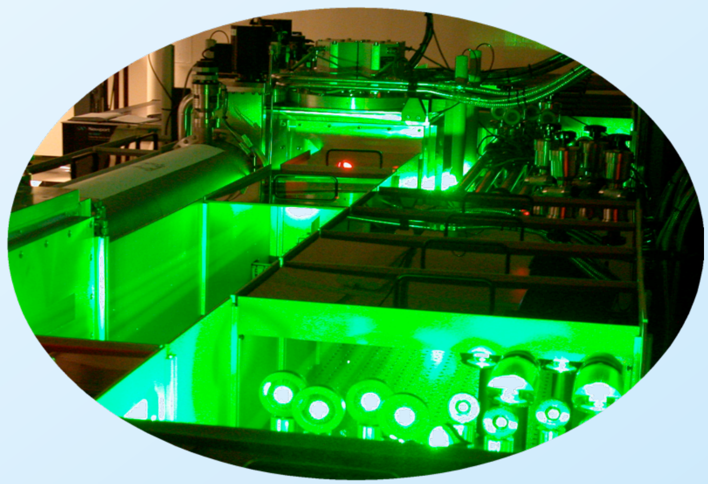
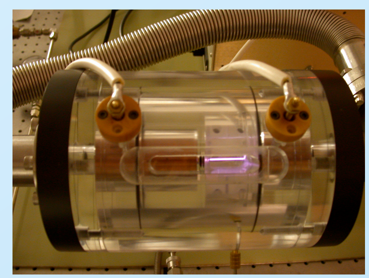
Contrast Enhancement of the LOASIS CPA Laser System and Effects on Electron Beam Performance of LWFA

Csaba TÓTH[1], Olivier ALBERT[1,2], Lorenzo CANOVA[2], Nicholas MATLIS[1], Guillaume PLATEAU[1], Anthony GONSALVES[1], Dmitriy PANASENKO[1], and Wim LEEMANS[1]

[1]LOASIS Program, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

[2]Laboratoire d'Optique Appliquée, ENSTA, Ecole Polytechnique, CNRS, Palaiseau, FRANCE





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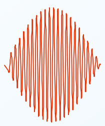
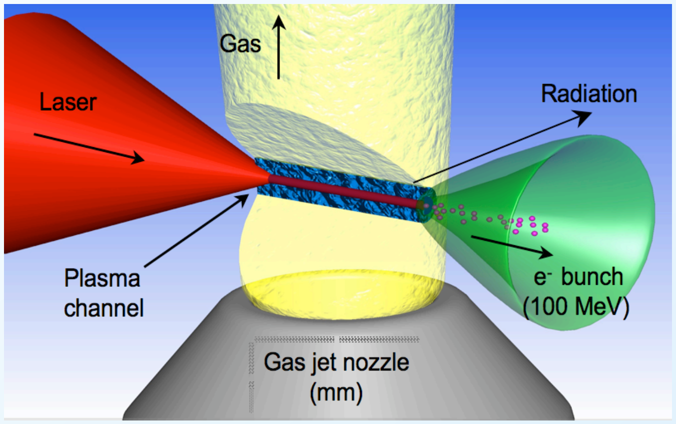
http://loasis.lbl.gov/

