APPLICATION NOTE 43

Synchronization of Two Spectra-Physics Spitfire® Pro Amplifiers for Pump-Probe Experiments

Technology and Applications Center
Newport Corporation

Introduction:

The invention of nanosecond pulsed lasers utilizing the Q-switch principle marked the advent of time-resolved spectroscopy[1]. Over the past four decades, the pulse duration has been reduced from nanosecond to attosecond regimes thanks to breakthroughs in technology and physics[2-4]. In this type of spectroscopy, the delays between pulses serve as controllable variables used to test and investigate the principles of physical science. "Delay lines" which introduce time separation by introducing displacements between pulses are therefore essential and critical to the success of time resolved experiments. For example, in state-of-the-art attosecond spectroscopy[5], piezo-stages with resolutions of tens of nanometers are used; from femto to nanoseconds regimes, high-precision mechanical stages having resolutions of sub-micrometers are usually employed. From micro to milliseconds, electronic triggering and synchronization takes over to control the delay of the pulses. Since molecular dynamics mainly occur within femto to nanoseconds, a reliable mechanical stage which can translate several meters with sub-micrometer resolution is crucial in understanding the physics behind it.

Although mechanical stages which can translate meters with resolution in the sub-micrometer regime exist[6], using them to cover delays from femtosecond to nanosecond separation and beyond is still challenging. The delayed laser beam interrogating the sample has to remain unperturbed throughout the entire range of delays. This puts strict requirements on the divergence and the quality of the beam, which should not change significantly after traveling several meters. The beam quality is never perfect *per se*, especially when a nonlinear process is involved. This issue can be solved by utilizing two synchronized chirped pulse amplifiers (CPAs) and introducing the time delay on the seed pulses. This arrangement has two great benefits: minimizing the spatial dependence of the beam quality and reducing strong nonlinear optical effects. Since the CPAs are running at the saturation limit, the seed beam quality is effectively washed out and the output pulses are insensitive to it. Therefore, putting an optical delay line on the seed pulse minimizes the effect caused by the spatially dependent beam quality. Also, the amplified pulses pass through fewer optics. This reduces the chances of strong nonlinear effects induced in the optics when high-energy pulses pass through them. These effects have been measured and described in detail in Application Note 41.

In this application note, we describe a dual amplifier setup seeded from one oscillator where the seed pulse is divided into two replicas. It eliminates the jitter between the two amplifiers caused by electronic synchronization of two independent oscillators. At the same time, it allows control of the delay between two amplified pulses by delaying one of the replicas. The repetition rate of the oscillator is around 80 MHz, which means every seed pulse is inherently separated by around 12 ns. As a result, we can introduce a time delay between two replica pulses of up to 12 ns. Here, we utilize an optical delay line covering this 12 ns delay range with better than 30 fs resolution. The described approach also provides cost savings compared with a two oscillator setup.

Experimental setup

Although in this note we describe the operation of the slave amplifier (Spitfire®-slave) only, the block diagram of the entire setup is presented in figure 1. The Tsunami® oscillator output is split in an 80/20 ratio with 20% of the beam seeding the master amplifier (Spitfire®-master). The remaining 80% is directed to a delay line of 0.6 m travel range. The delay line is equipped with two corner cube retroreflectors allowing a total of 8 passes. Over the full range of travel, it can provide 16 ns optical delay; more than enough for a 12 ns pulse separation. After traversing the delay line, a small portion of the beam is sent to the photodiode to trigger the slave Time Delay Generator (TDG), while most of the beam is directed to the slave amplifier. In this configuration, the timing between the Empower® of the slave amplifier and the seed pulse would not be affected by the delay of the seed pulse.

