LP603

Optical Parametric Oscillator
User's Manual

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The Manual contains information necessary for running the SOLAR LS Optical Parametric Oscillator (OPO) Model LP 603.

Installation of LP 603 must be only performed either by a SOLAR LS authorized representative or by personnel who have been trained adequately in SOLAR LS to run the LP 603 laser. All other terms should be specified and agreed in advance in the contract for delivery. Non-fulfillment of the above requirements voids all warranties.

LP 603 is a source of hazardous radiation. The safety precautions specified in the Manual should be observed when operating the laser.

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1. INTRODUCTION

OPO Operation Principle

The process of optical parametric oscillation (amplification) of light - OPO - is one of numerous types of frequency conversion in nonlinear crystals as opposed to lasers whose operation is based on amplification of spontaneous radiation.

At present, OPO is the most promising technique for achieving high-power laser output in a very wide spectral range. Neither of lasers available can ensure such a wide tuning range.

The process of radiation generation in OPO is quite opposite to a widely-known process of frequency mixing in nonlinear crystals when high-intensity radiation of two lower frequencies is converted to a higher total frequency radiation.

With OPO, the pump radiation with frequency ωp is converted to radiation of two lower frequencies: ωs (signal wave) and ωi (idler wave). The values of ωs and ωi are determined by the following two conditions.

- the conservation of energy requires that $\omega s + \omega i = \omega p$.
- the conservation of momentum demands that $Ks + Ki = Kp$,

  where **Kp**, **Ks** and **Ki** are the wave-vectors of the pump, signal and idler radiation.

For collinear beams $Kp = Ks + Ki$ holds, provided that

$$\omega p * np = \omega s * ns + \omega i * ni,$$

where **np**, **ns** and **ni** are the refractive indices at the wavelength of the pump, signal and idler wave.

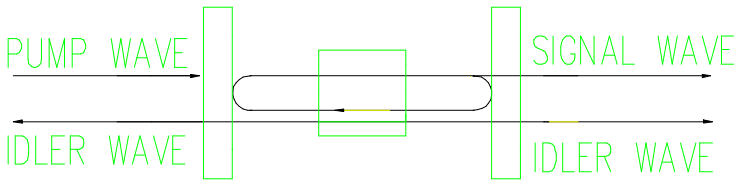
The angular dependence of birefringence in a nonlinear crystal allows for selection of three frequencies to meet both requirements. At a fixed pump wavelength, inclination of the crystal will inevitably lead to alteration of phase matching angle θ and, as a result, to simultaneous tuning of both signal and idler wavelengths. The tunability spectral range is restricted by the nonlinear crystal transparancy range for all three wavelengths.

Due to its outstanding properties (high nonlinearity, wide transparency range, high damage threshold), BBO crystal is widely used in OPO applications. At pumping BBO with third harmonic (355nm) of Nd^{3+}YAG laser, the theoretically allowed tunability range is 403-710nm for signal wave and 710-3100nm for idler wave. In practice, this range is reduced due to that BBO absorbs radiation with wavelengths more that 2200nm.

The correlation between signal and idler wavelengths for pump wavelength λp=355 nm is as follows:

λs, nm	**λi**, nm
420	2294
450	1682
500	1224
550	1001
600	869
650	782
700	720

By placing a nonlinear crystal in a special cavity that ensures a positive feedback for the signal, you can considerably reduce the energy thresholds, at which lasing occurs and conversion efficiency of pump radiation to signal and idler waves increases.



The main output parameters (energy threshold, conversion efficiency, spectrum linewidth) are determined by spatial, spectral and temporal properties of pump radiation.

