Model 3980

Frequency Doubler and Pulse Selector

User's Manual

Spectra-Physics
The Solid-State Laser Company

1335 Terra Bella Avenue
Mountain View, CA 94043

Part Number 0000-288A, Rev. C
August 2002

Preface

This manual contains information you need in order to safely install, operate, maintain, and service your Model 3980 frequency doubler/pulse selector on a day-to-day basis.

The “Introduction” chapter contains a brief description of the Model 3980. This is followed by an important chapter on laser safety. The Model 3980 is designed for use with a Spectra-Physics Tsunami® mode-locked Ti:sapphire laser that is pumped by either a Millennia® diode-pumped, solid-state cw laser or a BeamLok® 2060 or 2080 ion laser. These are all Class IV—high power lasers that emit laser radiation which can permanently damage eyes and skin. This laser safety section contains information about these hazards. To minimize the risk of injury or expensive repairs to the instruments involved, carefully follow these instructions. This chapter also contains information regarding system compliance to CDRH and CE regulations with regards to high power lasers.

The “Description” chapter contains an overview of the Model 3980, and it explains its intended use with the Tsunami laser. Following this overview is a more detailed description of the Model 3980 which concludes with specifications and outline drawings.

The next few chapters describe the Model 3980 controls and interconnects and guide you through its installation, alignment and operation. The last part of the manual covers maintenance and service and includes a replacement parts list and a list of world-wide Spectra-Physics service centers you can call if you need help.

While this manual contains a brief installation procedure, it is not intended as a guide to the initial installation and set-up of your Model 3980. Please wait for the Spectra-Physics service engineer who has been assigned this task as part of your purchase agreement. *Allow only those qualified and authorized by Spectra-Physics to install and set up your system.*

Whereas the “Maintenance” section contains information you need to keep your unit clean and operational on a day-to-day basis, “Service and Repair” is intended to help you guide your Spectra-Physics field service engineer to the source of any problems. *Do not attempt repairs yourself while the unit is still under warranty*; instead, report all problems to Spectra-Physics for warranty repair.

Finally, if you encounter any difficulty with the content or style of this manual, please let us know. The last page is a form to aid in bringing such problems to our attention.

Thank you for your purchase of Spectra-Physics instruments.

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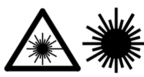
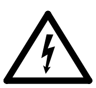
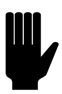
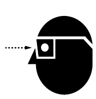
Warning Conventions

The following warnings are used throughout this manual to draw your attention to situations or procedures that require extra attention. They warn of hazards to your health, damage to equipment, sensitive procedures, and exceptional circumstances. All messages are set apart by a thin line above and below the text as shown here.

 **Danger!** Laser Radiation	Laser radiation is present.
Danger! 	Condition or action may present a hazard to personal safety.
 **Danger!** 	Condition or action may present an electrical hazard to personal safety.
Warning! 	Condition or action may cause damage to equipment.
Warning! ESD 	Action may cause electrostatic discharge and cause damage to equipment.
 **Caution!** 	Condition or action may cause poor performance or error.
Note 	Text describes exceptional circumstances or makes a special reference.
Don't Touch! 	Do not touch.
Eyewear Required 	Appropriate laser safety eyewear should be worn during this operation.
	Refer to the manual before operating or using this device.

Standard Units

The following units, abbreviations, and prefixes are used in this Spectra-Physics manual:

Quantity	Unit	Abbreviation
mass	kilogram	kg
length	meter	m
time	second	s
frequency	hertz	Hz
force	newton	N
energy	joule	J
power	watt	W
electric current	ampere	A
electric charge	coulomb	C
electric potential	volt	V
resistance	ohm	Ω
inductance	henry	H
magnetic flux	weber	Wb
magnetic flux density	tesla	T
luminous intensity	candela	cd
temperature	celcius	C
pressure	pascal	Pa
capacitance	farad	F
angle	radian	rad

Prefixes								
tera	(10^{12})	T	deci	(10^{-1})	d	nano	(10^{-9})	n
giga	(10^{9})	G	centi	(10^{-2})	c	pico	(10^{-12})	p
mega	(10^{6})	M	mill	(10^{-3})	m	femto	(10^{-15})	f
kilo	(10^{3})	k	micro	(10^{-6})	μ	atto	(10^{-18})	a

Unpacking and Inspection

Unpacking Your Model 3980

Your Model 3980 frequency doubler/pulse selector was packed with great care, and its container was inspected prior to shipment—it left Spectra-Physics in good condition. Upon receiving your unit, immediately inspect the outside of the shipping container. If there is any major damage (holes in the containers, crushing, etc.), insist that a representative of the carrier be present when you unpack the contents.

Carefully inspect your unit as you unpack it. If any damage is evident, such as dents or scratches on the cover or broken knobs, etc., immediately notify the carrier and your Spectra-Physics sales representative.

Keep the shipping container. If you file a damage claim, you may need it to demonstrate that the damage occurred as a result of shipping. If you need to return the unit for service at a later date, the specially designed container assures adequate protection.

System Components

The following components comprise the Model 3980 frequency doubler/ pulse selector:

- Model 3980 frequency doubler/pulse selector
- Model 3986 or 3983 electronics module (a Model 3980-4 requires only a heater controller)
- Accessory cables
- U. S. or European power cable (2.5 m)
- Accessory kit (see below)

Verify these components are present. They are all shipped in one container.

Accessory Kit

Included with the Model 3980 is this manual, a packing slip listing all the parts shipped, and an accessory kit containing the following items:

- a tool kit containing various Allen wrenches and drivers plus 3 foot clamps for the Model 3980
- a glass bottle for optics cleaning solution
- a plastic hemostat
- tweezers
- an infrared detector card

- a packet of Kodak Lens Cleaning Paper™
- an external 3 db attenuator
- a set of 38 mm lenses if you purchased a pulse selector system and a 75 mm lens if you purchased a fs frequency doubler/pulse selector system.
- You will need to supply several items, including:
- spectrophotometric-grade (HPLC) acetone and methanol for optics cleaning
- clean, lint-free finger cots or powder-less latex gloves for optics cleaning

Chapter 1 Introduction

The Spectra-Physics Model 3980 frequency doubler/pulse selector (Figure 1-1) is designed to operate as a companion product to the Spectra-Physics Tsunami® mode-locked Ti:sapphire laser product.

Overview

System Components

The following components comprise the Model 3980 frequency doubler/pulse selector:

- Model 3980 frequency doubler/pulse selector
- Model 3986 or 3983 electronics module (a Model 3980-4 requires no electronics module)

The Tsunami Ti:sapphire mode-locked laser is tunable over a broad range in the red and near infrared (ir) spectrum, 690 to 1080 nm. Within this range the laser emits a nominal 80 MHz pulse train of optical pulses with duration from 80 ps to less than 80 fs, with corresponding maximum peak power output of about 150 kW. The Model 3980 frequency doubler/pulse selector allows you to select pulses at a rate lower than the nominal 80 MHz rate and to frequency double those pulses.

Figure 1-1: The Model 3980 Frequency Doubler/Pulse Selector

Because of its modular design, the Model 3980 is available in several configurations: as a frequency doubler only, a pulse selector only, or both. Each combination can be set up for either fs or ps operation. A system initially purchased with a single function can be economically upgraded to include the other at any time.

The Model 3980 typically comprises two enclosures: an optical unit containing either the frequency doubler or pulse selector or both, and an electronics control unit. A Model 3983 electronics unit comes with systems having only a ps frequency doubler, and it contains only the heater electronics for the temperature stabilization of the ps LBO (lithium tri-borate) second harmonic generation (SHG) crystal. A Model 3986 electronics unit comes with systems containing a pulse selector, and it contains the drive electronics for the pulse selector as well as the heater electronics for systems that include ps frequency doubling. The pulsed rf amplifier delivers up to 10 W bursts of ≈ 390 MHz rf energy into the rf input of the Model 3980.

If ps frequency doubling is not included in the system, the heater electronics are disabled. No electronics unit is provided when a fs doubler is ordered alone. A fs doubler system uses a BBO (barium beta borate) SHG crystal, which requires no heater.

©

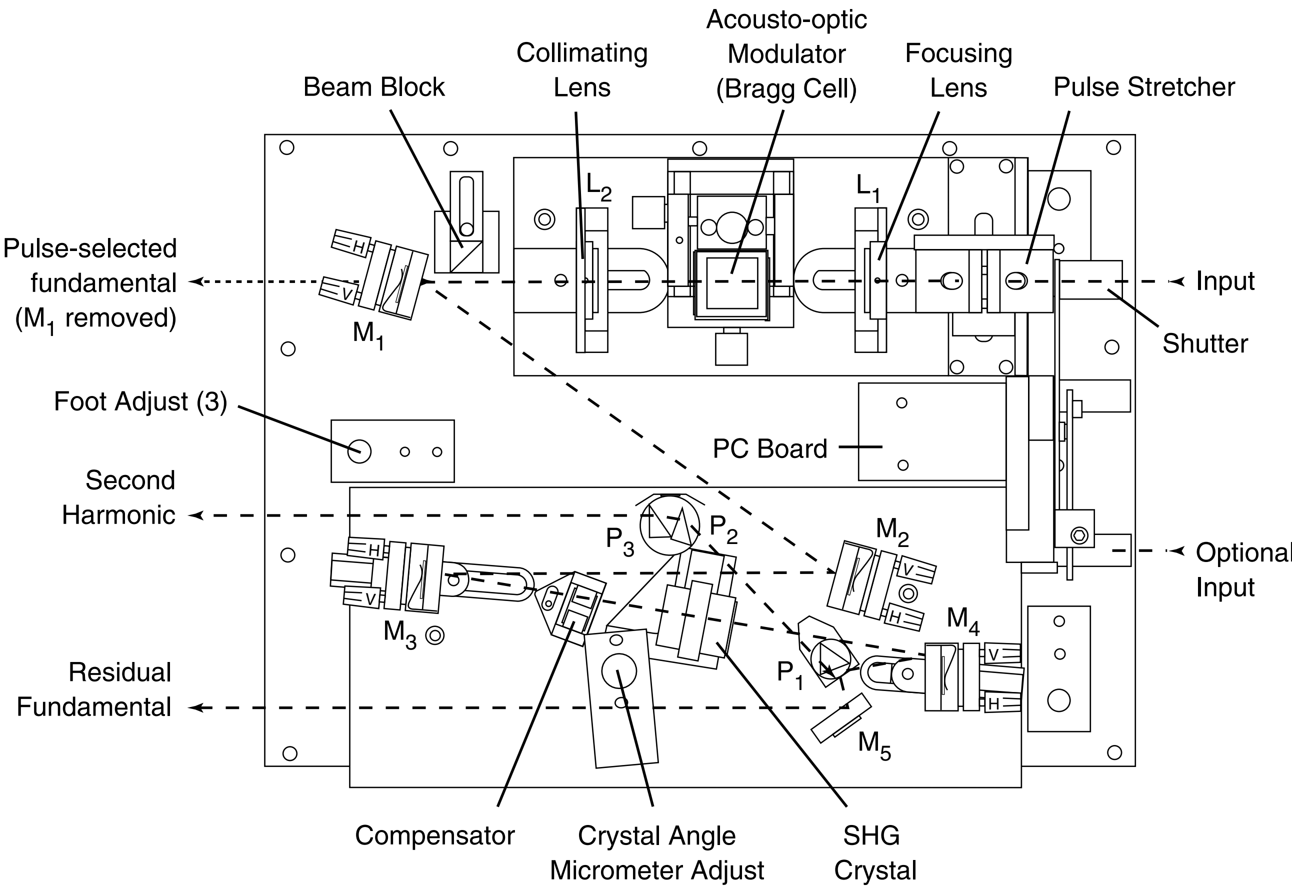


Figure 1-2: Model 3980 Schematic and Optical Beam Path

Figure 1-2 shows a Model 3980 containing both a frequency doubler and a pulse selector, each on separate platforms. There are two input ports and three output ports. In practice, only the pulse selector input port is used. This allows the Model 3980 to be butted against the Tsunami laser output bezel to save table space and preserve a collinear alignment of the two enclosures. Three output ports provide exits for the pulse-selected fundamental beam, the frequency-doubled output beam, and the residual fundamental beam from the frequency doubler.

Understanding the Model Numbers

The Model 3980 allows you to select (a) pulse selection alone, (b) frequency doubling alone, or (c) a combined operation, depending on the system purchased.

Model 3980-1	stabilized ps frequency doubling only
Model 3980-2	ps pulse selection capability only
Model 3980-3	combines the functions of the 3980–1 and 3980–2
Model 3980-4	fs frequency doubling only
Model 3980-5	ps or fs pulse selection capability only
Model 3980-6	combines the capability of the 3980-4 and 3980-5

A “B” or “S” indicates that optics and crystal are included for frequency-doubled operation from 690 to 840 nm, and “M” indicates that optics and crystal are included for frequency-doubled operation from 840 to 1080 nm. Models 3980-2S and -5S contain all the required components for pulse selection over the entire 690 to 1080 nm region for ps and fs operation respectively.

The Model 3986 electronics module contains a heater control for the frequency doubler and the electronics for the pulse selector. This unit is used with -2, -3, -5 and -6 systems. The Model 3983 electronics module contains only a heater control and is used with the -1 system. The -4 system requires no electronics.

For more information on model availability or for special requirements, please call your Spectra-Physics service representative.

Chapter 2 Laser Safety

Danger!
Laser Radiation

The Tsunami laser and its pump laser are Class IV—High Power Lasers, whose beams are, by definition, safety and fire hazards. This also applies to the beam from the Model 3980 frequency doubler/pulse selector. Take precautions to prevent exposure to both direct and reflected beams. Diffuse as well as specular reflections cause severe skin or eye damage.

Danger!
Laser Radiation

Invisible and short-pulse laser radiation present! The Model 3980 frequency doubler/pulse selector emits visible and invisible short-pulse radiation that is extremely dangerous to the eye. Infrared radiation, in particular, passes easily through the cornea, which focuses it on the retina, where it can cause instantaneous permanent damage.

Precautions for the Safe Operation of Class IV-High Power Lasers

- Wear protective eyewear at all times; selection depends on the wave length and intensity of the radiation, the conditions of use, and the visual function required. Protective eyewear is available from vendors listed in the *Laser Focus World, Lasers and Optronics,* and *Photonics Spectra* buyer's guides. Consult the ANSI or ACGIH standards listed at the end of this section for guidance.
- Keep the protective cover on the Model 3980 at all times.
- Avoid looking at the output beam; even diffuse reflections are hazardous.
- Avoid wearing jewelry or other objects that may reflect or scatter the beam while using the laser.
- Use an infrared detector or energy detector to verify that the laser beam is off before working in front of the laser or the Model 3980.
- Operate the laser at the lowest beam intensity possible, given the requirements of the application.
- Expand the beam whenever possible to reduce beam power density.
- Avoid blocking the output beam or its reflection with any part of your body.
- Establish a controlled access area for laser operation. Limit access to those trained in the principles of laser safety.
- Post prominent warning signs near the laser operation area (Figure 2-1).

- Set up experiments so the laser beam is either above or below eye level.
- Provide enclosures for beam paths whenever possible.
- Set up shields to prevent specular reflections.
- Set up an energy absorbing target to capture the laser beam, preventing unnecessary reflections or scattering (Figure 2-2).
- Maintain a high ambient light level in the laser operation area. This keeps the eye's pupil constricted, thus reducing the possibility of eye damage.

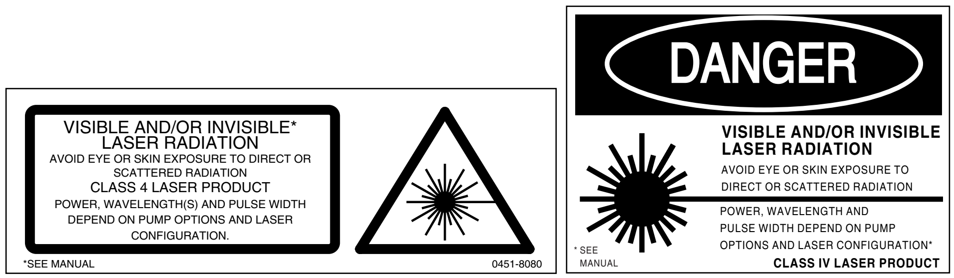


Figure 2-1: These CE and CDRH standard safety warning labels would be appropriate for use as entry warning signs (EN 60825-1, ANSI 4.3.10.1).

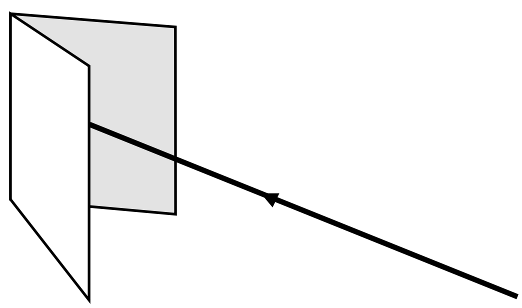


Figure 2-2: Folded Metal Beam Target

Danger! Use of controls or adjustments, or the performance of procedures other than those specified herein may result in hazardous radiation exposure.

Follow the instructions contained in this manual and your laser manuals for safe operation of your laser system. At all times during operation, maintenance, or service of your laser system, avoid unnecessary exposure to laser or collateral radiation* that exceeds the accessible emission limits listed in "Performance Standards for Laser Products," *United States Code of Federal Regulations*, 21CFR1040 10(d).

* *Any electronic product radiation, except laser radiation, emitted by a laser product as a result of, or necessary for, the operation of a laser incorporated into that product.*

Safety Devices

Interlock Shutter

Figure 2-3 shows the Model 3980 interlock shutter. The cover holds the shutter open during normal operation. When you remove the cover, the shutter closes automatically, blocking the laser beam. When the cover is off the unit and you need to access the beam, you must raise the red shutter lever to hold the shutter “open.” While in this position, the interlock obstructs the cover and the cover cannot be installed until the shutter lever is lowered to the “closed” position.

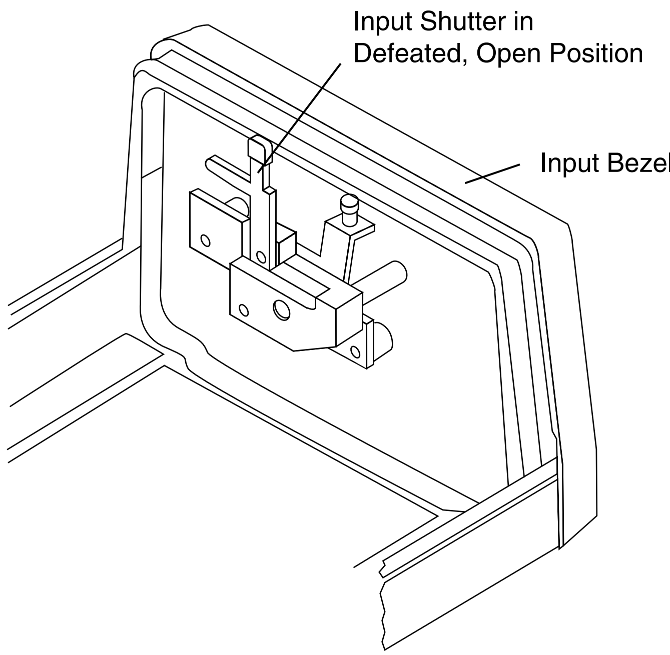


Figure 2-3: The Model 3980 Interlock Shutter

Maintenance Required to Keep this Laser Product in Compliance with Center for Devices and Radio logical Health (CDRH) Regulations

This section presents the maintenance required to keep this laser product in compliance with CDRH and CE Regulations.

This laser product complies with Title 21 of the *United States Code of Federal Regulations*, Chapter 1, Subchapter J, Parts 1040.10 and 1040.11, as applicable. To maintain compliance, verify the operation of all features listed below, either annually or whenever the product has been subjected to adverse environmental conditions (e.g., fire, flood, mechanical shock, spilled solvents). This maintenance is to be performed by the user, as out lined below.