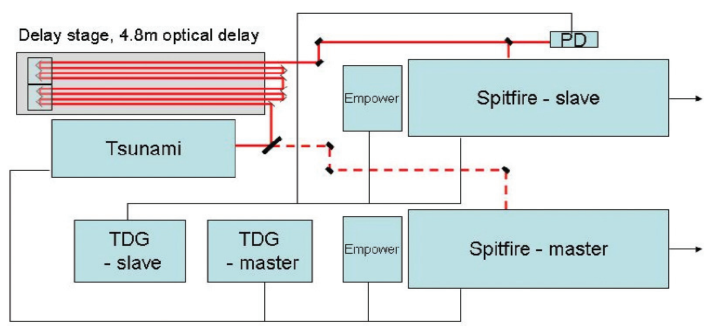


Fig. 1. Block diagram setup for synchronizing two amplifiers with a single oscillator. PD - photodiode; TDG - time delay generator.

Figure 2 shows the beam routing at the Tsunami oscillator output. 80% of the beam is reflected by the beamsplitter and directed toward the delay line shown in figure 3. Before entering the delay line, the beam passes through a 2x telescope, reducing the divergence of the beam. Careful alignment of the beam is performed with each additional set of passes on the delay line, making sure that the beam does not drift while moving the stage over the full travel distance. The total seeded power at the input of the slave amplifier was 30 mW. To compare the effect of the delay line, we also sent the seed beam directly into to the amplifier (shown as green dashed line figure 2). Losses along the delay line required that when seeding the amplifier with the delay seed, the timing of the amplifier has to be adjusted to get the same output energy as in the directly seeded case. In our case we had to increase the number of roundtrips in the amplifier by two to compensate for losses through the delay line. Also, the pulse width of the laser increased slightly to 45 fs after passing through the delay line as compared to 41 fs when seeded directly.

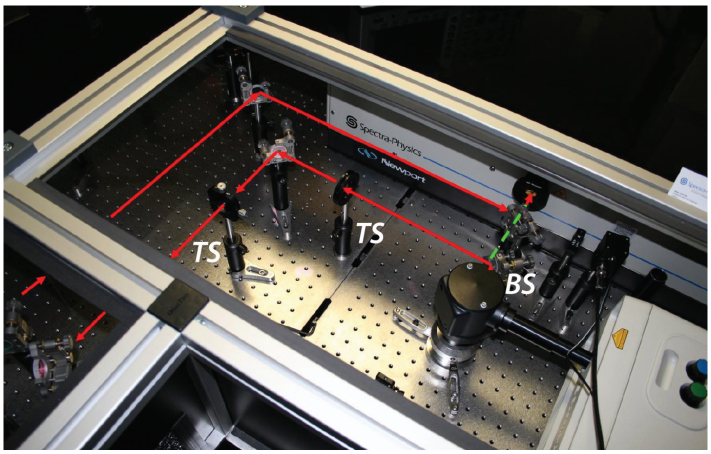


Figure 2. Beam routing at the Tsunami oscillator output. The seed beams for master and slave amplifiers are also shown by green dashed and solid red lines, respectively. BS - beamsplitter; TS - telescope set.

Figure 3 shows multiple views of the delay line. Utilizing the geometric characteristics of the retroreflector, a total of eight passes along the delay line is carefully set with better than 30 fs resolution. The beam path is shown on the inset of figure 3(b), where the beam is displaced diagonally but remains parallel after each pass on the retroreflector.

