

ADVANCED TEMPORAL CONTROL IN HIGH ENERGY ULTRAFAST LASERS DEDICATED TO MICROMACHINING AND BIOMEDICAL APPLICATIONS

SPARK LASERS

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OUTLINE

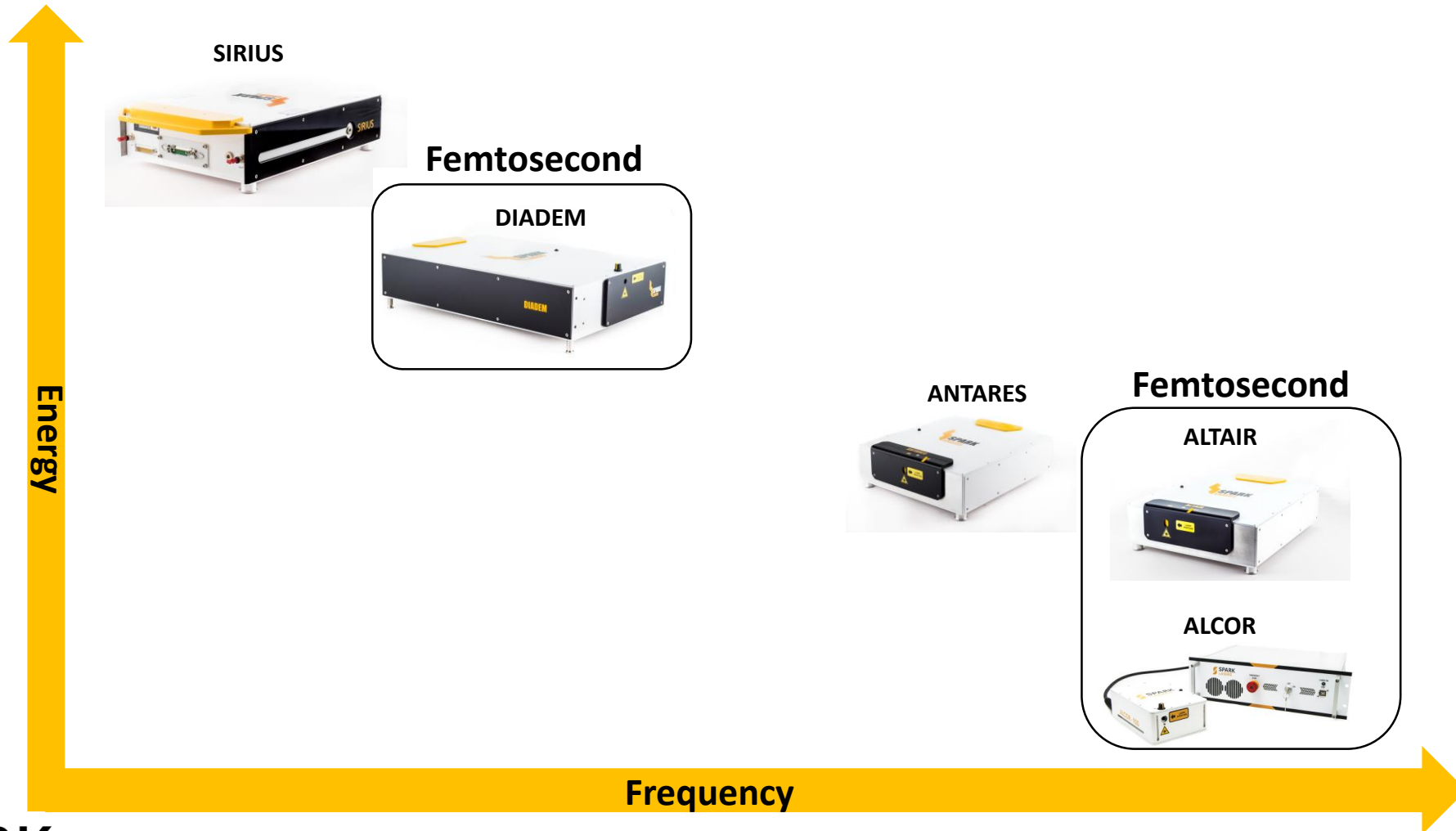
- Context
- Applications of ultrafast lasers
- Temporal control of ultrafast lasers
- Examples of applications:
 - Micromachining
 - 3D bioprinting
 - Diagnostic on high energy laser facility (LMJ)
 - Imaging in neurosciences
- Conclusion

SPARK LASERS

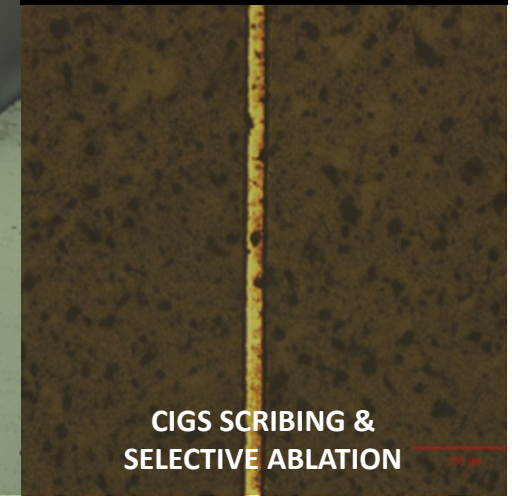
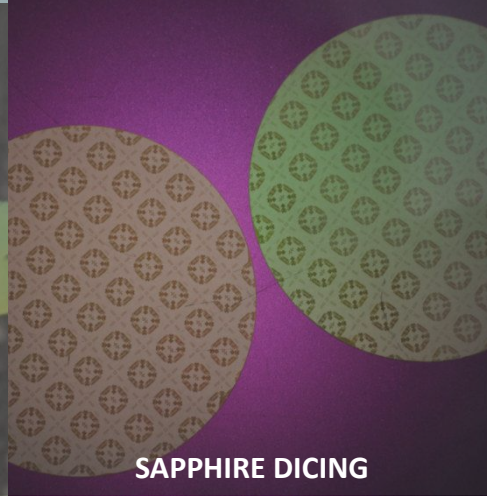
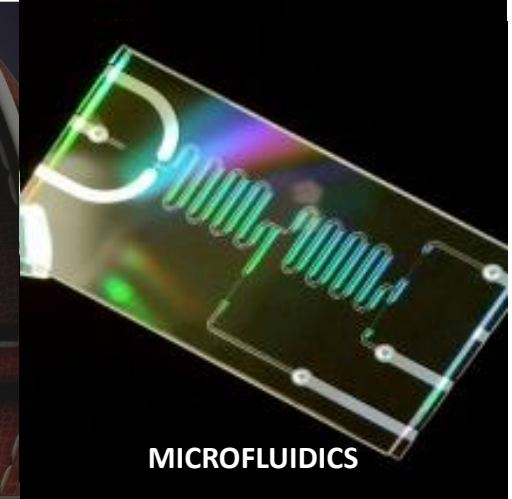
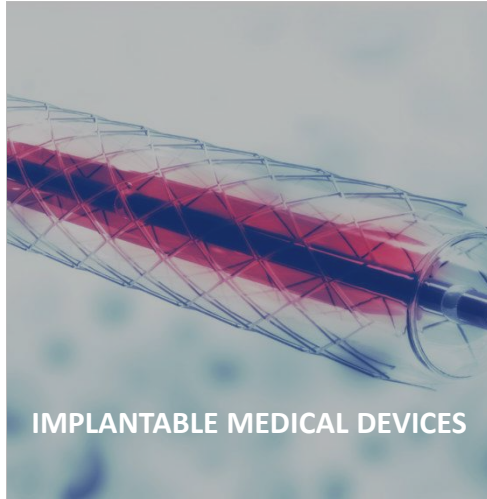
- **Ultrafast laser manufacturer : femtosecond and picosecond**
- Located near **Bordeaux, France.**
- An experienced team driven to manufacture **high quality lasers.**
- **Key international partnerships** to pursue Spark Lasers' development.



