Spectral Compression by All-Fiber, Classic, and Similaritonic Techniques

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ԵՐԵՎԱՆԻ ՊԵՏԱԿԱՆ ՀԱՄԱԼՍԱՐԱՆ
ՖԻԶԻԿԱՅԻ ՖԱԿՈՒԼՏԵՏ
ՕՊՏԻԿԱՅԻ ԱՄԲԻՈՆ

ՄԱԳԻՍՏՐՈՍԱԿԱՆ ԹԵԶ

Ֆեմտովայրկյանային իմպուլսների սպեկտրալ սեղմումը դասական, ամբողջովին լուսատարային և սիմիլարիտոնային մեթոդներով

Ուսանող՝ Հրաչ Տոնեյան
Ղեկավար՝ Լ. Խ. Մուրադյան

Frontiers in Optics 2014

19-23 October, 2014, Tucson, Arizona, USA

8x, 12x, and 23x Spectral Compression by All-Fiber, Classic, and Similaritonic Techniques

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XLIM Institut de Recherche, Faculté des Sciences, Limoges, France

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Newport Technology & Applications Center, Irvine, CA 92606, USA

*International Symposium on **OPTICS***
and its applications
1-5 September, 20141, Yerevan – Ashtarak, Armenia

Spectral Compression of Femtosecond Pulses: Classic, All-Fiber, and Similaritonic Techniques

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Applications

- spectral imaging of the pulse temporal profile
- femtosecond pulse undistorted delivery
- similariton fiber lasers
- nonlinear vibrational microscopy (CARS)

L. Kh. Mouradian, et al "Spectro-temporal imaging of femtosecond events," IEEE J. Quantum Electron. **36**, 795–801 (2000).

T. Mansuryan, et al "Parabolic temporal lensing and spectrotemporal imaging: a femtosecond optical oscilloscope," J. Opt. Soc. Am. B **25**, A101–A110 (2008).

S. W. Clark, et al "Fiber delivery of femtosecond pulses from a Ti:sapphire laser," Opt. Lett. **26**, 1320–1322 (2001).

S.Boscolo, et al "Amplifier similariton fiber laser with nonlinear spectral compression," Opt. Lett. **37**, 4531-4533 (2012).

A.F. Pegoraro, A. Ridsdale, D.J. Moffatt, Y. Jia, J.P. Pezacki, and A. Stolow, "Optimally chirped multimodal CARS microscopy based on a single Ti:sapphire oscillator," Opt. Express 17, 2984-2996 (2009).

Recent results

- 8.7x transform-limited SC through the shaping of negatively chirped parabolic pulses

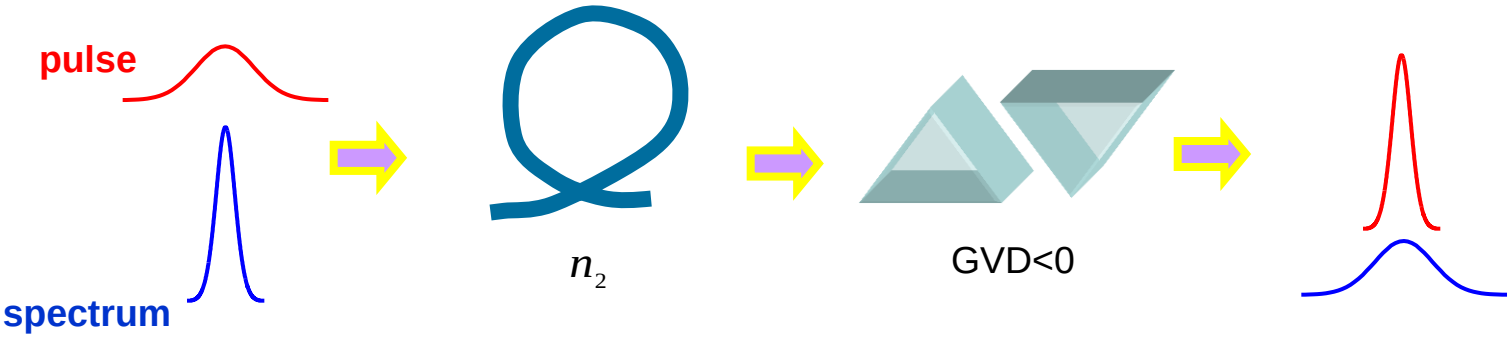
E. R. Andresen, et al
"Transform-limited spectral compression by self-phase modulation of amplitude-shaped pulses with negative chirp," Opt. Lett. **36**, 707–709 (2011).

- 12x compression ratio in an all-fiber configuration for telecommunication wavelengths

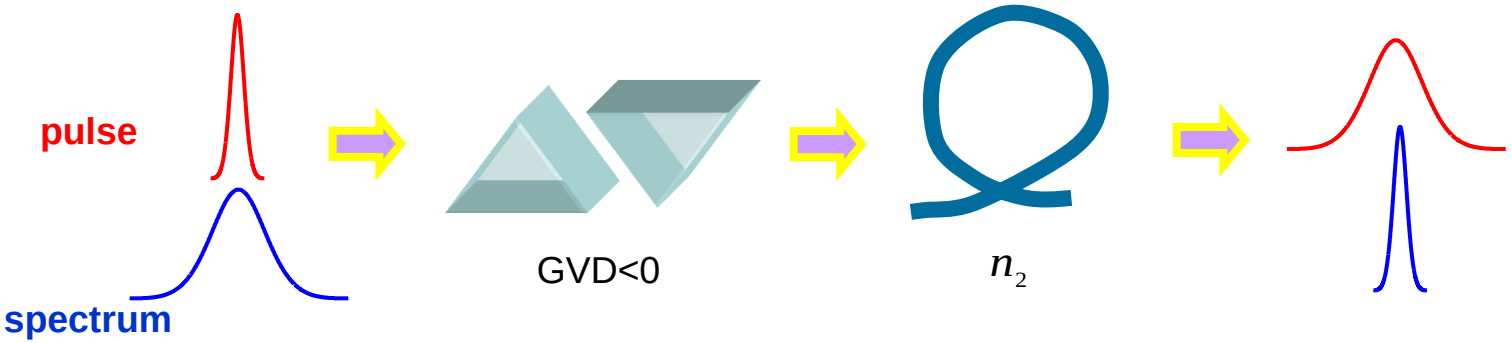
J. Fatome, et al
"All-fiber spectral compression of picosecond pulses at telecommunication wavelength enhanced by amplitude shaping," Appl. Opt. **51**, 4547–4553 (2012).