Applications require stability: driver for hyper-spectral source

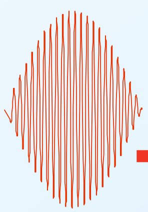


Up to 10 TW
40 fs 10 Hz

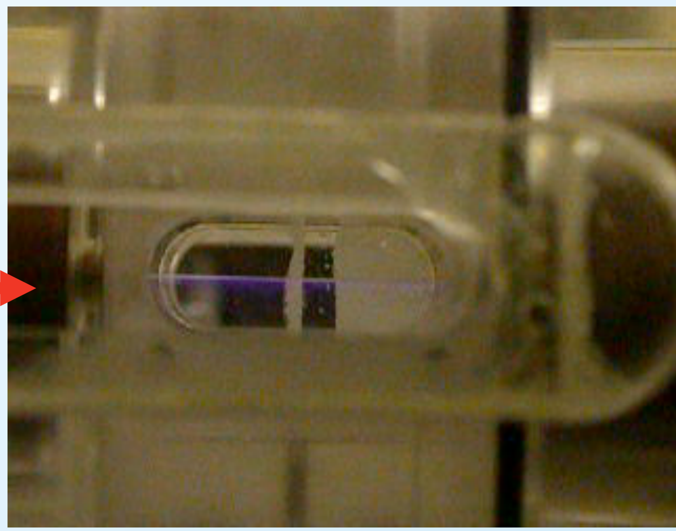


150 MeV

e- beam



Up to 60 TW
40 fs 10 Hz



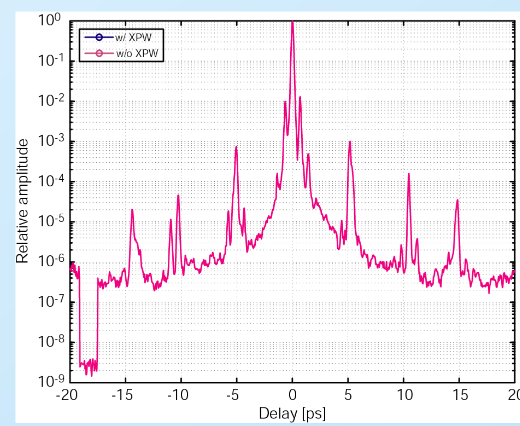
~3 cm

1 GeV

e- beam

High energy electrons

Compact accelerators

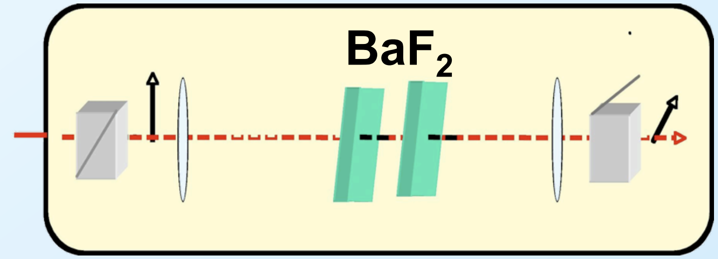


Performance with gas jet affected by laser pre-pulses

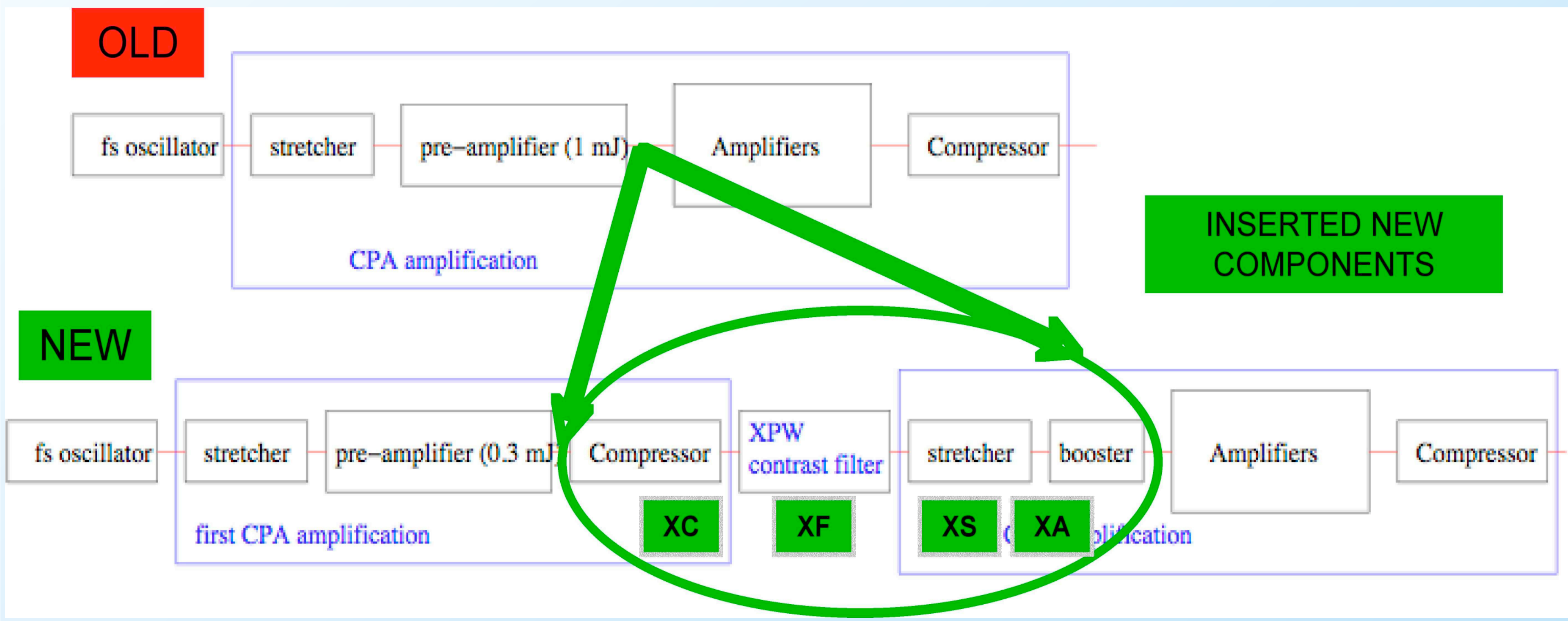
Hosokai *et al.*, PRE 2003; PRE2006; Mangles *et al.*, PPCF 2006

Cross-polarized wave contrast improvement: implementation at LOASIS, LBNL

- Designed by O. Albert *(LOA, France)*
- Non-linear birefringence in BaF_2
- Operates in air, not in vacuum



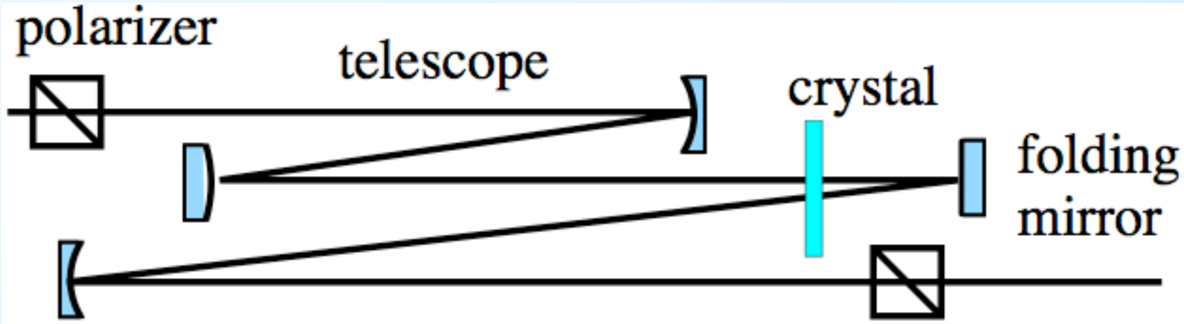
Jullien et al., Opt. Lett. 30, 920, 2005



‘In-air’ high efficiency XPW setup

DESIGN GOALS

- Two crystals XPW scheme for efficiency and reliability [Jullien2006]
- Appropriate input beam matching to maximize XPW efficiency [Albert2006]
- Parameter scaling to avoid SPM in air and SPM in polarizers
- Limit foot-print via folded setup



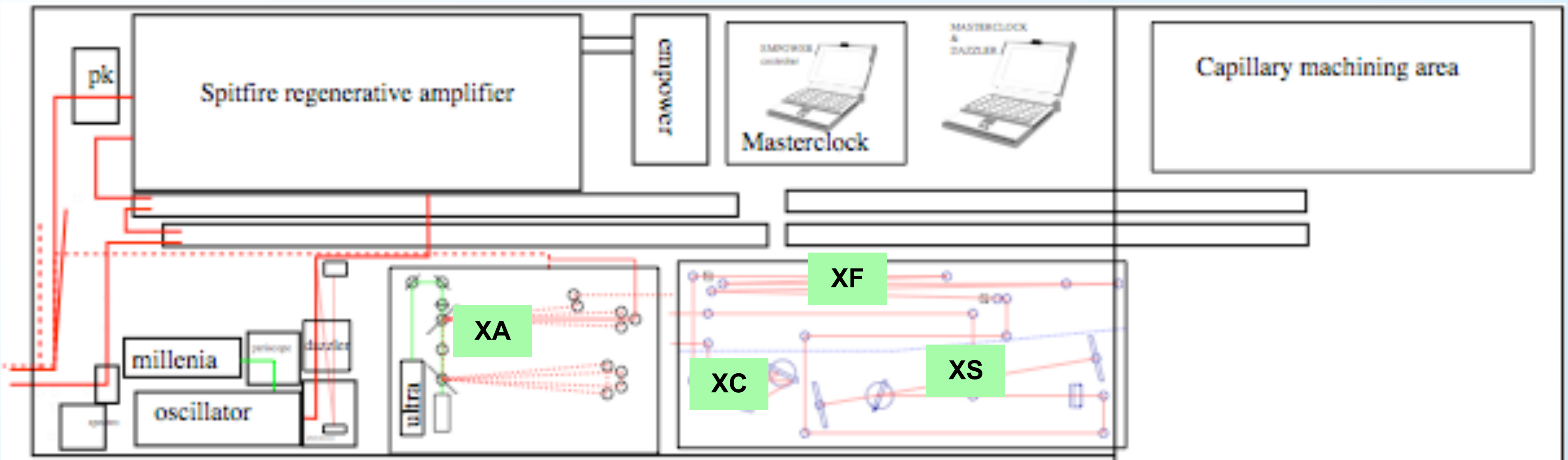
INPUT BEAM PARAMETERS

- **40 fs**
- **~ 300 uJ**
- **Quasi-Gaussian mode**
- **6 mm beam diameter**

DESIGN PARAMETERS

- **Focusing telescope : 4 m focal length**
- **BaF_2 crystal spacing ~ 60 cm**
- **Output beam diameter : ~ 2 mm**
- **50 μJ output in everyday operation**
- **25% max measured efficiency**
- **Small footprint 1.5 x 0.2 m^2**

