High average power Compton based X-ray source

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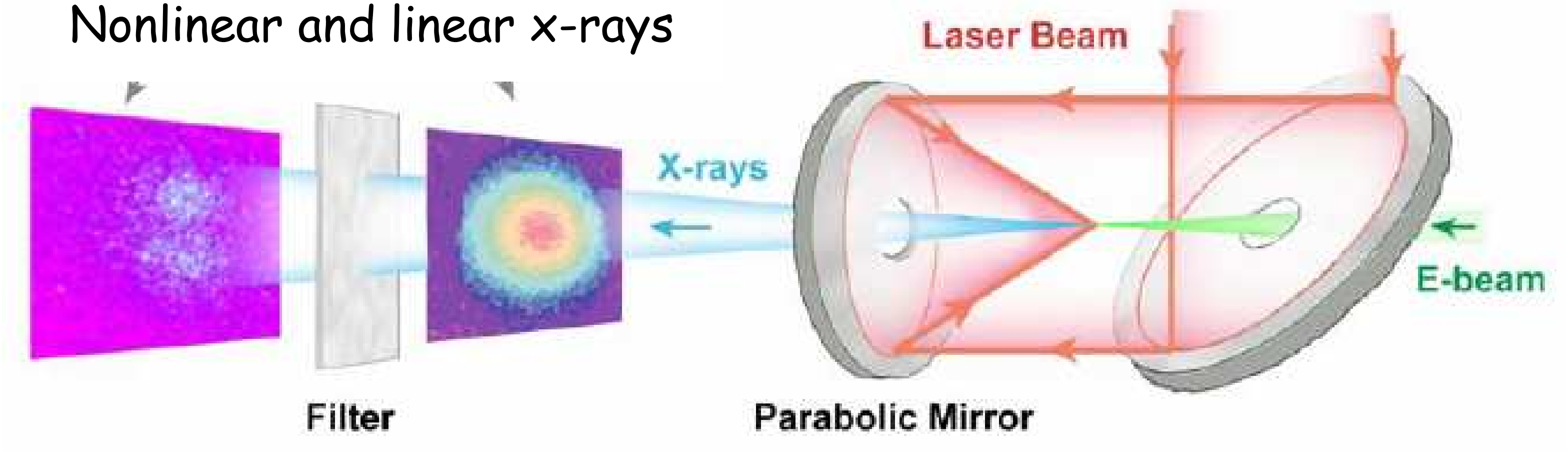
Compton Experiment at ATF

(record number of X-rays with 10 μm laser)

- More then 10^8 of x-rays/per pulse were generated in the experiment PR ST 2000. N_X/N_{e-} ~0.1.
- 0.35 in 2006- limited by laser/electron beams diagnostics
- Interaction point with high power laser focus of ~30μm was tested.
- Nonlinear limit (more then one laser photon scattered from electron) was verified. PRL 2005.

