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**PHOTOCHEMICALLY DRIVEN ACTIVE MEDIA
FOR ULTRAHIGH INTENSITY FS SYSTEMS:
TOWARDS EXAWATT POWERS**

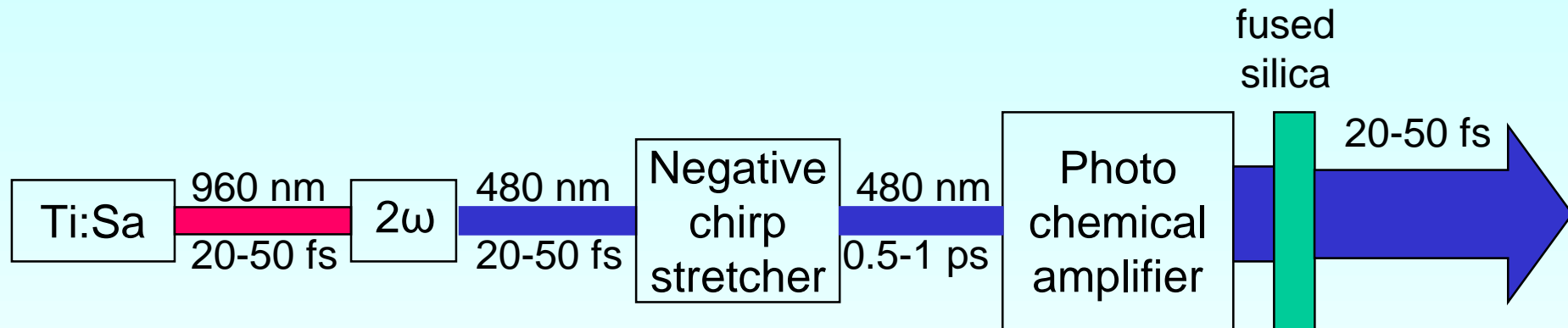
ELI Preparatory Phase

WP9-NECF: Alternative laser

PARTICIPANTS:

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- LP3, Aix-Marseille II University, Marseille, France
- Institute of High Current Electronics, Tomsk, Russia
- Moscow State University, Russia

Photochemically Driven Active Media: New Strategy in the Development of Ultra-high Power Fs Systems

