Pulse compression and autocorrelation signal analysis of a non-collinear optical parametric amplifier

Yen-Chen Chiang[1,2*], Yu-Jhen Chuang[2,3], Ning Kuo[2,4], Cheng-Tien Chiang[2,3,5,6]

[1]*Department of Physics, National Tsing Hua University, Hsinchu, Taiwan*

[2]*Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei, Taiwan*

[3]*Department of Physics, National Taiwan University, Taipei, Taiwan*

[4]*Interdisciplinary Program of Nuclear Science, National Tsing Hua University, Hsinchu, Taiwan*

[5]*Department of Physics, National Sun Yat-sen University, Kaohsiung, Taiwan*

[6]*Department of Physics, National Central University, Taoyuan, Taiwan*

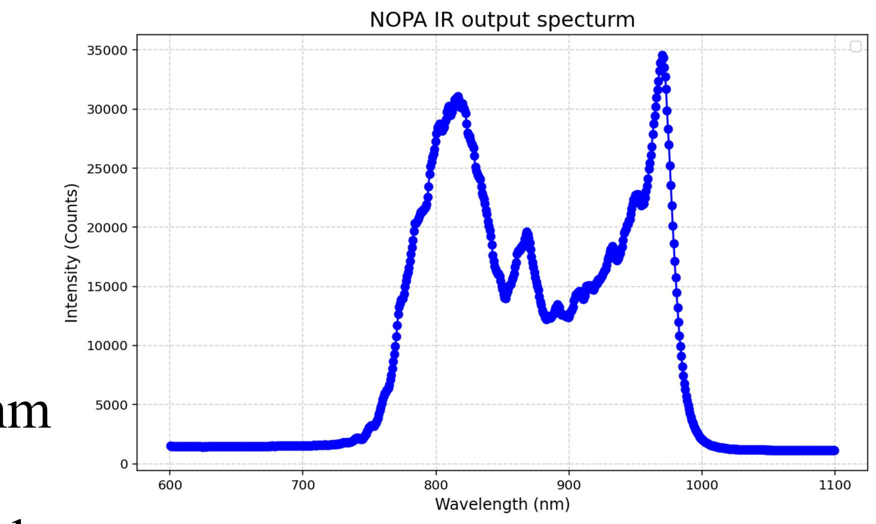
**email：carina.chiang.tw@gmail.com*

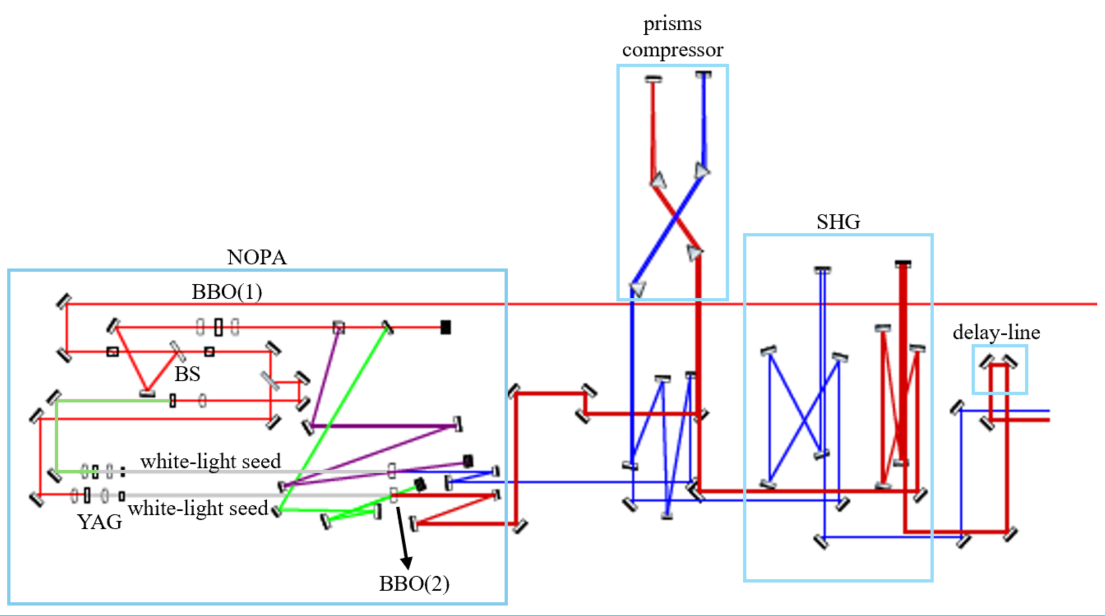
Motivation

Non-collinear optical parametric amplifier (NOPA) belongs to ultrafast laser technology and generates high-power, frequency-tunable pulses by mixing a pump beam and a white-light seed at an angle within a nonlinear optical crystal. The output pulses are temporally broadened due to dispersion and nonlinear processes. To enhance the temporal resolution of NOPA output. we use a pair of SF10 prisms to introduce negative group delay dispersion [2,3] to compensate for the broadening, and a commercial autocorrelator is used to measure the compressed pulses.