LP 603 Laser Specifications

Pump Parameters

Wavelength, nm.....355

Beam cross-section distribution.....80% Gaussian fit

Beam divergence, mrad.....≤ 1.0

Max. pulse energy, mJ.....70

Pulse repetition rate, Hz.....10

Pulsewidth, ns..... 12

Output parameters

Linewidth (for signal wave), nm.....< 0.2

Efficiency, %.....30-40

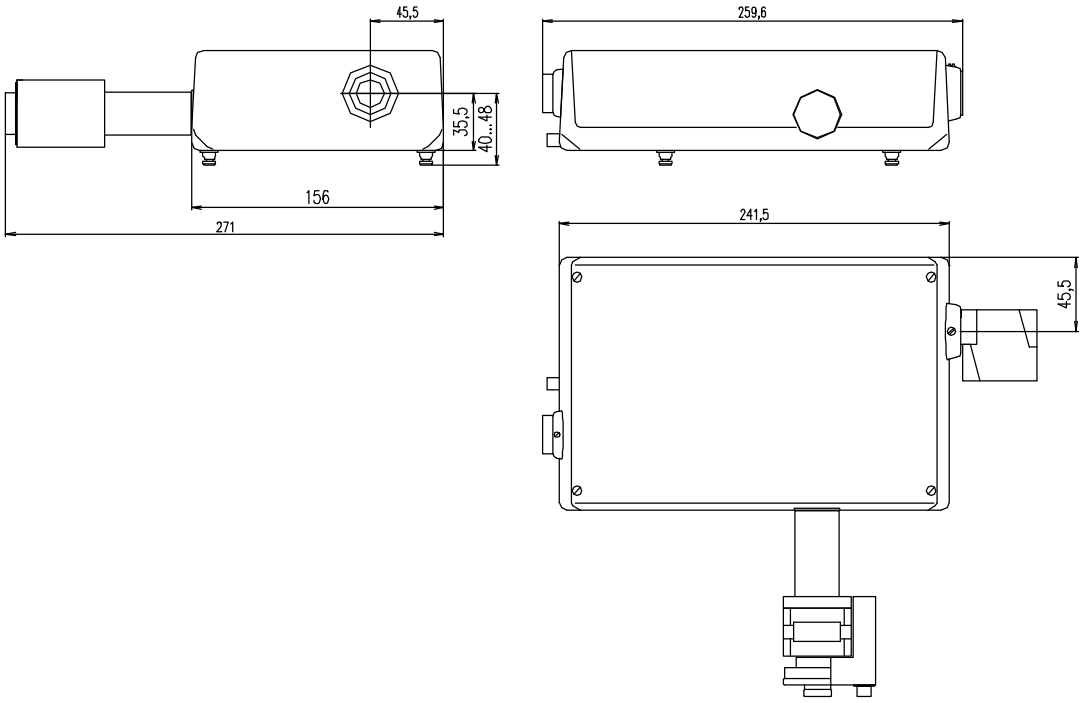
Tunability range,nm

for signal wave..... 420-710
for idler wave..... 710-2280

Pulsewidth, ns..... 1…2 ns less than pump pulsewidth

Pulse to pulse stability,%.....± 8

Dimensions, mm..... see below



Parameters obtained during LP 603 testing:

PUMP PARAMETERS				LP 601 PARAMETERS				
Pump wavelength, nm	Pump energy, mJ	Pulse duration, nsec	Beam diameter, mm	Telescope magnification, X	Pump power density on the LP 601 input, MW/cm²		Output energy, mJ	Spectral width, nm
					threshold	operation		

Testing engineer _____

LP 603 Optical Scheme and Design

LP 603 Optic Schematic is shown on Fig.1; Fig.2 shows LP 603 top view. The same elements are indicated by the same positions on both Figures.

The same elements are marked by the same numbers in both Figures.

Two pairs of BBO type II crystals are used in the LP603. One pair is cut to be used within the range of 420...520nm (signal wave)/1115...2280nm (idler wave).

The other one is used for the range of 520...710nm (signal wave)/710...1115nm (idler wave).

The output signal wave is horizontally polarised, while the idler wave is polarised in the vertical plane.

The cavity is formed by right-angle prism 8 which serves as a "rear" mirror, output coupler 6 and contains BBO crystals 7-1 and 7-2. The pump radiation passes through, double-lens telescope 2,3 and gets to the assembly of folding mirrors 4 and 5 which steer it to BBO crystals 7-1 and 7-2.

Alignment apertures D2, D3, D4 are used for cavity and pump beam axes matching.

Both signal and idler output waves pass through aperture 11 and get to spectral separation unit.

Wavelength tuning is performed with "TUNABILITY" tuner 20.

