Institute of Applied Physics of the Russian Academy of Sciences

Two-Stage Nonlinear Compression of High Intensity Pulses

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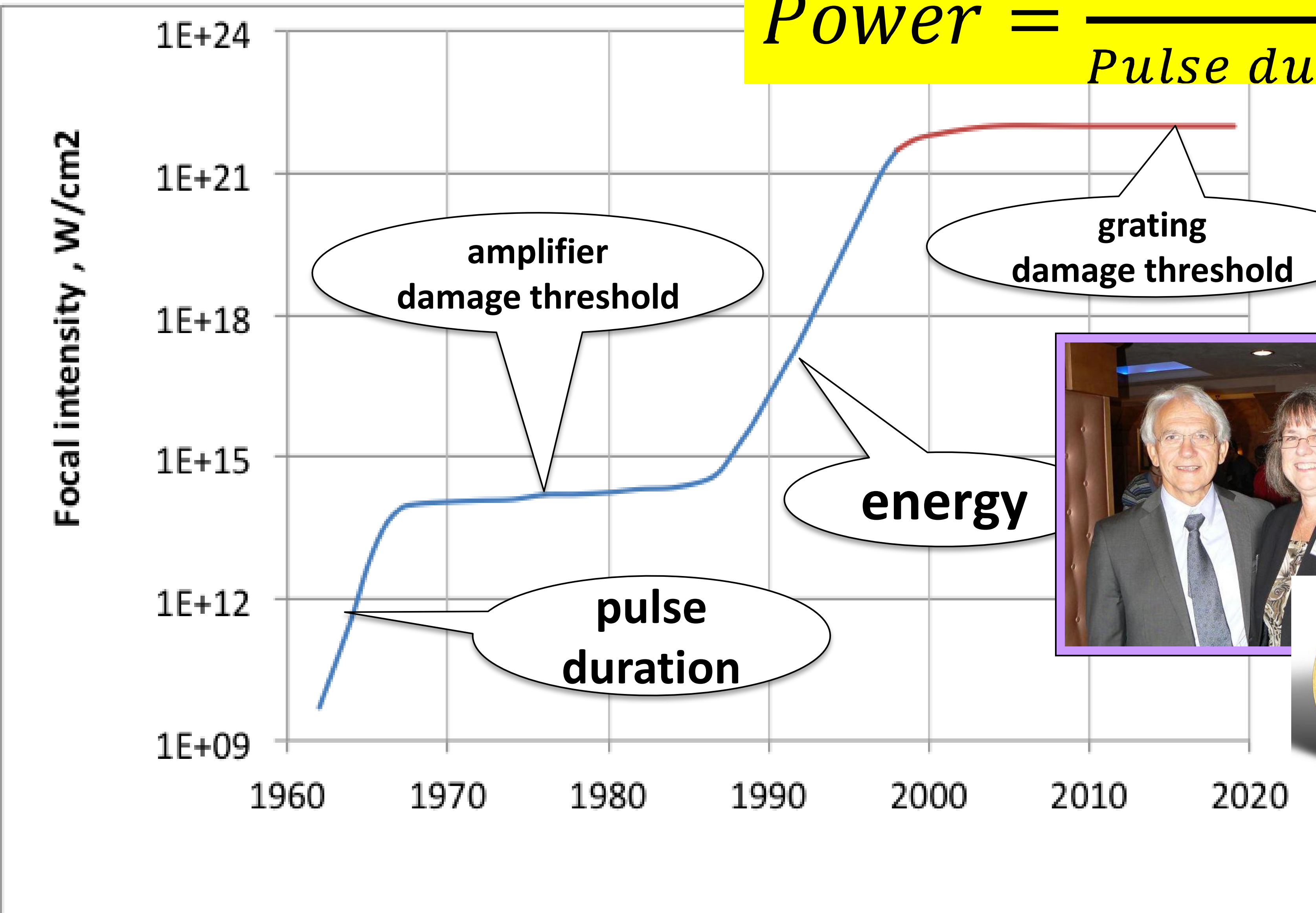
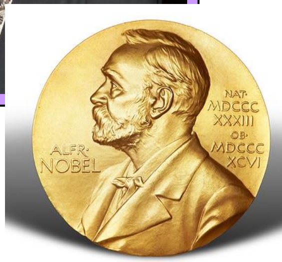
- **Motivation**
- **Compression after Compressor Approach (CafCA)**
- **Small-scale self-focusing suppression in powerful laser beams**
- **Experimental results**
- **Conclusions**