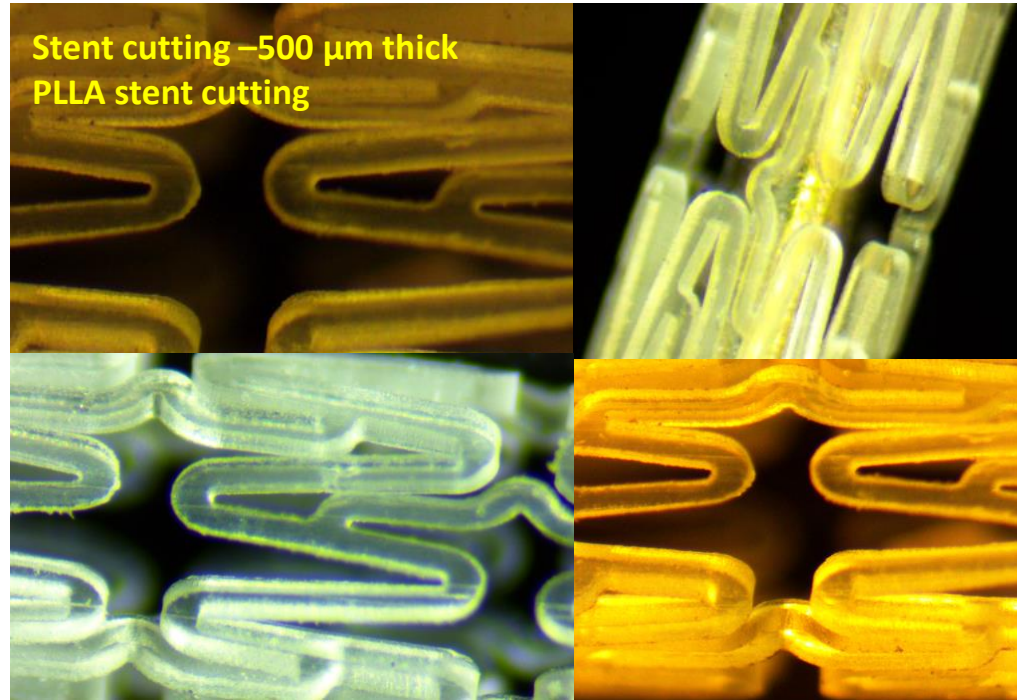
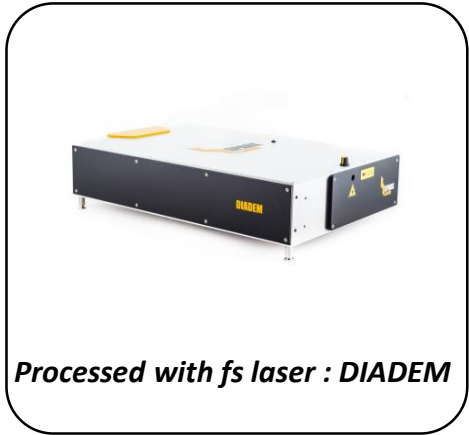
COVERING VARIOUS PULSE REGIME SPACE