Three adjustable legs 22 allow to change slightly the laser position. Two mounting holes 17 allow to fix the laser in the selected position with the use of screws from the Spare Parts Kit.

LP 603 can be available in both versions upon request - for manual and PC-controlled operation.

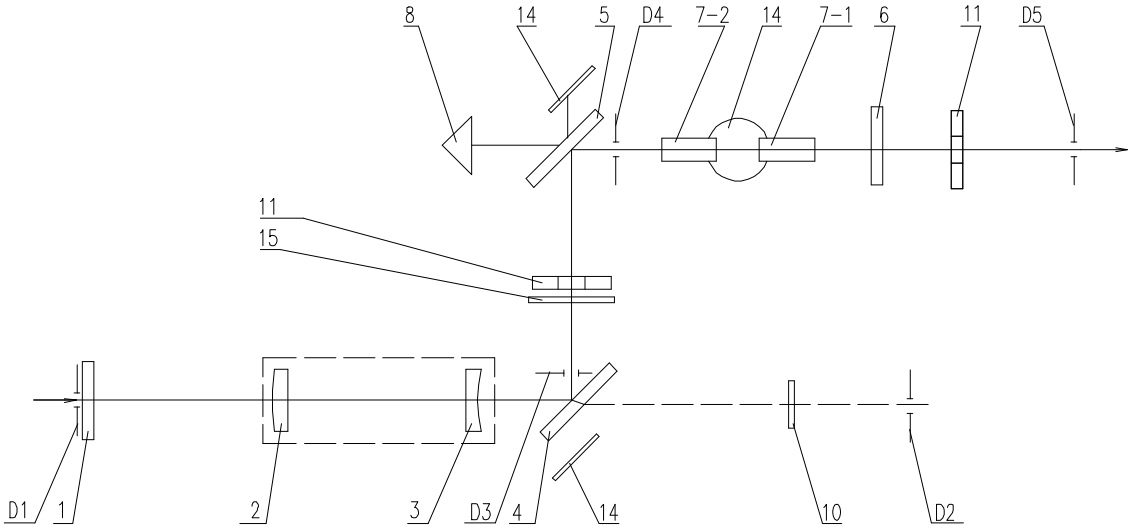


Fig 1. LP 603 Optical Schematic

1 - protective window, 2,3 - telescope lenses, 4,5 - folding mirrors, 6 - output mirror, 7-1,7-2 - BBO crystals, 8 - right angle prism, 10,14,15 - screens, 11 - apertures.