XPW layout: implementation at LOASIS



new beam pass
present beam pass

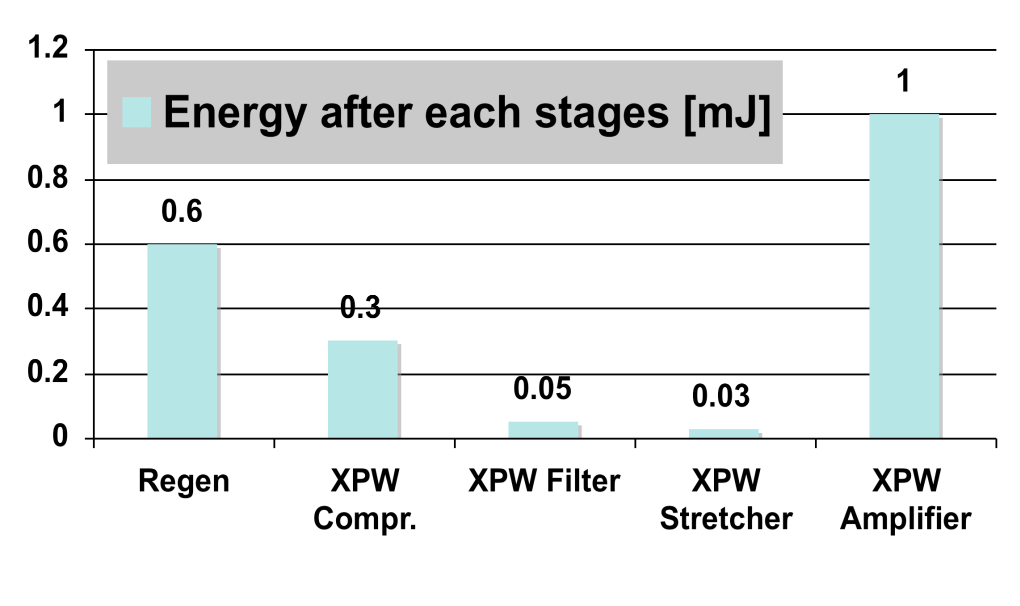
MAIN FEATURES

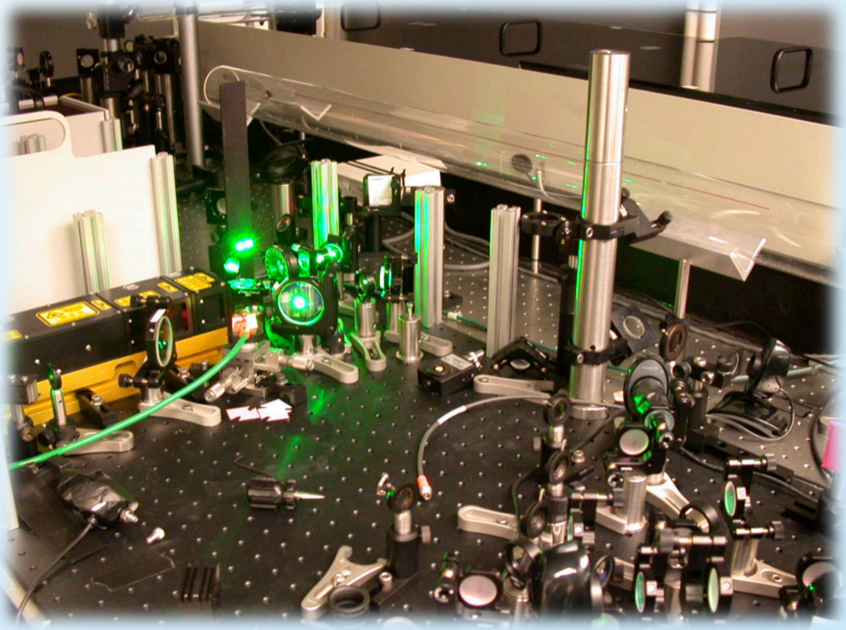
XC - XPW COMPRESSOR
XF - XPW FILTER
XS - XPW STRETCHER
XA - XPW AMPLIFIER

- 17% efficiency (300 μJ → 50 μJ)
- Spectral broadening: 25 nm to 41 nm
- Gaussian beam mode output
- Energy fluctuation ≤5%
- Optimized XPW design: XPW setup in air, no need to be in vacuum (adapted input beam diameter to avoid SPM in polarizer, good focal length to avoid SPM in air at focus)
- Folded design: small footprint (1.5 m x 0.2 m)

Second CPA & Booster Amplifier

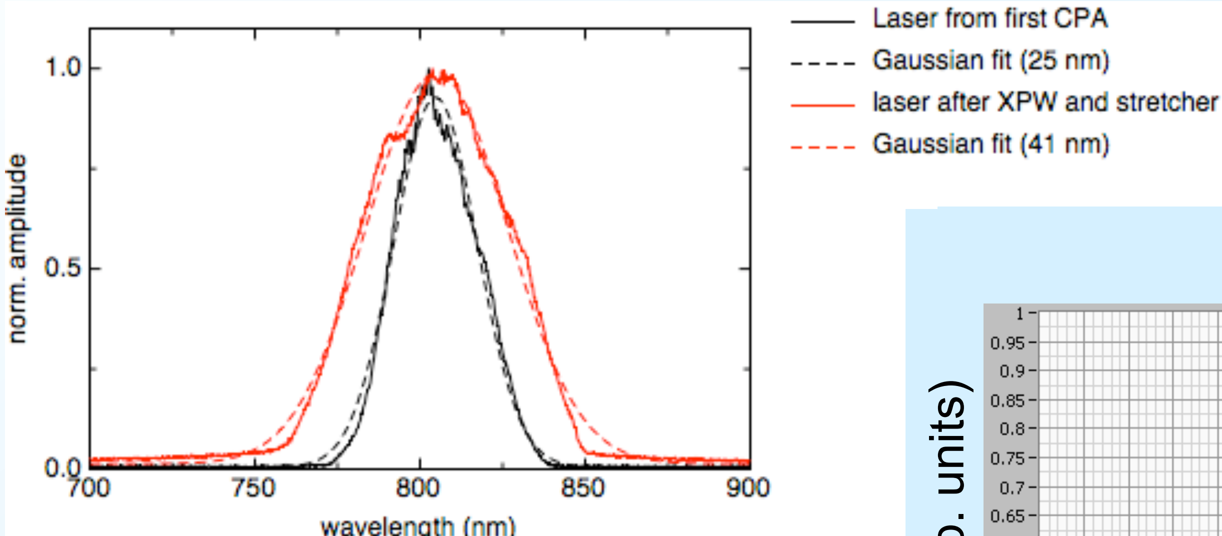
- Contrast preservation requirements:
  - Pump fluence: 1 to 1.4 J /cm^2
  - Passes with gain below 4/pass
  - Total 4 passes



