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CONSIGLIO NAZIONALE DELLE RICERCHE
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Front-end options
Pulse train options
Compressor issues

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On beahlf of
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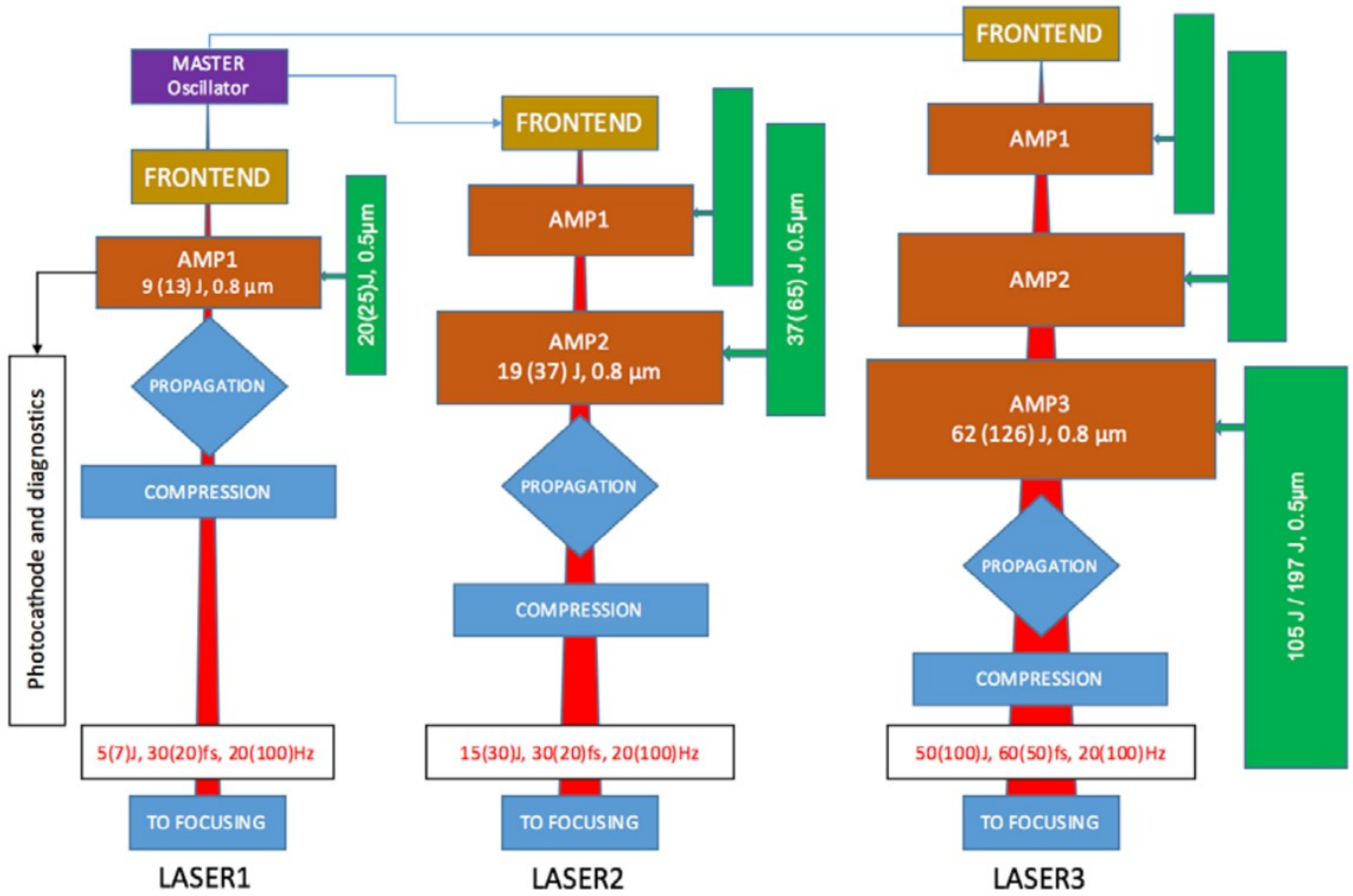
G. Toci, P. Tomassini

Outline (list of tasks)

- Study of front-end options
- Compressor (grating) thermal management: update on recent mesaurements and open issues
- "Efficient" generation of pulse train: ongoing work and perspectives

General architecture



Three different front-ends to allow independent spectral phase/amplitude adjustement – but same architecture

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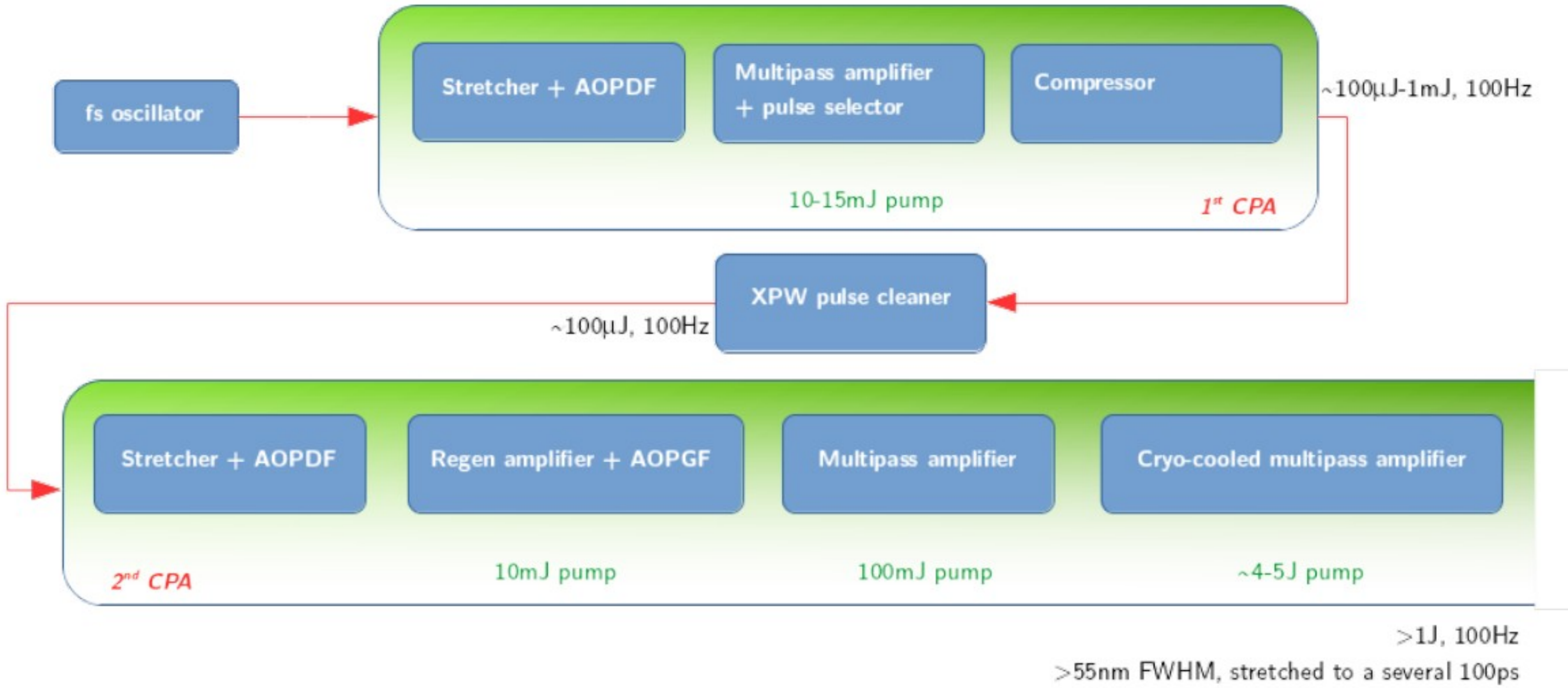
Front-end architecture