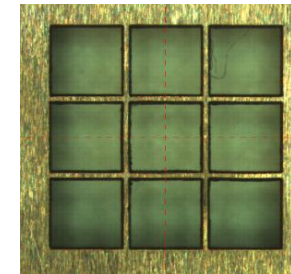
MICROMACHINING APPLICATIONS



EXAMPLE OF APPLICATIONS, PROCESSED WITH FEMTOSECOND LASER DIADEM



Inner glass
white marking



Matrix of 50 μm x 50 μm
ETCHING of 150 nm Ag
layer on PMMA

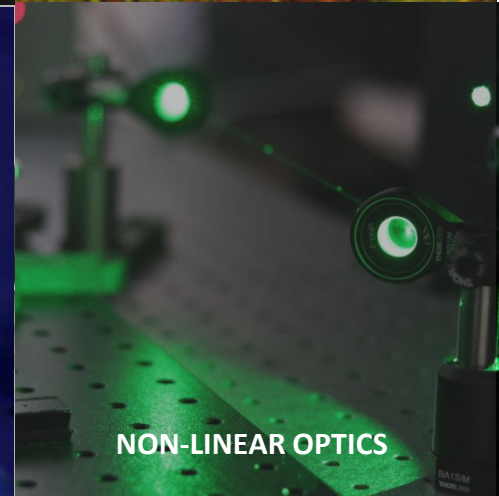
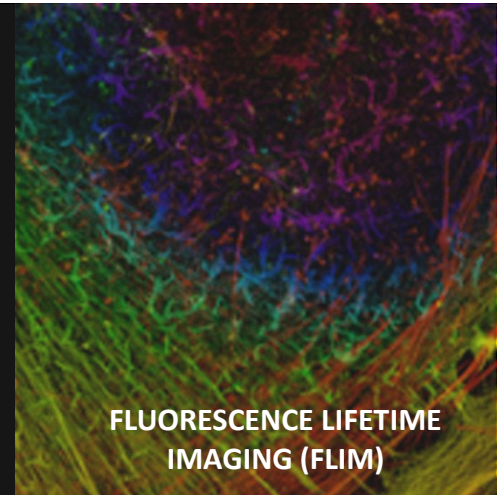
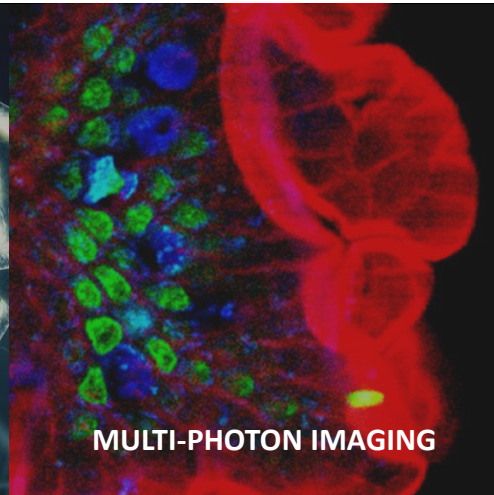
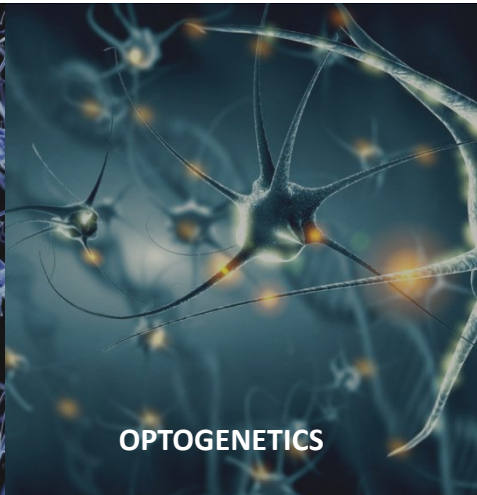
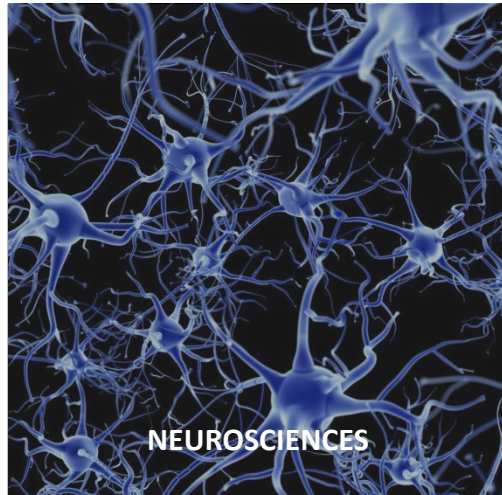
500 μm thick Asahi Corning glass



