RADIANTIS

Inspire Blue

OPERATOR´S MANUAL

Please, read this manual carefully before operating the Inspire Blue for the first time. Additionally to the safety information here provided, observe all the precautions detailed in your pump laser Operator's Manual.

*FCC *
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation and with the CE certification standards.

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Chapter I.- Introduction

This manual details information for the user of the Inspire Blue, an optical frequency doubler that can generate two simultaneous femtosecond laser beams, tunable in the spectral regions with wavelengths between 345 – 550 nm and 690 – 1100 nm.

For correct operation, the Inspire Blue must be pumped by a mode-locked femtosecond Ti:Sapphire laser with up to 3 Watts maximum average power, 70 – 90 MHz repetition rate and maximum wavelength range between 690 – 1100 nm.

The system is not intended to be used with pump lasers of other kind, such as femtosecond lasers with higher average powers or pulse energies. The use of different pump lasers is not recommend since this may cause permanent damage to the optical components and may be fatal for the system operation.

Below, standard pump laser and Inspire Blue specifications are detailed:

Pump Laser

Pulse Duration: 80 – 200 fs

Repetition Rate: 70 – 90 MHz

Maximum Average Power: 3 W

Wavelength Range: 690 – 1100 nm (typically 690 – 1040 nm)

Inspire Blue

Pulse Duration: 130 – 200 fs

Repetition Rate: 70 – 90 MHz

Output Beam 1

Wavelength Range: 345 – 550 nm (typically 345 – 520 nm)

Maximum Average Power: 1.5 W

Output Beam 2

Wavelength Range: 690 – 1100 nm (typically 690 – 1040 nm)

Maximum Average Power: 3 W

Chapter II.- Laser Safety

II.1 General Optical Safety Issues

Unlike light from conventional sources, laser beams have high optical intensities, even after propagation over relatively long distances. The human eye is extremely sensitive to laser radiation and as a result, direct or reflected laser beams can cause permanent damage to the unprotected eye.

Ocular damage can happen at different eye regions such as the retina or the lens and the extent of the damage is determined by the laser irradiance, exposure duration, and beam size. Since some eye injuries, such as laser retinal burns, may be painless and the damaging beam sometimes invisible, maximal care should be taken to provide protection for all persons in the laser suite.

II.2 Safety Information for the User

Although the Inspire Blue is not itself a laser source and so does not constitute a laser product, the level of hazard associated to its emission is equivalent to a Class 4 laser product. Additionally, since the Inspire Blue changes the emission wavelength of the pump laser, this affects the nature of the hazard and the necessary precautions to be taken for any system user.

Simultaneous output beams can be generated by the Inspire Blue over a range of wavelengths in the near-ultraviolet (near - UV), the visible and the near-infrared (near - IR) spectral regions. In particular, the frequency doubled output in the near – UV and Visible, (which is at half the wavelength of the input beam) may represent an INCREASE in hazard over the input beam, EVEN THOUGH THE EMITTED POWER IS LOWER, because

of the differing biophysical effects and variations in the maximum permissible exposure (MPE) limits at different wavelengths.

Exposure to any beam directly emitted by the Inspire Blue can result in serious injury to the eye. The viewing of diffuse beam reflections may also be unsafe. In addition, the beam can be hazardous to the skin and pose a risk of fire. It should only be used by those who understand the nature of these hazards and who have undergone appropriate training in laser safety.

Users of the Inspire Blue and their employers are responsible for undertaking a risk assessment and for ensuring that adequate protective measures are established in accordance with the recommendations given in PD IEC TR 60825-14 or other equivalent national or international safety guidelines.

The product should only be used within an enclosed area having suitable restrictions on access. Wherever possible the emitted beams should be enclosed in accordance with good laser safety practice, and remote (i.e. CCTV) viewing systems used for observation if necessary. Where this is not possible and the use of eye protection is necessary, users and their employers are responsible for ensuring that the most appropriate eye protection is used, taking into account both the emitted wavelength and the maximum level of any potential exposure. Particular care is required in selecting eye protection that is intended to provide simultaneous protection for both of the emitted beams. Such eye protection will have considerably reduced visible light transmission, and the working area in which the Inspire Blue is used should therefore be well lit, carefully laid out and uncluttered.