New idea is wanted for the next jump

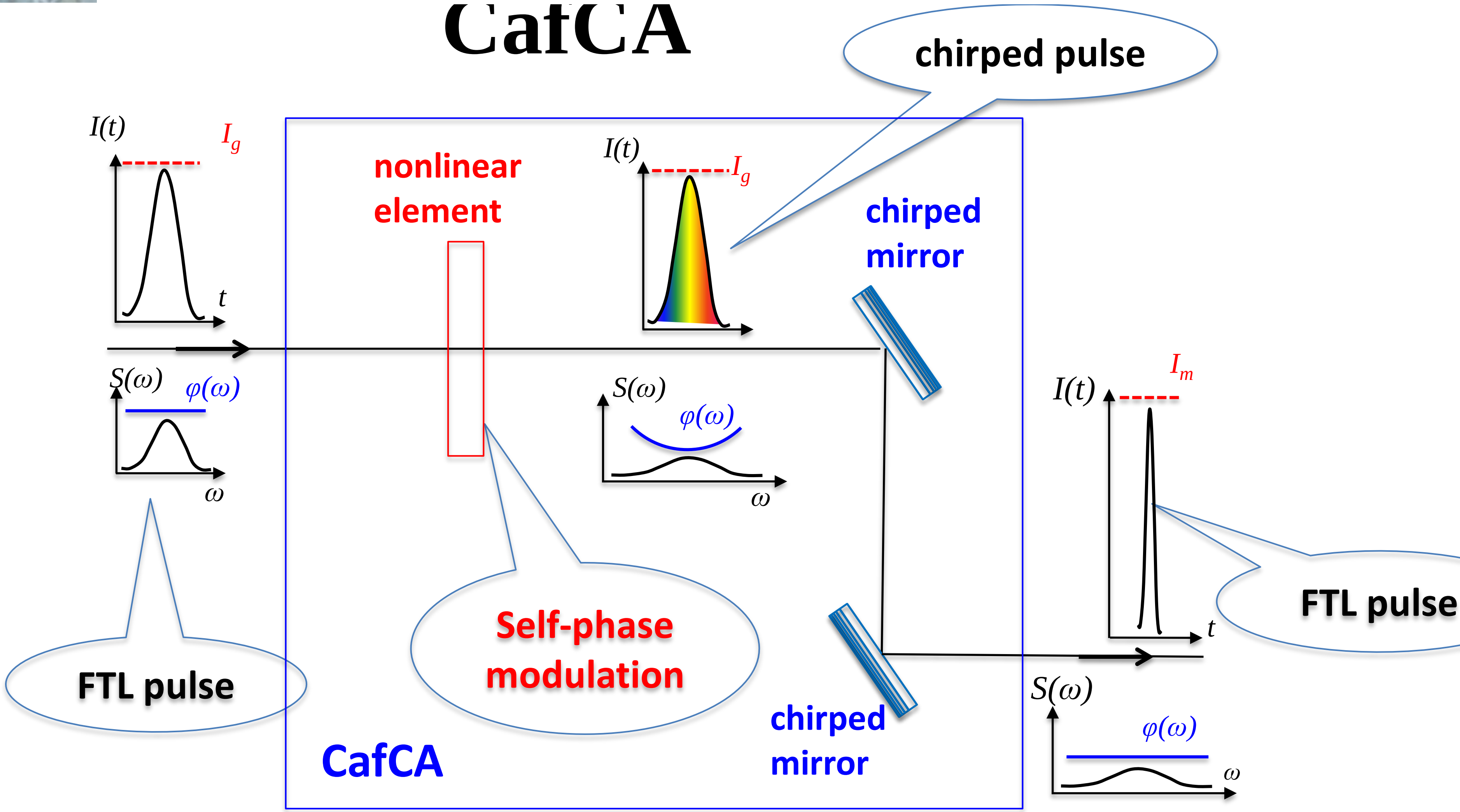
$$Power = \frac{Energy}{Pulse\ duration}$$



