Femtosecond Single Shot Autocorrelator

Model REEF-SS ASF-200

INSTRUCTION MANUAL

DEL MAR PHOTONICS

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The Single Shot Autocorrelator (SSA) Model REEF-SS ASF-200 was designed to monitor the pulsewidth of both oscillators and amplifiers of ultrafast systems in the range of 100fs to 2ps. Wavelength coverage 1500nm -1600nm (other range optional).

1. Principles of Operation.

For measuring the pulse duration of single ultra short laser pulses in SSA is used method based on the registration of cross distribution of Second Harmonic (SH) energy produced in nonlinear crystal under noncollinear interaction of two beams with determined aperture. The main idea of the method is illustrated in Fig.1 for the simplified case when initial laser pulse has rectangular time shape and uniform intensity cross distribution. Two identical pulses are produced by Beam Splitter (BS) from initial laser pulse. The SH is generated in the field of pulse superposition in nonlinear crystal. As it shown in Fig.1 cross size Dz of SH beam depends on pulse duration t of base frequency beam :

$$Dz = (tu) / \sin \varphi/2 \qquad (1)$$

where u -light velocity of base frequency in crystal and φ - an angle of combined beams in crystal. If there is the time delay Δt between the pulses then the center of SH cross distribution shifts by an amount Zo :

$$Zo = (u\, \Delta t) / 2\sin\varphi/2 \qquad (2)$$

From (1) and (2) it is easy to yield expression for the pulse duration t :

$$t = (Dz\, \Delta t) / 2Zo \qquad (3)$$

Therefore measuring Dz , Δt and Zo it is possible to determine pulse duration t of initial beam.

The equation (3) is correct when initial pulse has rectangular time shape and uniform intensity cross distribution

If pulse has "sech^2" time shape then (3) changed to

$$t = (\Delta t\, Dz) / (1.543\, Zo) \qquad (3a)$$

In Appendix 1 are represented results of deduction expression (3) for the Gaussian time and cross section shapes of initial pulse:

$$t = (\Delta t\, Dz) / (\sqrt{2}\; Zo) \qquad (4)$$

It should be noted that (4) is correct under condition

$$n\, u\, t << D\, tg\psi/2 \qquad (5)$$

where n - refraction index of nonlinear crystal,
t - pulse duration of initial pulse at FWHM,
D - beam diameater at FWHM of intensity,
Ψ - angle between the two beams out of crystal.

It is clear that direct measurement of Δt and Zo with sufficient accuracy is rather difficult task. To avoid this difficulty is used the next method. The optical scheme of SSA is shown on Fig.2. With the help of optical delay DL it is possible to change the value of Δt. Simultaneously the center of the SH energy distribution Zo (See Fig.1) is changed with the correspondence of (2). If for two centers of SH energy distribution Zo_1 and Zo_2 are corresponding the micrometric head positions L_1 and L_2 then it is may be written :

$$(\Delta t_1 - \Delta t_2) = 2(L_1 - L_2)/ c \qquad (6)$$

From the other hand, it is follows from (4):

$$(\Delta t_1 - \Delta t_2) = (t \sqrt{2})(Z_{01} - Z_{02})/ Dz \qquad (7)$$

From (6) and (7) one can get:

$$(t \sqrt{2})(Z_{01} - Z_{02})/ Dz = 2 (L_1 - L_2)/ c \qquad (8)$$

The expression for t follows from (8)

$$t = (\sqrt{2} Dz)(L_1 - L_2)/ (Z_{01} - Z_{02}) c \qquad (9)$$

For the "sech^2" time shape of initial pulse expression (9) is changed with correspondence to (3a)

$$t = 2Dz(L_1 - L_2)/ 1.543 (Z_{01} - Z_{02}) c \qquad (10)$$

2. Specifications

Spectral range: 1500 – 1600nm (other spectral ranges on request);
Temporal range: 100 – 2000fs;
Spatial mode of input beam: TEMoo
Beam diameter: >3mm for pulses 100-500fs;
>6mm for pulses 500-2000fs;
Input polarization: horizontal;
Pulse energy: >0.3nJ at repetition rate 70MHz;

Nonlinear crystal: 2 mm BBO, type I
CCD camera: 14-bit, number of pixels 782(W) X 582(H), pixel size 8.3 X 8.3 µ

3. Device Installation.

1. Remove cover and wall nearest to the input diaphragms D1, D2.

2. Accurately take out soft gasket inserted between the Microscrew and the stopper of moving part of Delay Line DL (See Fig.3). Set the Microscrew position 4.15mm. This position corresponds to the equal optical passes in both shoulders of SSA.
3. Install the Microscrew Head as it shown at Fig.4.

4. Return the wall at former position.

5. Using variable height legs of SSA mount the SSA device in horizontal position at the height you need and fix the legs tightly to the optical bench by the supplied clasps.

6. By means of outer folded mirrors let the input beam pass through the diaphragms D1 and D2 (See Fig.2). At proper input beam direction the both passed and reflected by Beam Splitter BS beams should intersects at the center of the Nonlinear Crystal NC.