The requirements for the EuPRAXIA lasers may be reached with a double CPA + XPW front end



Fulfill all the requirements on the front-end to meet the final requirements (pulse duration, rep rate, contrast, ...)

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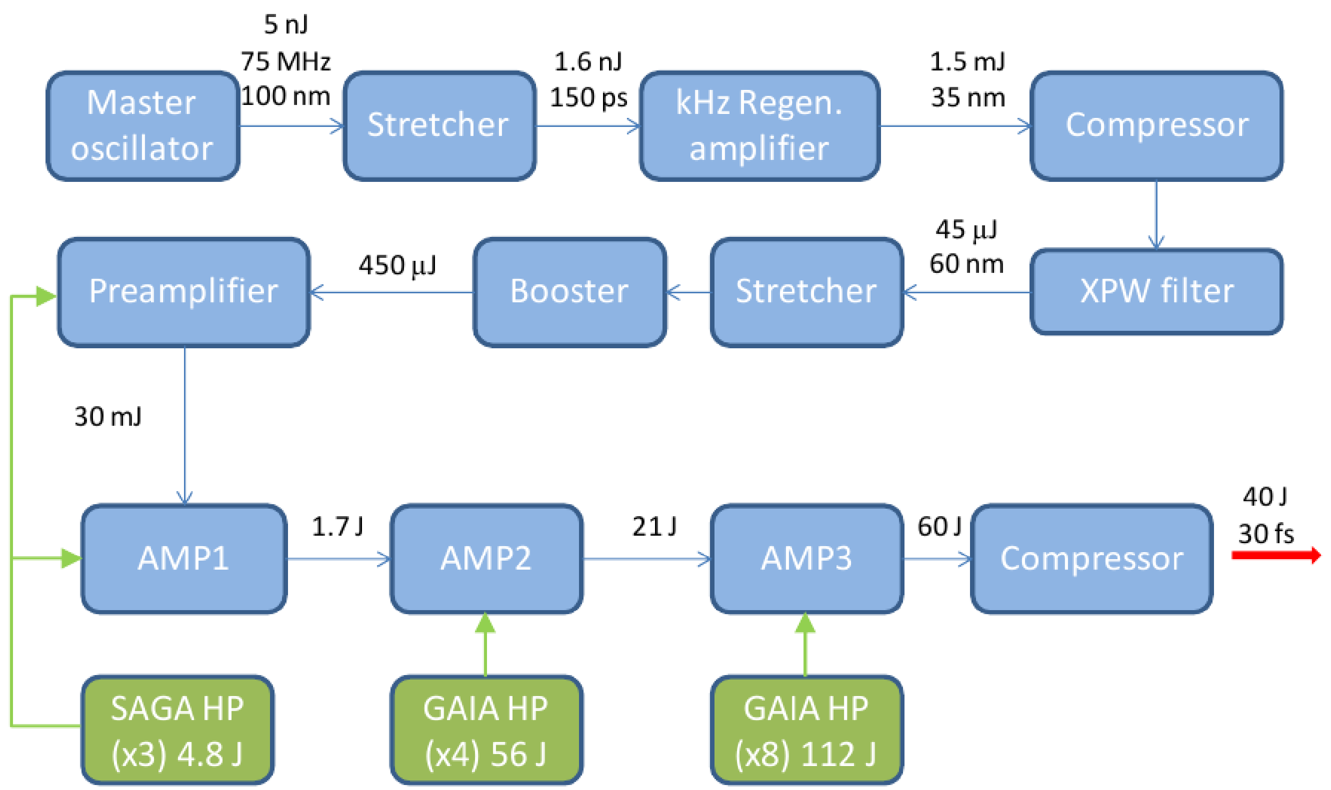
Similar architecture: BELLA front-end



Front-end architecture

Even at the P1 level rep rate, may become available at the industrial level from different suppliers

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Study of the spatio-temporal effects of grating heatings

Zeudi MAZZOTTA, Lucas RANC, Dimitri PAPADOPOULOS, Catherine LE BLANC, Francois MATHIEU
Apollon, LULI, Institute D'Optique

Motivations

Average power estimated for the 3 systems (at the P1 level):

Injector 150 MeV: 1.2 kW (12J @ 100Hz)

Injector 1GeV: 5kW (50J @ 100Hz)

Accelerator 5 GeV: 16kW (160J @ 100Hz)

Average intensity on the 3 compressors: set by the current technology grating LIDT (~100mJ/cm2)

With the EuPRAXIA rep rate, this results into ~10 W/cm2

Study needed to assess possible effects on the beam quality/pointing due to thermal issues on the gratings