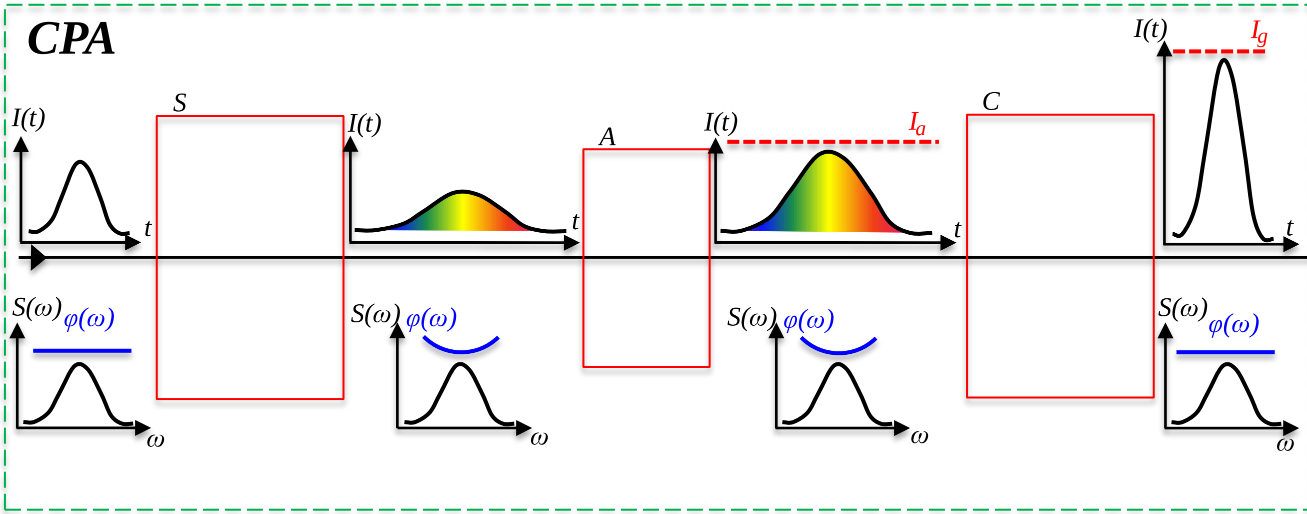


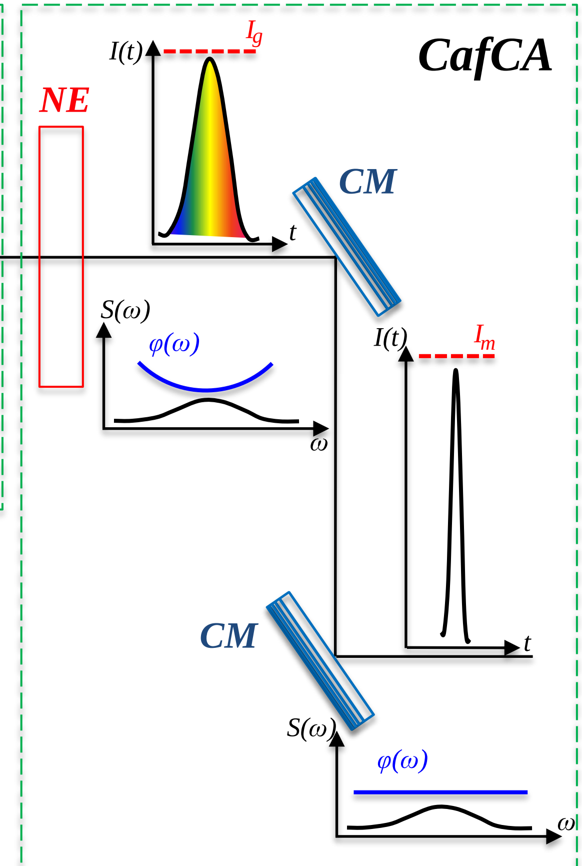
Compression after Compressor Approach

CafCA



CPA + CafCA





S – stretcher,

A – laser amplifier

C – compressor

NE – nonlinear element

CM – chirped mirror

I_a , I_g and I_m– breakdown threshold of the amplifiers, diffractions gratings and chirping mirrors.

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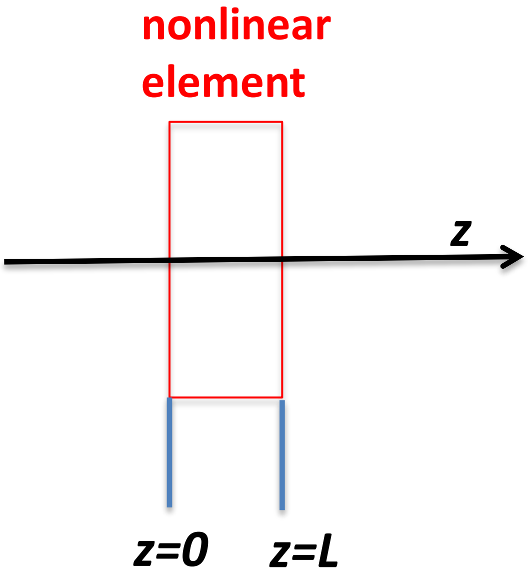
CafCA theory basics

$$\frac{\partial a}{\partial Z} - i\frac{D}{2}\frac{\partial^2 a}{\partial \eta} + iB|a|^2 a = 0$$



a=E(t,z)/E(0,0) : electric field

Z=z/L : normalized distance

$\eta = (t - z/u)/\tau_{pulse}$, : normalized time

τ_{pulse} : pulse duration

$B = n_2 IkL = L/L_{nonlinear}$

$D = k_2 L(\tau_{pulse})^2 = L/L_{dispersion} << 1$

$$F_{power} \approx 1 + B/2$$

CafCA hystory from nJ to mJ

nJ

Fisher, R.A., Kelley, P.L., and Gustajson, T.K., "Subpicosecond pulse generation using the optical Kerr effect " Applied Physics Letters 14(4), 140-143, 1969.
idea

Laubereau, A., "External frequency modulation and compression of picosecond pulses," Physical Letters 29A(9), 539-540, 1969.
liquid