II.3 Hazardous Laser Emission

The Inspire Blue has two exit apertures marked as:

LASER APERTURE Beam 1 UV: 345 to 550 nm 2W (max)
LASER APERTURE Beam 2 IR: 690 to 1100 nm 4W (max)

LASER APERTURE Beam 1 is the frequency doubled output (which is at half the wavelength of the input beam) and may represent an INCREASE in hazard over the input beam EVEN THOUGH THE EMITTED POWER IS LOWER.

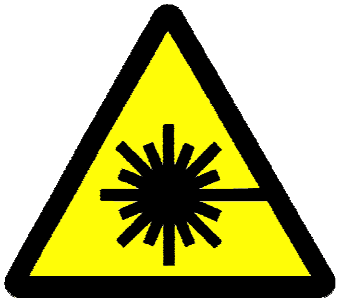
LASER APERTURE Beam 2 is the depleted pump (which is at the same wavelength than the input beam) and represents similar hazard to the input beam (Class 4).

The system is intended to be used with the cover on, which acts as a protective housing from hazardous laser beams and reflections generated inside the box.

II.4 Safety Labels

The Inspire Blue satisfies all labelling requirements. The following are included:

1. **Triangular laser warning**: alerts the user to the presence of hazardous visible and invisible laser radiation.



2. **Class 4 explanatory label**: alerts the user to the presence of Class 4 visible and invisible laser radiation and specifies the wavelength range and maximum average power emitted by the system at each output.

3. **Emission aperture warning labels**: alerts the user to the location of laser radiation exit and the wavelength range and maximum average power emitted. Beam 1 is the frequency doubled output and Beam 2, the depleted pump.

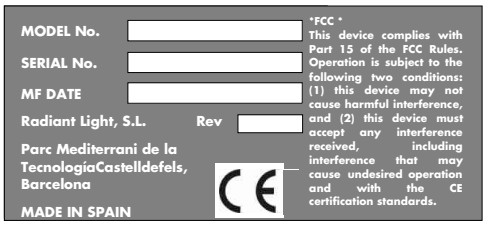
LASER APERTURE

Beam 1 UV: 345 to 550 nm 2W (max)

LASER APERTURE

Beam 2 IR: 690 to 1100 nm 4W (max)

4. **Certification and Identification label:** Informs the user of the manufacturer name and address, the place and date of manufacture and the compliance with International and European laser product safety standards.



II.5 Examples of Eye Protection

1. Type LM 14

Laser protective eyewear for 190 - 534 nm, 730 - 1064 and 10600 nm

Optical density > 7 for 180 - 315
Optical density > 6 for 315 - 534
Optical density > 5 for 730 - 740
Optical density > 6 for 740 - 1064

Visible light transmission 11 %

EN 207 markings:

190 - 315 D L7, R L3, M L5
315 - 534 D L4, IR L6, M L5
730 - 740 D L4, IRM L5
740 - 1064 D L4, I L6, RM L5
1064 D L4, IR L6, M L5

Frame style A Order code: LM-A-14
Frame style B Order code: LM-B-14
Frame style C1 Order code: LM-C-14

2. Type LM 28

Laser protective eyewear for 180 - 532, and 750 - 1064 nm

Optical density > 8 for 180 - 315
Optical density > 7 for 315 - 532
Optical density > 7 for 750 - 1064

CE Marked

EN 207 markings:

180 - 315 D L8, IR L5

315 - 532 D L5, I L7, R L4

750 - 1064 D L5, I L7, R L4

633 R1

Visible light transmission 7 %

The above eye protection is available from

Lasermet Ltd

67 Portchester Road, Bournemouth

BH8 8JX

United Kingdom

Tel +44 (0) 1202 770740

www.lasermet.com

Chapter III: Description and Layout

III.1 Description

The Inspire Blue is designed to be pumped by a mode-locked Ti:Sapphire laser, with pulse durations between 80-200 femtoseconds, repetition rates between 70 - 90 MHz and average power up to 3 W.