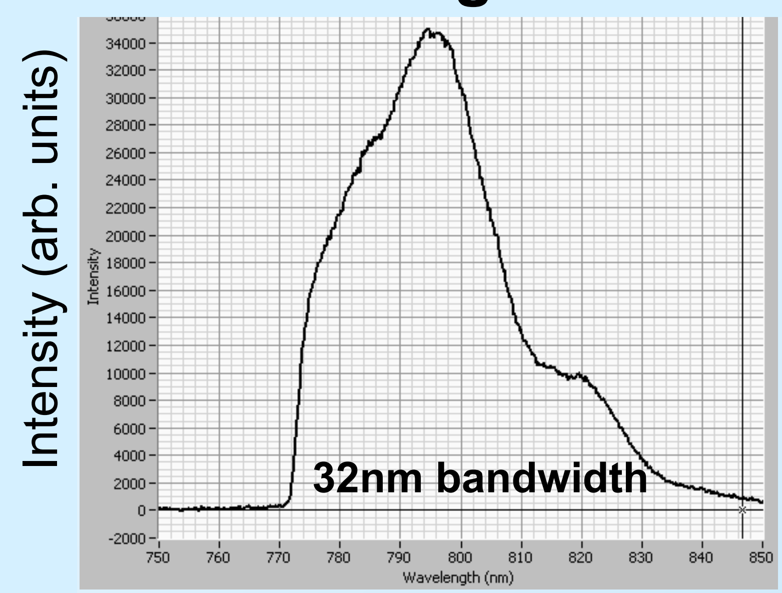


‘Amp0’ with pump laser – ’Ultra’ from Big Sky Lasers

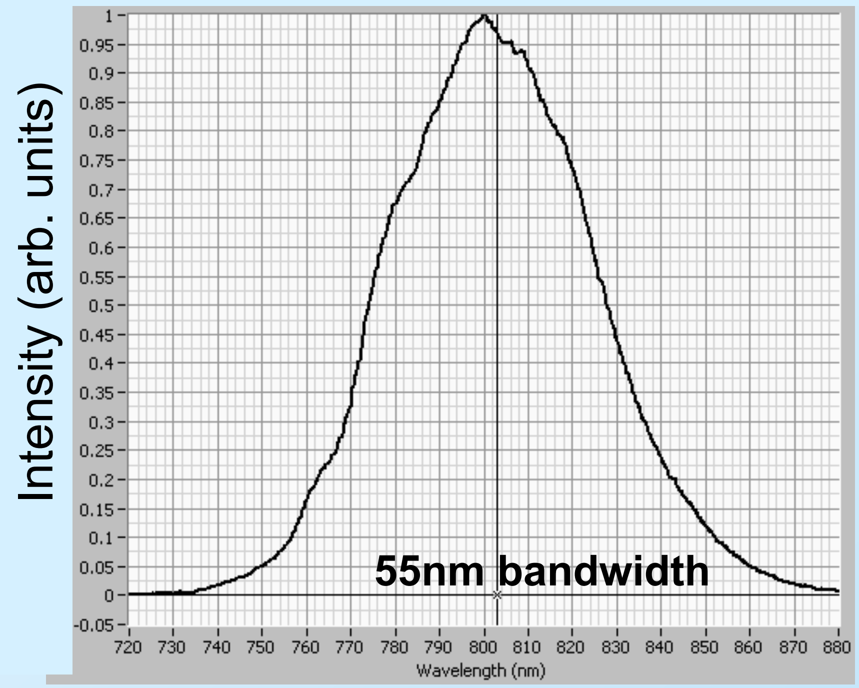
Spectrum broadened after XPW but very sensitive to compressor alignment



Misaligned

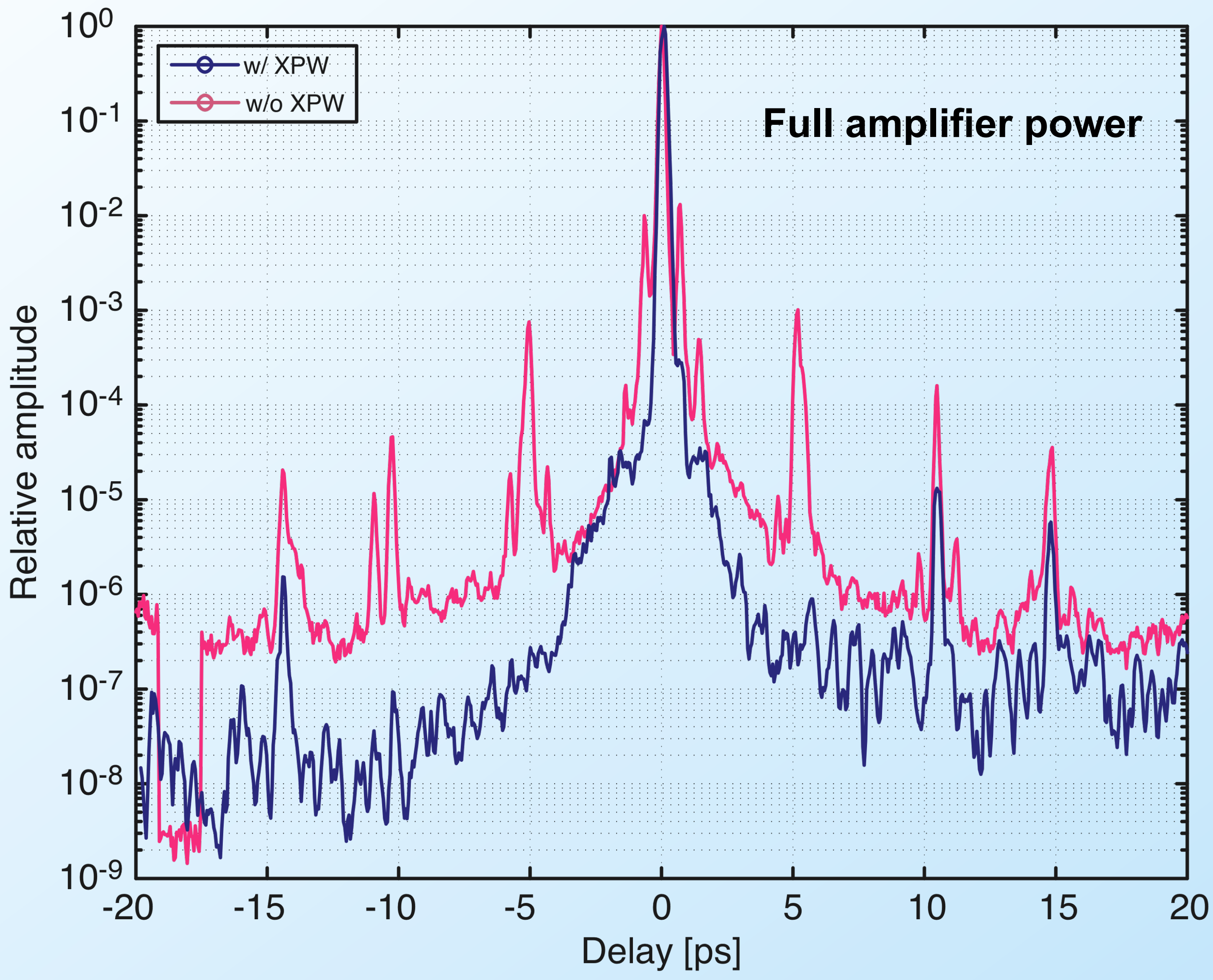


Aligned



Wavelength (nm)