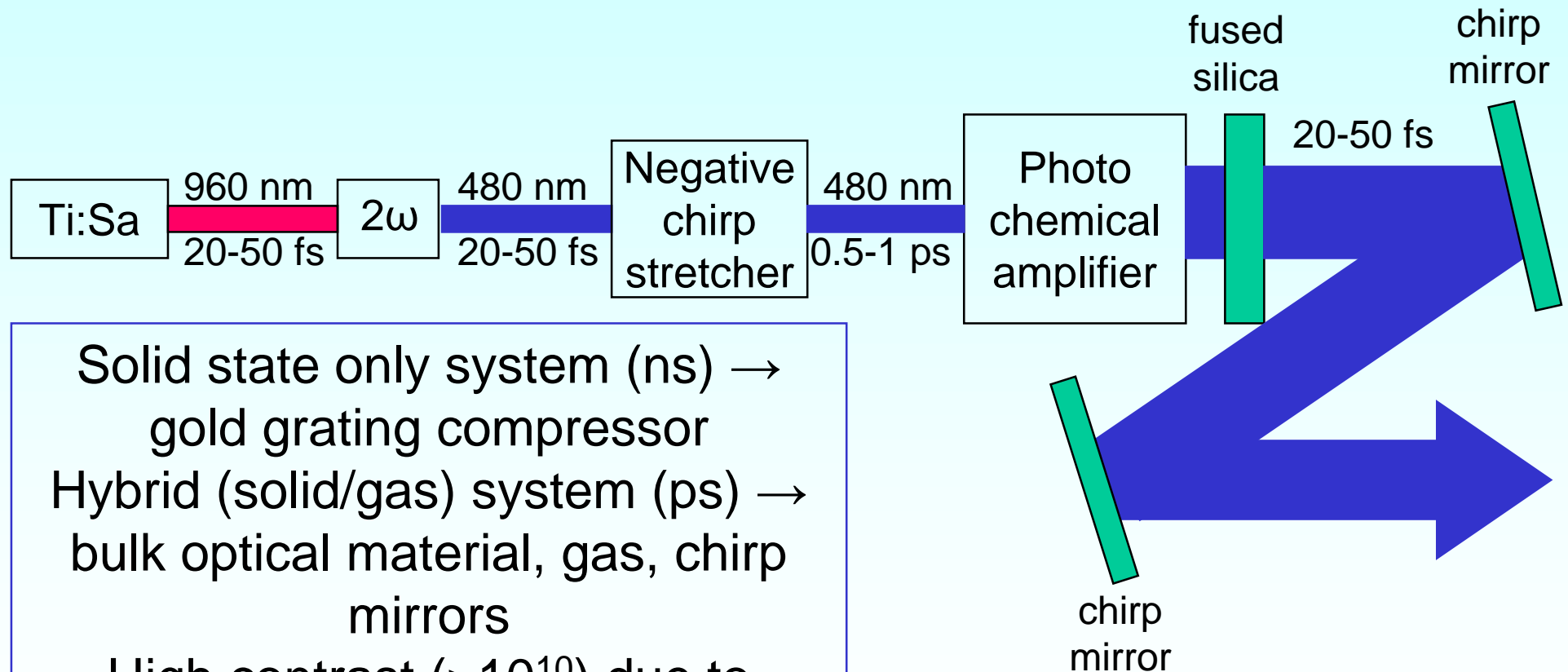


Solid state only system (ns) →
gold grating compressor

Hybrid (solid/gas) system (ps) →
bulk optical material, gas, chirp
mirrors

High contrast ($>10^{10}$) due to
frequency doubling

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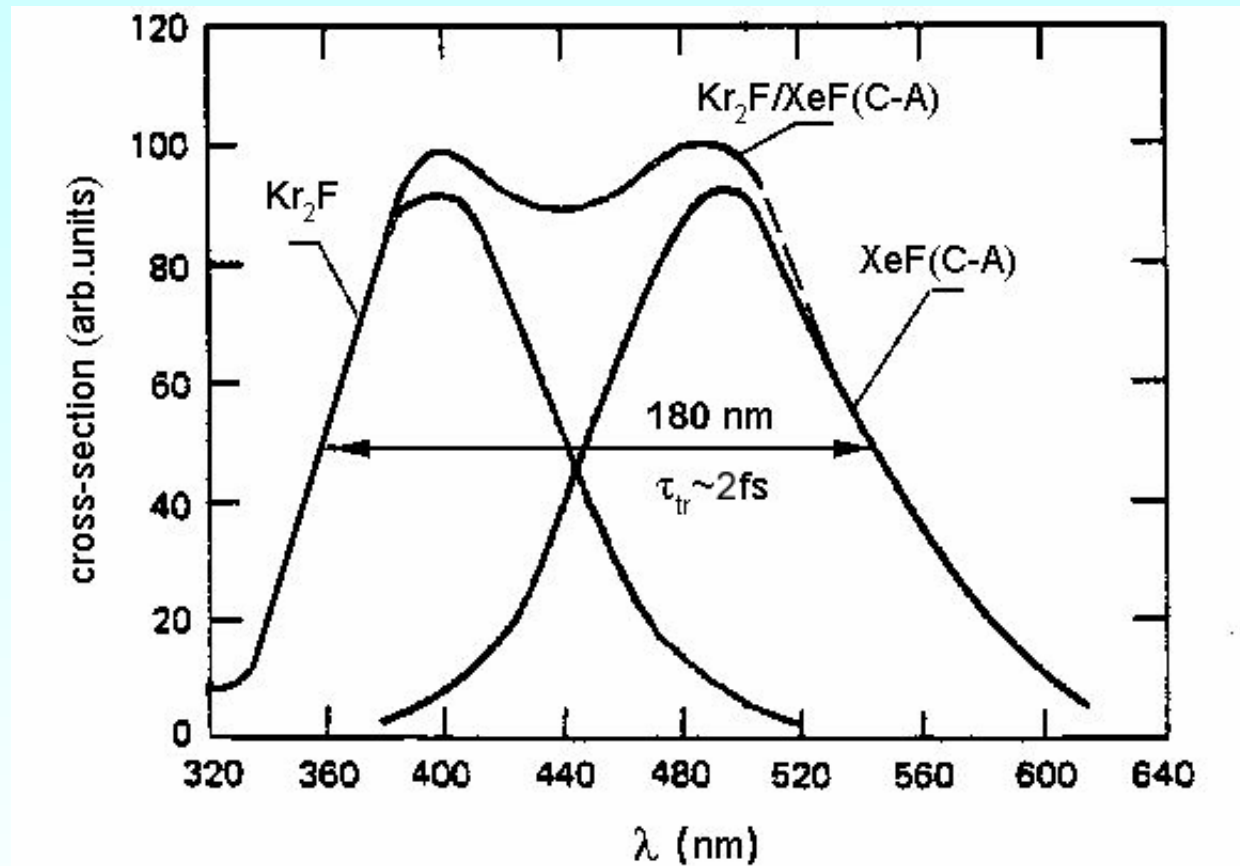
Advantages of gaseous optically pumped active media: Low optical nonlinearity → CPA in subps time domain
 Scalability to very large volumes
 Low cost of realization
 High temporal contrast ($>10^{10}$)

