Engineering Press

Short Communication

# Design and optimize a generator for high energy ultrafast laser pulses

***Walid Tawfik****

*National Institute of Laser NILES, Cairo University, Cairo, Egypt*

*****Corresponding author***
**Walid Tawfik**
National Institute of Laser NILES
Cairo University
Cairo, Egypt
**E-mail:** Walid_tawfik@hotmail.com

***Received:** August 30th, 2017*
***Accepted:** September 12th, 2017*
***Published:** September 18th, 2017*

***Citation***
Tawfik W. Design and optimize a generator for high energy ultrafast laser pulses. *Eng Press*. 2017; 1(1): 1-3. doi: 10.28964/Eng-Press-1-101



**ABSTRACT**

In this paper, a special design of an ultrafast high energy femtosecond laser system is demonstrated. The pulse duration of the ultrafast pulses has been controlled using optimized pressure of an inter-gas filled hollow-core fiber. The observed pulses found to be transform limited with peak pulse energy of ~600 mJ and repetition rate from 1 Hz up to 1 KHz. The observed pulses were extremely-compressed by self-phase modulation (SPM) in a nonlinear medium of neon gas filled a hollow fiber. Then the dispersion compensation was performed via a pair of chirped mirrors. The spectral phase of the obtained ultrafast pulses was found to be stable. The experimental consequences may give an opportunity to create VUV attosecond pulses by high harmonic generation.

**KEY WORDS:** Ultrashort lasers; Femtosecond; Self-phase modulation; Self-phase modulation.

## INTRODUCTION

Advanced development has been recognized in ultrafast laser schemes for few cycle pulses in the NIR.[1] However, for several recent applications, for instance the consideration of ultrashort dynamics in femtochemistry, ultrafast pulses in the optical range UV-VIS with high energy levels are required.[2] Unfortunately, the available sources of these pulses experience from complexity and difficulty of the tuning both the pulse duration and the wavelength.[3,4]

In the current work, a developed design includes Ti: sapphire, followed by a chirped-pulse amplification (CPA) technique to generate optical broad bandwidth is demonstrated. The observed laser pulse output include the spectral phase and pulse profile is studied at 1 kHz repetition rates.[5]

## EXPERIMENTAL SETUP

A schematic diagram for the developed setup to enhance the optical fiber throughput spectral bandwidth for ultrashort pluses is shown in Figure 1. In this schematic, a mode-locked Ti: sapphire that generates pulses of duration ~18 fs at wavelength 800 nm with average peak power of 400 mW at repetition rate ~80 MHz was used as a femtosecond seed beam. The construction of the seed laser system composed of a solid-state 4 W CW DPSS laser to pump the Ti: Sapphire laser and two pump beam mirrors to direct the produced green laser beam of 532 nm beam into the Ti:Sapphire. Then the seed beam is introduced into a CPA at repetition rate from single pulse to one kilohertz. This amplifier generates a beam of 30 fs pulses at 800 nm and average power of ~2.4 W. The CPA regenerative amplifier comprises several passes gain medium with a Pockels cell optical switch to control the number of round trips inside the cavity to allow for a high gain output. The energy of these pulses were optimized to reach a maximum value of about 3 mJ after adequate figures of resonator round trips. Another Pockels cell was employed as an optical switch to switch the composed high energy pulses after the regenerative amplifier. A short bell-shaped

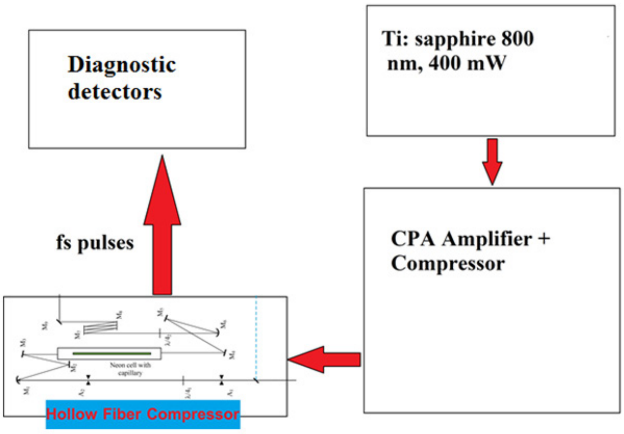


**Figure 1:** Setup for the generator of 4.8 fs optical pluses composed of four parts: a 18 fs mode-locked Ti:sapphire seed oscillator(400 mW and 75 MHz at 800 nm) generates femtosecond laser pulses in the $TEM_{00}$ mode, an amplification stage includes a regenerative kHz amplifier with a compressor that produces high-power femtosecondpulses (2.5 W, 32 fs and the wavelength 800 nm), a hollowfibre compressor of a one-metre hollow fibre filled withneon gas and a set multilayer chirped-mirror compressor and diagnostic detector which is a spectral phase interferometry for direct electric field reconstruction (SPIDER).

high voltage electric pulses was used to synchronize the Pockels cell opening times.

In this design, to reach extremely short pulse durations, the laser pulses are spectrally broadened in an inert gas contained within a long one meter, hollow-fiber, that works as a dielectric waveguide for the light. The long fiber allows for considerably longer interaction lengths than conventional unguided interactions.