Non-collinear optical parametric amplifier (NOPA)

- Pulse laser
  - Wavelength：1030 nm
  - Duration：180 ± 1 fs
  - Repetition rate ：1001.9 kHz
- Pump light
  - Green pump : second harmonic generation, 515 nm
  - Ultraviolet (UV) pump: From third harmonic generation, 343 nm

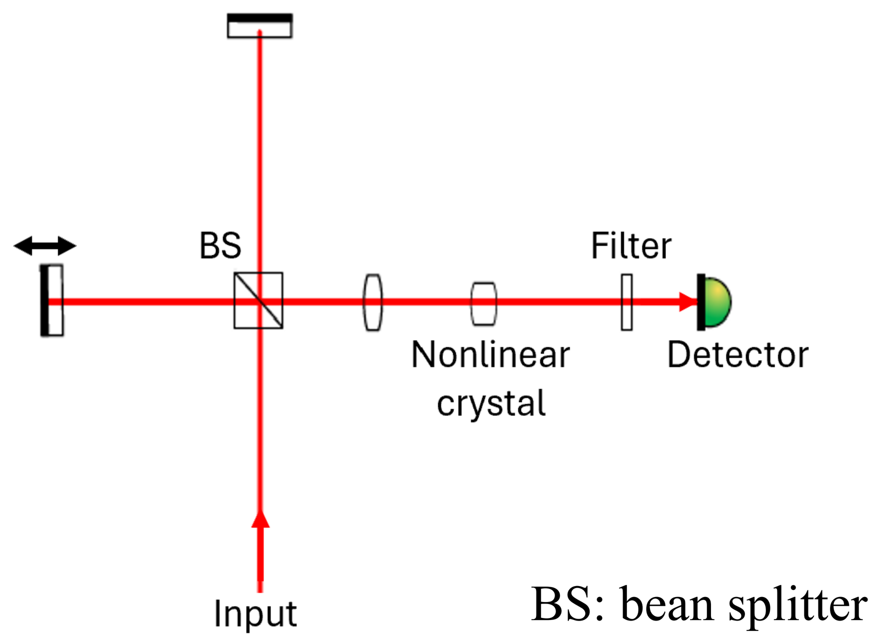




- White- light seed
  - Supercontinuum generation 700 - 1600 nm
- NOPA [1]
  - Interaction of white-light seed and pump light
  - Frequency - tunable
    - Green pump : 670-970 nm
    - UV pump : 470-570 nm

Second-order interferometric autocorrelator

- Michelson interferometer + nonlinear crystal
- Measure laser pulse duration in Full Width at Half Maximum (FWHM).



BS: bean splitter

Prism compressor

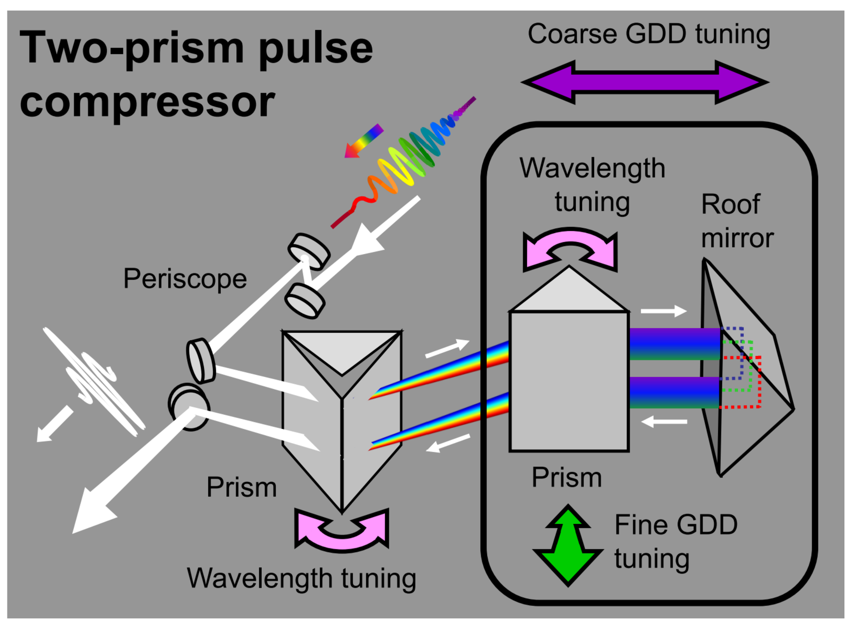
Pulses come through the first prism which introduces a positive group delay dispersion (GDD) and their components are dispersed angularly by refraction. Then adjust the second prism location to synchronize these components at the mirror, resulting effectively negative GDD. After reflection, compress again.