***Photochemically driven broadband active media
 for the fs optical pulse amplification***

Transition	XeF(C-A) /1/	Kr ₂ F (4 ² Γ-1,2 ² Γ) /2/	Xe ₂ Cl (4 ² Γ-1,2 ² Γ) /3/
λ_{\max} , nm	474	405	485
$\Delta\lambda$, nm	60-100	80	100
τ_{lim} , fs	8-12	7	8
τ_{sp} , ns	100	181	245
σ_{st} , cm ²	10^{-17}	2.3×10^{-18}	2.8×10^{-18}
ϵ_{sat} , J/cm ²	0.05	0.2	0.15
I, TW/cm ² ($\tau = 25$ fs)	2	8	6

1. L.D.Mikheev, D.B.Stavrovskii, V.S.Zuev: J. Rus. Las. Res., v.16, 427 (1995)
2. N.G.Basov, V.S.Zuev, A.V.Kanaev, L.D.Mikheev, D.B.Stavrovskii: Kvantovaya Elektron.(Moscow) v.7, 2660 (1980)
3. N.G.Basov, V.S.Zuev, A.V.Kanaev, L.D.Mikheev: Kvantovaya Elektron. (Moscow) v.12, 1954 (1985)

HYBRID SYSTEMS



Amplification of pulses shorter than 10 fs is realistic in the hybrid $Kr_2F/XeF(C-A)$ or Kr_2F/Xe_2Cl systems

Principles of photochemical active media excitation

XeF(C-A) (480 nm):



Pump sources: radiation from a surface discharge or
an e-beam driven Xe flash-lamp

Experimental results: 120 J in free-running regime, 100-
fold amplification of fs pulses

Kr₂F (420 nm):*



Pump sources: radiation from a surface discharge or
an e-beam driven Xe flash-lamp