The Inspire Blue partially converts the near-IR Ti:Sapphire laser spectrum, tunable between 690 and 1100 nm, into the near-UV and visible, with wavelengths between 345 and 550 nm. The converted laser beam is emitted by one of the two output apertures, as illustrated in Figure III.1. Additionally, the depleted near-IR pump, with wavelengths between 690 and 1100 nm, is simultaneously emitted by the second output aperture.

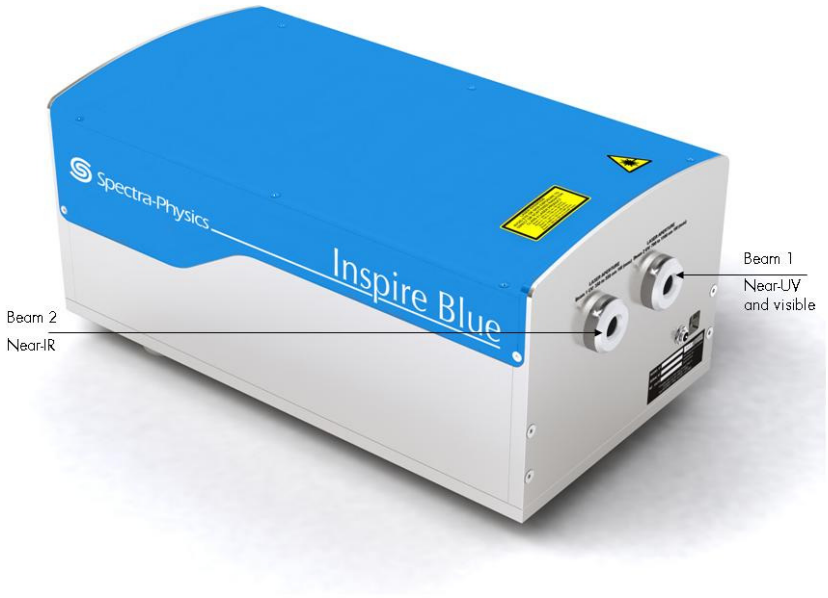


Figure III.1.- The Inspire Blue output apertures

The frequency conversion is achieved by applying the Second Harmonic Generation (SHG) technique. This is a second order nonlinear optical process which has the

capability to partially double the frequency of an input laser beam by propagating through an appropriate nonlinear crystal.

III.2 System Layout and Operation

The Inspire Blue is composed of high quality optical and opto-mechanical components that have been specially designed and arranged to provide optimum performance and stability, while allowing very simple use. These components are secured on a sturdy metal platform that enhances stability and reliability.

The system is provided with a cover that protects the user from hazardous radiation during operation, minimises unwanted scattered light in the laboratory and protects the internal components from dust and damage. In the case of the Inspire Blue Manual, two external actuators allow the user to tune the system and optimize its performance, with the cover on. In the case of the Inspire Blue Auto, computer-controlled automated actuators are used to tune the system and optimize its performance.

The system provides ease of tuning and alignment for optimum performance. Aligning the beam through both the input and output iris diaphragms when gradually closing the apertures, ensures the system is correctly aligned. The following components can be used for alignment:

1. 3 Built-in alignment pinholes
    - 1 Entrance alignment pinhole
    - 2 Exit alignment pinholes

2. 3 Screw-legs for levelling and adjusting the system height

Next, a description of the Inspire Blue layout is provided.

Lens-based system: As illustrated in Figure III.2, the near-IR Ti:Sapphire pump beam enters the system through the entrance aperture and impinges on lens L1 that focuses it onto the nonlinear crystal C1.