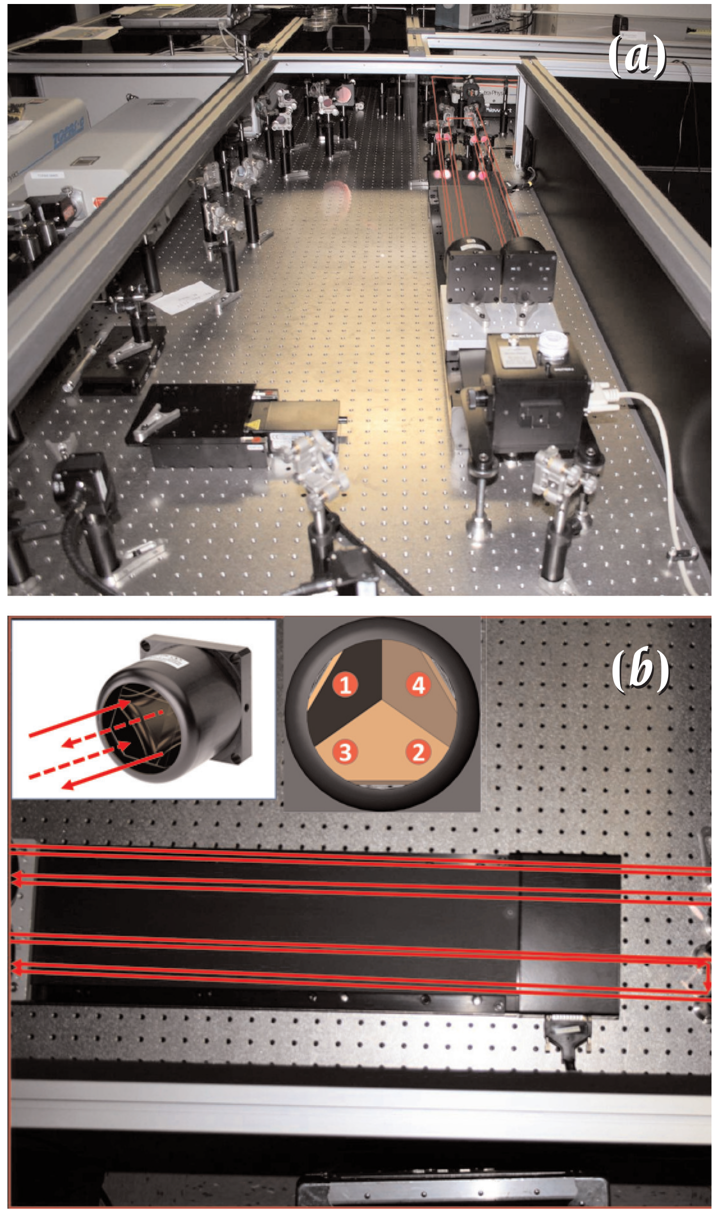


Figure 3. (a) Elevated end view of the delay line. (b) An 8-pass delay line using two retroreflectors. Inset of (b) shows the beam path. The solid line indicates the first and the second passes while the dashed line shows the third and the fourth passes. This pattern is repeated on the second retroreflector adjacent to the first. Also shown is the front view of the retroreflector. The beam path within the retroreflector is not shown.

Results

About 1 mJ of the output of the slave amplifier was used to pump an OPA (white light seeded TOPAS™). A small portion of the output from the TOPAS at 580 nm was picked off and sent to a photodiode (figure 4). The second photodiode was used to monitor intensity of the fundamental 800 nm beam (the output of slave amplifier).

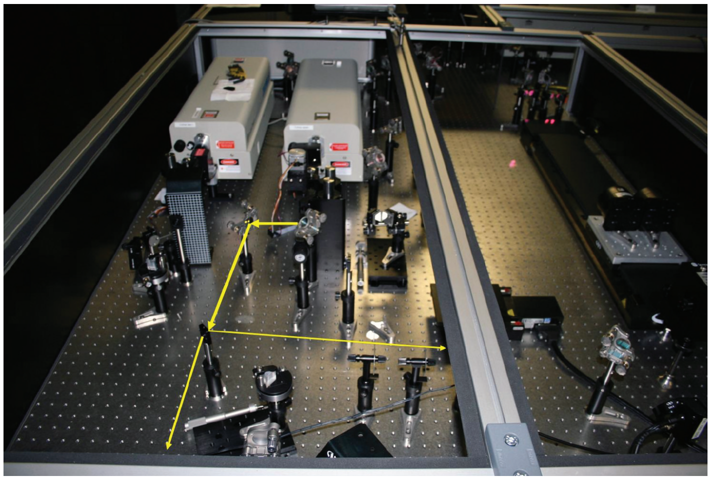
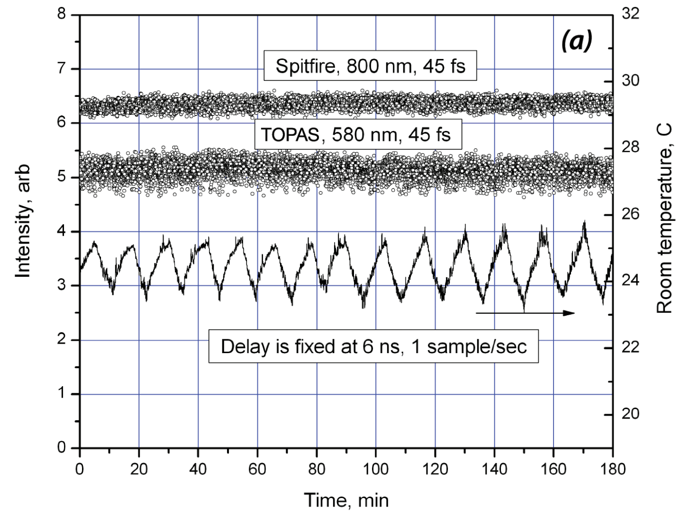


