispersive filter



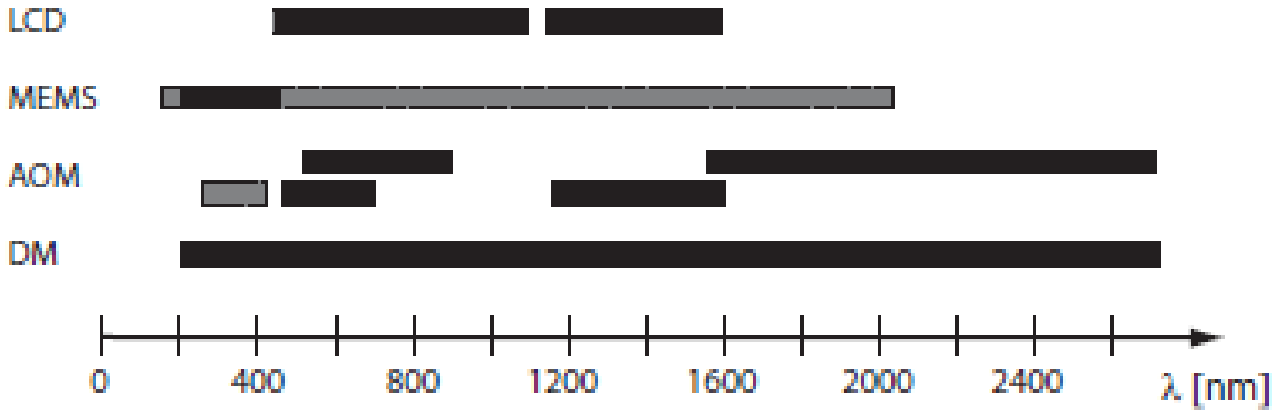
Fastlite (*Dazzler family*)

- Transverse: liquid crystal array in a zero-dispersion line



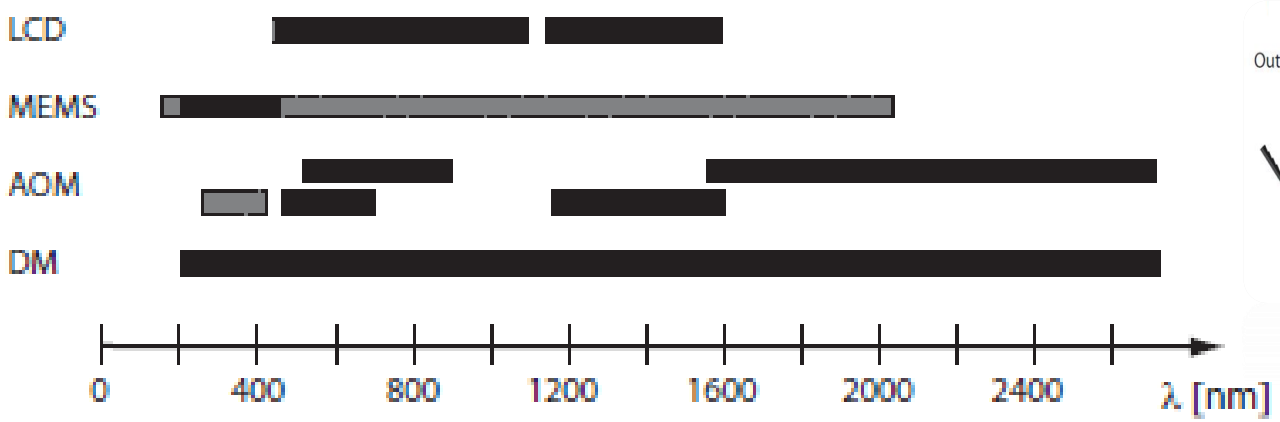
Jenoptik
CRI
Hamamatsu
Holoeye
…

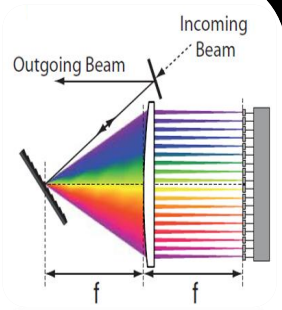
Programmable pulse shapers Specs



	Phase	Amplitude	Polarization	Indep. Parameters
LCD	■ ■	■ ■	■ ■	128, 640, 4096, 12288
MEMS	■ ■	■		100, 240
AOM	■ ■	■ ■		Several Hundreds
DM	■ ■			19, 38