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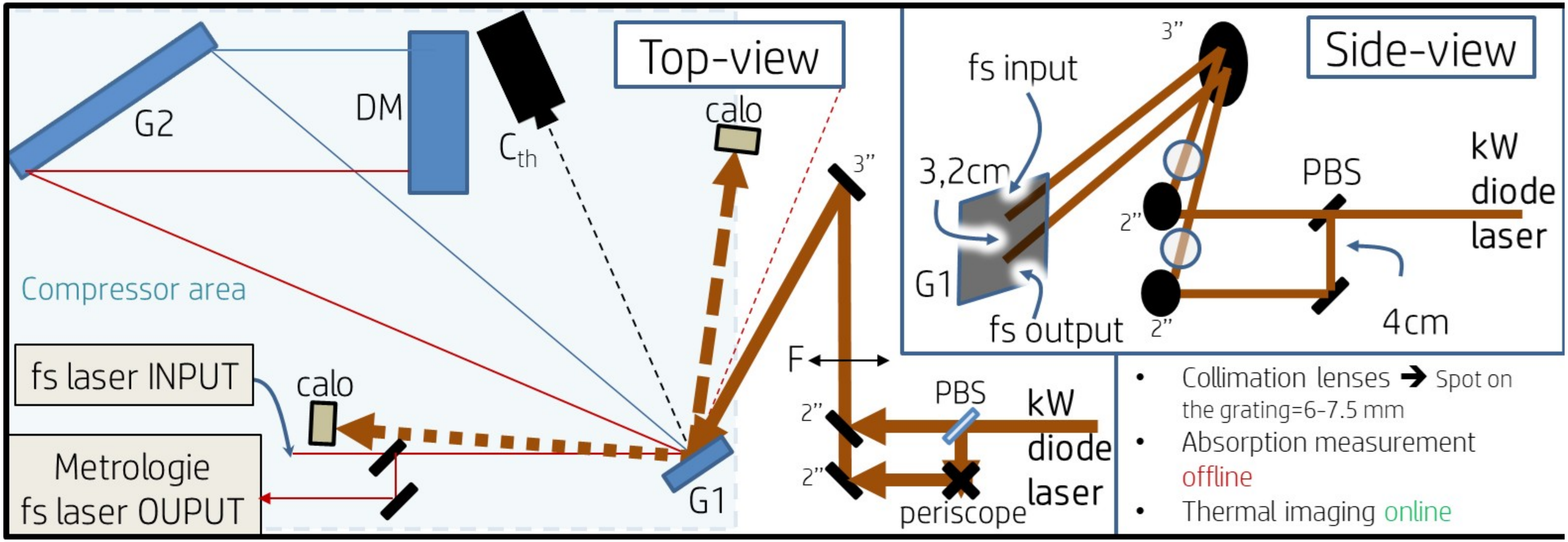
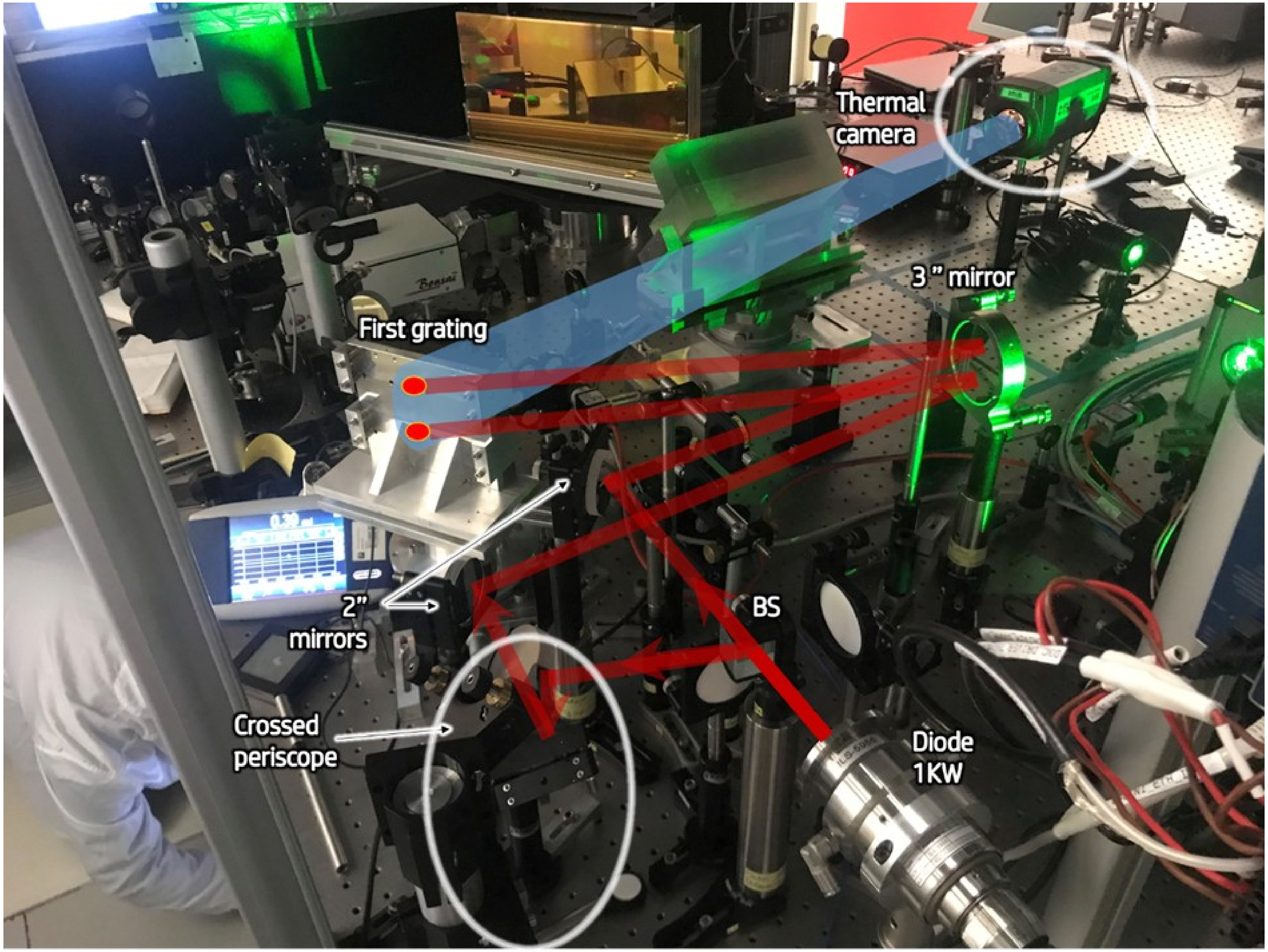
Experimental study @ APOLLON

Aim: measuring possible thermal effects on
- spatial quality
- time profile
- spatio-temporal coupling



- Collimation lenses → Spot on the grating=6-7.5 mm
- Absorption measurement offline
- Thermal imaging online