Spectral compressor

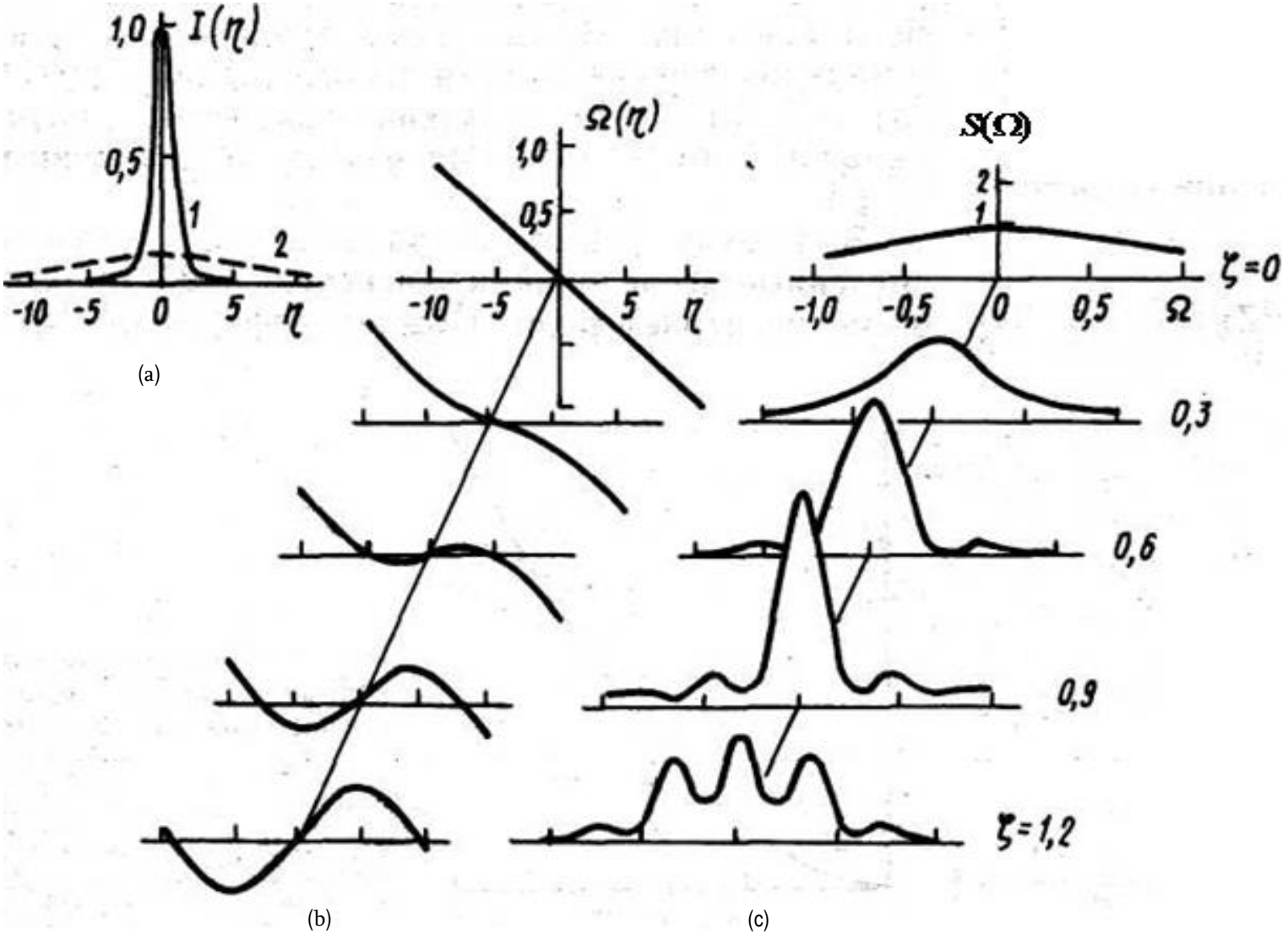
pulse compressor



spectral compressor

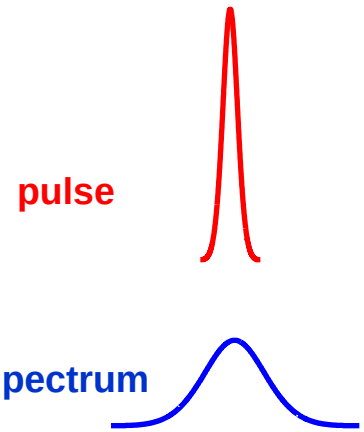


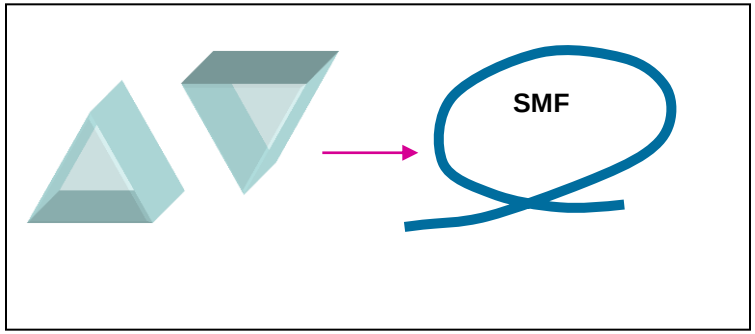
Physical pattern of the process

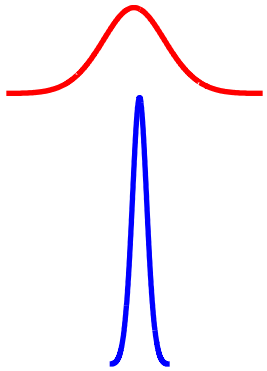


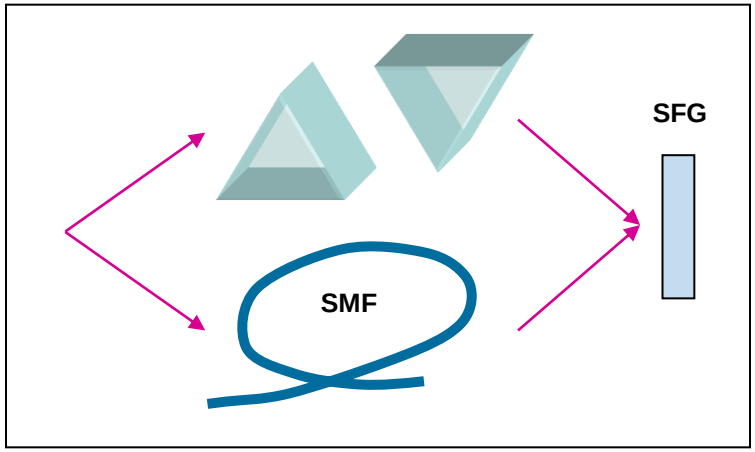
Research objectives

Classic scheme









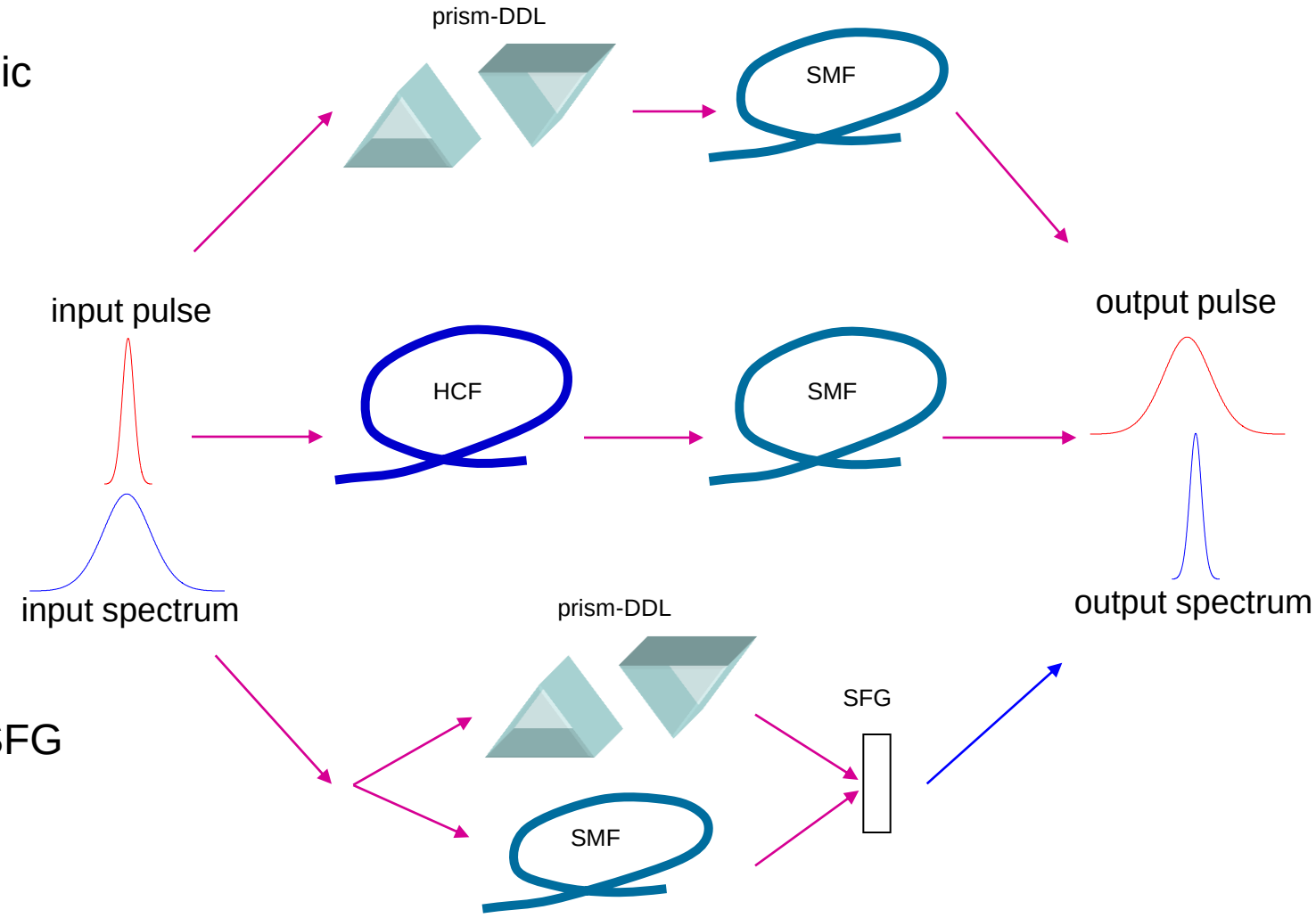
Parallel scheme

Research subjects

SC by classic technique

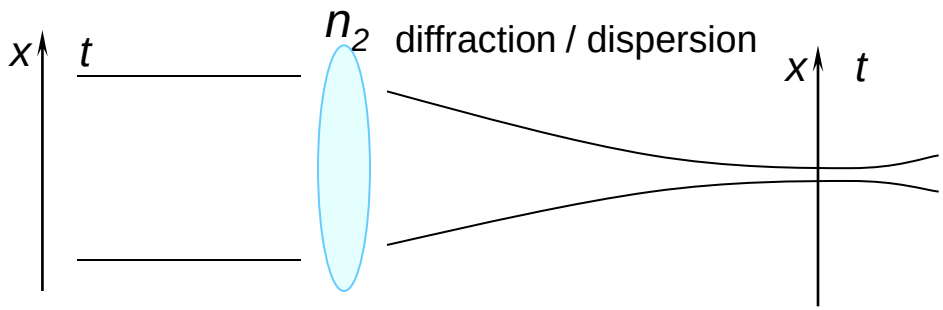
all-fiber SC

SC by the SFG similaritonic technique



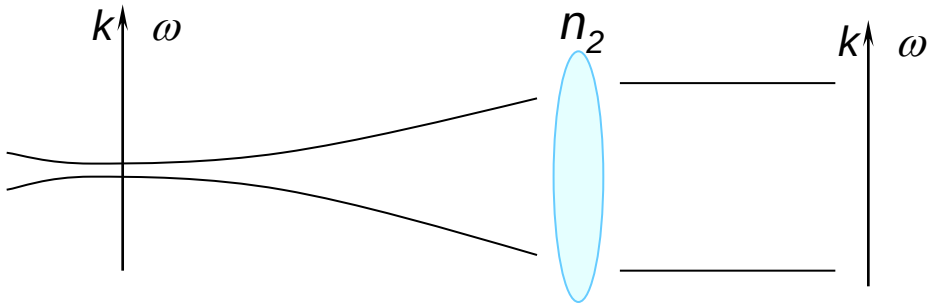
Concept

spatio-temporal analogy:



beam focusing / pulse compression

spectral domain (k / ω):



beam collimation / spectral compression

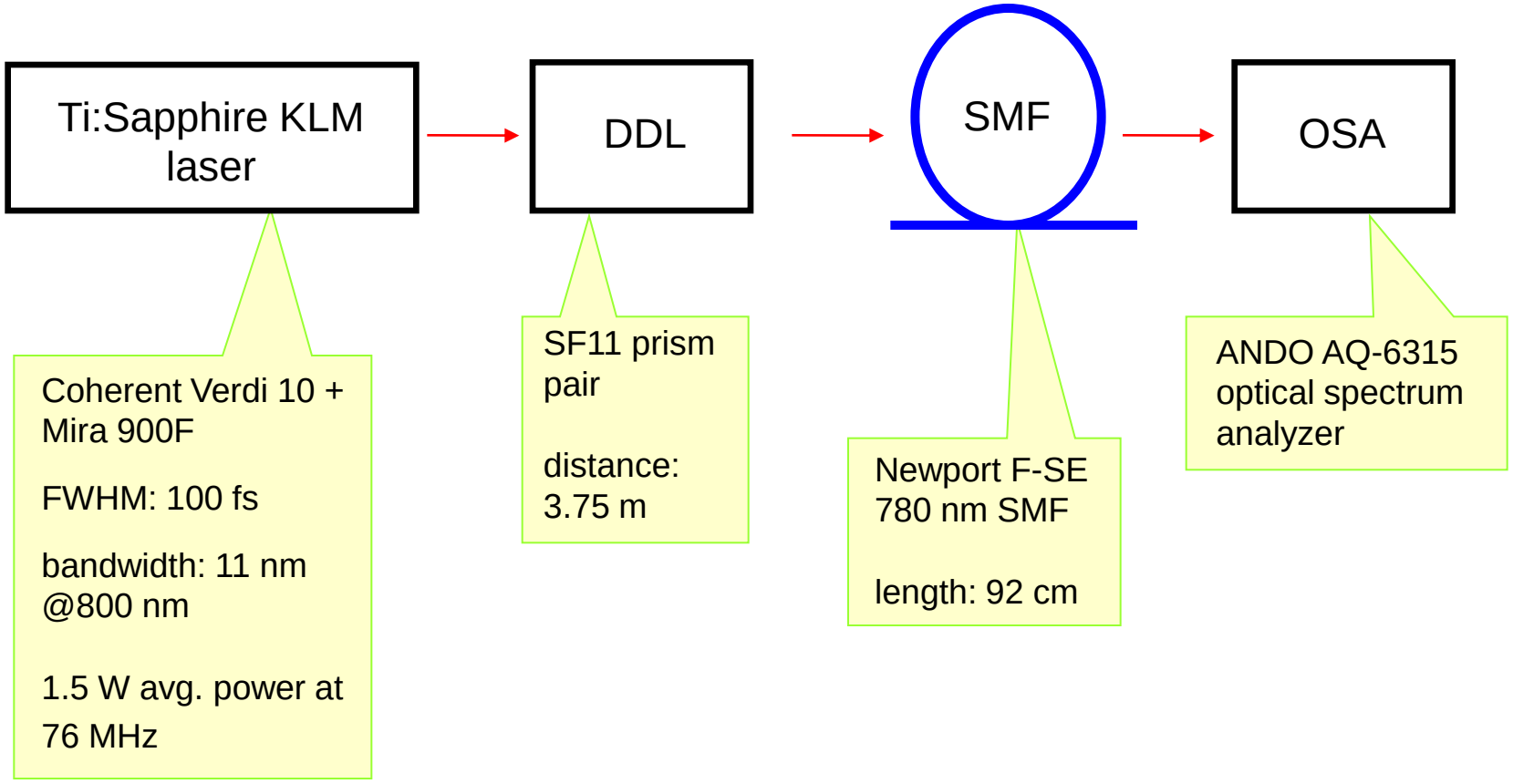
Spectral compressor is a temporal Kerr-lens, which "collimates" the radiation in time, and "focuses" the spectrum.