Figure 4. Output beam of TOPAS is picked off and sent to photodiode.

We conducted two measurements. First, the delay line was kept in a fixed position corresponding to the middle of travel (~ 6 ns delay). The signals from both photodiodes along with the ambient temperature were recorded without processing or averaging, with a sampling rate of 1 sample/sec (figure 5 (a)). This gave us a reference measurement. Secondly, the delay line was scanned and the intensity of the 800 nm and 580 nm pulses were once again recorded at the same rate. The results are presented in figure 5 (b). Clearly in both cases, the output stability of the TOPAS remained similar. The slightly better stability in the latter experiment is because the scan was completed within minutes such that the slow fluctuation of the temperature did not manifest its effect. Comparable behavior was observed for the output of the slave amplifier. These results demonstrated that scanning the long delay line has only a minor effect on the pulse stability and corroborated the feasibility of introducing a long optical delay line before the amplification process.



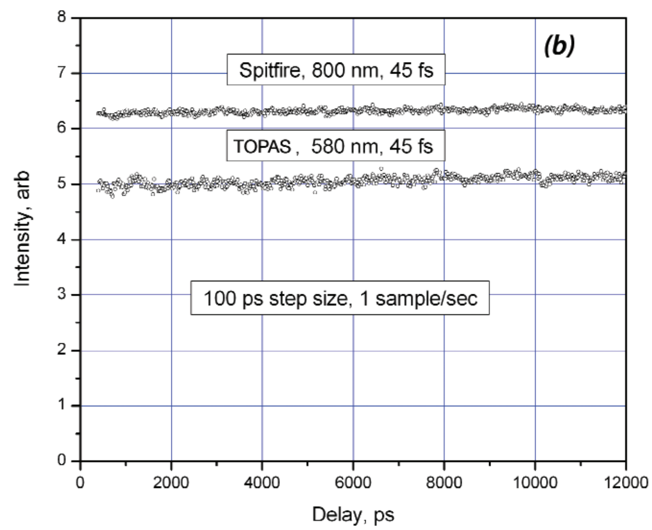


Figure 5. (a) The output of the slave amplifier and TOPAS at fixed delay. (b) Stability of the output of slave amplifier and TOPAS vs. delay.

For comparison, figure 6 shows the data using the output of the master amplifier to drive the OPA, collected under the same conditions as Figure 5. It is clear that stability of the OPA output was similar in all three cases.