Programmable pulse shapers Specs

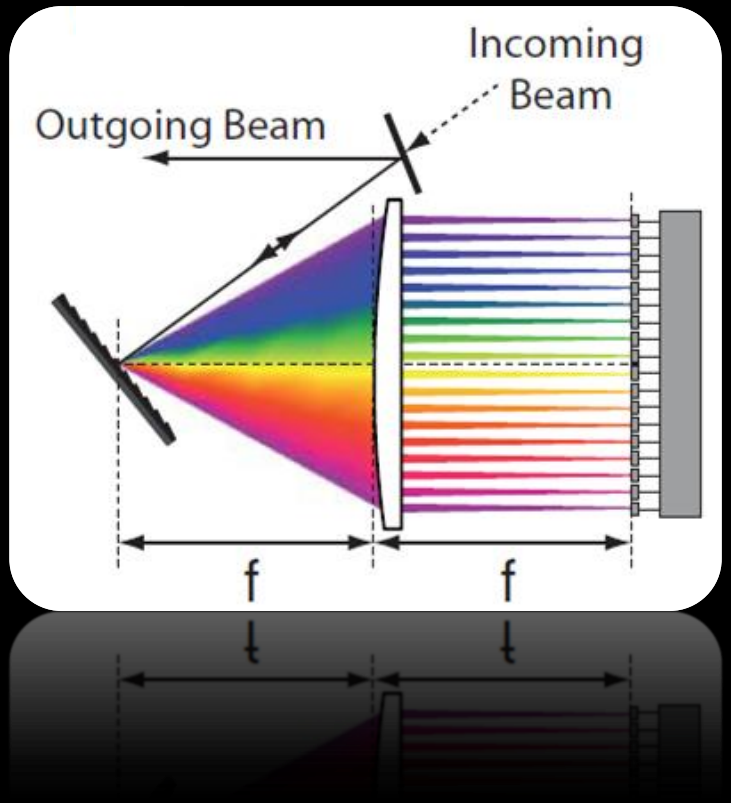




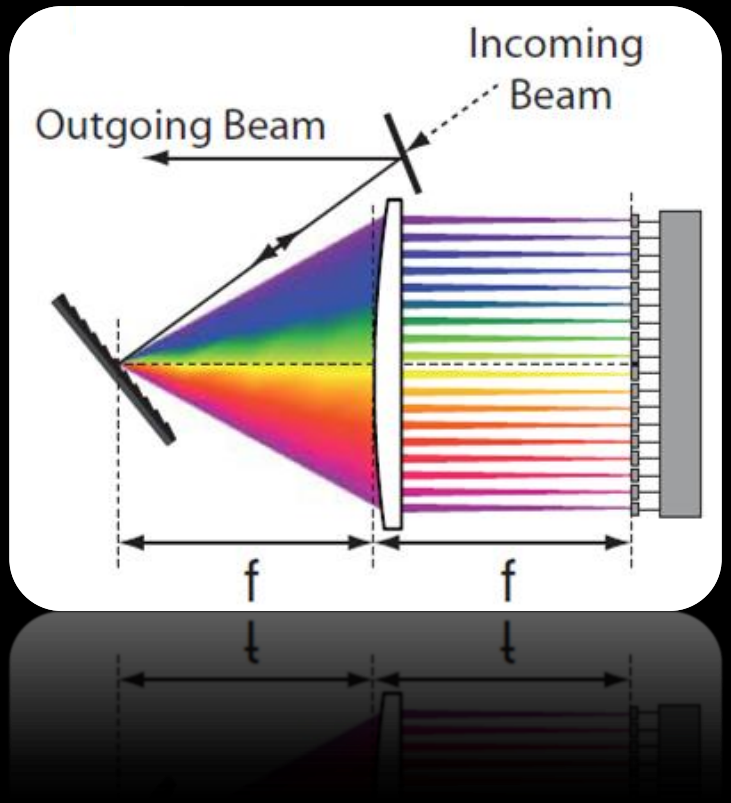
	Phase	Amplitude	Polarization	Indep. Parameters
LCD	■ ■	■ ■	■ ■	128, 640, 4096, 12288
MEMS	■ ■	■		100, 240
AOM	■ ■	■ ■		Several Hundreds
DM	■ ■			19, 38

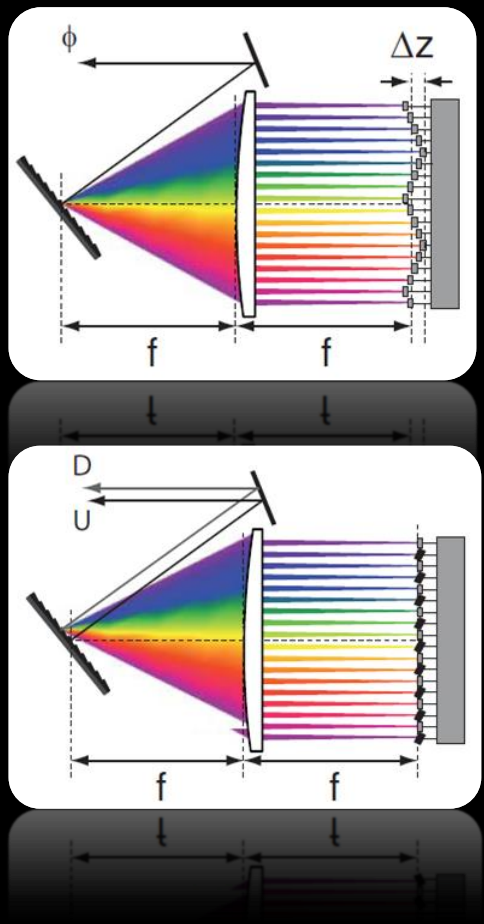
Reflective: broad spectral bandwidth, high damage threshold

Reflective pulse shaping



Reflective pulse shaping





Phase modulation (piston)

Binary amplitude modulation (tilt)

