# Fourth harmonic generator

MODEL AFG800

**S/N 0008**

**INSTRUCTION MANUAL**

DEL MAR PHOTONICS

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## GENERAL SAFETY INFORMATION

In order to ensure the safe operation and optimal performance of the product, please follow these warnings in addition to the other information contained elsewhere in this document.

**WARNING:** If this instrument is used in a manner not specified in this document, the protection provided by the instrument may be impaired.

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## 1. ACCESSORIES

| Part | Quantity | Note |
|---|---|---|
| Box | 1 | Opto-mechanical box |
| Crystal | 2 | Nonlinear crystal for second harmonic generation |
| Table clamp | 3 | Clamps for securing the Optical Unit on optical table |
| Manual | 1 | This document |

## 2. INTRODUCTION

### *2.1) Introducing device*

Fourth harmonic (FH) generator is developed for producing the laser radiation at doubling frequency from the second harmonic radiation of TiSa oscillator in the wavelength range from 410 nm to 460 nm. It is based on second harmonic generation technique and provides stable radiation at the wavelength range λ= 205-230 nm in down to fs scale.

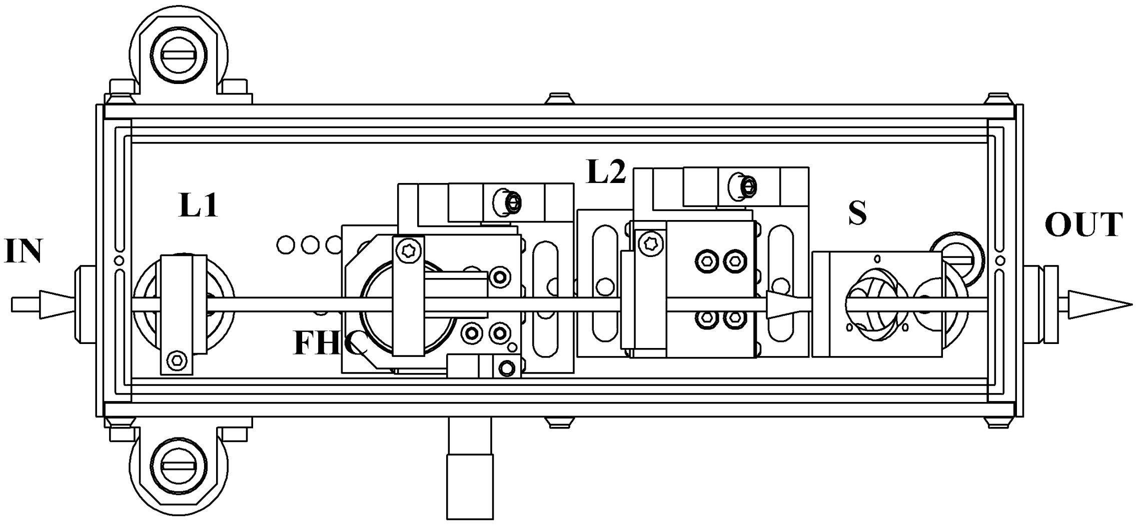


Fig.1. Basic scheme.

The basic scheme of generator is depicted on Fig.1. Conventional doubling scheme uses tight focusing to get better conversion efficiency into the FH radiation. An incoming pulse focused onto FHC (BBO crystal, type I) by lens L1, generates SH signal. Then two beams are separated from each other by two-components separator S. Lens L2 is placed to recollimate the pump and SH beams. An adjustable incline of BBO crystal in the horizontal plane provides tuning the wavelength of the FH output.

Device consists of the following optical elements:

**1**. FHG crystal - BBO (type I): №1 - 0.6 mm thick crystal (λ= 205-212 nm);
 №2 - 0.5 mm thick crystal (λ= 212 – 230 nm);

**2**. Separator (S) – two-mirror separator with high transparent for input radiation (410-460 nm) and high reflective for FH radiation (205 – 230 nm).