Aberrations of temporal Kerr lens

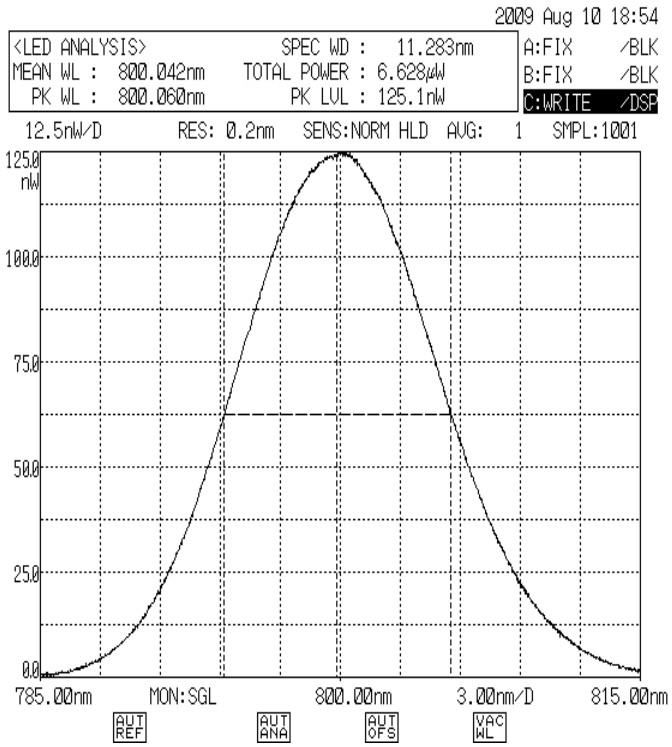
NL Schrödinger equation:

$$i\frac{\partial\psi}{\partial\varsigma} = -\frac{1}{2}\frac{\partial^2\psi}{\partial\eta^2} + R|\psi|^2\psi$$
$$-R\mu_r\psi\frac{\partial}{\partial\eta}|\psi|^2 + i\frac{\mu_{TOD}}{6}\frac{\partial^3\psi}{\partial\eta^3} - i\mu_{sh}R\frac{\partial}{\partial\eta}\left(|\psi|^2\psi\right)$$