7. Screw out the input diaphragm D1 and accurately flip down the diaphragm D2.

8. Install the ACORE software to your PC and look through software Help. Connect the CCD output and the USB port of your PC by supplied USB and power supply cable.

9. If the repetition rate of the tested laser pulse is 50Hz or less you should use the outer synchronization of the CCD camera. For this purpose connect the synchronization port of CCD camera and the synchronization pulse source by means of supplied cable marked by the arrows directed <u>from the synchronization source toward the CCD camera.</u> The synchronization pulse should be positive, 5-20V in amplitude, about 1µs pulse front duration and precede the laser pulse 20µs or more. Another synchronization cable (marked by arrows directed <u>from the CCD camera)</u> should be used if for some purpose you need in CCD camera output synchronization pulse.

4. ACORE HARDWARE INSTALLATION

Installing device drivers

Disconnect your PC from Internet before installing hardware. If there is an available Internet connection, Windows XP may silently connect to the Windows Update web site and install any suitable driver it finds for the device in preference to the driver manually selected.

1. **Connect the CCD camera to a spare USB port on your PC. Power up the camera. This will launch the Windows Found New Hardware Wizard.**

2. **Select "Install from a list or specific location (Advanced)" and then click "Next" button.**

3. **Select "Search for the best driver in these locations" and enter the file path in the combo-box to point to the Drivers\USB2XP folder in your ACore distribution or browse to it by clicking the browse button. Once the file path has been entered in the box, click "Next" button to proceed.**

4. **If Windows XP is configured to warn when unsigned (non-WHQL certified) drivers are about to be installed, click on "Continue Anyway" when warning is displayed to continue with the installation. If Windows XP is configured to ignore file signature warnings, no message will appear.**

5. **Now Windows will copy the required driver files to the system folders.**

6. **Click "Finish" to complete the installation.**

NOTES:

- **Sometimes Windows may ask you to show it the location of files SLLOADER.SYS or usb2ph.sys. In this case you just navigate to the Drivers\USB2XP folder in your ACore distribution and select the appropriate file.**

Check that Windows correctly installed CCD camera drivers. Open the Device Manager (located in "Control Panel|System" then select the "Hardware" tab and click "Device Manger") and select "View > Devices by Type". The device appears as an "Ormins CCD registration system" connected to a USB port.

To reinstall the device driver you right-click the device in the Device Manager and choose "Update driver…" in the popup menu. Repeat the procedure of driver installation described above.

5. Configuring software

1. **Launch ACore using Windows Start menu or desktop shortcut. The main window of the application will be opened.**

2. **Under 'Options' menu choose 'Driver|Change…' item. The Image Acquisition Driver dialog box will be opened.**

3. **In The Image Acquisition Driver dialog box click the 'Load...' button. With the Open dialog box navigate to the folder where you've installed ACore, and then to subfolder DRV\OrminsCCD. Select the file named OrminsCCD.dll**

and click the 'Open' button. The OrminsCCD Configuration dialog box will be opened (the CCD device must be connected to computer at that time).

4. **In the ‘OrminsCCD Configuration’ dialog box you'll see devices serial numbers. Select device with the serial number corresponding to your CCD camera and click 'OK' button in this dialog box.**

Now you click 'Close' button in the Image Acquisition Driver dialog box (or you will be unable to access the application’s main window).

6. Measuring Procedure.

1. Check once more if the input beam passes appropriately through the diaphragms D1, D2 and then screw out D1 and accurately flip down D2. Check initial position of the DL Microscrew – 4.15 mm.

2. Start the ACORE program.

3. Get the image of noncollinear SH generation at CCD camera and maximize intensity of SH by slow adjustments of NC and DL Microscrew position.
<u>Attention! Don’t overexpose CCD array. The overexposed pixels are shown by red color.</u>

4. Using adjustments of M6 set the image of noncollinear SH near the CCD Array center.

5. Close SSA by cover.

6. Clear out the background of CCD image as it described in ACORE software Help.

7. **An example of factory test measurement is shown at Fig.5.**

   NOTE:
   In the case of insufficient input pulse energy you may use supplied cylindrical

lens with focal length 600mm mounting it near the device entrance at appropriate height.

Appendix 1

At real experimental conditions it is difficult to achieve rectangular time shape and uniform intensity cross distribution of laser beam. Propose that time and cross section profiles of each beam have Gaussian form:

$$I(T)=I_0 \exp[-4\ln2(T/t)^2] \qquad (A1)$$
$$I(r)=I_0 \exp[-4\ln2(r/D)^2] \qquad (A2)$$

where t is pulse duration at FWHM, D - beam diameter at FWHM of intensity. Propose the time delay between two arms is Δt . Then SH energy distribution on (z;x) plane at output side of nonlinear crystal is

$$W^{2\omega} \sim \exp[-4\ln2(\Delta t/t)^2 \cdot (Dz\cos\psi/2/D)^2]\ \exp[-4\ln2(x/Dx)^2]\ \exp\{-\ln2[(Z+Zo)/Dz]^2\} \quad (A3)$$

where parameters Dx and Dz determine the SH distribution width along x and z axes and are equal to

$$Dx=D/\sqrt{2}\ ,\ Dz=tu/(\sqrt{2}\sin\varphi/2)\ \{1+[(t)^2u^2\cos^2(\psi/2)]/[D^2\sin^2\varphi/2]\}^{-1/2} \qquad (A4)$$

