Group meeting talk Sep. 23 05

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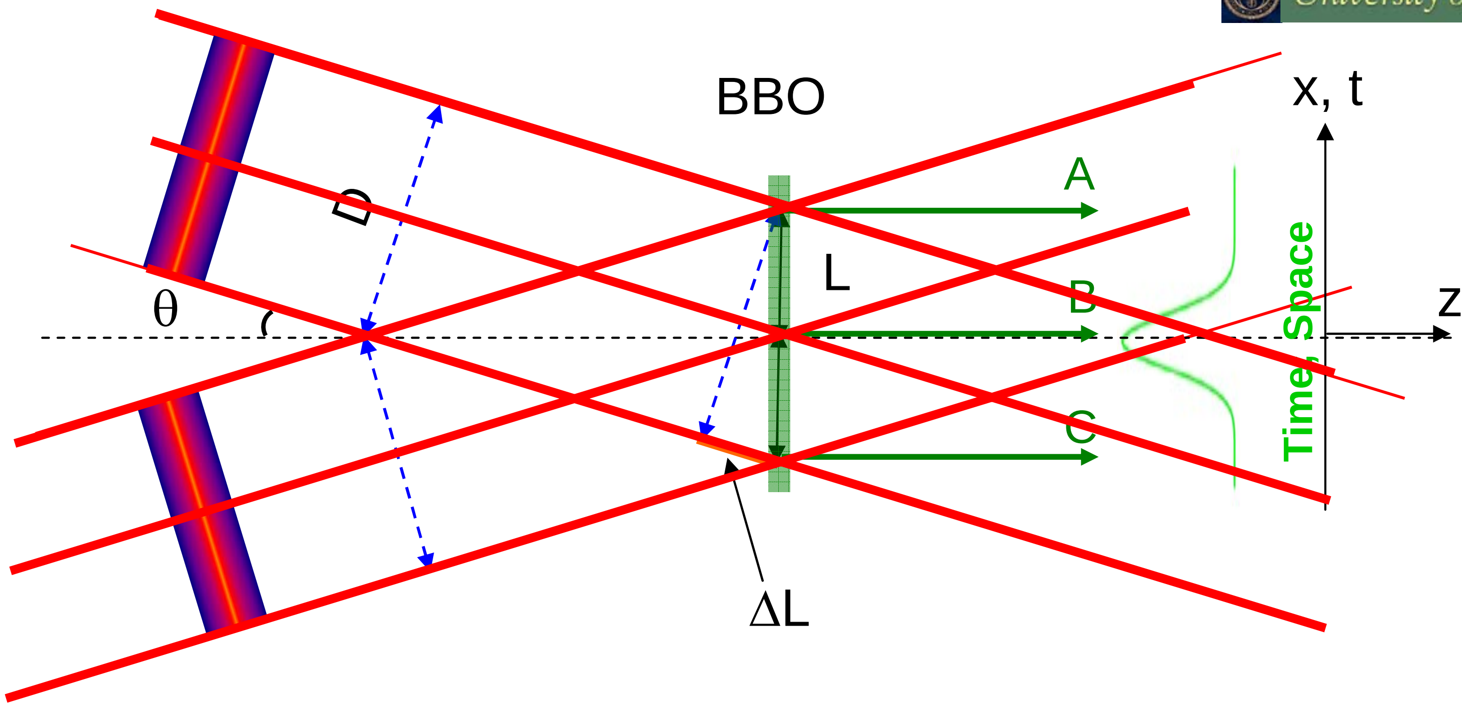
- Work that has been done in laser room: single shot aut-correlator and long pulse train
- Future laser work for SMTF
- EO sampling
- Laser system for polarized electron sources at ILC

Schematic top view of single shot auto-correlator

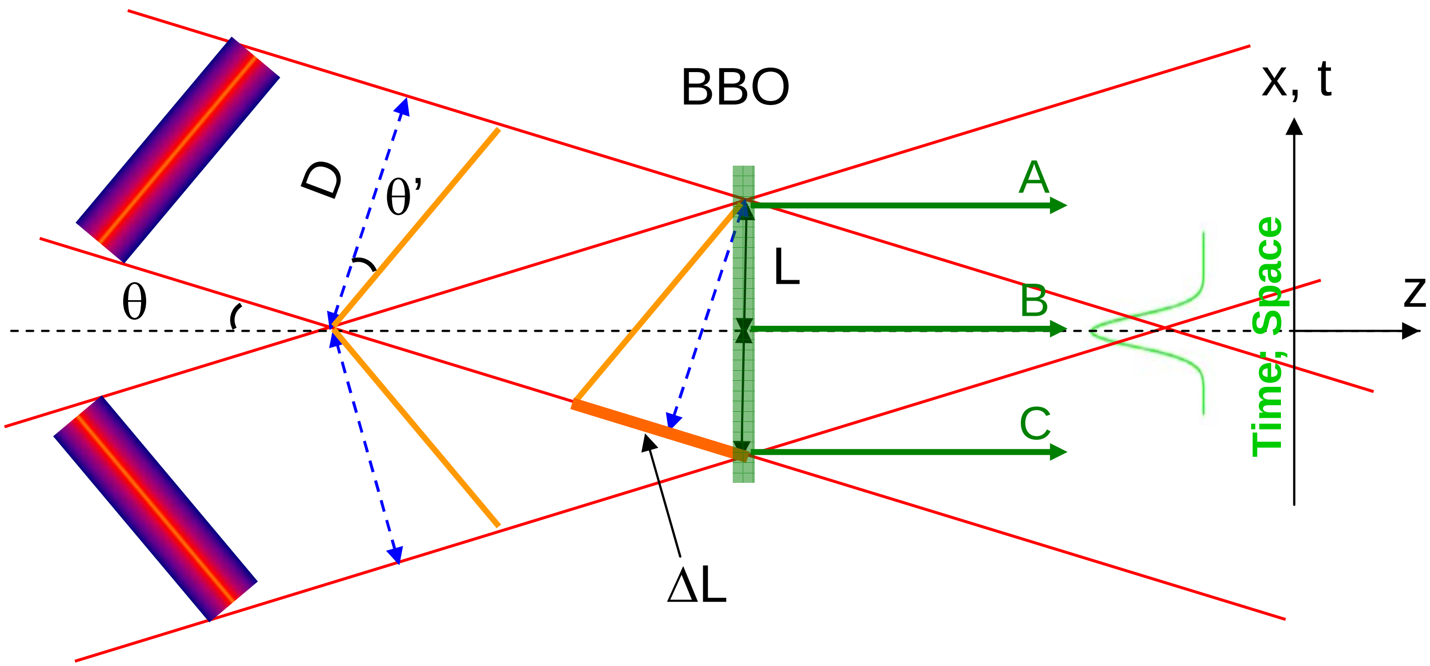


The time window is determined by the maximum delay of the two beams,

$$\Delta T_{\text{time\_window}} = \frac{\Delta L}{c} = \frac{20}{3} \bullet \mathrm{L} \bullet \sin(\theta) = \frac{10}{3} \bullet D \bullet \tan(\theta)$$

where ΔT is in ps, x and D mm. Usually θ is a small angle ~ 5°, implying a time window of 2 ps or so. It is not enough for our pulse length of 5 ps.

Single shot auto-correlator with tilted wavefront



A grating can be used to tilt the wavefront so that

$$\Delta T_{\text{time\_window}} = \frac{20}{3} \bullet L \bullet [\sin(\theta) + \sin(\theta')] = \frac{10}{3} \bullet D \bullet [\tan(\theta) + \sin(\theta')/\cos(\theta)]$$

If it is tilted by 45°. The time window becomes 12 ps about enough for the 5 ps pulse.

Setup of single shot auto-correlator

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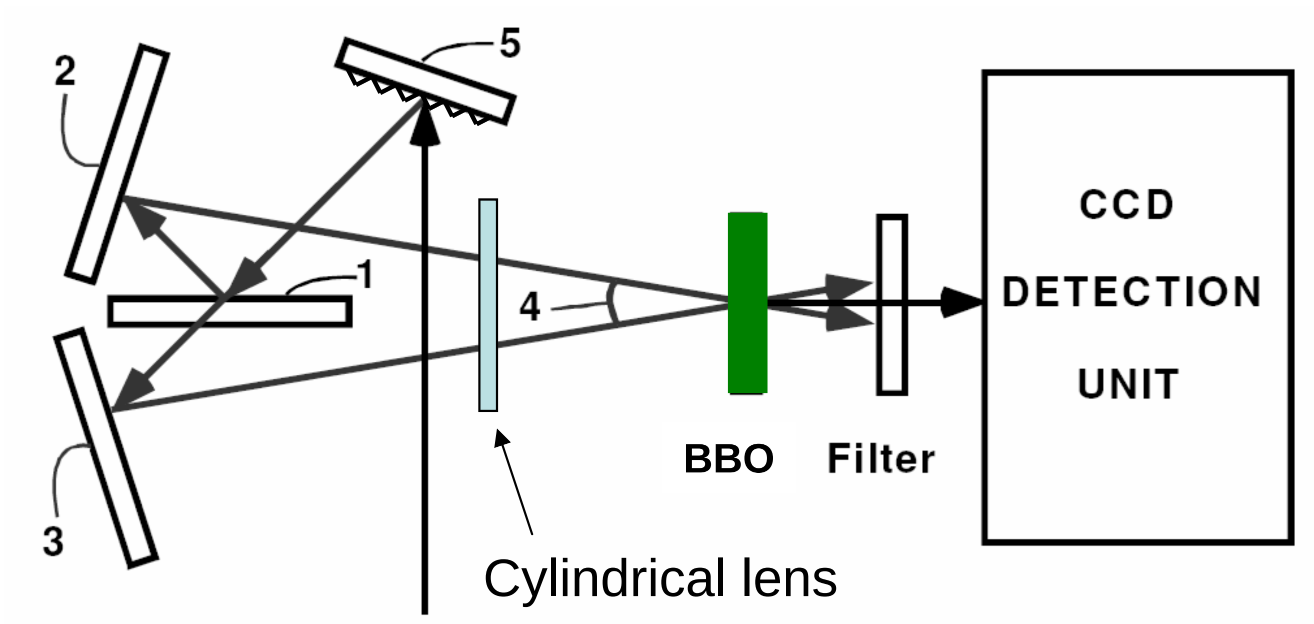

1, 50% beam splitter; 2 and 3, mirrors coated for IR beams; 4, the angle between two beams. 5, grating to tilt the wavefront of the laser beam.

From technical report of Minioptic Technology Inc.

Result of Single Shot AC

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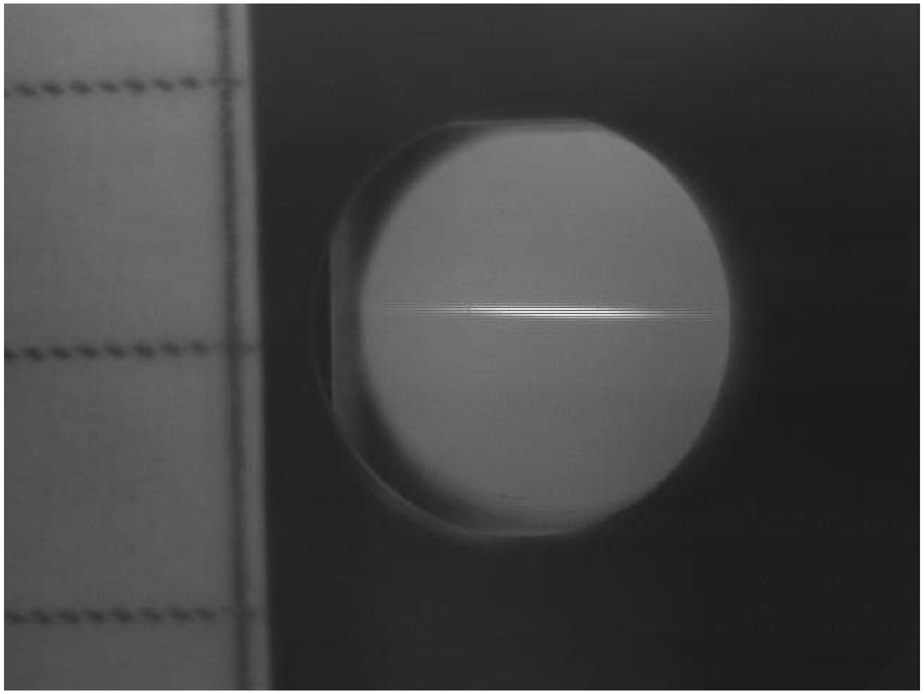

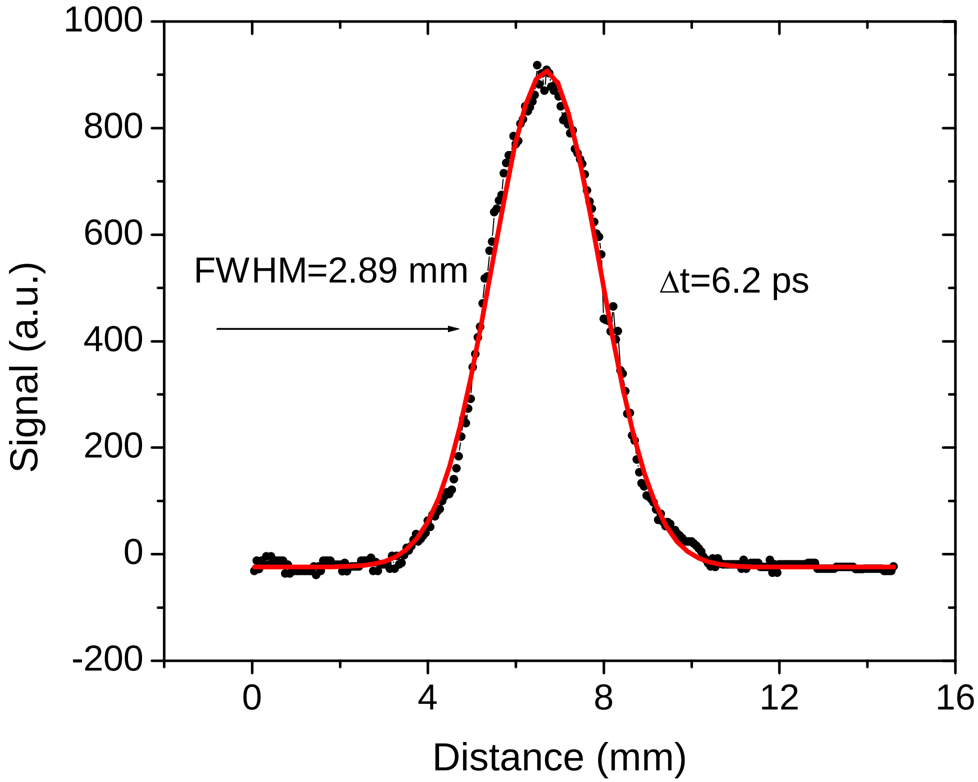

The FWHM was determined to be ~6.2 ps, which corresponds to 4.4 ps for single pulse. This is a little shorter than 5.4 ps UV pulse measured by streak camera. The discrepancy may be caused by the non-uniform transverse profile of the input beam.