Surface grating on polished SS



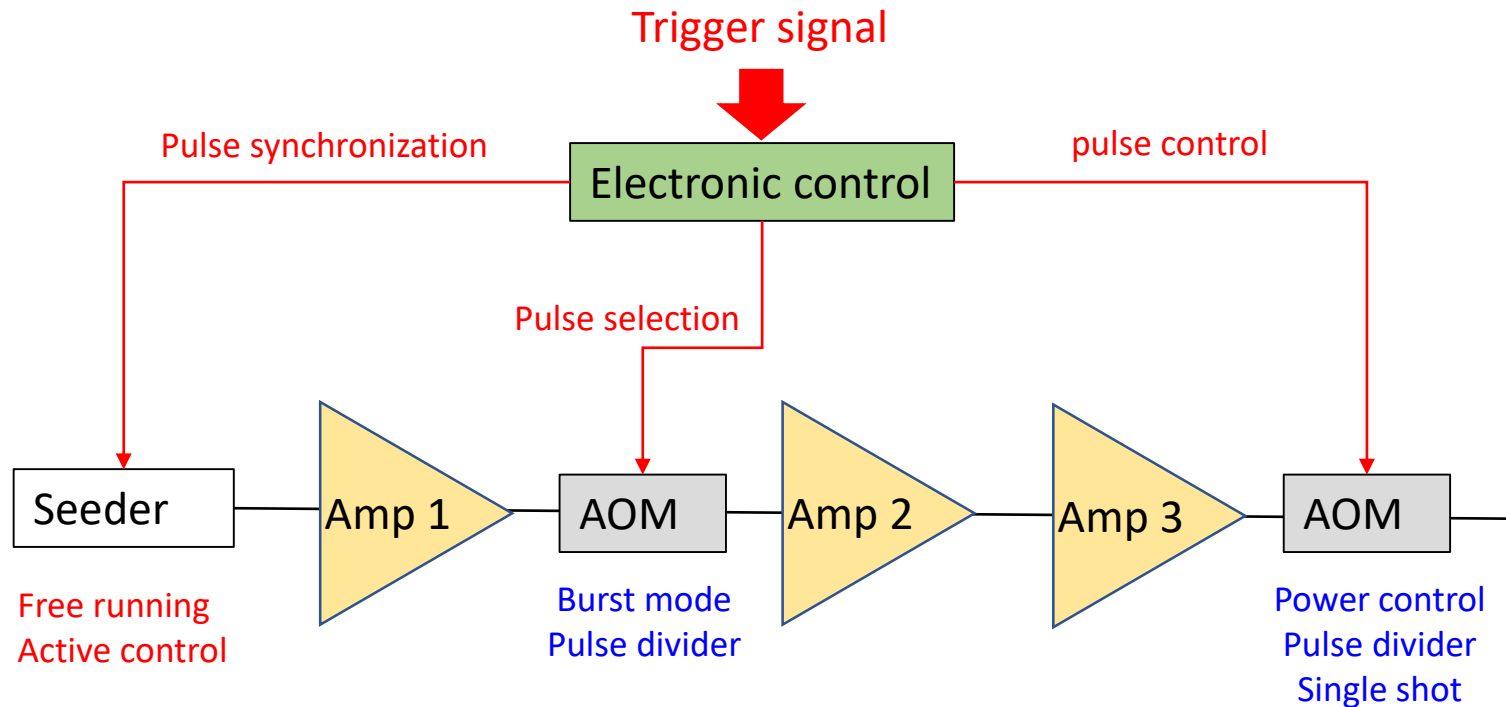
BIOPHOTONICS/SCIENTIFIC APPLICATIONS



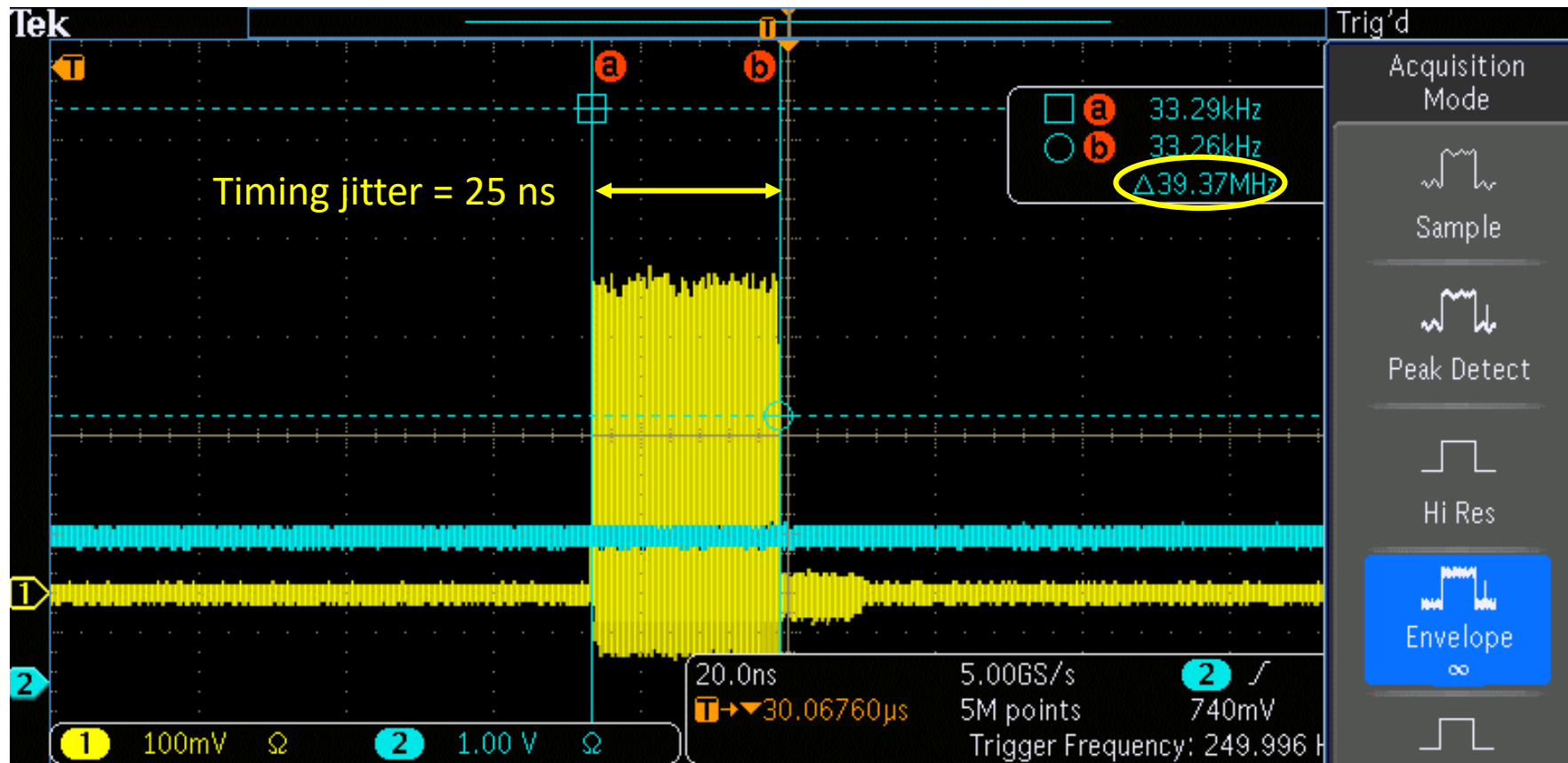
TEMPORAL CONTROL OF ULTRAFAST LASERS

- Frequency adjustment from single-shot to multi-MHz
- Pulse divider
- Burst generation : fixed or variable pulse interval
- Pulse frequency synchronization
- Pulse on demand : standard and ps range timing jitter