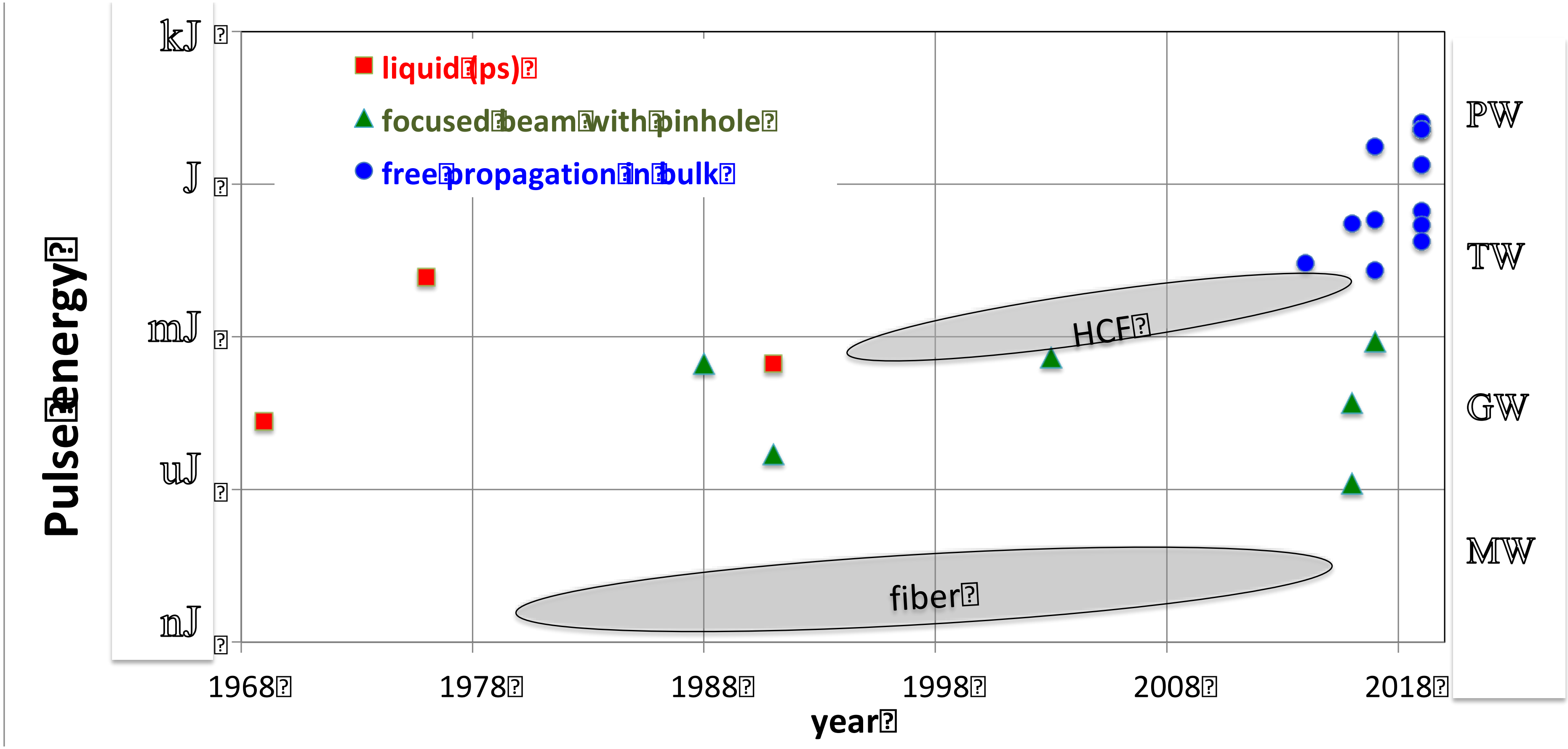
Nakatsuka, H., Grischkowsky, D., and Balant, A.C., "Nonlinear Picosecond-Pulse Propagation- through Optical Fibers arith Positive Group Velocity Dispersion," Physical Review Letters 47(13), 910-913, 1981.
fiber

Rolland, C. and Corkum, P.B., "Compression of high-power optical pulses," Journal of the Optical Society of America B 5(3), 641-647, 1988.
focused beam

Nisoli, M., Silvestri, S.D., and Svelto, O., "Generation of high energy 10 fs pulses by a new pulse compression technique," Applied Physics Letters 68(20), 2793-2795, 1996.
hollow core fiber

mJ

CafCA hystory from nJ to J



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Small-scale self-focusing basics