1. Verify that removing the Model 3980 cover closes the shutter and blocks the beam.
2. Verify that, when the cover interlock is defeated (the shutter override), the defeat mechanism is clearly visible and prevents installation of the cover until it is disengaged.
3. Verify that all the labels listed in Figure 2-4, "Model 3980 CE/CDRH Warning Labels" are present and firmly affixed.
4. Verify removing the remote interlock plug on the pump laser prevents laser operation.
5. Verify the laser system will only operate when the pump laser's interlock keyswitch is in the ON position, and that the key can only be removed when the switch is in the OFF position.
6. Verify the emission indicator on the pump laser works properly; that is, it emits a visible signal whenever the laser is on.
7. Verify that the time delay between turn-on of the pump laser emission indicator and that starting of that laser gives you enough warning to allow action to avoid exposure to laser radiation.
8. Verify removing the cover of the pump laser shuts off the laser.
9. Verify, when the cover interlock on the pump laser is defeated, the defeat mechanism is clearly visible and prevents installation of the cover until disengaged.

CE/CDRH Warning Labels

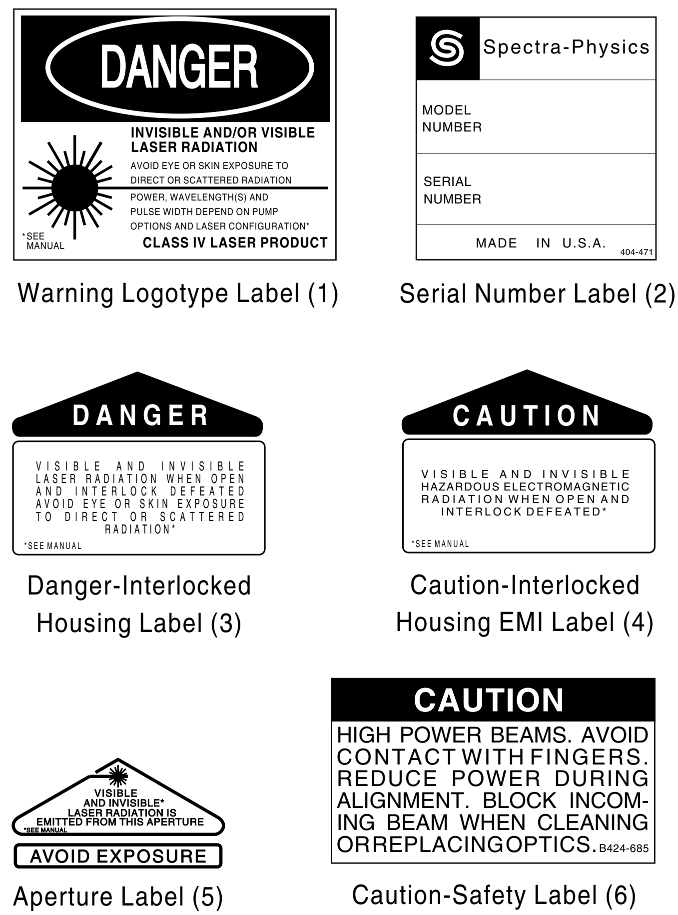


Figure 2-4: Model 3980 CE/CDRH Warning Labels

Label Translations

For safety, the following translations are provided for non-English speaking personnel. The number in parenthesis in the first column corresponds to the label number listed on the previous page.

Table 2-1: Label Translations

Label #	French	German	Spanish	Dutch
(1) CDRH Logotype Danger Label	Attention–Rayonnement Laser Visible et Invisible en Cas D'Ouverture et lorsque la securite est neutralisee; exposition dangereuse de l'oeil ou de la peau au rayonnement direct ou diffus. Puissance et longueurs D'onde dependant de la configuration et de la puissance de pompe. Laser de Classe 4.	Vorsicht; Austritt von sichtbarer un unsichtbarer Laserstrahlung wenn Abdeckung geoffnet und Sicherhetisschalter uberbruckt; Bestrahlung von Auge oder Haute durch direkte oder Streustrahlung vermeiden. Leistung, Wellenlange und Pulsbreite sind abhangig von Pumpquelle und Laserkonfiguration. Laserklasse 4.	Peligro, al abrir y retiar el dispositivo de seguridad exist radiacion laser visible e invisible; evite que los ohos o la piel queden expuestos tanto a la radiacion directa como a la dispersa. Potencia, Longitud de onda y anchura de pulso dependen de las opciones de bombeo y de la configuracion del laser. Producto laser clase 4.	Gevarr, zichtbare en neit zichtbare laserstraling wanneer geopend en bij uitgeschakelde interlock; Vermijd blootstelling van oog of huid aan directe straling of weerkaatsingen daarvan. Vermogen golfleugten en pulsduur afhankelijk van pomp optics en laser configuratie. Klasse 4 Laser Produkt.
(3) Danger, Defeatable Interlock Label	Attention- Rayonnement Laser visible et invisible en cas D'Ouverture et lorsque la securite est neutralisse; exposition dangereuse de l'oeil ou de la peau au rayonnement dirct ou diffus.	Vorsicht; Austritt von sichtbarer un unsichtbarer Laserstruhlung, wenn Abdeckung geoffnet und Sicherhetisschalter uberbruckt; Bestrahlung von Auge oder Haut durch direkte oder Streustreustrahlung vermeiden.	Peligro, al abrir y retirer el dispositivo de seguridad exist radiacion laser visible e invisible; evite que los ohos o la piel queden expuestos tanto a la radiacion dircta como a la dispersa.	Gevaar; zichtbare en niet zichtbare laser-straling wanneer geopend en bij uitgeschakelde interlock; Vermijd blootstelling van oog of huid aan directe straling of weerkaatsingen daarvan.
(4) Caution, Defeatable Interlock EMI Label	Attention. Rayonnement visible et invisible dangereux en cas d'ouverture et lorsque la sécurité est neutralisée.	Achtung! Sichtbare und unsichtbare schädliche elektromagnetische Strahlung wenn Abdeckung geöffnet und Sicherheitsverriegelung überbrückt. Bedienungsanleitung beachten!	Precaución, radiación peligrosa electromagnética visible e invisible con el dispositivo de seguridad abierto o con su indicación alterada.	Let op. Zichtbare en onzichtbare gevaarlijke electromagnetische straling indien geopend en interlock overbrugd.
(5) Aperture Label	Ouverture Laser - Exposition Dangereuse - Un Rayonnement laser visible et invisible est emis par cette ouverture.	Austritt von sichtbarer und unsictbarer Laserstrahlung; nicht dem Strahl aussetzen.	Por esta abertura se emite radiacion laser visible e invisible; evite la exposicion.	Vanuit dit apertuur wordt zichtbare en niet zichtbare laser-straling geemiteerd; vermijd blootstellilng.

CE Declaration of Conformity

We,

Spectra-Physics, Inc.
Industrial and Scientific Lasers
1330 Terra Bella Avenue
P.O. Box 7013
Mountain View, CA. 94039-7013
United States of America

declare under sole responsibility that the:

Model 3980 Frequency Doubler and Pulse Selector

manufactured after June 18, 2001,

Meets the intent of “Directive 89/336/EEC for Electromagnetic Compatibility.”

Compliance was demonstrated (Class A) to the following specifications as listed in the official *Journal of the European Communities*:

EN 61326: 1997 Emissions
EN 55011 Class A Radiated
EN 55011 Class A Conducted
EN 61326: 1997 Immunity
EN 61000-4-2: Electrostatic DIscharge
EN 61000-4-3/ENG 50204: 3 Volt/Meter Field Test
EN 61000-4-4: Electrical Fast Transient Test
EN 61000-4-5: Surge Test
EN 61000-4-6: Modulated 3 Volt Interfering Signal Test

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards.

Bruce Craig
Vice President and General Manager
Spectra-Physics, Inc.
Industrial and Scientific Lasers
August 22, 2002

CE Declaration of Conformity

We,

Spectra-Physics, Inc.
Industrial and Scientific Lasers
1330 Terra Bella Avenue
P.O. Box 7013
Mountain View, CA. 94039-7013
United States of America

declare under sole responsibility that the:

Model 3980 Frequency Doubler and Pulse Selector

manufactured after January 1, 2000,

Meets the intent of “Directive 73/23/EEC for Product Safety.”

Compliance was demonstrated to the following specifications as listed in the official *Journal of the European Communities*:

EN 61010-1: 2000 Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use
EN 60825-1: 1993 Safety for Laser Products

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directives and Standards.

Bruce Craig
Vice President and General Manager
Spectra-Physics, Inc.
Industrial and Scientific Lasers
August 22, 2002

Sources for Additional Information

The following are some sources for additional information on laser safety standards, safety equipment, and training.

Laser Safety Standards

Safe Use of Lasers (Z136.1: 1993)
American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
Tel: (212) 642-4900

Occupational Safety and Health Administration (Publication 8.1-7)
U. S. Department of Labor
200 Constitution Avenue N. W., Room N3647
Washington, DC 20210
Tel: (202) 693-1999

A Guide for Control of Laser Hazards, 4th Edition, Publication #0165
American Conference of Governmental and
Industrial Hygienists (ACGIH)
1330 Kemper Meadow Drive
Cincinnati, OH 45240
Tel: (513) 742-2020
Internet: www.acgih.org/home.htm

Laser Institute of America
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826
Tel: (800) 345-2737
Internet: www.laserinstitute.org

Compliance Engineering
70 Codman Hill Road
Boxborough, MA 01719
Tel: (978) 635-8580

International Electrotechnical Commission
Journal of the European Communities
EN60825-1 TR3 Ed.1.0—Laser Safety Measurement and Instrumentation
IEC-309—Plug, Outlet and Socket Coupler for Industrial Uses
Tel: +41 22-919-0211
Fax: +41 22-919-0300
Internet: http://ftp.iec.c.h/

Cenelec
European Committee for Electrotechnical Standardization
Central Secretariat
rue de Stassart 35
B-1050 Brussels

Document Center
1504 Industrial Way, Unit 9
Belmont, CA 94002-4044
Tel: (415) 591-7600

Equipment and Training

Laser Safety Guide
Laser Institute of America
12424 Research Parkway, Suite 125
Orlando, FL 32826
Tel: (407) 380-1553

Laser Focus World Buyer's Guide
Laser Focus World
Penwell Publishing
10 Tara Blvd., 5th Floor
Nashua, NH 03062
Tel: (603) 891-0123

Lasers and Optronics Buyer's Guide
Lasers and Optronics
Gordon Publications
301 Gibraltar Drive
P.O. Box 650
Morris Plains, NJ 07950-0650
Tel: (973) 292-5100

Photonics Spectra Buyer's Guide
Photonics Spectra
Laurin Publications
Berkshire Common
PO Box 4949
Pittsfield, MA 01202-4949
Tel: (413) 499-0514

Chapter 3 Laser Description

The Model 3980 frequency doubler/pulse selector was briefly described in Chapter 1. In this chapter, we discus, in detail, how the Model 3980 provides frequency doubling and how the pulse selector works. Specifications and outline drawings are provided at the end of this chapter.

Frequency Doubling

Because of the high peak powers available from the Tsunami® laser, frequency doubling is conveniently accomplished extracavity (the higher the peak power, the higher the conversion efficiency). Mirrors M_1 and M_2 shown in Figure 3-1 direct the output beam from the pulse selector platform to the frequency doubler platform. Mirror M_3 focuses the beam to a small waist into a critically phase-matched (angle-tuned) Type I second harmonic generation (SHG) crystal. This process produces a horizontally polarized second harmonic beam while leaving the residual fundamental vertically polarized. Mirror M_4 recollimates the beam.

The second harmonic and residual fundamental beams are separated by prism P_1, which has a high reflective (HR) coating for the residual fundamental ir wavelengths. Prism P_1 diffracts the second harmonic to prisms P_2 and P_3. These latter prisms are anti-reflection (AR) coated for the second harmonic and serve three purposes: (a) to redirect the second harmonic beam roughly parallel to the fundamental beam through the SECOND HARMONIC OUTPUT port, (b) to keep the output beam direction constant as the crystal is tuned, and (c) to compensate for the ellipticity of the second harmonic beam.

M_5 directs the residual primary beam to the RESIDUAL FUNDAMENTAL OUTPUT port.

Second harmonic output power ($P_{2\omega}$) is given by:

$$P_{2\omega} \alpha \frac{d_{eff}^2 P_\omega^2 l^2 [\phi]}{A} \qquad [1]$$

where d_{eff} is the effective nonlinear coefficient, P_ω is the fundamental input power, l is the crystal length, [ϕ] is a phase-matching factor, and A is the cross-sectional area of the beam in the crystal.

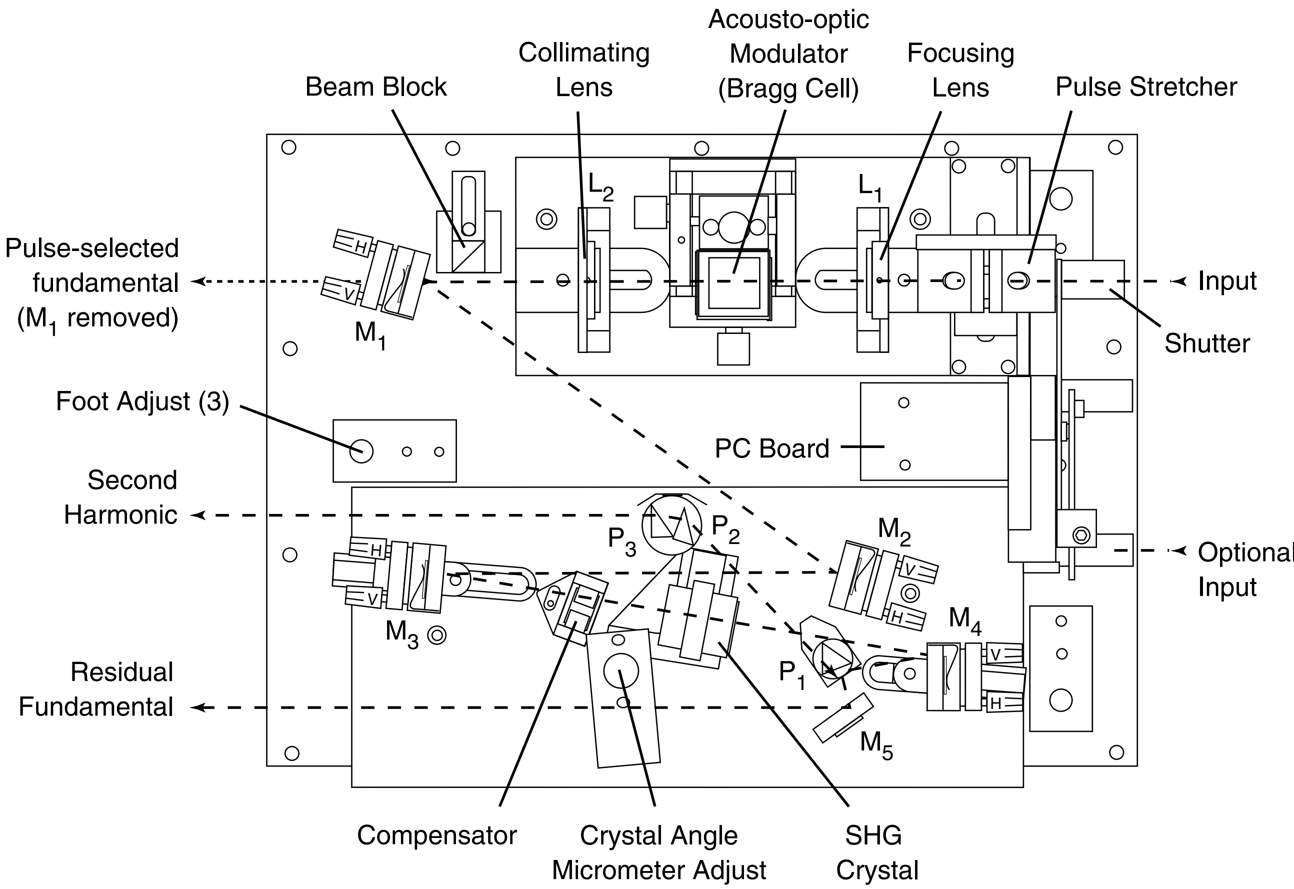


Figure 3-1: Model 3980 Schematic and Optical Beam Path

Picosecond Frequency Doubling

An LBO SHG crystal is used in picosecond (ps) systems. The crystal assembly contains one of two cuts of LBO; one cut for 690 to 900 nm operation (the "B" or "S" designation in the model dash number) and one for 840 to 1080 nm operation (the "M" designation). The crystal is AR-coated, damage resistant, and non-hygroscopic. For optimum performance, it is temperature stabilized. Because of the high acceptance angle of LBO and beam shaping within the doubler optical path, the Model 3980 maintains good output beam symmetry. In a ps system, an AR-coated silica compensating optic automatically corrects for any beam offset as the SHG crystal is angle tuned.

Pulse broadening due to material dispersion is insignificant in ps systems, which have lower peak powers than femtosecond (fs) systems. Consequently, an SHG crystal longer than that used in the fs system can be used to obtain more second harmonic power without increasing the pulse width.

Femtosecond Frequency Doubling

To minimize pulse broadening due to group velocity dispersion (GVD) in a fs system, it is necessary to employ a thin SHG crystal to obtain short, second harmonic output pulses. However, in order to maintain high conversion efficiencies, this necessitates (a) using BBO rather than LBO as the SHG crystal, and (b) using a small beam waist. An optimum beam waist is achieved by using the L_1 and L_2 lenses on the pulse selector platform as a 1.3:1 beam-expanding telescope, with L_1 = 38 mm and L_2 = 50 mm. When the pulse selector is not present, a pulse selector platform is provided with mounts only for L_1 and L_2. (See “Changing Optics” later in this chapter for exceptions.)

BBO is slightly hygroscopic and is, therefore, sealed in a small cylinder with AR-coated windows and filled with an index-matching fluid. Since a very thin SHG crystal is used, two benefits are derived: no compensating crystal is required, and only a single SHG crystal is required to phase-match over the entire tuning range (690–1080 nm).

Pulse Selection

General Description

Pulses enter the input port and are focused by lens L_1 to a narrow waist into the acousto-optic modulator (AOM). They are then recollimated by lens L_2 and either exit through the selected fundamental output port or are routed to the frequency doubler via mirror M_1. When used with fs pulses, a pulse stretcher is placed between the input port and focusing lens L_1 to minimize peak power in the AOM crystal.

The efficient, Bragg-angle AOM is synchronized to the nominal Tsunami mode-locked 80 MHz pulse train. It selects pulses from the train, at a maximum pulse selection rate of 8 MHz. The AOM changes the direction of propagation of the selected pulse by diffracting the beam about 3°, and provides a high level of discrimination between selected pulses and adjacent pulses. The crystal medium used in the AOM is chosen for its high diffraction efficiency and high level of resistance to mechanical and optical damage.

Gating Pulses Through the Bragg Cell

The Bragg cell comprises an rf-driven lithium niobate transducer and an AOM Bragg crystal cut to prevent interfering acoustic reflections. The transducer generates a 389 MHz acoustic wave that travels across the AOM crystal, interacts with the optical beam, and diffracts it. Figure 3-2 shows the beam diffraction through a typical AOM.

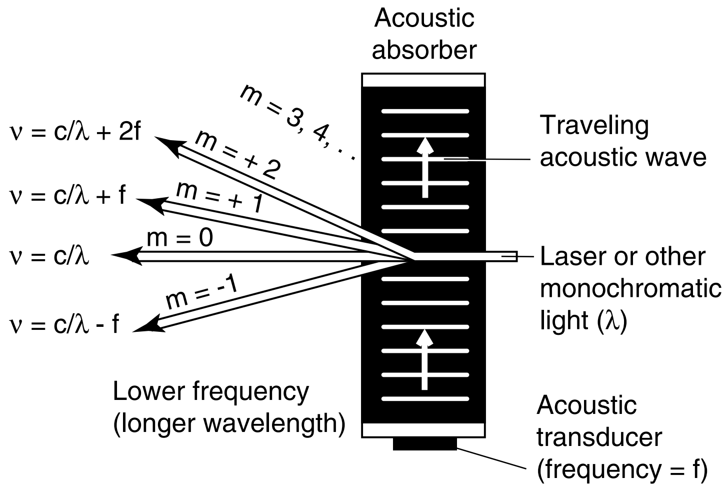


Figure 3-2: Beam Diffraction Through A Typical Acousto-optic Modulator (AOM).