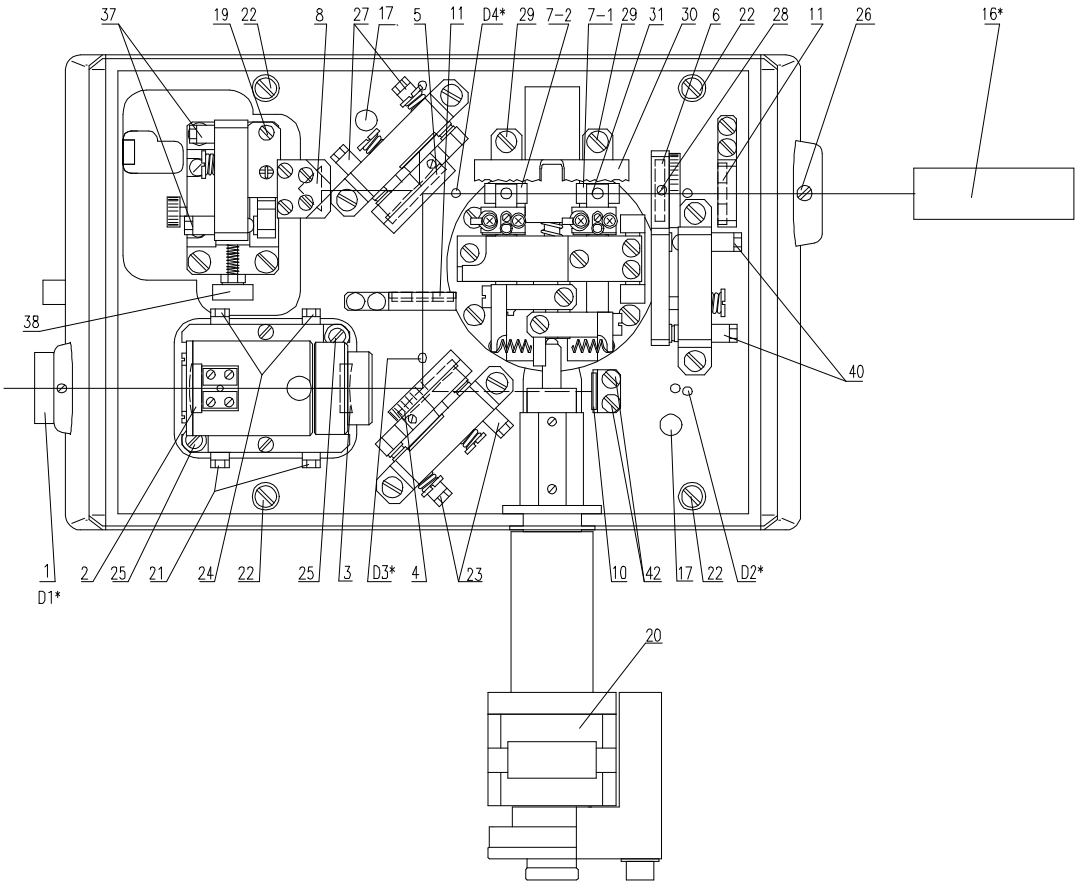


Fig 2. LP 603 Top Wiev

LASER SAFETY

The following is a summary of general safety precautions which are to be observed by anyone operating the LP 603.

DANGER! Visible and Invisible Laser Radiation!

LP 603 OPO refers to IV-class high-power lasers.
Since the OPO radiation can be visible as well as invisible it can severely injure both eyes and flesh.

1) Never look directly into the OPO beam or its reflection; even diffuse reflections are hazardous. Permanent damage to the eye can occur.

2) Keep all unnecessary personnel out of the work area. Remove all shiny reflective surfaces and all flammable materials with their containers from the work area.

3) Operate the OPO only in well-marked areas with controlled access. Be sure to post appropriate warning signs visible to all.

4) Operate the OPO under the supervision of qualified personnel only. When not in use, shut down the laser completely.

5) Never leave the OPO running unattended.

6) Wear protective eyewear at all times.

7) Keep the protective cover on the OPO head at all times.

8) Operate the OPO at the lowest beam intensity possible.

9) Expand the beam wherever possible to reduce beam intensity.

10) Use a laser beam detector to verify that the OPO beam is off before working in front of the OPO.

11) Set up experiments so that the OPO beam is either above or below eye level.

12) Provide enclosures for beam paths whenever possible.

13) Set up shields to prevent unnecessary specular reflections.

14) Set up an energy absorbing beam trap to capture the OPO beam, preventing unnecessary reflections or scattering.

INSTALLATION AND ALIGNMENT

Unpacking Your LP 601

Before unpacking the OPO, check the crate for damage. If the top, body or any component has been damaged during transportation, or your OPO does not operate after installation, or the output parameters of your OPO are not in compliance with those specified (in spite of all requirements of the pump have been met (see section "LP 603 Specifications"), contact the transport agency and SOLAR Laser Systems on the subject of damage.

The laser is delivered with a spare parts kit:

Spare Parts Kit and Accessories

1. BBO crystals ..... __ pcs
2. LP 603 alignment apertures.....__ pcs
3. Mounting screws .....__ pcs
4. Glan Prism __ pcs
5. Alignment wrench 5.5mm.....1 pce
6. Optical wrench .....__ pce
7. Alignment post.....__ pce
8. Protective window .....__ pce

Installing the LP 603

Install the LP 603 in a closed and clean location. It is advisable to set up the system in a temperature-stabilized environment in an air-conditioned room.

AMBIENT REQUIREMENTS

Temperature.....15 to 27°C
Relative humidity.....45 to 80%
Atmospheric pressure.....84 to 106 kPa

Due to the LP 603 laser features, its installation and startup together with a pump laser require that the cavity complete alignment is performed. Therefore all OPO installation steps should be performed either by a SOLAR LS authorized service representative or by personnel who has been trained in SOLAR LS to run SOLAR LS lasers adequately.
The present section is intended to be of help to a SOLAR LS service engineer when installation is made at the Customer's site and by no means should be considered as a manual guide for the User.