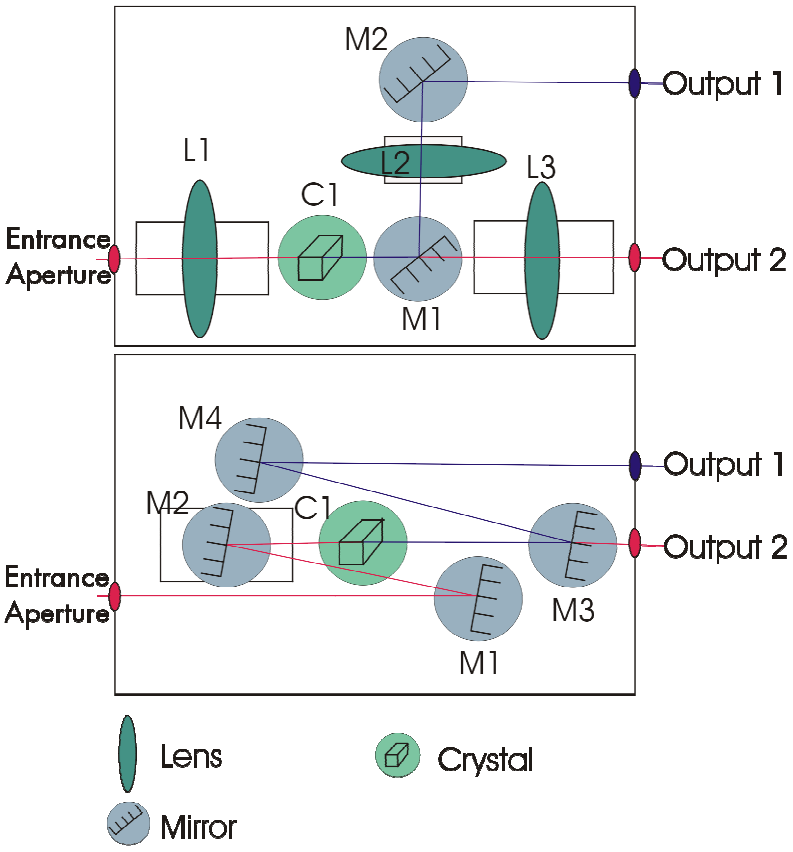


Figure III.2. Layout of the adjustable components of the Inspire Blue, lens-based (top) and mirror-based system (bottom)

At the nonlinear crystal C1, frequency doubling of the pump beam takes place. A percentage of the pump near-IR power is converted into the near-UV. The rest of the power, the depleted pump, will be transmitted throughout the crystal C1.

Both the converted near-UV and the depleted near-IR pump will propagate until dichroic mirror M1 where the depleted near-IR beam is transmitted and the converted near-UV beam reflected towards Mirror M2.

The near-UV and near-IR beams exit the system through the exit apertures referred as Output 1 and Output 2 respectively, on Figure III.2.

Mirror-based system: the near-IR Ti:Sapphire pump beam enters the system through the entrance aperture and impinges on mirror M1 that reflects the beam onto mirror M2 that focuses it onto the nonlinear crystal C1.

At the nonlinear crystal C1, frequency doubling of the pump beam takes place. A percentage of the pump near-IR power is converted into the near-UV. The rest of the power, the depleted pump, will be transmitted throughout the crystal C1.

Both the converted near-UV and depleted near-IR pump will propagate until dichroic mirror M3 where the depleted near-IR pump is transmitted and the converted near-UV beam reflected and collimated towards Mirror M4.

The near-UV and near-IR beams exit the system through the exit apertures referred as Output 1 and Output 2 respectively, on Figure III.2.

Chapter IV. Installation and Alignment

The installation procedure is as follows:

1. Install the Ti:Sapphire pump laser in accordance with the manufacturer's laser operator manual.
2. Measure the pump laser beam output characteristics (average power, pulse duration, beam quality and wavelength). Verify that these satisfy:
    - Pulse Duration: 80 – 130 fs
    - Repetition Rate: 70 – 90 MHz
    - Maximum Average Power: 3 W
    - Wavelength 820 nm
    - M^2<1.1(vertical) M^2<1.26 (horizontal)

    For different pump output properties, the Inspire Blue specifications detailed in Chapter I may not be achieved.
3. Set the power of the laser to 1.5W in order to minimize the risk of damage.
4. With the iris diaphragm of the entrance aperture closed, position the Inspire Blue in front of the pump laser so that its input face is perpendicular to the incoming beam. The recommended beam propagation distance between the exit of the pump laser and the entrance of the Inspire Blue is 15-30 cm.
5. Adjust the height of the Inspire Blue using the three leg screws so that the incoming beam is levelled with the centre of the input aperture and the two output apertures are also at the same height as the input aperture.
6. When the height is correct, open the iris diaphragm of the entrance aperture and ensure that the input beam passes through the centre of the input and output apertures.