When operated at the Bragg angle, only the 0 and ±1 orders are emitted. The exit angle θ of the diffracted beam is given by:

$$\theta = mf\left(\frac{\lambda}{\nu}\right) \qquad [2]$$

where m is an integer representing the diffracted order (±1 in the Bragg condition), f is the acoustic frequency, λ is the wavelength of the incident optical beam, and ν is the velocity of the acoustic wave through the crystal.

The polarization wave also modifies the optical wave such that the optical wavelength (or frequency) is slightly increased or decreased. The new frequency is given by:

$$\nu = \left(\frac{c}{\lambda}\right) \pm mf \qquad [3]$$

The intensity of the different diffracted orders, with respect to the unshifted zeroth order, is directly proportional to the acoustic power and a material figure of merit. For convenience, in the Model 3980 we utilize the $m = -1$ diffracted beam and employ a beam block to capture the low power undiffracted beam.

Maintaining Good Beam Size

To achieve good pre- and post-pulse discrimination, it is necessary to use a small beam size in the AOM crystal. Lens L_1 produces a waist in the modulator of about 40 µm. Lens L_2 recollimates the diffracted beam. Below 1000 nm, 50 mm AR-coated lenses are employed; above 1000 nm, 38 mm lenses are used in order to maintain a small beam waist. Both sets of lenses are provided with the ps or fs pulse selectors.

Protecting the AOM

The AOM in the Model 3980 can be damaged with optical power > 1 GW/cm^2. While this means the system can be safely operated with ps input pulses, for fs systems suitable precautions must be employed to prevent damage to the AOM Bragg cell. Because the peak powers in fs pulses can easily exceed those of ps pulses by a factor of 20, the electric field strength/peak power density in the Bragg cell must be reduced.

To accomplish this, a pulse stretcher must be placed in front of the AOM for fs systems. The pulse stretcher increases the pulse width and decreases the peak electric field in the Bragg cell to prevent dielectric breakdown. Figure 3-3 shows the pulse width from the pulse stretcher as a function of input pulse width for two higher power input wavelengths, 790 and 850 nm. Note that if the input pulse is shorter than 80 fs for 790 nm, the output pulse is greater than 200 fs and the peak power in the Bragg cell will be reduced below the damage threshold. When the input pulses are greater than 80 fs, they are stretched less and the peak power may be high enough to cause damage. As also indicated in this figure, input pulses between 80 and 180 fs should be avoided *or damage to your Bragg cell will result.* Please note that the 1053 and 900 nm wavelengths do not contain enough energy to warrant concern.

At longer wavelengths than 850 nm, the input pulses undergo less pulse width broadening in the stretcher, but the average output power from the Tsunami decreases. Consequently, the AOM is not susceptible to damage. However, the stretcher should be employed for all fs input pulses, irregardless of wavelength.

Warning!

When selecting fs pulses, input pulses must be shorter than 80 fs with input power <1.1W, and the pulse-stretcher must be mounted in the system. Failure to do this can result in damage to the Bragg cell. *Such damage is not covered under your warranty.*

Because maintaining minimum pulse width and maximum bandwidth is important, have diagnostic equipment available capable of measuring pulse width (an autocorrelator) and/or bandwidth (a spectrometer). If there is 1.1 W of average power with less than 80 fs input pulse width, or greater than 15 nm bandwidth at 800 nm, the system will operate safely.

If you inadvertently damage the Bragg cell because the focused spot is less than 40 µm, it is possible to translate the AOM to a new region in the material. However, this region will probably have a lower diffraction efficiency.

Warning!

To prevent thermal damage to the antireflection coating on the optics, power must be kept below 1.1 W for fs systems and below 1.3 W for ps systems. *Such damage is not covered under your warranty.*

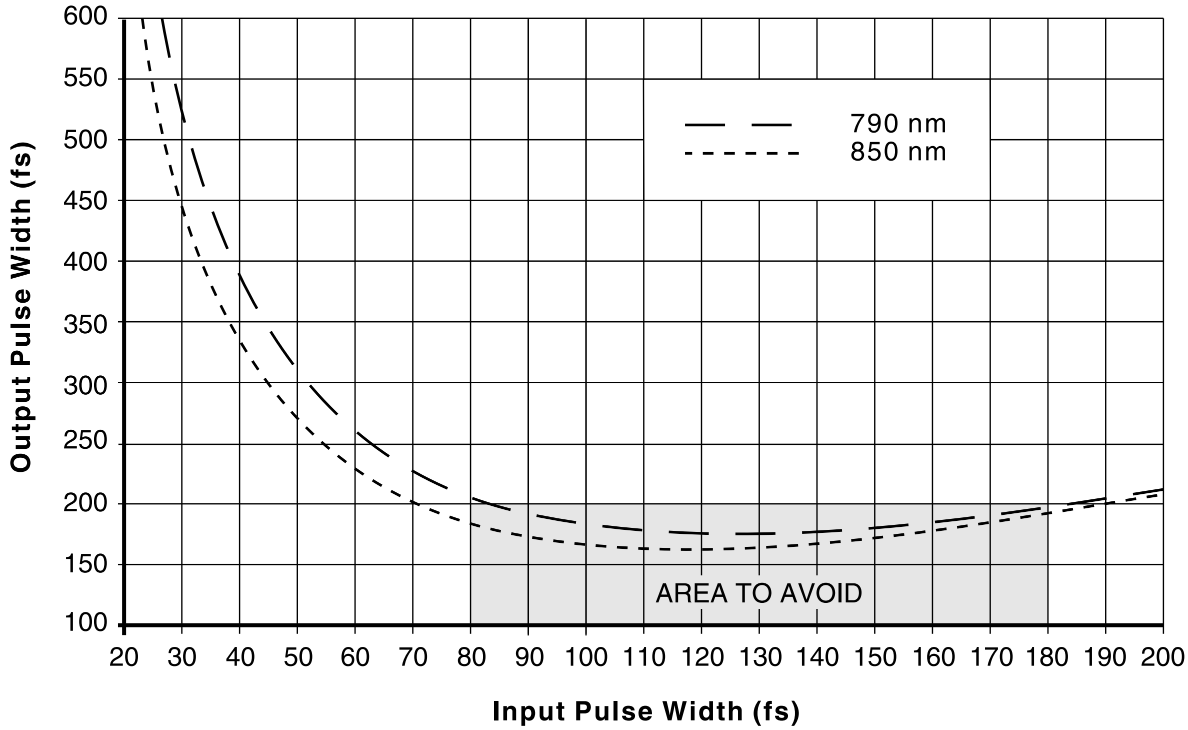


Figure 3-3: Output pulse width from the AOM as a function of input pulse width.

Changing Optics

Because every optical element in the Model 3980 frequency doublers is either HR or AR coated, it is necessary to replace each optical element when changing between tuning ranges 690–840 nm and 840–1080 nm (with the exception of L_1 and L_2 and the BBO SHG crystal in a fs system).

For the pulse selector version, two standard lens sets are provided which cover the entire wavelength range. For pulse selection only, 50 mm lenses are used for both L_1 and L_2 for wavelengths < 1000 nm, and 38 mm lenses are used for those > 1000 nm.

The Model 3986

The Model 3986 delivers up to 10 W bursts of ≈ 390 MHz rf energy to the AOM. Burst duration is ≈ 10 ns, which is roughly four rf cycles. It allows the user to modify the ratio of the selected pulse to the adjacent pulses. While pre- or post-selected pulses can be suppressed in magnitude, the contrast ratio between them and the selected pulse are maintained at a minimum ratio of 300:1. The Model 3986 ensures control of this contrast ratio and maintains high Bragg diffraction efficiency over the entire Tsunami laser tuning range.

The frequency of the rf burst is phase-locked to be an exact multiple (9.5 x) of the ≈ 80 MHz free spectral range of a ≈ 1.8 m laser cavity (round trip time ≈ 12 ns).

The time interval between the rf bursts is also phase-locked with the laser cavity frequency and may be from 10 to 8000 cavity periods, selectable from 16 divider ratios. To aid with generating special divider ratios externally, synchronizing output and input connections are provided.

The synchronizing signal derived from the laser may be either ≈ 80 MHz or ≈ 40 MHz. An internal oscillator is provided for stand-alone unit testing.

The optical pulses selected may be frequency doubled using the Model 3980 options described in “Understanding the Model Numbers” earlier in this chapter. The doubling crystal temperature control electronics are included in the Model 3986.

Performance Specifications

The performance specifications for the Model 3980 frequency-doubling operation are highly dependent upon the performance of the Tsunami laser, particularly its pulse width (which effects peak power) and average power.

Table 3-1: Model 3980-1 ps Frequency Doubler Performance[1]

Specification	355 nm (B)	395 nm (S)	450 nm (M)
Average Power[2]			
with Millennia® Xs pump	40 mW	200 mW	100 mW
with Millennia VIIIs pump	30 mW	150 mW	80 mW
with Millennia Vs pump	15 mW	55 mW	30 mW
Pulse width[2,3]	<2 ps	<2 ps	<2 ps
Tuning range[4]	345–420 nm	360–450 nm	420–540 nm
Repetition rate[5]	≈ 80 MHz	≈ 80 MHz	≈ 80 MHz
Beam diameter at $^1/_{e^2}$ points	<2 mm	<2 mm	<2 mm
Beam divergence, full angle	<1.5 mrad	<1.5 mrad	<1.5 mrad

Table 3-2: Model 3980-4 fs Frequency Doubler Performance[1]

Specification	355 nm (B)	395 nm (S)	450 nm (M)
Average Power[2]			
with Millennia Xs pump	40 mW	200 mW	100 mW
with Millennia VIIIs pump	30 mW	150 mW	80 mW
with Millennia Vs pump	15 mW	65 mW	30 mW
Pulse Width[3]	<200 fs	<200 fs	<250 fs
Tuning Range	345–420 nm	360–450 nm	420–540 nm
Repetition rate[5]	≈ 80 MHz	≈ 80 MHz	≈ 80 MHz
Beam diameter at $^1/_{e^2}$ points	<2 mm	<2 mm	<2 mm
Beam divergence, full angle	<1.5 mrad	<1.5 mrad	<1.5 mrad

[1] *Specifications subject to change without notice and only apply when the Model 3980 is used in conjunction with a Tsunami® laser pumped by a Spectra-Physics Millennia Vs, VIIIs, or Xs solid state laser.*
[2] *Specifications apply to operation at the wavelength noted.*
[3] *Based upon the pulse width of the fundamental.*
[4] *Based upon the tuning range of the fundamental.*
[5] *Operation is specified at a nominal repetition rate of 80 MHz.*

Table 3-3: Model 3980-2 ps Pulse Selector Performance[1]

Specification	710 nm	790 nm	900 nm
Average Power[2] (at 8 MHz)			
with Millennia Xs pump	>40 mW	>78 mW	>60 mW
with Millennia VIIIs pump	>34 mW	>66 mW	>46 mW
with Millennia Vs pump	>24 mW	>46 mW	>30 mW
Pulse Energy[2,3]			
with Millennia Xs pump	>5.0 nJ	>9.7 nJ	>7.5 nJ
with Millennia VIIIs pump	>4.2 nJ	>8.2 nJ	>5.7 nJ
with Millennia Vs pump	>3.0 nJ	>5.7 nJ	>3.7 nJ
Tuning range[4]	690−1080 nm	690−1080 nm	690−1080 nm

Table 3-4: Model 3980-3 ps Pulse Selector/Doubler Performance[1]

Specification	710 nm	790 nm	900 nm
Average Power[2] (at 8 MHz)			
with Millennia Xs pump	>3.0 mW	>6.0 mW	>5.0 mW
with Millennia VIIIs pump	>2.4 mW	>5.0 mW	>3.0 mW
with Millennia Vs pump	>1.0 mW	>3.2 mW	>1.6 mW
Pulse Energy[2,3]			
with Millennia Xs pump	>0.37 nJ	>0.75 nJ	>0.62 nJ
with Millennia VIIIs pump	>0.30 nJ	>0.62 nJ	>0.37 nJ
with Millennia Vs pump	>0.12 nJ	>0.40 nJ	>0.20 nJ
Tuning range[4]	345−420 nm	360−450 nm	420−540 nm

[1] *Specifications subject to change without notice and only apply when the Model 3980 is used in conjunction with a Tsunami laser pumped by a Spectra-Physics Millennia® Vs, VIIIs or Xs solid-state laser.*
[2] *Specifications apply to operation at the wavelength noted.*
[3] *Pulse energy is independent of repetition rate (available from 8 JHz to single shot).*
[4] *Based upon the tuning range of the fundamental.*

Table 3-5: Model 3980-2 ps Pulse Selector, -3 ps Pulse Selector/Doubler Performance[1]

Specification	
Diffraction Efficiency	60%
Contrast Ratio[2]	300:1
Repetition Rate	Available from 8 MHz to single shot
Beam Diameter at $^1/_{e^2}$ points	<2 mm
Beam Divergence, Full Angle	<1.5 mrad

[1] *Specifications subject to change without notice and only apply when the Model 3980 is used in conjunction with a Tsunami laser pumped by a Spectra-Physics Millennia Vs, VIIIs or Xs solid-state laser.*
[2] *Contrast ratio applies to the fundamental beam. Second harmonic generation in the Models 3980-3, -5 will increase contrast ratio to >10^4:1.*

Table 3-6: Model 3980-5 fs Pulse Selector Performance[1]

Specification	710 nm	790 nm	900 nm
Average Power[2] (at 8 MHz)			
with Millennia Xs pump	>26 mW	>66 mW	>40 mW
with Millennia VIIIs pump	>22 mW	>66 mW	>30 mW
with Millennia Vs pump	>18 mW	>46 mW	>22 mW
Pulse Energy[2,3]			
with Millennia Xs pump	>3.2 nJ	>8.2 nJ	>5.0 nJ
with Millennia VIIIs pump	>2.7 nJ	>8.2 nJ	>3.7 nJ
with Millennia Vs pump	>2.2 nJ	>5.7 nJ	>2.7 nJ
Tuning range[4]	690–1080 nm	690–1080 nm	690–1080 nm

Table 3-7: Model 3980-6 fs Pulse Selector/Doubler Performance[1]

Specification	710 nm	790 nm	900 nm
Average Power[2] (at 8 MHz)			
with Millennia Xs pump	>0.5 mW	>1.8 mW	>0.8 mW
with Millennia VIIIs pump	>0.4 mW	>1.8 mW	>0.6 mW
with Millennia Vs pump	>0.3 mW	>1.0 mW	>0.4 mW
Pulse Energy[2,3]			
with Millennia Xs pump	>0.06 nJ	>0.22 nJ	>0.10 nJ
with Millennia VIIIs pump	>0.05 nJ	>0.22 nJ	>0.07 nJ
with Millennia Vs pump	>0.04 nJ	>0.12 nJ	>0.05 nJ
Tuning range[4]	345–420 nm	360–450 nm	420–540 nm

[1] *Specifications subject to change without notice and only apply when the Model 3980 is used in conjunction with a Tsunami laser pumped by a Spectra-Physics Millennia® Vs, VIIIs or Xs solid-state laser.*
[2] *Specifications apply to operation at the wavelength noted.*
[3] *Pulse energy is independent of repetition rate (available from 8 JHz to single shot).*
[4] *Based upon the tuning range of the fundamental.*

Table 3-8: Model 3980-5 fs Pulse Selector, -6 fs Pulse Selector/Doubler Performance[1]

Specification	
Diffraction Efficiency	60%
Contrast Ratio[2]	300:1
Repetition Rate	Available from 8 MHz to single shot
Beam Diameter at $^1/_{e^2}$ points	<2 mm
Beam Divergence, Full Angle	<1.5 mrad

[1] *Specifications subject to change without notice and only apply when the Model 3980 is used in conjunction with a Tsunami laser pumped by a Spectra-Physics Millennia Vs, VIIIs or Xs solid-state laser.*
[2] *Contrast ratio applies to the fundamental beam. Second harmonic generation in the Models 3980-3, -5 will increase contrast ratio to >10^4:1.*

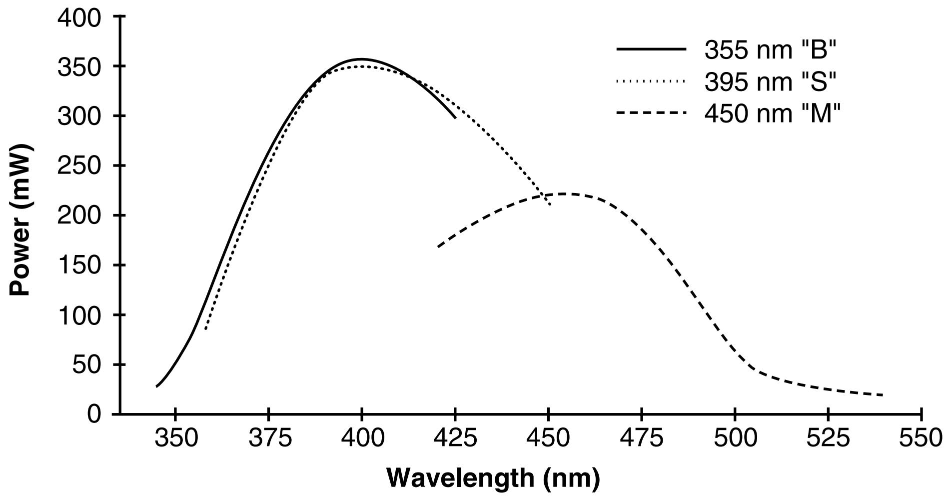


Figure 3-4: Typical frequency-doubled, Tsunami ps tuning curves using 10 W TEM_{00} pump power from a Millennia Xs.

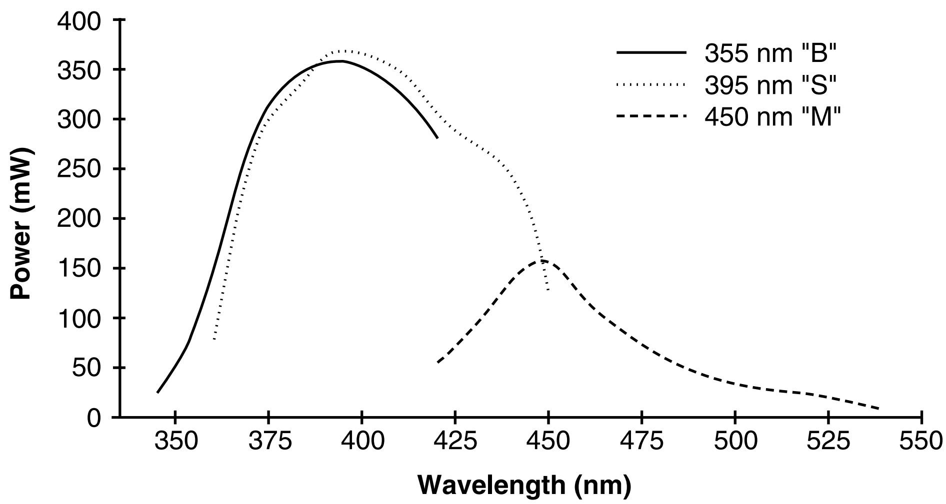
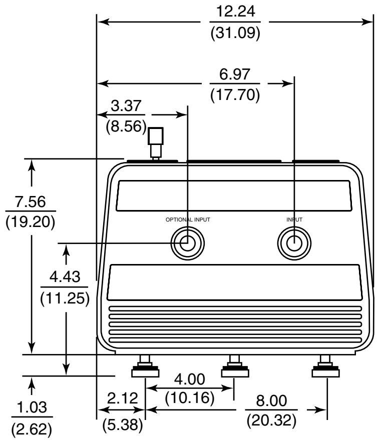


Figure 3-5: Typical frequency-doubled, Tsunami fs tuning curves using 10 W TEM_{00} pump power from a Millennia Xs.