Experimental results: laser action

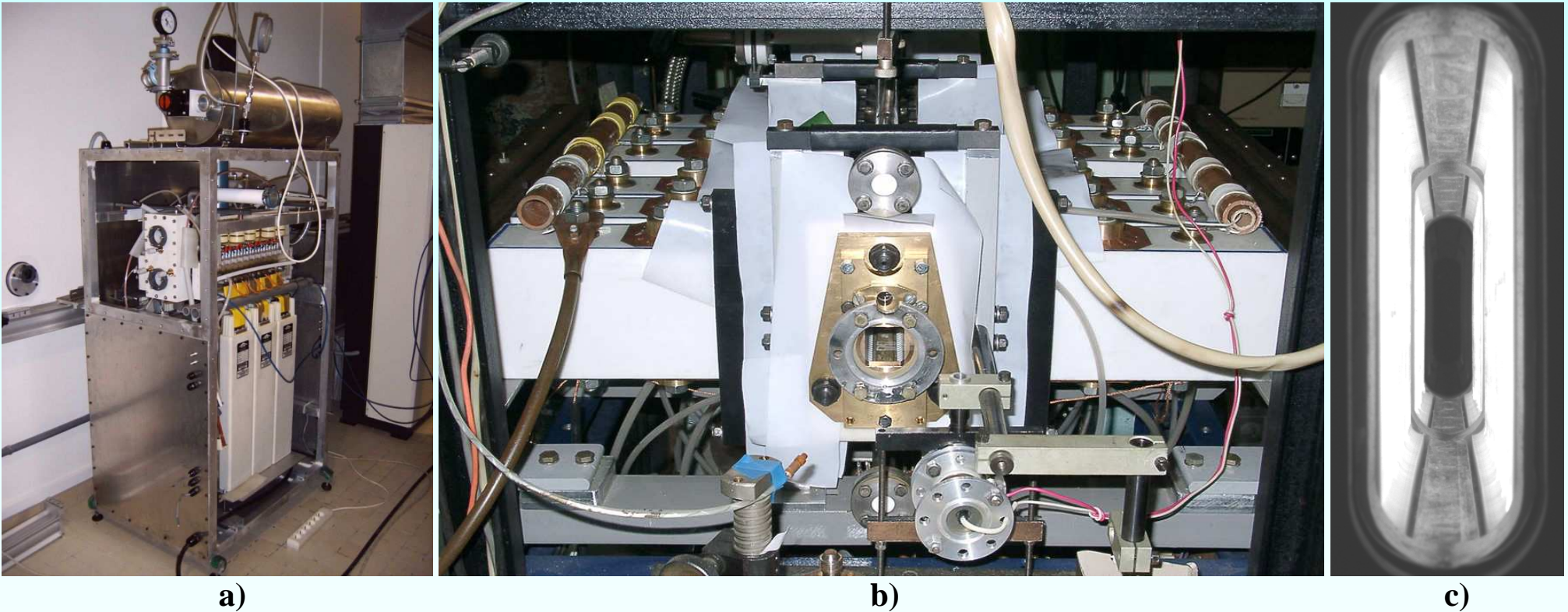
Xe₂Cl (490 nm):*



Pump sources: radiation from quartz flash-lamps
and/or excimer XeCl lasers

Experimental results: laser action

XeF(C-A) amplifier pumped by radiation from a surface discharge



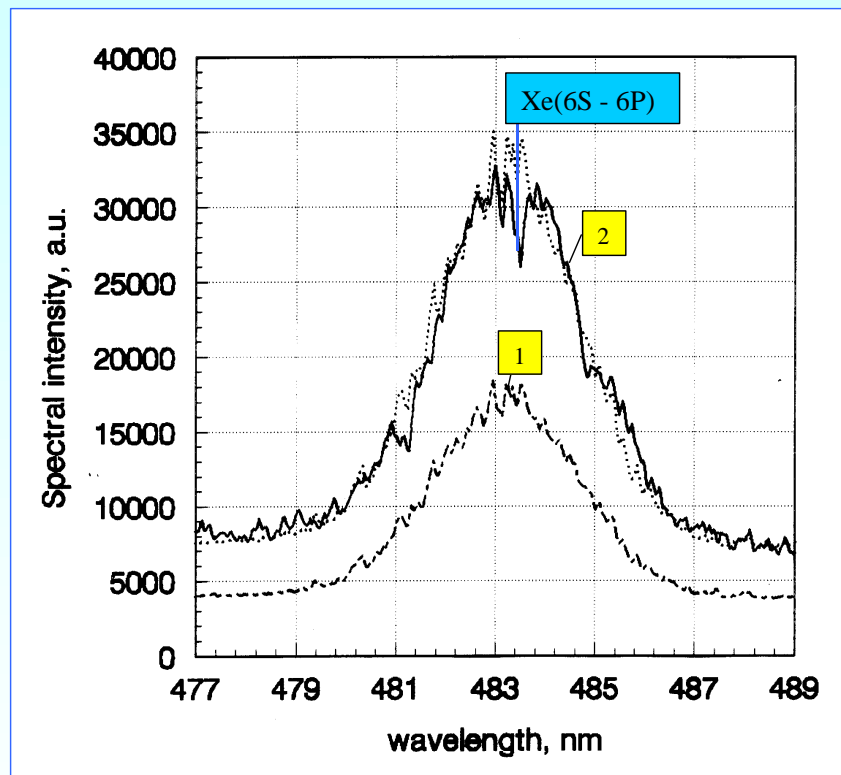
Photos of the photolytical XeF(C-A) amplifiers: a) LP3 of Marseille Univ.(active volume: $5 \times 18 \times 40 \text{ cm}^3$); b) P.N.Lebedev Inst. (active volume: $3 \times 11 \times 50 \text{ cm}^3$); c) XeF(C-A) amplifier viewed from its front when surface discharge is initiated.

Small-signal gain: $2 \times 10^{-3} \text{ cm}^{-1}$
Total amplification factor: 10^2