Prism material： SF10

Sellmeier Equation： $n^2(\lambda) = 1 + \sum_{i=1}^{3} \frac{B_i \lambda^2}{\lambda^2 - C_i}$

i	B_i	C_i
1	1.62153902	0.012224146
2	0.256287842	0.0595736775
3	1.64447552	147.468793

Adapted from [7,8] $\lambda : \mu m$



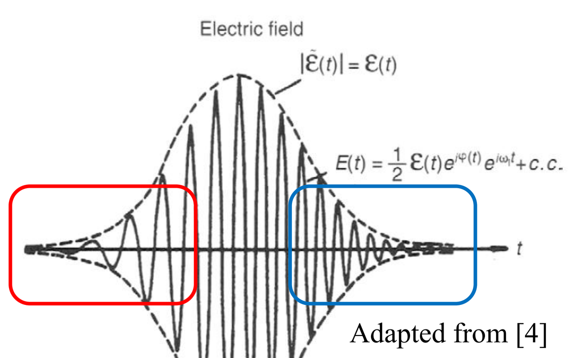
Adapted from [9]

Autocorrelation analysis

- Gaussian distribution：

$$y = A \times e^{-\frac{x^2}{2\sigma^2}} + B$$

- Fourier inequality：$\Delta\nu \times \Delta t \geq K$ [4]
  - Transform limit：$\Delta\nu \times \Delta t = K$=0.441
- $FWHM = 2\sqrt{2ln2}\sigma$
- Fit



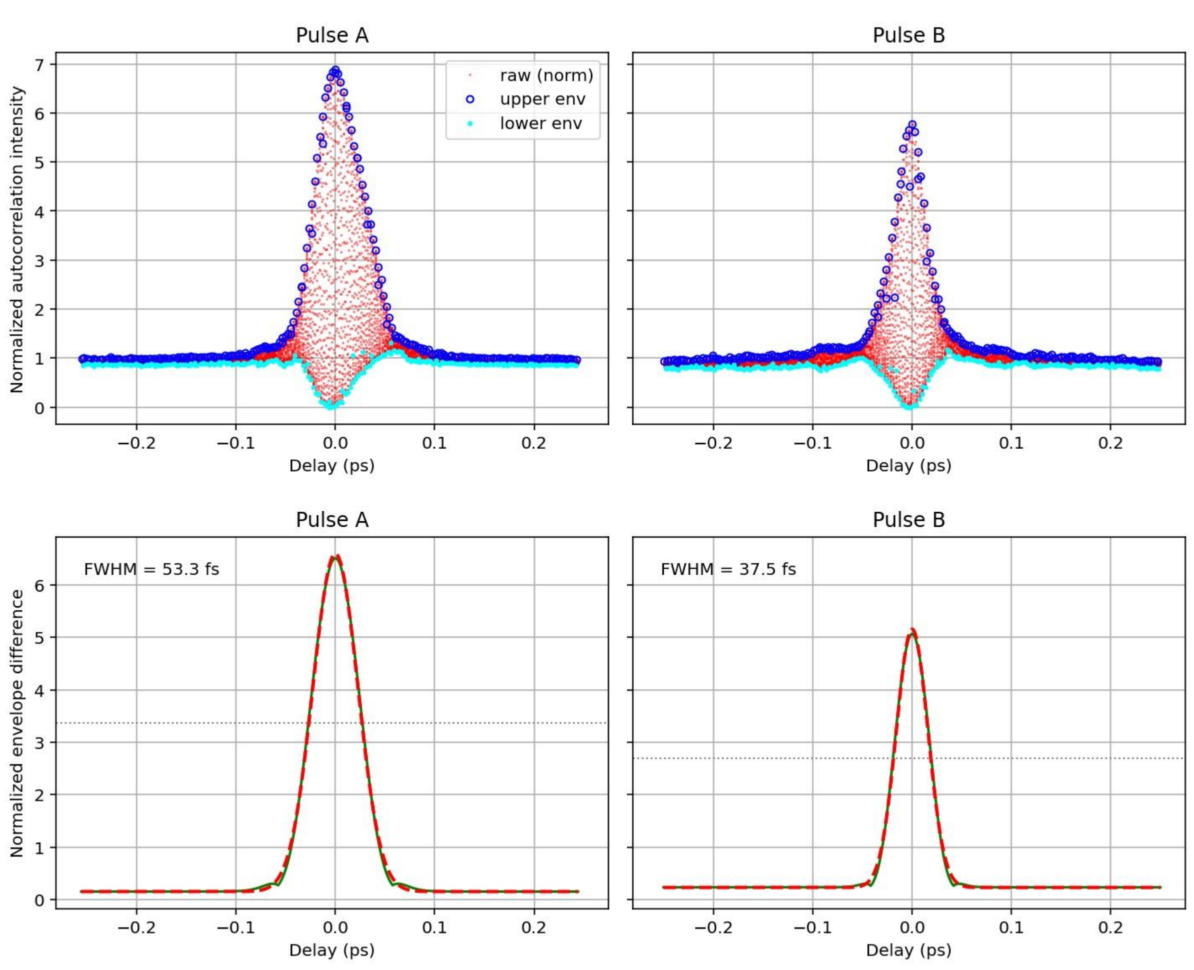
$$G(\tau) = \begin{Bmatrix} 1 + 2e^{-\left(\frac{\tau}{\tau_G}\right)^2} + 4e^{-\frac{a^2+3}{4}\left(\frac{\tau}{\tau_G}\right)^2} \cos\left[\frac{a}{2}\left(\frac{\tau}{\tau_G}\right)^2\right] \cos(\omega_l \tau) \\ +e^{-(1+a^2)\left(\frac{\tau}{\tau_G}\right)^2} \cos(2\omega_l \tau) \end{Bmatrix}$$