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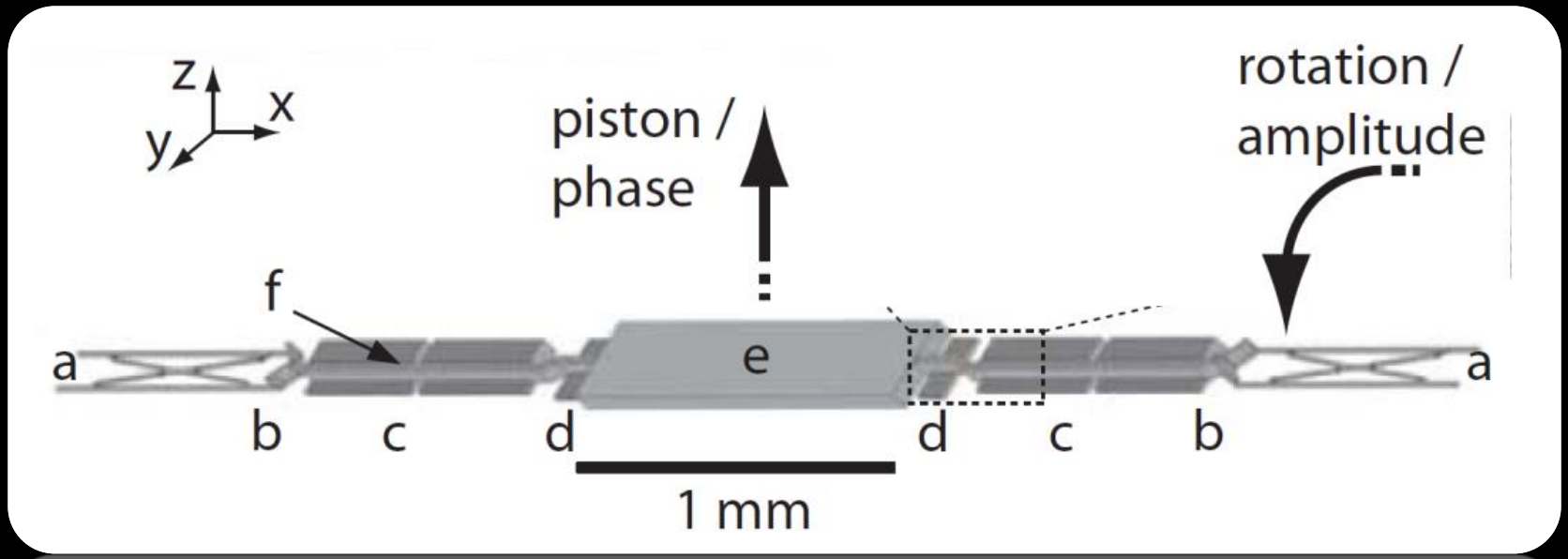
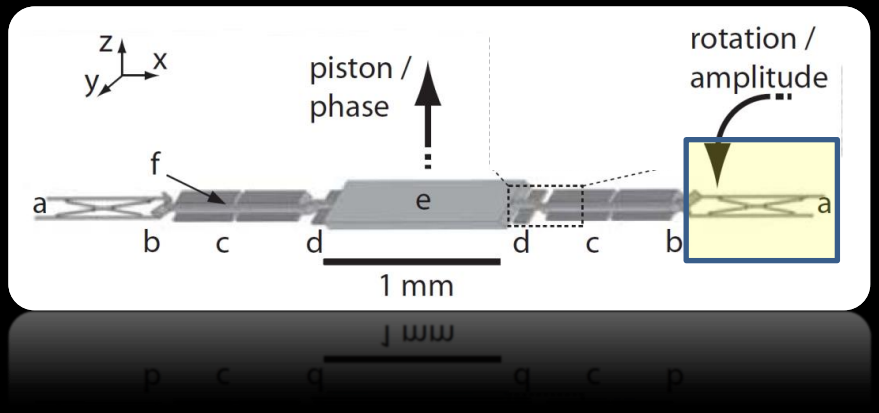
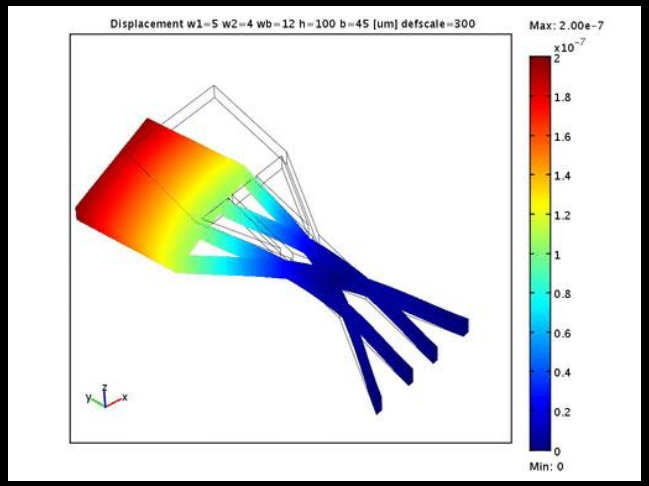
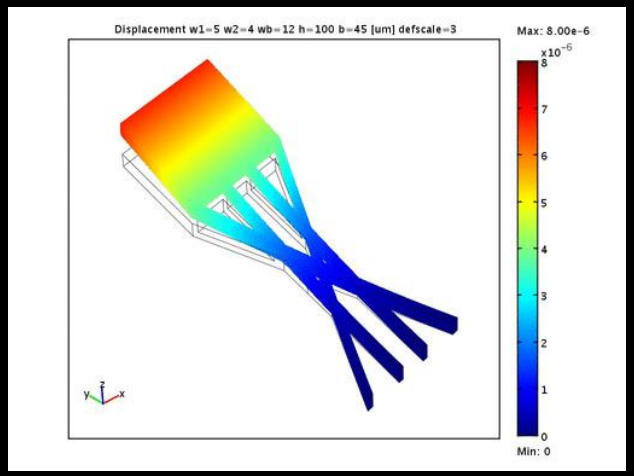
PuShME technology: mirror element

