Preface

Thank you for purchasing the Δ single shot Autocorrelator from U-Oplaz Technologies. The Δ Autocorrelator series are designed for measuring the laser pulse width from femtoseconds to picoseconds. Combining with our grating delay line, the Δ autocorrelator can measure the pulse width up to hundreds picoseconds. The Δ autocorrelators can measure the pulse width of a low repetition rate laser (<1Hz) to a high repetition rate laser (>100KHz).

This manual contains information you will need for day-to-day operation and maintenance of your Δ Autocorrelator. You will find instructions for installation, operation, preventive maintenance, trouble shooting and repair guide.

The U-OPLAZ TECHNOLOGIES Δ Autocorrelator product is designed to be efficient and reliable. Because we make almost every key components in the laser system, we could guarantee fast and reliable service whenever you have any trouble. We encourage you to interact with our engineers so we could provide you with high quality service. We are committed to customers' satisfaction.

Table of content

Chapter 1 Introduction

Chapter 2 Installation and Operation

Chapter 3 Maintenance

Chapter 4 Customer Service

Chapter 1 Introduction

Family of the Δ single shot Autocorrelator

A. The standard Δ models

The standard Δ model is suitable for measuring the laser pulse from a laser amplifier or from an OPA pumped by an amplifier though it also can measure the pulse from an oscillator. The standard Δ model can measure the pulse width from 50 fs to a few ps. With the short pulse option (Δ-S model) the pulse as short as 10 fs can be measured. For pulse width from several to Hundreds ps please add the option of the grating delay line to you order and check the information of the grating delay line below.

B. The Δ-L models

The Δ-L model is for lower energy pulses such as those from an oscillator since the Δ-L model includes the focal lenses to increase the sensitivity. The standard Δ-L model can also measure the pulse width from 50 fs to a few ps. With the short pulse option (The Δ-LS model) the pulse as short as 10 fs can be measured. Also for pulse width from several to Hundreds ps please add the option of the grating delay line to you order and check the information of the grating delay line below.

C. The grating delay line

The grating delay line is a standalone option to extend the pulse width measurement to the range of hundreds ps. It generates a time delay distribution along the beam cross section. The time delay is adjustable up to hundreds ps. For example, to measure a 10 to 100 ps pulse simply let the pulse go through the grating delay line to extend the time delay then the pulse output from the grating delay line is sent to the Δ single shot autocorrelator for measuring the pulse width as if in a femtosecond pulse measurement.

Chapter 1 Introduction

Other necessary equipment

An oscillator (20MH or higher) is needed for monitoring the autocorrelation signal from the Δ single shot autocorrelator.

Principles of the Δ Autocorrelator

The Δ Autocorrelator is based on second harmonic generation (SHG) to characterize an unknown laser pulse. The SHG process can be represented by

SHG: $\omega_1 + \omega_1 \Rightarrow \omega_2$

where ω_1 and ω_2 are the fundamental and second harmonic frequencies, respectively. In the Δ Autocorrelator, an input beam (fundamental) is first separated into two beams. Then the two fundament beams are recombined at a cross angle θ in a SHG crystal to generate the SHG signal.

In a single shot autocorrelator the time delay information are transformed into a special distribution and recorded by a multichannel CCD detector. As shown in Figure 1 the time delay between the two beams along the cross section is a function of the cross angle (2θ) of the two beams and the distance (x) from the center,

$$\Delta t=(20/3)\cdot x\cdot n\cdot \sin(\theta),$$

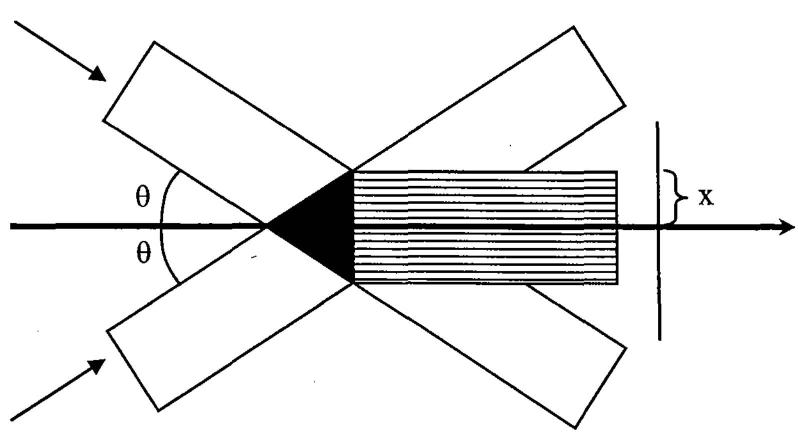
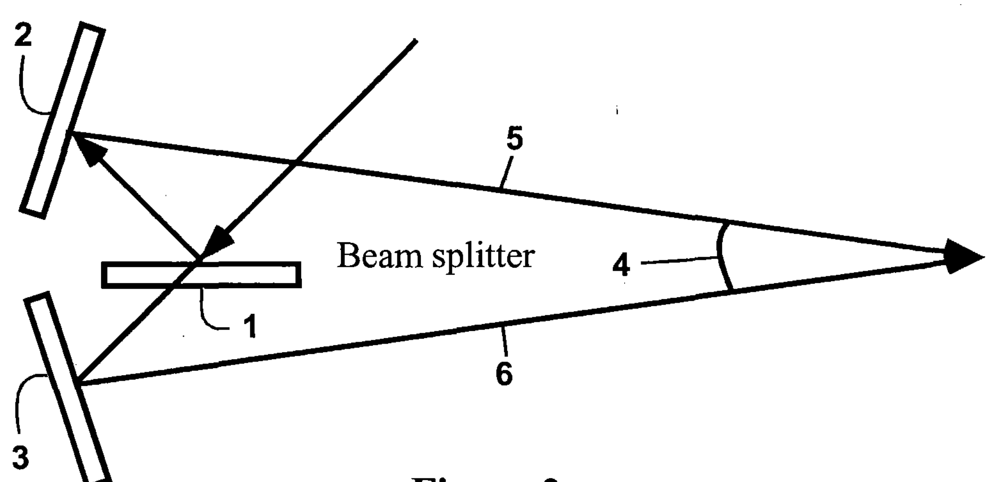