**3**. L1, L2 – lenses (f=60 mm).

## *2.2) General information*

If the matter interacts with the high power laser radiation the material properties are changed by the incident field. In this case the induced polarization has the high components depending on the electrical field:

$$P = \chi^{(1)}(\omega)E(\omega) + \chi^{(2)}(2\omega)E(\omega)E(\omega) + \chi^{(3)}(3\omega)E(\omega)E(\omega)E(\omega) + ... \quad (1)$$

The $\chi^{(2)}$ is the tensor of second-order nonlinear optical susceptibility and it is responsible for second-harmonic generation (SHG). Assuming the plane wave front and neglecting group velocity dispersion (GVD) and pulse broadening the SH efficiency can be written as:

$$\frac{I_2}{I_1} = \frac{2\pi^2 d^2 L^2 I_1}{\varepsilon_0 c n_1^2 n_2 \lambda_2^2} Sinc^2\left(\frac{|\Delta k| L}{2}\right). \quad (2)$$

Where $I_1$ and $I_2$ are the fundamental and SH intensities, respectively, $L$ – the length of the crystal, *d*- the dipole moment of the interaction, $|\Delta k| = 2k_1 - k_2$ is a phase mismatch. In the case of type-I *oo-e* interaction in which the fundamental ordinary (*o*) wave produces extraordinary (*e*) wave, respectively, the phase-matching angle $\theta$ of birefringent crystal can be easily obtained:

$$|\Delta k| = 2\frac{\omega}{c}(n_e(\omega) - n_o(2\omega, \theta)) = 0. \quad (3)$$

For example, the phase-matching angle for BBO-type-I crystal is $\theta$=29° at $\lambda_\omega = 0.8 \mu m$.

Due to birefringence the pump and second-harmonic-generated beams separate spatially while propagating through the crystal. It is important to take into account transversal walk-off angle $\rho$. After a distance $l \cong \frac{d}{\rho}$ the two beams are no longer overlapped in the transverse plane; hence the coherence of the generation process along the propagation direction is lost.

If the ultra-short laser pulse sources are used the effects of group velocity mismatch (GVM) and group velocity dispersion (GVD) can seriously effect on SH pulse propagation. In case of exact phase matching fundamental pulse does not suffer losses and the SH electrical field at the end of crystal of the length $L$ can be written as:

$$E_2(2\omega, t-\frac{L}{\upsilon_2}, L) = -i\chi^{(2)}\frac{\omega_2^2}{4c^2k_2}\int_0^L E_1^2\left[t-\frac{L}{\upsilon_2}+z\left(\frac{1}{\upsilon_2}-\frac{1}{\upsilon_1}\right)\right]dz. \tag{4}$$

The term $z(\upsilon_2^{-1}-\upsilon_1^{-1})$ describes the longitudinal walk-off between the SH pulse and the fundamental pulse owing to the different group velocities. The result is a broadening of the second harmonic pulse. Only for crystal lengths

$$L << L_D = \frac{\tau_p}{\upsilon_2^{-1}-\upsilon_1^{-1}}, \tag{5}$$

the influence of GV mismatch can be neglected. In this case the SHG intensity varies with the square of the product of crystal length and intensity of the fundamental pulse. Because of this quadratic dependence the SH pulse is shorter than the fundamental one (by a factor $\sqrt{2}$ for Gaussian pulses). For instance, for the BBO type-I crystal $(\upsilon_2^{-1}-\upsilon_1^{-1})$=187 *fs/mm* and $L_D = \frac{\tau_p}{\upsilon_2^{-1}-\upsilon_1^{-1}} = 260\mu m$. To have SH pulses as short as fundamental ones length of crystal must be less than $L_D$. For example the SH pulse will be broadened to 150-180 *fs* after 50 *fs* fundamental pulse passes the length crystal with $L$=1 *mm*.

However the focusing femtosecond pulses with lenses can reduce the effect of GVM due to angular dispersion. When achromatic phase matching is considered, an angular dispersion of the pulse allows phase matching and GVM simultaneously. In this case the generation of SH pulses as short as fundamental pulses is available.