Long pulse train I

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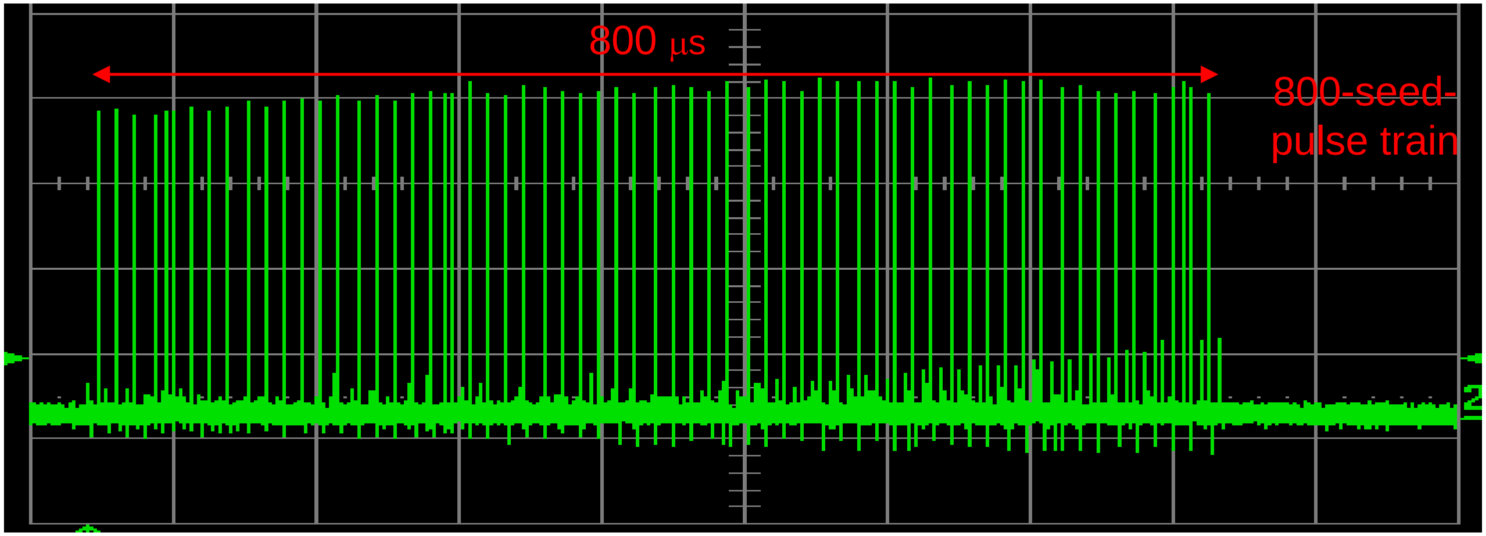
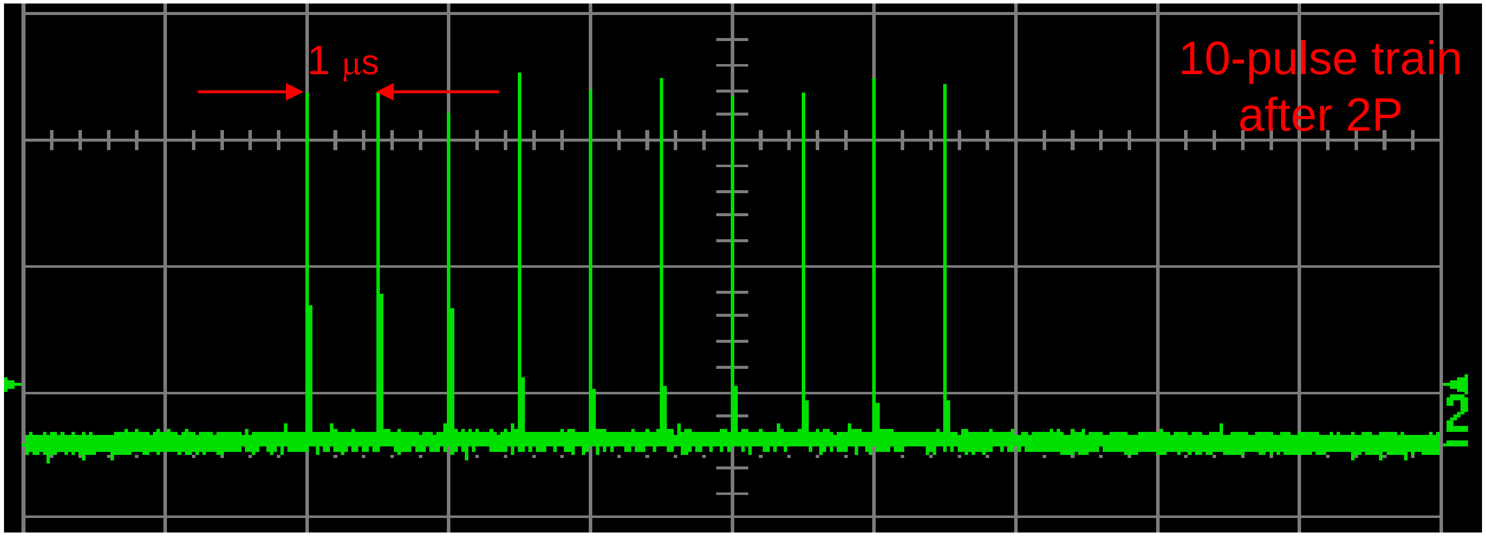
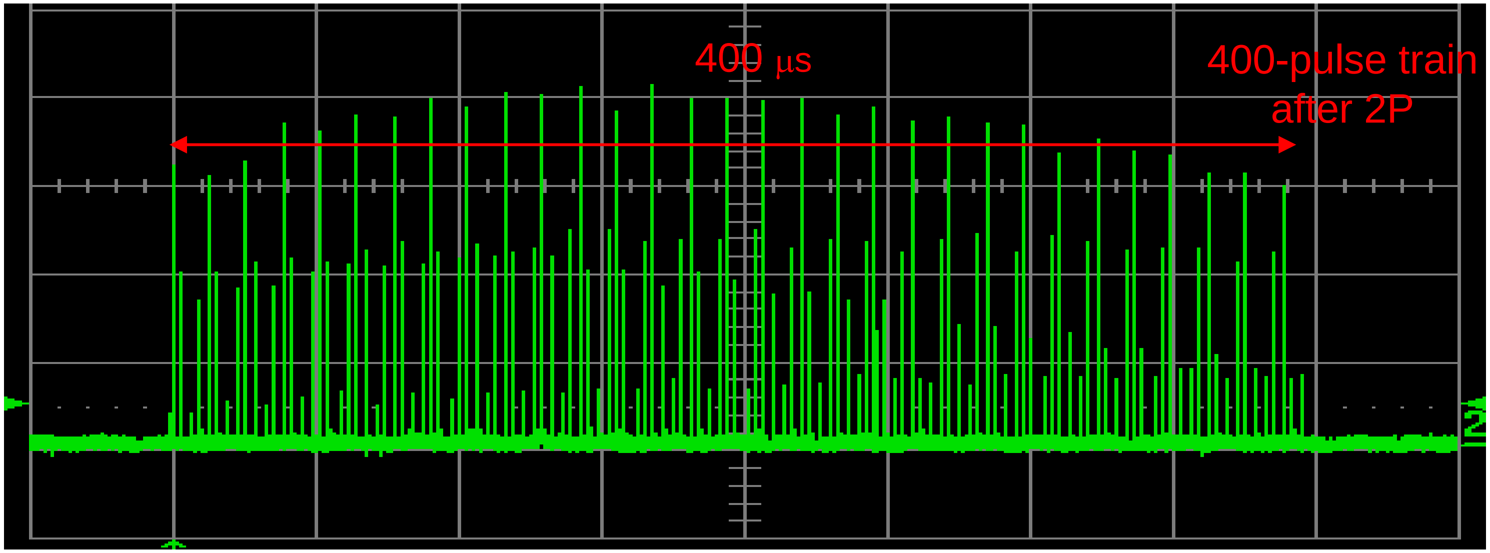
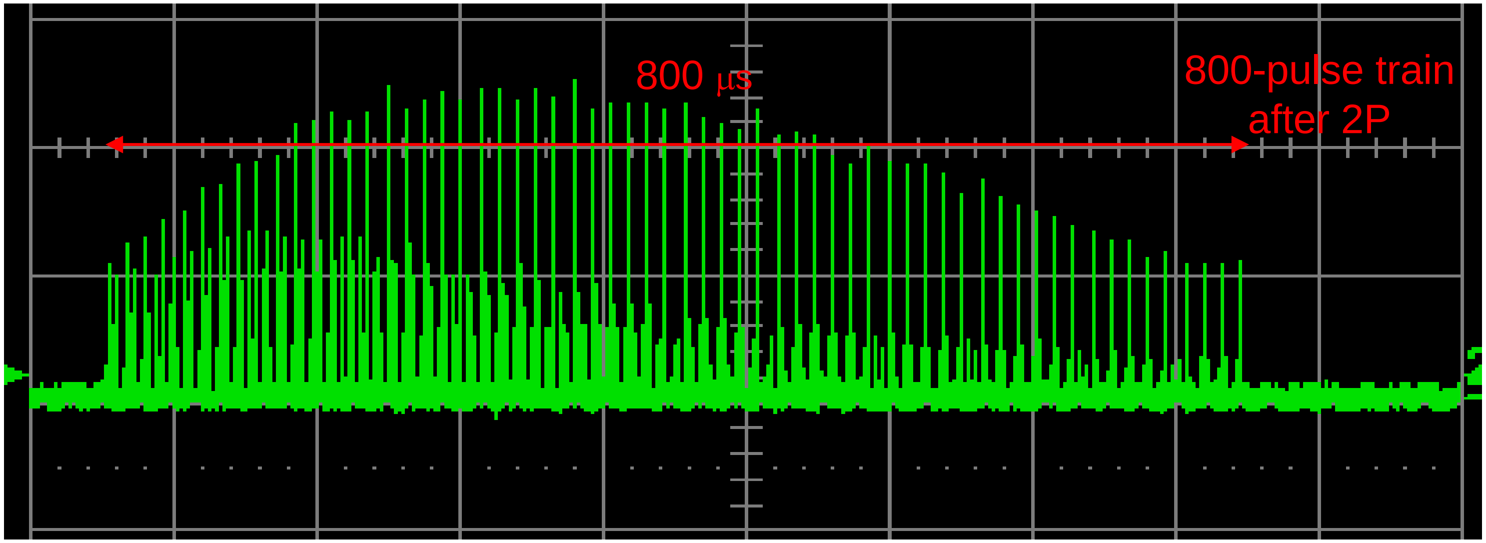




Long pulse train II





Laser requirements of SMTF

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Parameters	A0	SMTF
Beam pulse length	~0.8 ms	1 ms
Bunch charge	>4 nC	3.2 nC
Charge stability	5%	5%
Micro bunch distance	1000 ns	337 ns
Number of bunches	~800	up to 2820
Pulse rep-rate	1 Hz	up to 5 Hz

We need to increase the duty cycle and the number of bunches in each pulse train and reduce the distance between bunches.