Figure 1

where n is the diffraction indices of the material, in air n is 1. The time delay Δt is in the unit of picosecond when the distance x is millimeter. Therefore the generated SHG signal due to the two crossed beams will have an intensity distribution along the x direction depending on the laser pulse width. A longer pulse will generate a broader SHG signal while a shorter pulse will generate a narrower SHG signal along the x direction. For $\theta=8°$ in the Δ Autocorrelator a 100 fs and a 1 ps pulse will have about 0.1 mm and 1 mm width, respectively. Thus measuring the intensity of the SHG signal along the x direction will give the pulse width of a laser beam. Usually, the SHG signal is recorded by a CCD multichannel detector.

Triangle delay line in the Δ single shot autocorrelator

In the Δ single shot autocorrelator we used the triangle delay line design (US Patent pending) to achieve the reliable performance and easier operation. The benefit from the triangle delay line design is the alignment free operation. In principle there is no need for alignment after the initial alignment done in the manufactory except of aligning the input laser into the autocorrelator at a right direction and adjusting the SHG crystal angle. In a few minutes a pulse width can be measured without the difficulties suffered by other autocorrellators.



Patent Pending

Figure 2

In Figure 2 we show a diagram of the triangle delay line. Basically it is consisted of a beam splitter (1) and two mirrors (2 and 3). An input laser beam is separated into two beams by the beam splitter and then they are recombined at a cross angle (4). Due to the simple but very reliable design of the triangle delay line the Δ single shot autocorrelator can be constructed with very compact size and is user friendly.

Chapter 2. Operation

2.1 Unpacking the Δ single shot autocorrelator

Unpack the package carefully. In the package of the Δ single shot autocorrelator, you will find the following items (see figure 1):

1. A Δ single shot autocorrelator,
2. A 5V DC power supplier,
3. A Manual of the Δ Single Shot Autocorrelator.

2.2 The connection panel

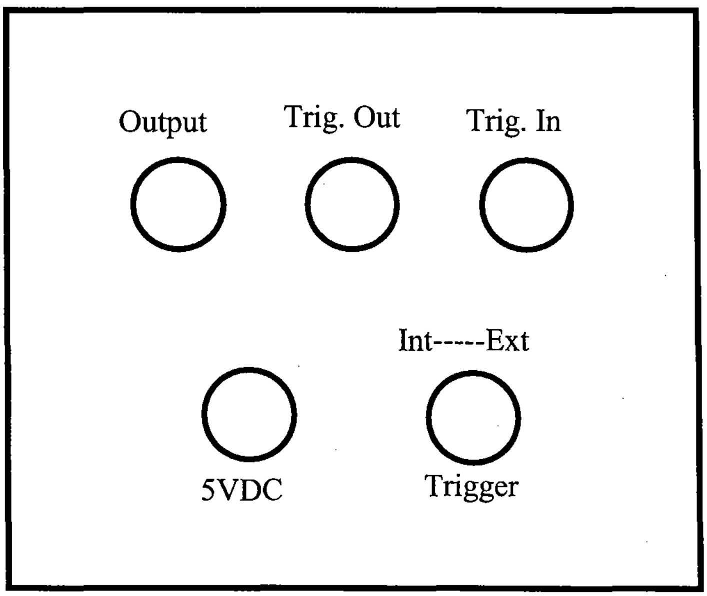


Figure 3 Connection panel.

Output:	The connection of the output of the autocorrelation Signal from the CCD detector of the autocorrelator to the signal channel of an oscilloscope for in real time observation. The impedance of the oscilloscope must be selected to 1MΩ.
Trig. Out:	The connection of the trigger output from the autocorrelator to the external trigger of the oscilloscope for synchronization.
5VDC:	Connection to the 5V DC power supplier.
Trigger:	The switch for the internal (Int) or external (Ext) trigger mode. Turn to Int is for the internal trigger mode and turn to Ext for the external trigger mode.

Trig. In: For the external trigger model, an external trigger has to be provided. The external trigger signal is connected here.

Two trigger modes

The Δ single shot autocorrelator can operate at two different trigger models, internal and external trigger model. The internal trigger mode is suitable for a high repetition (1 kHz or higher) laser while the external trigger mode is better fit for a Low repetition laser (1 Hz for example). In the internal trigger mode, the output autocorrelation signal is averaged over many single shot autocorrelation signals and has better signal to noise ratio. While in the external trigger mode the output is truly single shot autocorrelation signal.