$B<2\ldots3$

$F_{\mathrm{power}} \approx 1+B/2$

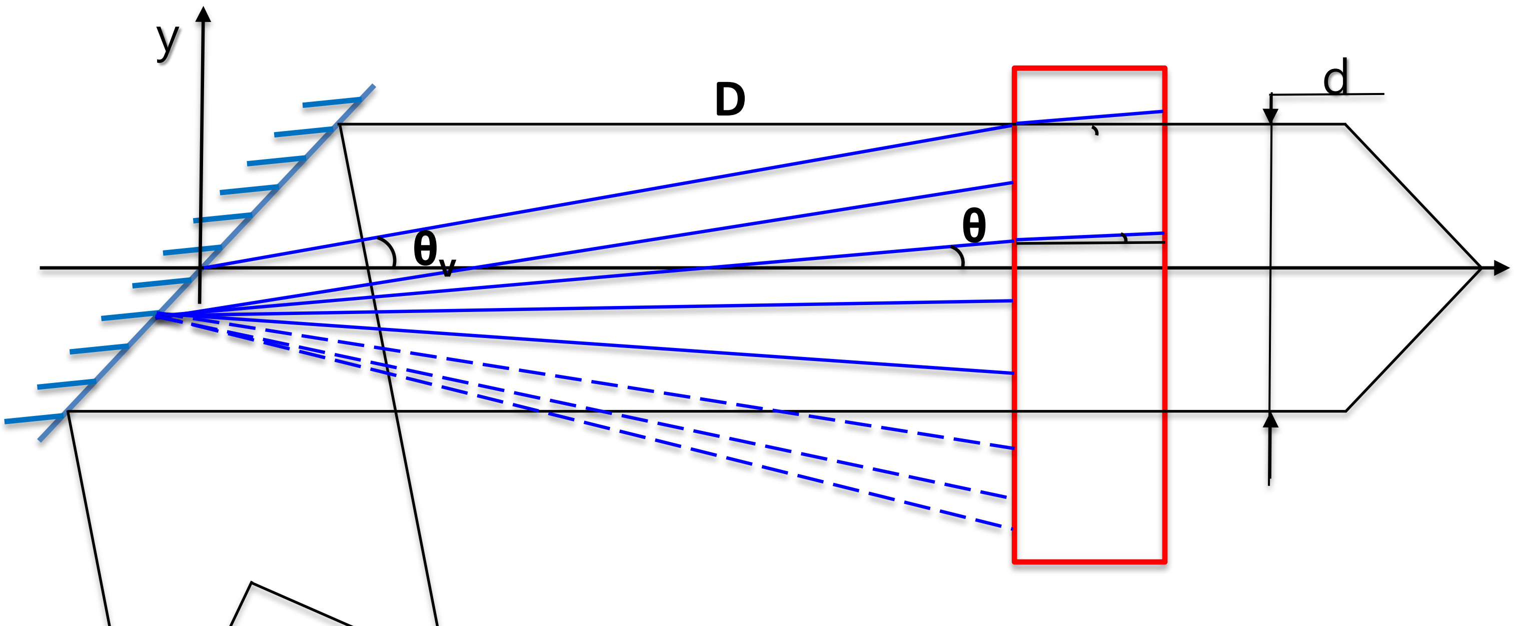
$F_{\mathrm{power}}<2\ldots2.5$

Beam self-filtering

The technique of beam filtering depends on the intensity level

For ns laser beams intensities I ~ 1÷10GW/cm^2 θ_{max}=0.73÷2 mrad

For fs laser beams intensities I ~ 1÷10TW/cm^2 θ_{max}=20÷50 mrad



Free space propagation leads to beam self-filtering

I=1TW/cm^2, d=100mm: the safety distance D>1.6m

$$q_{cr} = 2\sqrt{\frac{gI}{n}}$$

S. Mironov, V. Lozhkarev, G. Luchinin, A. Shaykin, and E. Khazanov, Applied Physics B, 113, 147-151 (2013).