Real CCD images
Nonlinear and linear x-rays

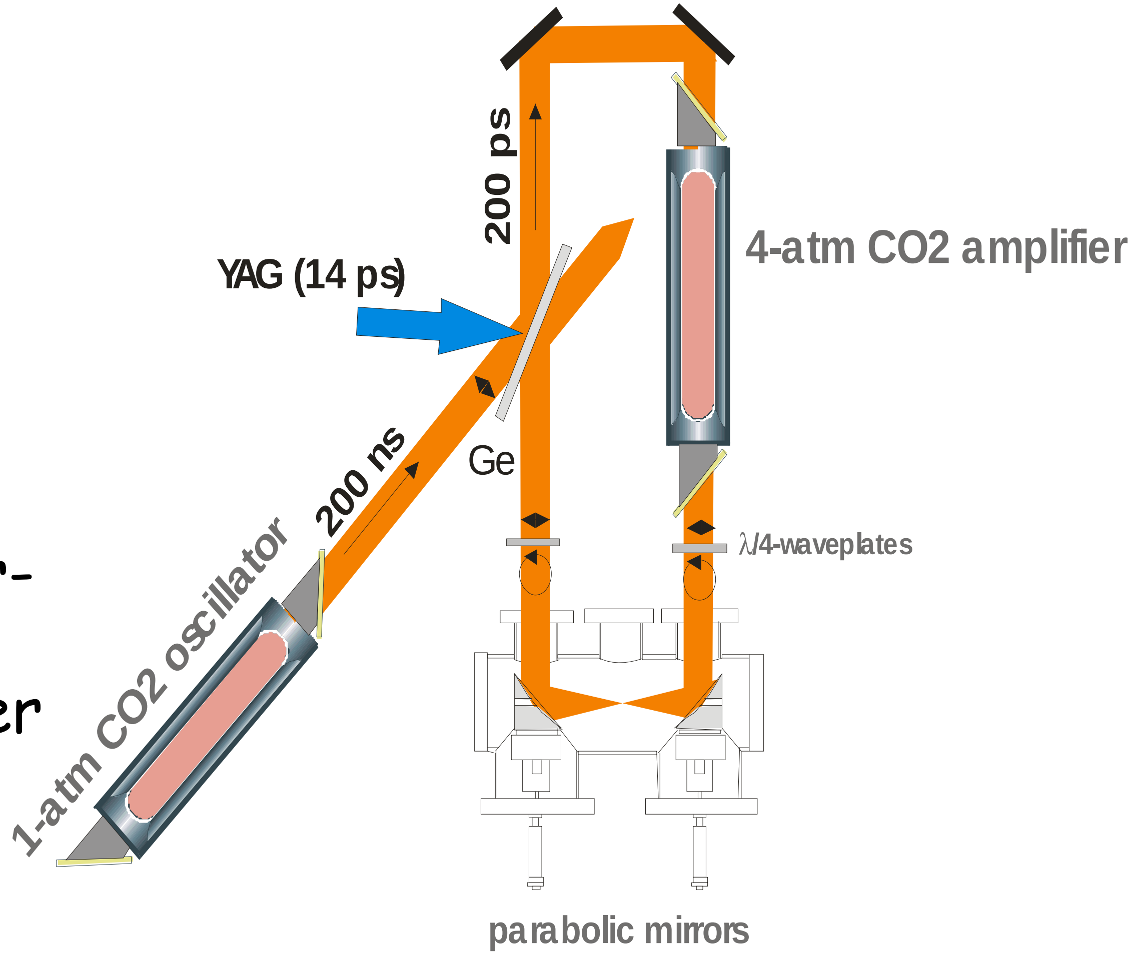


CO2 cavity

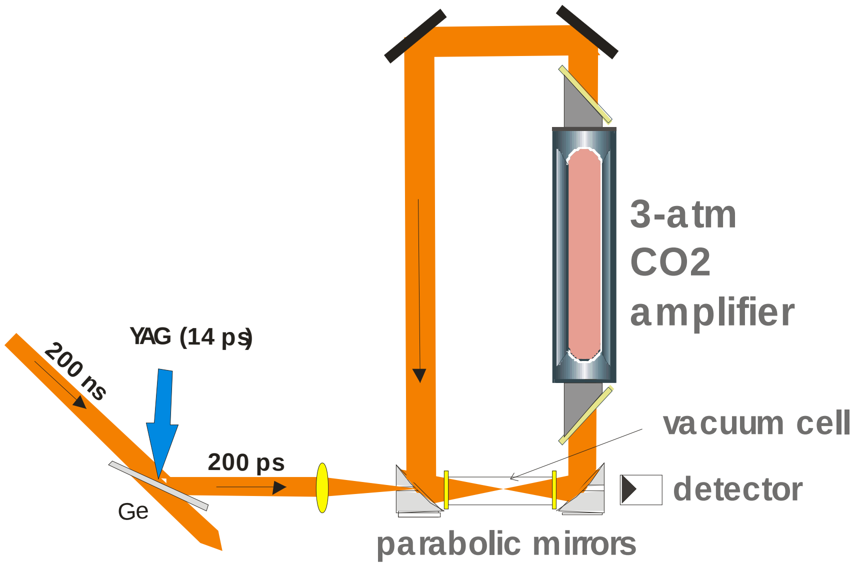
- Has a potential to increase average intra-cavity power ~100 times at 10.6 microns.