2.3 The setup and alignment of the autocorrelator

1. Open the cover of the Δ single shot autocorrelator. Mount the autocorrelator to a platform mount (having X and Y adjustment that the alignment is much easier with this type of mount) or to a post. Then mount the platform mount to a post and to a post holder.
2. Find the connection panel. Connect the Output to the signal channel (1MΩ) and the Trig. Out to the external trigger of an oscilloscope (≥20MHz).
3. For high repetition laser (≥1kHz), turn the trigger switch to the Int (internal trigger) and no trigger input is needed. For low repetition laser or true single shot autocorrelation model, turn the trigger switch to the Ext (external trigger) and connect the Trig. In to an external trigger for synchronization.
4. Plug in the 5V DC power supplier. It may take a few minutes for the autocorrelator to warm up.
5. Set the autocorrelator to the position of the laser beam whose pulse width is to be measured. Adjust the position and height of the autocorrelator to allow the laser beam to pass the center of the entrance iris. It may be necessary to adjust the laser beam in the horizontal direction.
6. Close the entrance iris to minimum aperture size (0.5 mm). As shown in figure 4, the input laser beam will go through the iris and the half wave plate (WP) and reach the directing mirror (M1). The laser beam is then separated into two beams by the beam splitter (BS) and they are reflected separately by the mirror M2 and M3 to recombine at the center of the

SHG crystal. The generated SHG signal then passes the filter to reach the CCD detector.

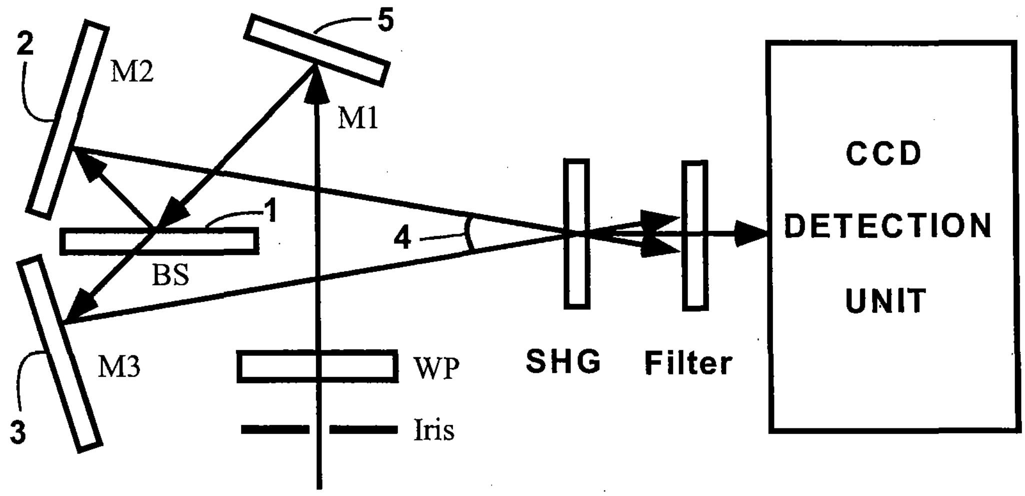


Figure 4 Layout of the standard Δ single shot autocorrelator.

7. Rotate the half wave plate (WP) to change the relative intensity of the two beams until both beams can be clearly seen on a business card or sensor. Note the intensity of the two beams may be different depending on the wavelength.
8. When the two beams from mirror M2 and M3 have different beam level from the center of the SHG crystal adjust the platform X and Y direction to move the two beams to the same level of the SHG crystal center as in figure 5.

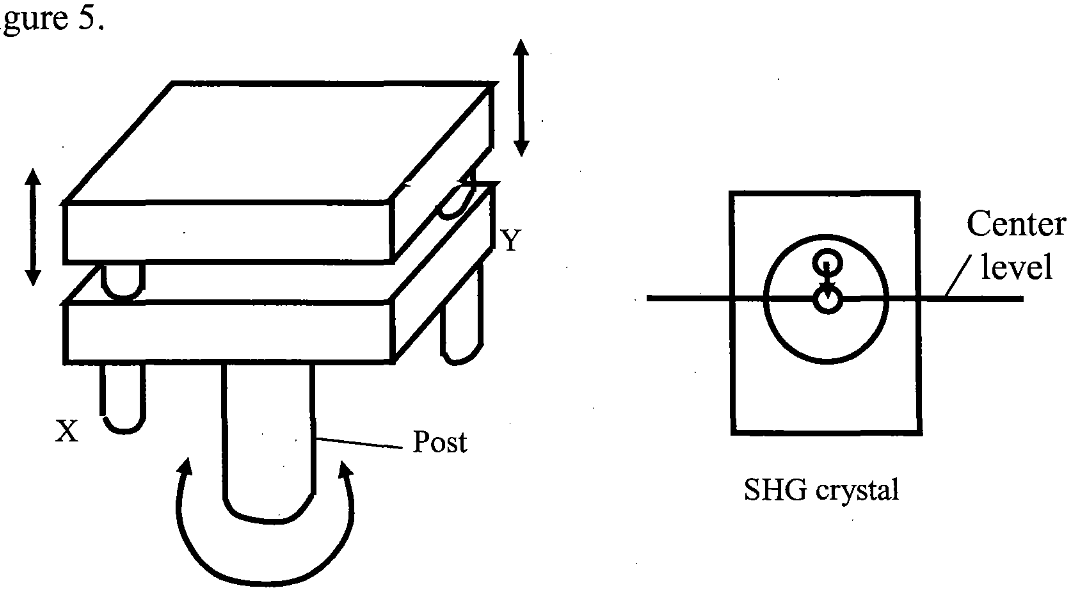


Figure 5 Adjustment of the platform mount X and Y direction to move the laser beams to the center of the SHG crystal.