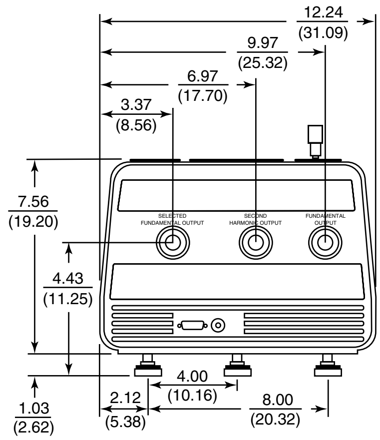
Table 3-9: Electrical/Mechanical Specifications

Electronics Unit	
Model 3986	90 to 250 Vac, 3.15AH 250 VA
Model 3983	100/120 Vac @ 0.125 A 250 V or 220/240 Vac @ 0.25 A 250 V
Weight	
Model 3980	16.0 kg (35.4 lb)
Model 3986	11.0 kg (24.3 lb)
Model 3983	2.3 kg (5.0 lb)

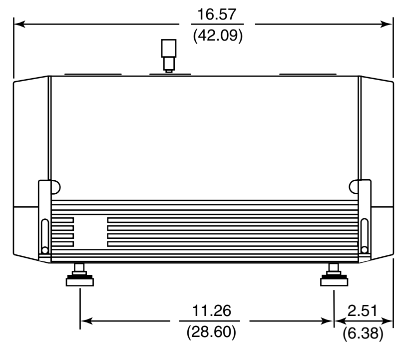
Outline Drawings



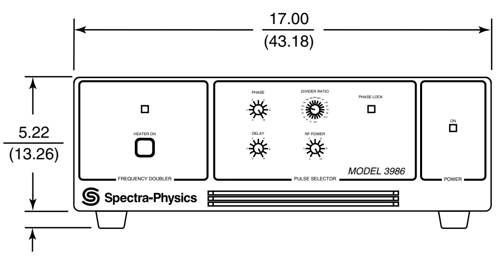
Model 3980 (Input End)



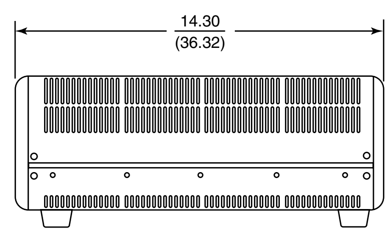
Model 3980 (Output End)



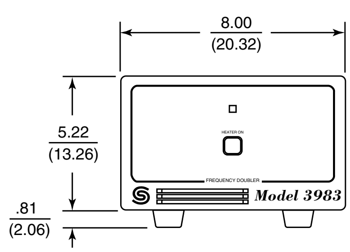
Model 3980 (Side View)



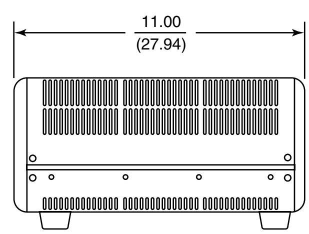
Model 3986 (Front View)



Model 3986 (Side View)



Model 3983 (Front View)



Model 3983 (Side View)

All dimensions in $\frac{\text{inches}}{\text{(cm)}}$

Figure 3-6: Outline Dimensions for the Model 3980, Model 3986, and Model 3983

Chapter 4 Controls, Indicators and Connections

Optical Unit

External Controls

The external controls are described from left to right, top to bottom as they are shown in Figure 4-1.

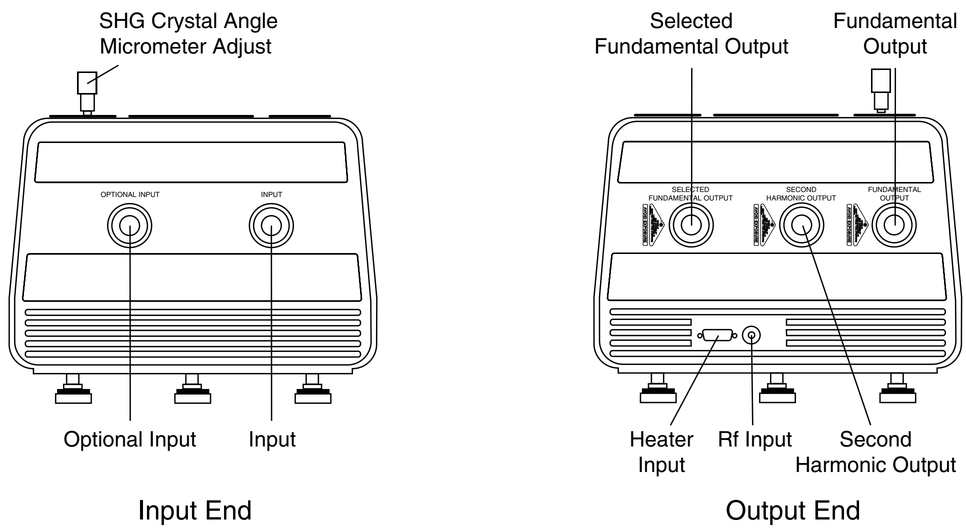


Figure 4-1: External Controls and Ports

SHG crystal angle micrometer adjust—rotates the SHG crystal (and the compensator in ps systems) horizontally about the vertical axis to phase-match the crystal for optimum second harmonic output. The scale markings on the micrometer are relative and do not indicate absolute position.

OPTIONAL INPUT port—provides an alternative input when the pulse selector is not present. In practice, only the pulse selector INPUT port is used (see INPUT port below).

INPUT port—provides an input for the Tsunami® beam to enter the pulse selector. When the pulse selector is absent, M_1 is used to redirect the beam to M_2 of the frequency doubler.

SELECTED FUNDAMENT OUTPUT port—provides an exit for the pulse selected beam.

FUNDAMENTAL OUTPUT port—provides an exit for the residual fundamental beam reflected from the frequency doubler P_1 beam splitter prism.

Heater input connector (9-pin D-sub)—provides attachment for the heater cable from the HEATER connector on the Model 3986 or 3983. This connection is only present when the ps frequency doubler is installed and provides power to and sensor signals from the LBO SHG crystal heater. It is located on the output bezel.

Rf input connector (BNC)—provides attachment for the AOM rf drive signal cable from the RF OUT connector on the Model 3986. It is located on the output bezel.

SECOND HARMONIC OUTPUT port—provides an exit for the second harmonic output beam from the frequency doubler.

General Purpose Controls

Foot adjust (3)—moves the feet up and down to adjusts the tilt and height of the Model 3980. There is one foot in each corner on the input side, and one centered on the output side. Each foot screws up and down in the bottom cover and is locked in place by a jam nut (ring) located on the foot just under the cover. To move the foot, loosen the jam nut, then use a 5/32 in. hex driver from inside the unit to screw the foot up and down. When all feet have been properly positioned, tighten the jam nuts to lock the feet in place.

Shutter—blocks the Tsunami laser input beam as a safety precaution when the Model 3980 cover is removed. With the cover off, it can be defeated by manually raising the red-tipped lever. Refer to Chapter 2, "Laser Safety," for information and warnings on defeating the shutter. The lever must be lowered before the cover can be replaced.

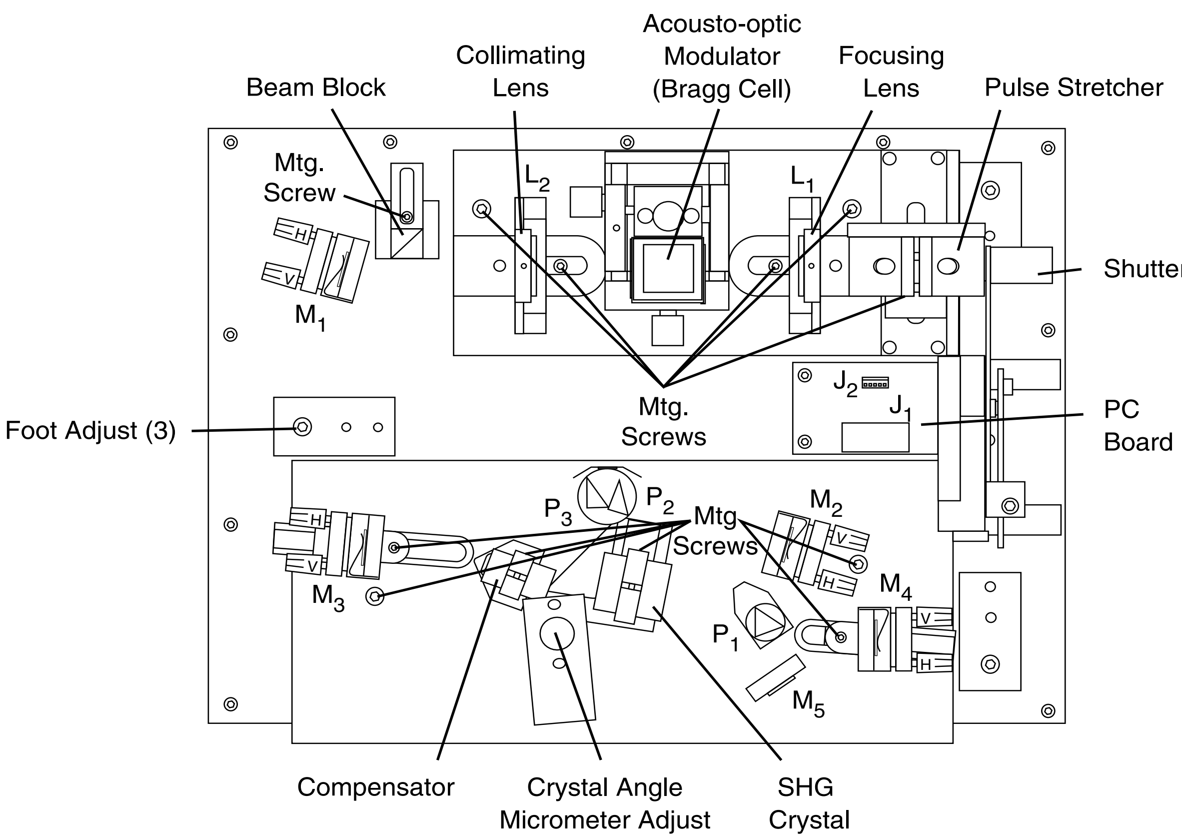


Figure 4-2: Model 3980 Optical Elements

Pulse Selector Controls

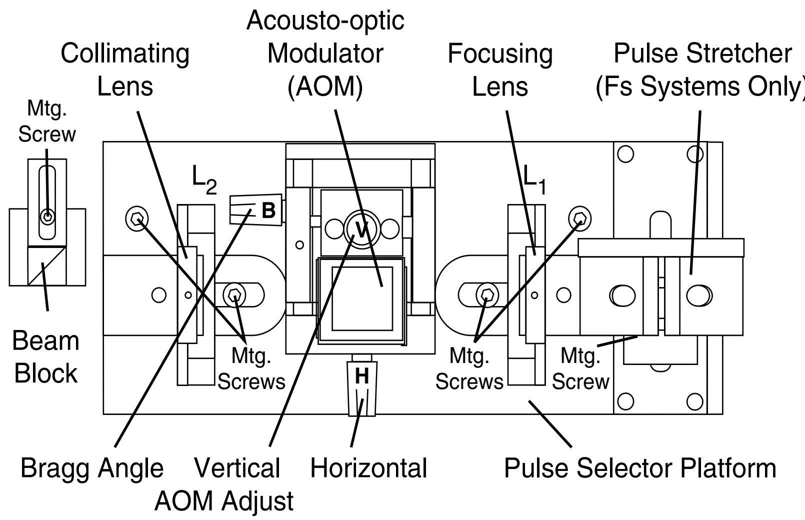


Figure 4-3: Pulse Selector Components and Controls

For systems with only a pulse selector, or for those who only use the pulse selector, routing mirror M_1 is absent or removed and the pulse-selected beam passes out through the SELECTED FUNDAMENTAL OUTPUT port.

Pulse stretcher—used with fs systems to prevent damage to the AOM Bragg cell. Two Brewster's angle SFL-57 glass rods broaden the pulse. A single mounting screw on the foot, when loosened, allows you to slide it horizontally in and out of the beam. Loosening the screw on the vertical stem allows you to adjust the rods up and down.

Warning! A fs pulse can permanently damage the AOM Bragg cell if the pulse stretcher is not installed. This is a very expensive crystal and *such damage is not covered by your warranty.*

Focusing lens L_1—focuses the input beam into the active region of the acousto-optic modulator for proper pulse selection. To focus, loosen the single mounting screw in the slide that secures it to the floor and move it back and forth along the beam direction. Adjust L_1 horizontally by loosening the two screws in the slotted lower mount and manually moving the upper structure. Adjust it vertically by loosening the single screw in the slotted lens holder and manually moving the lens holder up and down. To insert or remove the optic, pull back on the spring clip holding it in place.

L_1 is also used in conjunction with L_2 as a 1.3:1 beam expanding telescope when the Model 3980 is configured for use as a fs frequency doubler.

Acousto-optic modulator (AOM)—diffracts the optical beam by means of the Bragg effect when an rf-generated acoustic wave interacts with the optical beam. The AOM has three adjustments: Bragg angle, vertical, and horizontal (Figure 4-4). Four screws fasten the AOM shield to the mount, and a slot on both sides of the shield allows the beam to pass through while protecting the transducer from damage. One edge of the slot is aligned to keep the incoming beam from burning the transducer wires.

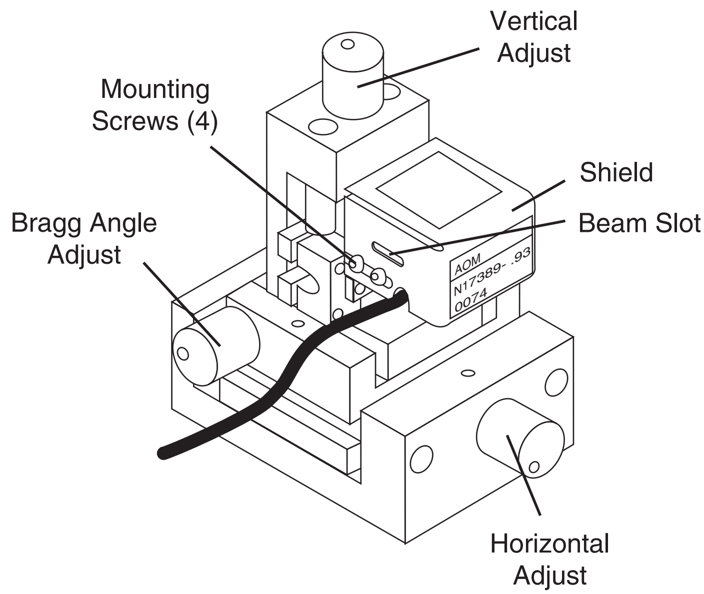


Figure 4-4: **AOM and Controls**

The Bragg control rotates the Bragg cell horizontally with respect to the input beam for selecting the output order and to optimize the performance of the selected order. The vertical and horizontal controls provide adjustment for placing the Bragg cell's active region in the beam. The region of highest diffraction efficiency is located about 1 mm horizontally from the transducer (which is on the side nearest the AOM label).

The horizontal control is also used to move the Bragg cell out of the beam when you want to bypass the pulse selector and only use the frequency doubler. Refer to Figure 5-2

Collimating lens L_2—collimates the diverging AOM exit beam, and directs it to either the SELECTED FUNDAMENTAL OUTPUT port if only the pulse selector unit is installed (M_1 is absent), or fold mirror M_1 when the frequency doubler is installed (Figure 4-3).

L_2 is also used in conjunction with L_1 as a 1.3:1 beam expanding telescope when the Model 3980 is configured for use as a fs frequency doubler.

L_2 has the same adjustments as L_1 (refer to "Focusing lens L_1"above).

Beam block—blocks the undiffracted zeroth order beam. It has a single mounting screw that secures it in a slide in the floor and, when loosened, allows you to slide the beam block horizontally in and out of the beam (Figure 4-3). The beam block is not part of the pulse selector platform but mounts directly to the Model 3980 chassis floor.

Frequency Doubler Controls

Refer to (Figure 4-5).

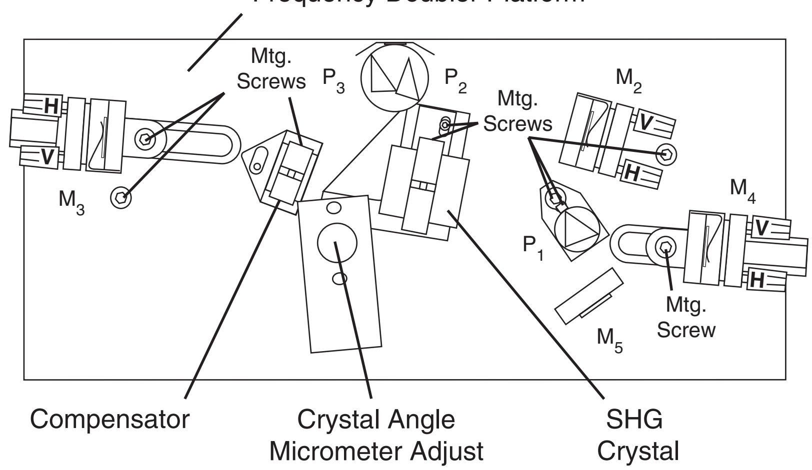


Figure 4-5: Frequency Doubler Components and Controls

Beam routing mirrors M_1 and M_2—route the Tsunami input beam from the pulse selector platform to the frequency doubler assembly. Each mirror has vertical and horizontal adjustment knobs. While mirror M_2 is part of the frequency doubler platform, M_1 is not. It is located near the SELECTED FUNDAMENTAL OUTPUT port and is mounted directly to the floor of the Model 3980 chassis (Figure 4-2). To remove or replace the optic, pull back on the spring clip holding it in place; you do not need to remove the entire mount.

Focusing mirror M_3—focuses the input from M_2 to a beam waist in the center of the SHG crystal. This mirror has vertical and horizontal adjustment knobs for modifying beam direction. Loosening the single mounting screw securing it to the floor allows you to slide it back and forth to optimize the location of the beam waist in the SHG crystal for maximum doubling efficiency.

Compensator—maintains beam alignment by rotating counter to the picosecond (ps) LBO SHG crystal when the SHG crystal is angle-tuned for optimum power. It is made of antireflection-coated (AR) fused silica, and is approximately the same optical thickness as the LBO SHG crystal.

The compensator crystal is removed for femtosecond (fs) operation by loosening the clamping screw at the top of the holder and sliding the crystal out. A single adjustment, a setscrew inside a jam nut, allows rotation of the assembly. This adjustment is made at the factory and should not need readjustment.

Second harmonic generating (SHG) crystal—converts the fundamental input from mirror M_3 into second harmonic radiation. The LBO crystal in a ps system is much longer than the BBO crystal in a fs system. Upon exiting the crystal, the diverging residual fundamental beam and the frequency-doubled beam travel collinearly to collimating mirror M_4. These beams are polarized in orthogonal directions.

The micrometer adjust that extends through the top cover rotates the crystal to optimize the frequency-doubled output. If the beam becomes clipped while using this adjustment, the small screw next to the crystal may be loosened and the crystal manually moved so that the beam is no longer clipped. Unlike the BBO crystal, the LBO crystal is removed along with the heater assembly by loosening the clamping screw on the top of the holder and sliding the crystal out. Also unplug the heater cable at J_2 on the PC board. (Remember to plug it back in when replacing it.)

Collimating mirror M_4—collimates the divergent fundamental and frequency-doubled components from the SHG crystal. This mirror has vertical and horizontal adjustment knobs for modifying beam direction. Loosening the single mounting screw securing it to the floor allows you to slide the assembly back and forth to optimize the collimation of the SHG beam.

Beam splitter prism P_1—separates the SHG harmonic from the fundamental radiation. The coated surface reflects the fundamental beam to routing mirror M_5. The frequency-doubled component diffracts through the prism and is directed to Littrow prisms P_2 and P_3. Any residual fundamental radiation is diffracted away from the Littrow prisms. Loosening a single setscrew on the side of the mount allows you to rotate the prism and move it up and down. The location of the mount is set at the factory and the large mounting screw in the foot should not require readjustment.