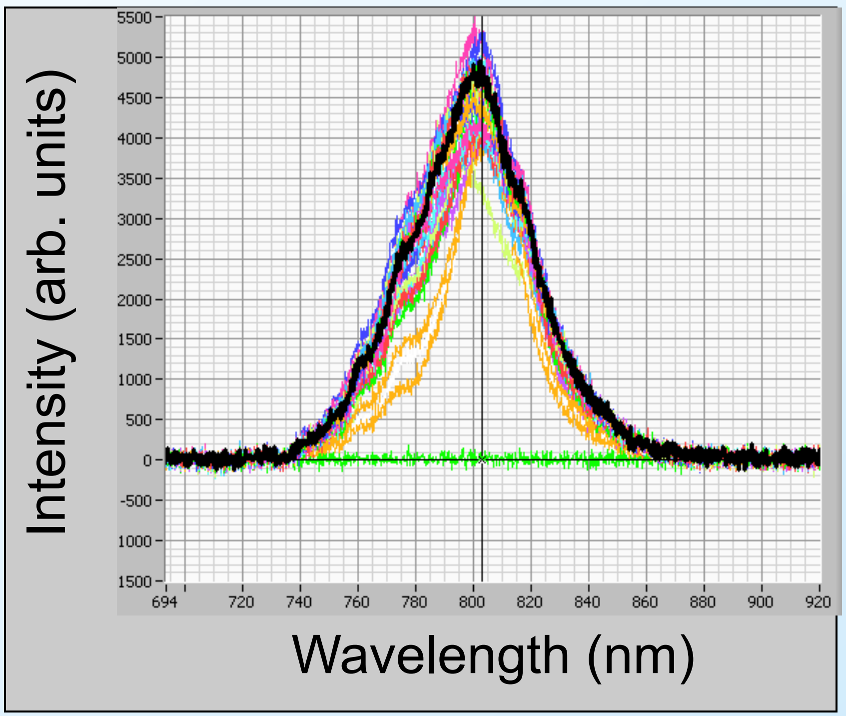
XPW reduces pre-pulse by 3-4 orders



XPW stability

- Spectrum and energy was unstable
  - Turned down input power to make stable (+ some minor tuning of compressor)

20080318



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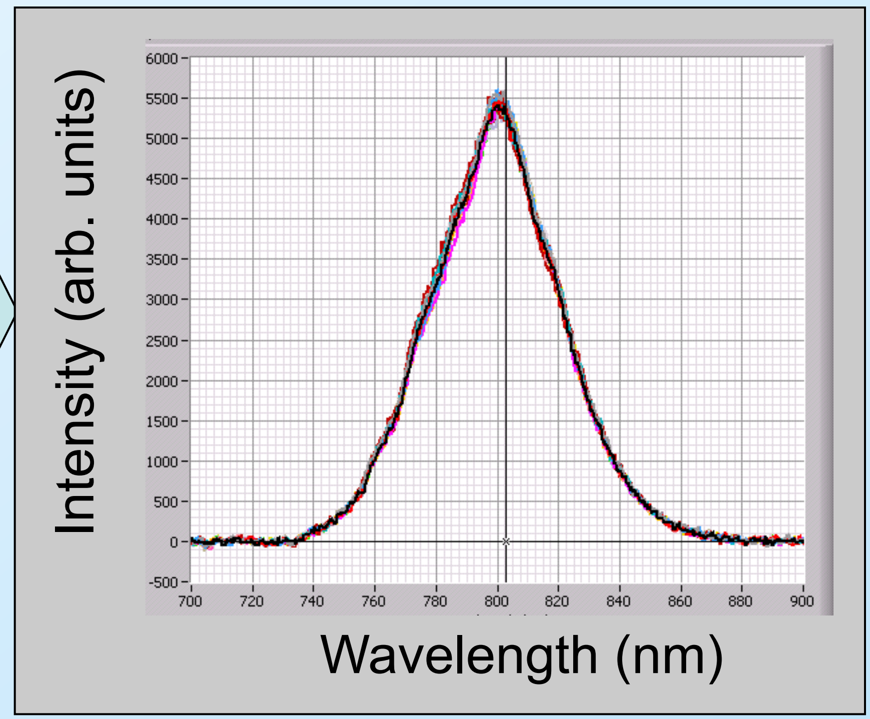
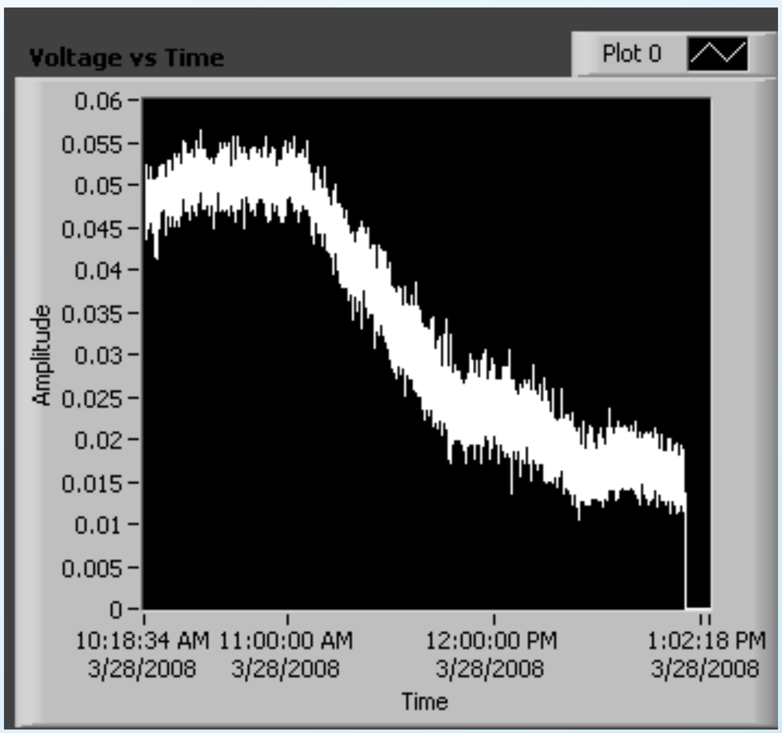
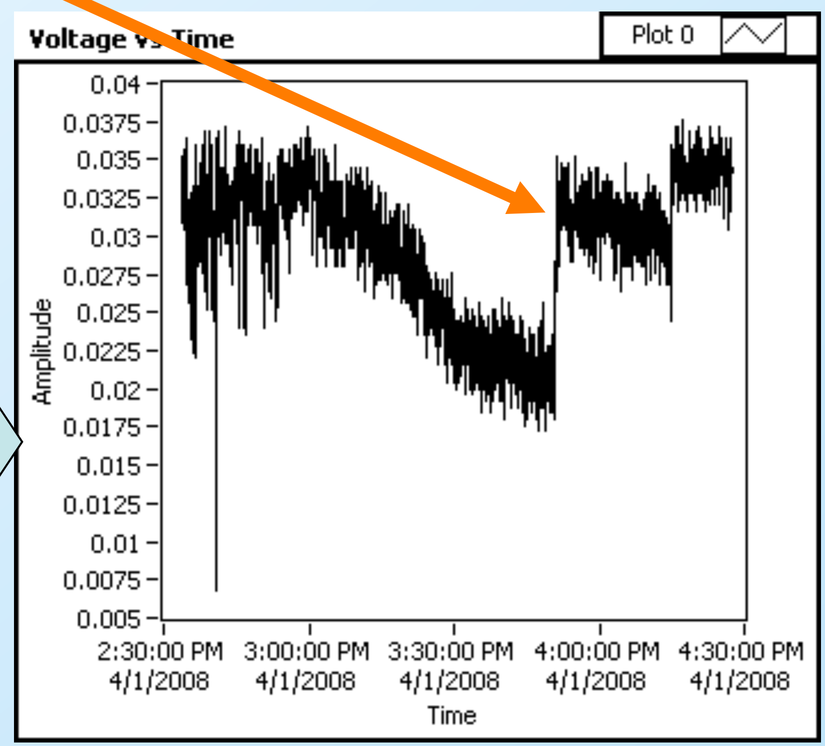