7. Partially close the irises and ensure the beam goes through the centre of the apertures. Otherwise re-position the device following instructions on points 4 and 5.
8. When the position is correct, clamp the feet of the Inspire Blue to the optical table and open the iris diaphragm of the entrance aperture.
9. Close both output aperture diaphragms and then increase the power of the pump laser.
10. In the case of the Inspire Blue Manual, place a power-meter in front of output 1 and open the diaphragm to measure the power of the frequency doubled beam.
11. Using Actuator A2 to rotate the crystal, find the position offering maximum frequency doubled output power.

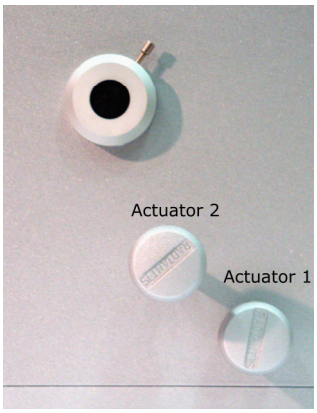


Figure IV.1. Inspire Blue Control program, "Configuration" mode.

12. Using Actuator A1 to translate the crystal, find the position offering maximum frequency doubled output power. (Repeat steps 11 and 12 until the maximum frequency doubled output power is reached).
13. In the case of the Inspire Blue Auto system, place a power-meter in front of output 1 and open the diaphragm to measure the power of the frequency doubled beam.

14. Launch the software.
15. Run the Tune procedure. For more information, refer to Chapter V.

Chapter V. Operation

V.1 Common features

Mirrors M1, M2 for the lens-based version and mirrors M1, M2, M3 and M4 for the mirror-based version are mounted on adjustable mounts as illustrated in Figure V.1, which allow tilting and alignment of the input beam.

Figure V.1.- Illustration of mirror mounts

The nonlinear crystal C1 is positioned on a rotation stage which facilitates tuning and power optimization, by varying the angle of incidence of the input light onto the crystal.

Figure V.2.- Illustration of crystal box

The nonlinear crystal C1 and the rotation stage are mounted on a translation stage so that the distance to the Lens L1 can be adjusted. This allows optimization of the output power when tuning the system.

V.2 Operation of the Inspire Blue Manual version

With the Inspire Blue Manual, the external actuators A1 and A2 (see Figure IV.1) increase safe operation by allowing tuning with the cover on. This is the procedure for the optimisation of the frequency doubled signal:

1. Tune the pump laser to the desired input wavelength (twice the desired output wavelength) according to the manufacturer's laser operator manual.
2. Open the irises of the Inspire Blue entrance and output apertures.
3. Place a power-meter in front of output 1 to measure the power of the frequency doubled beam.
4. Using Actuator A2 to rotate the crystal, find the position offering maximum frequency doubled output power.
5. Using Actuator A1 to translate the crystal, find the position offering maximum frequency doubled output power. (Repeat steps 4 and 5 until the maximum frequency doubled output power is reached).

V.3 Operation of the Inspire Blue Auto version

The Inspire Blue Auto has no external actuators. Tuning is performed automatically by the software. The Auto version of the Inspire Blue comes with an integrated DAQ card, a photodiode, an automated rotation stage and an actuator. A control program using our in-house developed Free-Scan technology is also provided that can be installed on any computer with a USB socket running Microsoft Windows. This is the procedure for the optimization of the frequency doubled signal.

1. Install the control software as explained in section V.4 Program installation.
2. Plug the Inspire Blue to the mains and to the USB port of a computer.
3. Start "IB Automated Control" application. When started, the front panel is displayed and the program is in an idle state in which the voltage read from the photodiode is displayed in volts.
4. Press "Exit", only if you desire to exit the program and close this interface.