9. When the two beams from mirror M2 and M3 are not overlapped at the center of the SHG crystal rotate the autocorrelator around the axis of the mounting post (see figure 5) to move the position of the two beams to center of the SHG crystal as shown in figure 6.

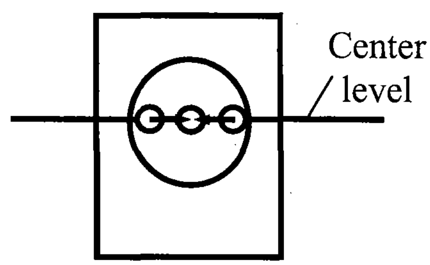


Figure 6 Rotate the autocorrelator around the vertical axis of the mounting post to make the two separated beams to recombined at the center of the SHG crystal

10. Adjust the position and height of the autocorrelator to make sure the input laser is going through the center of the iris.
11. Repeat the procedures 8 to 10 until the input laser beam is at the center of the iris and the separated two beams are recombined at the center of the SHG crystal.

Alignment of SHG crystal

12. Open the iris to about 2 mm (normal operation fully open the iris). Put a business card behind the SHG crystal and rotate the angle of the crystal. Two SHG (2ω) spots on the business card or sensor generated by the two input beams (ω) at two different angles should be observed, respectively, as shown by the dashed line in figure 7. A filter between the SHG crystal and the business card will help to see the SHG spots
13. Then set the angle of the SHG crystal in the middle of these two angles (shown by the solid line). A new SHG spot between the previous two SHG signals may be observed if time delay is right as shown in figure 7. The SHG signal at the center may look like a line depending on the pulse width (100fs and 1ps pulses are about 0.1 and 1 mm width, respectively, see the Principles of the Δ Autocorrelator). The SHG autocorrelation signal due to the two crossed input laser beam will be sensitive to the time delay.

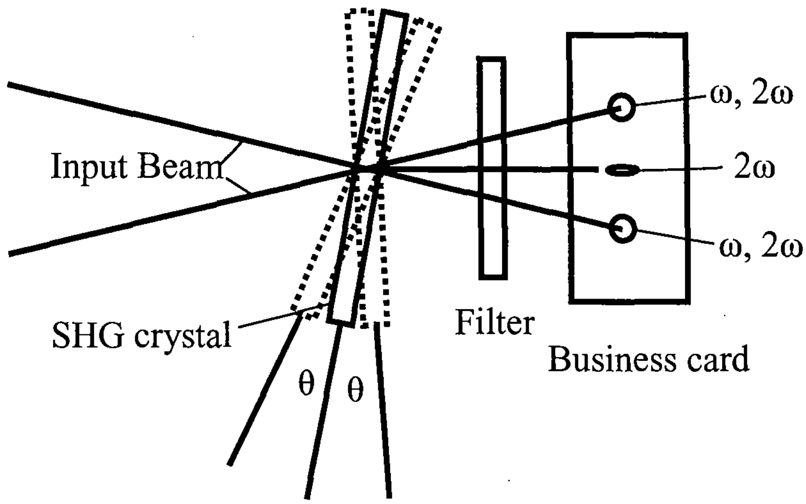


Figure 7. Illustration of the SHG alignment. The SHG autocorrelation signal is located at the center

14. If the autocorrelation signal is not observed the time delay may not be right. Move the translation stage inside the autocorrelator by rotating the micrometer to change the time delay while observe the SHG signal on the business card.
15. If the SHG signal still can not be seen when change the time delay then rotate a little bit angle of the SHG crystal and move the translation stage.
16. Repeat the procedures 14 and 15 until the SHG autocorrelation signal is observed as shown in figure 7.
17. Rotate the angle of the SHG crystal and adjust the time delay to optimize the intensity of the autocorrelation Signal.

Calibration of the time

18. Fully open the iris and turn on the oscilloscope. The autocorrelation signal may be observed on the oscilloscope. Adjust the trigger, the sensitivity, and the time scale of the oscilloscope to observe the signal clearly. A full scan of the CCD takes about 33 ms. A 100 fs pulse has a time scan width about 0.7 ms
19. It is important to adjust the X and Y direction of the platform to optimize the signal on the oscilloscope.
20. To obtain the pulse width from the observed autocorrelation signal the time of the signal must be calibrated. As shown in figure 8 move the translation stage a distance (L) by rotating the micrometer to change the peak position of autocorrelation signal on the oscilloscope. Measure the

change of time (or the distance of the peak positions) ΔT. The minimal division of the micrometer is 10 μm. By moving 100 μm of the traslation stage the ΔT is about 3 ms.