Long pulse train with high rep-rate

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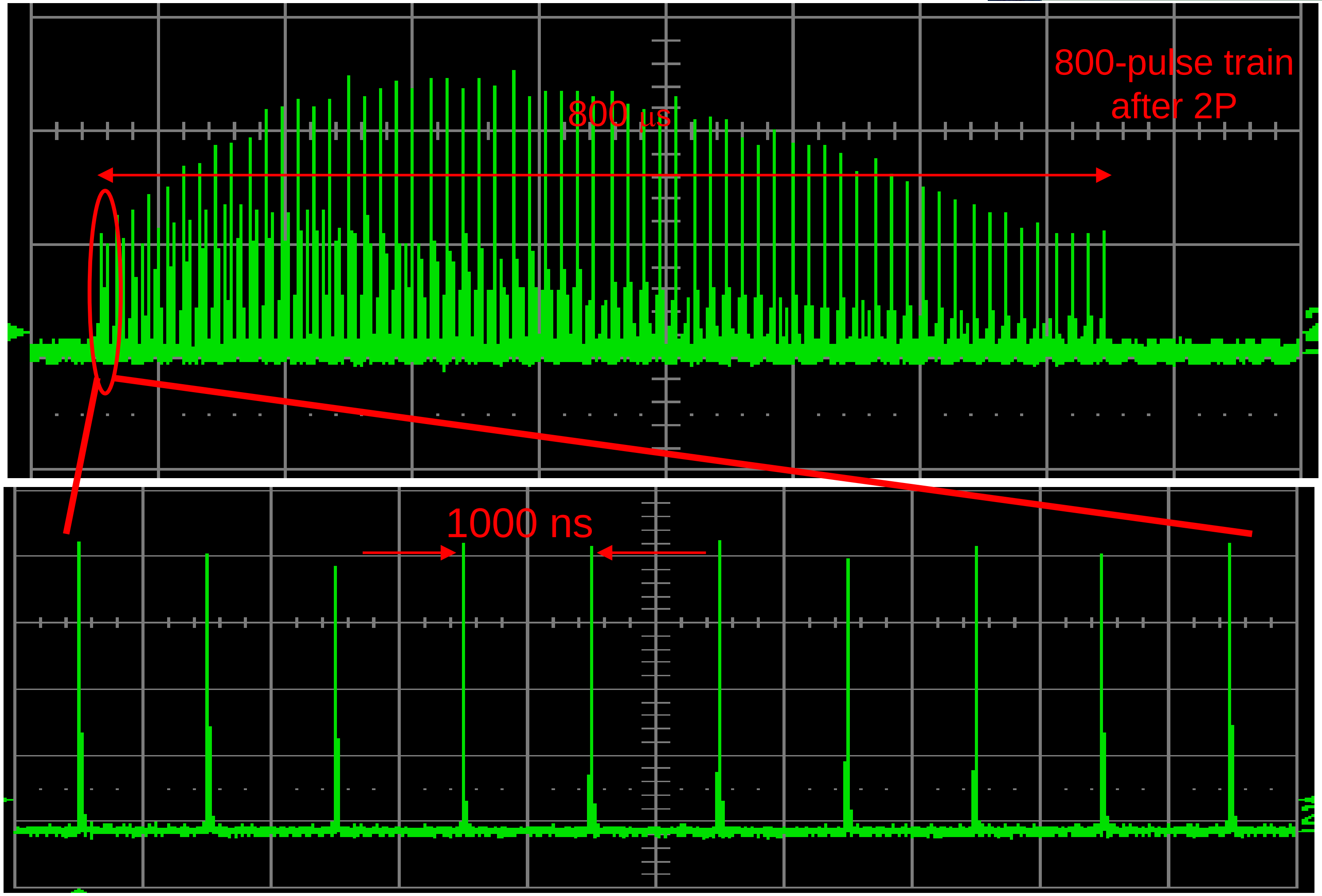
Increase pulse length from 800 μs to 1 ms.



Decrease the bunch spacing from 1 μs to 337 ns.

Make it happen five times per second (Nd:YLF has five times larger thermal conductivity than Nd:glass).

Make the long train flat (pre-shaping and Optical Limiting).

Optical limiting effect can be used to reduce the intra-train pulse fluctuation

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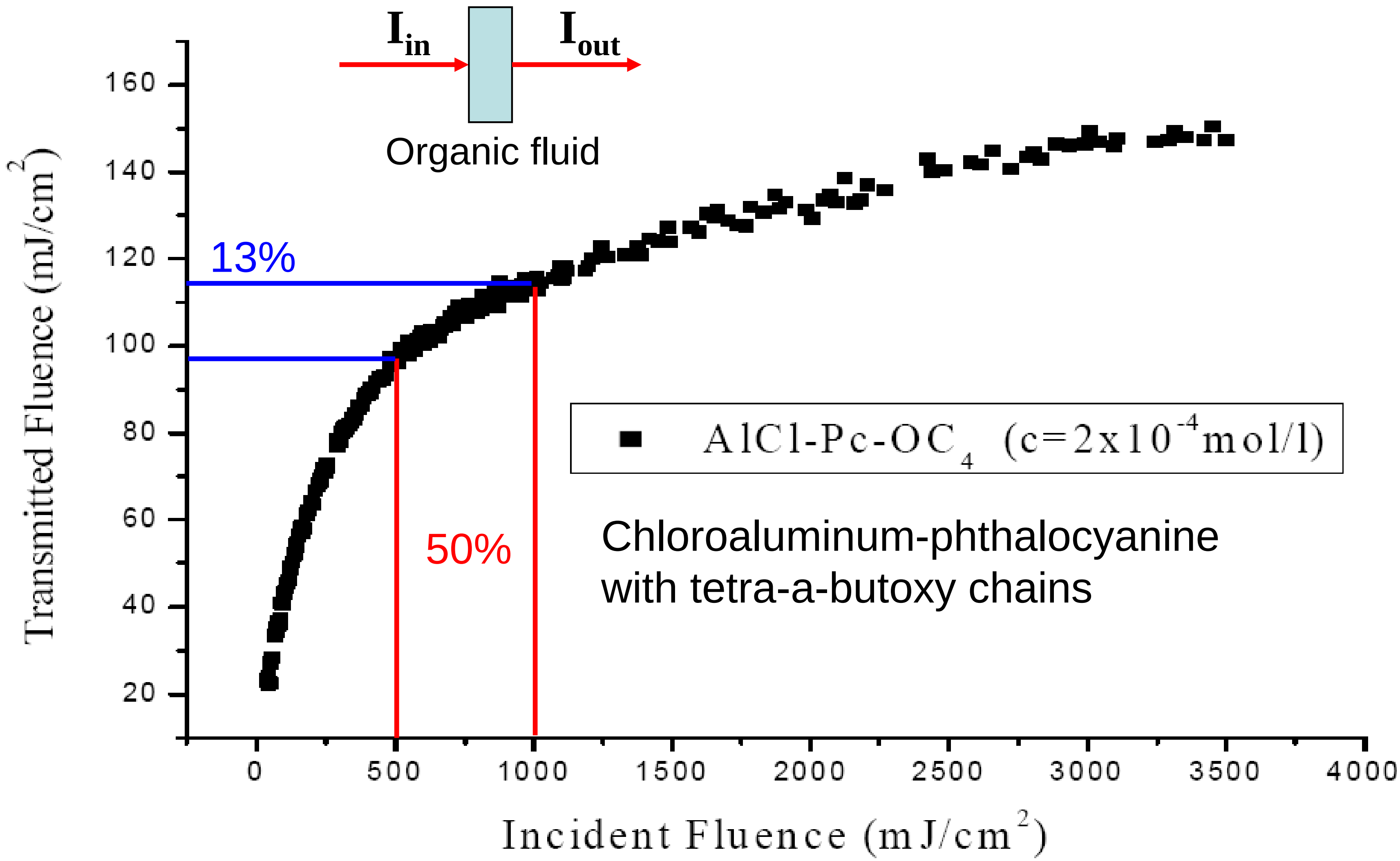
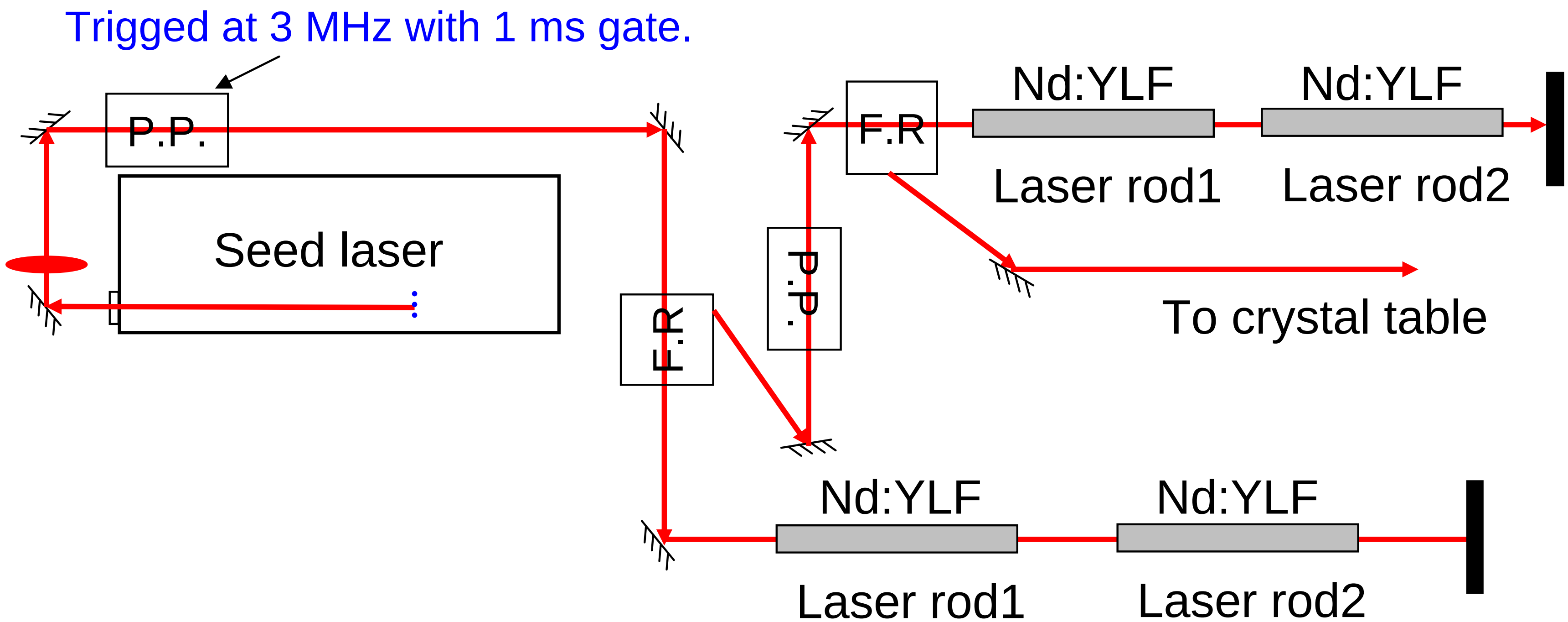


From Quan Gan et al., Optics Express, Vol. 13, No. 14, 5424(2005)

New schematic design for future upgrade of the laser system



1. All the optics should be installed on one optical table.
2. Flash pumped Nd:glass should be replaced by diode pumped Nd:YLF.
3. The system must be trigged at 3 MHz with 1 ms gate and 5 Hz rep-rate.
4. Flattop intra-train envelope must be achieved.
5. Another P.P. is needed to increase extinguish ratio and reduce beam loading.
6. Redesign the imaging relay system.

What could we do now?