Experimental study @ APOLLON



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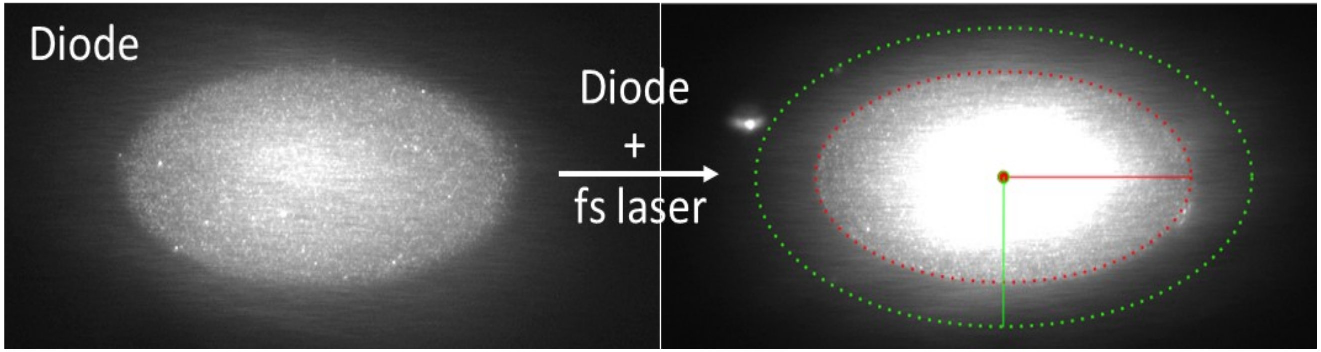
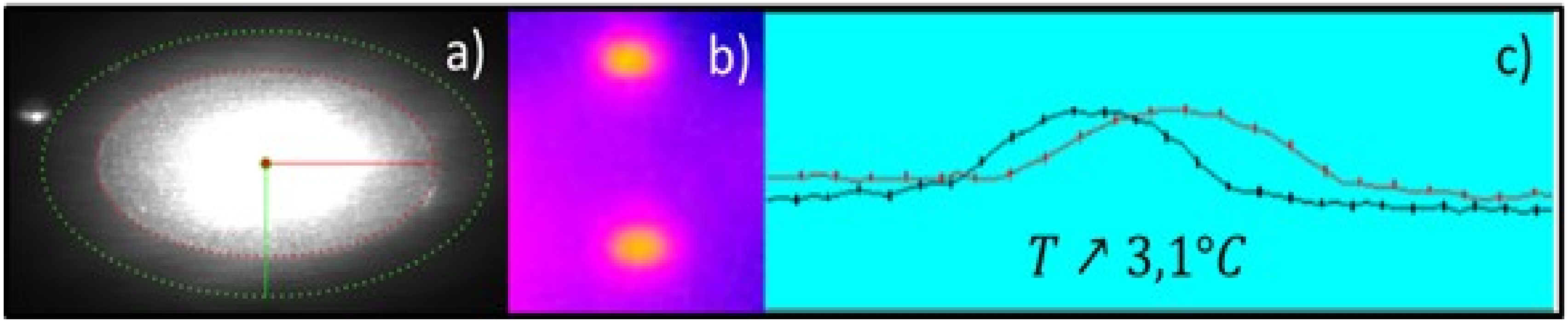
Experimental study @APOLLON: alignment on gratings





Alignment of laser (more Gaussian, green) and diode (top hat, red)