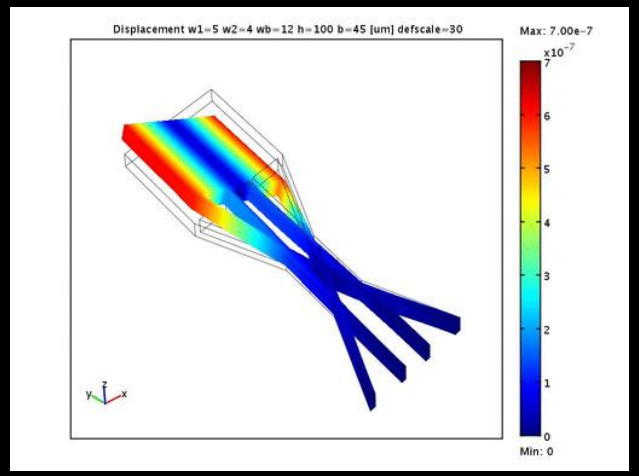


Parametric optimization of mechanical properties

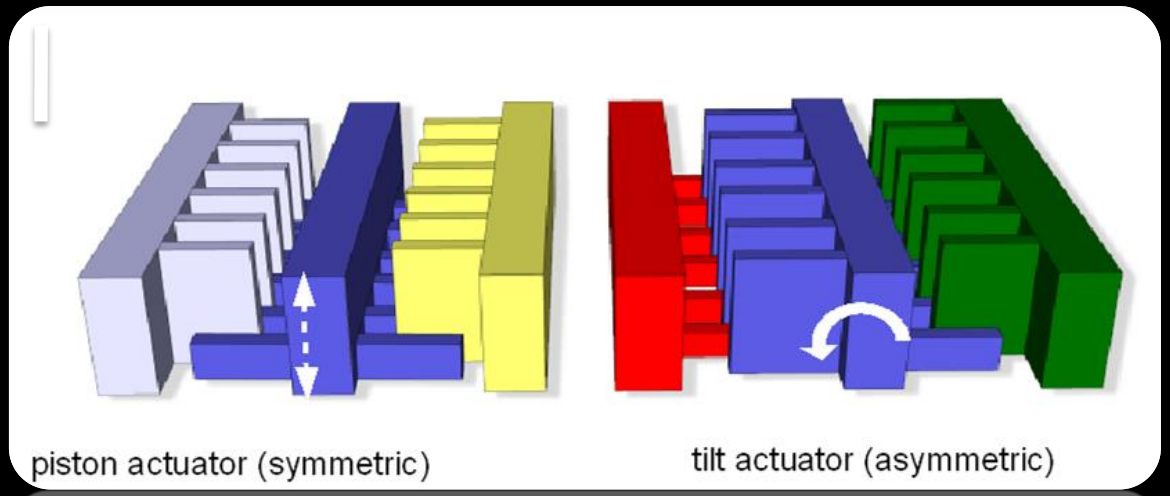


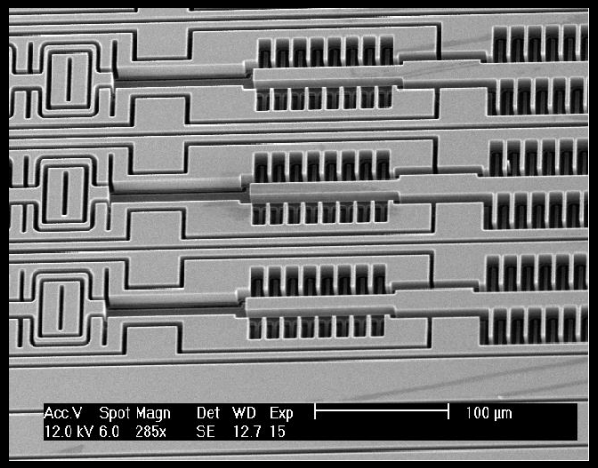






Comb-Drive Actuators

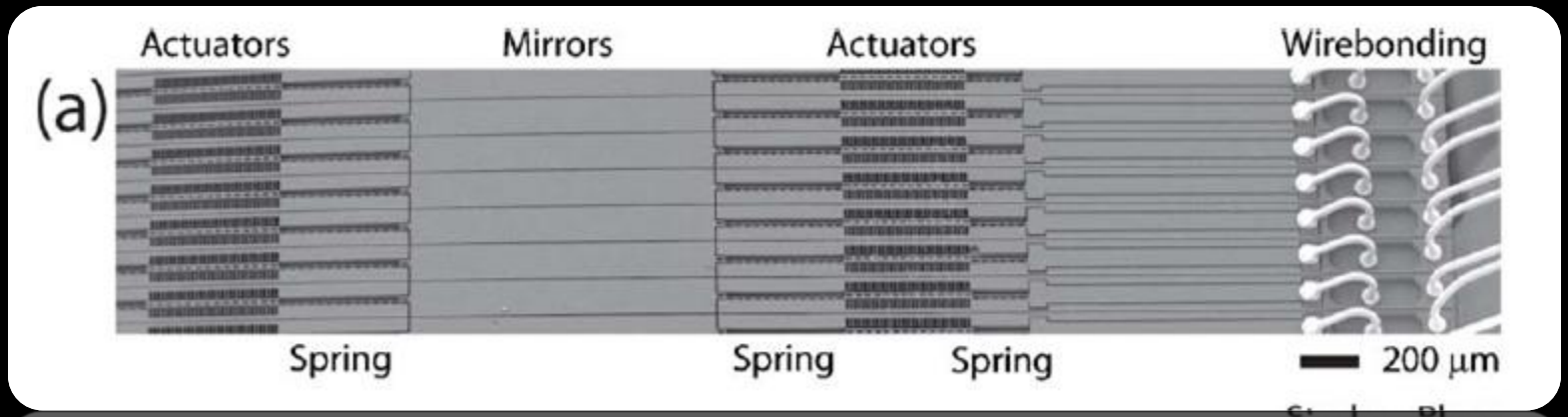


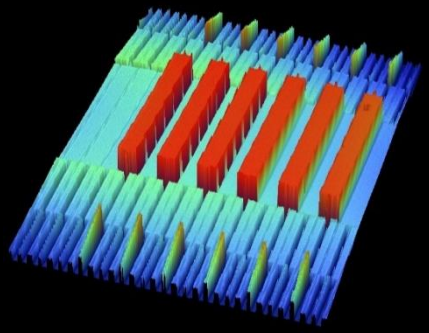


Mirror movements → Coulombic repulsion between actuator and moving part

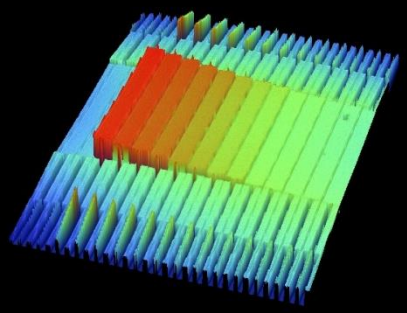
Resolution → limited by electronic encoding (and surface flatness)

PuShME: Pulse Shaper MEMS

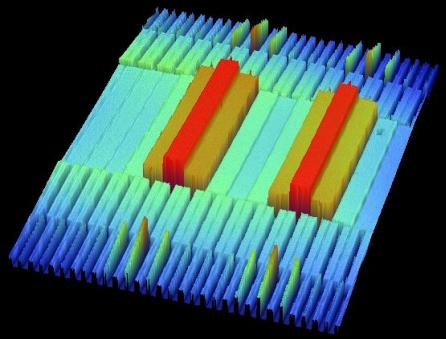




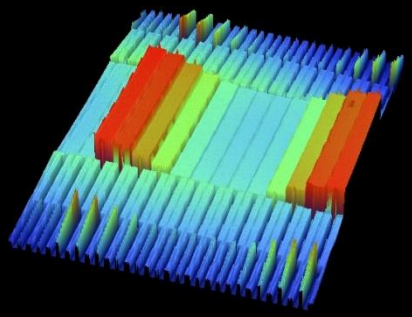
grating / π steps
→ pulse sequence



linear ramp
→ pulse shift in time

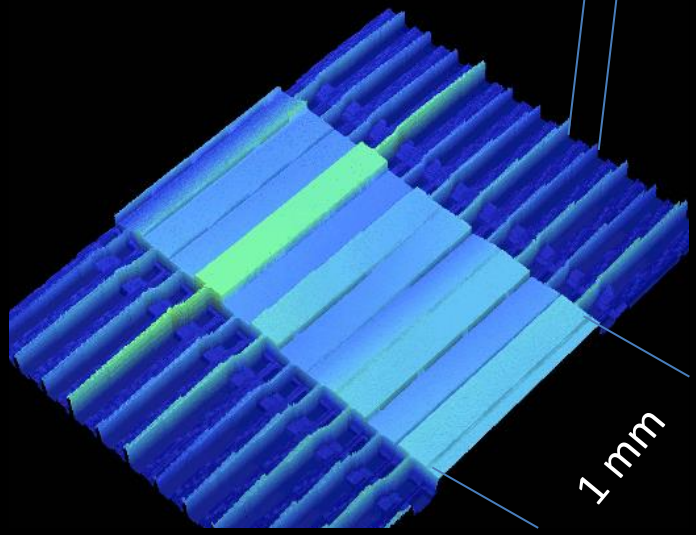


sine-modulation
→ pulse sequence
different Δt



parabola
→ pulse chirp management
(i.e. compression)