LASER DESIGN FOR LOW TIMING JITTER PULSE ON DEMAND

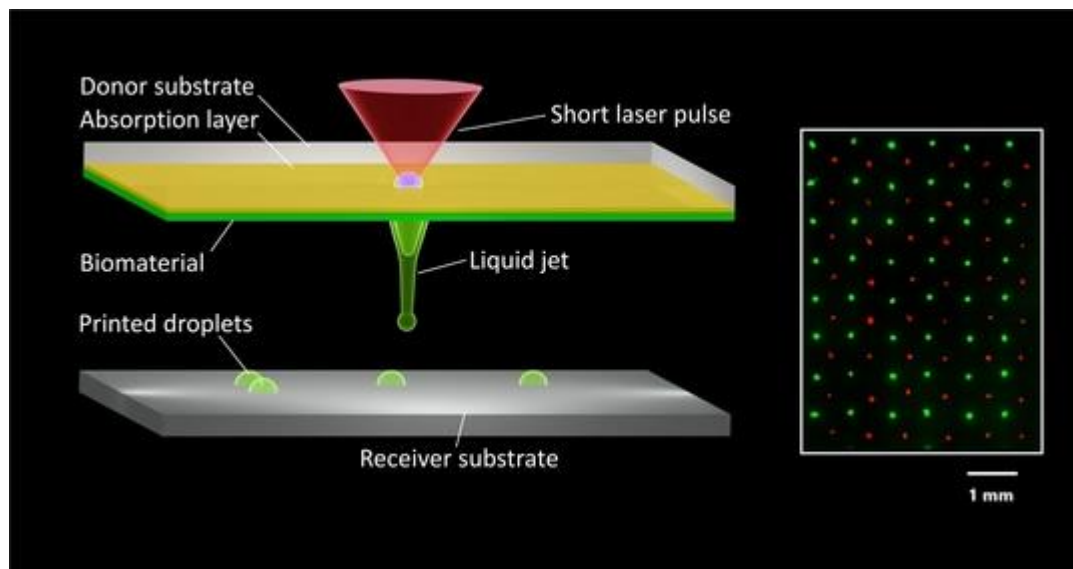


TIMING JITTER WITHOUT ACTIVE CONTROL

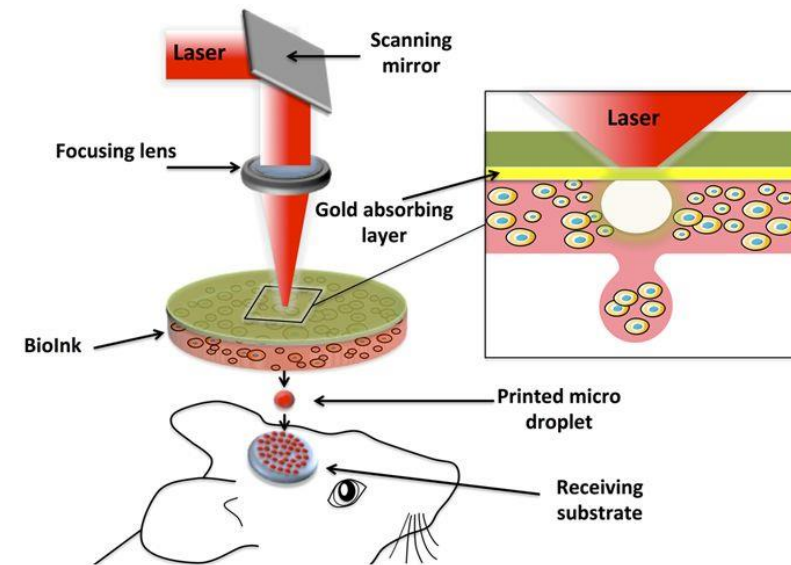


LASER ASSISTED BIOPRINTING

- 3D printing living cells to produce tissues or organs
- Based on Laser Induced Forward Transfer (LIFT) : projection of living material onto a substrate




<https://www.iqo.uni-hannover.de/1862.html>



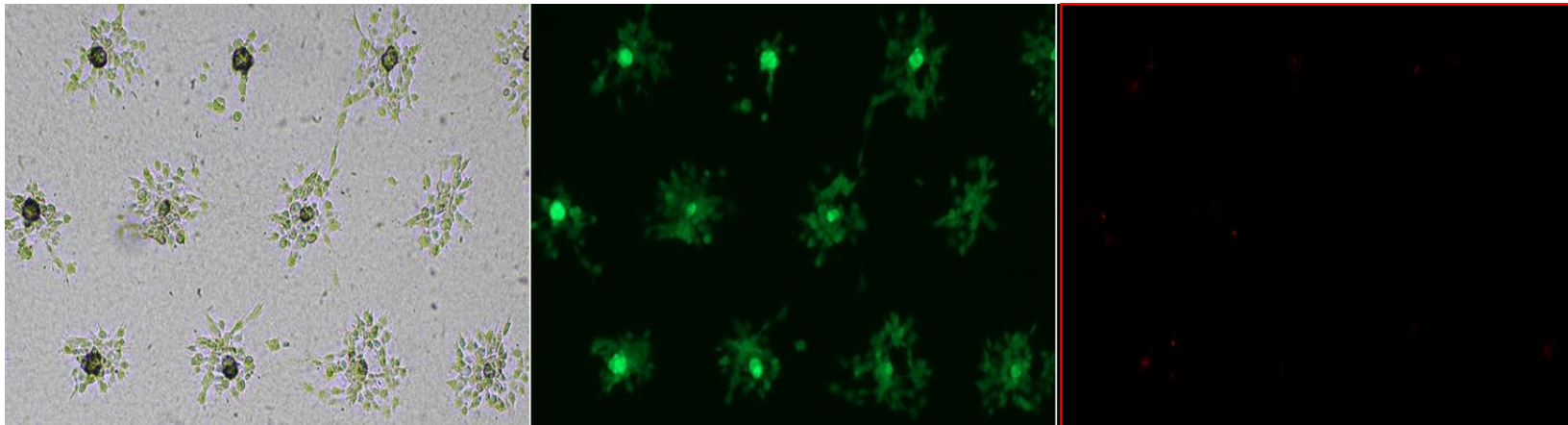
Scientific Reports, volume 7, Article number: 1778 (2017)

BIOPRINTING WITH SPARK LASERS

- In collaboration with  poietis
make tissues real
- Requirements:
 - High energy stability
 - High temporal control between spots : low timing jitter pulse-on-demand

PRINTING LIVING CELLS WITH SPARK LASERS

2D view of cells printed in the predefined pattern with SPARK Lasers ultrashort pulses.




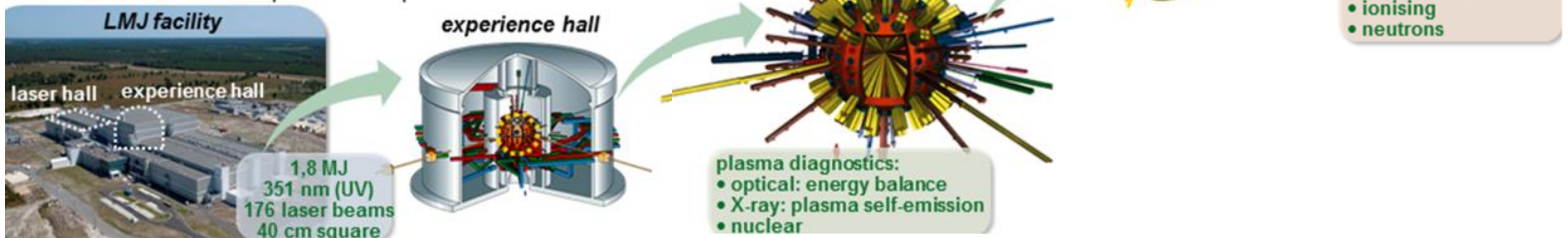
Microscope views of printed cells

Live/dead test : 100%
success (all cells lived)