Littrow prisms P_2 and P_3—(a) correct the output beam horizontal displacement caused by tuning the SHG crystal, (b) compensate for the elliptical beam shape caused by the SHG crystal itself, then (c) redirect the frequency-doubled beam to the SECOND HARMONIC OUTPUT port. Loosening the setscrew on the side of the mount allows you to rotate the prisms and move them up and down.

Fundamental high-reflecting mirror M_5—directs residual fundamental radiation from the frequency doubler to the FUNDAMENTAL OUTPUT port. M_5 has a spring-loaded rotational adjustment range of about 10°. If it should need adjustment, grasp the mount and manually rotate it.

SHG crystal angle-adjust micrometer—rotates the SHG crystal (and the compensator in ps systems) horizontally about the vertical axis to phase-match the crystal for optimum second harmonic output. The scale markings on the micrometer are relative and do not indicate absolute position.

Model 3986 Electronics Unit

The controls are described from left to right, top to bottom.

Front Panel Controls

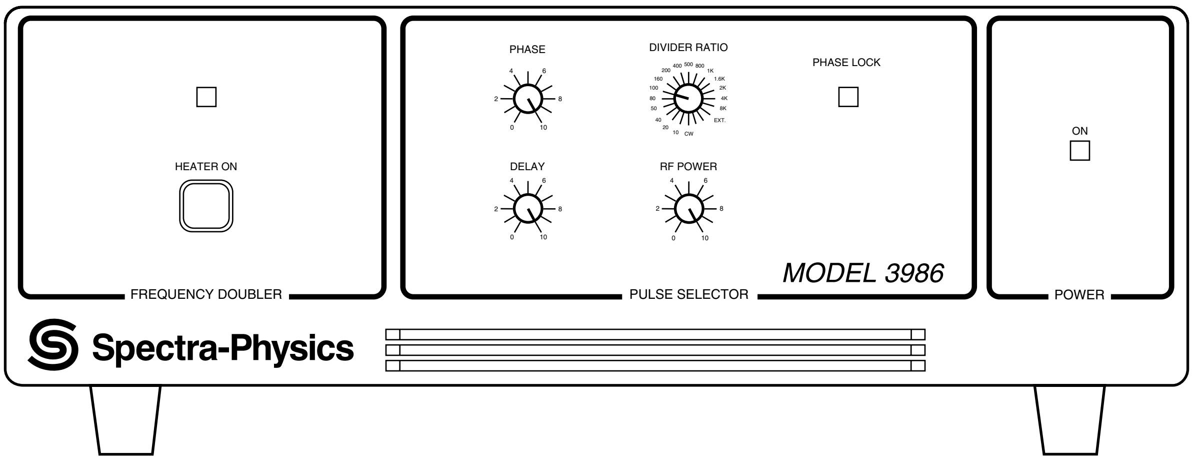


Figure 4-6: Model 3986 Front Panel

FREQUENCY DOUBLER: heater status indicator—when green, indicates the SHG crystal is at operating temperature; when red, indicates power is applied to the heater but the SHG crystal is not at operating temperature; when flashing red, indicates the heater circuit is not connected or has an open circuit (refer to the Troubleshooting Guide in Chapter 8). When the system is turned on initially, expect a delay of 5 minutes for the heater to reach operating temperature.

FREQUENCY DOUBLER: HEATER ON push-button switch—toggles on and off power to the heater for the ps LBO SHG crystal.

PULSE SELECTOR: PHASE and DELAY controls—synchronize the pulse selector to the incoming mode-locked pulse. Use the delay control for coarse adjustment and the phase control for fine adjustment.

PULSE SELECTOR: DIVIDER RATIO control—selects one of three modes of operation. The CW setting applies a continuous rf signal to the AOM and yields about 5% to 10% of maximum diffracted output to the SELECTED FUNDAMENTAL OUTPUT port or to the frequency doubler, depending on system optical configuration. The CW position is normally only used to optimize the Bragg diffraction condition and to assist in optical beam alignment.

The divider ratio settings produce a pulse train that is based on and is synchronous with the laser pulse train but is reduced in frequency by the selected setting. The divider ratios are shown below. As an example, to select every 10th pulse, set the unit to “10,” etc.

10	100	500	2000
20	160	800	4000
40	200	1000	8000
80	400	1600	

The EXT mode allows external pulse control. See “EXT TRIG IN connector” under the “Rear Panel Controls and Connections” section below for the definition of, and requirements for, external signals.

PULSE SELECTOR: RF POWER control—sets the amount of pulse power applied to the AOM and, thus, the intensity of the diffracted –1 order (selected) beam.

PHASE LOCK indicator—when green, indicates that the phase loop has a sync signal and is functioning.

POWER ON indicator—glows green when the Model 3986 is turned on, i.e., when the power cord is connected to facility power and the rear panel power switch is turned on.

Rear Panel Controls and Connections

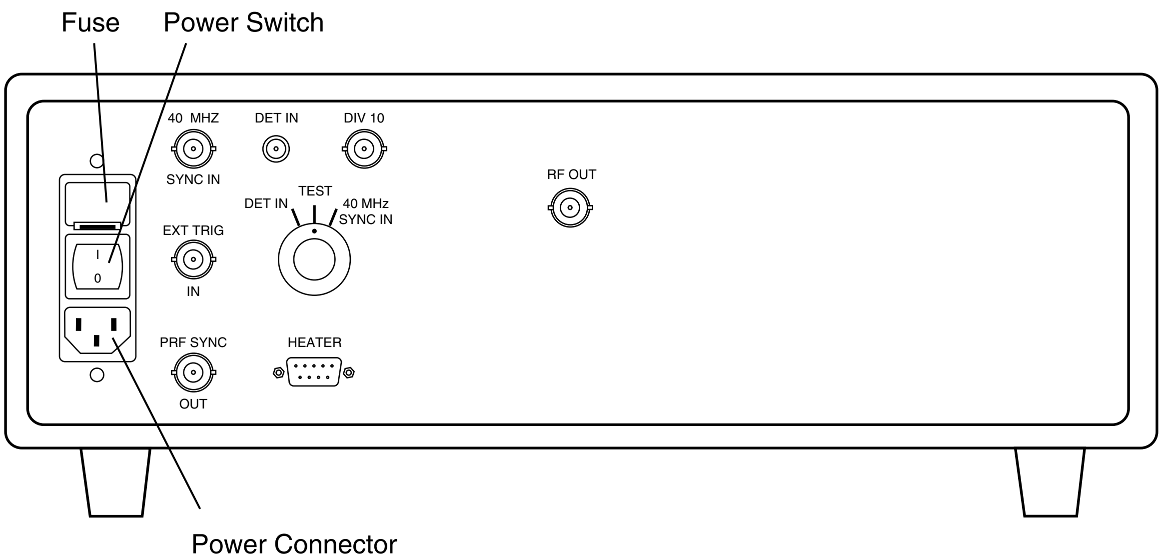


Figure 4-7: Model 3986 Rear Panel

Fuse—provides a safety switch to protect internal components in the event there is a power surge. Use fuse type F3.15AH, 250 V (5 x 20 mm).

Power on/off switch—applies ac power to the system if the power cord is connected to your facility power source.

Power cord connector—provides attachment for the ac power cord. Input is 90 to 250 Vac, 47 to 63 Hz.

40 MHZ SYNC IN connector (BNC)—attaches to the SYNC OUT connector on the Tsunami electronics module. As part of the PHASE and DELAY control circuit, it provides the sync signal from the Tsunami electronics for synchronizing the pulse-selector to the mode-locked pulse from the Tsunami laser. Minimum input level is 0.2 Vptp (–10 dbm). Set switch to 40 MHZ SYNC IN.

DET INPUT connector (SMA)—provides connection for a synchronizing input for systems that have only a ≈ 80 MHz signal which is derived from a photodetector that senses the laser light. The input level should be between 0.2 Vptp and 0.63 Vptp (–10 dbm to 0 dbm). Set switch to DET IN.

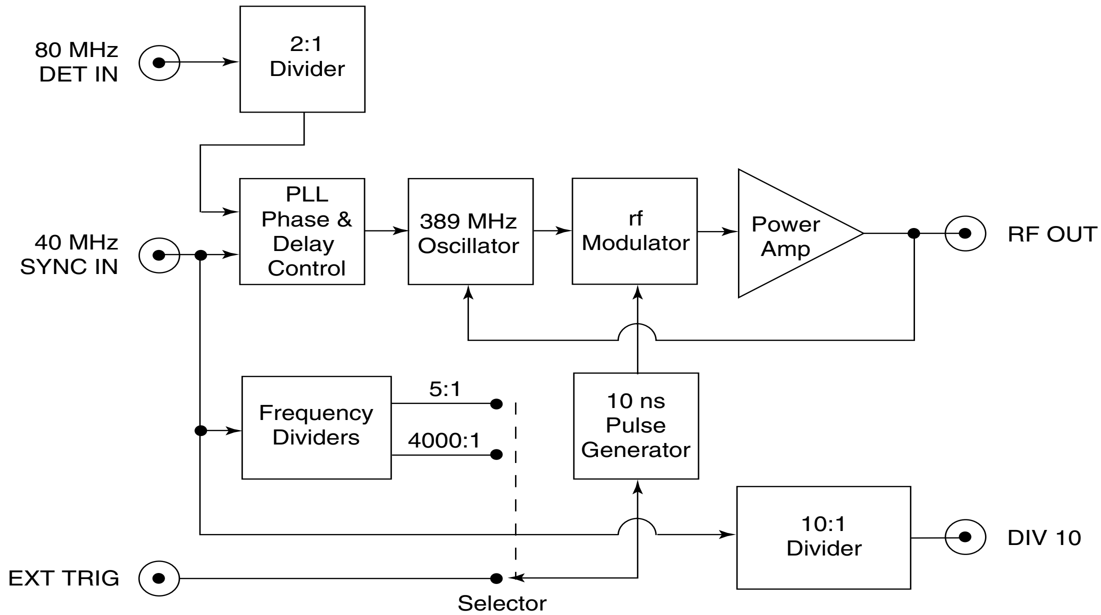


Figure 4-8: AOM Driver Schematic Block Diagram

The following connectors are provided so that special-purpose electronics can be synchronized with the laser pulse train. Special frequency dividers or waveform synthesizing generators can be used to provide divider ratios or special pulse patterns that are not available from the internal dividers.

DIV 10 connector (BNC)—provides a signal that is $^1/_{10}$ of the 40 MHz clock or $^1/_{20}$ of the 80 MHz DET IN synchronizing signal. The signal is a square wave from +0.4 V to –0.4 V with a positive-going 60% duty cycle.

EXT TRIG IN connector (BNC)—accepts an external TTL trigger signal. Input impedance is 50 Ω The rf output burst occurs about 50 ns after the signal goes to +5 V. This is *not* synchronous with the light pulses unless it is derived from a generator that is synchronized by one of the sync signals derived from the laser. The maximum input pulse rate is about 1 per 100 ns.

Warning! Pulse patterns more frequent than 1 pulse per 10 laser pulses may have an average rf power that can damage the AOM. The maximum average power accepted by the AOM is 0.5 W.

Input select switch—selects DET IN, TEST or 40 MHZ SYNC IN as the input signal.

PRF SYNC OUT connector (BNC)—provides a signal that is synchronous with the internally divided down rf bursts sent to the AOM. This TTL signal is normally +5 V and falls below 0.7 V for ≈ 25 ns, then returns to +5 V for ≈ 25 ns before the rf burst is turned on. This signal is useful for triggering oscilloscopes and other external electronics. Terminate with 50 Ω

HEATER connector—connects to the 9-pin heater connector on the Model 3980 when a ps frequency doubler is present, and it provides power to and sensor signals from the SHG crystal heater.

RF OUT connector (BNC)—provides connection for the AOM rf drive signal (into a 50 Ω matching network). A 3 db attenuator is usually connected between the unit and the cable. This reduces the rf level to the AOM, which is pushed to its absolute maximum average power capability if the RF POWER control is set to maximum and the DIVIDER RATIO is set to minimum.

The 3 db attenuator may be removed to increase optical diffraction efficiency if the laser is being operated beyond 900 nm. When this is the case, the DIVIDER RATIO control should be increased to "20". The optical pulse that occurs approximately 36 nm after the selected pulse will increase from about 0.25% to about 0.5% of the selected pulse.

Model 3983 Electronics Unit

Front Panel Controls

FREQUENCY DOUBLER: HEATER ON push-button switch—toggles on and off power to the heater for the SHG crystal.

FREQUENCY DOUBLER: heater status indicator—when green, indicates the SHG crystal is at operating temperature; when red, indicates power is applied to the heater but the SHG crystal is not at operating temperature; when flashing red, indicates the heater is not connected or has an open circuit (refer to the Troubleshooting Guide in Chapter 8). When the system is turned on initially, expect a delay of 5 minutes for the heater to reach operating temperature.

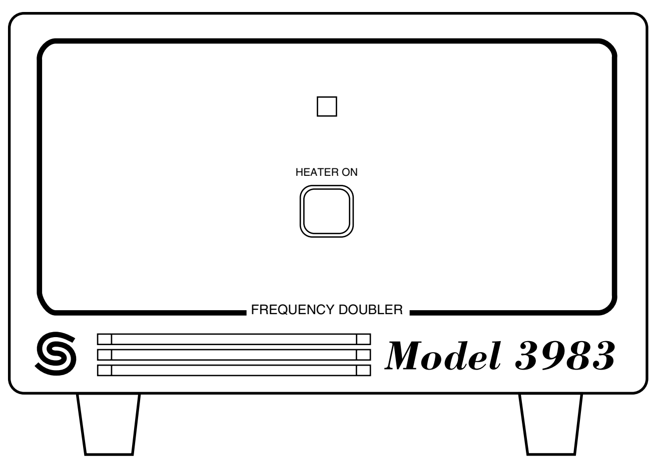


Figure 4-9: Model 3983 Front Panel

Rear Panel Controls and Connectors

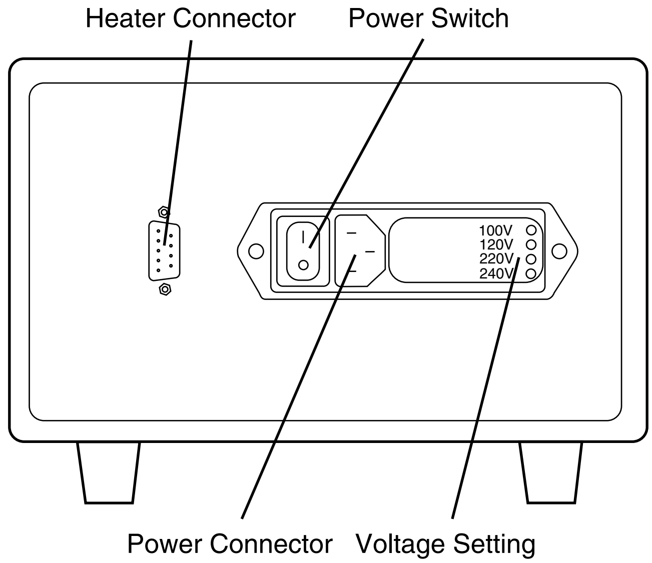


Figure 4-10: Model 3983 Rear Panel

Heater connector—connects to the 9-pin heater connector on the Model 3980 output bezel, and provides power to and sensor signals from the SHG crystal heater.

Power on/off switch—applies AC power to the system if the power cord is connected to your facility power source.

Power cord connector—provides attachment for the ac power cord.

Voltage select switch—sets the Model 3983 to match your facility line voltage. Input voltage selections are 100, 120, 220, and 240 Vac. Fuse selection is:

100/120 Vac	0.25 A Slow Blow
220/240 Vac	0.125 A Slow Blow

Warning!

Verify the voltage setting of the Model 3983 matches the ac line voltage of your facility. An improper voltage selection will damage your equipment. Refer to Appendix A for information on changing this setting.

Chapter 5 Installation and Alignment

Installation

Note

The following installation procedure is not intended as a guide to the initial installation and set-up of your Model 3980. Call your Spectra-Physics service representative to arrange an installation appointment, *which is part of your purchase agreement*. Allow only those qualified and authorized by Spectra-Physics to install and set up your Model 3980. You will be charged for repair of any damage incurred if you attempt to install the system yourself, and such action may void your warranty.

The Model 3980 optical unit and the Model 3986/3983 electronic control units are designed for operation with the Tsunami® mode-locked, Ti:sapphire laser. The optical unit contains the frequency doubler, pulse selector or both. The Model 3983 contains just the heater electronics for use with the Model 3980-1 ps frequency doubler only system. The Model 3986 contains heater electronics the drive electronics for the pulse selector.

Prior to installing the Model 3980 and its associated electronics unit, verify the Tsunami laser is operating to specification. Refer to Figure 4-2 in Chapter 4 for the location of the components and controls inside the Model 3980 enclosure, and to Figure 4-6 through Figure 4-10 for the location of controls and connectors on the Model 3986 and Model 3983 control units. Use the following procedure to install your system. If you have a Model 3983 heater-only unit, ignore any steps that refer to controls for the pulse selector.

Danger! Laser Radiation

Invisible and short pulse laser radiation is present! Because the Tsunami laser emits cw and pulsed infrared radiation, it is extremely dangerous to the eye. Infrared radiation passes easily through the cornea, which focuses it on the retina, where it can cause instantaneous permanent damage.

Danger! Laser Radiation

The Tsunami is a Class IV high power laser. Bypassing the Model 3980 safety interlock shutter may expose the user to hazardous radiation. Always wear proper eye protection and follow the safety precautions in Chapter 2, "Laser Safety."

Required Equipment

The following equipment is required to perform an alignment of the Model 3980 system. If these items are not available, equivalent items can be used.

- ET2000 Photodiode from Electro Technology
- Tektronix 7104 Main Frame 1 GHz Oscilloscope
- Tektronix 7A29 50 Ω Vertical Amplifier
- Tektronix 7B92A Variable Delay Time Base
- 3 m (10 ft) 50 Ω BNC Cables (2)
- Newport 50G00 AV-1 Variable Neutral Density Filter
- Infrared viewer

General Installation and Alignment

Refer to chapter 3, "Introduction: Understanding the Model Numbers," for an explanation of what comprises your Model 3980. It is important to know what is included in your system as you go through the installation and alignment procedures. For example, if the Tsunami laser is set up for femtosecond (fs) pulses and the Model 3980 is set up for picosecond (ps) pulses, *you can easily damage the Model 3980 AOM*.

1. Verify the Tsunami laser mode locks properly throughout its tuning range with the desired pulse width.

   Refer to the *Tsunami User's Manual* and to Appendix B in this manual, "Optimizing the Tsunami Laser."

Danger!
Laser Radiation

Invisible and short pulse laser radiation is now present! Because the Tsunami laser emits cw and pulsed infrared radiation, it is extremely dangerous to the eye. Infrared radiation passes easily through the cornea, which focuses it on the retina, where it can cause instantaneous permanent damage. Wear proper eyewear at all times!

2. Tune the Tsunami laser to either 790 nm ("B" or "S") or 900 nm ("M").
3. Use a power meter to measure the Tsunami laser output power, and reduce pump laser power until you have a reading of 200 mW.

   At 200 mW, the Tsunami laser output is cw.

Warning!

A fs pulse can permanently damage the AOM crystal if the pulse stretcher is not installed. This is a very expensive crystal and *such damage is not covered by your warranty.*

Warning!

To prevent thermal damage to the antireflection coating on the optics, power must be kept below 1.1 W for fs systems and below 1.3 W for ps systems. *Such damage is not covered under your warranty.*

4. Place a target 1 m beyond the output bezel of the Model 3980 and align it on the output beam.
5. Remove the Model 3980 cover.
   a. Pull outward on the bottom of each of the four cover latches until it snaps.
   b. Press downward on the cover to release the pressure on the latches, then pull the top portion of the latch from the notch in the cover.
   c. Remove the cover.

      The shutter will close to prevent the beam from entering the unit.
6. If the beam block is present (systems with a pulse selector), loosen the base mounting screw of the triangular-shaped block and slide the beam block out of the beam path.
7. Remove the M_1 mirror (unclip the optic from the mount) and set it aside.
8. If not already installed, install an alignment target in both the INPUT and SELECTED FUNDAMENTAL OUTPUT ports, and install bezel plugs into the other ports as beam stops.