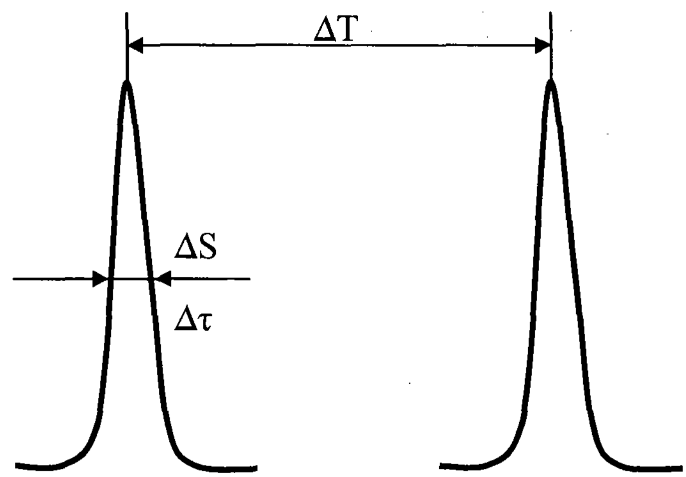


Figure 8 Illustration for the time calibration: ΔT is the time difference of the peak positions by moving the distance (L) of the translation stage the ΔS is the time of the full width at the half maximum (FWHM) of the signal on the oscilloscope and the Δτ is the pulse width.

21. Measure the time (or distance) width of the autocorrelation signal on the oscilloscope (FWHM) ΔS. Then the pulse width of the laser beam Δτ can be obtained from the moving distance L and the measured time ΔT and ΔS by

$$\Delta\tau = 0.707 \cdot C \cdot (\Delta S / \Delta T) \cdot L$$

Where C =6 ps/mm is the time delay constant of the delay line for each millimeter moving distance L and the constant 0.707 is for a Gaussian pulse.

Alignment of the mirror M2 and M3

The autocorrelator is designed for easy alignment. In the routine operation there is no need for aligning the optics in the autocorrelator except the SHG crystal. However, in the initial installation (finished in the manufactory) and in the case of some parts to be changed the alignment of the mirror M2 and M3 is necessary.

22.Position the autocorrelator and let the aligning laser beam passes the center of the entrance iris. Close the iris to minimum aperture (0.5 mm). Adjust the X and Y direction of the platform mount and rotate autocorrelator around the axis of the mounting post as shown in figure 5 to make the laser beam reach the center of the mirror M1. The laser beam level at the M1 should be the same as that at the iris.
23.The laser beam after the mirror M1 will be separated into two beams by the beam splitter (BS) as shown in figure 4. The separated two beams should be recombined at the center of the SHG crystal.
24.Unscrew the screws and move away the end board behind the mirror M2 and M3.
25.As shown in figure 9 the mirror M2 and M3 can be adjusted by the three mounting screws and a locking setscrew. Slowly adjust the mounting screws and the locking setscrew to move the laser beams to the center of the SHG crystal and make sure the mirrors are firmly locked.
25.After the finished the alignment put the end board back.

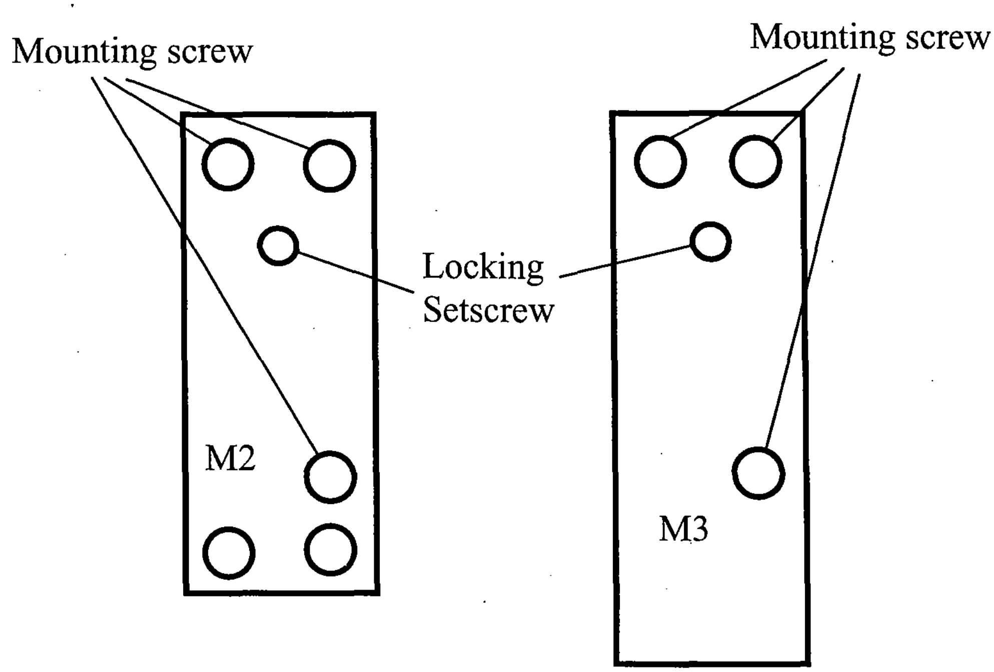


Figure 9. Adjustment of the mirror M2 and M3.

2.4. Options and other models

1. Short pulse option for the standard Δ model

For pulse less than 50 fs the short pulse option is needed. A cylindrical diversion lens is added to expand the signal beam size, which leads to the better time resolution, as shown in figure 10. The alignment of the Δ-S model is same as that of the standard Δ model.