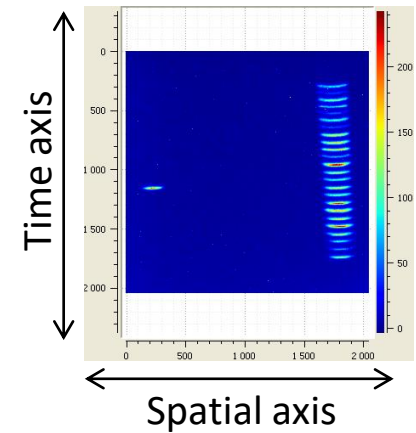
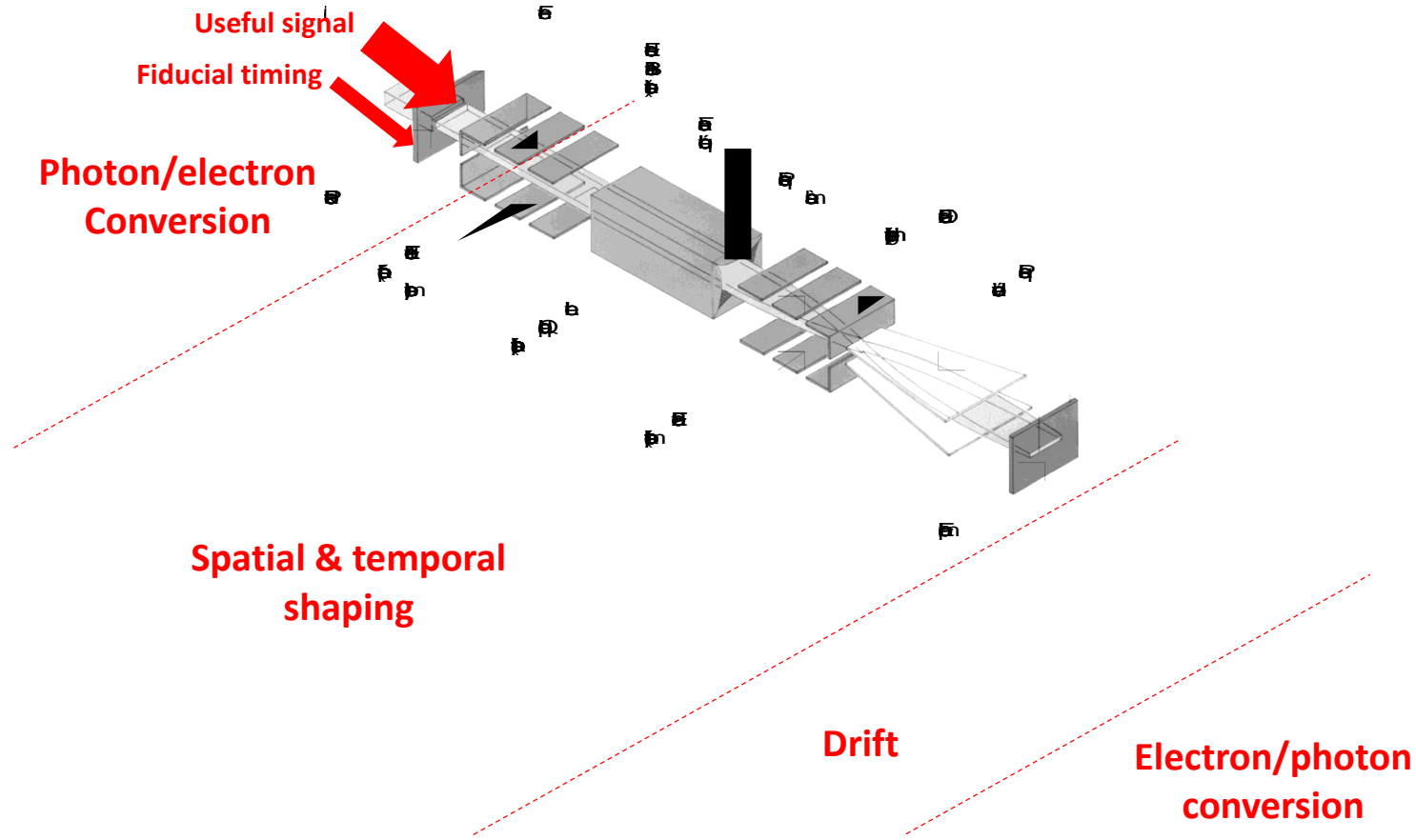
CONTEXT : PLASMA DIAGNOSTICS ON LMJ* FACILITY

*Laser MegaJoule :

- High power laser facility near Bordeaux (France)
- Designed, built and operated by the CEA 
- Validation of theoretical models concerning the behavior of matter in extreme conditions



STREAK CAMERA BASICS



CEA REQUIREMENTS VS. LAB RESULTS

- Single-shot laser
- Wavelength: 266 nm
- Jitter < 15 ps (RMS)
- Amplitude > 30 μJ / pulse