# 3. SPECIFICATIONS

| | | |
|---|---|---|
| • Pulse width | - | < 100 fs |
| • Efficiency | - | 1-6% * |
| • Max. input peak intensity | - | 50 $GW/cm^2$ |
| • Input beam size, full (D, diameter) | - | < 4 mm |
| • Temporal broadening | - | < 500 fs |
| • Input polarization | - | Linear- vertical |
| • Output polarization | - | Linear- horizontal |
| • Input wavelength | - | 410 – 460 nm |
| • Output wavelength | - | 205 – 230 nm |
| • Dimensions | - | 270mm x 140mm x 180mm |

* - at input average power > 300 mW and pulse duration < 100 fs

# 4. INSTALLATIONS AND ALIGNMENT

## *4.1) Unpacking generator*

Your generator was packed with great care and all containers were inspected prior to shipment: the generator left Del Mar Photonics in good condition. Upon receipt of your laser, immediately inspect the outside of the shipping containers. If there is any major damage, such as holes in the box or cracked wooden frame members, insist on that a representative of the carrier should be present when you unpack the contents.

Carefully inspect generator box as you unpack it. If you notice any damage, such as dents, scratches or broken knobs immediately notify the carrier and your Del Mar Photonics Sales representative.

Open the cover of the box head and remove the bags which covering the elements of generator and fixing elements which are used for transport. Do it very carefully, try not to misalign the generator, and damage optical elements during this procedure. **We recommend you to cut elastic bands that fasten the bags before removing.**

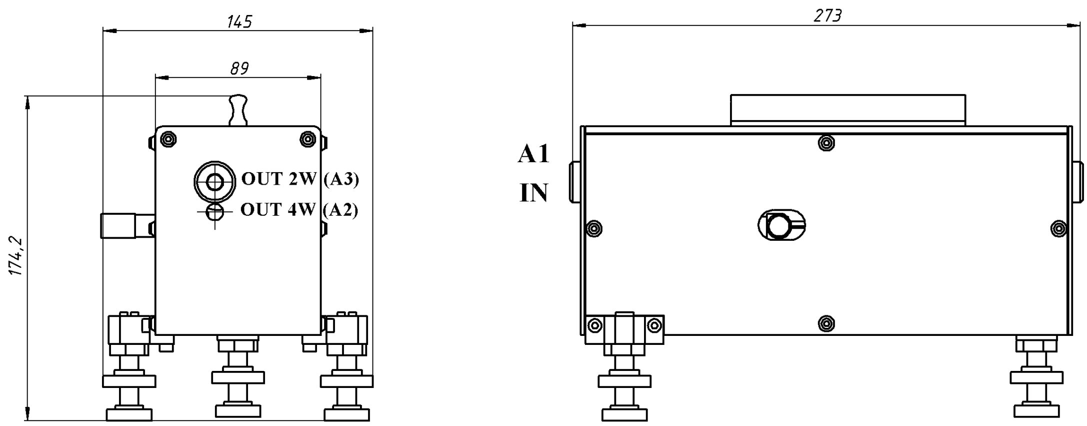


Fig.2. Outline drawing of SH generator

## *4.2) Aligning the generator*

1) Adjust the height of the pump laser beam so that the output beam of pump laser will be parallel to the table top surface.

2) Install optical unit of the generator on the optical table horizontally at the same height as the SH beam from the third harmonic generator ATsG800 (the SH output beam from the ATsG800 must be parallel to the table).

3) Remove lenses L1 and L2 from their mounts (see Fig.3). **Be careful! Block the pump beam before the generator while removing L1 and L2!**

4) Use low screws to adjust a level. Change the height and position of generator to let the pump beam be passed through the aperture A1 inside and strikes the center of gag A3.

5) Attach the optical unit to the table using clamps. Remove the diaphragm A1 (Fig.2)..