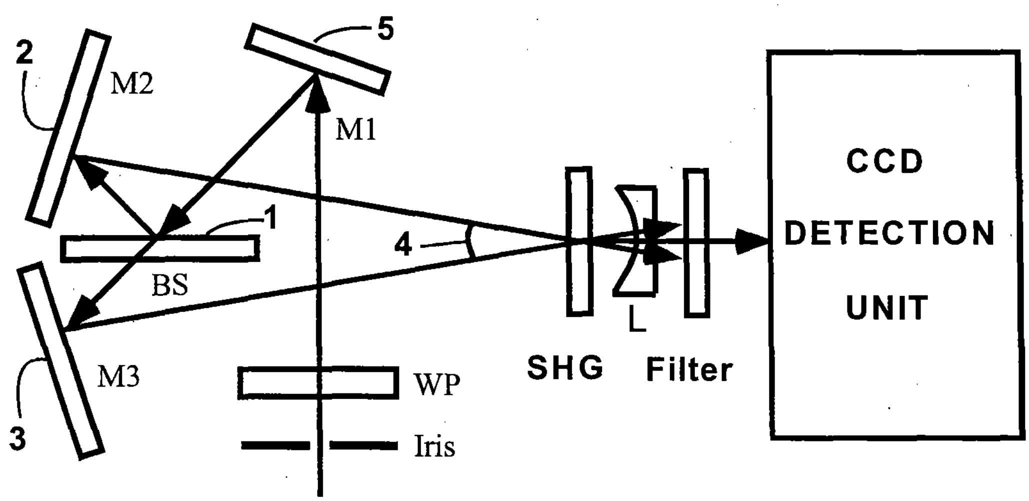


Figure 10 Layout of the Δ-S single shot autocorrelator.

2. The lower power model (Δ-L model)

As shown in figure 11 the Δ-L model has two additional lenses, L1 is to focus the laser pulse at the SHG crystal and leads to the higher intensity and the stronger signal and L2 is to collimate the signal to the CCD detector. The basic alignment of the Δ-L mode is the same as that of the standard Δ mode. However, the distance of L1 and L2 to the SHG crystal may be adjusted to optimize the performs by moving the mounting base (see figure 12).

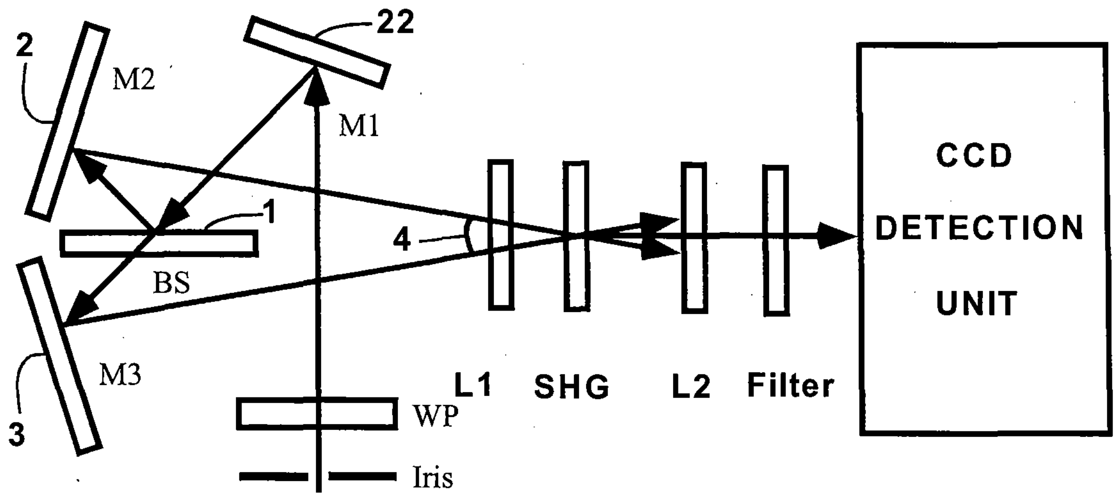
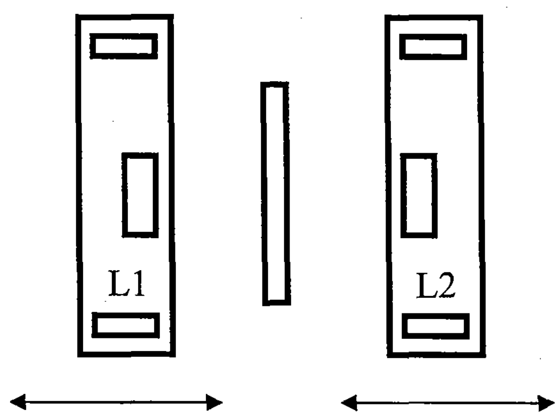


Figure 11 Layout of the Δ-L single shot autocorrelator.

Figure 12



3. Short pulse option for the Δ-L model

For pulse less than 50 fs the short pulse option is needed. A cylindrical diversion lens (L3) is added to expand the signal beam size on the CCD detection, which leads to the better time resolution, as shown in figure 13. The alignment of the Δ-LS model is the same as that of the Δ-L model.