Booster amplifier stability strongly affected by pointing due to small gain volume

- System has been equipped with motorized controls
- Closed feedback installation in process but drift slow enough for operator to give occasional correction kick



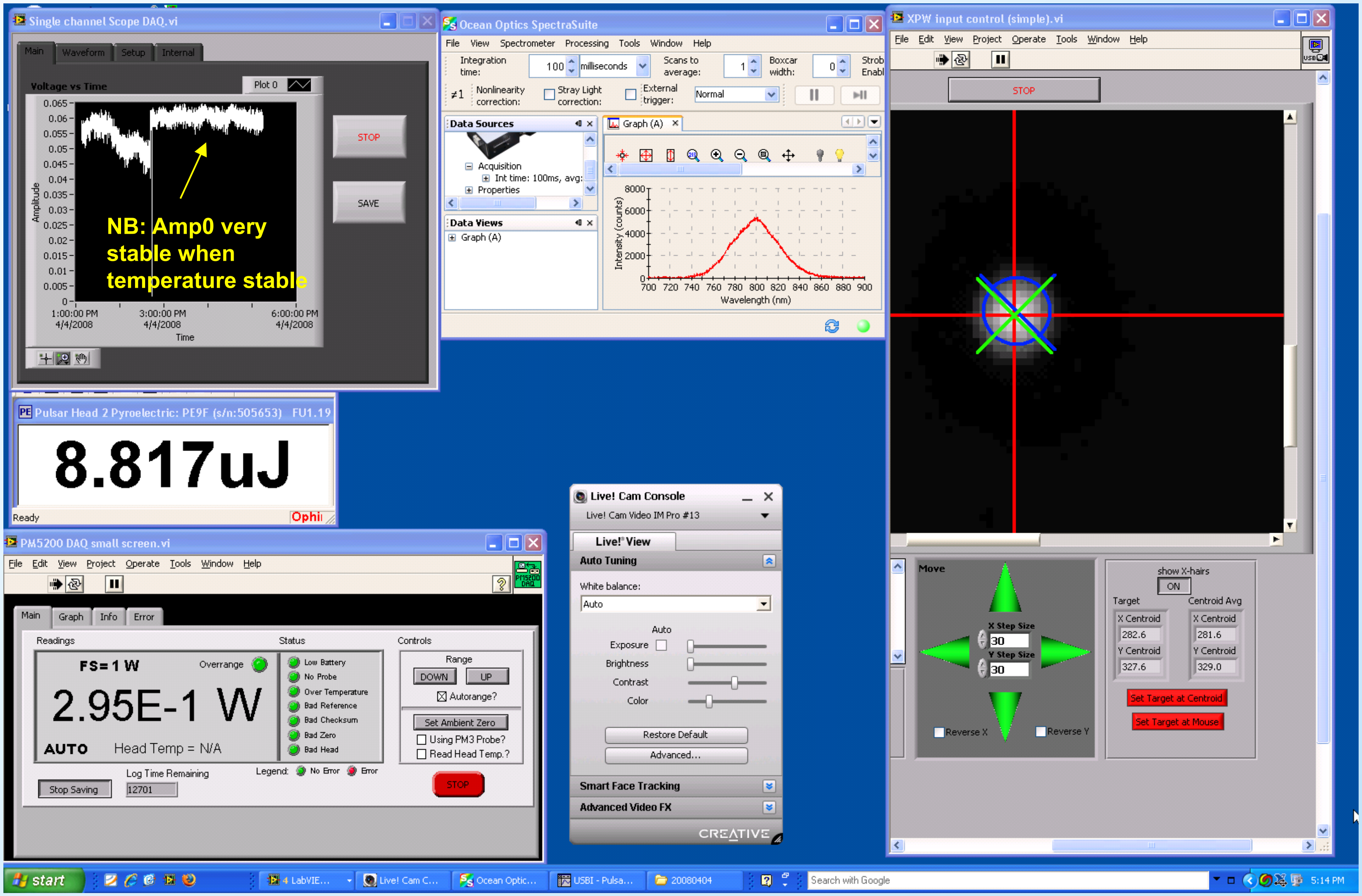


XPW logging and control summary

Amp0 energy **XPW output spectrum** **XPW pointing to Amp0**

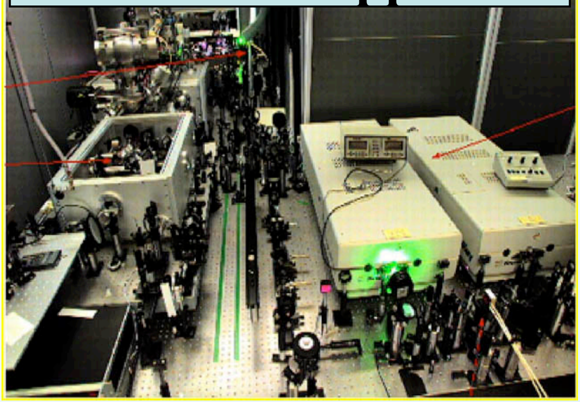
Regen energy

Preamp1 power

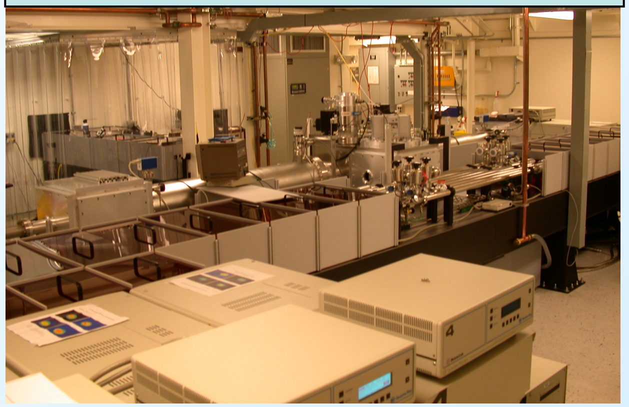


LOASIS multi-terawatt laser systems

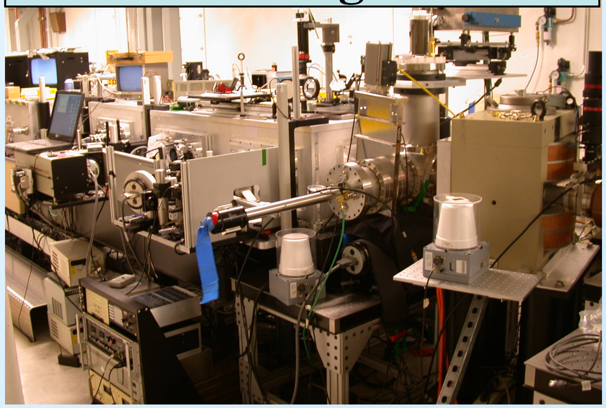
10 TW Ti:sapphire



TREX laser



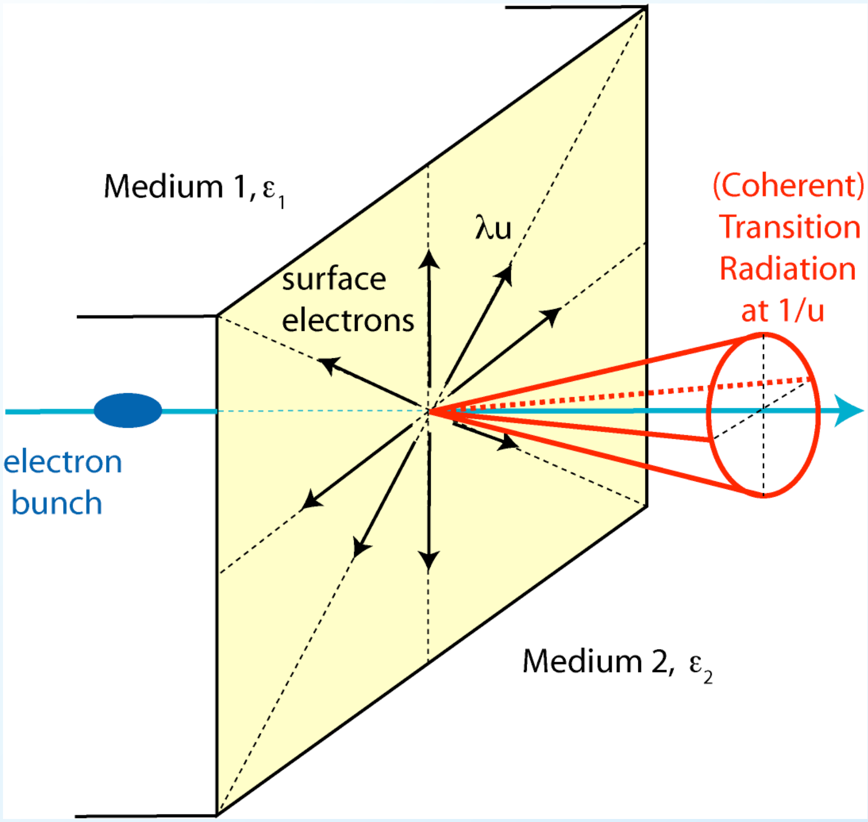