Optimization of pump radiation.

When manufactured and adjusted at SOLAR LS, your LP 603 laser has been completed with telescope 1.5^X (lenses 1,2, Fig.2) which provides the optimum conditions for matching the pump laser.

Still, optimization of pump radiation is the main requirement for OPO efficient operation.

The optimum pump power density at the LP 603 laser input should be 65-80 MW/cm^2 for a pump pulse of 10-15 ns.

For determining the pump power density at the LP 603 input, proceed as follows:

- with the use of photo-sensitive paper, determine the pump beam spot diameter at the LP 603 input

- calculate the pump power density from:

$$P = \frac{4 * E * X^2}{\pi * d^2 * \tau} = \frac{1.273 * E * X^2}{d^2 * \tau}$$

where E is the pump energy, mJ

τ is the beam pulse duration, nsec

d is the pump beam diameter at the LP 603 input, cm

X is telescope magnification (in your case X = 1.5)

P is the pump energy density, MW/cm^2.

- **be sure the pump power density is 65-80 MW/cm^2.**

CAUTION! To avoid optics damage, do not increase the pump power density to more than 100 MW/cm^2 !

Aligning the LP 603.

1. Withdraw from the laser housing wavelength separator, output mirror 6 and screen 10 (fig.2) having preliminary released fixing screws 21 (2 pcs), 26, 28 and 42 correspondinly.
2. Switch on the pump laser in the free running mode. Carry out the alignment following the low-intensity third harmonic (355 nm) beam.
3. Insert alignment apertures - D1 into the OPO input window and D2 - according to Fig.2. Adjust the OPO body so that the second harmonic beam travels through the centres of apertures D1 and D2. Use four screws 22 to adjust the height of the OPO body. Secure the OPO to the optical table with screws 17 (available in the spare parts kit).

4. Adjust folding mirror 4 with screws 23 so that 355 nm beam strikes the centre of aperture D3.
5. Insert alignment aperture D4 and D5 into the OPO output window.
6. By adjusting folding mirror 5 with screws 27 make so that 355 nm beam passes through the centres of apertures D4 and D5.
7. Switch off the pump laser. Position the He-Ne laser ~ 1,5 m from the OPO; align the He-Ne laser so that its beam travels through the OPO output window and further strikes the centres of apertures D4 and D5.
8. With the use of adjusting screws 37 and 38 obtain the appearance of one He-Ne laser beam reflected from the prism 8 and match it with the centre of the He-Ne laser aperture.

Note: Adjusting screw 19 is intended for installation of "sharp" edge of the prism perpendicular to the laser base. This procedure has been already performed during the initial start-up of your laser at SOLAR LS; screw 19 is usually not used in the process of installation and alignment of LP 603.

9. Chose the required pair of BBO crystals. In each pair the crystal marked with one dot corresponds to crystal 7-1; the crystal marked with two dots corresponds to crystal 7-2.
10. Install and fix BBO crystal 7-1. By rotating screw I set BBO crystal 7-1 so that its ends were perpendicular to the He-Ne laser beam. If it is necessary to slightly adjust BBO crystal 7-1 in the horizontal plane release screws 35 and with holder 36 set BBO crystal 7-1 so that its ends were perpendicular to the He-Ne laser beam. Tighten screws 35. Make sure that the He-Ne laser beam passes through the BBO crystal centre.