   Plugs not already installed should be in the tool kit. Always block ports not being used. The INPUT alignment target can always be left installed.
9. Place the Model 3980 near the output bezel of the Tsunami laser.

   The Model 3980 has two ports on the input bezel, three on the output bezel. The design of the input bezel allows it to butt against the Tsunami laser output bezel to save table space. For now, just place the unit close to the Tsunami laser output bezel.

Steps 10 through 18 involve setting up the Model 3986 or 3983 electronics unit. If you have a Model 3980-4 and, thus, no electronic unit, skip to Step 19.

10. Place the Model 3986 or Model 3983 electronics unit close to the Model 3980 optical unit.

    The connecting cables are 3 m (10 ft).
11. Turn off power to the Tsunami Model 3955 electronics module. Verify the Model 3986 or 3983 module is off.
12. Connect the 9-pin D-sub cable (ps frequency doubler systems only) between the heater connector on the back of the Model 3986/3983 electronics unit and the mating connector on the output bezel of the Model 3980 optical unit.

If your system does not have a pulse selector, skip to Step 16.

13. Connect a BNC cable between the SYNC output on the rear of the Tsunami Model 3955 electronics module and the 40 MHZ SYNC IN connector on the Model 3986.
14. Install the 3 db rf attenuator from the tool kit onto the RF OUT connector on the Model 3986.

15. Connect a BNC cable between the rf attenuator (Step 14) on the Model 3986 electronics unit and the mating connector on the Model 3980 output bezel.

Warning!

To prevent damage to your equipment, complete Step 16 and Step 17 before applying ac power to the Model 3986/3983 controller. *Damage due to disregard for these instructions is not covered by your warranty.*

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16. Verify the correct fuse is in place on the Model 3986 or 3983.

    The following table shows the proper fuse ratings:

Line Voltage	Model 3986 Fuse	Model 3983 Fuse
90 to 120 Vac	3.15 A slow blow	0.25 A slow blow
220 to 240 Vac	3.15 A slow blow	0.125 A slow blow

17. Verify the power switch is off and install the ac power cord.
18. Turn on the power switch.

    The Model 3986 front panel POWER: ON indicator glows green and the frequency doubler heater status indicator glows red. When the temperature of the frequency doubler crystal assembly stabilizes, the heater status indicator turns green. Expect a delay of approximately 5 minutes.

    Ignore the heater status indicator (which will flash or remain red) for fs systems and for systems using the Model 3980-2, which have no SHG crystal heater.
19. Turn on the Model 3955 and verify output power from the Tsunami laser is about 200 mW.
20. Open the Model 3980 shutter.

    Pull up on the red-tipped shutter lever.
21. Move the Model 3980 into the Tsunami output beam and adjust its feet height and side to side position so the beam passes through the center of the port alignment targets in the INPUT and SELECTED FUNDAMENTAL OUTPUT ports, and is recentered on the external target installed in Step 4.

    Use a $^{5}/_{32}$ in. hex driver to adjust the three feet from the inside of the Model 3980.
22. Set the locking nut on each foot all the way up against the bottom of the lower cover and tighten.
23. Clamp the Model 3980 to the table with the foot clamps provided in the tool kit.
24. Verify the beam is still aligned on the external target when you are done adjusting and clamping the feet.

Pulse Selector Installation

If you have a system containing only a frequency doubler, skip to "Frequency Doubler Installation: Part I, For Systems Not Using the Pulse Selector." Otherwise, continue with this pulse selector installation.

Warning!

The beam must never come in contact with the AOM transducer element, its base or its wires. If this happens, these elements will be immediately destroyed. The position of the AOM shield is factory-set to block the input beam from contacting the transducer element. If you remove the shield for cleaning, make sure the shield is replaced and correctly positioned before exposing the AOM to the laser beam (refer to Figure 5-2). The AOM is a very expensive device, and *damage to it caused by improper shield placement is not covered by your warranty.*

Warning!

Because fs pulses contain higher peak power than those from a ps system, three conditions must be met in order to prevent damage to the AOM: (a) the Tsunami laser *must meet specified power of <80 fs* (refer to Figure 3-3), (b) once set for <80 fs, do not lower power by reducing the pump laser power because this may broaden the pulse, and (c) you must have the fs pulse stretcher installed. Failure to comply can result in permanent damage to the AOM. *Such damage is not covered by your warranty.*

Warning!

To prevent thermal damage to the antireflection coating on the optics, power must be kept below 1.1 W for fs systems and below 1.3 W for ps systems. *Such damage is not covered under your warranty.*

Your Model 3980 came with two sets of optics for lenses L_1 and L_2, a 50 mm set and a 38 mm set. If yours is a fs unit with a frequency doubler, it also includes a 75 mm lens.

Ps and fs systems with only a pulse selector (Models 3980-2 and -5) are optimized and shipped with the 50 mm lenses installed for use with wavelengths <1000 nm. Use the 38 mm lens set only for wavelengths >1000 nm. Fs systems with both pulse selector and frequency doubler (Model 3980-6) must be modified with L_1 = 50 mm and L_2 = 75 mm for wavelengths <1000 nm, and L_1 = 38 and L_2 = 50 mm for wavelengths >1000 nm. Use Table 5-1 to select the proper L_1 and L_2 lens set for your configuration.

Table 5-1: L_1 and L_2 Lens Selection

System Type	Picosecond System				Femtosecond System			
Wavelength Used	<1000 nm		>1000 nm		<1000 nm		>1000 nm	
Lens (mm)	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
Pulse Selector Only	50	50	38	38	50	50	38	38
Frequency Doubler Only	absent (50)*	absent (50)*	absent 38)*	absent (38)*	38 (50)*	50 (75)*	38	50
Pulse Selector + Frequency Doubler	50	50	38	38	50	75	38	50

** Acceptable alternative configuration for frequency doubler only operation when the pulse selector is also installed.*

The following procedure will guide you through the set-up and alignment of your pulse selector.

1. Verify Tsunami laser power is <200 mW.
2. Verify the beam is not clipped by the pulse stretcher (fs systems).

   Loosen the vertical and horizontal mounting screws and adjust the pulse stretcher so that the beam is not clipped, then tighten the screws.
3. Remove L_2 and set aside. Refer to Figure 5-1.

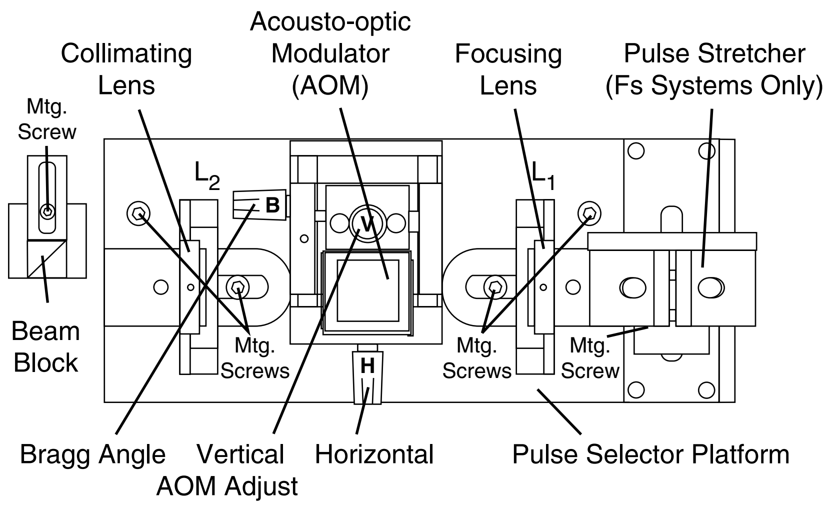

Figure 5-1: The Pulse Selector Platform

4. Verify the correct focusing lens for L_1 is installed (refer to Table 5-1), and set the distance between the lens and the center of the AOM Bragg cell to the focal length of the lens (38 mm = 1.50 in., 50 mm = 1.96 in.)
5. Adjust lens L_1 vertically and horizontally so that the beam passes through the slot in the AOM shield and centers on the external alignment target.

Warning! Remember, do not allow the incoming beam to hit the AOM transducer as you move L_1.

6. Use an ir viewer to scan the optical surfaces of the AOM and adjust the AOM so that the beam passes through the AOM vertically centered and approximately 1 to 2 mm from the transducer side (the side nearest the horizontal control knob). Refer to Figure 5-2.

   The beam should remain centered on the external target. If it is not centered, readjust L_1 so that it is.
7. Install the appropriate collimating lens L_2 from Table 5-1 and adjust its distance to the AOM according to its focal length in a manner similar to that performed for L_1.
8. Adjust L_2 vertically and horizontally so that the beam remains centered on the external target.
9. Close the shutter and remove the alignment target from the SELECTED FUNDAMENTAL OUTPUT port.
10. Set the Tsunami output to the desired power by adjusting the pump laser power. Do not allow the mode-locked pulse to become unstable.

Warning! Because fs pulses contain higher peak power than those from a ps system, three conditions must be met in order to prevent damage to the AOM: (a) the Tsunami laser *must meet specified power of <80 fs* (refer to Figure 3-3), (b) once set for <80 fs, do not lower power by reducing the pump laser power because this may broaden the pulse, and (c) you must have the fs pulse stretcher installed. Failure to comply can result in permanent damage to the AOM. *Such damage is not covered by your warranty.*

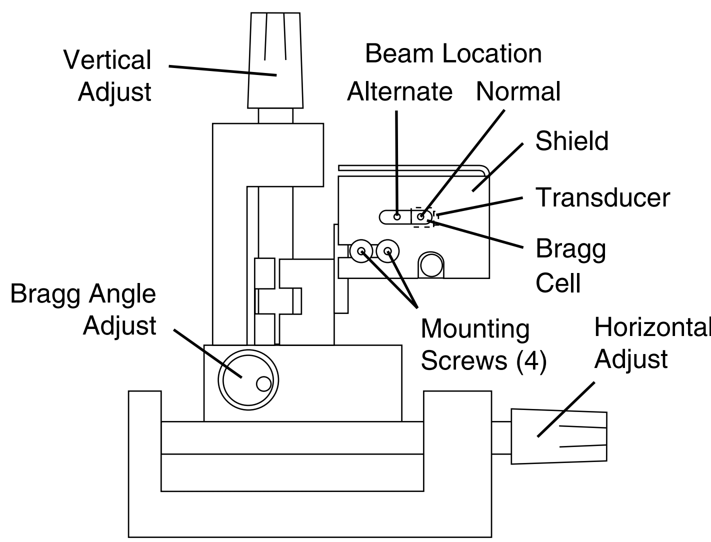

Figure 5-2: Beam Location Through the AOM

11. Turn the PULSE SELECTOR: DIVIDER RATIO selector knob on the Model 3986 to CW.

    The rf status light glows.
12. Turn the PULSE SELECTOR: RF POWER knob fully clockwise (full on).
13. Open the shutter.

14. Place an ir card in front of the beam block, and adjust the AOM vertically, first to yield a –1 order diffracted beam, then to maximize that beam.

    The –1 order beam is located just to the right of the undiffracted zeroth order beam when looking at the AOM from the output side of the Model 3980.

15. Position the beam block to block the zeroth order beam, but not so far as to block the –1 order beam, and tighten the mounting screw.
16. Set the PULSE SELECTOR: DELAY and PHASE adjustment knobs to "5," and set the DIVIDER RATIO control to 10 (for approximately 8 MHz output). Reduce the rf power.
17. Place a power meter in front of the SELECTED FUNDAMENTAL OUTPUT port and adjust the vertical, horizontal, and Bragg controls of the AOM for maximum diffracted output power.
18. Replace the power meter with a fast photodiode, such as an ET2000 from Electro-Optics Technology, and center it on the beam.
19. Connect the photodiode to a 1 GHz oscilloscope, such as a Tektronix 7104, to monitor the extinction ratio (the ratio of the amplitude of the selected pulse to the adjacent pulses).
20. Connect a BNC cable between PRF SYNC OUT and the EXT TRIG input of the scope time base. Set the time base to external trigger, 1 MΩ, and the time scale to ~ 5 or 10 ns/div.
21. Place the variable neutral density (ND) filter in front of the photodiode, and attenuate the selected main pulse for a 1.0 V signal level on the oscilloscope.

    Make sure the photodiode position is optimized for maximum signal, but take care not to saturate the photodiode.

22. Set the oscilloscope amplifier gain to 10.0 mV/div and measure the pre- and post-pulse amplitude.

    With a 1.0 V selected main pulse, the adjacent pulses should be <2.0 mV.

23. Adjust the PHASE, DELAY and RF POWER controls to maximize the main pulse amplitude while minimizing the pre- and post-selected pulses.

    Some iteration between adjusting the AOM controls and the electronics is necessary.

24. Verify the extinction ratio meets specification.
25. Make small incremental changes to the distance from L_1 to the AOM, and readjust the AOM controls each time to maximize diffracted power.
26. Iterate Steps 23 to 25 as needed until the extinction ratio is maximized.
27. Verify the extinction ratio and diffraction efficiency meets or exceeds specifications.
28. Adjust the distance between L_2 and the AOM to recollimate the selected beam.

29. Verify all mounts are secured.

Stop here if you only have a pulse selector unit. If the selected pulse needs to be frequency doubled, continue with the frequency doubler installation.

Frequency Doubler Installation: Part I
For Systems Without or not Using the Pulse Selector

If you have a ps system, skip to “Frequency Doubler Installation: Part II.”

If you have a fs frequency doubler with no pulse selector, the pulse selector platform came with mounts only for the L_1 and L_2 lenses. If you have a pulse selector but are not going to use it, you need to move the AOM Bragg cell out of the way and remove the pulse stretcher (fs systems) from the beam path.

1. Select the lens set from Table 5-1 that is appropriate for your configuration.
2. Place the lenses a distance apart equal to their combined focal lengths.

   For example, if you are using a 50 mm and 38 mm lens, place them 88 mm apart. (38 mm = 1.50 in., 50 mm = 1.96 in., 75 mm = 2.95 in.)

   For a fs unit, the values for L_1 and L_2 from the table provide a beam expansion of about 1.3:1 (required for reducing the size of the beam waist in the BBO doubling crystal).
3. If you have a pulse selector and do not intend to use it, (a) adjust the AOM horizontally to move the Bragg cell out of the beam path (Figure 5-2) and, (b) loosen the screw under the pulse stretcher windows and slide the pulse stretcher out of the beam path.

   Remember to replace the pulse stretcher in the beam path before using the pulse selector for fs pulses, or you will damage the AOM Bragg cell. Except for a very slight reduction in output power, the pulse stretcher does not affect ps pulses and may be left in place.

Continue with the following section.

Frequency Doubler Installation: Part II
All Systems

1. Turn off the rf power if the Model 3986 is present.
2. Replace the M_1 routing mirror that was removed during general alignment.
3. Adjust M_1 vertically and horizontally to center the beam on routing mirror M_2 (Figure 5-3).
4. Adjust M_2 vertically and horizontally to center the beam on focusing mirror M_3.
5. Adjust M_3 vertically and horizontally to guide the beam through the compensator (ps systems only) and the SHG crystal, and center it on focusing mirror M_4.

The next step is performed by your Spectra-Physics service representative during the initial installation and should not need to be done by you.

6. Remove the lock-down screws from the SHG crystal mount assembly and the compensator assembly (if present). Models 3980-4, and -6 have no compensator assembly.

Caution!

The lock-down screws secure the two mounts to the base plate during shipping. Replace these screws before returning the unit to Spectra-Physics for upgrade or service.

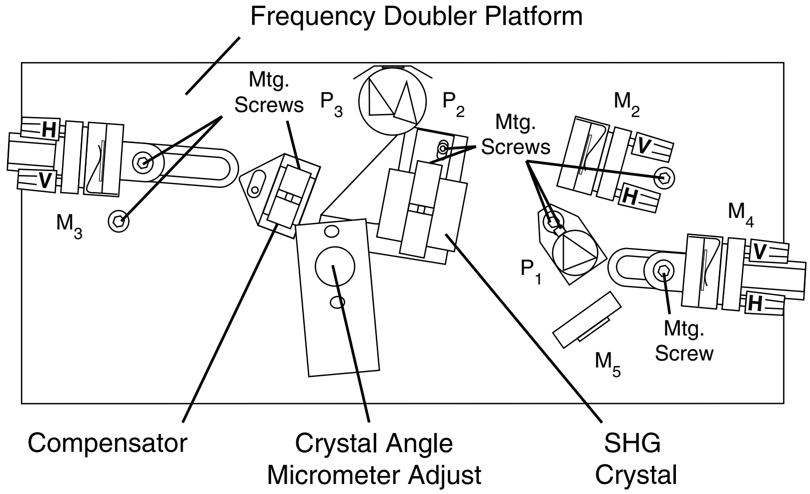

Figure 5-3: The Frequency Doubler Platform

7. Adjust the micrometer from end to end and check for clipping of the fundamental beam.

   The following adjustments are made at the factory and should not need readjustment. However, if beam clipping is observed, it may be caused by either the SHG crystal or the compensator.

   a. To adjust the SHG crystal, loosen the small screw next to the crystal and move the crystal manually so that the beam is no longer clipped.
   b. To adjust the compensator, loosen the jam nut, then the setscrew inside it to rotate it (the mount is spring-loaded).
   c. Tighten the screws.
   d. Rotate the micrometer from end to end and verify the beam is not clipped.

8. Use the micrometer to search for and to maximize the second harmonic output.
9. Place an ir card outside the SECOND HARMONIC OUTPUT port, and adjust M_4 to minimize the fundamental beam leakage from that port (by varying the angle of the beam between beam splitter P_1 and the Littrow prism set P_2 and P_3).
10. Rotate routing mirror M_5 to direct the residual fundamental out through the RESIDUAL FUNDAMENTAL OUTPUT port.

The residual beam can be sent to an autocorrelator, such as the Spectra-Physics Model 409, for monitoring pulses from the Tsunami laser.

If you performed this alignment because you made a large change in wavelength, you might need to repeat Steps 8 through 10.

11. Remove the ir card and place a power meter in front of the SECOND HARMONIC OUTPUT port.
12. Position M_3 for highest output power.
    a. Loosen the mounting screw of M_3, and slowly slide it back and forth (in line with the SHG crystal) while watching the power meter.
    b. Position M_3 for optimum output power, then tighten the screw.
13. Place a white card in front of the power meter, and position M_4 for a non-elliptical output.
    a. Loosen the mounting screw of M_4, and slowly slide it back and forth while watching the image on the card.
    b. Position M_4 where the image loses its elliptical shape and becomes round, then tighten the screw.

This completes the installation and alignment of your Model 3980.

Converting Your System

Detailed instructions are included with the upgrade conversion kit(s) for installing either a pulse selector or frequency doubler platform. *Do not discard these instructions. Keep them with this manual.* Once you upgrade your system to include both platforms, do not remove the platforms when you reconfigure the system. Simply change, move, and remove individual components. Doing so allows you to align the system more easily. A list of available upgrade kits is located at the end of Chapter 3.

Table 5-2 is a conversion matrix showing what changes are needed to reconfigure your system for a particular upgrade. Where the table lacks room to provide detailed information, such detail is provided in the examples that follow it. Be sure to read this information when it applies to your configuration. Chapter 4 contains descriptions of the various components referenced in the table. It describes their controls and the adjustments for installing, moving, and removing each component.