Reflective pulse shaping



Damage threshold
$5x10^8$ W/cm^2
@ 266 nm fs pulses
Al coated

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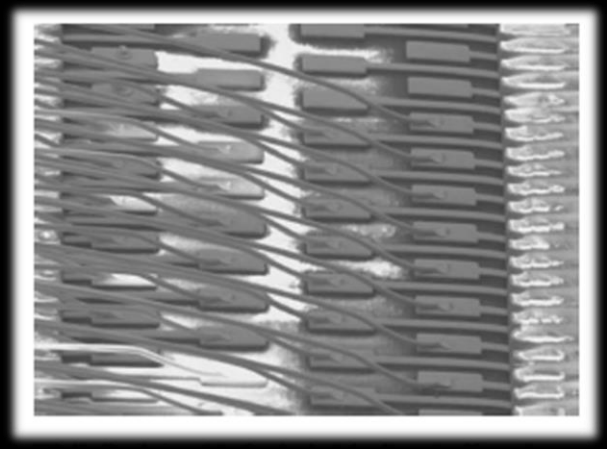
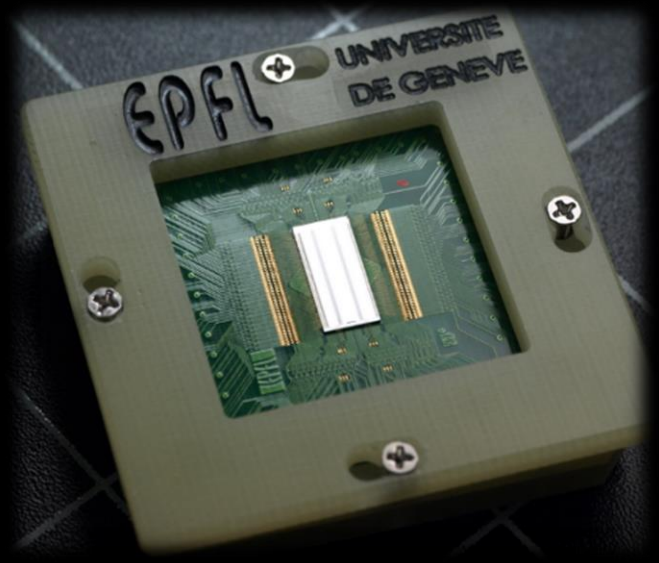
Reflective pulse shaping

Four level wire-bonding



Assembled MEMS chip



Review of scientific instruments **82**, 075106 (2011)

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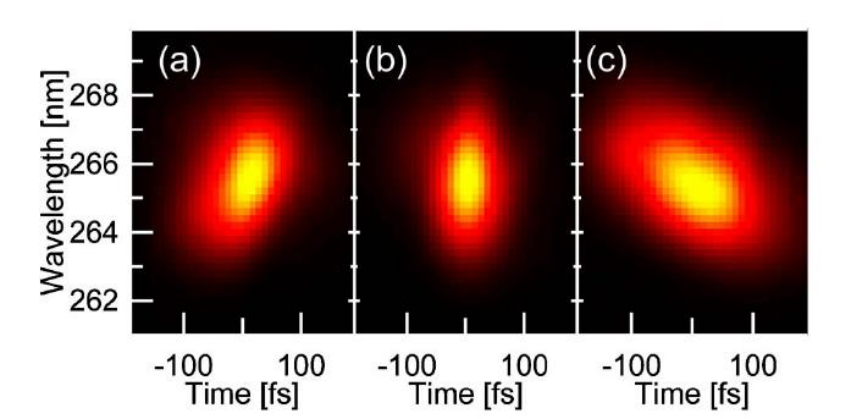
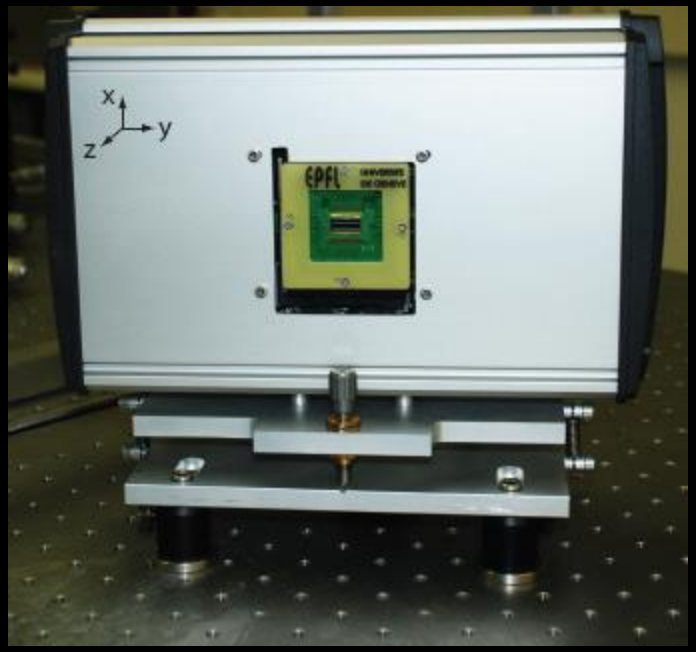
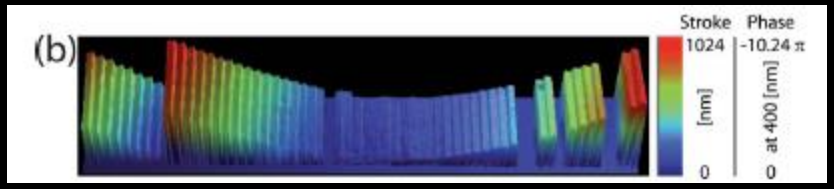