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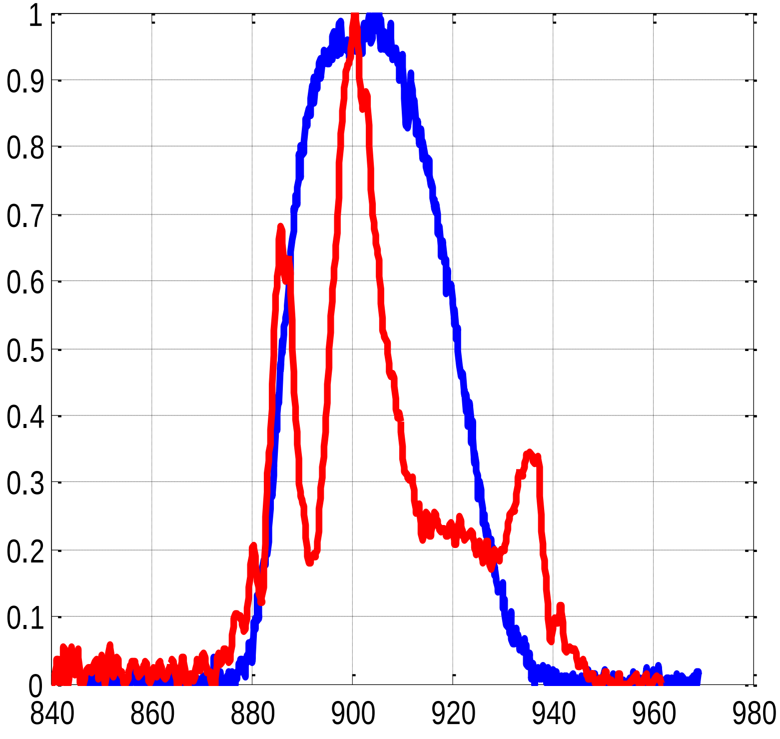
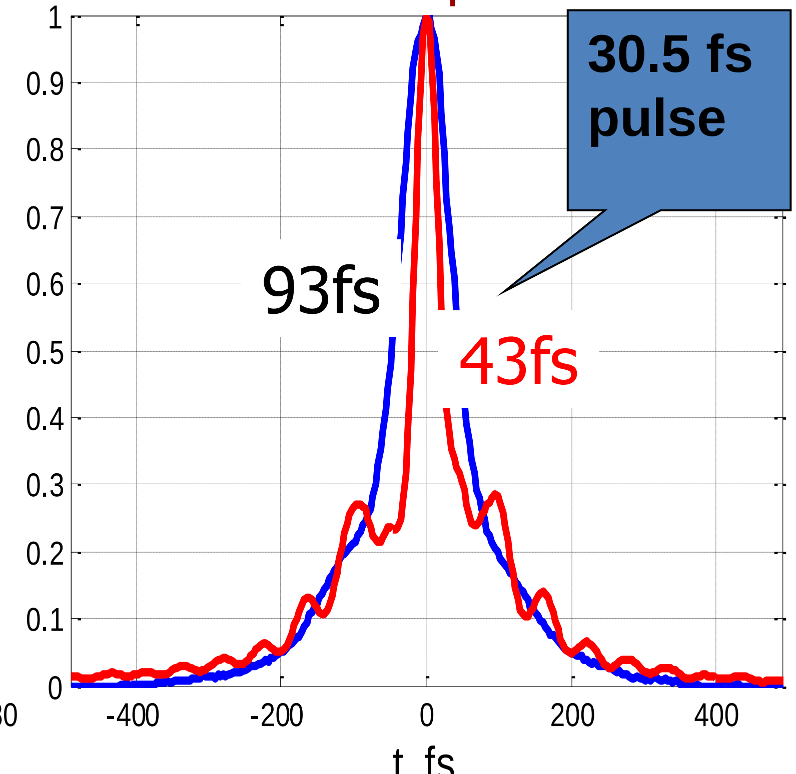
Example 1: at the output of the PEARL front-end

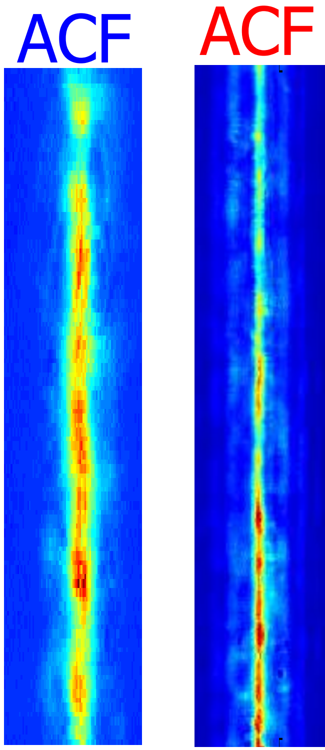
Ø 20mm, W=20mJ, T_{pulse}=66fs -> 30fs, $L_{plastic}$=3mm, B~2

Spectra before and after SPM



ACF w/o SPM and after SPM & chirped mirrors





V. N. Ginzburg, A. A. Kochetkov, I. V. Yakovlev, S. Y. Mironov, A. A. Shaykin, E. A. Khazanov, Influence of the cubic spectral phase of high-power laser pulses on their self-phase modulation Quantum Electronics, 46, 106, 2016