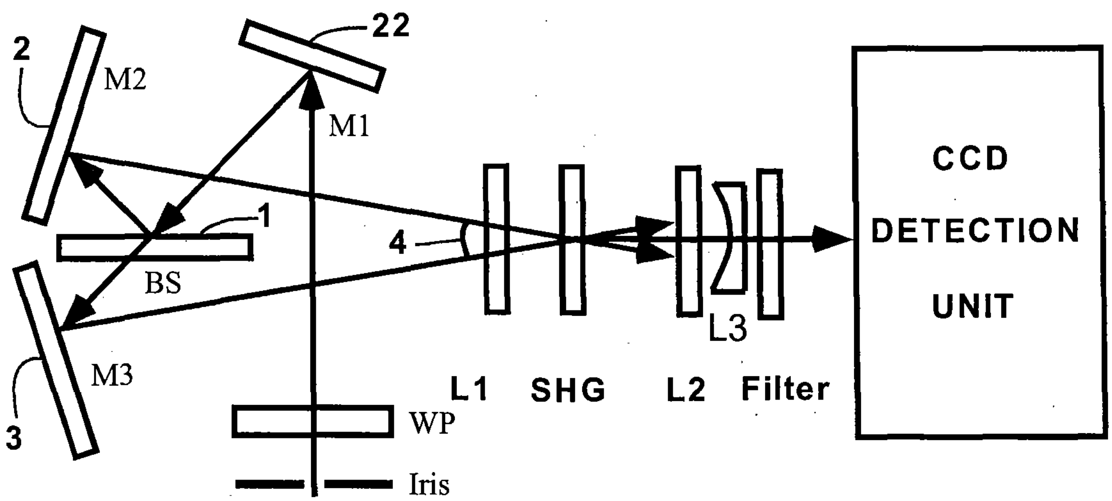


Figure 13 Layout of the Δ-LS single shot autocorrelator.

4. The grating delay line

The grating delay line can generate a distribution of the time delay along the beam cross section. The time delay is adjustable up to hundreds ps. As shown in figure 14 an input beam is reflected by the mirror M1 and is diffracted by the grating. Then the laser beam is retroreflected by the mirror M2 but a little bit down to be reflected out by the mirror 3. The output beam from the grating delay line has a distribution of the time delay along the beam cross section.

$$T=(20/3)\cdot(D/\cos(\theta_i))\cdot(\lambda/d),$$

where T is the total time delay (ps) for the laser beam with size D (mm), θ_i the incident angle, d the grating line separation, and λ the laser wavelength. The factor $D/\cos(\theta_i)$ in the equation is in fact the projection of the laser beam on the grating and the maximum factor $D/\cos(\theta_i)$ depends only on the grating size not on the laser input beam size. The time delay can be adjusted by rotating the angle of the grating and the angle of the retroreflection mirror M2.

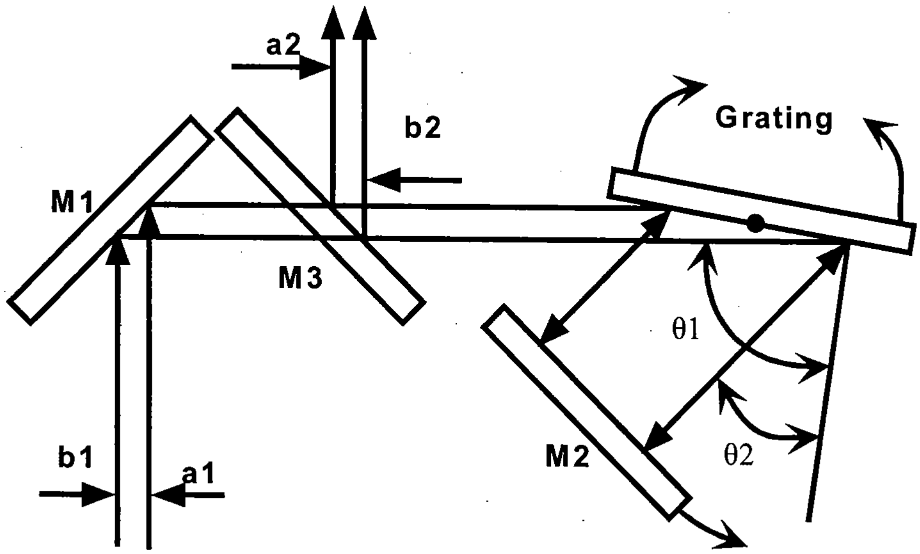


Figure 14 Layout of the Grating delay line.

Chapter 3 Maintenance

Maintaining the alignment

The design of the Δ autocorrelator makes the maintaining the alignment very easy. But for best performance, several precautions have to be taken:

1. Use stable mirror mount for directing input beams.
2. Avoid bumping the optics, the laser and the autocorrelator.
3. keep the laser beam going through the center of crystals and optics.

Maintaining the crystal and optics

The optics and crystals in the autocorrelator have to handle intense high power laser pulses all the time, so it is very important to keep them in a dust free clean environment. Prevent dust from getting into the autocorrelator box; try to keep the box covered all the time.

When clean the crystals and optics try to blow the impurity off by using a dust blower and always use optical cleaning tissues (e.g. Kodak lens tissue) and pure methanol to clean the surfaces. Always wear clean (PVC) gloves when handling optics and crystals.