130W sent on each position

Temperature profile of input and output spots

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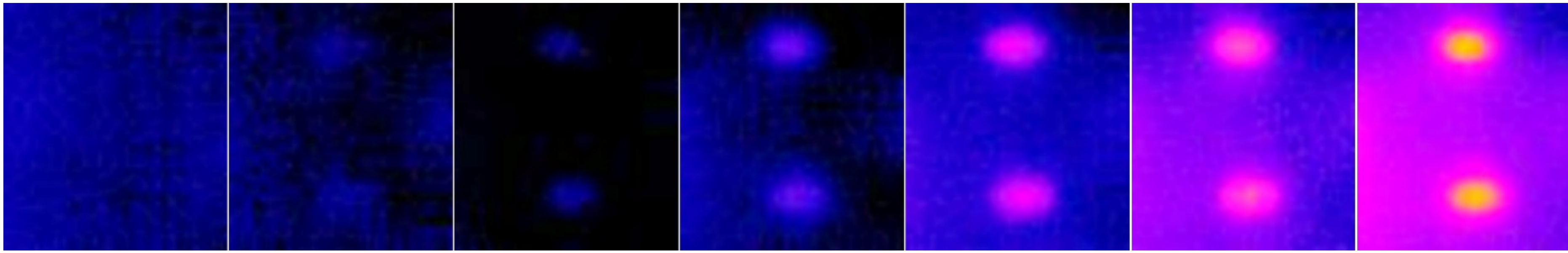
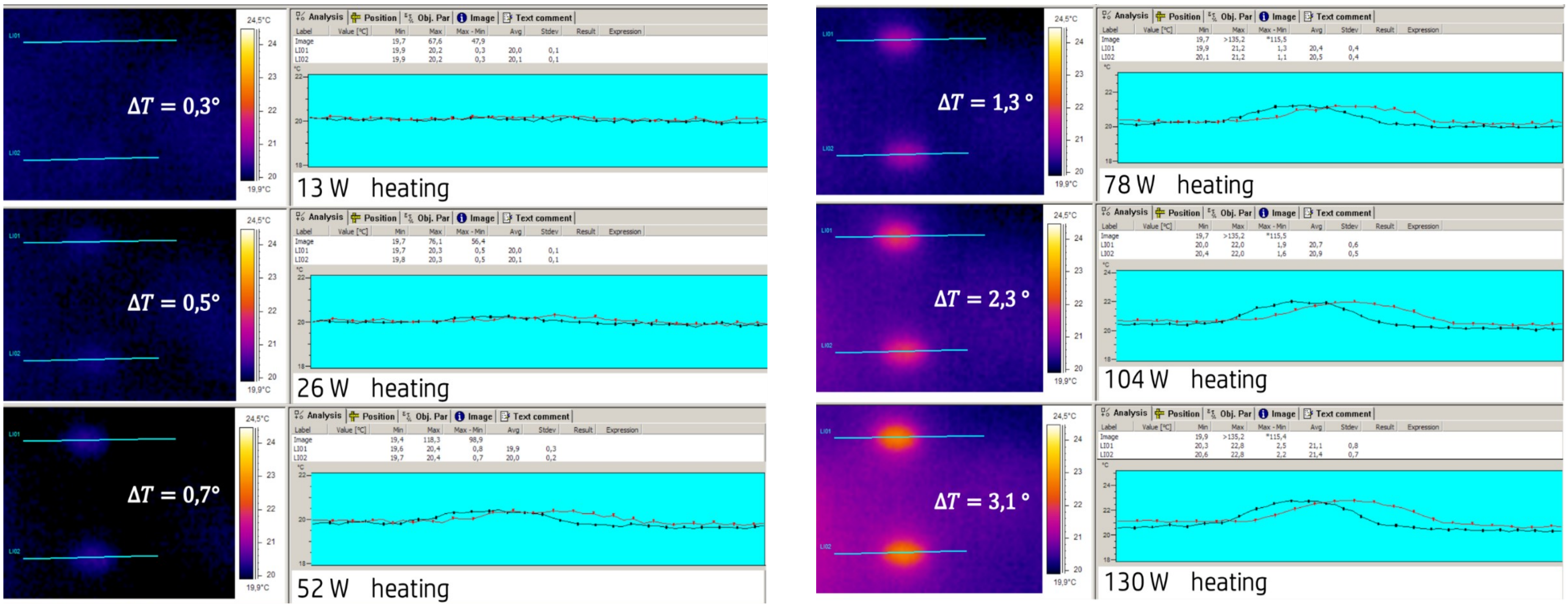
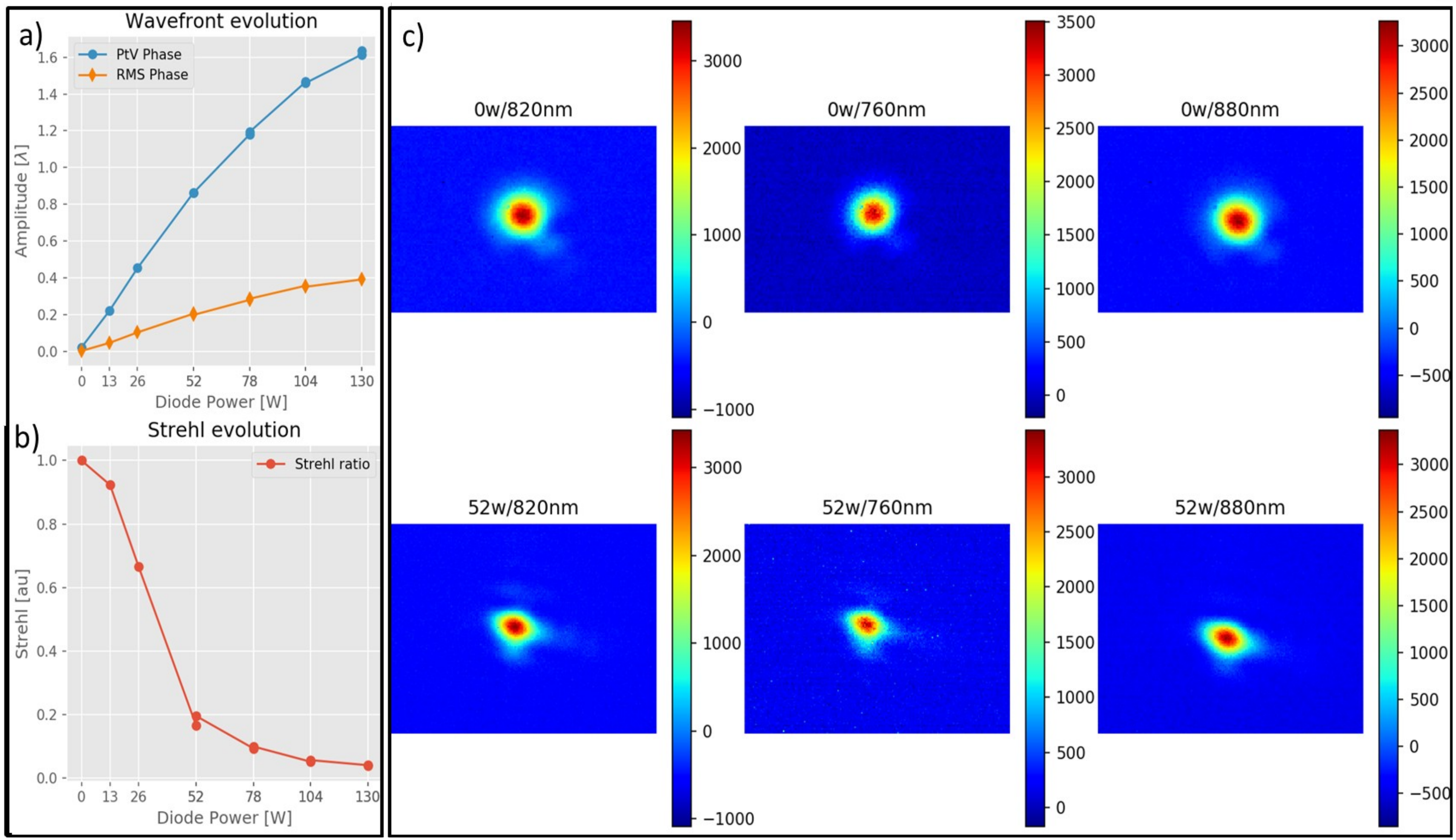
Experimental study @APOLLON: temperature increase





Experimental study @APOLLON: induced wavefront aberrations



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Experimental study @APOLLON: conclusions

- There is a strong spatial deformation and worsening. This has to be taken into account when we align on target. This is why attenuation is needed and not running at low power with the front end
- There is no increase in the temporal width, even when we sent 100W per spot, when the fs laser was 20fs long. This means that for EuPRAXIA the issue is mainly spatial than temporal, having durations of less than 25 fs requested.
- We suspect a spatio-temporal coupling. If the defocus is different for different wavelength, focusing the beam on target will be very difficult.

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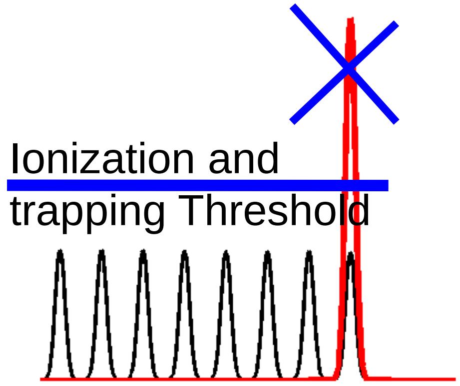
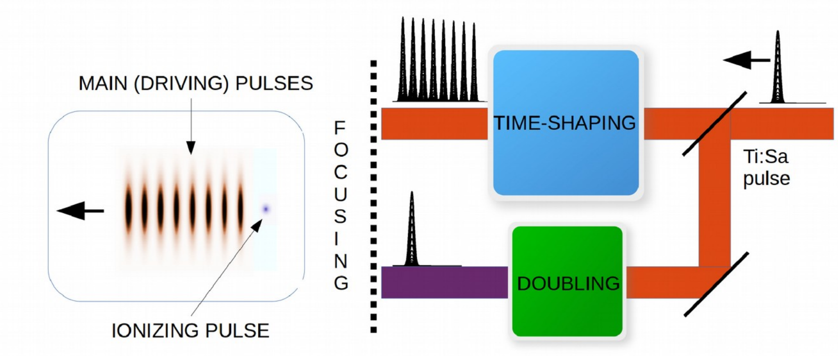
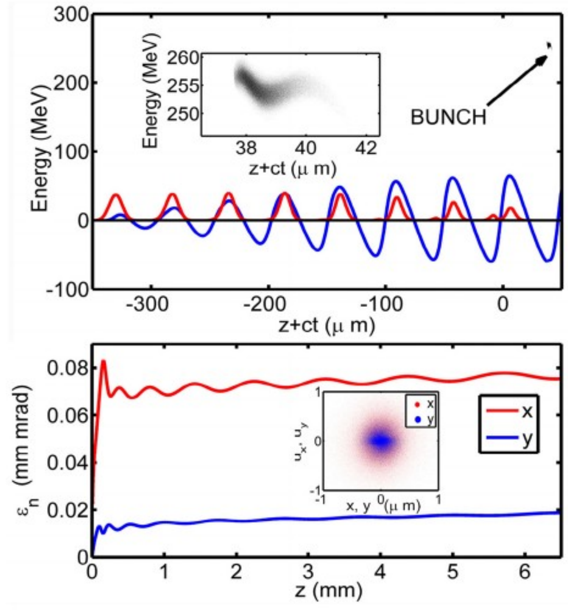
Motivations: the ReMPI scheme