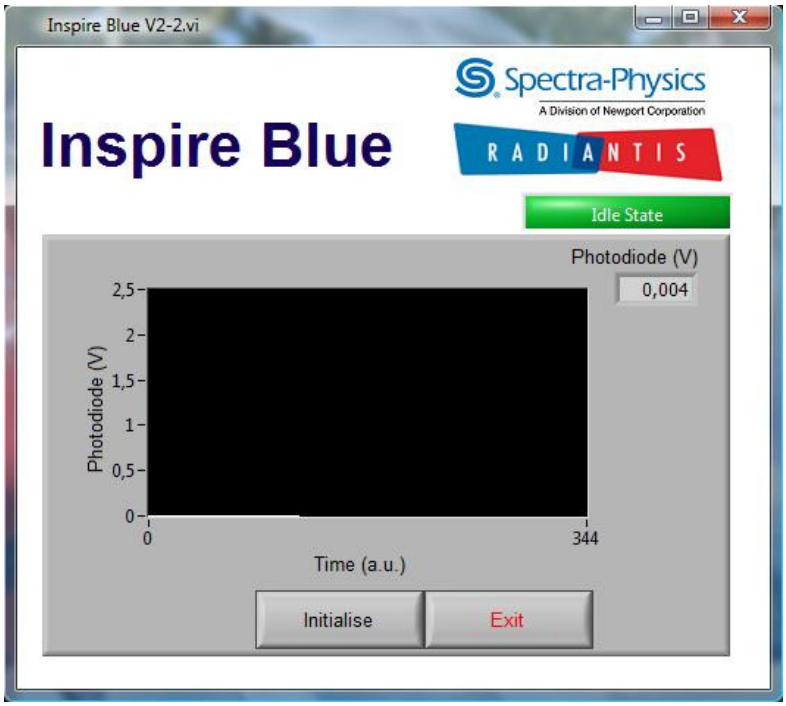


Figure V.3. IB Automated Control program

5. Press "Initialise" to bring the actuators to the home position. A pop-up window appears, as illustrated in Figure V.4.

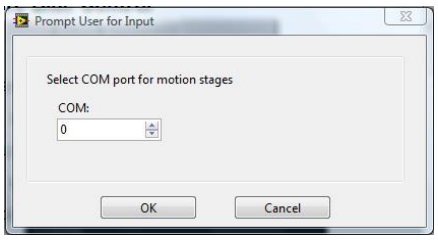


Figure V.4. IB Automated pop-up window.

6. Enter the com actuator port number in the pop-up window. It can be found by opening National Instrument´s Measurement and Automation Explorer program and going to the section Devices and Interfaces/Serial and Parallel. The correct com port number is tagged as "USB Serial port". The system initialises all devices and the program enters an idle state in which the voltage read from the photodiode is displayed in volts. A new screen appears, as illustrated in Figure V.5, where two new buttons, "Tune" and "Maximise", are available.