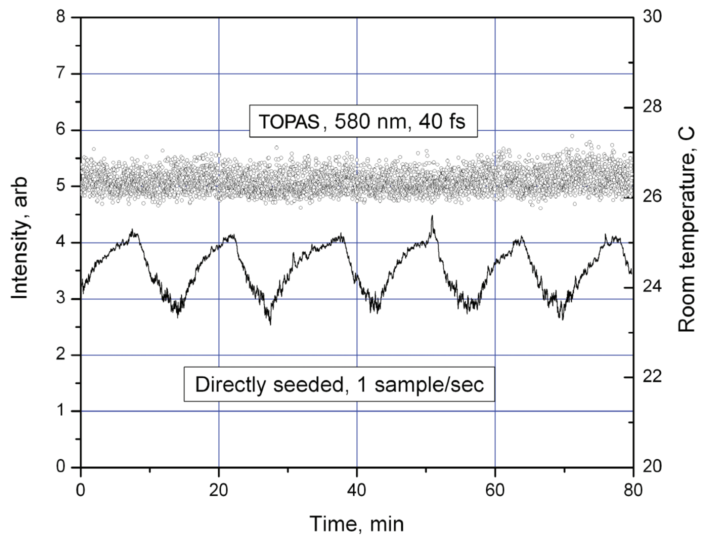


Figure 6. The output stability of TOPAS *when pumped by the master amplifier.*

Conclusions

Optical synchronization of two amplifiers seeded from the same oscillator through a long optical delay line is feasible. Reliable and stable operation can be achieved. With this setup, a delay line with less than 30 fs resolution can cover femtosecond to nanosecond regimes, without noticeable degradation of the beam quality. It provides an alternative solution to a dual oscillator setup for researchers in the field of ultrafast chemical physics.

References

1. R. Torre, Time-Resolved Spectroscopy in Complex Liquids: *An Experimental Perspective*. *1st ed*. (2007).
2. M.E. Fermann, A. Galvanauskas, G. Sucha. Ultrafast Lasers: *Technology and Applications*. *1st ed*. (2002).
3. C. Rulliere. Femtosecond Laser Pulses: *Principles and Experiments*. *2nd ed*. (2004).
4. J.-C. Diels, W. Rudolph, Ultrashort Laser Pulse Phenomena: *Fundamentals, Techniques, and Applications on a Femtosecond Time Scale*. (1996).
5. P. Agostini, L.F. DiMauro, The Physics of Attosecond Light Pulses. *Reports on Progress in Physics*. (2004). 67(6): 813-855.
6. On the Origin of Motion Control Specifications--*App Note* 1, *Newport Corporation*.(2003)

Newport Corporation

Worldwide Headquarters
1791 Deere Avenue
Irvine, CA 92606

(In U.S.): 800-222-6440
Tel: 949-863-3144
Fax: 949-253-1680

Email: sales@newport.com

Newport
Experience | Solutions

Visit Newport Online at: **www.newport.com**

This Application Note has been prepared based on development activities and experiments conducted in Newport's Technology and Applications Center and the results associated therewith. Actual results may vary based on laboratory environment and setup conditions, the type and condition of actual components and instruments used and user skills.

Nothing contained in this Application Note shall constitute any representation or warranty by Newport, express or implied, regarding the information contained herein or the products or software described herein. Any and all representations, warranties and obligations of Newport with respect to its products and software shall be as set forth in Newport's terms and conditions of sale in effect at the time of sale or license of such products or software. Newport shall not be liable for any costs, damages and expenses whatsoever (including, without limitation, incidental, special and consequential damages) resulting from any use of or reliance on the information contained herein, whether based on warranty, contract, tort or any other legal theory, and whether or not Newport has been advised of the possibility of such damages.

Newport does not guarantee the availability of any products or software and reserves the right to discontinue or modify its products and software at any time. Users of the products or software described herein should refer to the User's Manual and other documentation accompanying such products or software at the time of sale or license for more detailed information regarding the handling, operation and use of such products or software, including but not limited to important safety precautions.

This Application Note shall not be copied, reproduced, distributed or published, in whole or in part, without the prior written consent of Newport Corporation.

BSI REGISTERED
ISO 9001
FM 27207

Newport Corporation, Irvine, California, has been certified compliant with ISO 9001 by the British Standards Institution.

MM#9000103
DS-05099