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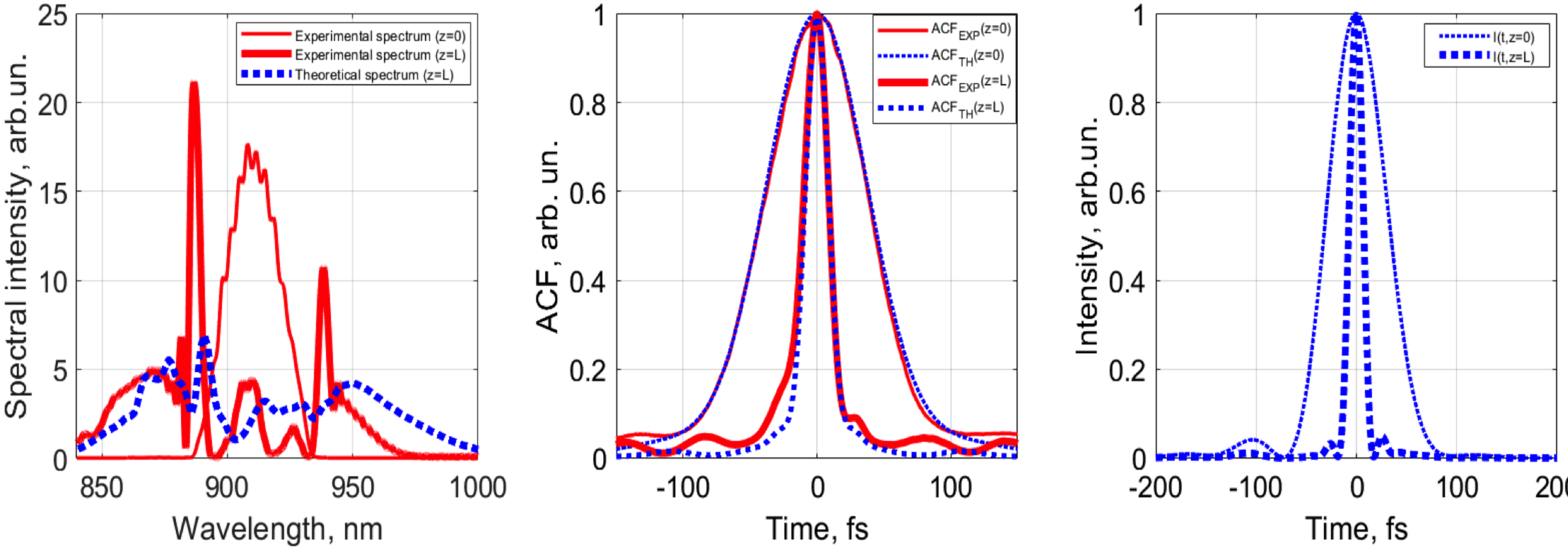
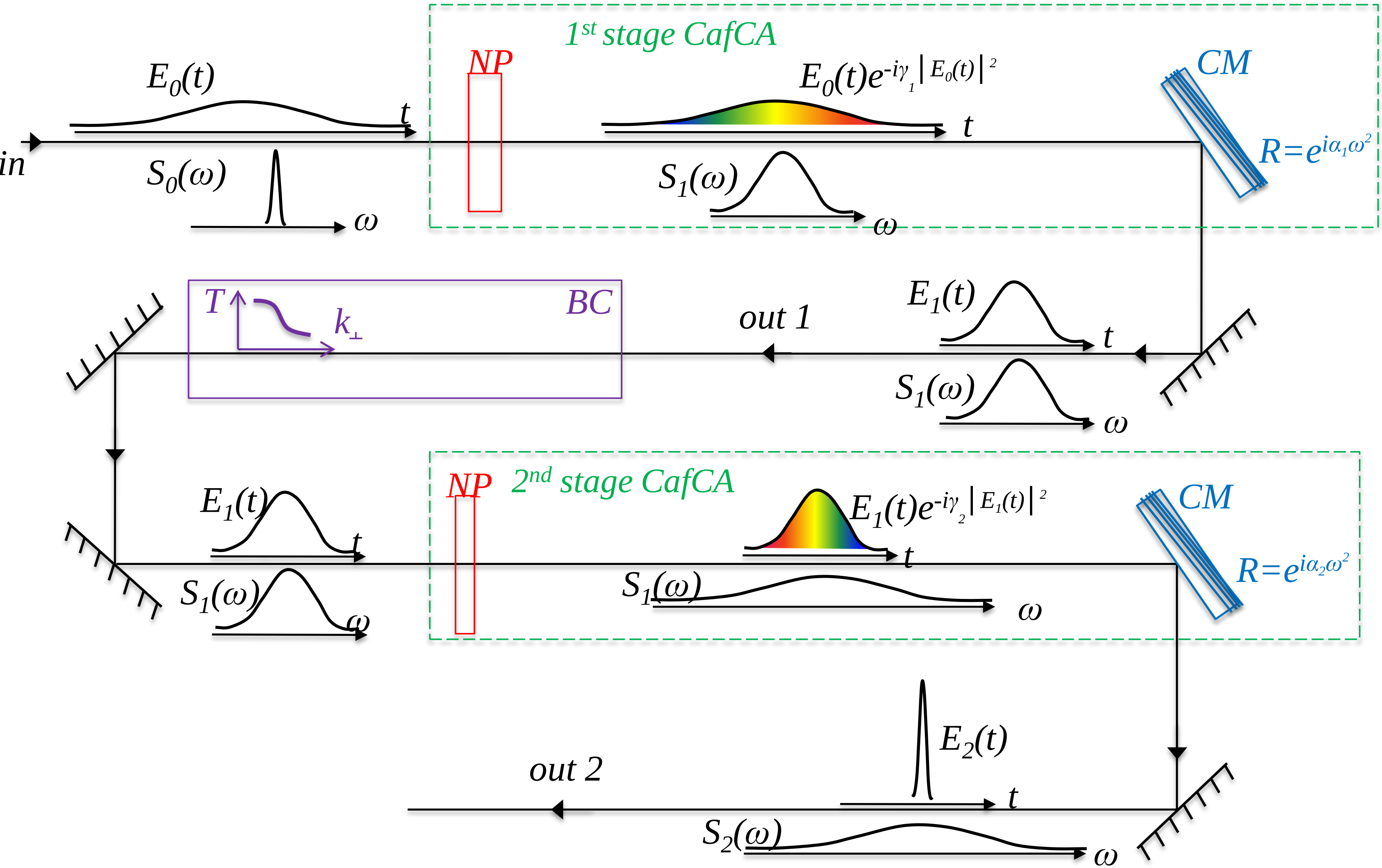
Fresh new results