Experimental setup of classic technique of SC

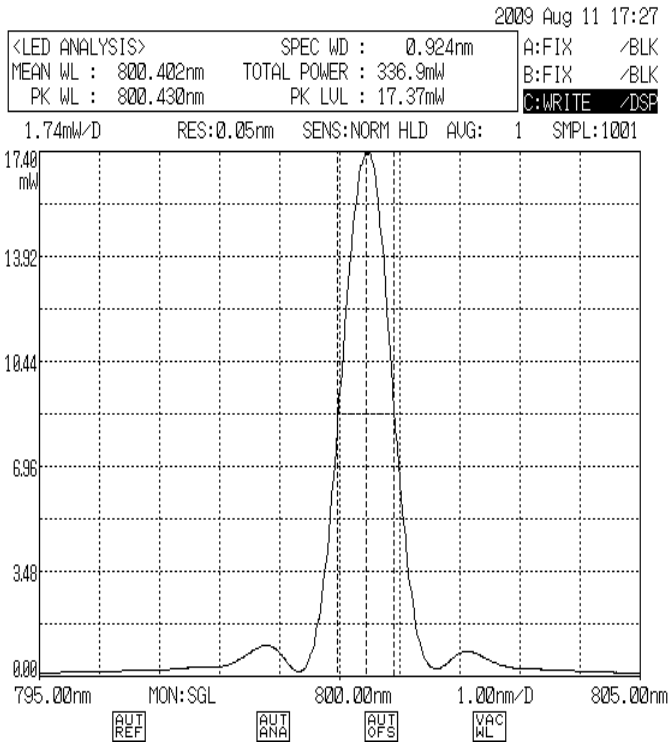


Classic SC



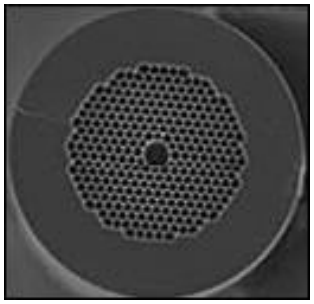
11.3 nm spectrum

12x SC

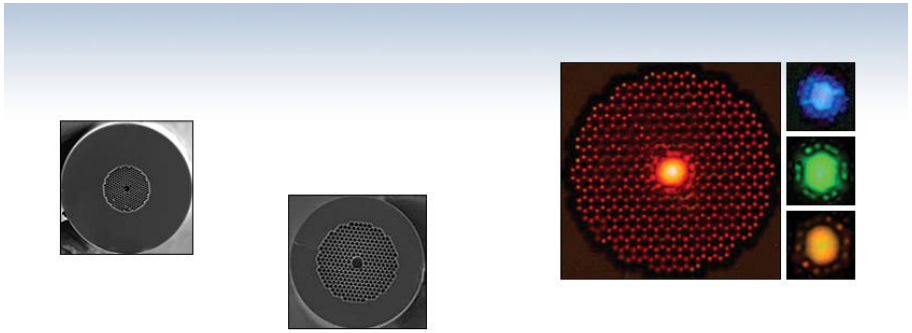


0.92 nm spectrum

Experimental setup of Self SC scheme



ThorLabs HCF-800



Coherent Verdi 10 + Mira 900F

FWHM: 100 fs

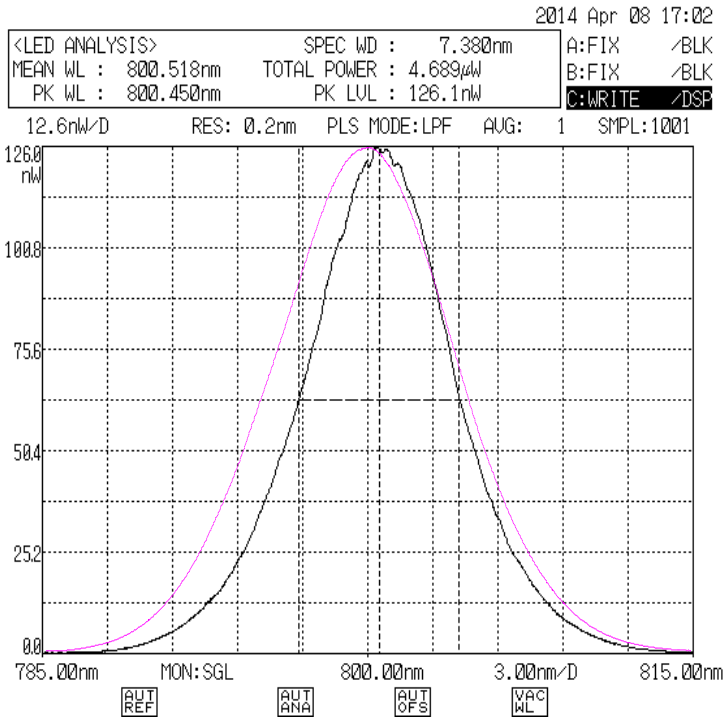
bandwidth: 11 nm @800 nm

1.5 W avg. power at 76 MHz

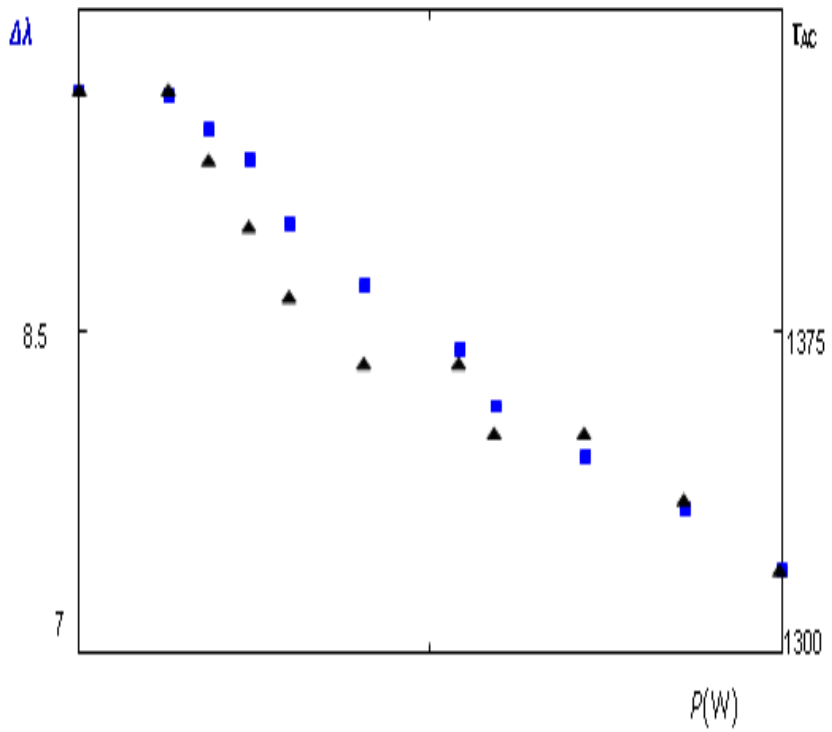
ThorLabs HCF-800 length: 2 m

ANDO AQ-6315 optical spectrum analyzer

Self-SC



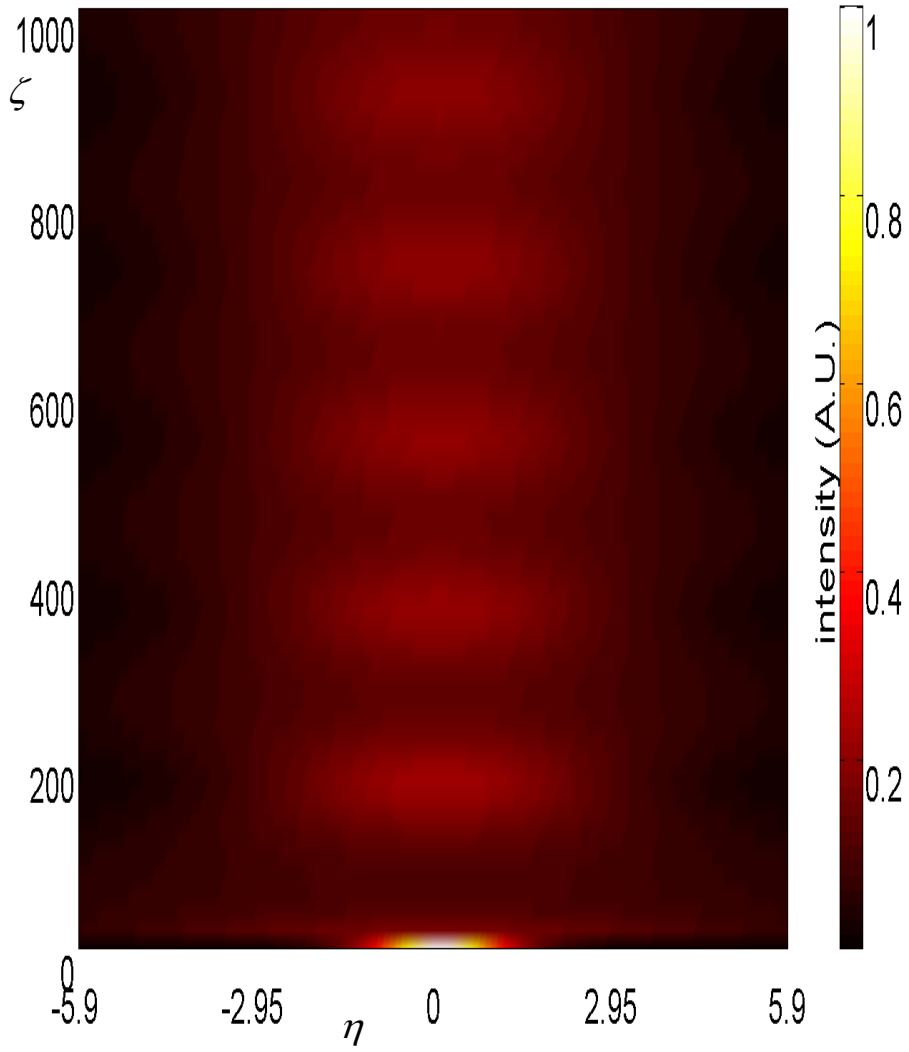
1.3x SC

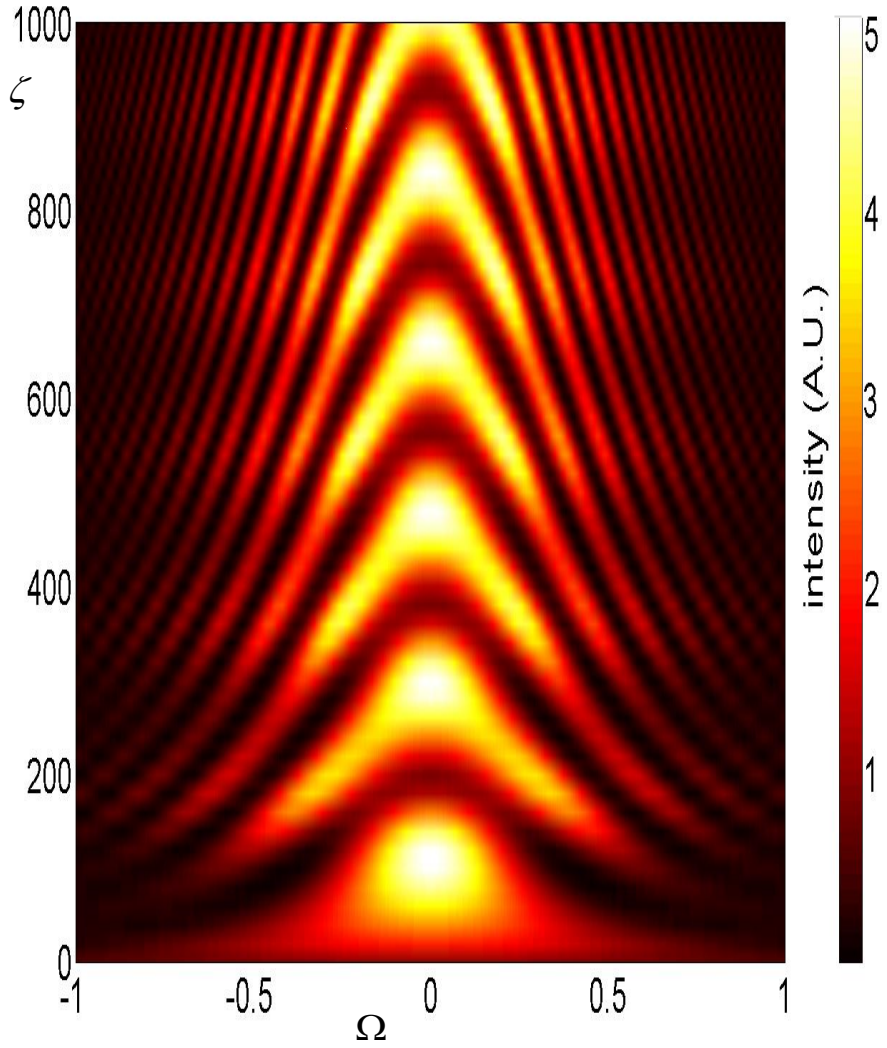


spectral width and autocorrelation duration vs power

Evolution “map” for self-SC process

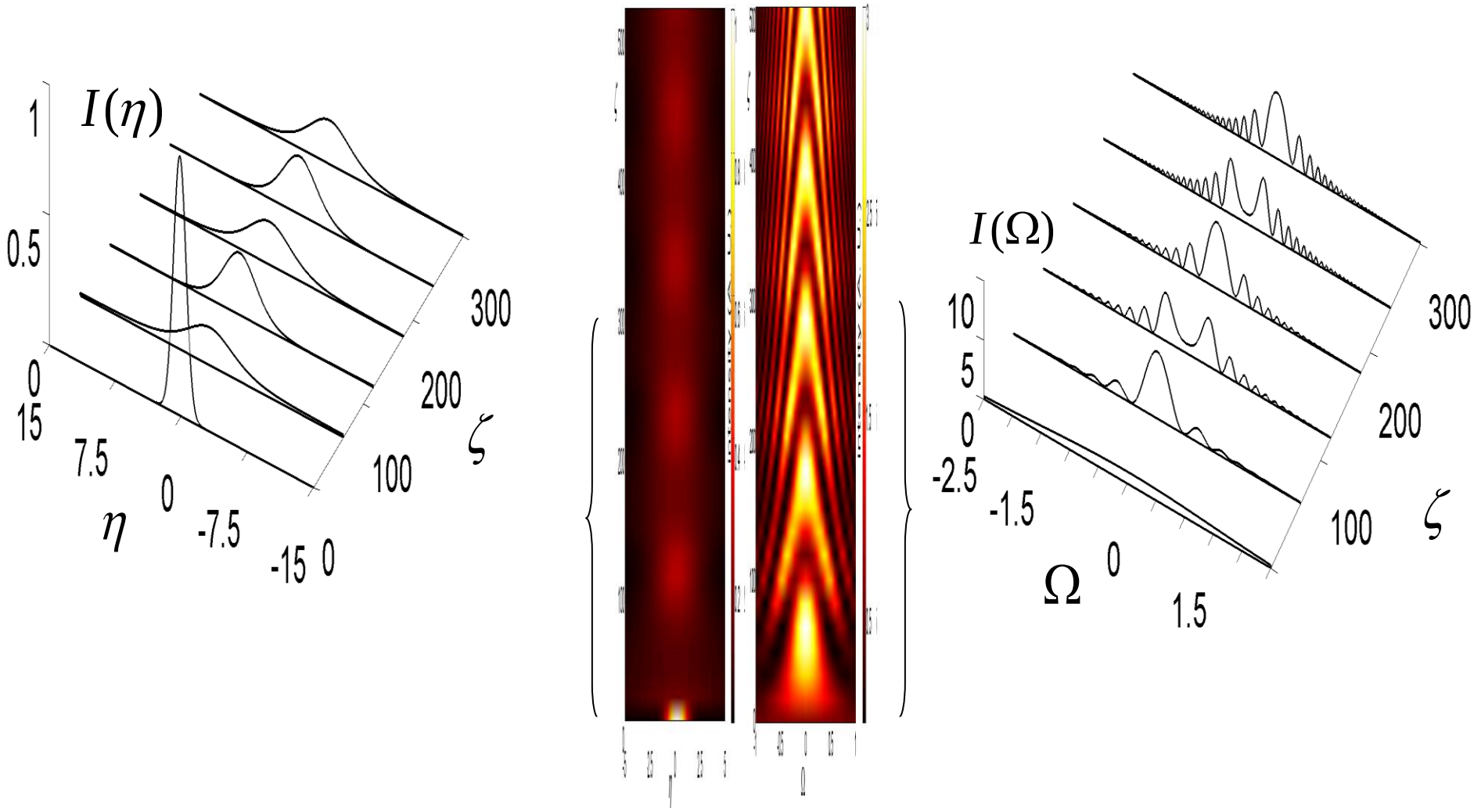
for initial secant-hyperbolic pulse *R=0.4*



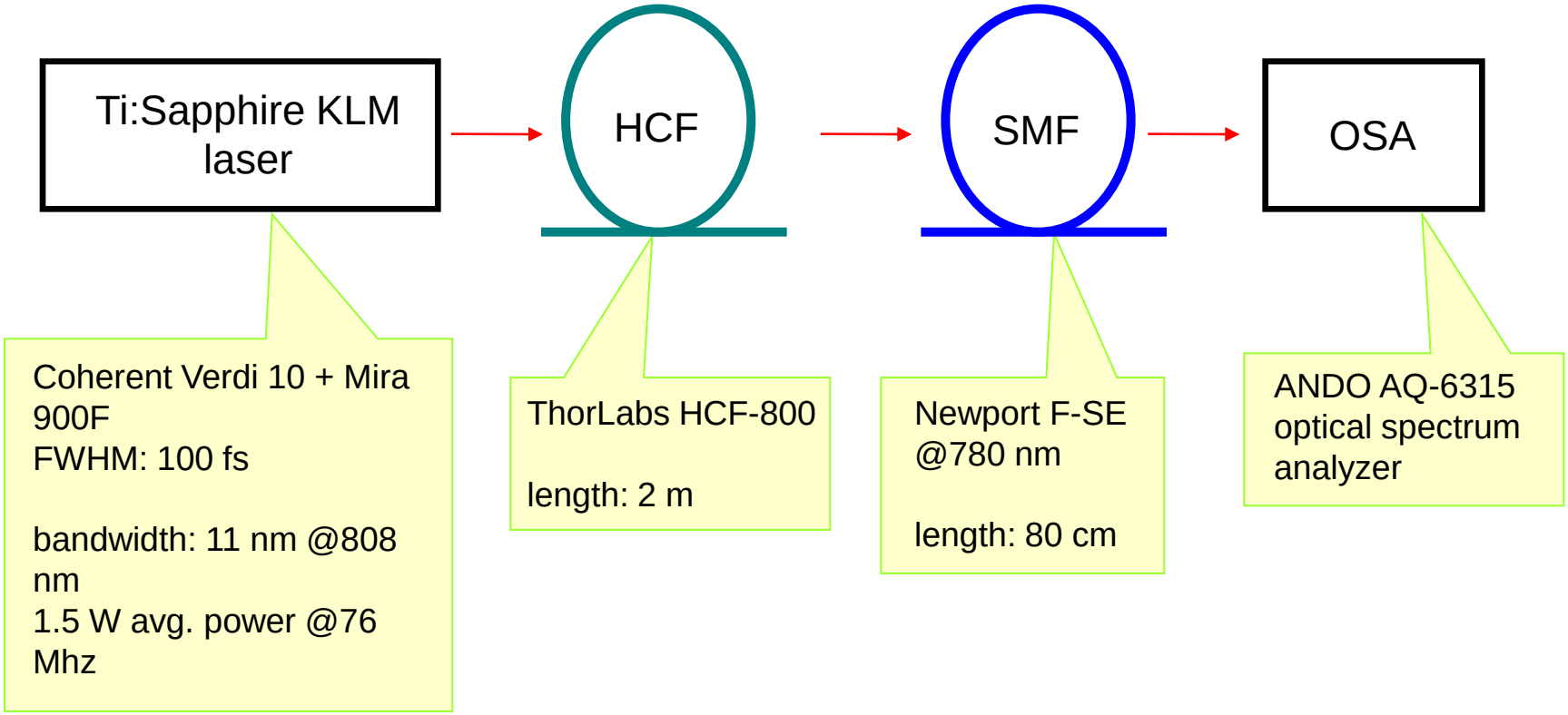


3D pattern of self-SC

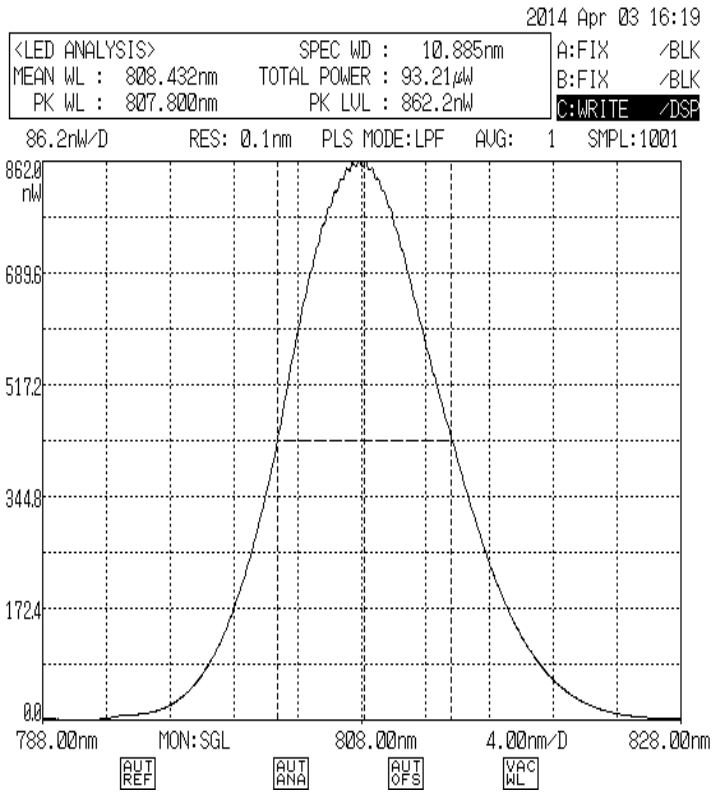
for initial Gaussian pulse (R=0.6)