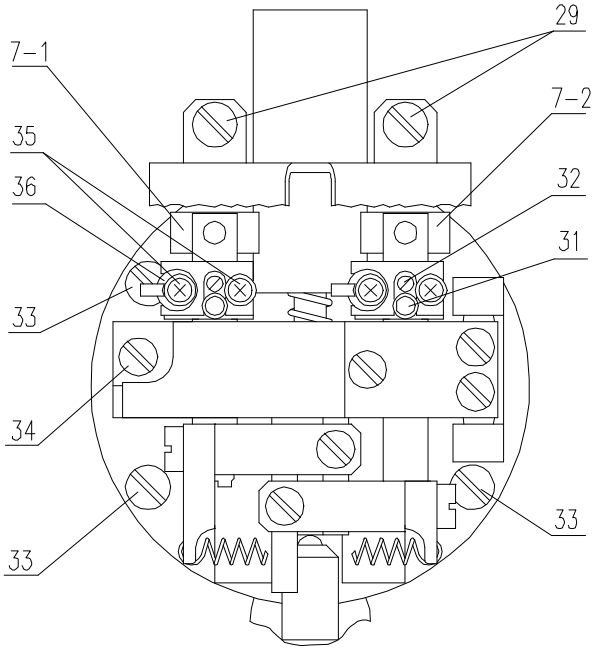


Fig. 3. BBO crystals unit. Top view.

I. Screw for BBO crystal 7-1 rough tuning.

II. Screw for BBO crystal 7-2 rough tuning.

III. Screw for BBO crystal 7-2 fine tuning.

11. Installation of BBO crystal 7-2. Take handle 31 of BBO crystal 7-2 holder and carefully insert it into the mounting hole as far as it will go. Fix crystal holder with screw 32.
    By rotating screw II set BBO crystal 7-2 so that its ends were perpendicular to the He-Ne laser beam. If it is necessary to slightly adjust BBO crystal 7-2 in the horizontal plane release screws 35 and with holder 36 set BBO crystal 7-1 so that its ends were perpendicular to the He-Ne laser beam. Tighten screws 35. Make sure that the He-Ne laser beam passes through the BBO crystal centre.
12. Install output mirror 6 and fix it with screw 28. Adjust output mirror with the help of screws 40 for the reflected beam to route back into the He-Ne laser.
13. Remove all the alignment apertures. Remove or screen the He-Ne laser to avoid its damage with the OPO output radiation.
14. Start up the pump laser in the free running mode. Verify the beam passes through all the components. Switch the pump laser to the Q-swithed mode (pump power density is 50 MW/cm^2).
15. Make sure there is lasing. Obtain maximum efficiency of the OPO output by alternately rotating screws 40 of output coupler 6.
    Set output wavelength with microscrew 20:
    - 445nm for the first pair of BBO crystals.
    - 665nm for the second pair of BBO crystals.
16. Obtain the optimum generation as follows:
    - match mutual angular position of crystals 7-1 and 7-2 with screw 34.
    - sligtly align output mirror 6 with screws 40 and prism 8 with screws 37.
17. Increase the pump energy to the operation value (65-80 MW/cm^2). Place protective screens 30 and 10 and fix them with screws 29 and 42 correspondingly.
18. Install the Glan prism for signal and idler waves separation.

OPERATION

CAUTION! BBO crystal is hygroscopic and requires special care in handling. When not in use with OPO, keep the both crystals in holders in an exicator (available in the spare parts kit).
Do not wipe or touch the crystal!
Clean the crystal with pure dry air only!

System Startup/Shutdown

Remove the fluoroplastic cap from the OPO input window.

Withdraw the BBO in the holder from the exicator and install it into the OPO body and fix it with corresponding screws. The crystal installation procedure is described in Chapter "Installation and Alignment", items 8-10.

After fulfilling all operational steps, specified in section "Installation and

Alignment", the daily running of LP 603 will require minimum efforts from the user.

Startup and shutdown of the system should be performed in accordance with the Manual for your pump laser (355 nm).

When the OPO operation is over, shutdown the pump laser, undo fixing screw of the crystals holders, withdraw crystals in holders from the laser housing and put them into the exicator.

Put the protective cap into the laser input window.

Wavelength Tuning

Wavelength tuning is performed with "TUNABILITY" tuner 20 located on the OPO side panel.

To separate the signal wave from the idler wave your laser is equipped with following spectral separation units:

- three spectral separation units for signal wave
  S1 - for 420-480 nm output,
  S2 - for 480-560 nm output,
  S3 - for 560-685 nm output,

- protective window (BK 7) - PW.

The spectral separation unit is put into the laser output window and fixed with screw 26.

Note: *While replacing spectral separators, there is a possibility of slight shifting of the LP 603 output beam.*

Tunability curves for signal wave with appropriate spectral separators are shown in the Fig.3. Total LP 603 output is shown in the Fig.4.