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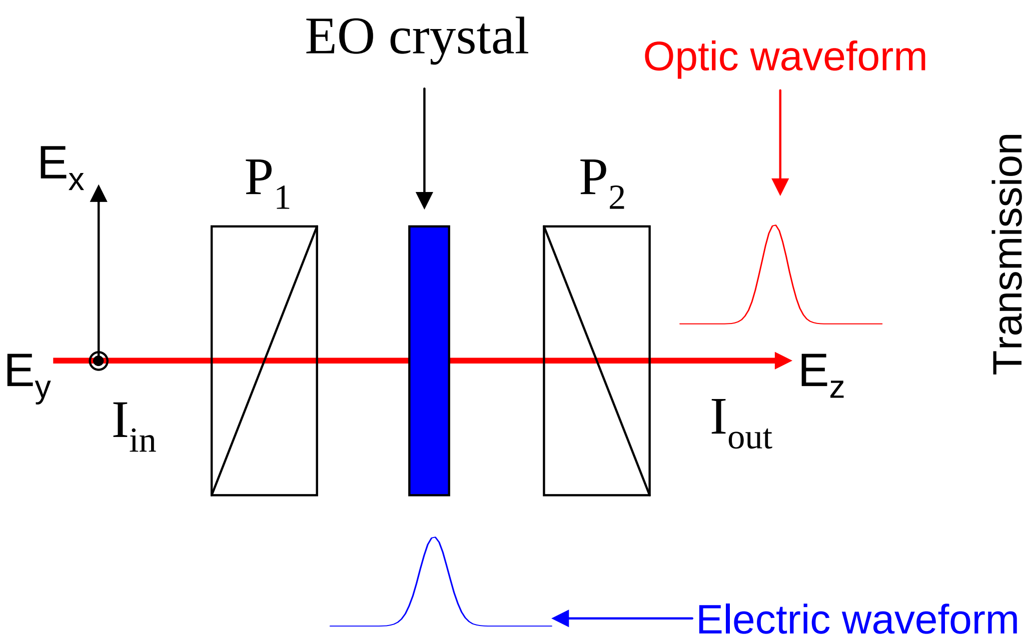
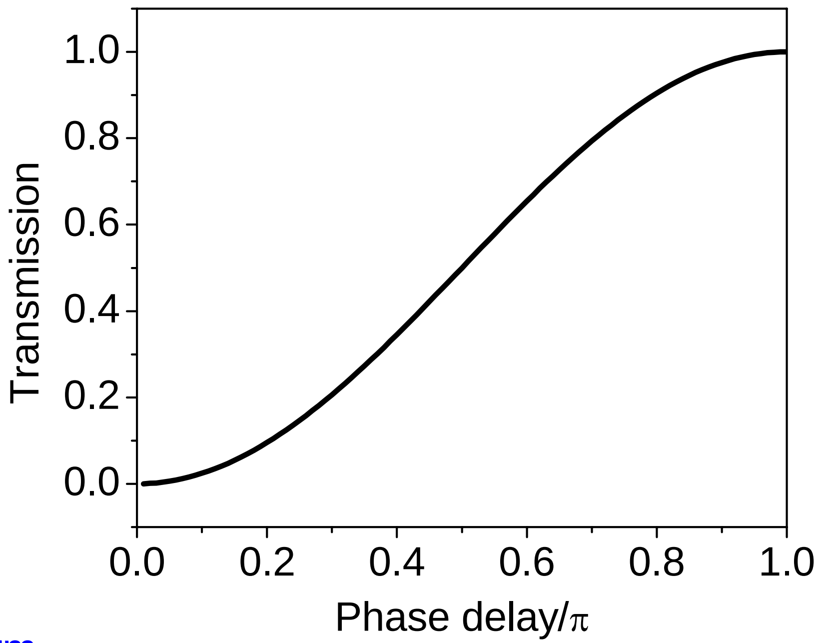
- **Get at least one set of Nd:YLF laser head and diode pump laser as a test line (~$ 31k).**
- Try the 3 MHz spacing, prolong the time gate to 1 ms and increase rep-rate to 5 Hz in the test line.
- Try to construct flattop long train with both pre-shaping and optical limiting (if needed) in the test line.
- **After these are done, we should be able to deliver mini-version laser beam for SMTF.**

Principle of EO sampling





No external electric field,
no EO effect,
no output ➔ $T=I_{out}/I_{in}=0$.

Under external electric field, EO effect introduces phase delay between E_x and E_y of the laser beam. The phase delay can be determined by the measured T.

Single shot EO sampling with temporal decoding

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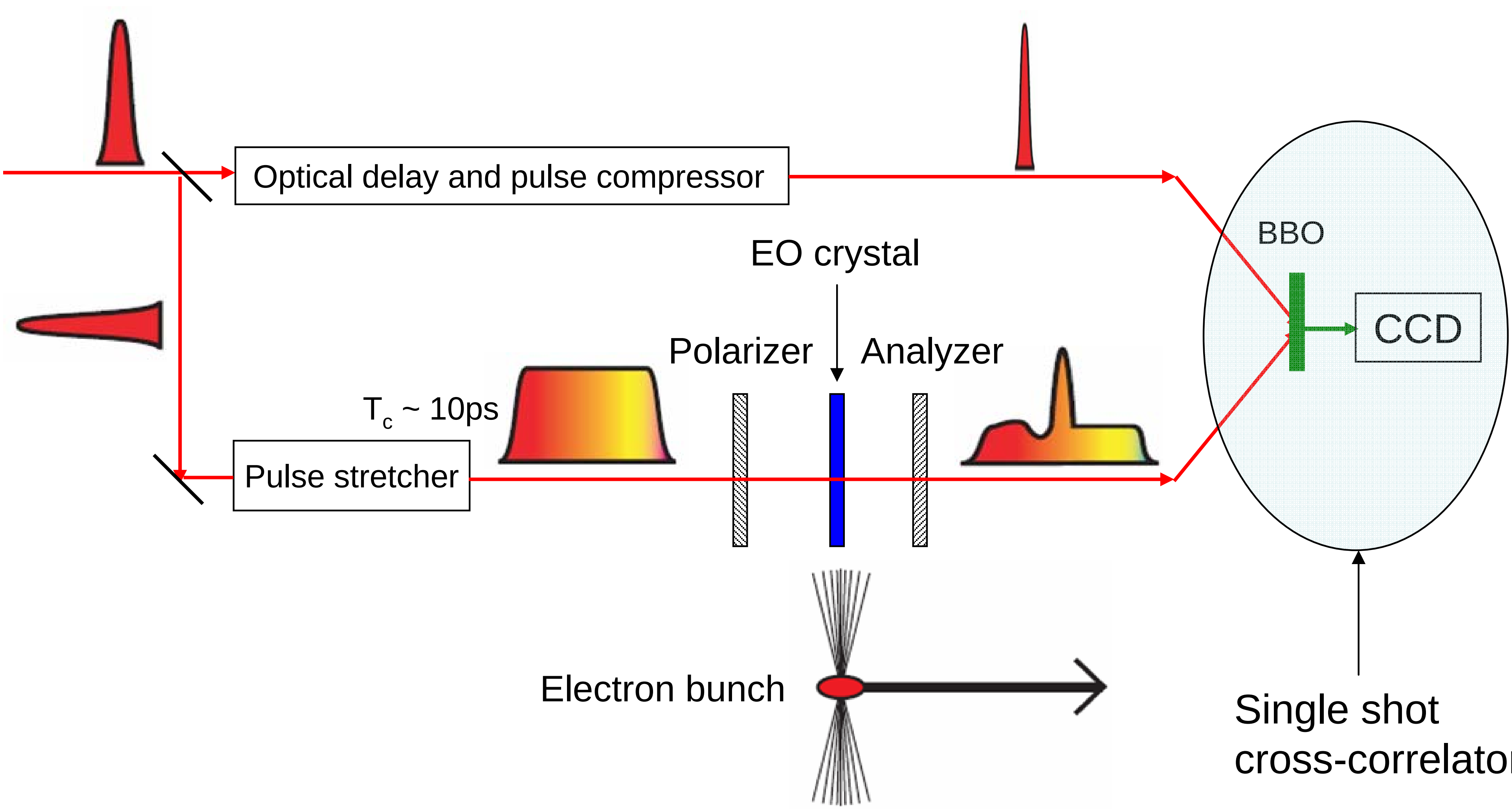

From G. Berden, et al., Phys. Rev. Lett., Vol. 93, No. 11, 114802(2004)

Difficulties of conducting EO sampling now

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- Space issue. Do we have enough room for both stretcher and compressor and single shot cross-correlator?
- Transport issue. How to transport IR pulse to cave? Fiber? How much energy?
- Delay issue. If fiber is used, how could IR pulse catch up UV pulse?
- Resolution issue. We will be limited by the pulse duration, ~ 5 ps.
- All of these can be solved after we move to SMTF and get a Ti:Sa femtosecond laser.

Laser acceleration simulation with single electron

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Parameters:

2a=1mm;

$\alpha > \lambda/a$;

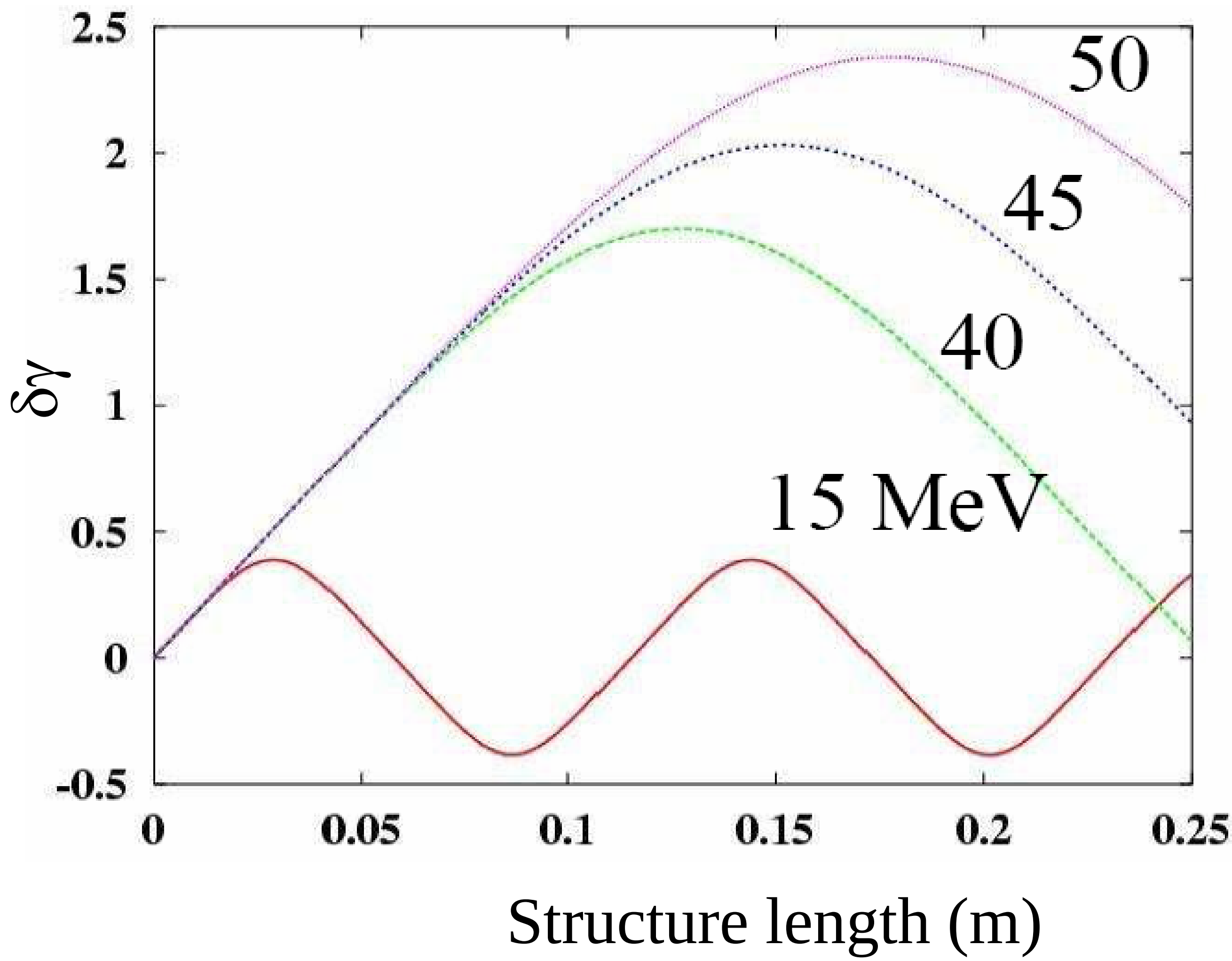
Elements #: 50

L=2mm;

λ=1054 nm;

E_{laser}=20 mJ;

Pulse length=2ps;



Done by Ph. Piot

Difficulties at A0 and future improvement

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- The stability of seed laser caused the poor repeatability of TEM_{01}^{*} mode.
- The new seed laser could solve it (hopefully).

- The electron energy is only 15 MeV, too low for significant acceleration.
- At SMTF, the electron energy will exceed 200 MeV.

- Laser intensity is not yet 20 mJ/pulse.
- Another amplifier after re-gen is needed.

- Laser beam can not be compressed and sent to cave.
- At SMTF, another IR transport line should be installed so that the laser pulse is transported and compressed and then the TEM_{01}^{*} is produced.

Laser parameters recommended for ILC

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Laser parameter	Value	Unit
Micro-pulse energy at photocathode	~3 (1.5)	μJ
Micro-pulse length	~2	ns
# micro-pulse per train	2820 (5640)	Number
Intensity jitter	2	% (rms)
Micro-Pulse spacing	337 (169)	ns
Repetition rate	5	Hz
Wavelength	750-850	nm

From WG3a ILC Electron Source Recommendation

Drive laser for polarized e⁻ photocathode

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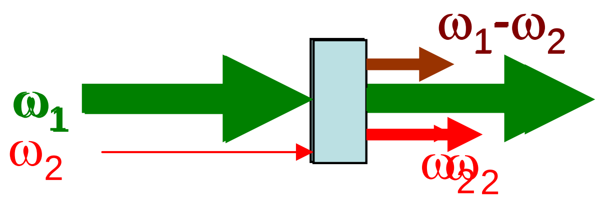
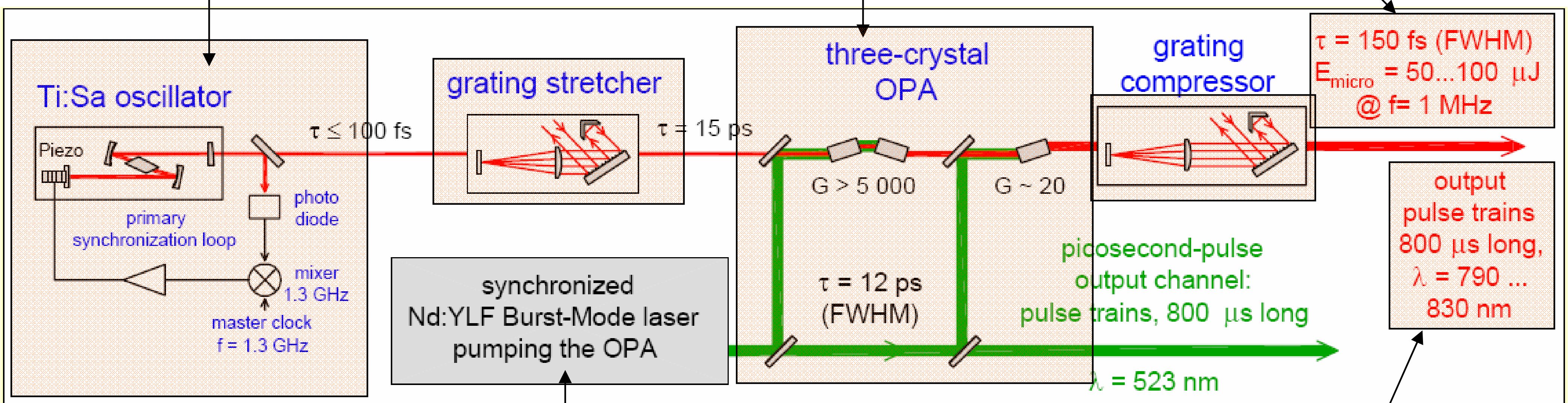


Longer pulse and higher rep-rate are needed.