Experimental setup of all-fiber technique of SC

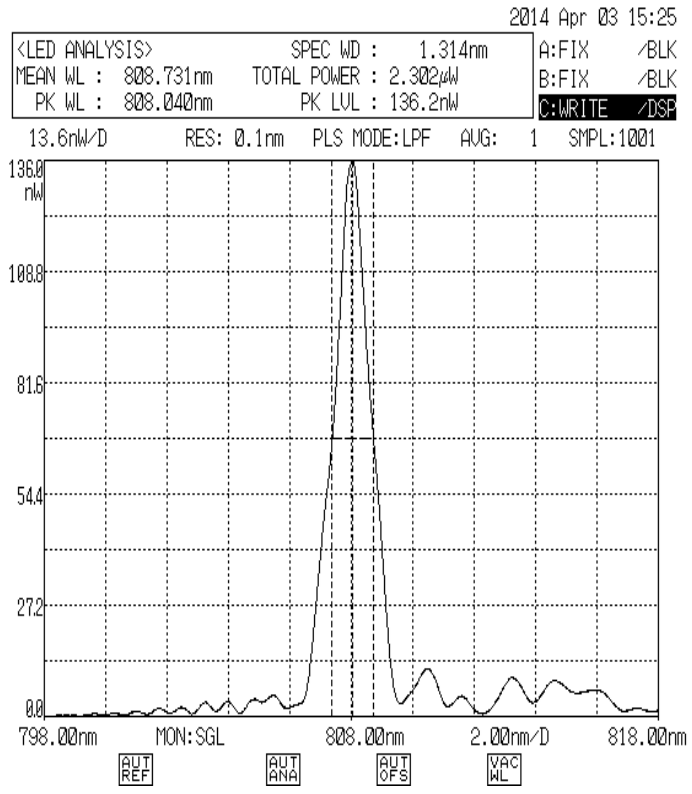


All-fiber SC



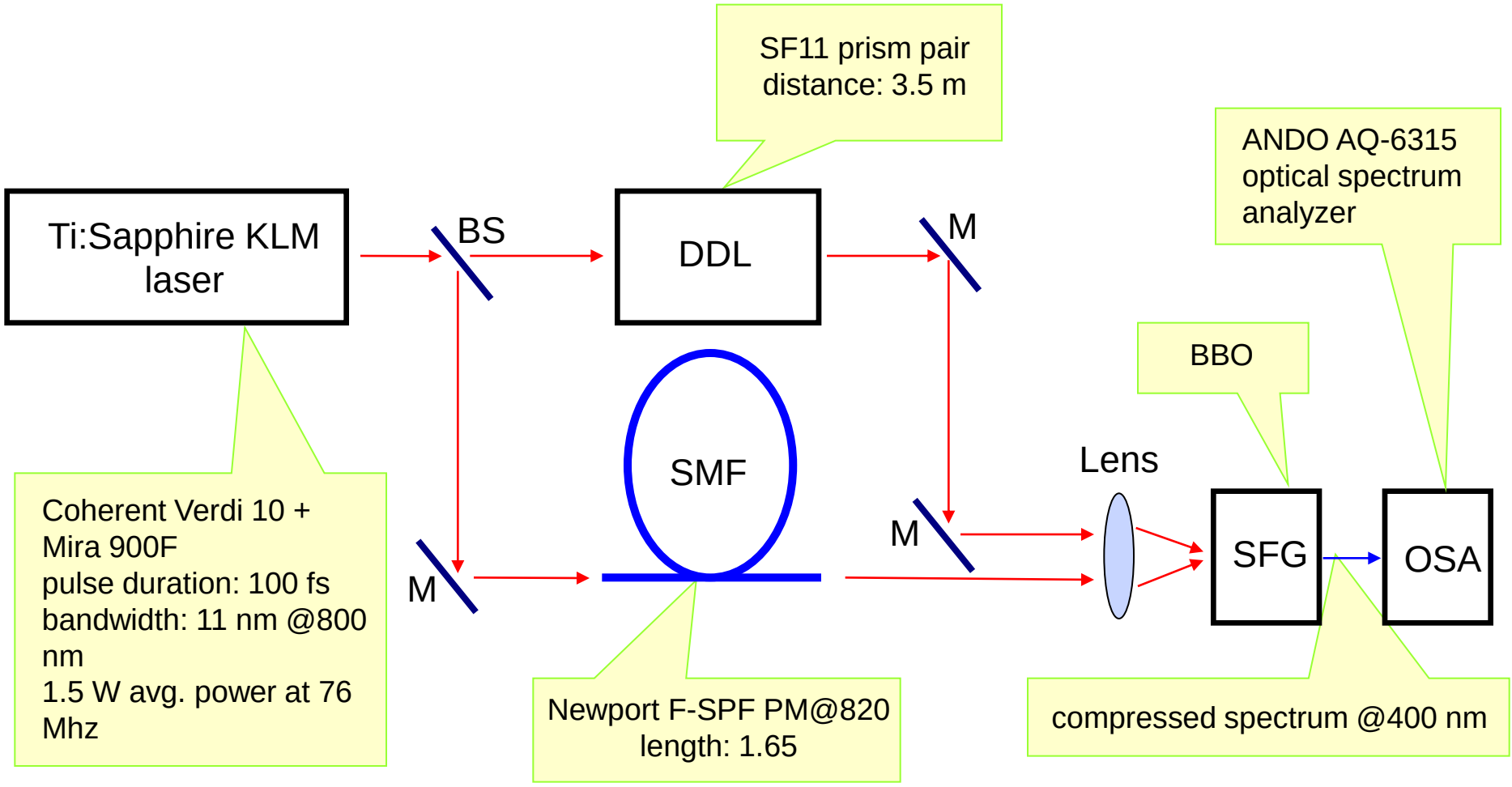
10.9 nm spectrum

8x SC

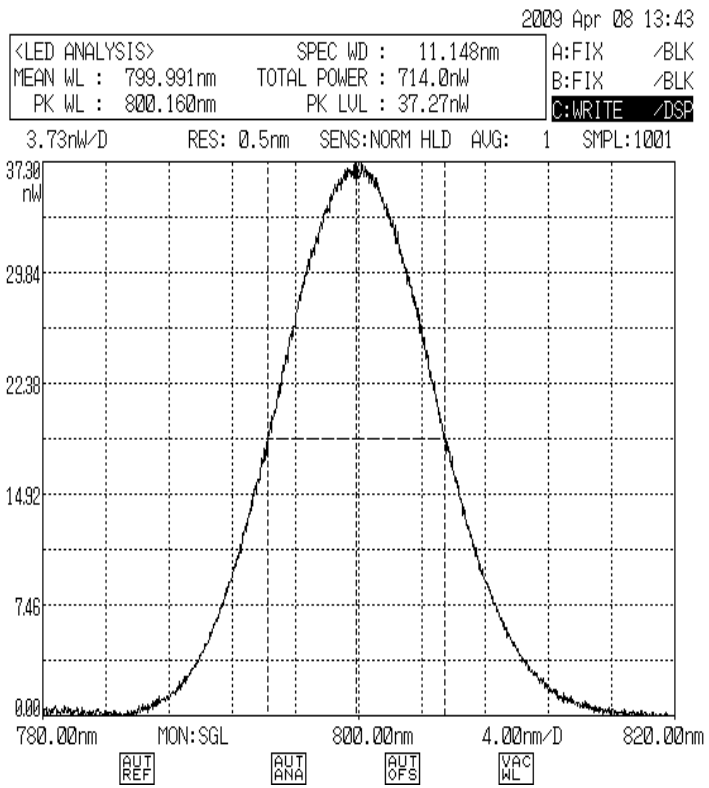


1.3 nm spectrum

Experimental setup of similaritonic technique of SC

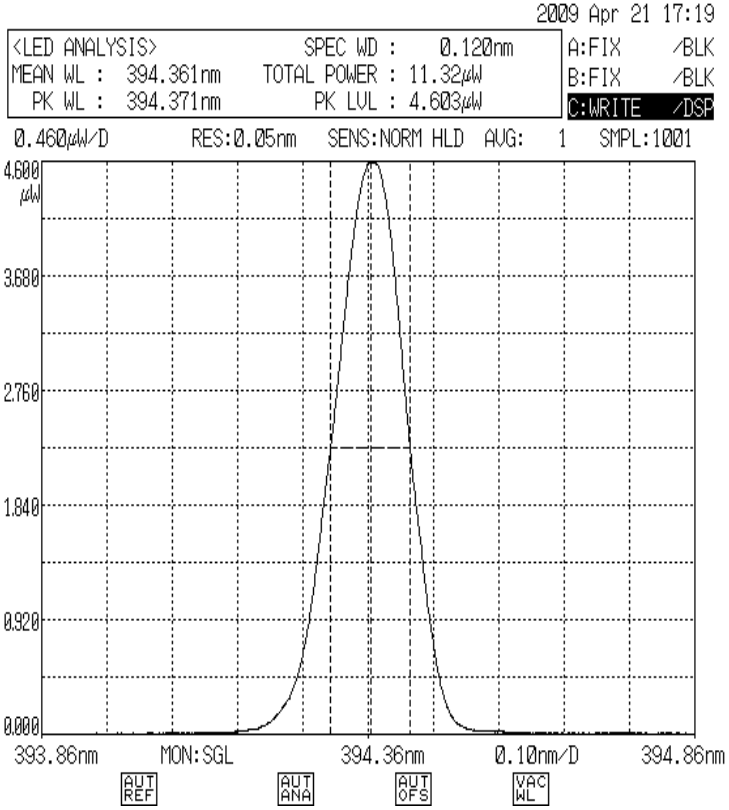


SC with similaritonic technique



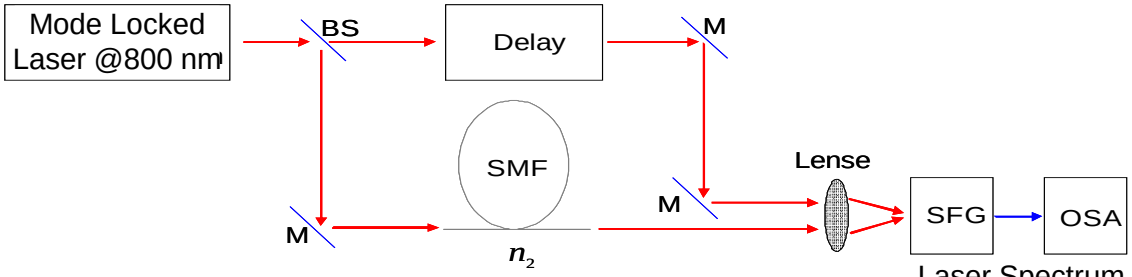
11.1 nm spectrum @800 nm

23x SC

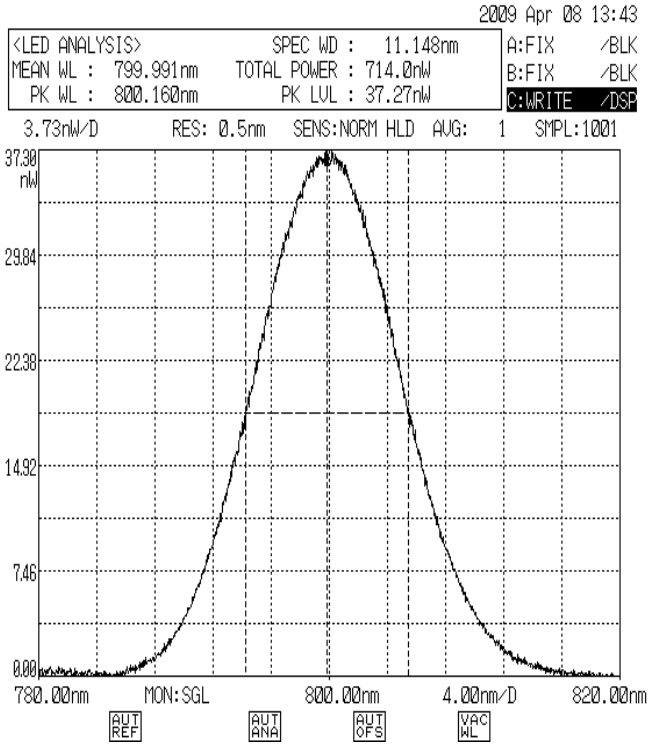


0.12 nm spectrum @400 nm

SFG without SC

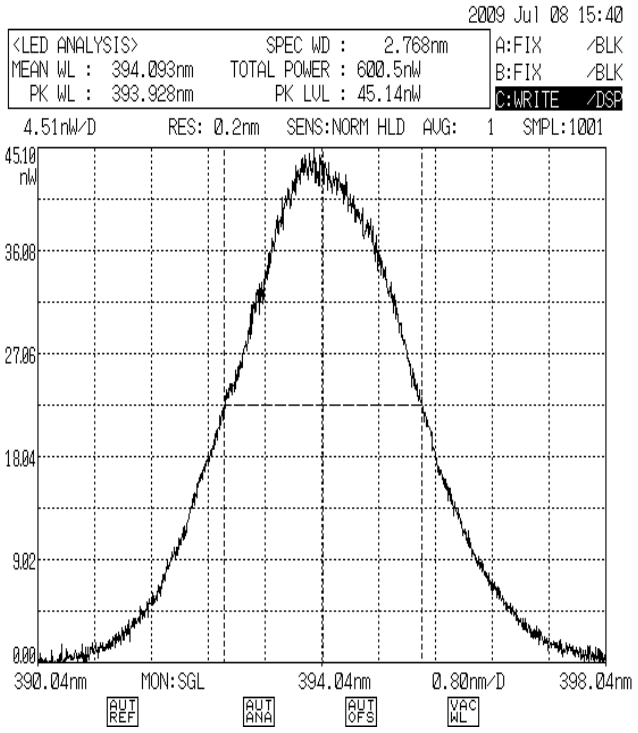


Laser Spectrum
@400 nm



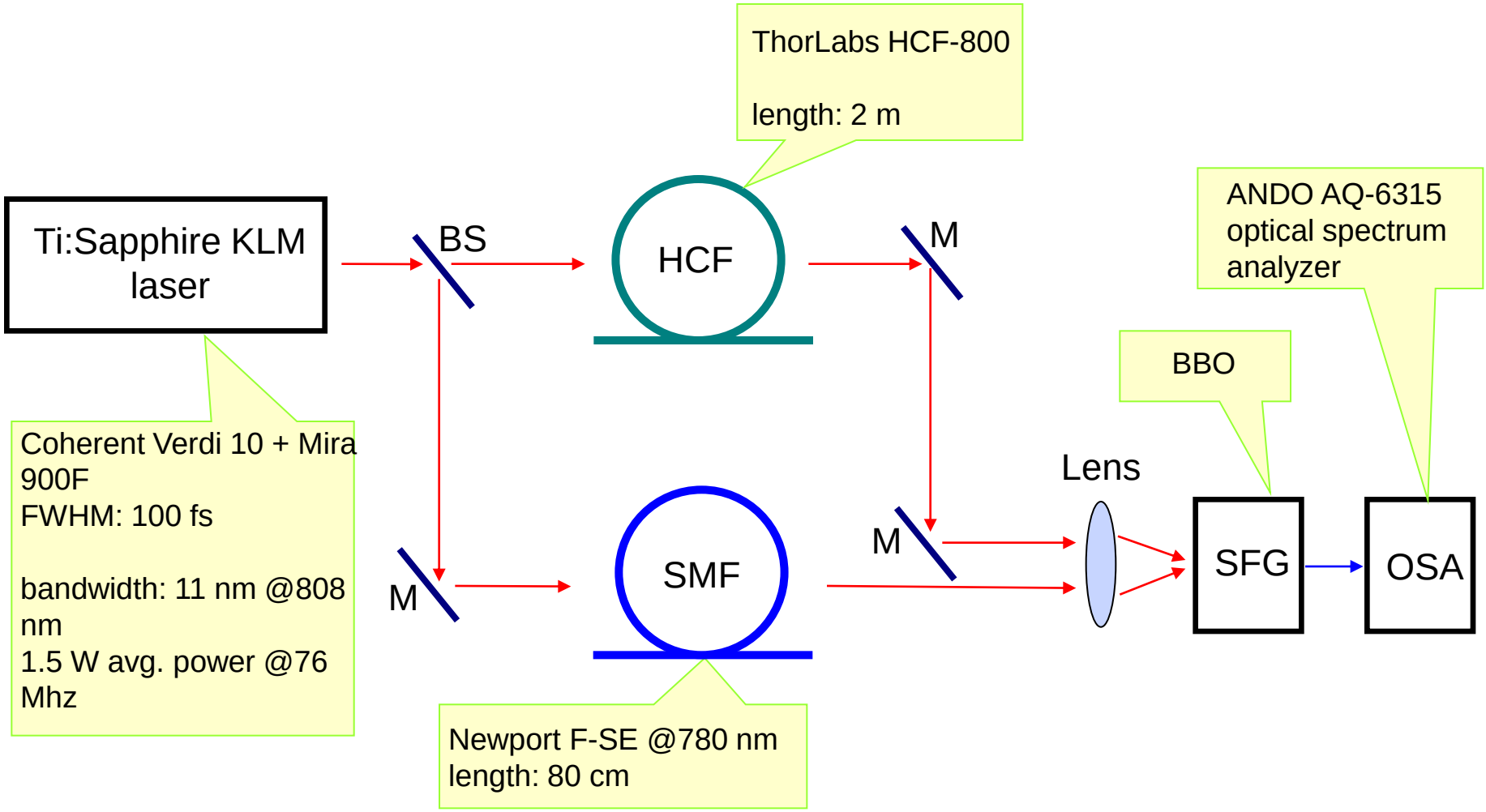