Shielded target room



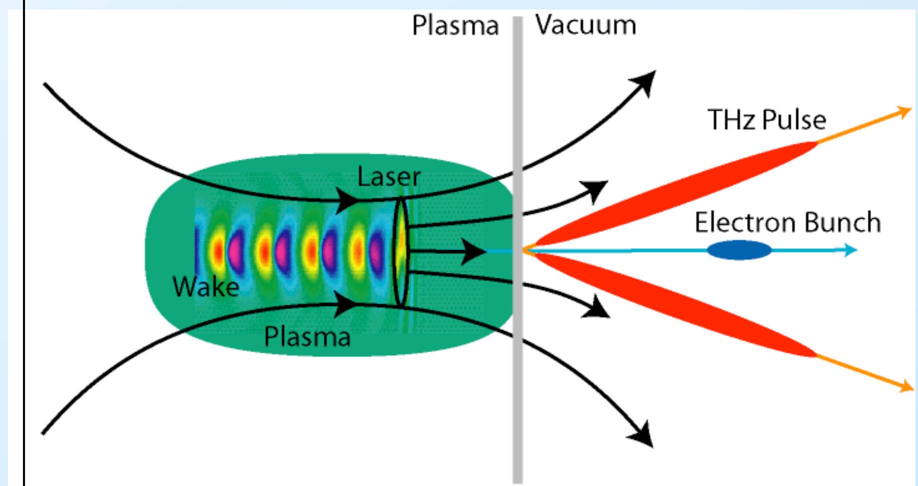
<u>Three main amplifiers (Ti:sapphire,10 Hz):</u>

- "Godzilla":
  0.5-0.6 J in 40-50 fs (10-15 TW) ===> drive beam for gasjet exps
- "Chihuahua":
  20-50 mJ in 50 fs ===> ignitor beam } guiding
  250-300 mJ in 200-300 ps ===> heater beam } guiding
  20-80 mJ in 50 fs ===> colliding beam
- "TREX":
  2.7 J in 35-40 fs (60 TW) ===> capillary guiding exps

Application: improving laser accelerators



At LOASIS: emission from plasma-vacuum boundary



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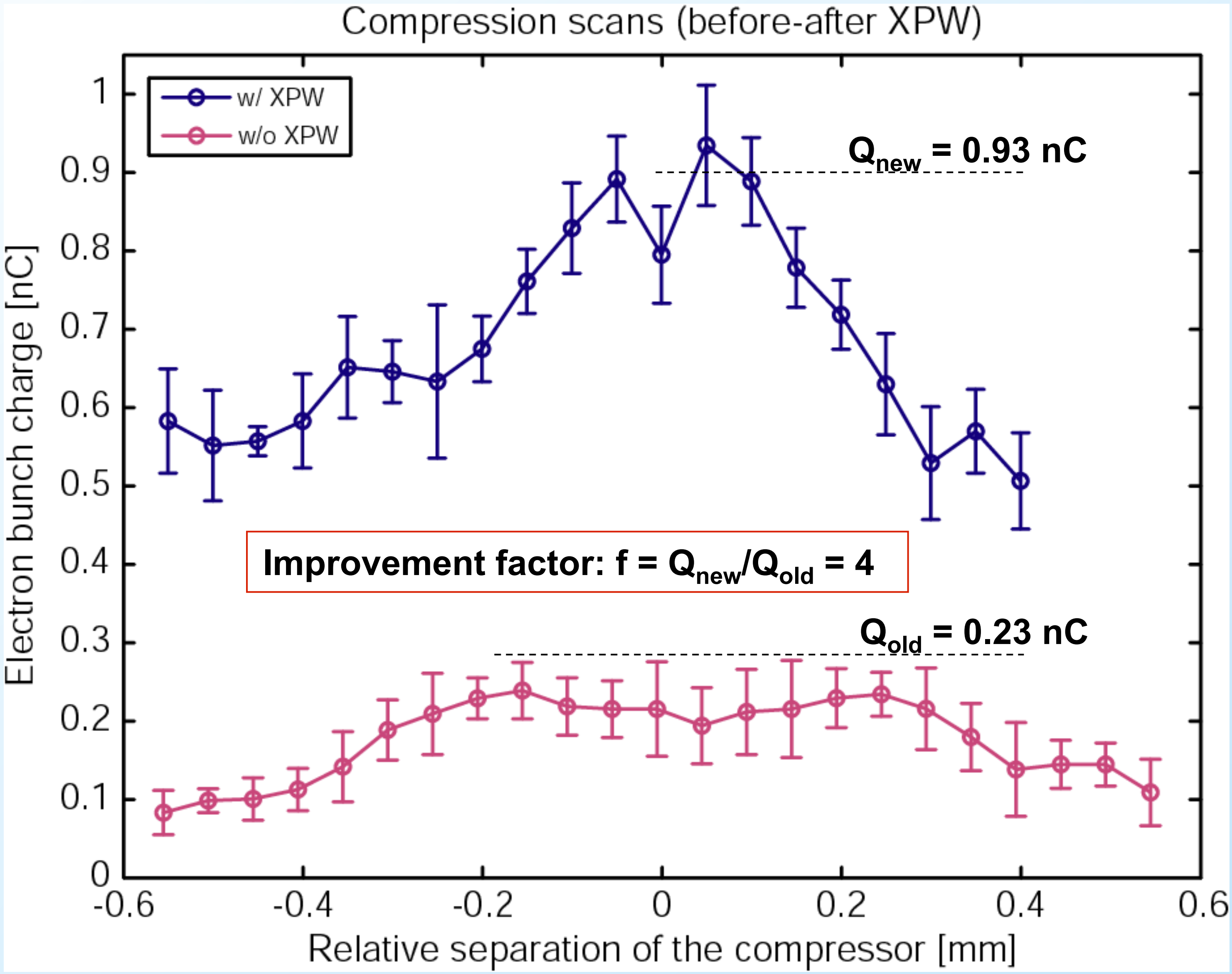
van Tilborg *et al*., Opt. Lett. **32**(3), 313 (2007)