The REMPI* scheme, pursued at the ILIL lab in the framework of EuPRAXIA, employs a (short wavelength) pulse train to drive the wake





PIC simulations show that bunches with normalized emittances as low as ~10^{-2} mm mrad, energy spread ~0.6%, with bunch charge ~1pC, can be obtained



Mandatory: the amplitude of the different pulses must be comparable within ~10%

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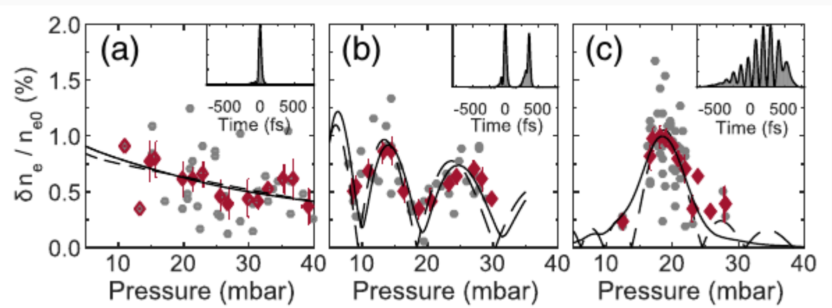
*P. Tomassini et al, PoP 24 (10) 2017

Background 1. Scheme employed by the group of Hooker

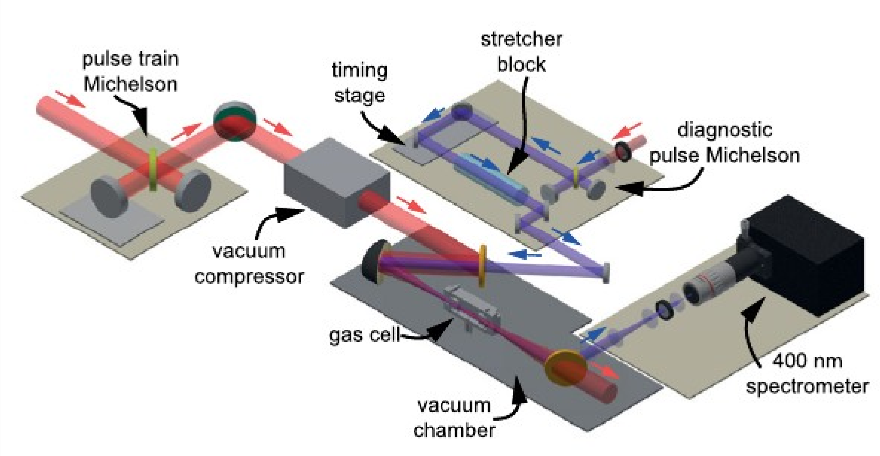
PRL 119, 044802 (2017) PHYSICAL REVIEW LETTERS week ending 28 JULY 2017

Excitation and Control of Plasma Wakefields by Multiple Laser Pulses

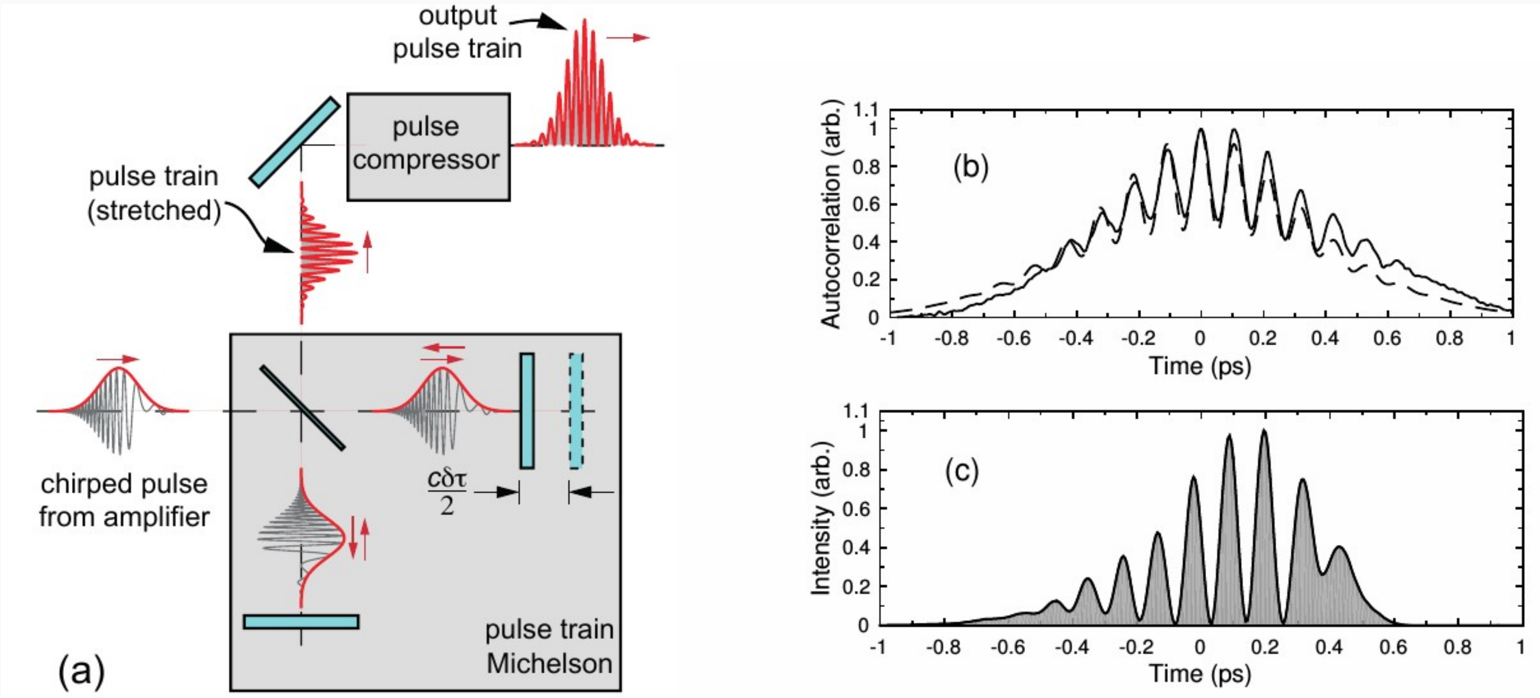
J. Cowley,[1] C. Thornton,[1] C. Arran,[1] R. J. Shalloo,[1] L. Corner,[1] G. Cheung,[1] C. D. Gregory,[2] S. P. D. Mangles,[3] N. H. Matlis,[4] D. R. Symes,[2] R. Walczak,[1] and S. M. Hooker[1,*]