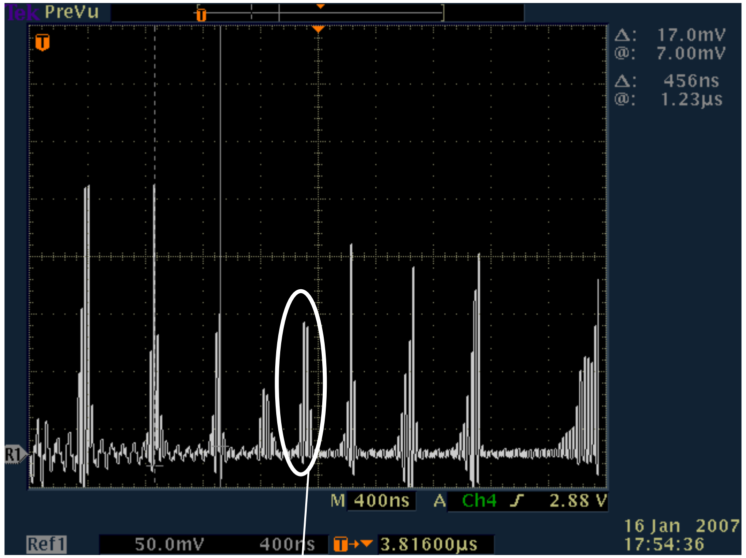
Purpose of the test:

- Demonstration of 100-pulse train inside regenerative amplifier that incorporates Compton interaction point.
- Demonstration of linear-to-circular polarization inversion inside the laser cavity.
- Test of the high power injection scheme