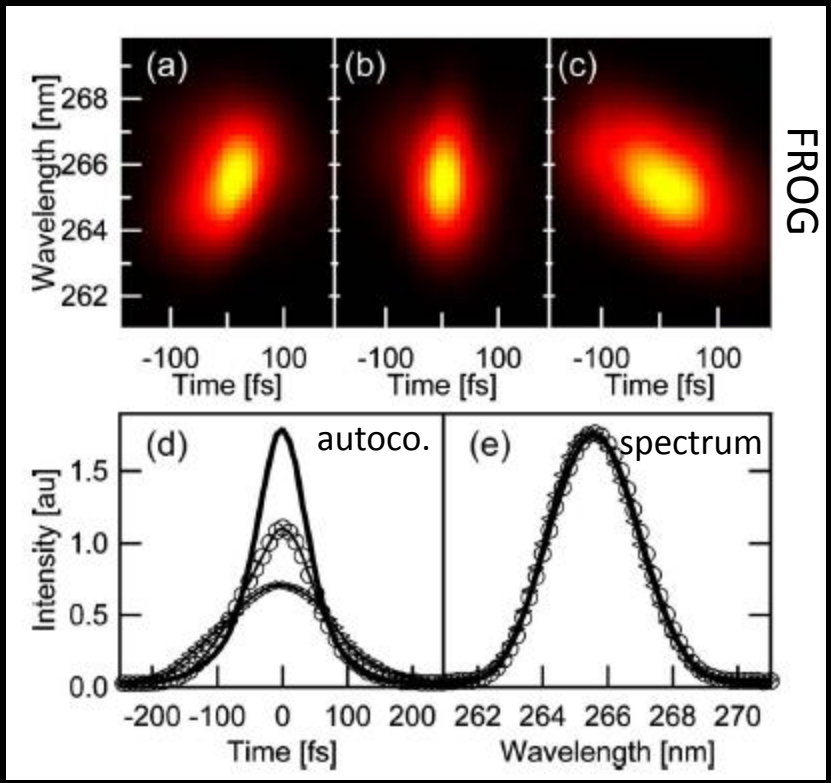
PuShME successfully employed in the NIR, vis-UV, DUV, and XUV: *pulse compression, amplitude shaping, 1D spatial chirp control, coherent spectroscopy of bio-molecules, amplitude modulation of high harmonics .*

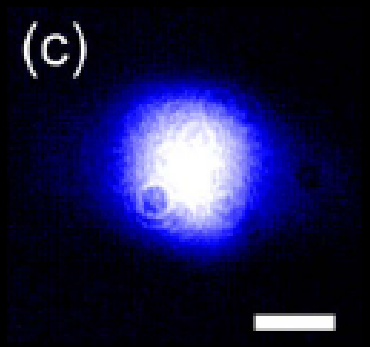
APB **111**(4), 541-549 (2013)
PCCP **14**, 9317 (2012)
Rev. Sci. instr. **82**, 075106 (2011)
Opt. Express **19**(8), 7580-7586 (2011)
Opt. Lett. **35**, 3102-3104 (2010)

PuShME: Phase-shaping





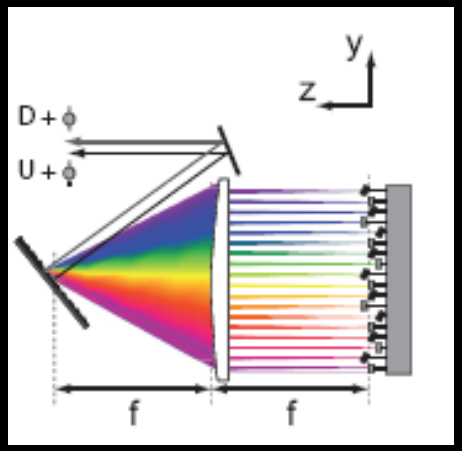


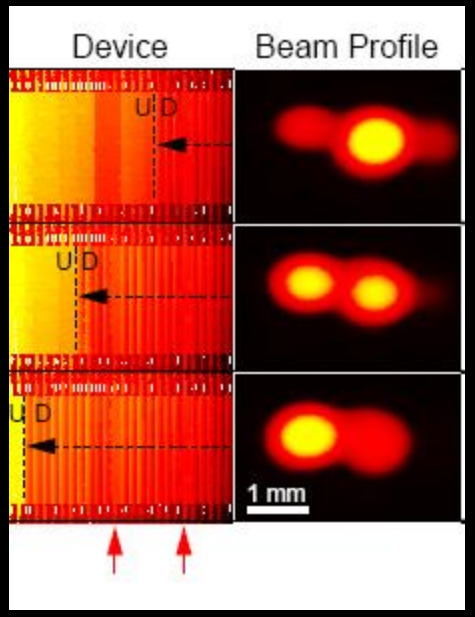


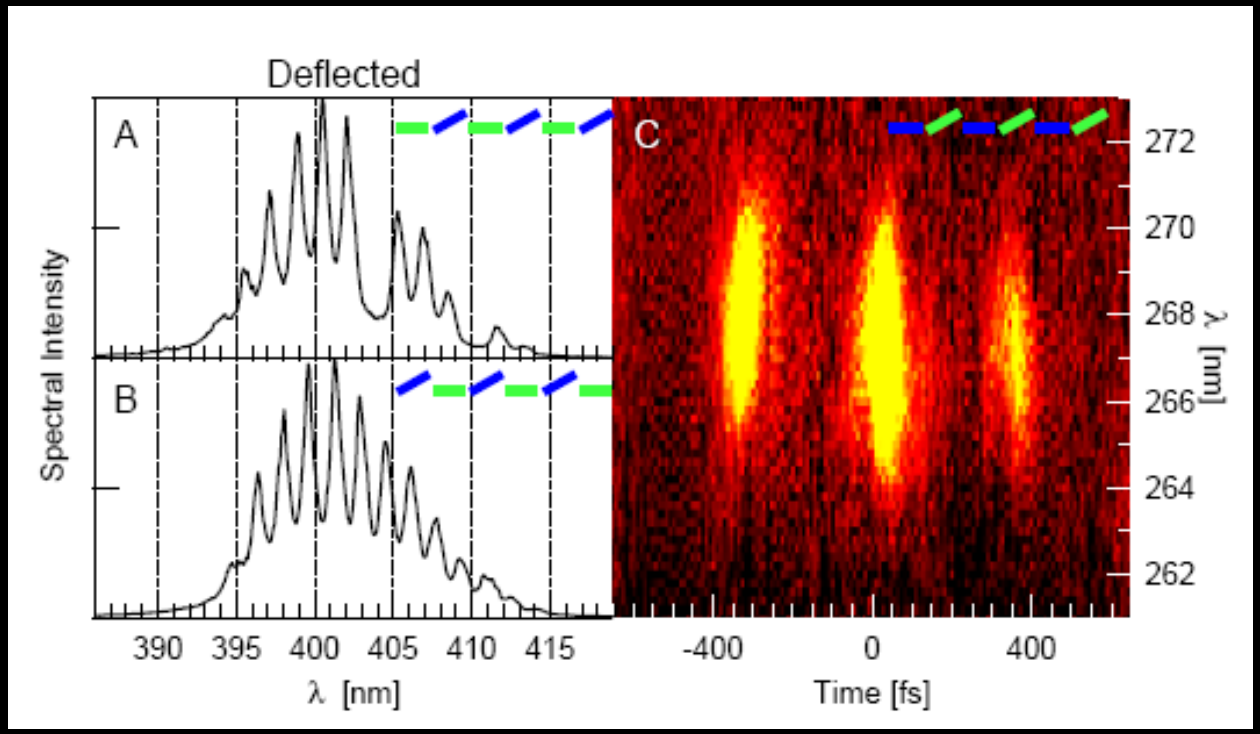
Shaped Beam profile (log colormap)