<u>Ø 160mm, W=17J,</u> T_{pulse}=70fs -> 14fs, L_{glass}=3 mm, B~7.5



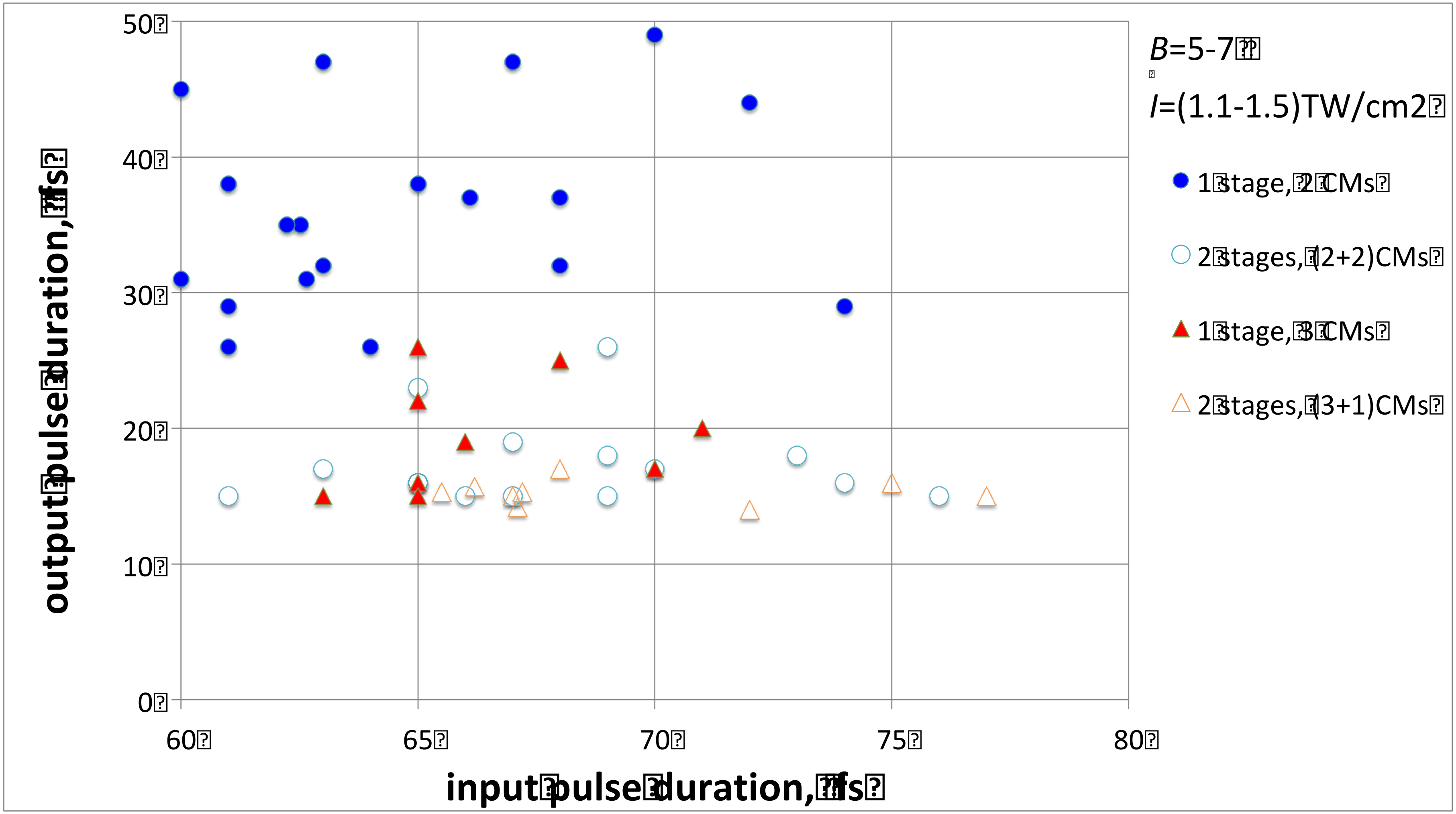
PRA, 101, 013829 2020

CafCA: two-stage



Single-stage vs two-stage

Ø 160mm, W=17J, T_{pulse}=70fs -> 14fs, L_{glass}=3 mm, B~7.5



Quantum Electronics, v.50, p.331–334 (2020)

Instead of conclusion

CafCA is simple, robust and cheap recipe:
just add free space, glass plate and chirp mirror(s)

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Thank you

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