Ti:Sa Seed laser

Optical parameter amplifiers



Our current system can be used as the pumping laser.

Longer train and more wavelength range are needed.

From I. Will, et al., Status Sep. 2004

Summary

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- **Near future**
  - Get a set of diode pumped amplifier as a test line to deliver mini-version long train for SMTF (~ $ 31k).
  - Strong support is needed for conducting EO sampling experiment.
- **Far future**
  - Laser acceleration becomes doable at SMTF.
  - R&D on drive laser for polarized electron source at ILC.

Large gain for Nd:YLF diode pump laser

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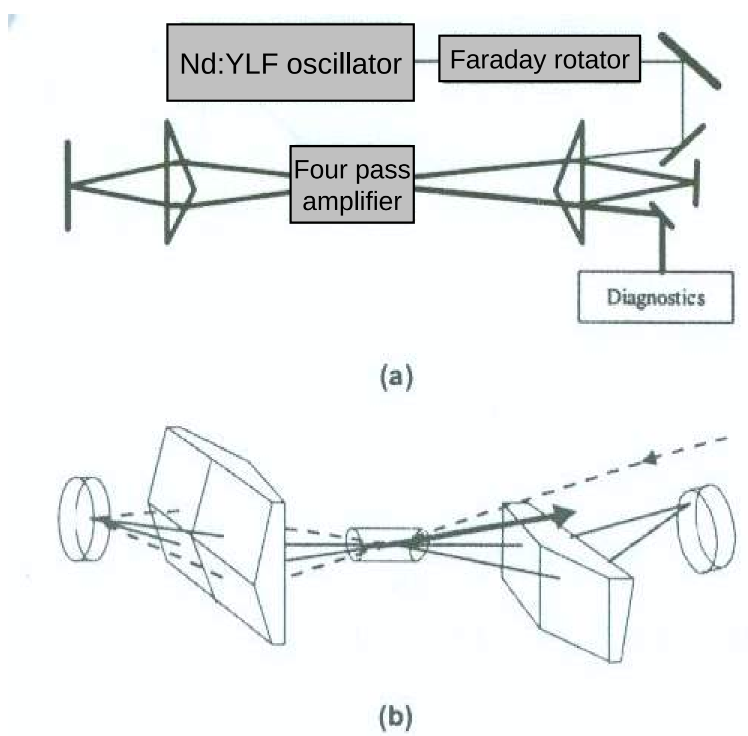


Fig. 3. (a) Experimental arrangement for the diode-pump amplifier system. (b) The four-pass amplifier geometry.

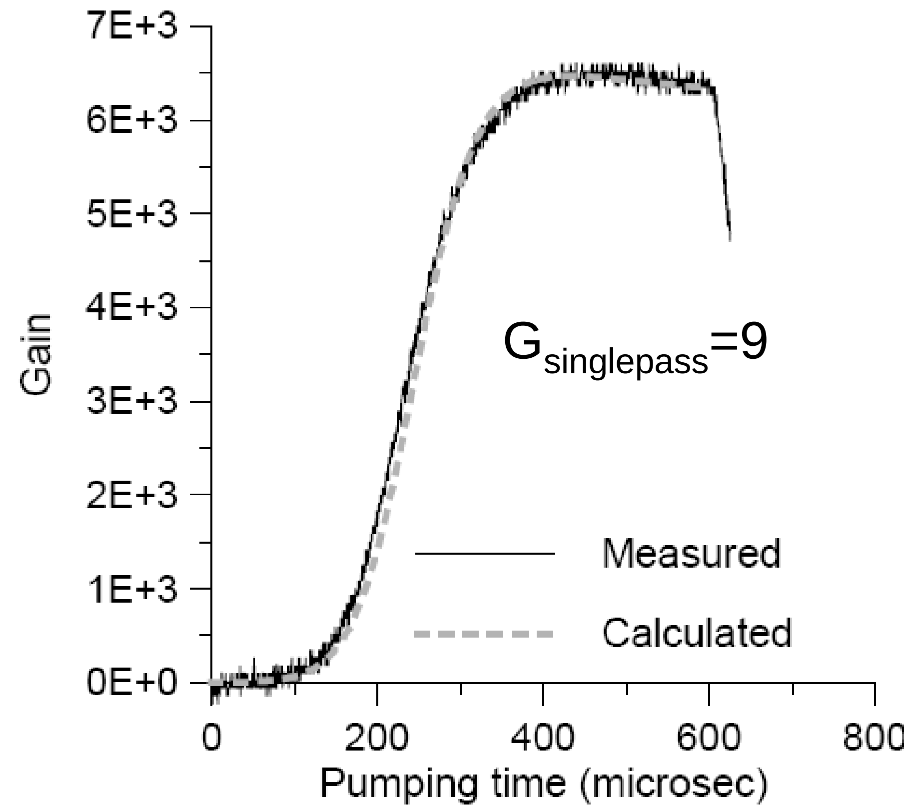
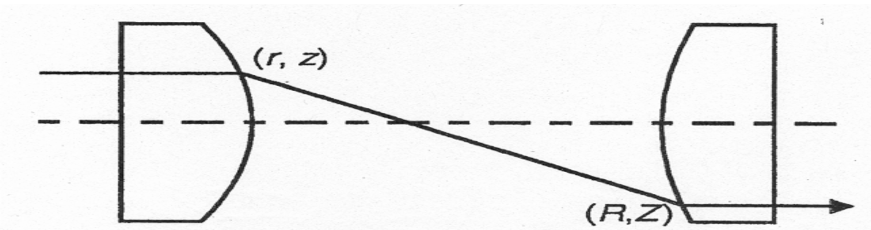


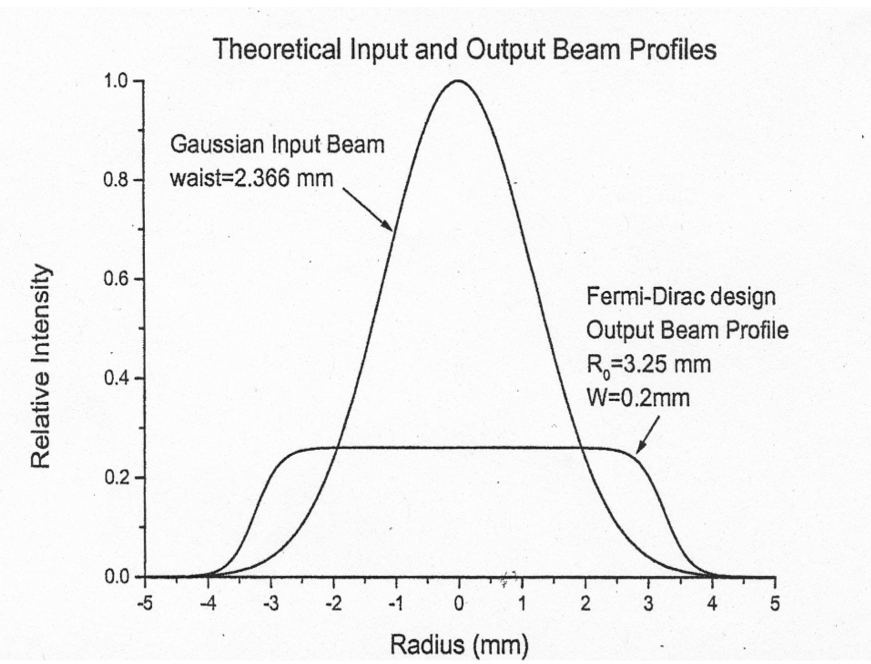
Fig. 8. Calculated and measured gain for amplifier under strong saturation.

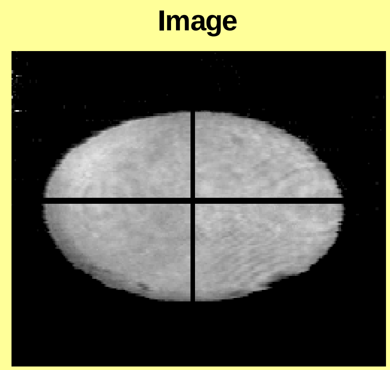
With diode pump and Nd:YLF crytal, amplification of up to 6,000 was achieved after a 4-pass amplifier.

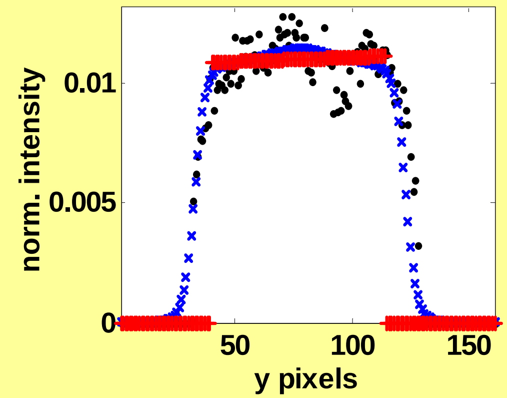
From Ian Ross et al., Applied Optics, Vol. 42, No. 6, 1040(2002)

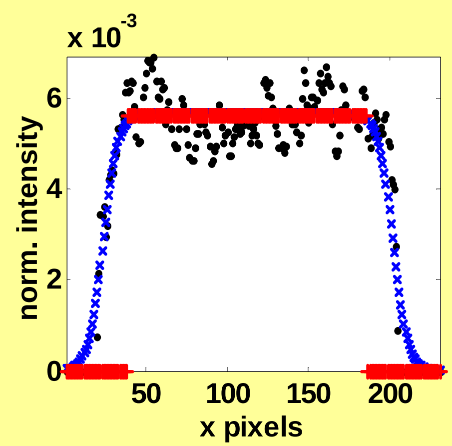
A plano-aspheric lens pair to convert a Gaussian to a flattop beam











	x	y
centroid, um	3.95e+003	5.37e+003
FWHM, um	3.16e+003	3e+003
beta	20.2	18.9
F-D err	8.46e-005	0.00019
slope	6.55e-008	3.53e-006
lin. err	0.00678	0.00866

From Paul Bolton's talk at ANL, Feb. 18 2005.