OK

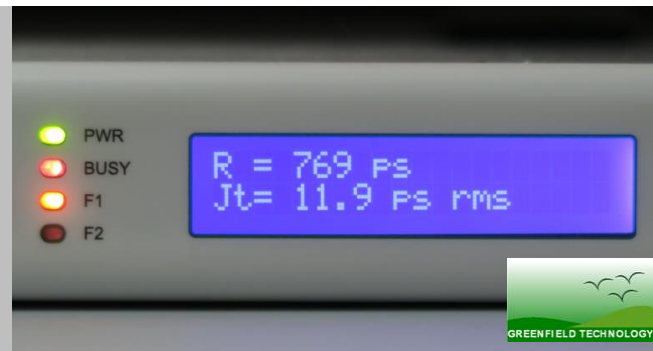
OK

< 12 ps - OK

40 μJ - OK

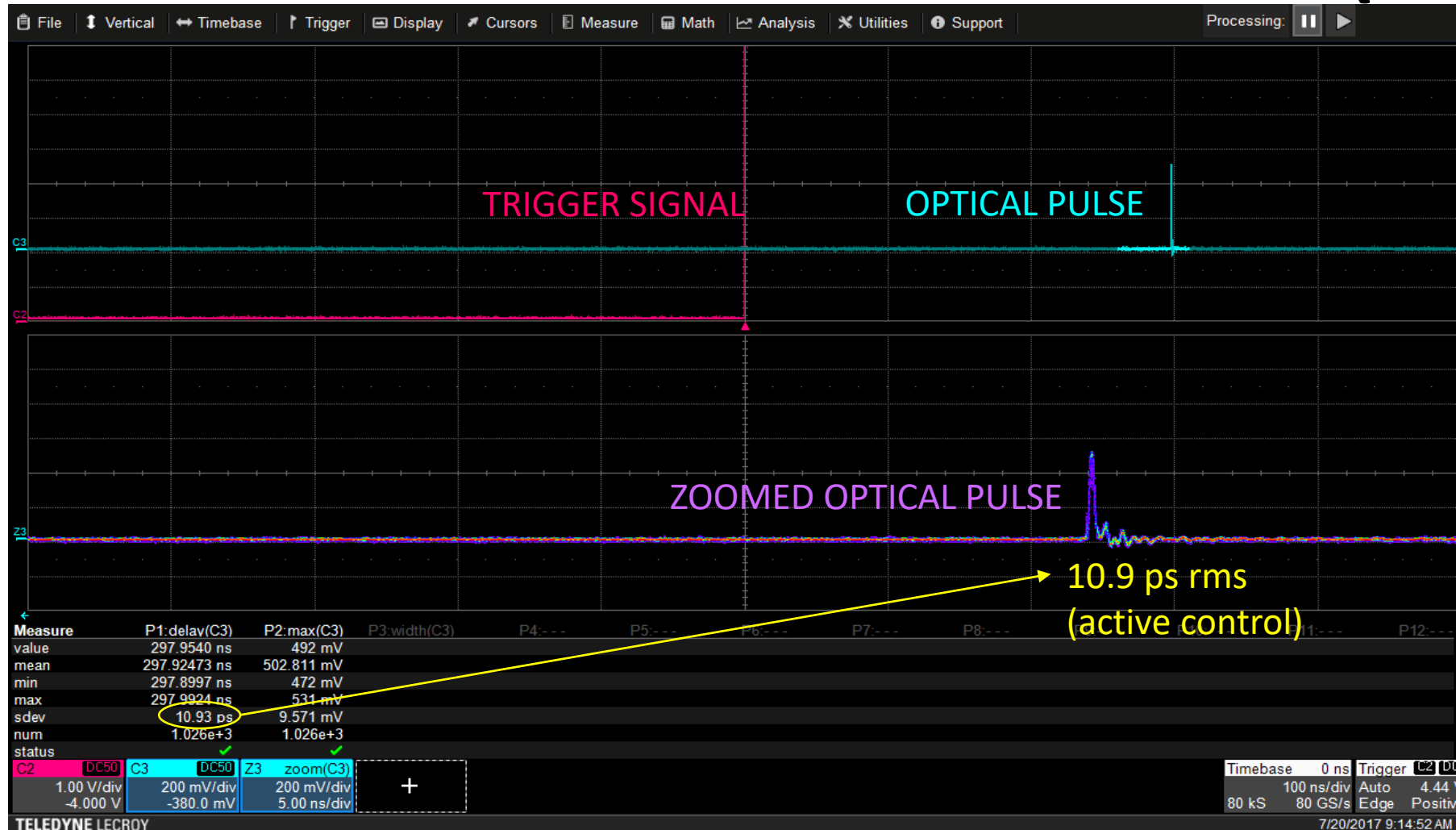
Example over 14 hours
of operation:

- $\sigma \sim 12\text{ps rms}$
- 67ps pp



Measured with a GFT2002
Time interval meter

~10 PS SINGLE SHOT TIMING JITTER (RMS)

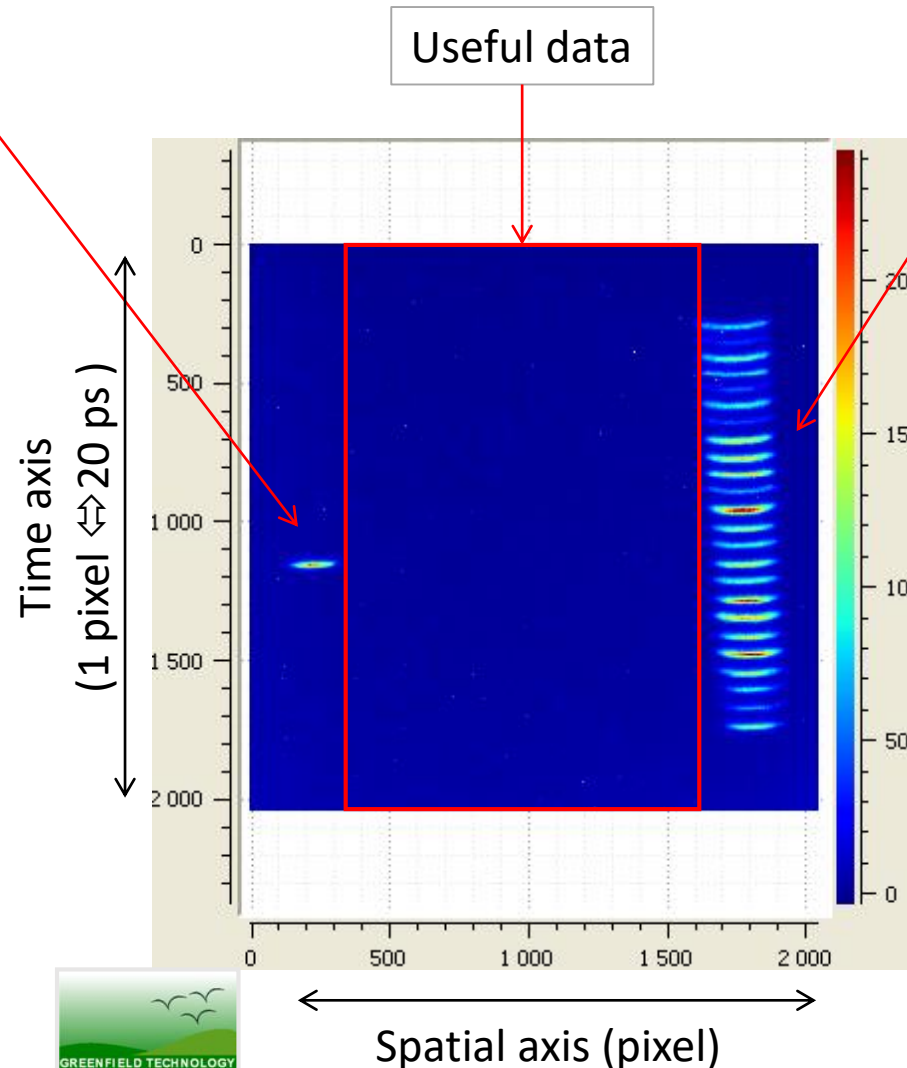


UV TIMING FIDUCIAL FOR X-RAY STREAK CAMERA : EXPERIMENTAL RESULTS

T_0 Chronometry
Jitter < 15 ps (RMS)