6) Install the lens L1. **Be careful! Block the pump beam before the generator while inserting L1!**

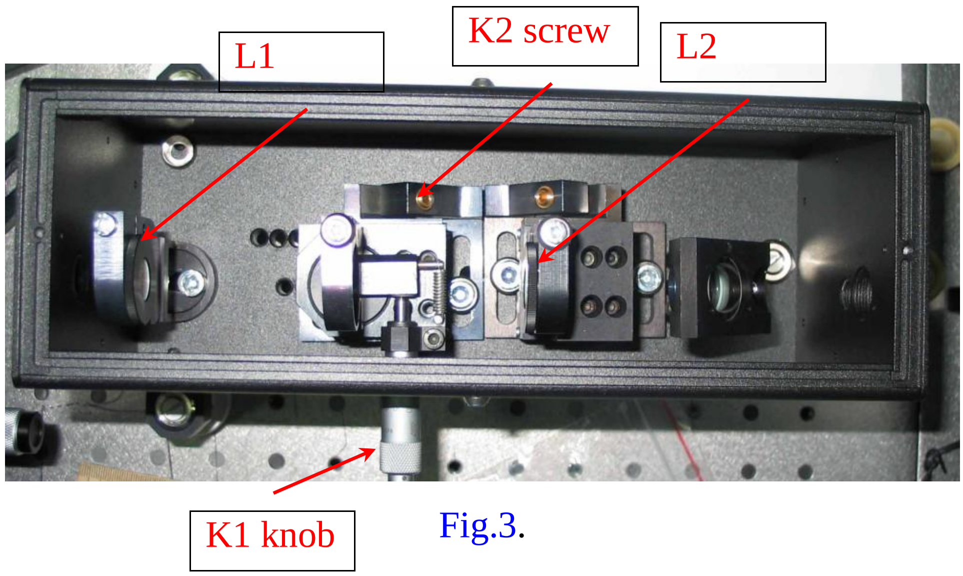


Fig.3.

7) Install the lens L2. Check that the pump passes through the center of the output gag A3. If it is not so try to rotate lens L2 in holder around its rotational axis.

8) If the SH beam can not be directed on the center of A3, loose the screw on L2 holder (Fig.4) and shift the L2 to do that.

Fig.4.

9) **The generator left Del Mar Photonics aligned at the fundamental wavelength λ=423 nm**. So the crystal №1 (λ= 205-212 nm) is installed by default. TH holder is rotated about on (-5) ÷ (- 7)° according to the direction of the SH beam (Fig.6).

10) Check that the FH beam goes out of the output hole A2 (remove the gag A2 before).

11) Adjust a knob K1 to get the maximal FH intensity (Fig.3).

12) Adjust a screw K2 (translation of FH crystal along the focused beam) to get more energy in FH signal (Fig.3).

13) Now the generator is ready for operating.

14) Follow this step if you have a large divergence of the SH or the FH beams. *Adjust the screw of the L2 table (screw K3)(Fig.5) to collimate the output FH beam. Direct FH beam onto the white sheet of paper.*

*The distance between the output hole and paper must be 2-3 meters. Check that the beam size and shape are the same as at the output of TH generator.*

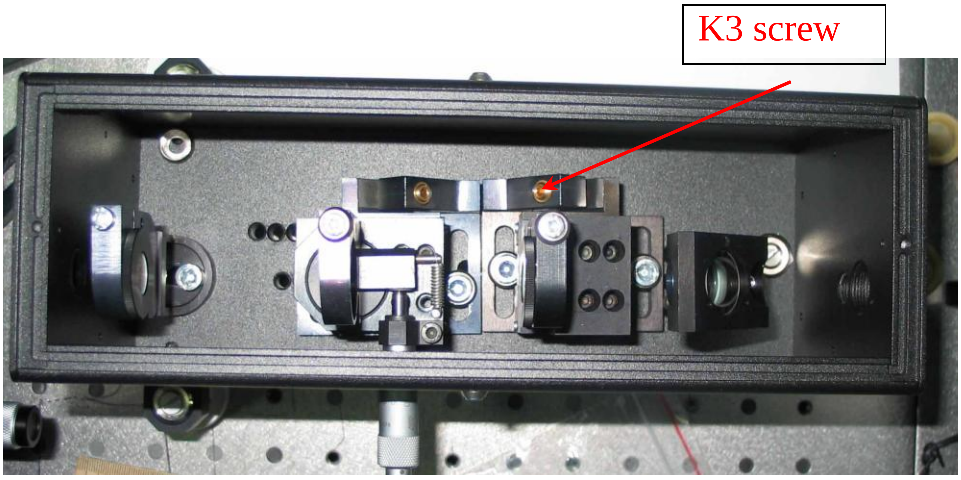


Fig.5.