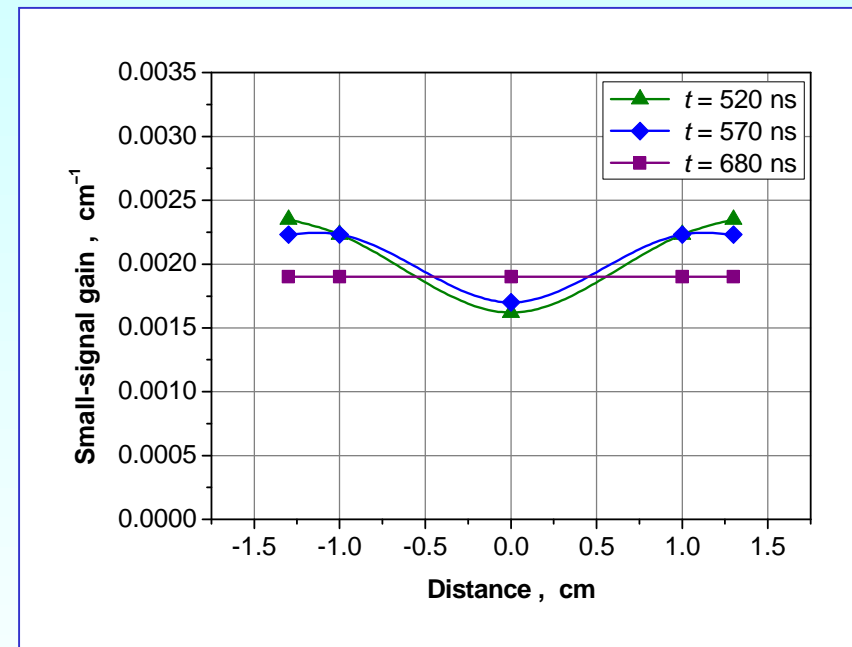


XeF(C-A) amplifier photochemically driven by radiation from a surface discharge. Experimental results.