Fig.5 shows LP 603 laser linewidth dependence on wavelength.

All the curves have been measured while starting up your LP 603 at the manufacturer with SOLAR LS pump laser which parameters are stated in the Table "Parameters obtained during LP 603 laser testing", p.7.

MAINTENANCE

The BBO crystal is hygroscopic. When not in use, keep it in an exicator with silicagel.

Cleaning Optics

CAUTION! Clean the BBO with pure dry air only!
Do not wipe or touch the crystal!

When it is necessary to clean other optics, it is recommended that the user obtain a large bottle of reagent grade methanol plus a large box of Kodak lens tissues.

Laser optics should be handled with utmost care, the slightest scratch, trace of dirt, or film can severely diminish the laser's efficiency. Before starting to clean optics, be sure your hands are thoroughly wiped and a clean soft surface to be used for optics cleaning is available.

To clean the optics, proceed as follows:

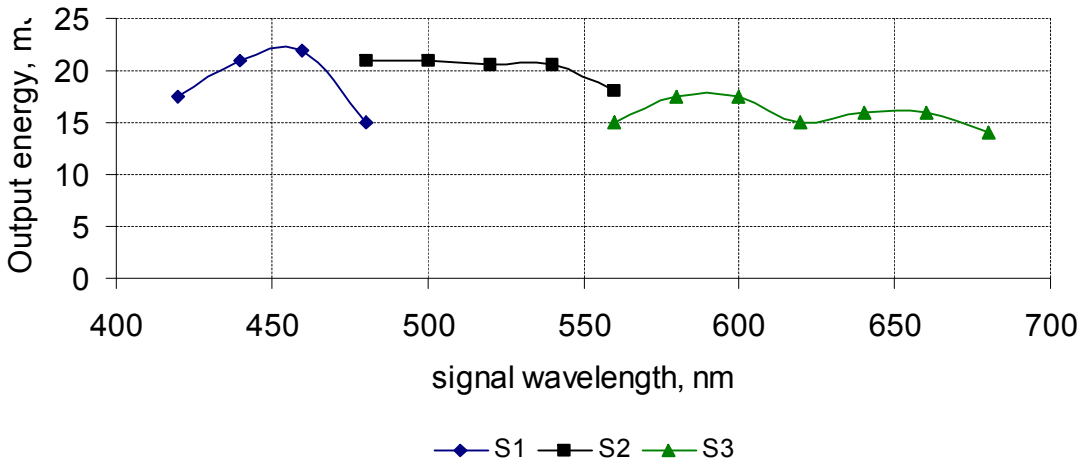


Fig 3. Signal wave tunability curves with appropriate spectral separators

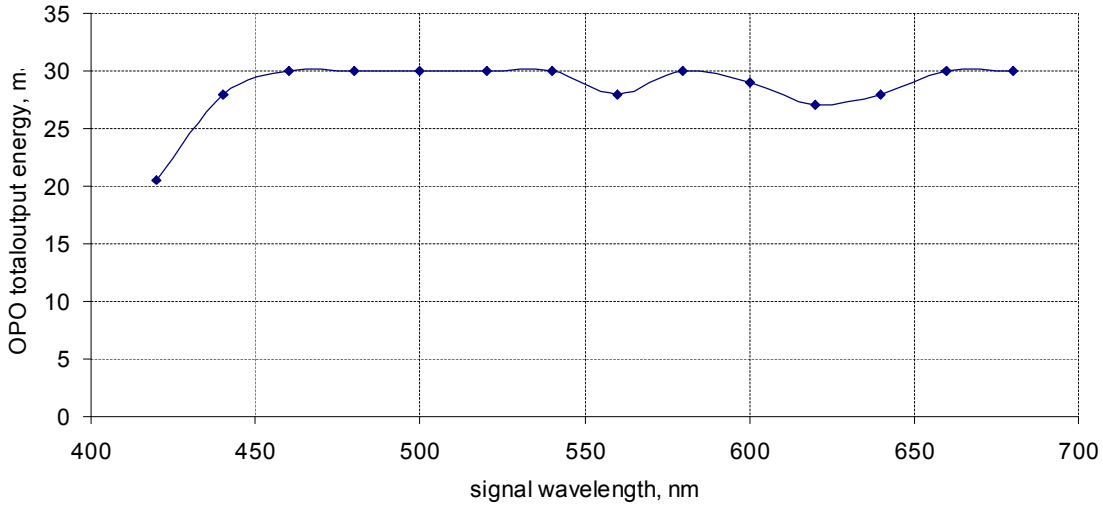


Fig 4. Total LP 603 output

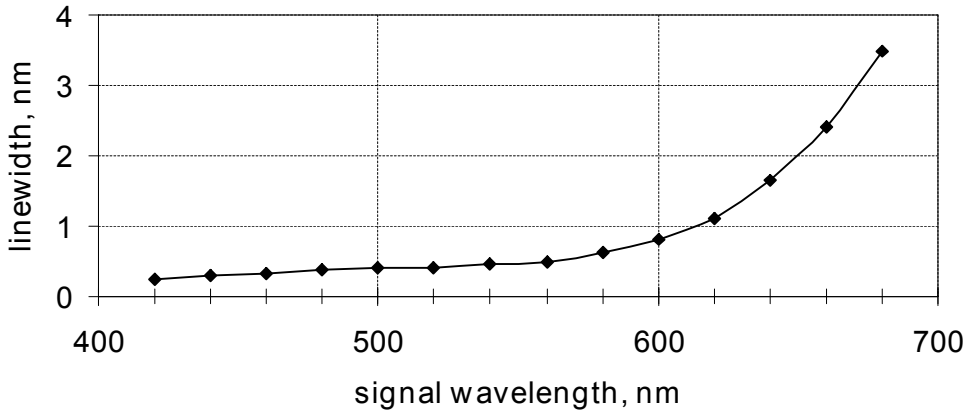


Fig.5. LP 603 laser linewidth dependence on wavelength

- blow off any dust or dirty particles that may scratch the optics in the course of cleaning, using pure dry air;
- place a drop of methanol in the centre of a tissue. Hold the mirror assembly in one hand; place the wetted portion of the tissue onto the optical component and drag it across. The tissue and the component should become dry before the latter comes to the tissue end;
- inspect the optics surface in different lights for streaks of film. If any, repeat the procedure using a fresh tissue.

WARRANTY

For the periods and subject to the conditions specified below, SOLAR LS warrants to the original purchaser that products specified in the present Manual will perform to our publiched specifications when used and maintained in accordance with our written instructions.