π Shaper

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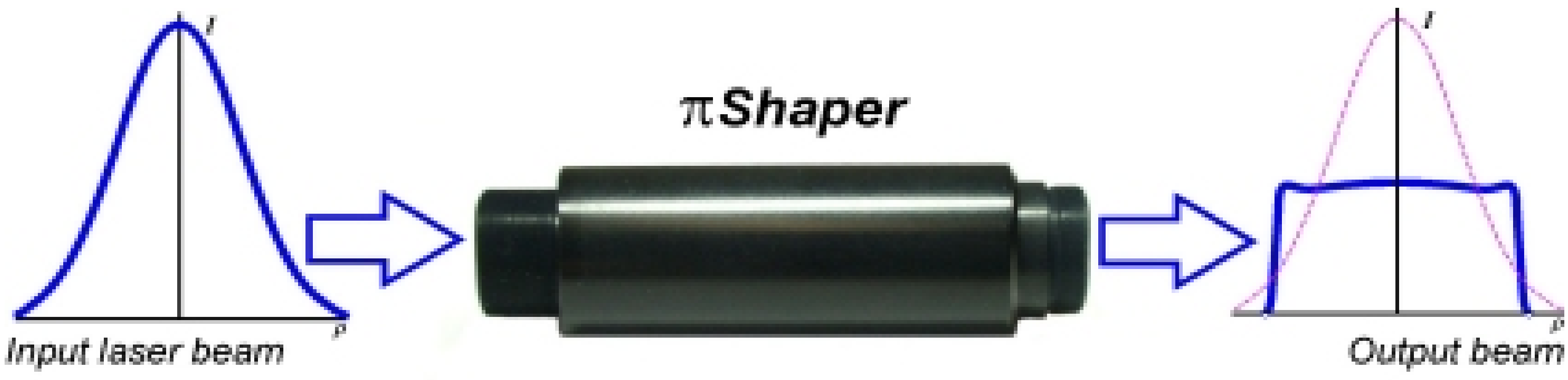


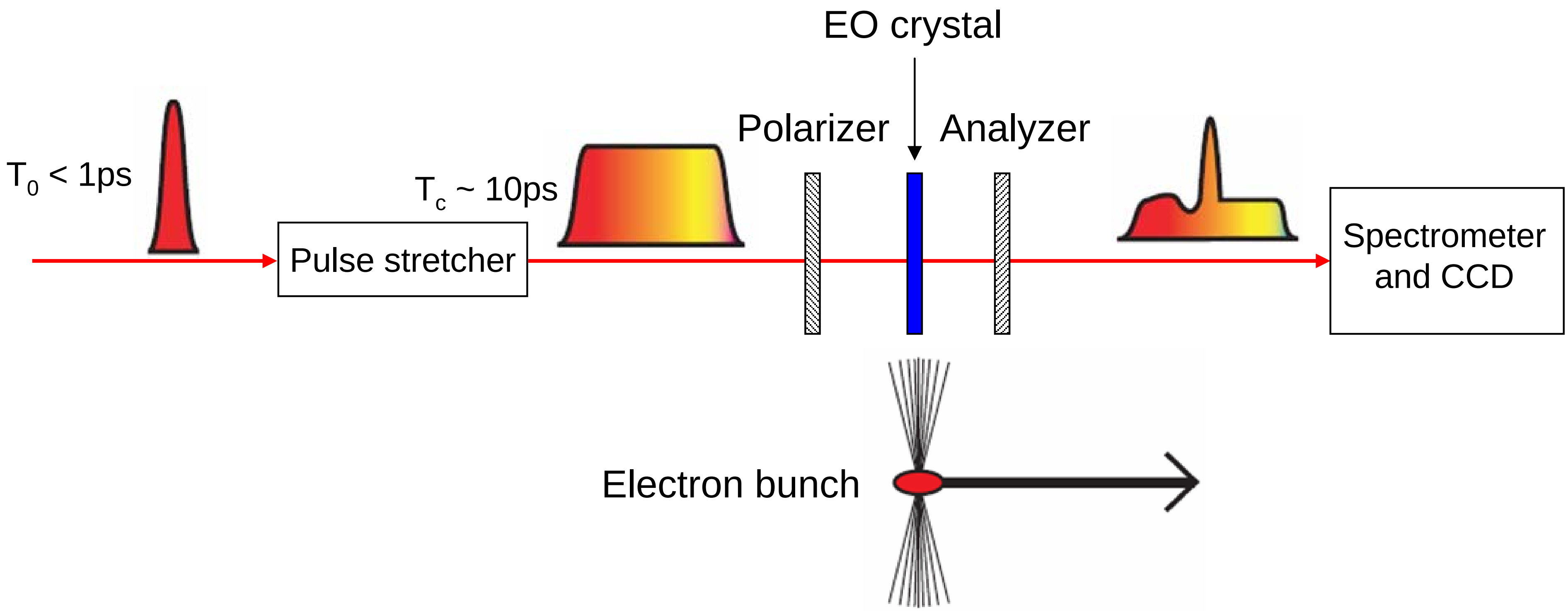
Gaussian input with 6 mm diameter ($1/e^2$)

Flat top output with intensity fluctuation within ±2%

Operating wavelength: 355 – 1200 nm; fixed input; no good for long transport.

From http://www.mt-berlin.com/frames_home/shaper_descr.htm

Single shot EO sampling with spectral decoding



From I. Wilke et al., Phys. Rev. Lett., Vol. 88, No. 12, 124801(2002)

Limitations of spectral decoding

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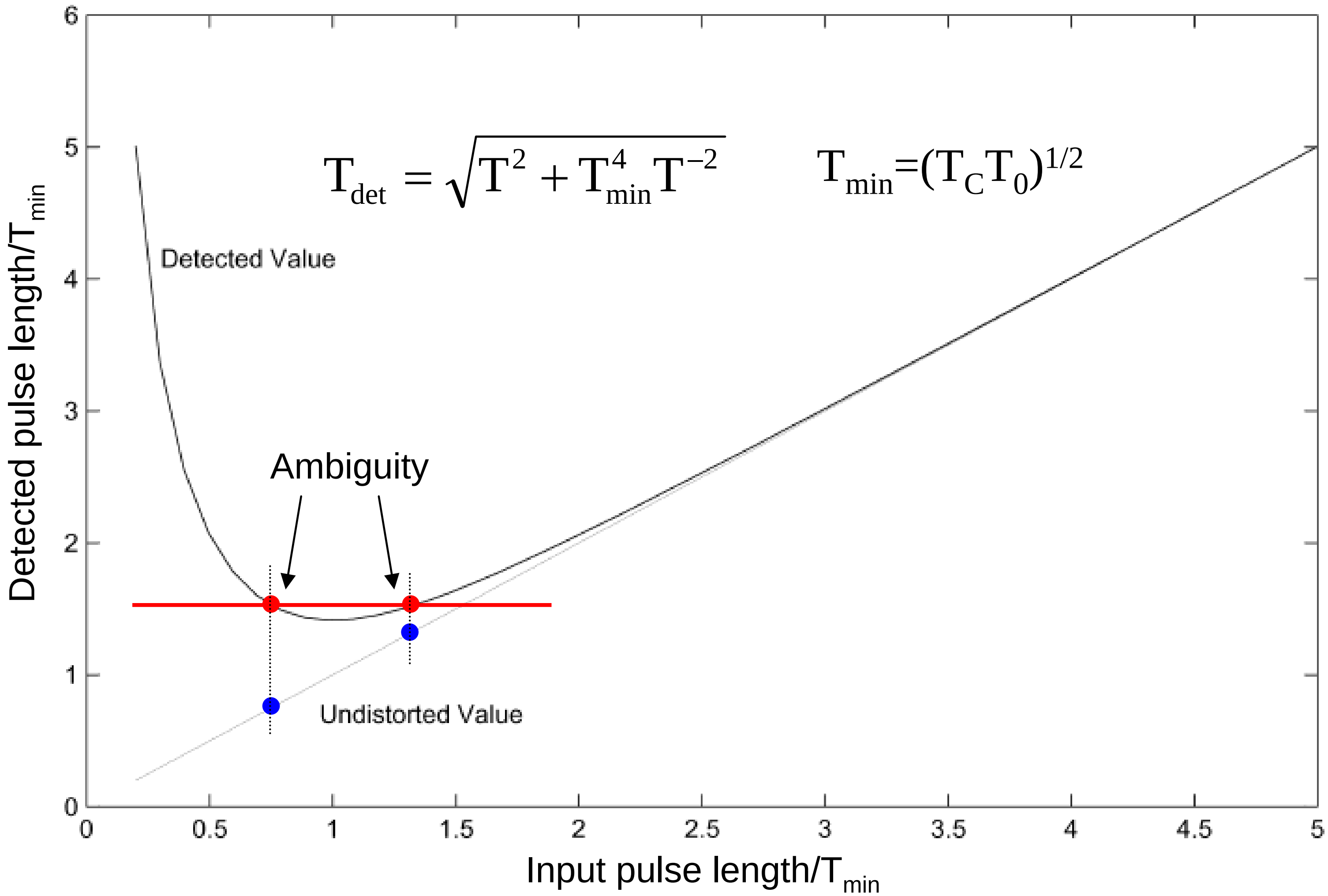

Fig. 1. Variation of detected pulse length versus input pulse length for strong signals.

From J. R. Fletcher, Optics Experess, Vol. 10, No. 24, 1425(2002)

EO sampling with spatial decoding

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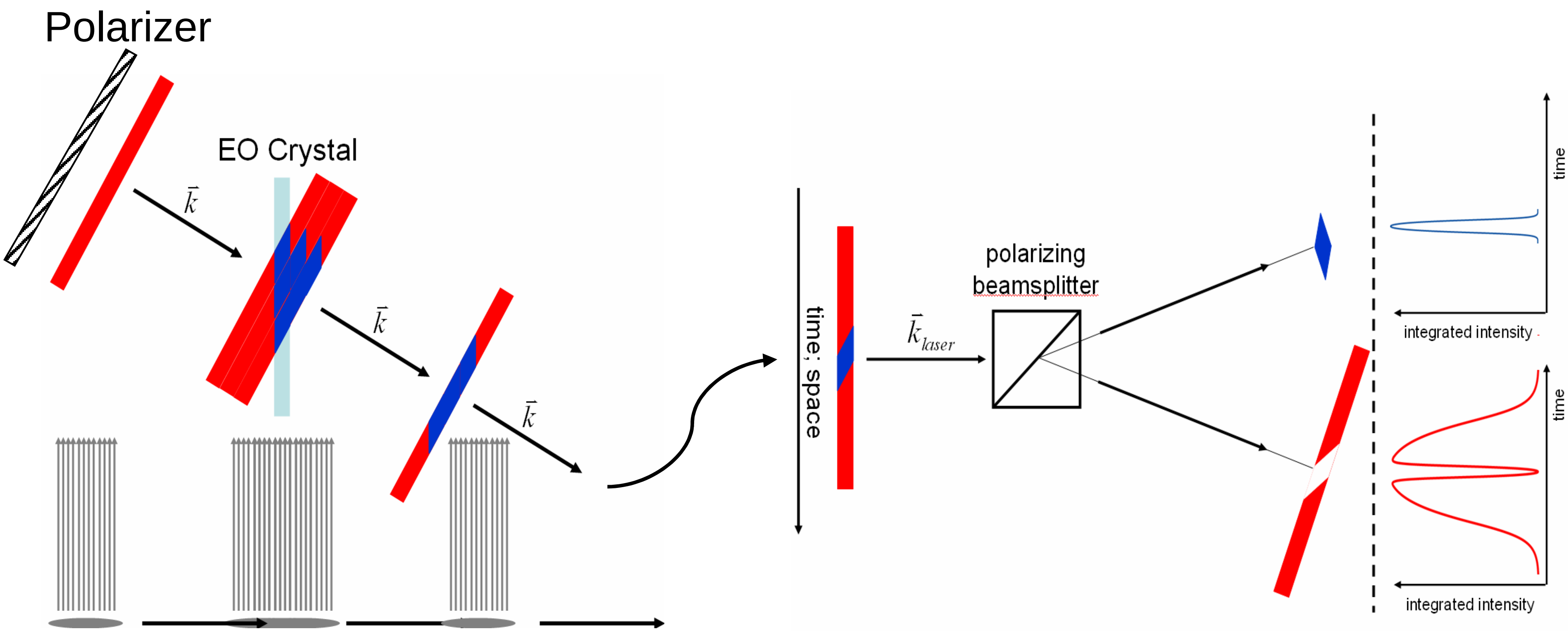

From A. L. Cavalieri, et al., Phys. Rev. Lett., Vol. 94, 114801(2005)

BPM with sub-picosecond time resolution

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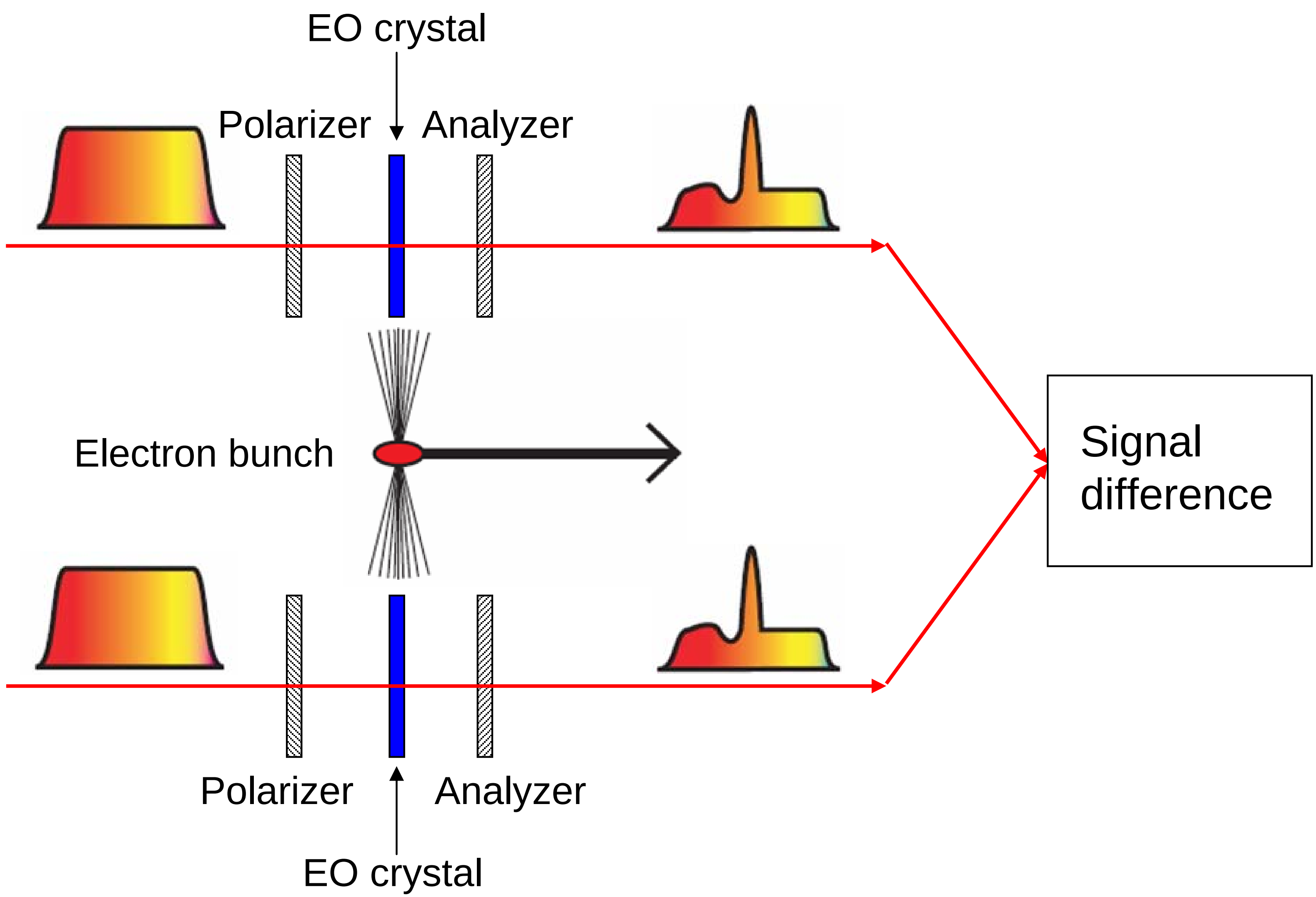