Table 5-2: System Conversions for the 3980

	Picosecond System			Femtosecond System		
To→ From↓	**FD -1**	**PS -2**	**FD + PS -3**	**FD -4**	**PS -5**	**FD + PS -6**
FD -1		PS platform add L_1/L_2 select AOM in beam Beam Block add M out	PS platform add L_1/L_2 select AOM in beam Beam Block add	PS platform add L_1 L_2 = 1.3:1	PS platform add Stretcher add L_1/L_2 select AOM in beam Beam Block add M_1 out	PS platform add Stretcher add L_1/L_2 = 1.3:1 AOM in beam Beam Block add
PS -2	AOM out beam Beam Block out M_1 add FD platform add LBO w/ Comp.		M_1 add FD platform add LBO w/ Comp.	L_1/L_2 = 1.3:1 AOM out beam Beam Block out M_1 add FD platform add BBO w/o Comp.	Stretcher add	Stretcher add L_1/L_2 = 1.3:1 M_1 add FD platform add BBO w/o Comp.
FD+PS -3	AOM out beam Beam Block out	M_1 out		L_1/L_2 = 1.3:1 AOM out beam Beam Block out LBO →BBO Comp. out	Stretcher add L_1/L_2 select M_1 out	Stretcher add L_1/L_2 = 1.3:1 LBO →BBO Comp. out
FD -4	BBO →LBO Comp. add	L_1/L_2 select AOM in beam Beam Block add M_1 out	L_1/L_2 select AOM in beam Beam Block add BBO →LBO Comp. add		Stretcher add L_1/L_2 select AOM in beam Beam Block add M_1 out	Stretcher add L_1/L_2 = 1.3:1 AOM in beam Beam Block add
PS -5	Stretcher out AOM out beam Beam Block out M_1 add FD platform add LBO w/ Comp.	Stretcher out	Stretcher out M_1 add FD platform add LBO w/ Comp.	Stretcher out L_1/L_2 = 1.3:1 AOM out beam Beam Block out M_1 add FD platform add BBO w/o Comp.		L_1/L_2 = 1.3:1 M_1 add FD platform add BBO w/o Comp.
FD+PS -6	Stretcher out AOM out beam Beam Block out BBO →LBO Compensator add	Stretcher out L_1/L_2 select M_1 out	Stretcher out L_1/L_2 select BBO →LBO Comp. add	Stretcher out L_1/L_2 = 1.3:1 AOM out beam	L_1/L_2 select M_1 out	

FD = frequency doubler
PS = Pulse selector
Comp. = compensator
Stretcher = pulse stretcher
out = remove the optic or move the component out of place
add = install the optic or move the component into place

Converting from a Picosecond Model 3980-2 to a Model 3980-5 Femtosecond Pulse Selector

Changing from a Model 3980-2 to a -5 or from a Model 3980-3 to a -6 with the frequency doubler present, requires that you move the pulse stretcher into the beam path. *Do not use fs pulses on an unmodified ps system!*

Warning! Because fs pulses contain higher peak power than those from a ps system, four conditions must be met before the beam reaches the AOM in order to prevent damage to the AOM: (a) reduce Tsunami output power to <1.1 W, (b) the Tsunami laser *must meet specified pulse width of* $\leq$*80 fs* (refer to Figure 3-3), (c) once set for <80 fs, do not lower power by reducing the pump laser power because this may broaden the pulse, and (d) you must have the fs pulse stretcher installed. Failure to comply can result in permanent damage to the AOM. *Such damage is not covered by your warranty.*

If you are going to use the frequency doubler, you also need to change lenses L_1 and L_2 so that they provide a 1.3:1 beam expander.

1. Move the pulse stretcher into the beam path.
2. Refer to Table 5-1 to verify you are using the correct lenses for L_1 and L_2.

Converting from a Femtosecond Model 3980-5 to a Model 3980-2 Picosecond Pulse Selector

The pulse selector in a Model 3980-5 or -6 fs unit can be used as-is when converting to a Model 3980-2 or -3 ps unit. *Note, however, that the opposite is not true*.

Warning! Even thought the AOM Bragg cell can handle the ps peak power, the coating on the AOM can be damaged by high average power. Reduce the average power to <1.3 W for ps operation.

The pulse stretcher does not affect ps pulses and can be left in place: there is very little power loss. However, if maximum power is required, move the pulse stretcher out of the beam path.

Warning! Remember to move the pulse stretcher back into the beam path before using the pulse selector for fs pulses *or you will damage the AOM Bragg cell.*

If you are converting from a Model 3980-6, you no longer need the 1.3:1 beam expander, so lenses L_1 and L_2 can be replaced accordingly for the wavelength selected.

1. Move the pulse stretcher out of the beam path.
2. Refer to Table 5-1 to verify you are using the correct lenses for L_1 and L_2.

3. If you are converting a Model 3980-6 to a -3 (i.e., you need to use the frequency doubler), you need to refer to "Converting From a Femtosecond to a Picosecond Frequency Doubler" below: there are several other changes you need to make.
4. If you are converting a Model 3980-6 to a -2 (i.e., you are *not* going to use the frequency doubler), simply remove mirror M_1 so that the beam passes out though the SELECTED FUNDAMENTAL OUTPUT port.

Converting From a Picosecond Model 3980-1 to a Model 3980-4 Femtosecond Frequency Doubler

Converting a Model 3980-1 to a Model 3980-4 (i.e., there is no pulse selector present) requires that you install the pulse selector platform to provide mounts for L_1 and L_2, and that you change the SHG crystal from the long LBO crystal to the shorter BBO crystal. With the shorter SHG crystal, there is minimal beam offset and the compensator crystal is no longer required.

If you are converting a Model 3980-3 to a -6 and are using the pulse selector, *move the pulse stretcher into the beam path* and change L_1 and L_2 on the pulse stretcher platform to so that they provide a 1.3:1 beam expander (refer to Table 5-1).

If you are *not* going to use the pulse selector, leave the pulse stretcher to the side, out of the way (it is only required for fs pulse selection), and use the horizontal adjust on the AOM to move the Bragg cell out of the beam path (Figure 5-2). Select the correct lenses for L_1 and L_2 (refer to Table 5-1).

1. Remove the compensator.
2. Remove the LBO SHG crystal and replace it with the BBO crystal.
3. Follow the instructions in "Frequency Doubler Installation: Part I."
4. Adjust L_2 for a slightly diverging beam.
5. Optimize M_3 and M_4 spacing for best frequency doubling and collimation.

Converting From a Femtosecond Model 3980-4 to a Model 3980-1 Picosecond Frequency Doubler

Converting a Model 3980-4 to a -1 (i.e., there is no pulse selector), requires that you mount the compensator and change from the BBO SHG crystal to the LBO crystal. Also, you no longer need the 1.3:1 beam expander, so lenses L_1 and L_2 can be removed (refer to Table 5-1).

If you are converting a Model 3980-6 to a -3 and are using the pulse selector, you can leave the pulse stretcher in the beam path. The pulse stretcher does not affect ps pulses, and there is very little power loss. However, if maximum power is required, move the pulse stretcher out of the beam path.

Warning! Remember to move the pulse stretcher back into the beam path before using the pulse selector for fs pulses *or you will damage the AOM Bragg cell.*

You no longer need a 1.3:1 beam expander, change L_1 and L_2 on the pulse stretcher platform accordingly (refer to Table 5-1).

1. Install the compensator from the ps upgrade kit.
2. Remove the BBO SHG crystal and replace it with the LBO crystal.
3. Follow the instructions in "Frequency Doubler Installation: Part I."
4. Adjust L_2 for a slightly diverging beam.
5. Optimize M_3 and M_4 spacing for best frequency doubling and collimation.

Converting from a Femtosecond Model 3980-6 to a Model 3980-4 Femtosecond Frequency Doubler Only Unit

Translate the AOM horizontally so that the beam does not pass through the Bragg cell, then move the pulse stretcher out of the beam path.

Warning! Remember to move the pulse stretcher back into the beam path before using the pulse selector for fs pulses *or you will damage the AOM Bragg cell.*

1. Move the pulse stretcher out of the beam path.
2. Adjust the horizontal control on the AOM until the beam no longer passes through the Bragg cell (Figure 5-2).
3. Follow the instructions under "Frequency Doubler Installation: Part I."
4. Adjust L_2 for a slightly diverging beam.
5. Optimize M_3 and M_4 spacing for best frequency doubling and collimation.

Converting from a Femtosecond Model 3980-6 to a Model 3980-1 Picosecond Frequency Doubler Only Unit

Translate the AOM horizontally so that the beam does not pass through the Bragg cell (Figure 5-2). The pulse stretcher does not affect ps pulses and can be left in place: there is very little power loss. However, if maximum power is required, move the pulse stretcher out of the beam path.

Warning! Remember to move the pulse stretcher back into the beam path before using the pulse selector for fs pulses *or you will damage the AOM Bragg cell.*

You no longer need the 1.3:1 beam expander. Verify the correct lens set for L_1 and L_2 is installed (refer to Table 5-1).

1. Move the pulse stretcher out of the beam path if desired.
2. Adjust the horizontal control on the AOM until the beam no longer passes through the Bragg cell (Figure 5-2).

3. Follow the instructions in “Frequency Doubler Installation: Part I” above.
4. Change the frequency doubler crystal and optimize the focus for best frequency doubling output power.

Converting from a Picosecond Model 3980-3 to a Model 3980-5 Femtosecond Pulse Selector Only Unit

Warning! Move the pulse stretcher back into the beam path before using the pulse selector for fs pulses *or you will damage the AOM Bragg cell.*

Remove mirror M_1 so that the beam passes out though the SELECTED FUNDAMENTAL OUTPUT port.

1. Move the pulse stretcher into the beam path.
2. Remove mirror M_1.

Chapter 6 Operation

Start-up

Once installed, the Model 3980 can be operated on a day-to-day basis as outlined below. Provided nothing is disturbed between operating sessions, only minor adjustments are required to maintain optimum performance. To modify or convert your system from a picosecond (ps) to a femtosecond (fs) system, or vice versa, or to upgrade a system with only a frequency doubler to one that includes a pulse selector, or vice versa, refer to Chapter 5, "Installation and Alignment."

All Models

1. Verify the Tsunami® laser and its pump laser are properly installed and are operating to specifications.
2. Verify the Model 3980 is installed in accordance with the procedures in Chapter 5.

   If you have not moved it since it was last used, it should not require realignment.

The remaining steps involve the electronics unit. Since the Model 3980-4 has no electronics unit, it is ready for use.

All Models except Model 3980-4

3. Turn on power to the Model 3986 or 3983 electronics unit.

Models 3980-1, -3

4. Press the HEATER ON button and wait for the front panel frequency doubler heater status indicator to glow green, indicating the temperature of the frequency doubler crystal assembly has stabilized (usually less than 5 minutes).

   The indicator lamp is disabled for systems not requiring a frequency doubler heater (Models 3980-2, -5, -6).
5. Adjust the SHG micrometer for optimum second harmonic output power.

Models 3980-2, -3, -5, -6

6. Set the PULSE SELECTOR: DIVIDER RATIO switch for the desired divider ratio.

The internal generator produces a pulse train that is synchronous with the laser pulse train. To select fewer pulses than those offered by the pulse train, a divide-by scheme is used. To select every 10th pulse, set the unit to “10,” etc.

If, after following the rest of these directions, you find the system does not meet specification, set this switch to the CW position and optimize the Bragg diffraction condition. You can also use this setting to assist in any optical beam alignment.

7. Set the RF POWER, DELAY and PHASE controls to “5.”
8. Place a power meter in front of the SELECTED FUNDAMENTAL OUTPUT port and adjust the vertical, horizontal, and Bragg controls of the AOM for maximum diffracted output power.
9. Replace the power meter with a fast photodiode, such as an ET2000 from Electro-Optics Technology, and center it on the beam.
10. Connect the photodiode to a 1 GHz oscilloscope, such as a Tektronix 7104, to monitor the extinction ratio (the ratio of the amplitude of the selected pulse to the adjacent pulses).
11. Place a variable neutral density (ND) filter in front of the photodiode, and attenuate the selected main pulse for a 1.0 V signal level on the oscilloscope.

    Make sure the photodiode position is optimized for maximum signal. Be careful to not saturate the photodiode.
12. Set the oscilloscope amplifier gain to 10.0 mV/div. and measure the pre- and post-pulse amplitude.

    With a 1.0 V selected main pulse, the adjacent pulses should be <2.0 mV.
13. Adjust the PHASE, DELAY and RF POWER controls to maximize the main pulse amplitude and also to minimize the pre- and post-selected pulses simultaneously.

    Some iteration between adjusting the AOM controls and the electronics is necessary.
14. Verify the extinction ratio meets specification.

This concludes the start-up procedure.

Shut-down

All Models Except Model 3980-4

1. Turn off the electronics unit.

Model 3980-4

2. There is no shut down procedure for the Model 3980-4. Follow the instructions in your Tsunami and pump laser manuals for shutting down those systems.

This concludes the shut-down procedure.

Changing Optics

Replace optics one at a time, and follow the directions in Chapter 5, "Installation and Alignment," for aligning each optic. Refer to the "Replacement Parts List" in Chapter 8 for optic part numbers and their positions.

System Conversions

Refer to Chapter 5, "Installation and Alignment: Converting Your System."

Chapter 7 Maintenance

The condition of the laboratory environment and the amount of time you use your Model 3980 affects your periodic maintenance schedule. Do not allow smoking in the laboratory: the optics stay clean longer. Condensation due to excessive humidity can also contaminate optical surfaces. The cleaner the environment, the slower the rate of contamination.

If the cover of the Model 3980 is left in place, there is little you must do day-to-day to maintain the unit. When you finally do need to clean the optics, follow the procedures below.

Notes on the Cleaning of Laser Optics

Laser optics are made by vacuum-depositing microthin layers of materials of varying indices of refraction onto glass or quartz substrates. If the surface is scratched to a depth as shallow as 0.01 mm (0.0004 in.), the operating efficiency of the optical coating can be reduced significantly and the coating can degrade.

Dust on optical surfaces can cause loss of output power, damage to the optics or total failure. Cleanliness is essential, and you must apply laser optics maintenance techniques with extreme care and with attention to detail.

"Clean" is a relative description; nothing is ever perfectly clean and no cleaning operation can ever completely remove contaminants. Cleaning is a process of reducing objectionable materials to acceptable levels.

Equipment Required

- dry, filtered nitrogen or canned air
- rubber squeeze bulb
- optical-grade lens tissue
- spectroscopic-grade methanol and/or acetone
- hemostats
- clean, lint-free finger cots or powderless latex gloves

Standard Cleaning Procedures

Follow the principles below whenever you clean any optical surface.

- Clean only one element at a time, then realign that element for maximum output power.

  If optics are removed and replaced as a group, some might get swapped. At best, all reference points will be lost, making realignment extremely difficult.

- Work in a clean environment and, whenever possible, over a soft, lint-free cloth or pad.
- Wash your hands thoroughly with liquid detergent.

  Body oils and contaminants can render otherwise fastidious cleaning practices useless.
- Always use clean, powderless and lint-free finger cots or gloves when handling optics and intracavity parts.

  Remember not to touch any contaminating surface while wearing gloves; if you scratch that itch, you will transfer oils and acids onto the optics.
- Use filtered dry nitrogen, canned air, or a rubber squeeze bulb to blow dust or lint from the optic surface before cleaning it with solvent; permanent damage can occur if dust scratches the glass or mirror coating.
- Use spectroscopic-grade solvents.

  Since cleaning simply dilutes contamination to the limit set by solvent impurities, solvents must be pure as possible. Use solvents sparingly and leave as little on the surface as possible. As any solvent evaporates, it leaves impurities behind in proportion to its volume.
- Store methanol and acetone in small glass bottles.

  These solvents collect moisture during prolonged exposure to air. Avoid storing methanol and acetone in bottles where a large volume of air is trapped above the solvent.
- Use Kodak Lens Cleaning Paper™ (or equivalent photographic cleaning tissue) to clean optics.
- Use each piece of lens tissue only once; dirty tissue merely redistributes contamination—it does not remove it.

Do not use lens tissue designated for cleaning eye glasses. Such tissue contains silicones. These compounds bind themselves to the optic coatings and can cause permanent damage. Also, do not use cotton swabs, e.g., Q-Tips. Solvents dissolve the glue used to fasten the cotton to the stick, resulting in contaminated coatings. Only use photographic lens tissue to clean optical components.

General Procedures for Cleaning Optics

All mirrors should be removed from their mounts for cleaning. The other optical components should be cleaned in place.

1. Use the “drop and drag” method for mirrors $M_1 – M_5$.
   a. Hold the optic horizontal with its coated surface up. Place a sheet of lens tissue over it, and squeeze a drop or two of acetone or methanol onto it.
   b. Slowly draw the tissue across the surface to remove dissolved contaminants and to dry the surface.

      Pull the tissue slow enough so the solvent evaporation front follows the tissue, i.e., the solvent dries only after leaving the optic surface.

2. Use the “tissue in a hemostat” method to clean optics when stubborn contaminants cannot be removed with the “drop and drag” method, or when there is limited access to optics or when optics are not removed from their holders.

   a. Fold a piece of tissue in half repeatedly until you have a pad about 1 cm (0.5 in.) square, and clamp it in a plastic hemostat (Figure 7-1).

Caution!

While folding, *do not touch* the surface of the tissue that will contact the optic, or you will contaminate the solvent.

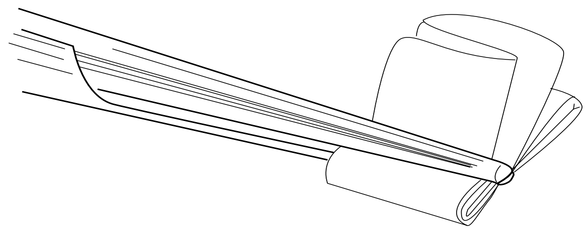

Figure 7-1: Lens Tissue Folded for Cleaning

   b. If required, cut the paper with a solvent-cleaned tool to allow access to the optic.

   c. Saturate the tissue with acetone or methanol, shake off the excess, resaturate, and shake again.

   d. Wipe the surface in a single motion.

   Harsh wiping will damage the optic coating. If you cannot clean a spot on the surface with a gentle wipe, mark the area and avoid using that area during operation. Be careful the hemostat does not touch the optic surface or the coating may be scratched.

Cleaning the AOM

Warning!

Do not clean the AOM Bragg cell unless absolutely necessary. It is very expensive, extremely fragile and easily misaligned. Resort to cleaning only after verifying the *Tsunami*® laser meets output specifications and all other Model 3980 optics are clean.

Warning!

The AOM is extremely fragile. Do not use pressurized air other than that from a squeeze bulb on the AOM. High-pressure air can damage the fine wires attached to the Bragg cell transducer and render it useless. This is a very expensive device, and *such damage is not covered by your warranty.*

Warning!

The beam must never come in contact with the AOM transducer element, its base or its wires. If this occurs, these elements will be immediately destroyed. The position of the AOM shield is factory set to block the input beam from contacting the transducer element. If you remove the shield for cleaning, make sure the shield is replaced and correctly positioned before exposing the AOM to the laser beam. The AOM is a very expensive device, and damage to it caused by improper shield placement *is not covered by your warranty.*

Note

The beam exiting the AOM appears brighter than the entering beam. This is normal and is not cause for concern.

1. Remove the AOM shield.
   a. Loosen the two screws on each side of the shield and remove the one on each side nearest the horizontal adjust (refer to Figure 4-3).
   b. Tilt the shield upward to free it from the transducer driver cable, and slide it off.
2. Note the warnings above, then use the “tissue in a hemostat” method under “General Procedures for Cleaning Optics” to clean the Bragg cell. **Be very careful!**
3. Replace the shield and position it so it blocks the beam from hitting the transducer.

   Reverse of Step 1. Be careful not to nick the transducer driver cable when placing the notch in the shield over it. Nicking the cable can short the wires inside. Make sure the shield is correctly positioned before exposing the AOM to the laser beam. The AOM is a very expensive device, and damage to it caused by improper shield placement is *not covered by your warranty.*

Cleaning the SHG Crystal

Warning!

Clean the SHG crystal with lab-grade methanol only. All other optics can be cleaned with either methanol or acetone.

Use the “tissue in a hemostat” method described under “General Procedures for Cleaning Optics” above. Do not remove the SHG crystal for cleaning.

Chapter 8 Service and Repair

The following information is provided to assist in isolating some of the problems that might arise while using your system. A complete repair procedure is beyond the scope of this manual. For information concerning repair by Spectra-Physics, see Chapter 9, “Customer Service.”

Troubleshooting Guide

Use this guide if performance drops below specifications and cleaning the optical lenses and mirrors does not help. Refer to Figure 3-1for component placement in the Model 3980 optical unit. If following the troubleshooting suggestions fail to return your Model 3980 to normal operation, call your Spectra-Physics service representative for assistance.