$$\frac{d^2 I_{e-}}{d\omega d\Omega} = \frac{e^2}{\pi^2 c}\left|\frac{u\sqrt{1+u^2}\sin\theta}{1+u^2\sin^2\theta}\right|^2$$

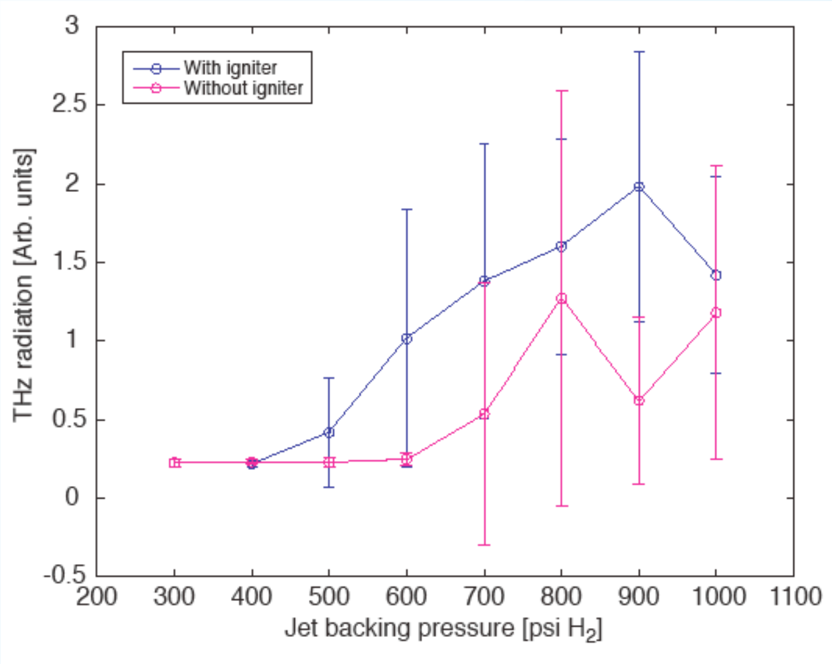
θ= emission angle
u = electron momentum

Improved contrast quadruples charge yield

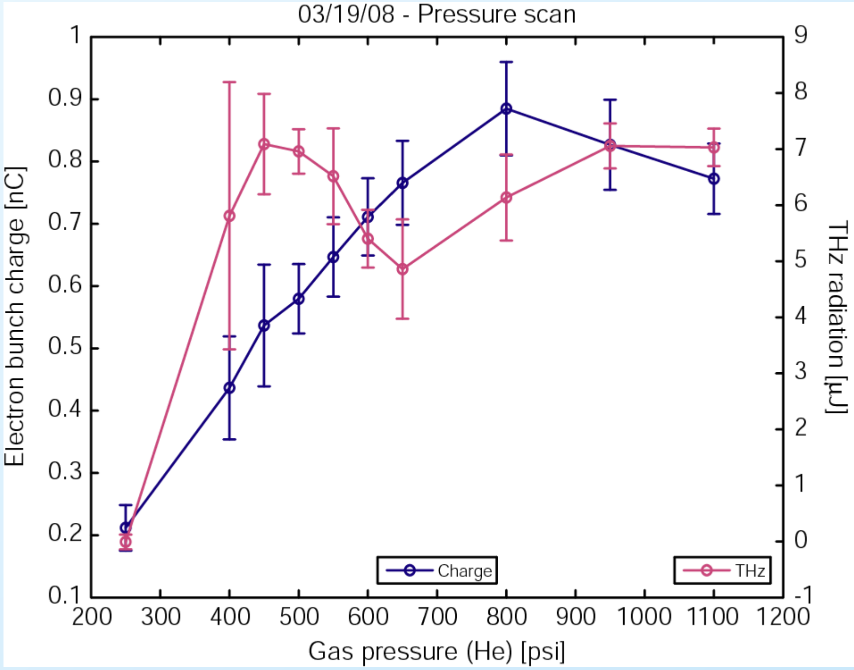


Improved pulse contrast increases THz stability

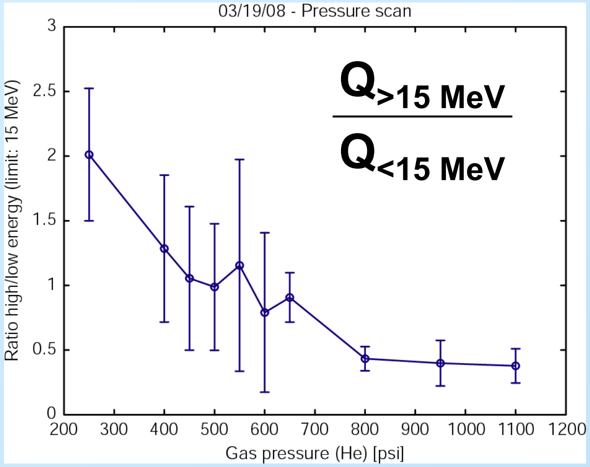
Pre-XPW: 50 – 100% variability



Post-XPW: 10 – 20% variability



Pressure scan shows transition from high-energy (*resonant*) regime to low-energy (*self-modulated*) regime



Conclusion

- Implemented XPW based contrast improvement
  - In-air design
  - Compact system
- Contrast improved by 3-4 orders
- Spectrum broadened from ~25 nm to ~40 nm
- Beam pointing stabilization essential to maintain stable operation of XPW
- Substantial improvement in operation of laser accelerator based on gas jet