Extermann et al. Optics Express **19**(8), 7580-7586 (2011)

Phase+amplitude-1D spatial-Shaping



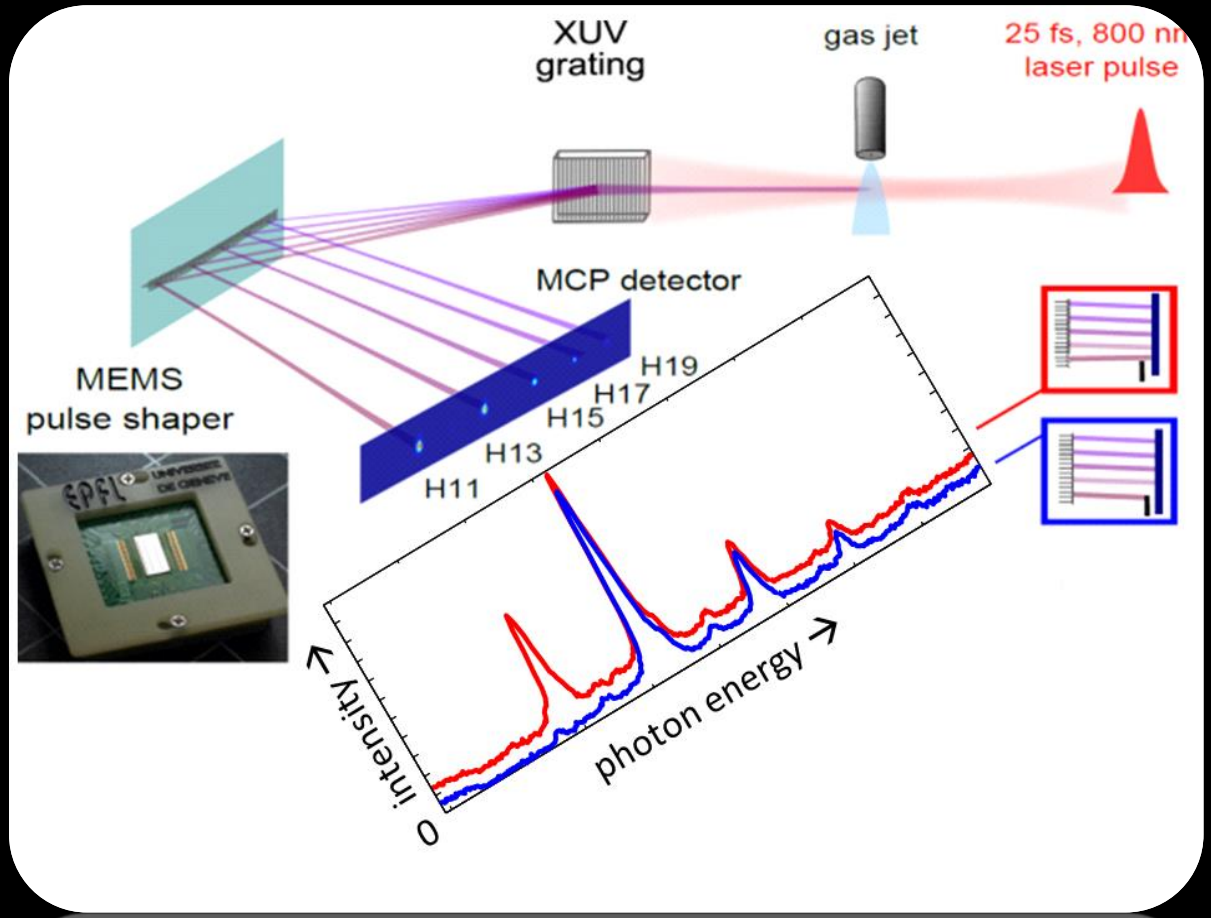




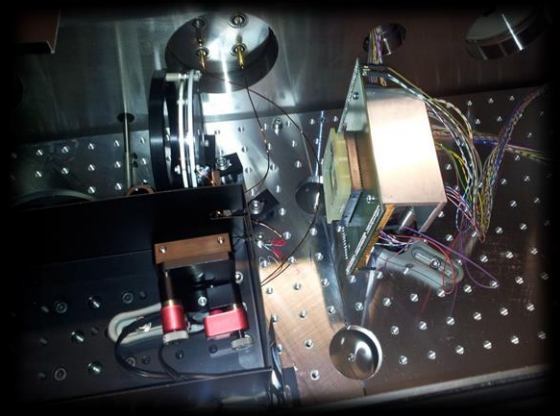
- Binary amplitude shaping
- Double beam-phase shaping
- Spatial shaping (spatial chirp, achromatic doubling, …)

Weber *et al. Opt. Lett.* **35**, 3102-3104 (2010)
Weber *et al. Rev. Sci. Instr.*, 82, 075106 (2011

Direct XUV –Pulse Shaping



In collaboration with
H. J. Wörner lab
ETH Zürich



OPTICS EXPRESS, **20** (23), 25843-25849 (2012)