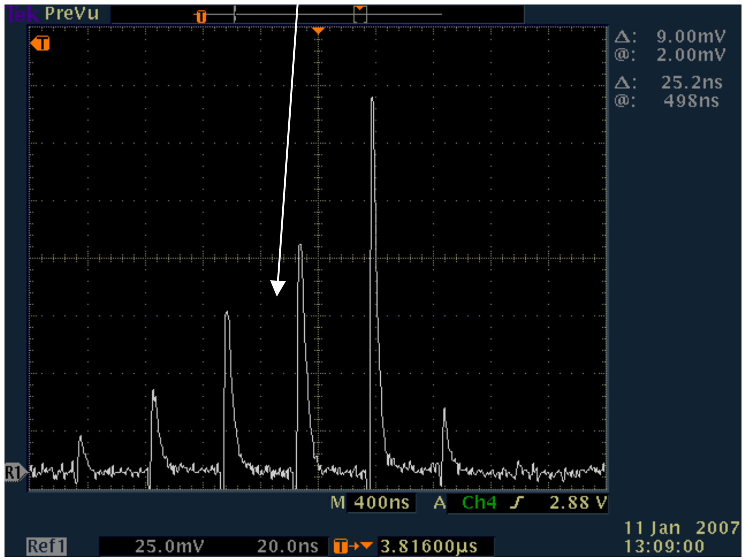
CO2 cavity: Simplified test setup



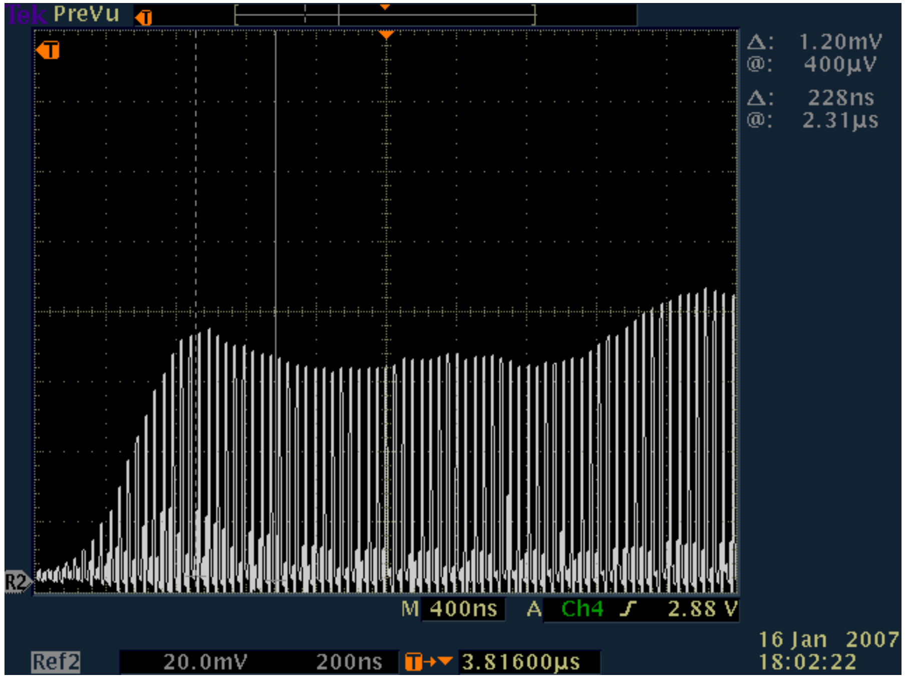


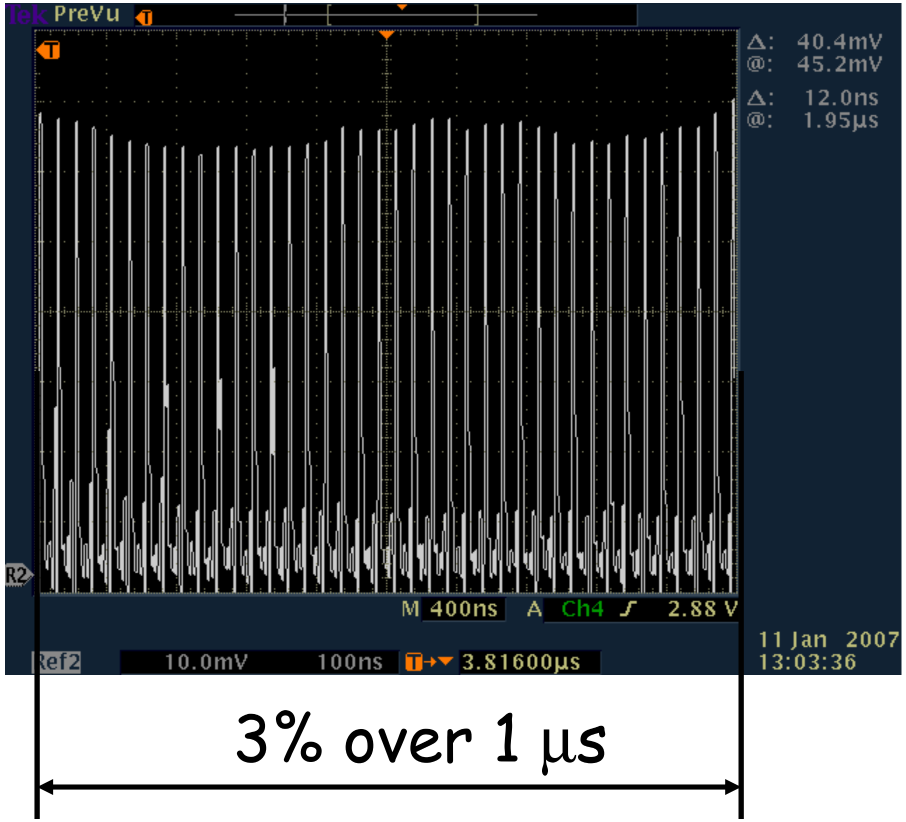
First observations:

- Optical gain over 4 µs
- Misbalanced gain/loss regime results in lasing interruption by plasma
- Single seed pulse amplification continues to the end



The best train uniformity achieved



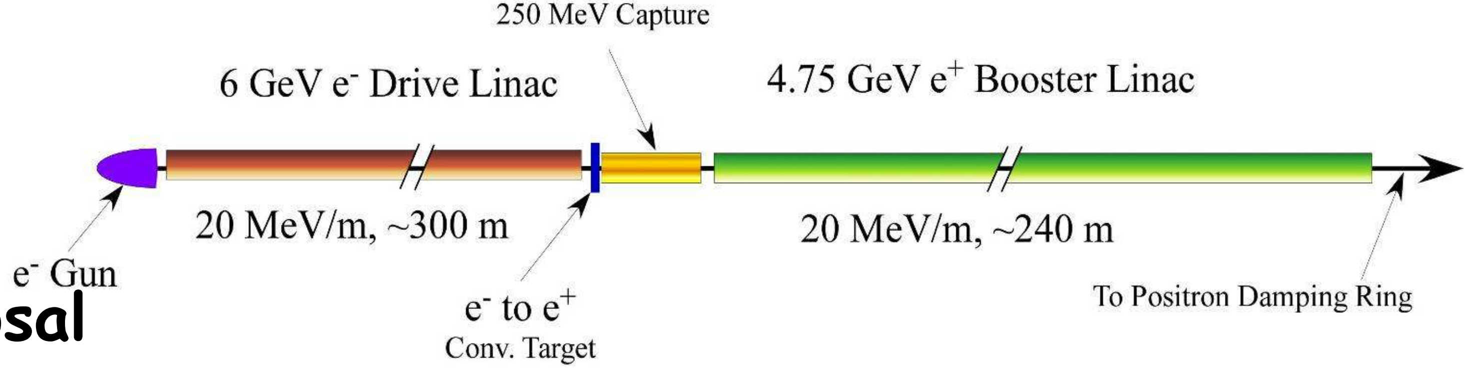


- Very encouraging results obtained with simplified cavity test setup: ~200 ps pulse of the order of 100 mJ circulated for >1 µs.

- Further test would require pulse length monitoring and high pressure or isotope mixture based amplifier (to sustain 5 ps beams).

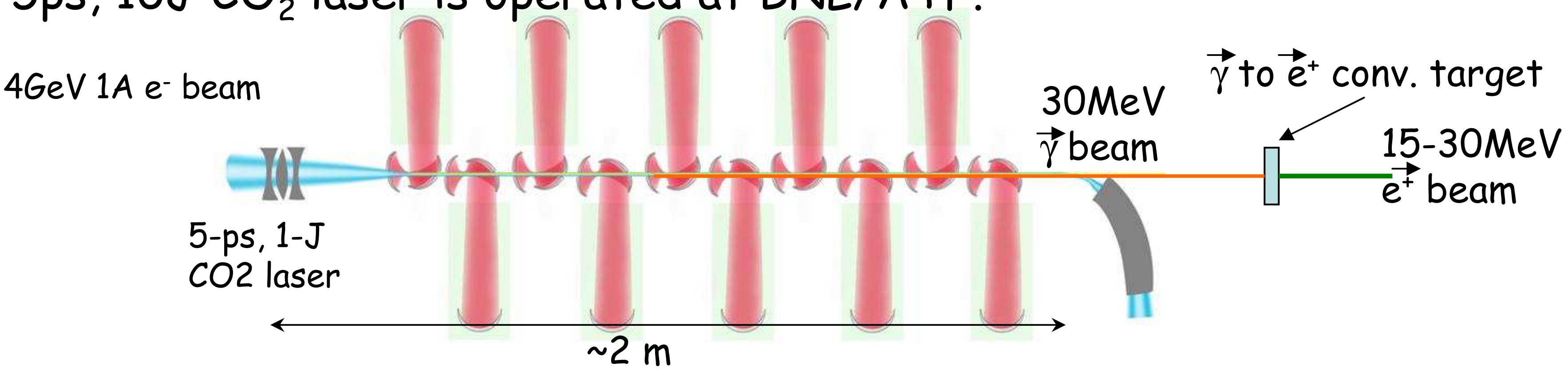
Polarized Positrons Source (PPS for ILC)