Total small signal gain of the multipass amplifier 10^2

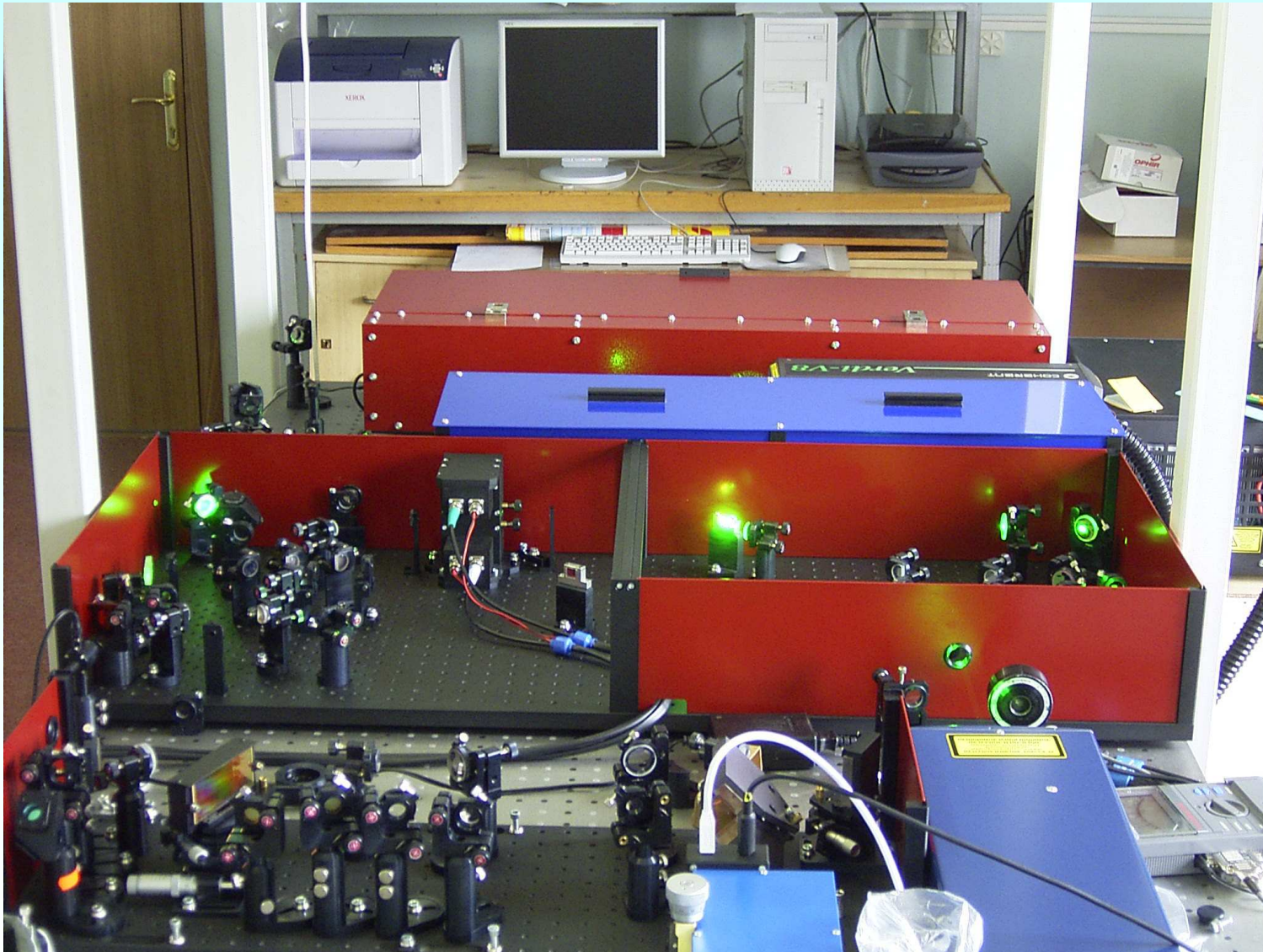


Spectra of fs pulse before (1) and after (2) amplification



Gain distributions versus the distance from the central plane of the amplifier at different instants of time

Ti:Sa front end (Avesta Project Ltd)