Eigenmode of open iris-loaded structure

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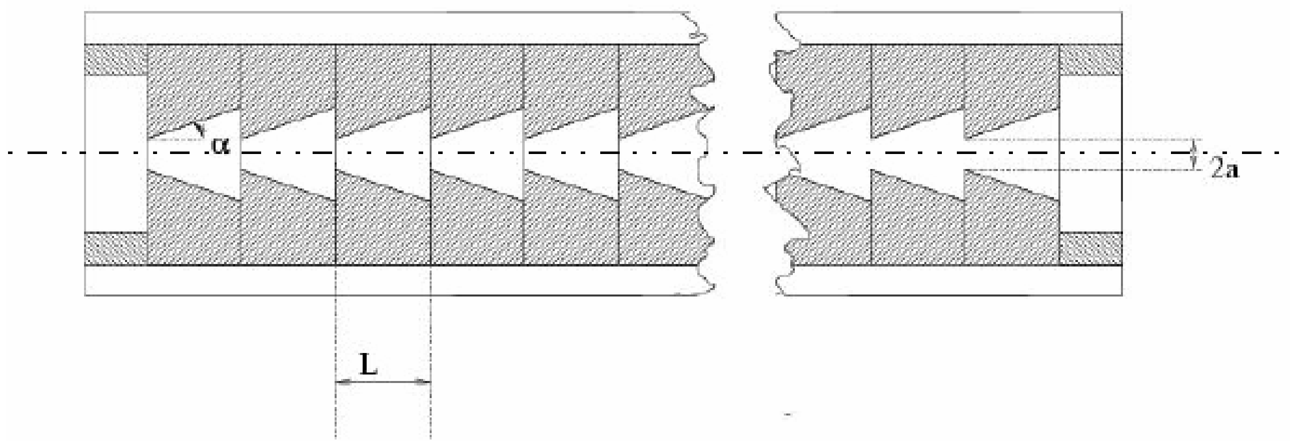
R. Pantell (NIM A 393, 1(1995))

M. Xie (LBNL-40558 and PAC 97)



The fields associated with TE_{01} eigen mode are given by,

$$E_z(r,z,t)=\widehat{E}\,J_0(k_r r)\exp(i(k_z z-\omega t))$$

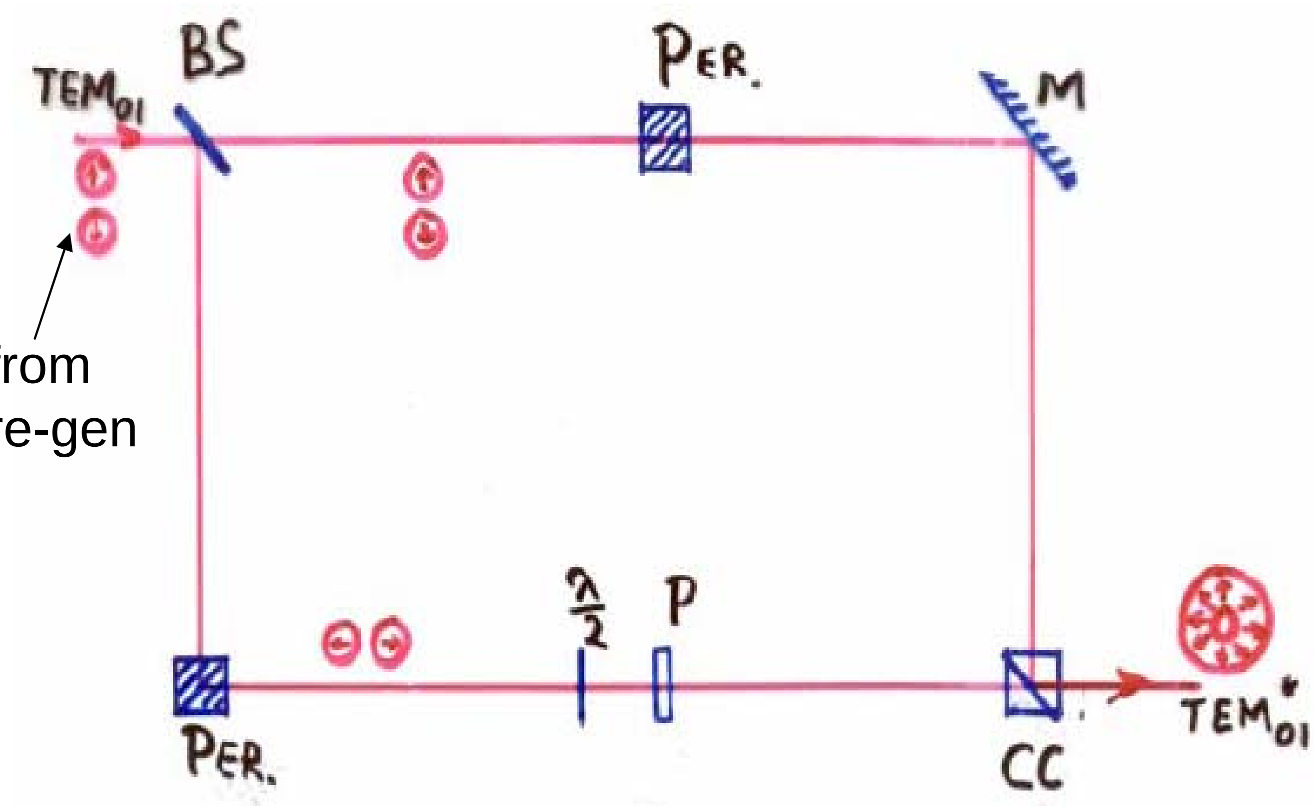
$$E_r(r,z,t)=Z_{TM}H_\phi=-i\frac{k_z}{k}\widehat{E}\,J_1(k_r r)\exp(i(k_z z-\omega t))$$

The phase velocity of the wave is,

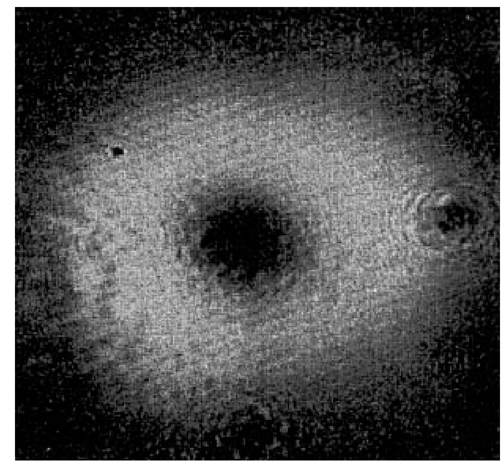
$$v_\phi=\frac{\omega}{\Re(k_z)}\approx\frac{c}{n}[1+\frac{1}{2}(\frac{p_{10}\lambda}{2\pi a})^2]$$

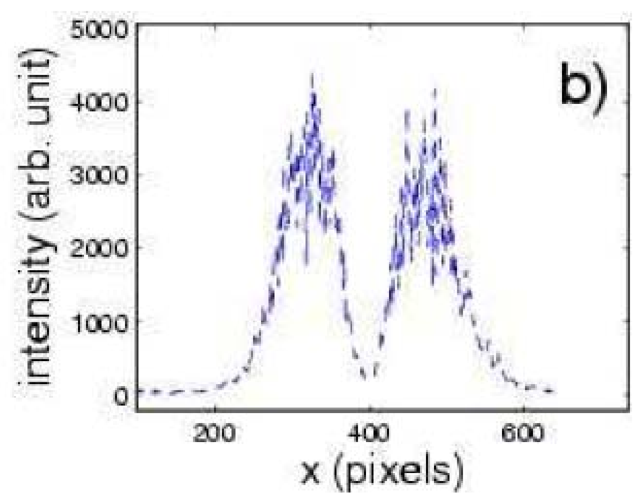
Where λ is the wavelength, $J(p_{10})=0$, n refractive index and c speed of light.

Generation of TEM_{01}^* donuts mode



from
re-gen





R. Tikhoplav et al., Proceedings of EPAC 2002, Paris, France

Diagram of laser acceleration

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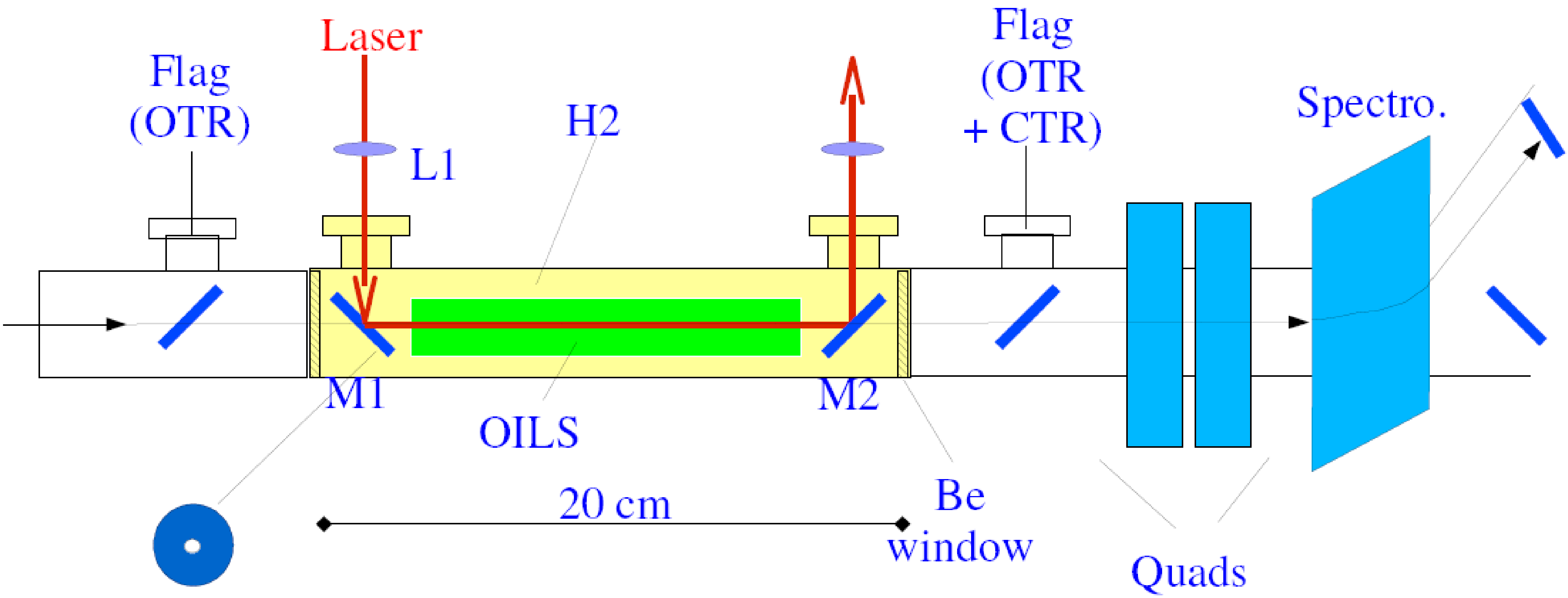

The chamber is filled with gas to compensate the speed.