15) **FOR TUNING**: Use knob K1 to tune the generator for the proper wavelength. Rotate knob K1 in clock-wise direction to tune from 212 to 205 nm (see Fig.7). You need to rotate the THC holder on +20° according to the direction of SH beam.

16) To tune generator from 212 nm to 230 nm change the crystal #1 on the crystal #2. Rotate the crystal to the position where the 205 nm is observed (as on Fig.7) (approximately). Block the beam before the box. Install the crystal №2 according to the green mark “up”. Rotate the crystal in anti-clock-wise direction to tune the generator from 212 to 230 nm.

17) Repeat the steps 11 and 12 till the maximum of TH signal is achieved.

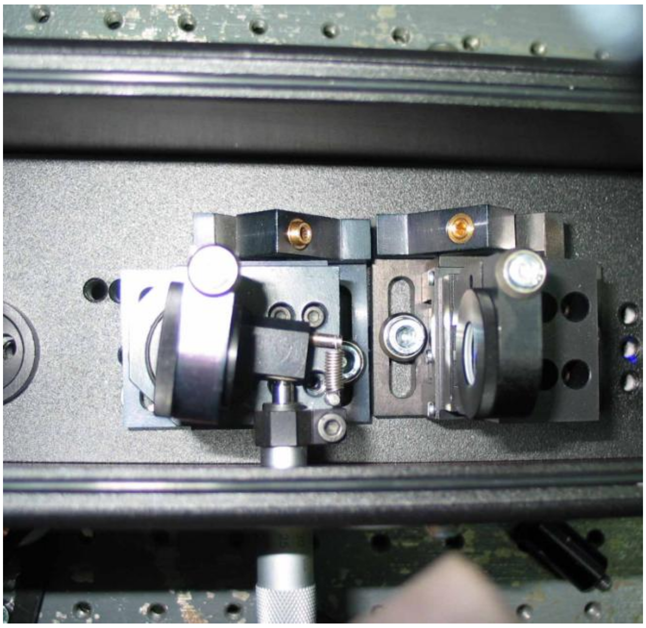

Fig.6. Position of TH holder at 423 nm (SH) (FH - 211.5 nm). Crystal #1.

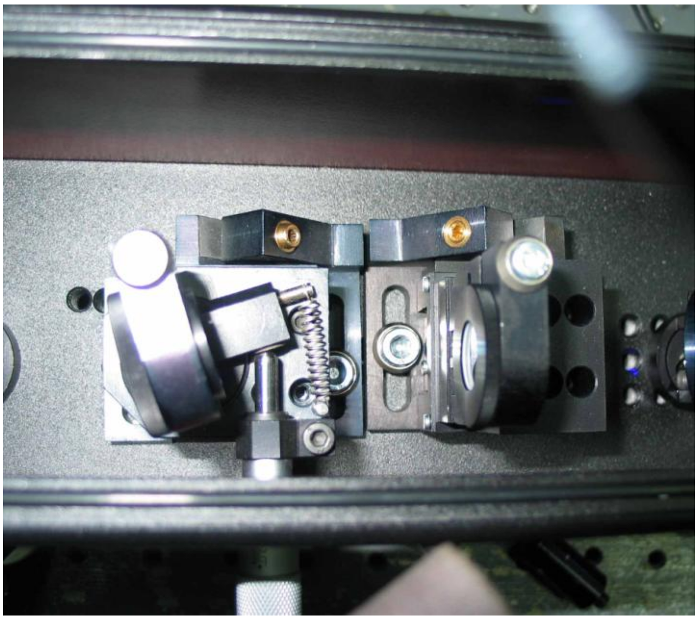

Fig.7. Position of TH holder at 410 nm (SH) (FH - 205 nm). Crystal #1.

***Note. Occasionally, it may be necessary to clean the optics and surfaces of the SH generator. The best method is to clean surfaces is to first block the pump beam and then blow excess particles from the surface.***

***WARNING: Don't clean the BBO crystal with acetone or alcohol. Use only blowing to clean the surface of crystal.***

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# NOTES