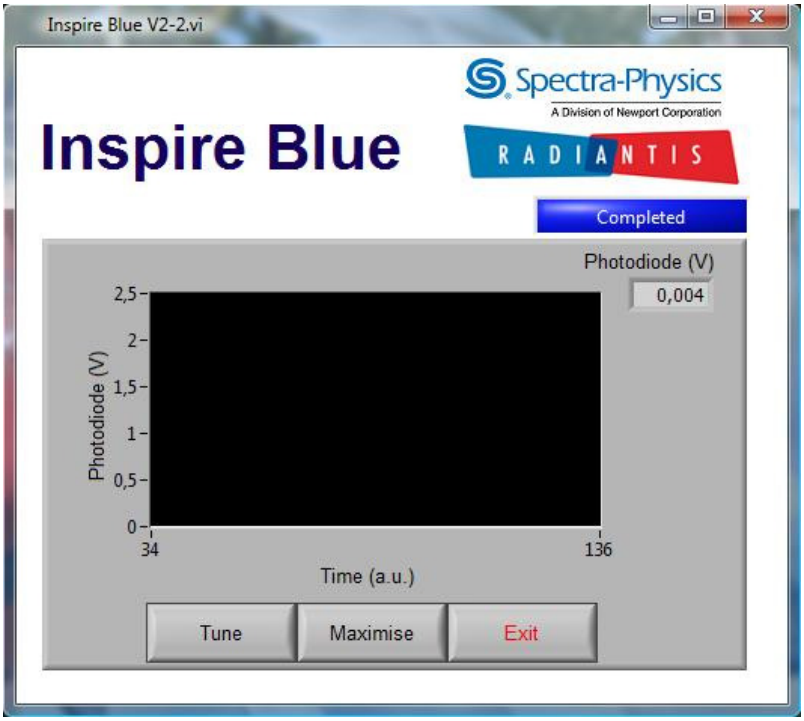


Figure V.5. IB Automated Control program, Idle state.

7. Tune the pump laser to the desired input wavelength (twice the desired output wavelength) according to the manufacturer's laser operator manual.

8. Open the irises of the Inspire Blue entrance and output apertures.

9. Press “Tune” to optimise the power of the frequency doubled signal. The actuators scan the whole range, one after the other, to find the maximum frequency doubled output power. “Tune” shall be pressed every time the pump wavelength is modified, in order to obtain optimized SHG power.
10. If the optimized doubled signal is left idle for a long period of time, its power might decrease. In this case, press “Maximise” to re-optimise the frequency doubled power.

Once the Inspire Blue output power has been optimised, the user can exit the program. Alternatively, the user may choose to leave the software running in the background, in case the SHG beam power needs to be maximised.

V.4 Program installation

1. Plug the Inspire Blue to the mains and to the USB port of a computer.
2. Turn the computer on.
3. Copy and extract files from the Radiantis pen drive.
4. Run setup (APT) to install the APT software.
5. Run start/program/Thorlabs/APT/APTconfig.
    - Select control unit → 1Ch DC Drive T-cube (TDC001).
    - Enter last 6 digits of serial number.
    - Select the line.
    - Press save then set as current.
    - Select the “stage” tab.
    - Select motor from “motor” indicator → select.
    - From “stage” pull down menu, select CR1-Z6.
    - Press “add/change stage association.
    - Select then exit program.

6. In the “installation IB Automated” folder, go to “my installer and run setup program.
7. Re-start computer.
8. Install EasySync driver.
9. Install IB Automated control program.
10. Run “Measurement and Automation” program.
11. Open “Device and interfaces”/”NIDAQmx devices and rename NI USB-6008 as Dev1.
12. Run program.

Chapter VI.- General Maintenance

Daily Operation: To prolong the lifetime of the Inspire Blue, ensure that it is kept in a clean, dry, dust-free environment. When transporting the Inspire Blue, lift carefully, holding the base and avoid excessive shock. Avoid use in low ambient temperature and/or high humidity as condensation can form, which may cause damage to optical components. Avoid spilling chemicals on or in the Inspire Blue as this can cause damage to optical and mechanical components.

Annex I.- Glossary

ABBREVIATION	DESCRIPTION
λ	Lambda (Wavelength)
fs	Femtosecond (10^{-15} Seconds)
IR	Infrared (Wavelength)
Kg	Kilograms (10^{3} Grams) (Weight)
MHz	MegaHertz (10^{6} Hertz) (Repetition Rate)
mm	Millimeters (10^{-3} meters) (Dimensions)
mW	MilliWatts (10^{-3}Watts) (Average Power)
nm	Nanometers (10^{-9} meters) (Wavelength)
SHG	Second Harmonic Generation
TEM	Transverse Electromagnetic (Beam Profile)
Ti:Sapphire	Titanium Sapphire
UV	Ultraviolet (Wavelength)
W	Watts (Power)

Table AI.1.- Abbreviations

Annex II.- Contact Details

For technical support, please contact our technical team at:

Tel: +34 934 134 167

E-mail: technical@radiantis.com