a : chirp parameter [4] τ: delay time

Δt: pulse duration τ_G: Gaussian pulse parameter

$\Delta\nu$: spectral bandwidth

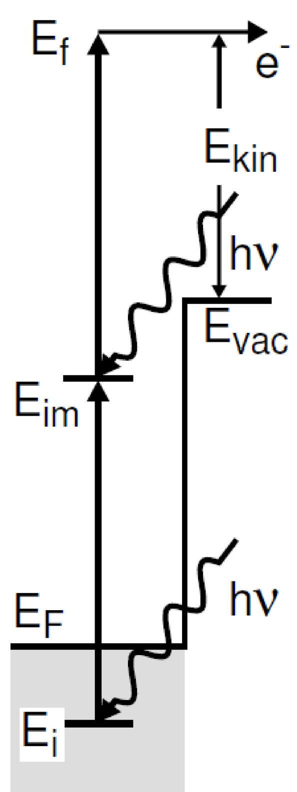
Results



Fitted chirp	2.4	1.9
Pulse Duration (fs)	37.6 ± 0.4	27.2 ± 0.3

Outlook

- Bichromatic two-photon photoemission (2PPE) [5]
- The signal intensity is proportional to the product of the intensities of the two incident beams.
- Probing specific intermediate states.
- Precision measurement of electron lifetimes in unoccupied states.



Reference

[1] E. Wittmann, Ph.D. Thesis, Ludwing Maximilian University of Munich (2019).

[2] R. L. Fork *et al.*, Opt. Lett. **9**, 150 (1984).

[3] A. M. Weiner, Ultrafast Optics (Wiley, 2009).

[4] J. C. Diels and W. Rudolph, Ultrashort Laser Pulse Phenomena (Academic Press, 2006).

[5] T. Fauster and W. Steinmann, in Electromagnetic Waves: Recent Developments in Applied Spectroscopy, edited by H. G. P. Williams (Springer, Boston, MA, 1995), pp. 347–411.

[6] A. Bessas, *et al.*, Phys. Rev. B **107**, 205141 (2023).

[7] W. Sellmeier, Ann. Phys. **219**, 272 (1871).

[8] SCHOTT, Optical Glass Datasheet N-SF10 (2014).

[9] Faculty of Physics, University of Warsaw, Dispersion and Ultrashort Pulses (n.d.).

Summary

A two-prism compressor was constructed to compensate for the broadening produced by dispersion and nonlinear processes, minimizing the chirp and pulse duration to nearly transform-limited values. Hereby, a commercial autocorrelator was used to measure the pulse duration.