Conventional Non-Polarized Positrons:

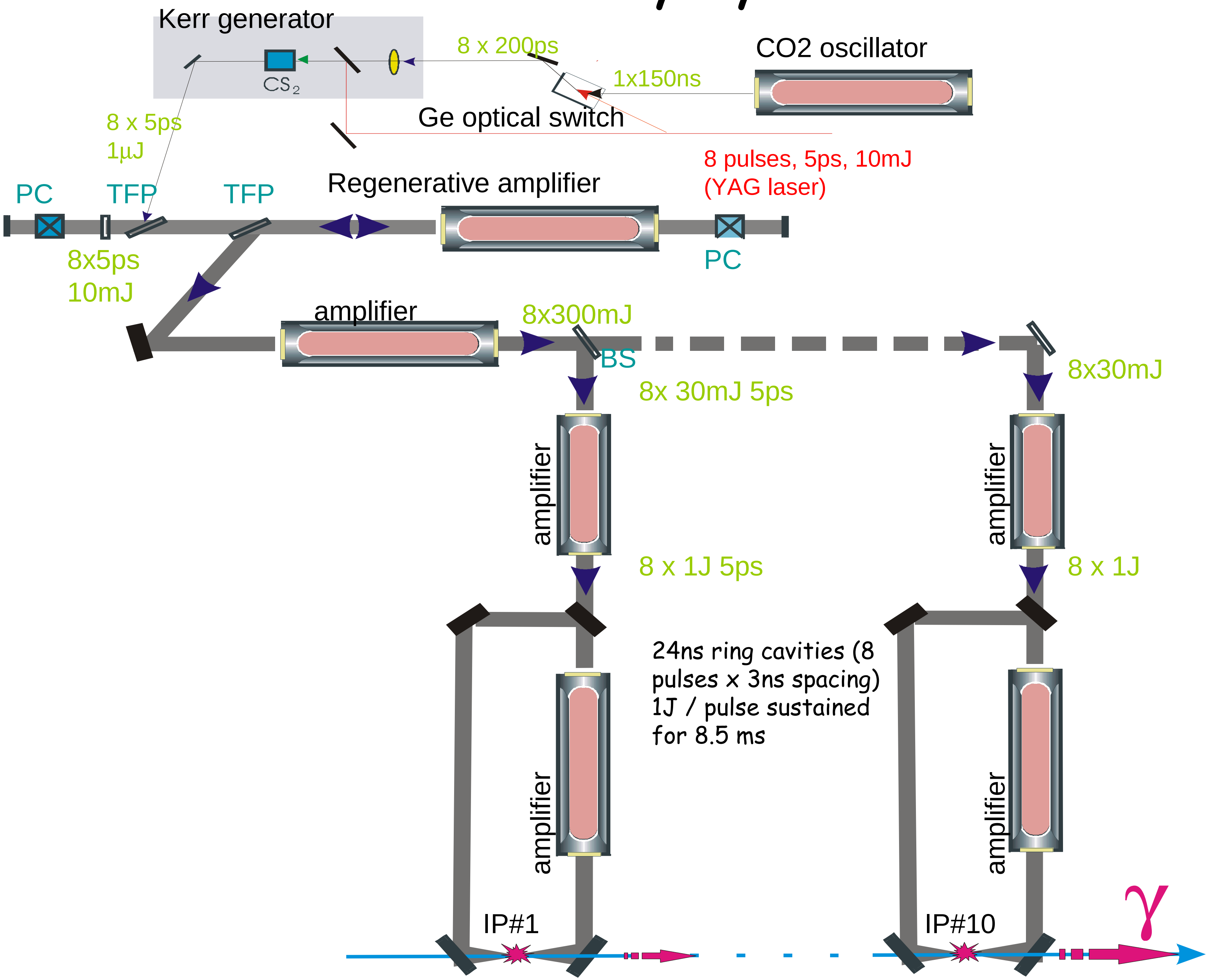


In the proposal

- Polarized γ-ray beam is generated in Compton backscattering inside optical cavity of CO_2 laser beam and 6 GeV e-beam produced by linac.
- The required intensities of polarized positrons are obtained due to 10 times increase of the "drive" e-beam charge (compared to non polarized case) and 5 to 10 consecutive IPs.
- Laser system relies on commercially available lasers but need R&D on a new mode of operation.
- 5ps, 10J CO_2 laser is operated at BNL/ATF.



Laser cavity system



100W 13 nm source for semiconductor industry

(based on 1 Joule 3ps CO2 laser and 7MeV electron beam)

Average electron current for 10IPs:

$$I_e = \frac{P_{OUT}\ q_e}{E_\phi\ N_{IP}} \qquad I_e = 100\ mA$$

Nonlinear limit: 1 scattered photon per 1 electron

Beam rate for 1nC bunches:

$$f_{beam} = \frac{I_e}{Q_{bunch}} \qquad f_{beam} = 100\ MHz$$