From Ph. Piot, ACC workshop, Stony Brook (2004)

Simulation with electron bunch

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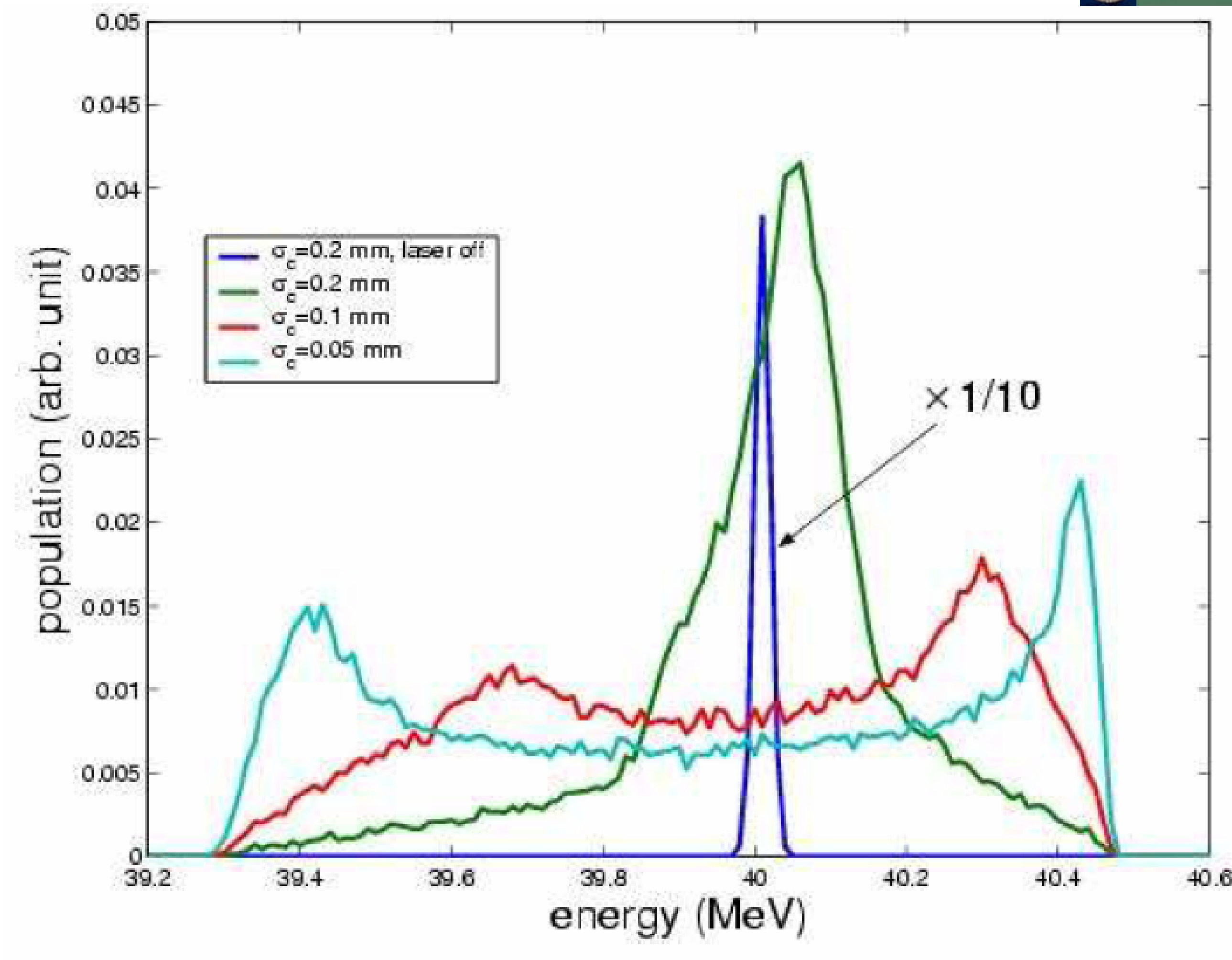
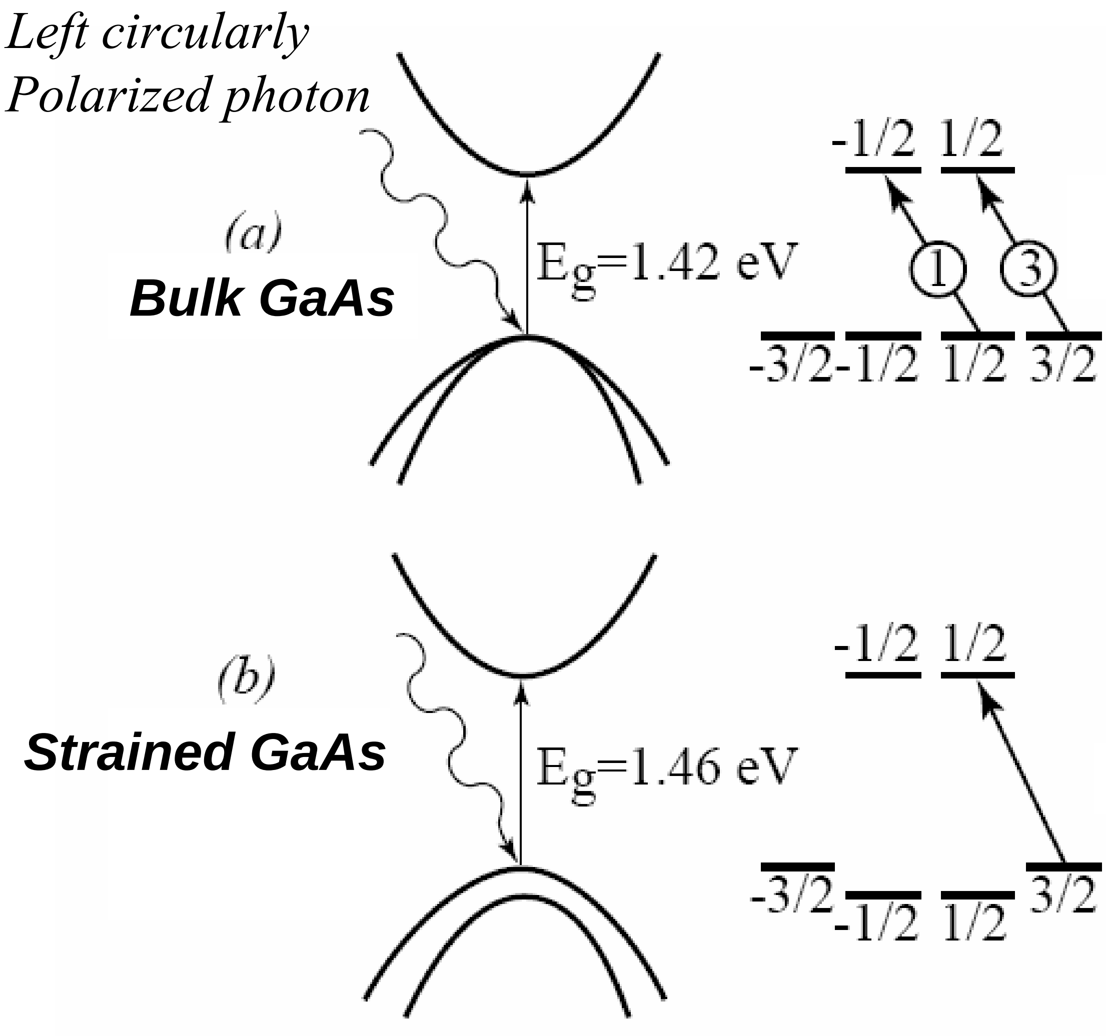


Evolution of the energy spectrum for electron bunch with various beam size propagating in the laser field.

Energy diagrams of bulky and strained GaAs



Polarization is at best 50%.

Polarization could be close to 100%.

Negative electron affinity (NEA) in GaAs

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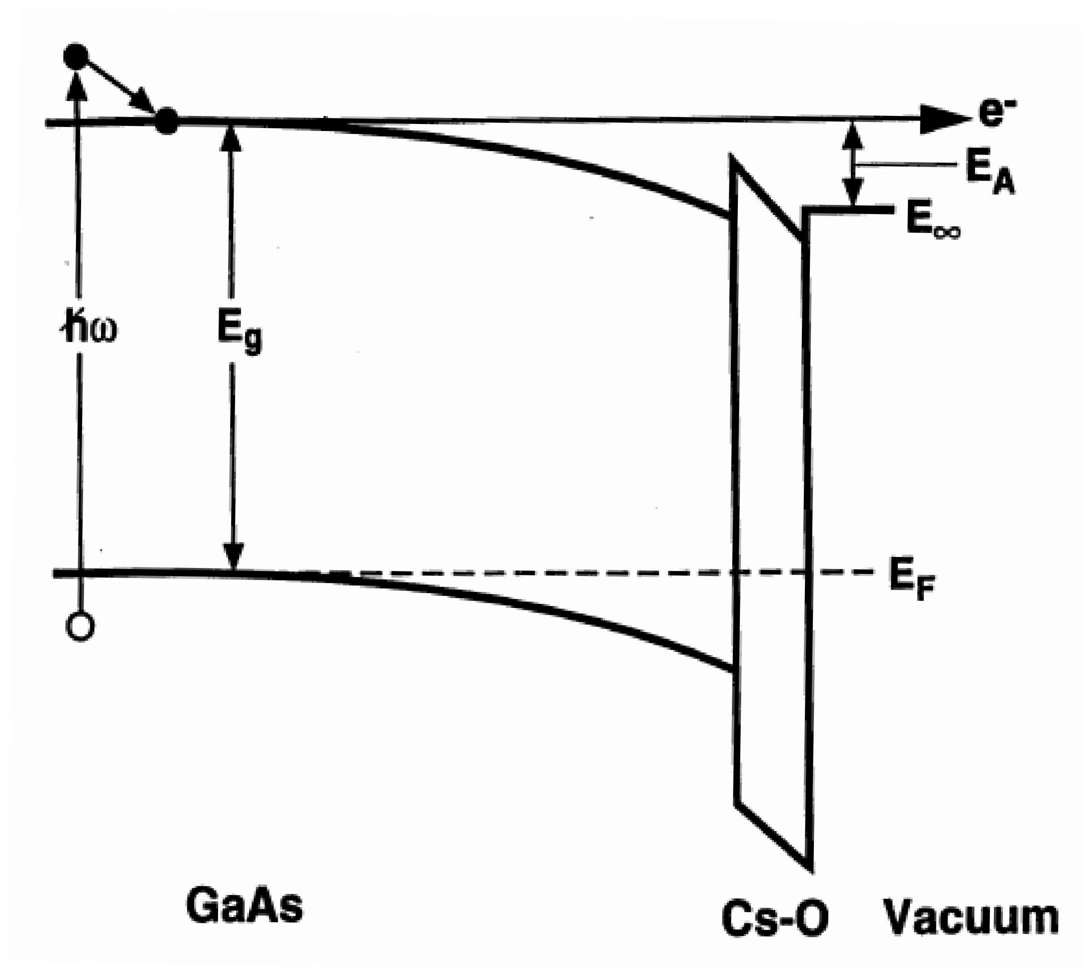

Most recent results on polarization and quantum efficiency

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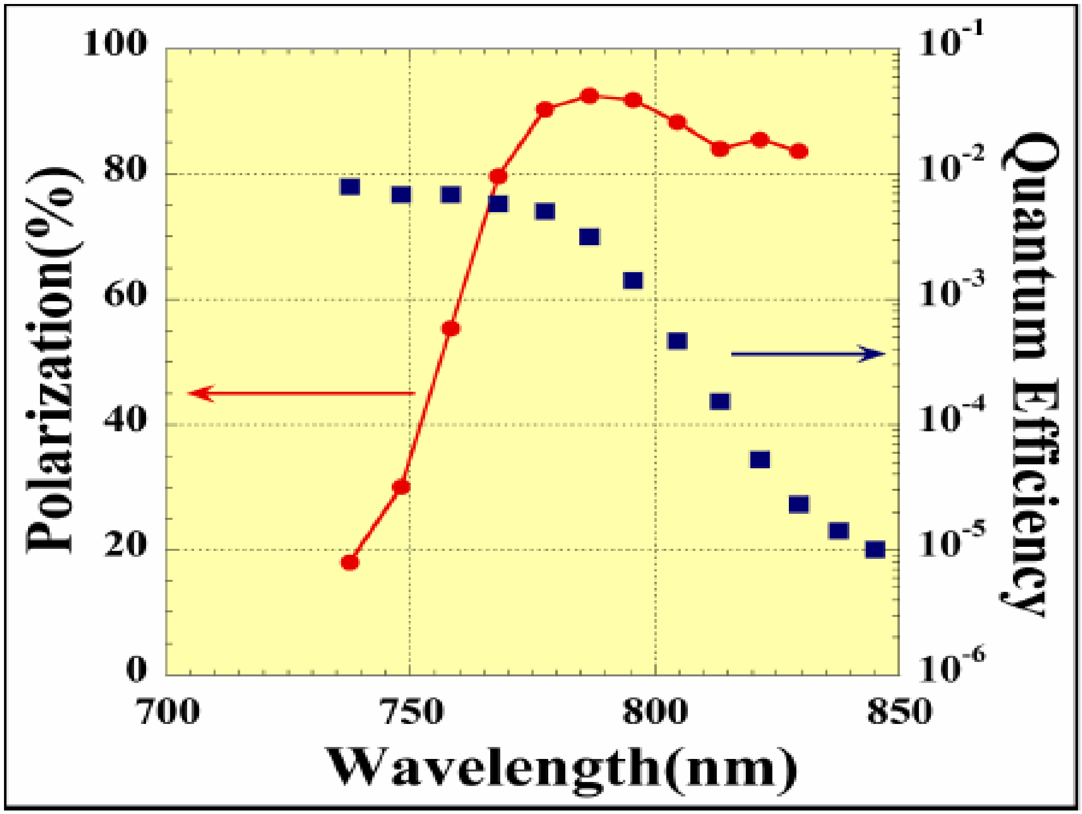
Nagoya (MOCVD)



Polarization 85 - 90%
QE 0.5 - 1%

From Takashi Maruyama, KEK ILC workshop (2004).