$$\lambda_{\omega} = 950 \text{ nm}$$

$$\lambda_{2\omega} = 475 \text{ nm}$$

$$\tau = 45\text{-}50 \text{ fs}$$

$$E = 5 \text{ mJ}$$

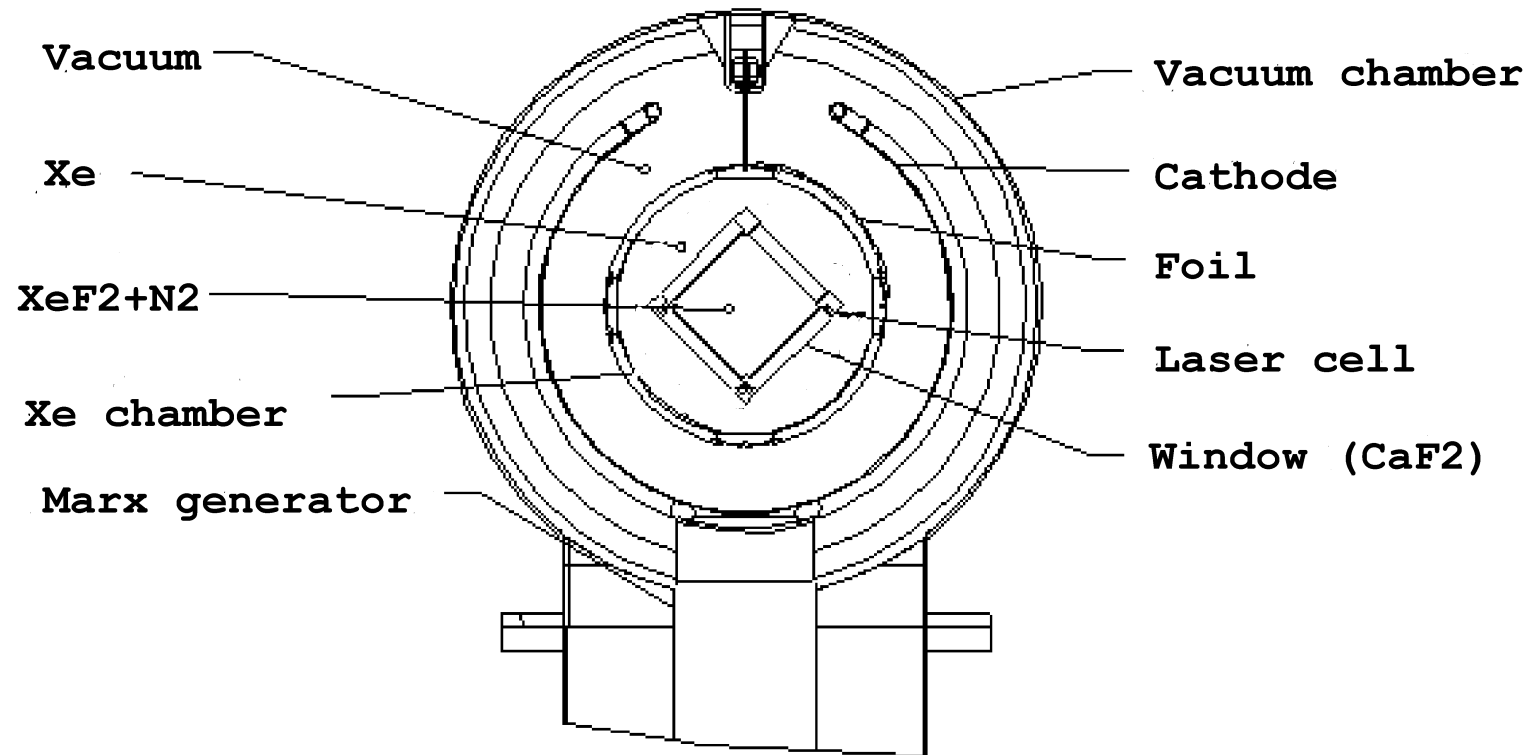
$$f = 10 \text{ Hz}$$

Final XeF(C-A) amplifier photochemically driven by 172 nm radiation from an e-beam pumped Xe converter

Active medium length - 1.2 m, clear aperture - 12 cm.

E-beam: $I=80 \text{ } \mu\text{A}$, $U_e= 420 \text{ keV}$, pulse-width – 400 ns.

Xe_2 fluorescence efficiency related to e-beam energy is 30-40%

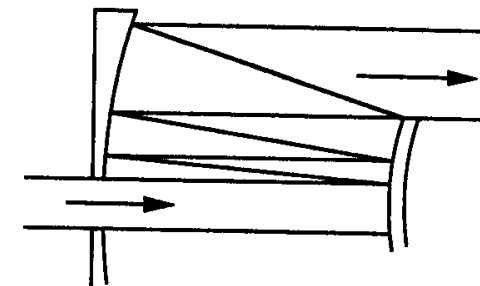


XeF(C-A) amplifier (IHCE, Tomsk)



Experiment:
Small signal gain
 $2.6 \times 10^{-3} \text{ cm}^{-1}$

Theory:
Small signal gain
 $5 \times 10^{-3} \text{ cm}^{-1}$
 $E_{\text{stor}} = 6 \text{ J}$
 $E_{\text{out}} = 2\text{-}2.5 \text{ J}$
 $P_{\text{out}} = 50 \text{ TW}$
 $\tau = 50 \text{ fs}$



Active medium length - 1.2 m, clear aperture - 12 cm.

**PROSPECTS OF PHOTOCHEMICAL FS XeF(C-A) AND Kr₂F AMPLIFIERS PUMPED
BY E-BEAM DRIVEN XENON FLASHLAMP**

Multipetawatt XeF(C-A) amplifier (480 nm) (project)

Vacuum diode (IHCE, Tomsk, Russia):

60 cm dia, 2 m long, $W_{eb} = 250$ GW.

$I_{eb} = 24$ A/cm². $U = 600$ keV. $\tau(\text{FWHM})=200$ ns.

At $\eta \approx 1\%$, instant energy $E_{inst} \approx 175\text{J} \Rightarrow 7$ PW (25 fs)

s.s.gain $\approx 1.7 \times 10^{-2}$ cm⁻¹ ($V_{ak} \approx 250$ л)

Scaling to 1kJ of output energy

XeF(C-A) amplifier (480 nm):

Saturating fluence $\varepsilon = 0.05$ J/cm²

At output fluence $2\varepsilon \rightarrow 1$ m aperture

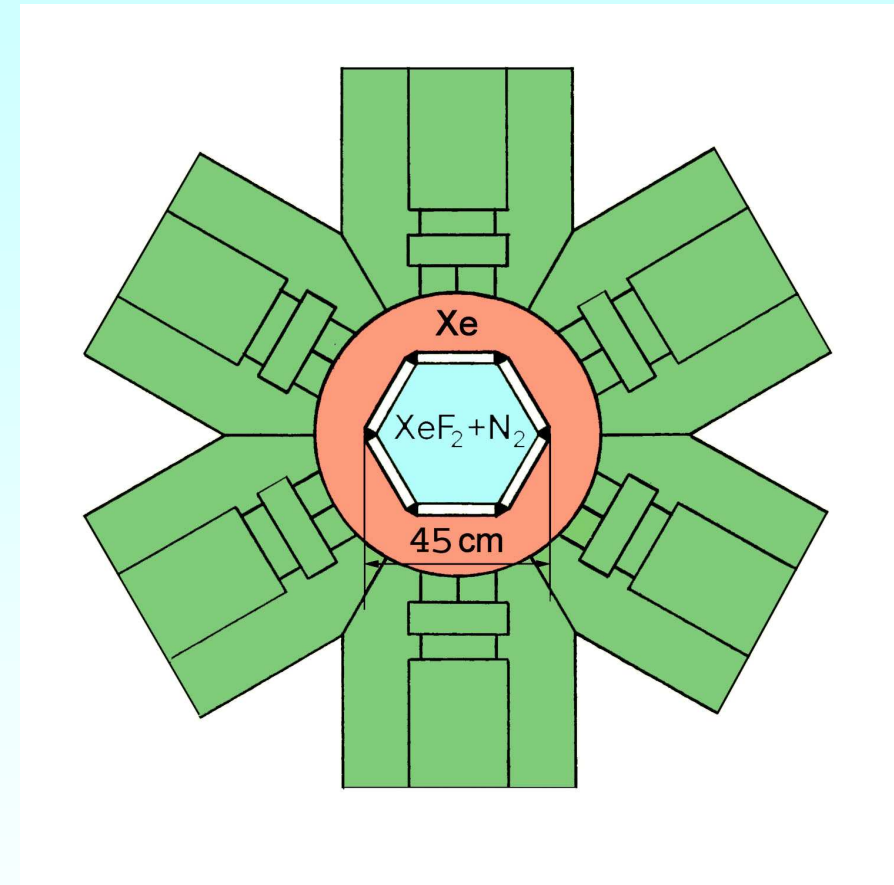
s.s.gain $\approx 5 \times 10^{-3}$ cm⁻¹ $\rightarrow \sim 6$ m long active medium.