Average per laser power for 0.1% round trip loss:

$$P_{laser} = f_{beam}\ E_{laser} / Q_{cavity} \qquad P_{laser} = 0.1\ MW$$

500 W and 3% loss is considered for ILC polarized positron source

3W average power 0.1 nm source

(1 Joule 3ps C02 laser and 85MeV electron beam)

Average electron current for 3IPs (1 laser):

$$I_e = \frac{P_{OUT}\ q_e}{E_\phi\ N_{IP}}$$

$$I_e = 80\ \mu A$$

Beam rate for 1nC bunches:

$$f_{beam} = \frac{I_e}{Q_{bunch}}$$

$$f_{beam} = 80\ kHz$$

~4μs, 200 bunch long trains at 400Hz

Average per laser power for 1% round trip loss:

$$P_{laser} = f_{beam}\ E_{laser} / Q_{cavity}$$

$$P_{laser} = 800\,W$$

1kW similar CO_2 excimer lasers commercially exist

5 10^{15} photons/sec emitted per IP with peak brightness of the order of 5 10^{23} ph/sec/mm^2/mrad^2/0.1%

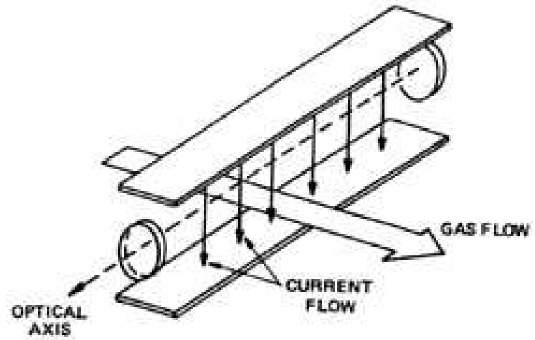
8 10^4 pulses/sec/IP at kW level of the order of 100 fs