Symptom: No output from the pulse selector

Possible Causes	Corrective Action
Cables from Model 3986 electronics unit not properly installed or are damaged.	Verify installation and condition of cables. Refer to “Installation and Alignment: General Installation.”
Rf power is not on or setting is too low.	Turn rf power on by pressing the RF ON switch, or turn the RF POWER control knob fully clockwise. Verify RF OUT is connected to the AOM.
The Tsunami® laser or its pump source not properly mode locked.	Verify a mode-locked condition exists using a Model 409-07 autocorrelator (or equivalent). Follow the installation and alignment procedures in the *Tsunami User's Manual*.
Pulse selector unit not properly aligned to the input beam.	Verify proper centering of the input beam through the input bezel alignment target and the alignment aperture on focusing lens L_1. Refer to “Installation and Alignment: General Installation.”
Misaligned acousto-optic modulator.	Set the repetition rate to cw to reference the spot and optimize throughput. Set rf power to maximize and, using the position control of the modulator, maximize the –1 order diffracted beam. Set the pulse rate. Refer to Chapter 5, “Installation and Alignment: Pulse selector Installation.”
Faulty electronics unit.	After confirming the Tsunami laser is properly mode locked and all cables are connected, use a 1 GHz oscilloscope and amplifier with a 50 Ω input to verify the presence of an rf signal at the RF OUT connector. (Always use a 20 dB attenuator to avoid damaging the oscilloscope amplifier.) For cw operations, the signal should be approximately 1.2 Vp-p through a 20 dB attenuator and about 4 V_{p-p} for other repetition rates. If there is no rf output, contact your Spectra-Physics service engineer.

Symptom: Pulse selector—low diffraction efficiency or extinction ratio	
Possible Causes	**Corrective Action**
Rf power set too low or too high.	Increase or decrease rf power with the RF POWER control.
Misaligned acousto-optic modulator.	If the alignment of the Model 3980 to the input beam is correct, set the repetition rate to CW, RF POWER to maximum and, using the position controls of the modulator, maximize the –1 order diffracted beam. Refer to Chapter 5, "Installation and Alignment: Pulse-selector Installation."
Improper delay and phase setting.	Adjust the PHASE and DELAY controls for maximum diffraction output and extinction ratio. Verify the AOM is properly adjusted. Refer to Chapter 5, "Installation and Alignment: Pulse-selector Installation."
The Tsunami laser is not properly mode locked or its pump source is misaligned.	Verify a mode-locked condition exists using a Model 409-07 autocorrelator (or equivalent). Follow the installation and alignment procedures in the *Tsunami User's Manual.*
Improper distance between the input focusing lens and AOM.	The distance between the lenses and the AOM are factory set for optimum diffraction efficiency and extinction ratio. Nevertheless, if the input beam parameters differ significantly from a standard Tsunami laser, the lenses may require repositioning (refer to Chapter 5). The 38 mm lens set supplied with the accessory kit is required for wavelengths above 1000 nm.
Improper sync signal from the Tsunami laser.	Verify the input signal to the 40 MHz SYNC IN connector on the electronics unit is within ECL logic level specifications.
Pulse selector not properly aligned to the input beam.	Verify proper centering of the input beam through the center of the alignment target on the input bezel and the alignment aperture on focusing lens L_1. Refer to "Installation and Alignment."

Symptom: Frequency doubler has low or no output	
Possible Causes	**Corrective Action**
Input beam is not properly aligned to the Model 3980.	Verify centering of input beam on all optics and realign if necessary. Refer to Chapter 5, "Installation and Alignment."
The SHG crystal is not aligned to the beam at a proper phase-matching angle for the chosen wavelength.	Use the angle adjustment micrometer to align the SHG crystal to the correct phase-matching angle. Refer to Chapter 5, "Installation and Alignment."
The Tsunami laser is not properly mode locked or its pump source is misaligned.	Verify a mode-locked condition exists using a Model 409-07 autocorrelator (or equivalent). Follow the installation and alignment procedures in the *Tsunami User's Manual*.
Model 3980 optical feedback is interfering with pulse generation in the Tsunami laser.	Offset the housing alignment of the Model 3980 to the Tsunami laser head just a little, and realign the Model 3980 to this new position. This should offset the beam just enough to prevent direct feedback.
Position of focusing mirror M_3 and collimating mirror M_4 is not optimized for the chosen wavelength.	The position of M_3 is optimized for doubling efficiency at the factory. Nevertheless, if the input beam parameter is different from that used at the factory, it is necessary to reoptimize the position of both M_3 and M_4. Refer to Chapter 5, "Installation and Alignment."
Optics are dirty.	Clean the optics using the procedures given in Chapter 7, "Maintenance."

Symptom: Pulse selector and frequency doubler—no or low output	
Possible Causes	**Corrective Action**
Pulse selector not optimized.	Verify operation of the pulse selector. Refer to the troubleshooting section on “No output from the pulse selector.”
Harmonic generator not optimized.	Verify operation of the harmonic generator. Refer to the trouble-shooting section on “Frequency doubler has no or low output.”
Incorrect PRF frequency selected for pulse selection and harmonic generation.	Verify the PRF frequency is set as desired.
The Tsunami laser is not properly mode locked or its pump source is misaligned.	Verify a mode-locked condition exists using a Model 409-07 auto-correlator (or equivalent). Follow the installation and alignment procedures in the *Tsunami User's Manual*.

Symptom: Electronic unit—heater light flashes or remains red longer than 5 min.	
Possible Causes	**Corrective Action**
The heater D-sub cable is not installed or is damaged.	Verify the cable is not damaged and is connected properly.
The P_1/J_1 connector in the electronics unit is disconnected or the heater cable from the pc board to the frequency-doubler crystal in the Model 3980 is disconnected.	These connectors are disconnected on units shipped as pulse selector only systems. When a frequency doubler is added later, attach the P_1 connector to J_1 on the pc board, and attach the heater cable from the SHG crystal to the pc board as well. Note: verify the ac power is off before removing the top cover from the electronics module or before plugging in any cable.
The heater element is open (burned out or damaged).	Unplug the heater cable to the frequency doubler and check for continuity.

Replacement Parts

The following tables contain component part numbers for items you may have damaged or lost.

Table 8-1: Replacement Parts, Frequency Doubler

Component	720–900 nm Part Number	840–1080 nm Part Number
M_1, M_2 Routing Mirror	G0072-028	G0072-027
M_3 Focusing Mirror	G0068-020	G0068-023
M_4 Focusing Mirror	G0068-021	G0068-022
M_5 Routing Mirror	G0072-023	G0072-026
LBO Crystal Assembly, Picosecond version	0446-8280	0446-8290
BBO Crystal Assembly, Femtosecond version	0445-6430	0445-6430
Compensator Optic	G0364-002	G0364-001
P_1 Beam Splitter Assembly	0446-8320	0446-8330
P_2, P_3 Littrow Prism Assembly	0446-8300	0446-8310

Table 8-2: Replacement Parts, Pulse Selector

Component	Part Number
L_1, L_2 50 mm Lens Assembly	0447-8520
L_1, L_2 38 mm Lens Assembly	0447-8530
L_2 75 mm Lens Assembly	0448-6950
AOM Acousto-optic Modulator	0447-3000

Table 8-3Replacement Parts, Hardware

Component	Part Number
Alignment Target	0446-7340
Bezel Plug	0445-6470
L_1, L_2 Lens Mount	0445-8440

Chapter 9 Customer Service

At Spectra-Physics, we take great pride in the reliability of our products. We place considerable emphasis on controlled manufacturing methods and quality control throughout the manufacturing process. Nevertheless, even the finest precision instruments will need occasional service. We feel that our instruments have favorable service records compared to competitive products, and we hope to demonstrate, in the long run, that we provide excellent service to our customers in two ways: first, by providing the best equipment for the money and, second, by offering service facilities that get your instrument repaired and back to you as soon as possible.

Spectra-Physics maintains major service centers in the United States, Europe, and Japan. Additionally, there are field service offices in major United States cities. When calling for service inside the United States, dial our toll-free number: **1 (800) 456-2552**. For the phone numbers or addresses of service centers in other countries, refer to the “Service Centers” listing located at the end of this section.

Order replacement parts directly from Spectra-Physics. For ordering or shipping instructions, or for assistance of any kind, contact your nearest sales office or service center. You will need your instrument model and serial numbers available when you call. Service data or shipping instructions will be promptly supplied.

To order optional items or other system components, or for general sales assistance, dial **1 (800) SPL-LASER** in the United States, or **1 (650) 961-2550** from anywhere else.

Warranty

This warranty supplements the warranty contained in the specific sales order. In the event of a conflict between documents, the terms and conditions of the sales order shall prevail.

Unless otherwise specified, all parts and assemblies manufactured by Spectra-Physics are unconditionally warranted to be free of defects in workmanship and materials for a period of one year for mechanical and electrical components and 90 days for optics following delivery of the equipment to the F.O.B. point.

Liability under this warranty is limited to repairing, replacing, or giving credit for the purchase price of any equipment that proves defective during the warranty period, provided prior authorization for such return has been given by an authorized representative of Spectra-Physics. Spectra-Physics will provide at its expense all parts and labor and one-way return shipping of the defective part or instrument (if required). In-warranty repaired or replaced equipment is warranted only for the remaining unexpired portion of the original warranty period applicable to the repaired or replaced equipment.

This warranty does not apply to any instrument or component not manufactured by Spectra-Physics. When products manufactured by others are included in Spectra-Physics equipment, the original manufacturer's warranty is extended to Spectra-Physics customers. When products manufactured by others are used in conjunction with Spectra-Physics equipment, this warranty is extended only to the equipment manufactured by Spectra-Physics.

This warranty also does not apply to equipment or components that, upon inspection by Spectra-Physics, discloses to be defective or unworkable due to abuse, mishandling, misuse, alteration, negligence, improper installation, unauthorized modification, damage in transit, or other causes beyond the control of Spectra-Physics.

This warranty is in lieu of all other warranties, expressed or implied, and does not cover incidental or consequential loss.

The above warranty is valid for units purchased and used in the United States only. Products with foreign destinations are subject to a warranty surcharge.

Return of the Instrument for Repair

Contact your nearest Spectra-Physics field sales office, service center, or local distributor for shipping instructions or an on-site service appointment. You are responsible for one-way shipment of the defective part or instrument to Spectra-Physics.

We encourage you to use the original packing boxes to secure instruments during shipment. If shipping boxes have been lost or destroyed, we recommend you order new ones. We can return instruments only in Spectra-Physics containers.

Caution!

The lock-down screws on the SHG crystal mount assembly and the compensator assembly secure the two mounts to the base plate during shipping. Replace these screws before returning the unit to Spectra-Physics for upgrade or service.

Service Centers

Benelux

Telephone: (31) 40 265 99 59

France

Telephone: (33) 1-69 18 63 10

Germany and Export Countries*

Spectra-Physics GmbH
Guerickeweg 7
D-64291 Darmstadt
Telephone: (49) 06151 708-0
Fax: (49) 06151 79102

Japan (East)

Spectra-Physics KK
East Regional Office
Daiwa-Nakameguro Building
4-6-1 Nakameguro
Meguro-ku, Tokyo 153
Telephone: (81) 3-3794-5511
Fax: (81) 3-3794-5510

Japan (West)

Spectra-Physics KK
West Regional Office
Nishi-honmachi Solar Building
3-1-43 Nishi-honmachi
Nishi-ku, Osaka 550-0005

Telephone:	(81) 6-4390-6770
Fax:	(81) 6-4390-2760
e-mail:	niwamuro@splasers.co.jp

United Kingdom

Telephone: (44) 1442-258100

United States and Export Countries**

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	(800) SPL-LASER (Sales) or
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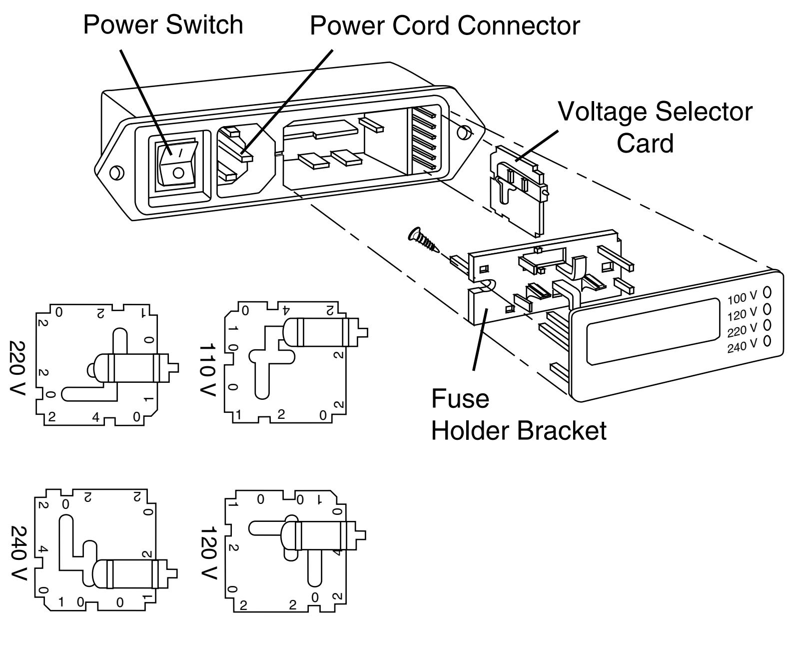
	(650) 961-2550 (Operator)
Fax:	(650) 964-3584
e-mail:	service@splasers.com
	sales@splasers.com
Internet:	www.spectra-physics.com

**And all European and Middle Eastern countries not included on this list.*
***And all non-European or Middle Eastern countries not included on this list.*

Appendix A Selecting Proper Line Voltage

The Model 3986 has an autoswitching line input of 90 to 250 Vac and needs no setting. However, the Model 3983 is not autoswitching and its line voltage switch (part of the power connector) must be set to match your facility line voltage. The controller is shipped from the factory with its line voltage set for the location of intended use. If it is incorrect, you must change it before applying power to the system *or you will damage the system*. Refer to Figure A-1while following the instructions below.



The four orientations of the voltage selector card.

Figure A-1: Power Switch, Line Cord, and Voltage Selector Module

1. Remove the cover plate/fuse block assembly to expose the voltage selector card.

   Use a small screwdriver to gently pry off the cover plate. A slot is provided for screwdriver access.

2. Remove the voltage selector card.

   The voltage selector card comprises a white plastic indicator pin attached to a small pc board about 2 cm (0.8 in.) square.

   Using needle nose pliers, grasp the pc board and pull out from side to side to remove it from the module.

3. Verify the correct fuse is installed:

Facility Line Voltage	Model 3983 Fuse
100 to 120 V_{ac}	0.25 A slow blow
220 to 240 V_{ac}	0.125 A slow blow

4. Select the voltage.

   There are four voltage selections, one written on each edge of the pc board with a small arrow pointing to it.

   a. Measure your facility line voltage and find the voltage printed on the edge of the pc board that matches it.
   b. Rotate the pc board so the edge you selected faces toward the inside of the module (its arrow points into the module).
   c. Move the white indicator pin in the slot so it points away from your selection.

5. Replace the voltage selector card.

   Install the pc board so the indicator pin protrudes through the correct hole in the cover plate when the plate is replaced in step 6.

   Make sure the pc board seats properly for good electrical contact.

6. Snap the cover plate into place.

   If the indicator pin is not in the correct position, repeat steps 4 and 5above.

This completes the procedure for changing the line voltage setting for the Model 3983 controller.

Appendix B Optimizing the Tsunami Laser Output

This appendix is intended as an extension to your *Tsunami User's Manual* and not a substitute for it. It contains information helpful in getting the most from your Tsunami®/Model 3980 picosecond (ps) and femtosecond (fs) systems.

Recommended Equipment

You must have the proper equipment to measure fs pulses from a Model 3980 with a pulse selector, (a) in order to maximize pulse bandwidth and create short pulses, (b) have the pulse stretcher work effectively, and (c) prevent catastrophic failure of the AOM due to the inability to properly set (a) and (b). The table below is a list of recommended equipment. Refer to Chapter 5, "Installation and Alignment: Pulse-selector Installation," for information on the safe operation of the fs pulse selector. Also refer to Spectra-Physics Application Note, Vol. 1, May 9, 1992, "Pre-compensation of GVD for Ultra-short Pulses, avail able from your Spectra-Physics service representative.

Item	Manufacturer	Model
Video Analyzer	Colorado Video	321
Monochromator Grating Slit	Oriel	77250 77299 77269
CCD Camera	Pulnix America	TM-7CN
Monitor	Video Media	TC1910A
Var. ND Attenuator Attenuator Mount	Newport	60G00 AV-1 940
2 ea. Translator Stage	Newport	425-1
2 ea. Al. Film Mirror 2 ea. Mirror Mount	Newport	AL.2 MM2-1A
2 ea. SF-10 Prisms 60° prisms	Optics for Research	

Optimizing Picosecond Tsunami Laser Output

1. Refer to your *Tsunami User's Manual* and follow the instructions in Chapter 5, "Operation," to start your Tsunami laser, then verify it meets specifications for ps operation.
2. If specified power and pulse width are not met, refer to the "Maintenance" chapter in your *Tsunami User's Manual* for instructions on

cleaning the optics. When done, verify the Tsunami laser meets specifications. The pump laser must also meet specifications.

3. If specified power and pulse width are still not met, refer to Appendix B in your *Tsunami User's Manual* and follow the instructions for further optimizing Tsunami laser output by “Walking the Beam.” When done, verify the Tsunami laser meets specifications.

If, after performing Steps 1 through 3, your Tsunami laser still does not meet specifications, call your Spectra-Physics service representative. Refer to Chapter 9, “Customer Service,” in this manual for the location and phone number of your nearest Spectra-Physics service center.

4. Verify the Tsunami laser mode locks properly throughout its tuning range.
5. Tune the Tsunami laser to the desired wavelength and optimize its output power by walking the beam, even if you did so in Step 3 above.
6. Verify the beam is centered on the output coupler and that the photodiode pc board is aligned. Refer to “Alignment: Aligning the Photodiode PC Board,” in your *Tsunami User's Manual.*
7. Monitor the output pulses with a Model 409 (or equivalent) autocorrelator and adjust the FINE PHASE, GTI POSITION and pump laser output power so the pulse remains stable for the largest variation in GTI POSITION settings without premature drop out.
8. Use the GTI POSITION control to select the best order (out of the several that are possible) where mode locking occurs.
9. Verify the Tsunami laser meets specified power.

Optimizing Femtosecond Tsunami Laser Output

1. Perform Steps 1 through 6 under “Optimizing Picosecond Tsunami Laser Output” above.
2. Using a Model 409-08 autocorrelator and wavelength and bandwidth measuring equipment, set up a pair of pre-compensation prisms.
3. While viewing the bandwidth monitor, use the prism dispersion compensation and slit width controls on the Tsunami laser to adjust for maximum output with shortest pulse width without observing cw breakthrough.
4. Lower pump laser output power and verify the system is operating in the first mode-locking regime; i.e., with a decrease in pump laser current there is a linear decrease in bandwidth and the system shows no cw breakthrough. If this is not the case, lower pump power and repeat these last two steps.

   Cw breakthrough is seen as an intense, narrow frequency component on the bandwidth monitor.
5. Verify the Tsunami laser meets specified power.

Notes

Report Form for Problems and Solutions

We have provided this form to encourage you to tell us about any difficulties you have experienced in using your Spectra-Physics instrument or its manual—problems that did not require a formal call or letter to our service department, but that you feel should be remedied. We are always interested in improving our products and manuals, and we appreciate all suggestions.

Thank you.

From:

Name ____

Company or Institution ____

Department ____

Address ____

____

Instrument Model Number ____________________ Serial Number ____________________

Problem: ____

____

____

____

____

Suggested Solution(s): ____

____

____

Mail To:

Spectra-Physics, Inc.
ISL Quality Manager
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Mountain View, CA 94039-7013
U.S.A.

E-mail: sales@splasers.com
www.spectra-physics.com

FAX to:

Attention: ISL Quality Manager
(650) 961-7101