**RESULTS AND DISCUSSION**

To achieve the ultrashort pulse with broad spectral bandwidth, both of the seeded and amplified pulses should be optimized. For the seeded laser beam, the pulses were optimized in mode-locked mode around wavelength of 800 nm with peak pulse energy of few nJ and duration of 18 fs. While the intense femtosecond laser beam propagates through the neon gas in the fiber, it induces continuum generation due primarily to self-phase modulation (SPM) which causes super continuum in the neon gas at different pressure values from 2.0 to 2.5 atm. To maximize energy throughput, it is important to well couple the beam into the fiber. This is attained by carefully matching the focal spot of the laser beam to the guided mode of the optical fiber. Finally, the output beam from the fiber is collimated using a concave mirror and then temporally compressed again with two chirped-mirrors though six beam passes to achieve the shortest possible pulse duration. During the optimization, sequences of measurements have been performed for different neon pressures and input pulse characterizations from the seed laser. The considered pulse-to-pulse variations are found to be about 2.5% for the final output after the compressor stage.

Figure 2 demonstrates the CPA output beam bandwidth of about 19 THz fundamental-width at half maximum (FWHM) measured for a pulse which starts at 325 THz and ends at 425 THz. These measurements of the spectral bandwidth were done using spectral phase interferometry for direct electric field recon-

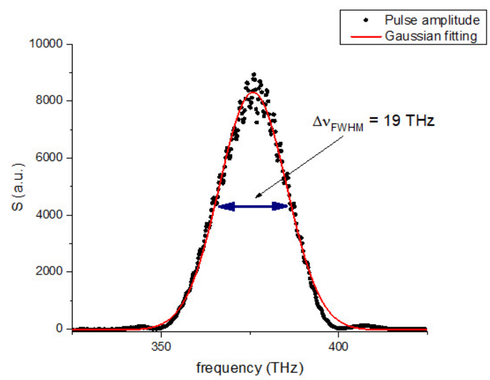


**Figure 2:** Spectral bandwidth of the developed femtosecond laser system.

struction (SPIDER) where S is the signal intensity in arbitrary unites measured using Fourier transform spectral interferometry as described before in details.[6] Moreover, the gas pressure inside the hollow fiber needs to be varied to control the output pluses characterizations.

The development in the present system comprises broad-band laser[7] and the introduction of broadband chirped multilayer coatings mirrors have allowed for ultrashort laser pulses with broadband dispersion control and exceptional high power levels ~600 μJ.[8]

## CONCLUSION

In conclusion, a developed design of ultrashort femtosecond laser system has been achieved. By maintaining optimized experimental conditions, the optical beam throughput of the hollow-fiber is enhanced. The applied method generates ultrafast pulses with bandwidth of about 19 THz. The energy of the output pulses reached 600 μJ. This modern scheme represents a relatively simple and direct technique compare to current complicated techniques to observe ultrafast pulses with wide bandwidth. The observed results are important since the observed pulses can be applied to generate high harmonic generation which can lead to VUV attosecond pulses.

## ACKNOWLEDGEMENT

This Project was funded by the National Plan for Science, Technology and Innovation (MAARIFAH), King Abdulaziz City for Science and Technology, Kingdom of Saudi Arabia, Award Number (12-ELE2628-02).

## CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

## REFERENCES

1. Emons M, Palmer G, Schultze M, et al. High energy/high repetition rate laser pulses from Yb based solid state oscillators with cavity-dumping and regenerative amplifiers. In: Nolte S, Schrempel F, Dausinger F, eds. *Ultrashort Pulse Laser Technology*. Berlin, Germany: Springer; 2016; 195: 3-22.

2. Rotermund F, Petrov V, Noack F. Femtosecond noncollinear parametric amplification in the mid-infrared. *Optics communications.* 1999; 169(1): 183-188. doi: 10.1016/S0030-4018(99)00397-1

3. Kummrow A, Wittmann M, Tschirschwitz F, Korn G, Nibbering E. Femtosecond ultraviolet pulses generated using noncollinear optical parametric amplification and sum frequency mixing. *Applied Physics B.* 2000; 71(6): 885-887. doi: 10.1007/s003400000483

4. Kiriyama H, Mori M, Nakai Y, et al. Generation of high-contrast and high-intensity laser pulses using an OPCPA preamplifier in a double CPA, Ti: Sapphire laser system. *Optics Communications.* 2009; 282(4): 625-628. doi: 10.1016/j.optcom.2008.10.067

5. Adachi S, Ishii H, Kanai T, Ishii N, Kosuge A, Watanabe S. 1.5 mJ, 6.4 fs parametric chirped-pulse amplification system at 1 kHz. *Optics letters.* 2007; 32(17): 2487-2489. doi: 10.1364/OL.32.002487

6. Tawfik W. Precise measurement of ultrafast laser pulses using spectral phase interferometry for direct electric-field reconstruction. *Journal of Nonlinear Optical Physics & Materials.* 2015; 24(04): 1550040. doi: 10.1142/S021886351550040X

7. Maine P, Strickland D, Bado P, Pessot M, Mourou G. Generation of ultrahigh peak power pulses by chirped pulse amplification. *Quantum electronics, IEEE Journal of.* 1988; 24(2): 398-403. doi: 10.1109/3.137

8. Szipöcs R, Spielmann C, Krausz F, Ferencz K. Chirped multilayer coatings for broadband dispersion control in femtosecond lasers. *Optics Letters.* 1994; 19(3): 201-203. doi: 10.1364/OL.19.000201