laser spectrum
11.1 nm spectrum @800 nm

SFG with
similariton

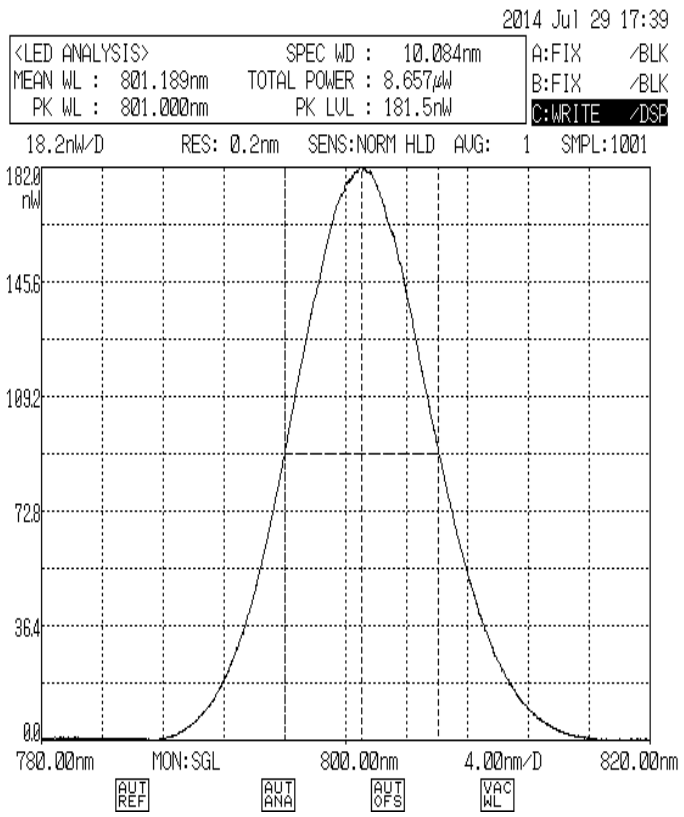


SH 2.7 nm spectrum @400 nm

Experimental setup of all-fiber similaritonic technique of SC

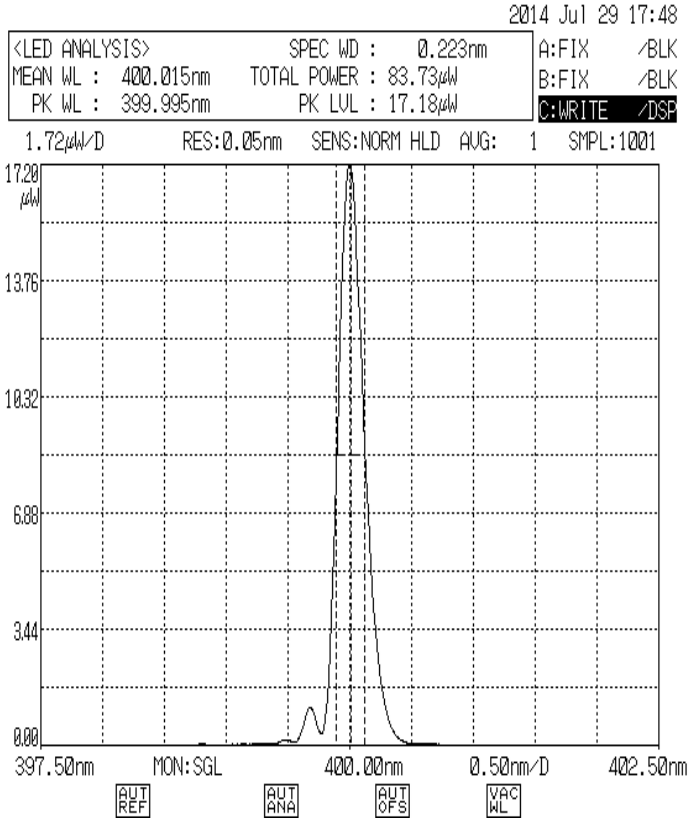


All-fiber similaritonic technique of SC



10.1 nm spectrum @800 nm

11x SC



0.22 nm spectrum @400 nm

Conclusion

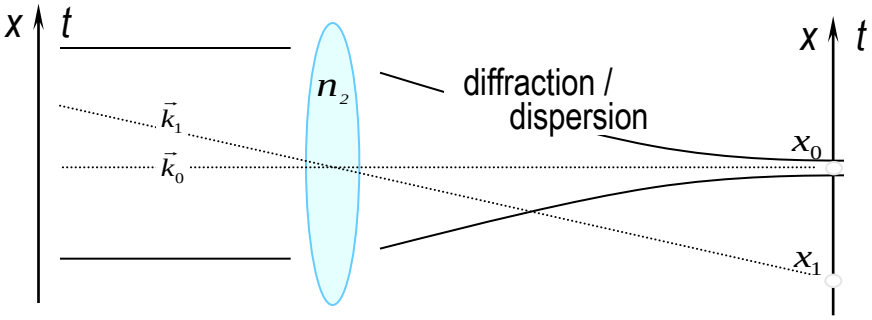
- 12x SC with classic technique
- 1.3x compression with self SC method
- 8x SC with all-fiber technique with use of HCF
- 11x SC by similaritonic technique with use of HCF
- 23x aberration-free SC by similaritonic technique with SFG