Excimer laser convertible to CO_2

France

10 J per pulse,
100 Hz repetition rate,
1 kW average power
Price ~5 M$

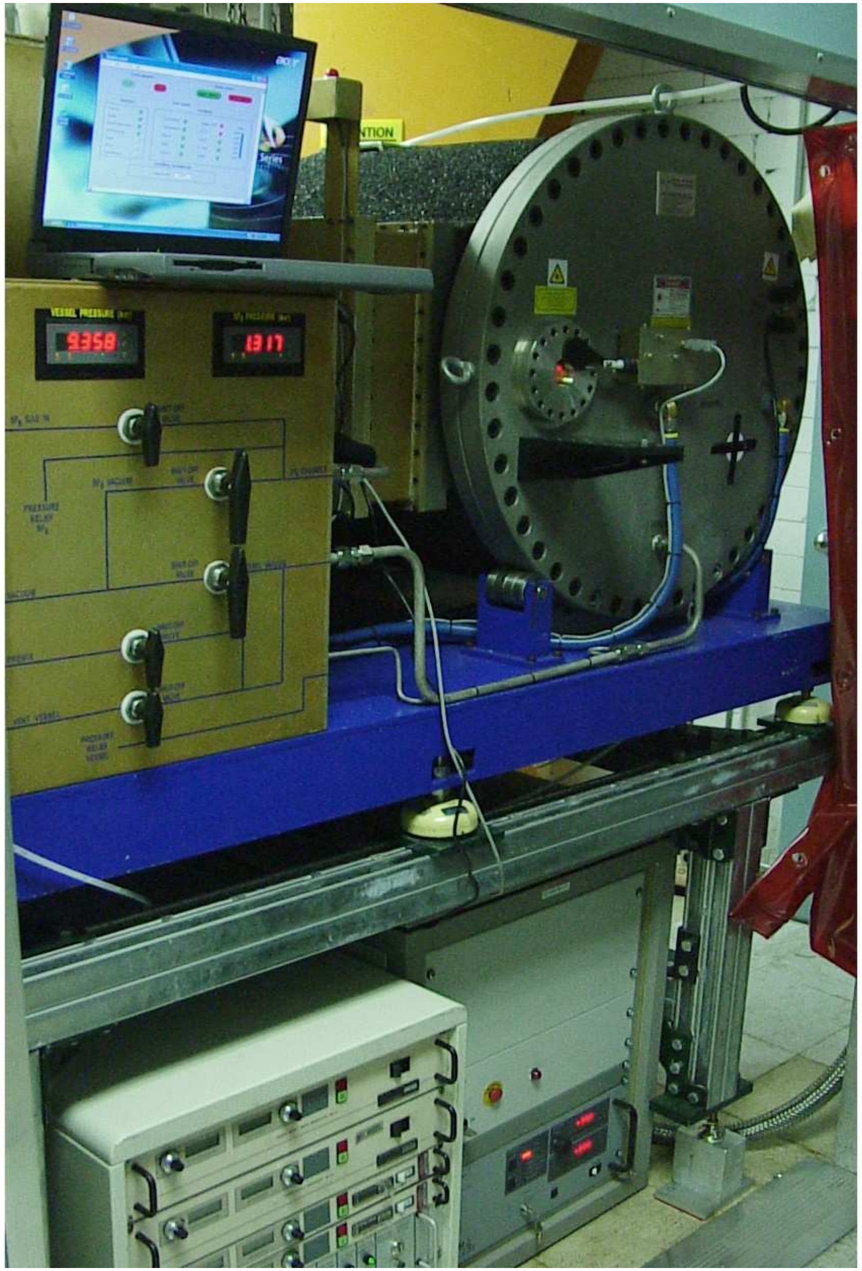
gas flow



Commercially Available High-Pressure CO_2 Lasers

SCIENTIFIC DEVELOPMENT & INTEGRATION (PTY) LTD

Repetition Rate	20 -500 Hz
Pulse Energy	1.5 J
Beam Size	13 x 13 mm^2
Average Power	750 W
Price	~ 0.2-1.5M$



Conclusion

- Proposed CO2 active cavity increases by orders of magnitude average laser power for efficient laser ebeam interaction

- Efficient operation of FEL and Compton based sources is magically divided around 0.1 nm