Kr₂F amplifier (420 nm):

Saturating fluence $\varepsilon = 0.2$ J/cm²

At output fluence $2\varepsilon \rightarrow 50$ cm aperture

s.s.gain $\approx 5 \times 10^{-3}$ cm⁻¹ $\rightarrow \sim 3$ m long active medium.

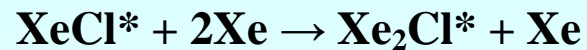


Pumping by Xe₂ radiation at $\lambda = 172$ nm

PHOTOCHEMICAL FS Xe₂Cl AMPLIFIER RELYING ON EXCIMER-LASER/FLASH-LAMP PUMPING

Pumping sources:

- 1) flash-lamps or XeCl lasers to produce Cl atoms
- 2) XeCl laser (308 nm) to excite Xe₂Cl:



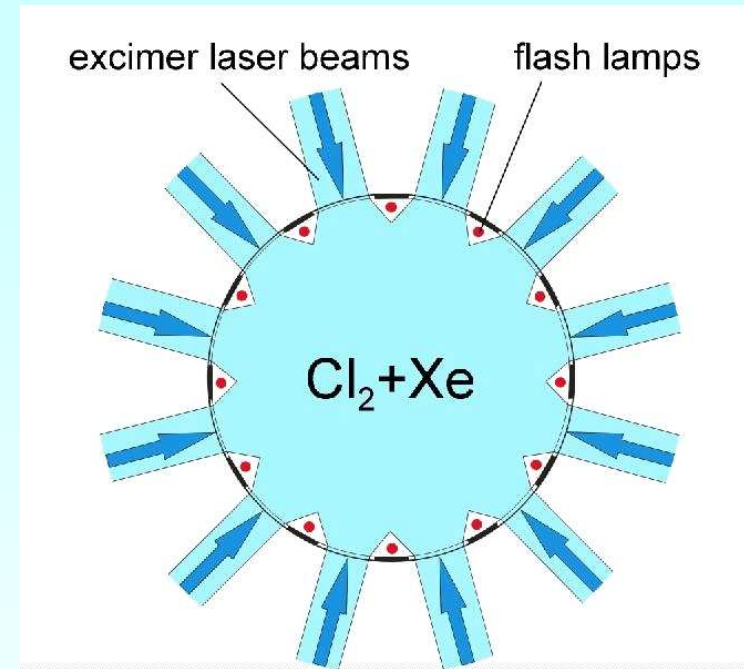
Pumping fluence $\approx 0.05 \text{ J/cm}^2 \rightarrow \text{s.s.gain} \approx 5 \times 10^{-3} \text{ cm}^{-1}$

Scaling to 1kJ of stored energy:

Saturating fluence $\varepsilon = 0.15 \text{ J/cm}^2$

At output fluence $2\varepsilon \rightarrow 70 \text{ cm aperture}$

s.s.gain $\approx 5 \times 10^{-3} \text{ cm}^{-1} \rightarrow 4 \text{ m long active medium}$



Xe₂Cl: $\lambda = 490 \text{ nm}$

Conclusion

- Photochemically driven active media seem to be promising candidates for ultra-high intensity fs systems towards exawatt powers