An important application of SC

Femtosecond Optical Oscilloscope

Concept of time lens

Space-to-time analogy:



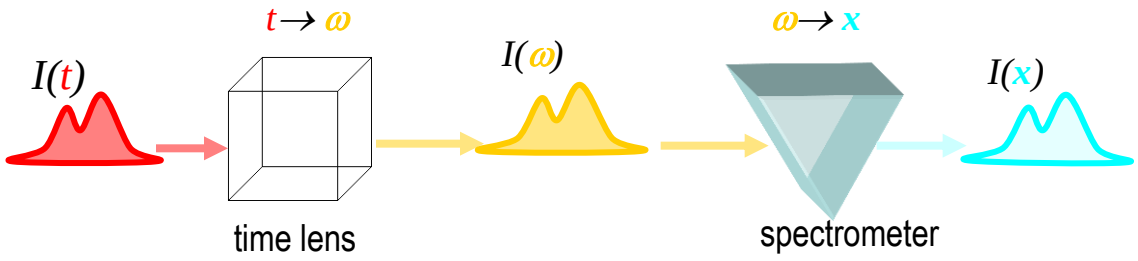
beam focusing / pulse compression

beam collimation / spectral compression

Spectral compressor is a time lens, which “collimates” the radiation in time, and “focuses” the spectrum.

FT in the usual lens ⇨ $x \rightarrow \vec{k}$ conversion.

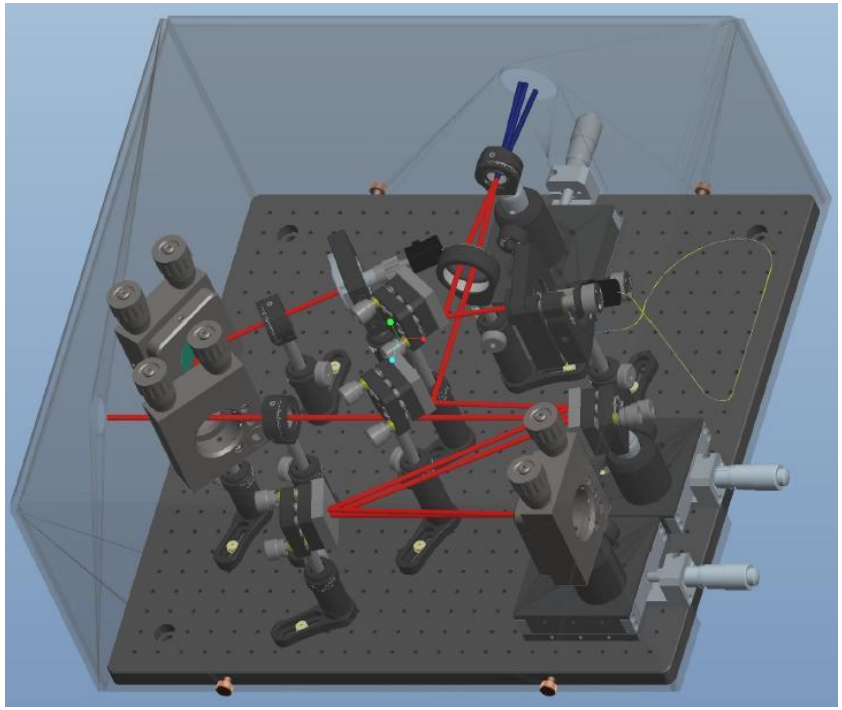
FT in the time lens ⇨ $t \rightarrow \omega$ conversion, frequency tuning, and spectrotemporal imaging.

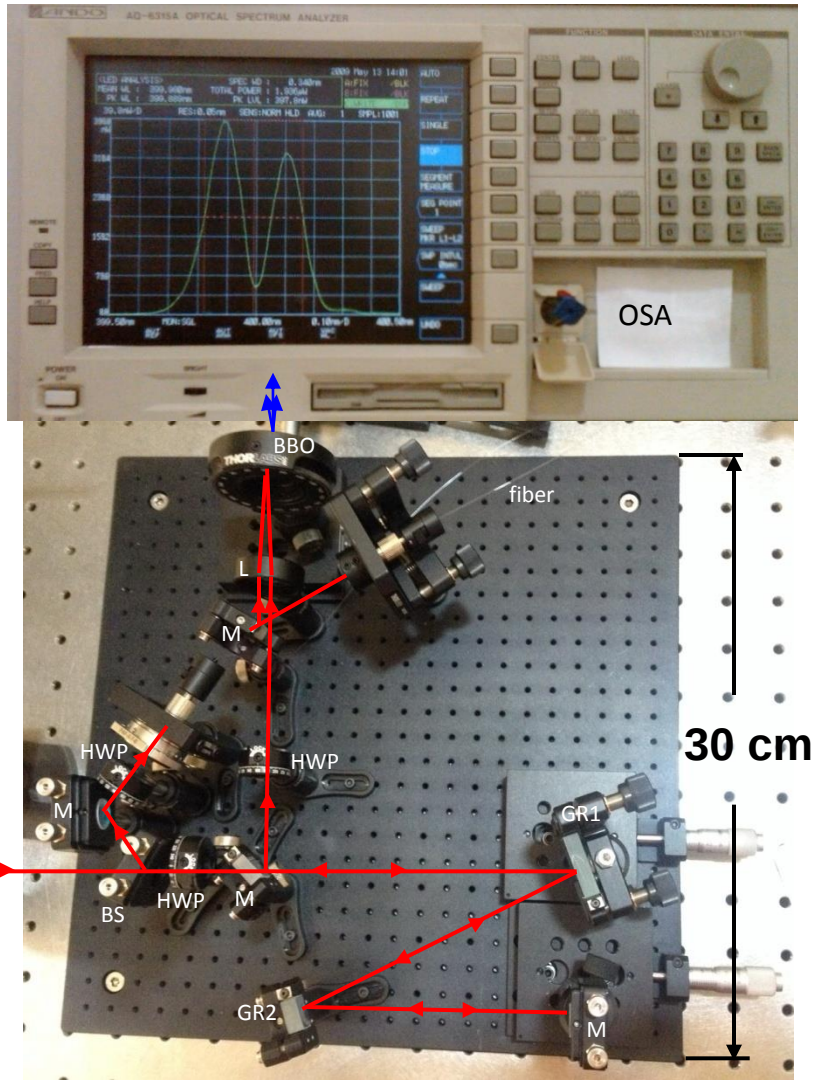


The use of similariton makes the time lens parabolic and aberration-free.

Prototype of fs oscilloscope

3D model

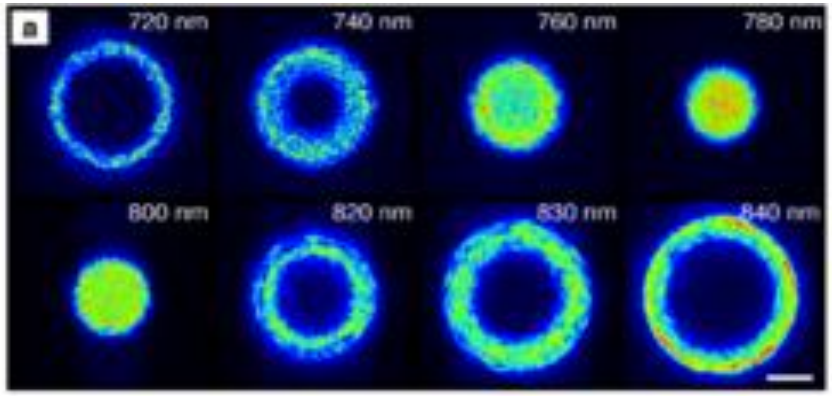


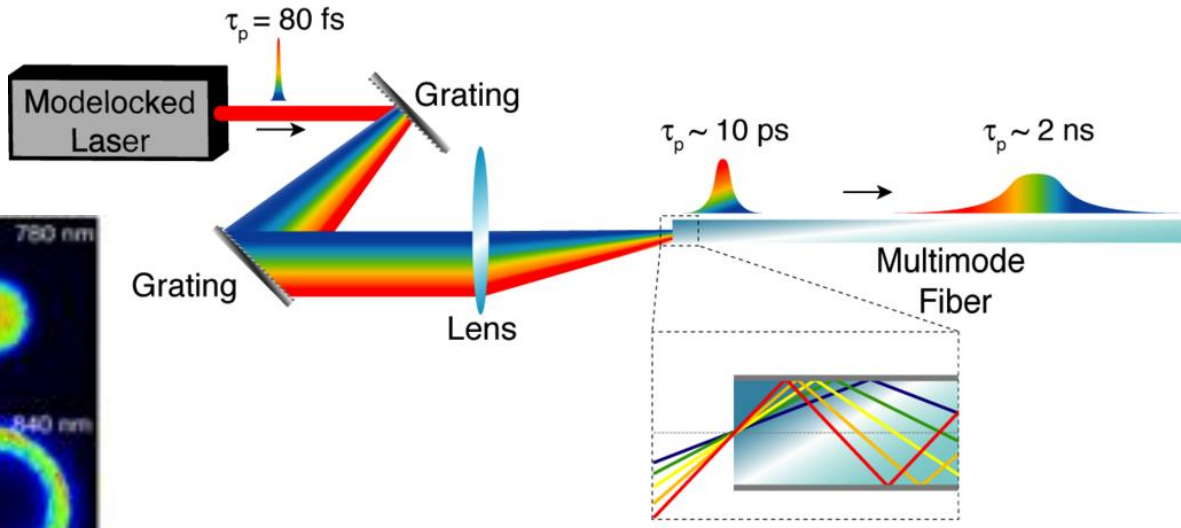


implemented prototype

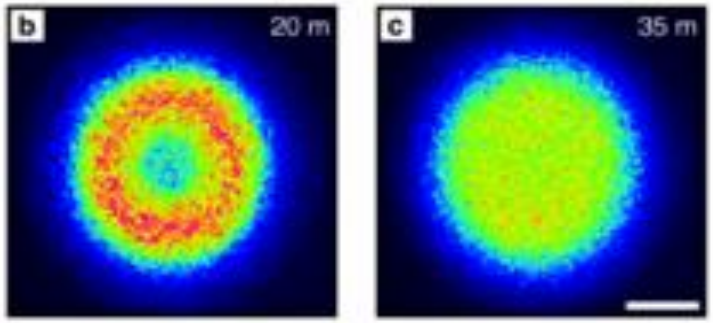
Chromo-modal dispersion

Eric D. Diebold et al.
"Giant tunable optical dispersion using chromo-modal excitation of a multimode waveguide"
Vol. 19, No. 24, Optics Express 23817 (2011).