Wakefield amplitude as a function of the plasma density for different laser pulse shapes



Background 1. Scheme employed by the group of Hooker



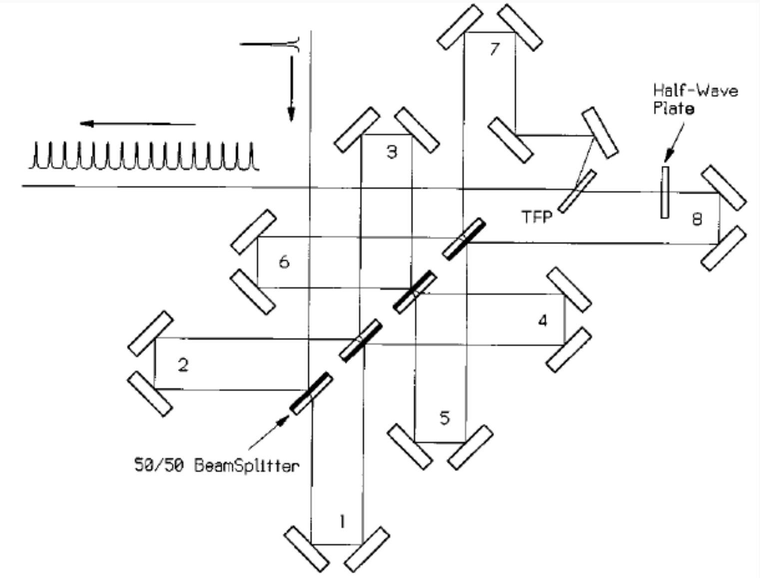
Issue: amplitude not constant along the train

Background 2. "2^n-pulse Michelson interferometer"

5302 APPLIED OPTICS / Vol. 37, No. 22 / 1 August 1998

Efficient high-energy pulse-train generation using a 2^n-pulse Michelson interferometer

Craig W. Siders, Jennifer L. W. Siders, Antoinette J. Taylor, Sang-Gyu Park, and Andrew M. Weiner



Array of Michelson 50/50 interferometers

Polarization multiplexing

100% throughput if orthogonal polarizations may be accepted in the final train (ReMPI scheme: yes!)

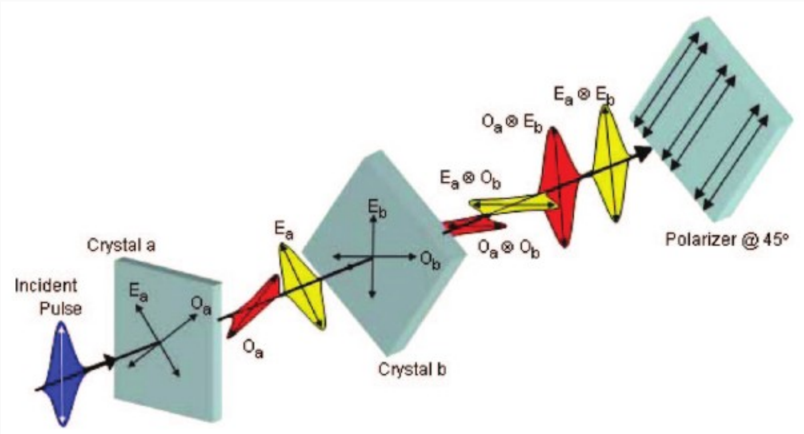
Needs to be placed after the compressor (if one wants to retain both the polarizations), so that it involves the usage of large aperture optics

Background 3. Birefringent crystal array

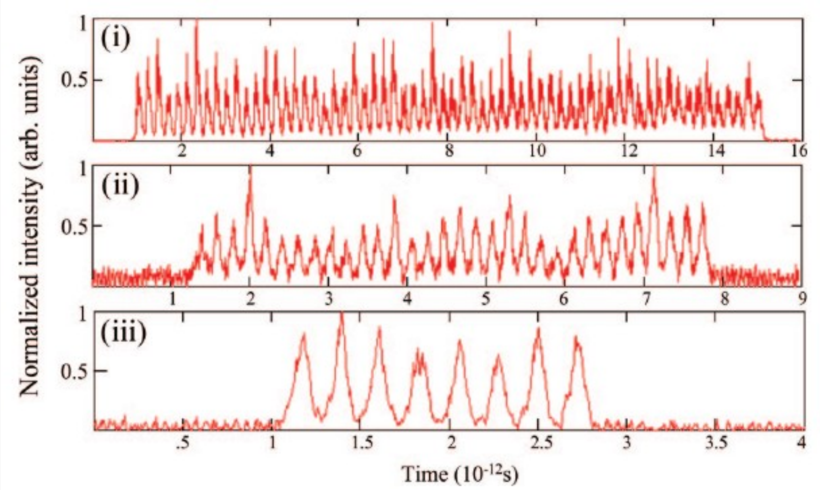
5142 APPLIED OPTICS / Vol. 46, No. 22 / 1 August 2007

Generation of a train of ultrashort pulses from a compact birefringent crystal array

B. Dromey,[1,*] M. Zepf,[1] M. Landreman,[2] K. O'Keeffe,[2] T. Robinson,[2] and S. M. Hooker[2]



Cross-correlation traces

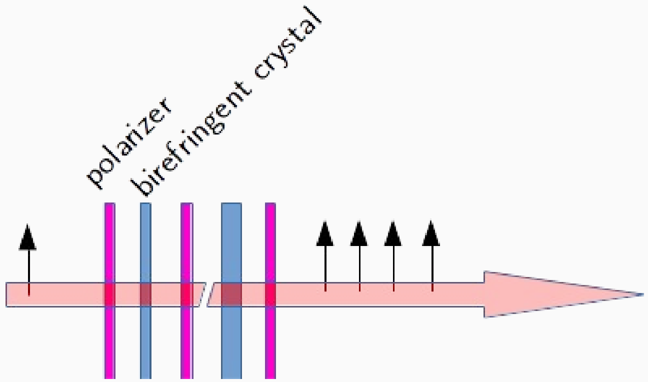


Shortcomings:

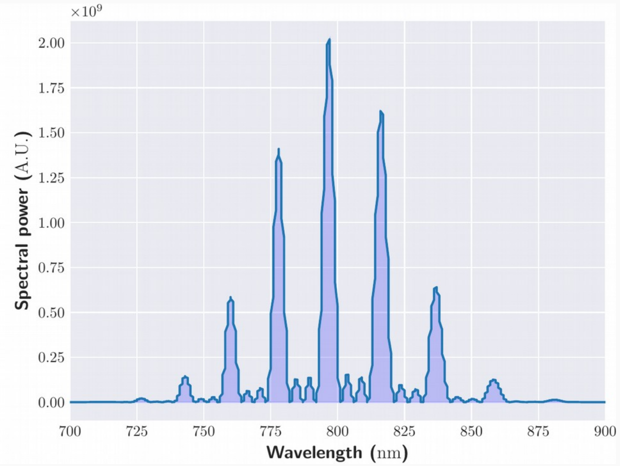
- cumbersome setup when used on the fully amplified beam
- remarkable energy losses (relevant in the EuPRAXIA design)

(Quasi) lossless generalization

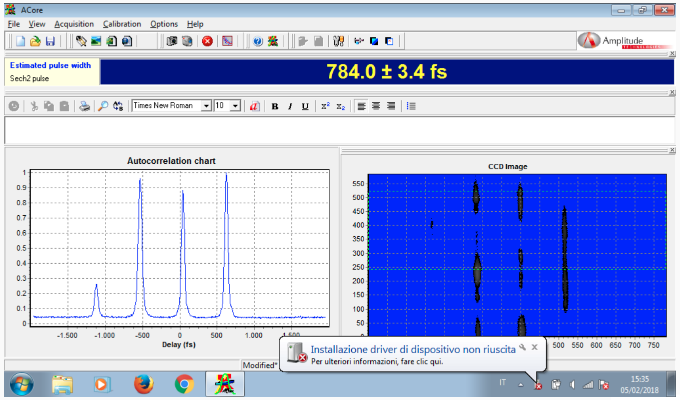
A stack of polarizers/birefringent crystals can be used early in the amplification chain (ideally just after the front-end)



Spectral interference expected (and occurring)



Test experiment carried out at the ILIL laboratory in Pisa



Time behavior matching the theoretical (simulated) profile

Pre- (and post-) pulses do appear

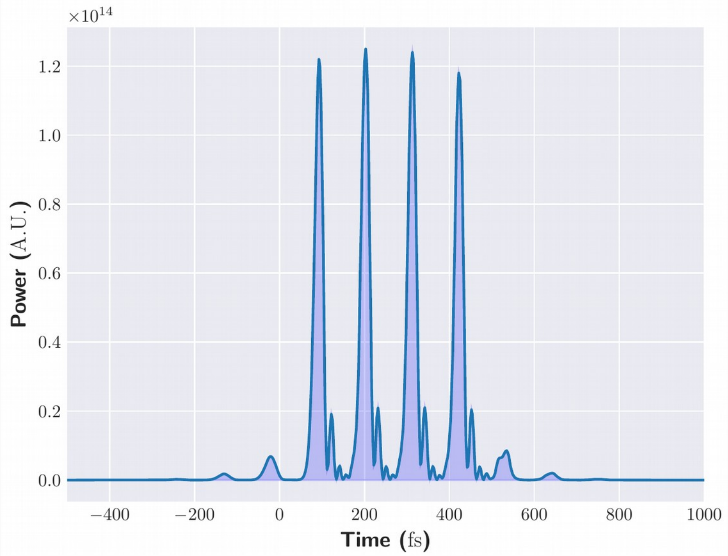
According to MIRO simulations, this is due to self-phase modulation (in the crystals) on the leading edge of the pulse

Simulations in the case of EuPRAXIA laser 1 (150MeV injector)

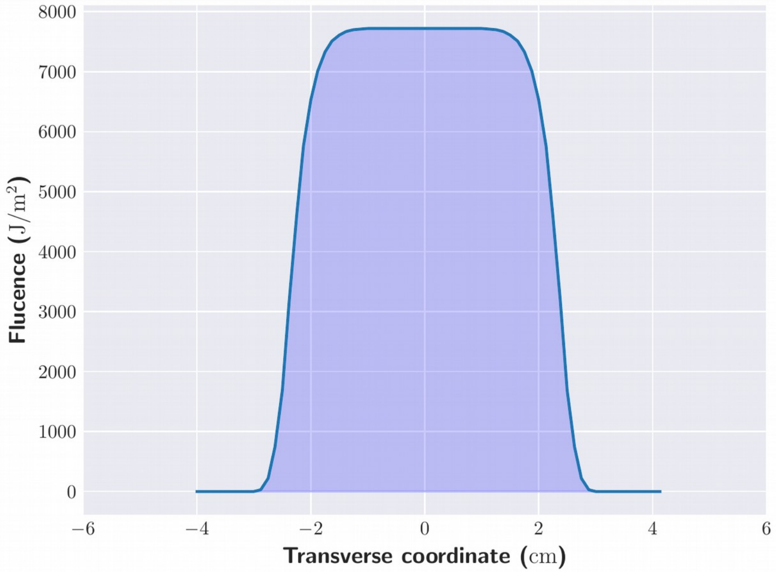
Simulation carried out in the case of the EuPRAXIA laser 1

Pulse stacking occurring after just front-end:
Input pulse: 1.5J
Energy loss: 50%
Booster amplifier considered (to recover the full energy from the front-end)

Simulation carried out using the MIRO code



Relatively low-power pulses also appearing after each pulse (acceptable as for the wake excitation)



No transverse spatial effect observed

Final considerations and brief summary

Quasi lossless scheme for the generation of a train of ultrashort pulses devised, possibly to be used for resonant schemes of wake excitation (see ReMPI)

quasi lossless Train gEneration by an early aMplitude dIvision (TEMPI)

Splitting occurs very early in the laser chain

Effects due to pulse interference manageable
Effects due to self-phase modulations not trivial
(although not leading to dramatic consequences)

The additional pump energy required for the EuPRAXIA laser 1 can be estimated to be of about 4J (over a total of ~35J)

Compared to the scheme proposed/used so far:
- Reduced footprint and complexity
- Much more favorable energy budget
- The train pulses exhibit the same amplitude (crucial for the ReMPI scheme)

Cons: limited room for tuning the relative pulse delay

Outline (list of tasks/open issues)

- Study of front-end options
- Compressor (grating) thermal management: update on recent mesaurements and open issues
- "Efficient" generation of pulse train: ongoing work and perspectives
- Pointing stability: ongoing work

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