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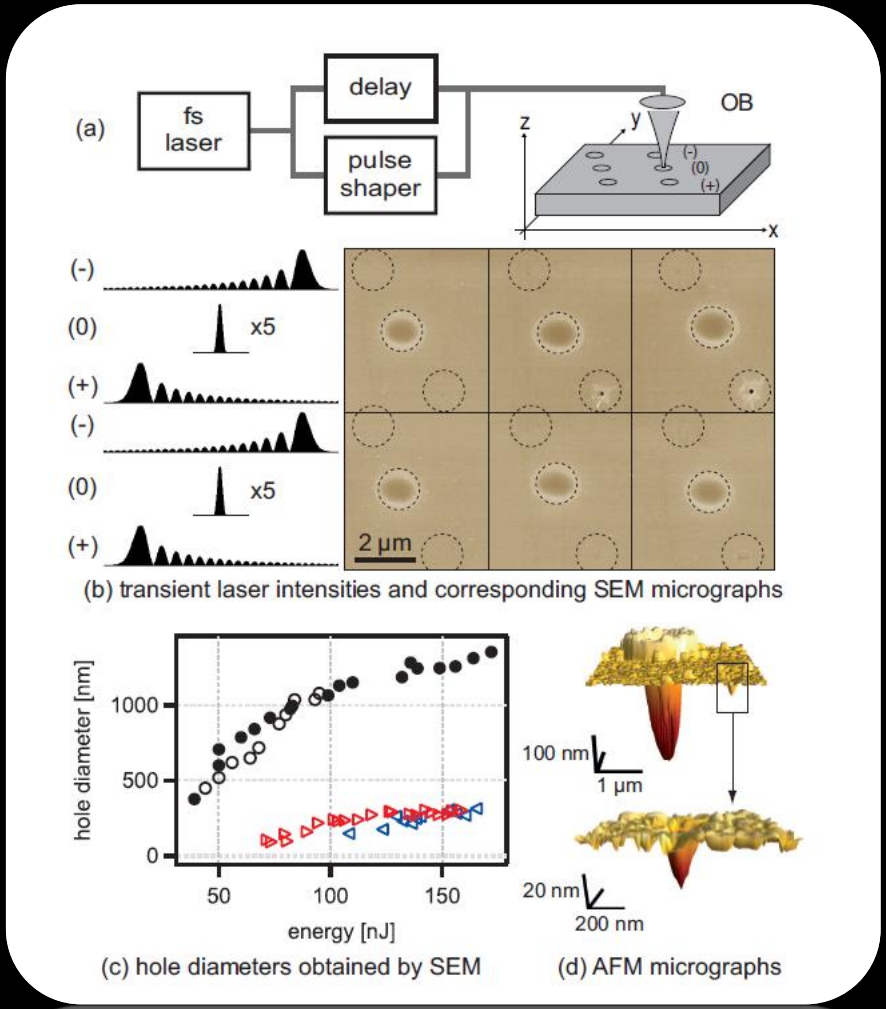
Micromachining

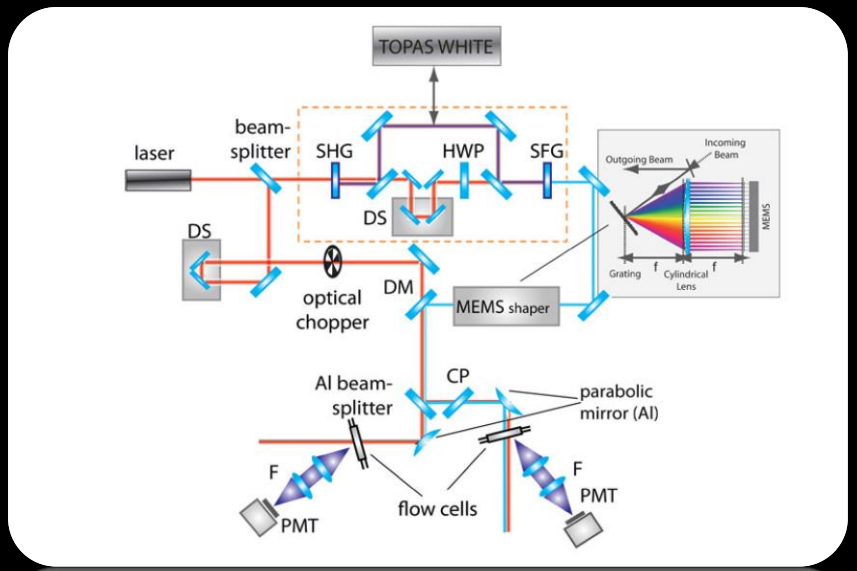


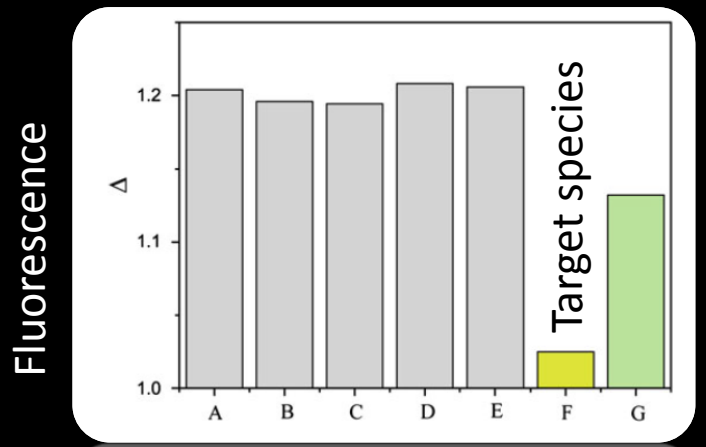
The control over pulse temporal structure can be used to optimize the aspect ratio of drilled holes in dielectrics

Baumert group, uni Kassel

DUV Coherent Immunoassays

The fluorescence response of selected bio-tracers in human serum is modulated by the phase shape of a DUV shape allowing their all optical identification





S. Afonina et al., Appl. Phys. B 111 (4), 541-549 (2013)
A. Rondi et al. Chem. Chem. Phys., 14, 9317-9322 (2012)

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- 120 independent mirrors
- Phase + binary amplitude
- Large bandwidth (XUV to IR)
- High damage threshold

UNIVERSITÉ DE GENÈVE

Optical design, electronics, measurements

S. Weber, D. Kiselev, J. Extermann, M. Moret, L. Bonacina, J.-P. Wolf*

* Now at Jenoptik

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Device mechanical design, MEMS fabrication

Y. Petremand, W. Noell, F. Jutzi, S. Lani, N. F. de Rooij

FNSNF FONDS NATIONAL SUISSE DE LA RECHERCHE SCIENTIFIQUE

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Additional slides

Spatial Chirp Control