Replacing crystals and optics

When you observe the damage on the crystals and optics please change them immediately. U-OPLAZ TECHNOLOGIES offers high quality replacing crystals and optics to the customers at the lowest prices possible.

Chapter 4 Customer Service

Warranty

All the mechanical parts and electronic parts are warranted to be free from defects for a period of one year. The warranty on optics and crystals is ninety days. We also offer customers free one-year repolishing and recoating service.

Return of the Instrument for Repair

Before returning the instrument or any parts for repair, please contact our service center and get an RMA#. As the autocorrelator product has many fragile optics and crystals, in order to provide maximum protection please be sure to ship them in the original packages.

Replacement Part List

Description	Part Number
6x8 SHG BBO crystal with mount	
Φ=0.5" silver mirror	
Φ=0.5" beam splitter 500-800 nm	
Φ=0.5" beam splitter 800-1200 nm	
Filter I Φ=1", 500-650 nm	
Filter II Φ=1", 750-1200 nm	
Filter III Φ=1", 650-750 nm	
Half wave plate, AR/AR @800nm	
BK7 cylindrical lens, FL=15mm, HxL=10x12	
UV fused silicon cylindrical lens, FL=12.7mm, HxL=10x15	
UV fused silicon cylindrical lens, FL= - 8mm, HxL=7.2x11	

NuAssembly, Inc.
9083 Arcadia Ave. San Gabriel, CA 91775
Tel: (626)497-4327, Fax: (626)585-0918

Date: August 11, 2005

SHIP TO:
ATTN: Building 46 PO# 5A-12327, BUYER: Edy M. Haus, Supervisor, Purchasing, The ANL technical contact for this requirement is Eric Landahl at phone number 630-252-0278.
ARGONNE NATIONAL LABORATORY
Building 46, 9700 S Cass Ave, Argonne, IL 60439
Your PO#: PO# 5A-12327
Tel: 630-252-0278

PACKING LIST

Qty	Unit	Description	Customer PO#	Invoice #
1	ea	SSA-S, Delta single shot autocorrelator with short pulse option	5A-12327	NU05097

Total Gross Weight:1.5kg
Country of Origin: CA, USA

The FEDEX tracking number of this shipment: 7911 8546 0377

NuAssembly, Inc.
9083 Arcadia Ave. San Gabriel, CA 91775
Tel: (626)497-4327, Fax: (626)585-0918

Date: August 29, 2005

BILL TO:
Accounts Payable, BLDG 201
ARGONNE NATIONAL LABORATORY
Building 201, OCF-PRO, 9700 S Cass Ave, Argonne, IL 60439
Your PO#: **PO# 5A-12327**
Tel: 630-252-0278

INVOICE

Date	Ship Via	Invoice#	Terms
August 28, 2005	FEDEX RED	NU05097	NET 30

Qty	Unit	Description	Unit Price	Total Amount
1	ea	SSA-S, Delta single shot autocorrelator with short pulse option	$8,800	$8,800.00
1	ea	Shipping and packing, Fed Express 2nd Day - Collect - Acct# 0604-0352-0	0	0
			Total	$8,800.00

Net Weight: 0.5kg
Total Gross Weight:1.5 kg

Signature: ______________

The FEDEX tracking number of this shipment: 7911 8546 0377

From: Origin ID: (626)497-4327
Sheng Wu
NUASSEMBLY, INC
9083 ARCADIA AVE

SAN GABRIEL, CA 91775

FedEx Express

E

Ship Date: 29AUG05
Actual Wgt: 2 LB
System#: 3791223/INET2200
Account#: S *********

REF: 5A-12327

Delivery Address Bar Code

SHIP TO: (630)252-0278 **BILL THIRD PARTY**

Eric Landahl
Argonne National Laboratory
Bldg 46, 9700 S. Cass Avjavascripe.

Argonne, IL 60439

**** 2DAY ****

WED
Deliver By:
31AUG05

TRK# **7911 8546 0377** FORM 0201

ORD A2

60439 -IL-US

VK ENLA

Shipping Label: Your shipment is complete

1. Use the 'Print' feature from your browser to send this page to your laser or inkjet printer.
2. Fold the printed page along the horizontal line.
3. Place label in shipping pouch and affix it to your shipment so that the barcode portion of the label can be read and scanned.

Warning: Use only the printed original label for shipping. Using a photocopy of this label for shipping purposes is fraudulent and could result in additional billing charges, along with the cancellation of your FedEx account number.

Use of this system constitutes your agreement to the service conditions in the current FedEx Service Guide, available on fedex.com. FedEx will not be responsible for any claim in excess of $100 per package, whether the result of loss, damage, delay, non-delivery, misdelivery, or misinformation, unless you declare a higher value, pay an additional charge, document your actual loss and file a timely claim. Limitations found in the current FedEx Service Guide apply. Your right to recover from FedEx for any loss, including intrinsic value of the package, loss of sales, income interest, profit, attorney's fees, costs, and other forms of damage whether direct, incidental, consequential, or special is limited to the greater of $100 or the authorized declared value. Recovery cannot exceed actual documented loss. Maximum for items of extraordinary value is $500, e.g. jewelry, precious metals, negotiable instruments and other items listed in our Service Guide. Written claims must be filed within strict time limits, see current FedEx Service Guide.