Useful data

Optical comb



ULTRAFAST LASERS FOR NEUROSCIENCES

Femtosecond pulses provide two-photon excitation for imaging and neuronal excitation



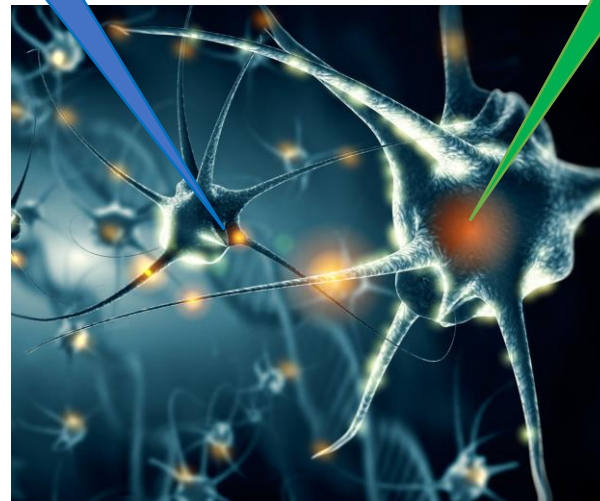
ALCOR-920
<140fs at 920 nm
2W average power

Measurement
At 920 nm

Excitation at
1040-1060 nm



ALTAIR IR-20
<140fs at 1040 nm
20 W average power



- GDD precompensation on each wavelength
- Pulse train synchronization and interleaving (F-Sync)

ULTRAFAST LASERS FOR NEUROSCIENCES

Femtosecond pulses provide two-photon excitation for imaging and neuronal excitation



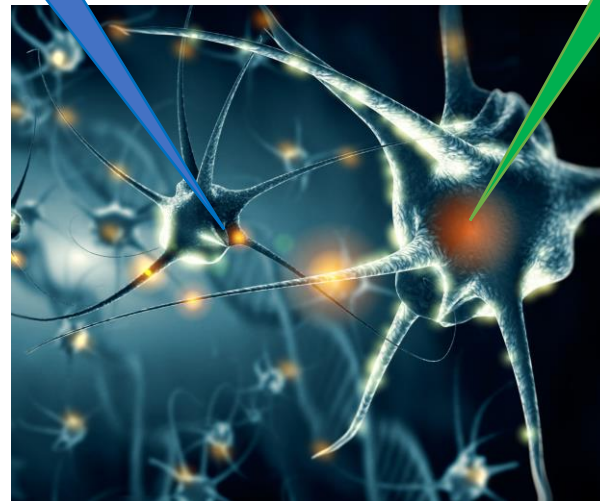
ALCOR-920
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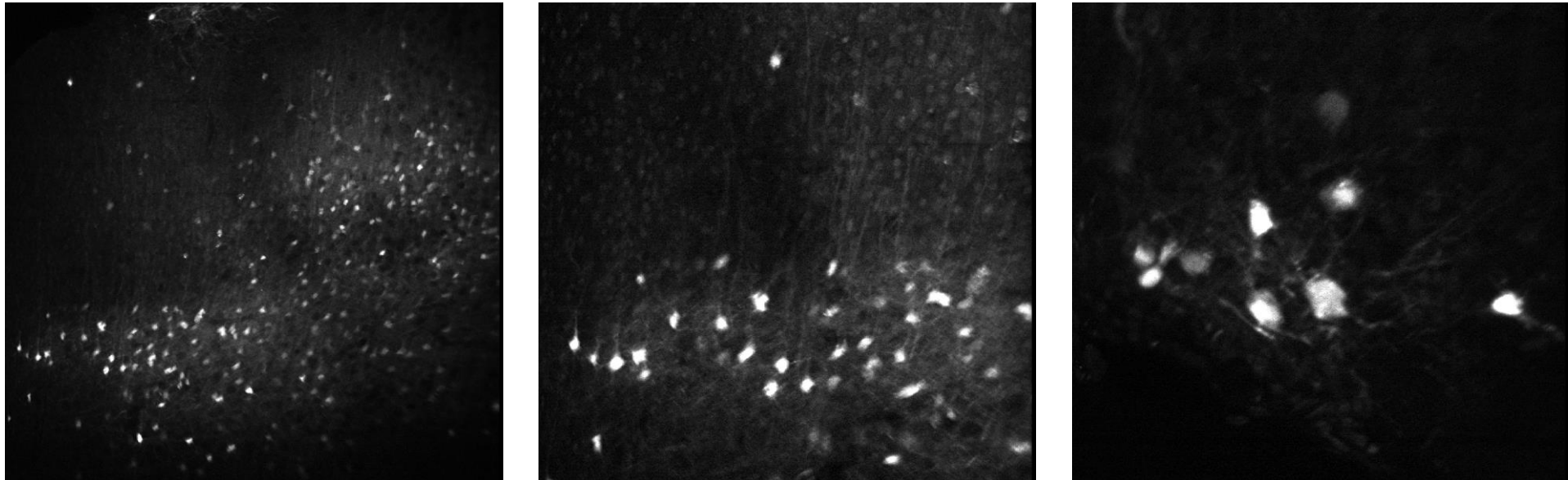
ALCOR-1040
<140fs at 1040 nm
2 W average power



- GDD precompensation on each wavelength
- Pulse train synchronization and interleaving (F-Sync)

NEUROSCIENCES : 2-PHOTON MICROSCOPY

Images of neurons in slices of mouse cortex expressing the fluorescent protein mCherry (obtained with Altair Laser)



Courtesy of Boston University, USA

CONCLUSION

- Tremendous growth in the variety of applications of ultrafast lasers
- Micromachining and recently developed fields such as 3D bioprinting and Neurosciences are pushing technical boundaries and requiring more advanced features from ultrafast lasers
- Spark Lasers have developed lasers offering on-the-fly pulse-on-demand with timing jitter of :
 - 25 ns without active control
 - Down to 10ps with active control
- The options are part of complete range of ultrafast lasers answering today's challenges thanks to unique features :
 - High optical performances
 - High-quality compact and robust package
 - Advanced high-speed electronics
 - Intuitive interface



THANK YOU FOR YOUR ATTENTION

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