The Model LP 603 is protected by a 12 month-warranty (except for BBO crystals and optics). BBO crystals and optics are not covered under standard warranty. With respect to laser optics, the warranty period is 3 months from the date of shipment from our factory. BBO crystal shall be free from defects in materials and workmanship when shipped from our factory.

Warranty includes cost-free delivery of replacement parts and service maintenance by a SOLAR LS engineer, while travel cost for the on-site service are not covered by warranty terms.

Replacement optical components purchased after original warranty expiration shall be free from defects when shipped from our factory.

If due to a defect in materials or workmanship a product fails to perform to our published specifications, or if a consumable is not

free from defects in materials and workmanship when shipped from our factory, SOLAR LS will, at its option, repair or replace the defective product or consumable without charge. SOLAR LS reserves the right to make repair in its factory, at any authorized repair facility, or at the purchaser's premises using new or remanufactured parts.

To make a warranty claim, the purchaser shall, prompty following discovery of the basis for the claim (and in any event within the applicable warranty period), contact SOLAR LS in writting or by telephone:

SOLAR Laser Systems
4 Stebenev line, Minsk, 220024 BELARUS
fax: 375 17 2019596, phone: 375 17 22019590,
e-mail: solarls@infonet.by

The warranty is null and void if the purchaser attemps to service or repair the product (other than the performance of routine maintenance as described in the User's Manual), or if service is performed by persons not authorized by SOLAR LS. In addition, the warranty is null and void if the product or consumable is used other than as specified in the User's Manual. Without limitation, the warranty does not cover damage to optical surfaces caused by improper cleaning or by customer misuse of a product.

LP 603, Serial Number _____

Quality Control Manager _____