scheme of chromo modal dispersion device

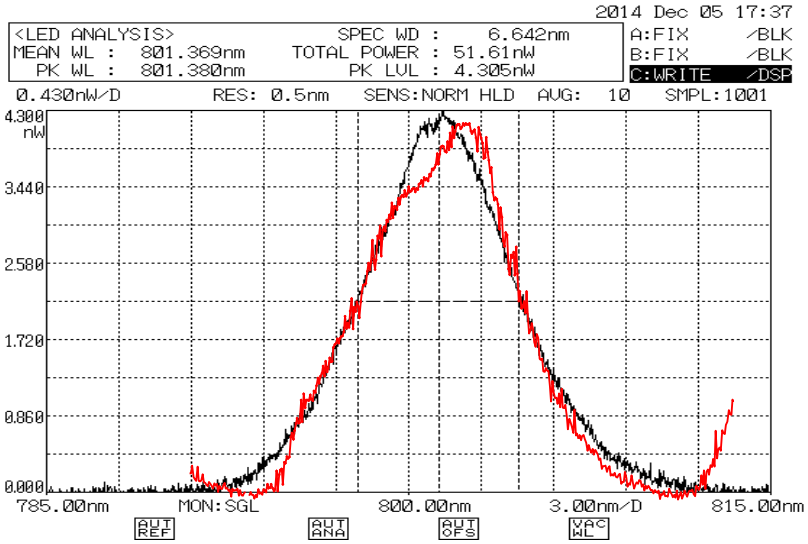


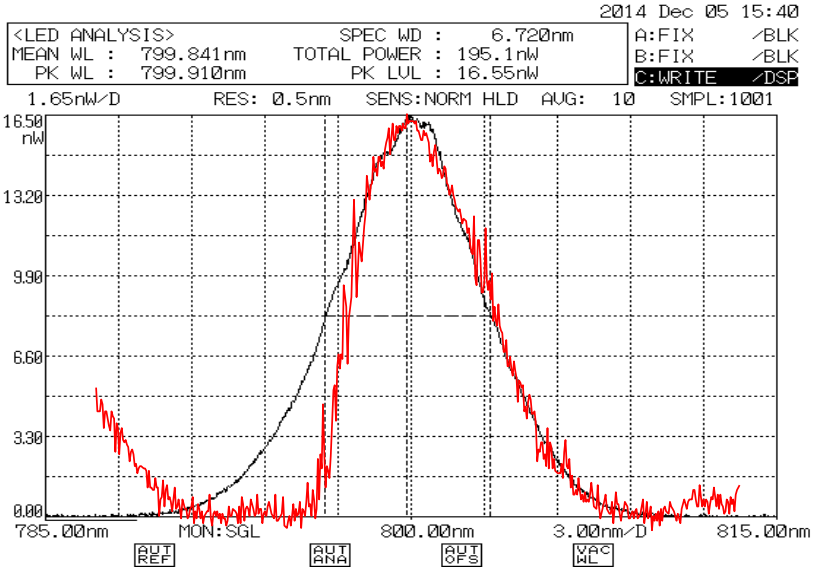
745nm, 20m
fiber propagation

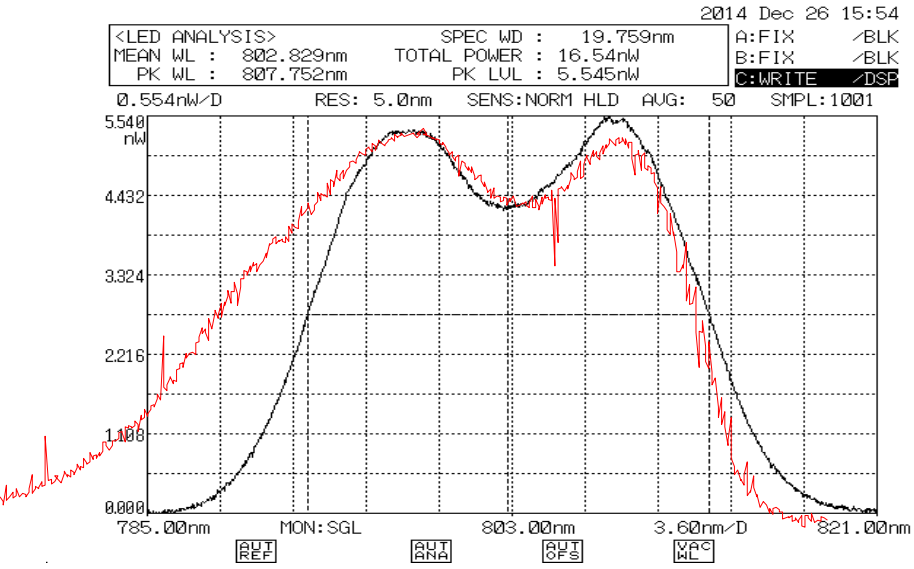
745nm, 35m
fiber propagation
scale bar=1mm
fiber tip approx 5mm from sensor

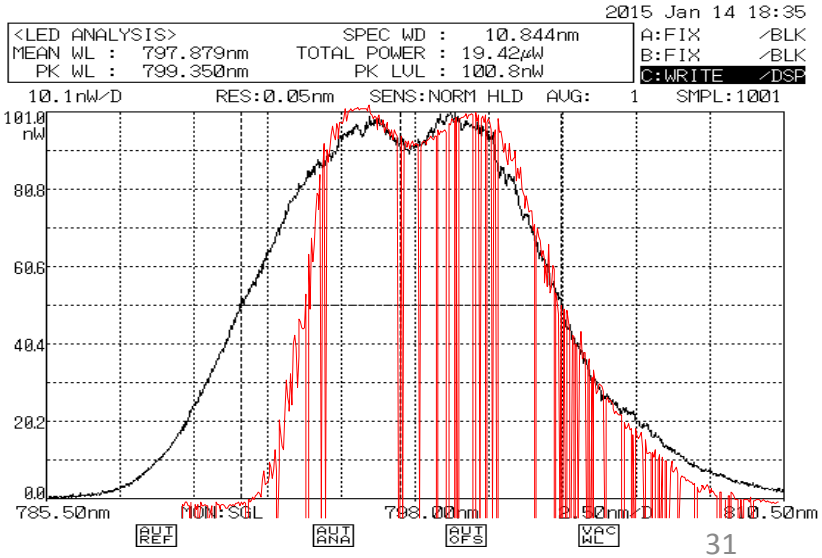
mode profiles
at the output of the CMD

Results of chromo-modal dispersion experiments









Երևանի Պետական Համալսարան
Ֆիզիկայի ֆակուլտետ
Օպտիկայի ամբիոն

Ավարտական աշխատանք

ՈՉ ԳԾԱՅԻՆ-ԴԻՊԵՐՄԻՈՆ ՄԻՄԻԼԱՐԻՏՈՆԻ ԳԵՆԵՐԱՑՄԱՆ ՀԱԿԱԴԱՐՁ ԽՆԴԻՐԸ

Ուսանող՝ Հրաչ Տոնեյան

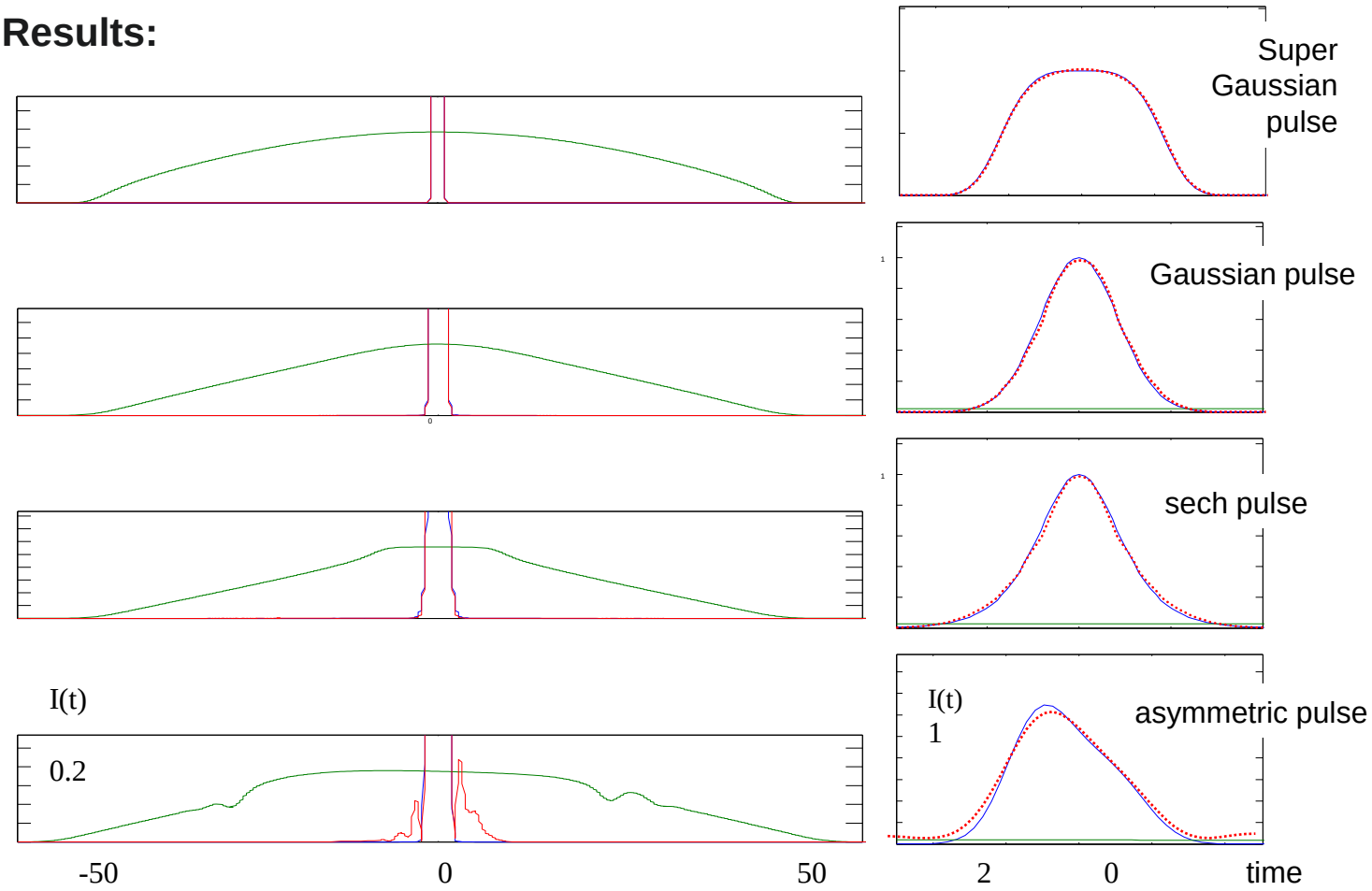
Ղեկավար՝ Լևոն Մուրադյան

ԵՐԵՎԱՆ – 2013

Reverse problem of NL-D similariton shaping

Principle:

Results:



input and retrieved pulses

Simulation parameters:

$R \equiv L_D / L_{NL} = 50$
$f \equiv z/L_D = 5$
$L_D \equiv \tau_0^2/\beta_2$
$L_{NL} \equiv (\beta_0 n_2 I_0)^{-1}$

THANKS