The value Zo characterizes position of SH energy distribution center determined by time delay Δt between two pulses

$$Zo = [(\Delta t \sin\varphi/2)/u(t)^2]\ (Dz)^2 \qquad (A5)$$

Substituting (A4) in (A5) yields

$$Zo= (\Delta t\ u)/\{2\sin\varphi/2\ [1+ (n\ u\ t/D\ tg\psi/2)^2]\} \qquad (A6)$$

Expression (A4) may be transformed to

$$Dz= [(t\ u)/(\sqrt{2}\sin\varphi/2)]\ \{1+ (n\ u\ t/D\ tg\psi/2)^2]\}^{-1/2} \qquad (A7)$$

If one proposes that condition

$$n\ u\ t << D\ tg\psi/2 \qquad (A8)$$

is correct then (A6) and (A7) may be simplified

$$Zo = (\Delta t\ u)/2\sin\varphi/2 \qquad (A6a)$$
$$Dz= (t\ u)/\sqrt{2}\sin\varphi/2 \qquad (A7à)$$

Excluding sinφ/2 from (A6a) and (A7a) yields

$$t = (\Delta t\ Dz)/(\sqrt{2}\ Zo) \qquad (A9)$$

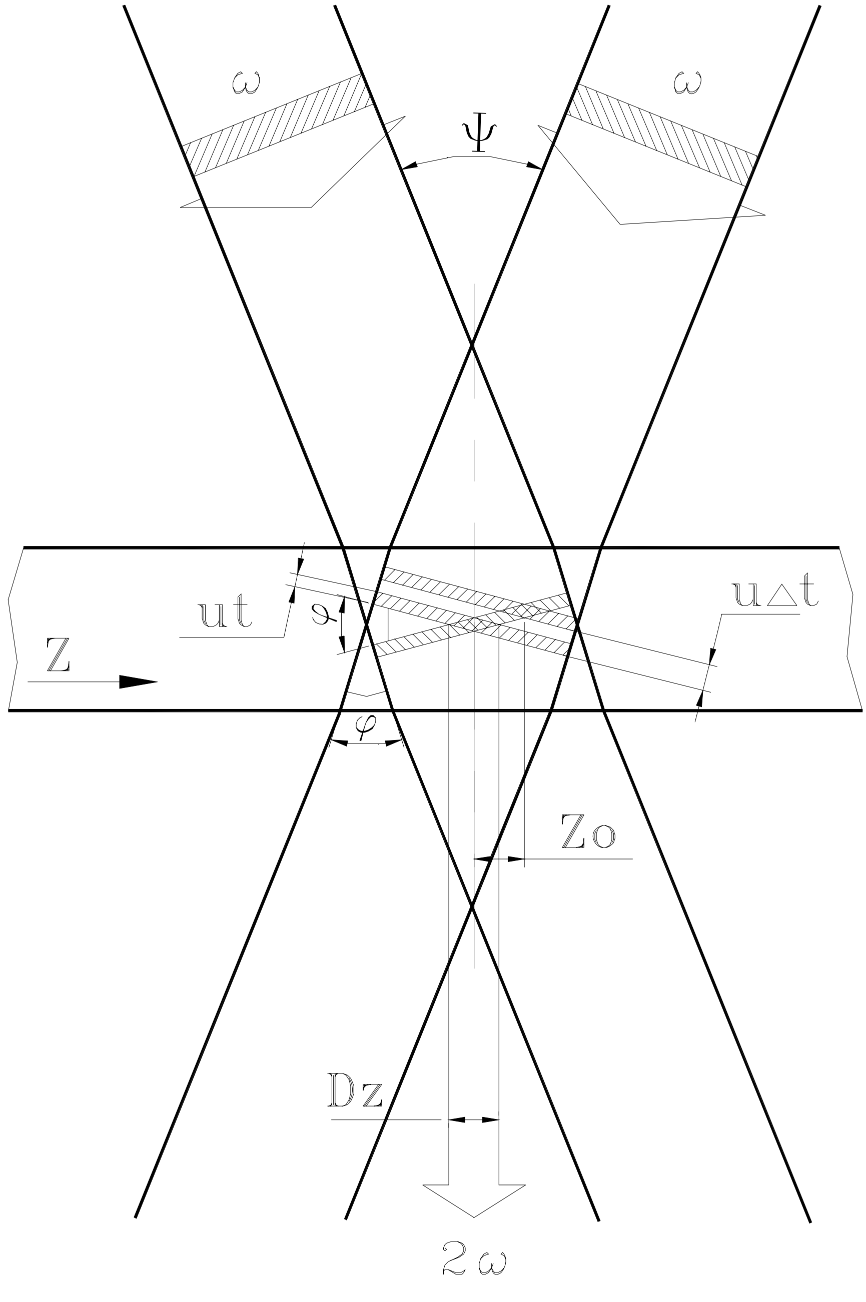

Fig.1

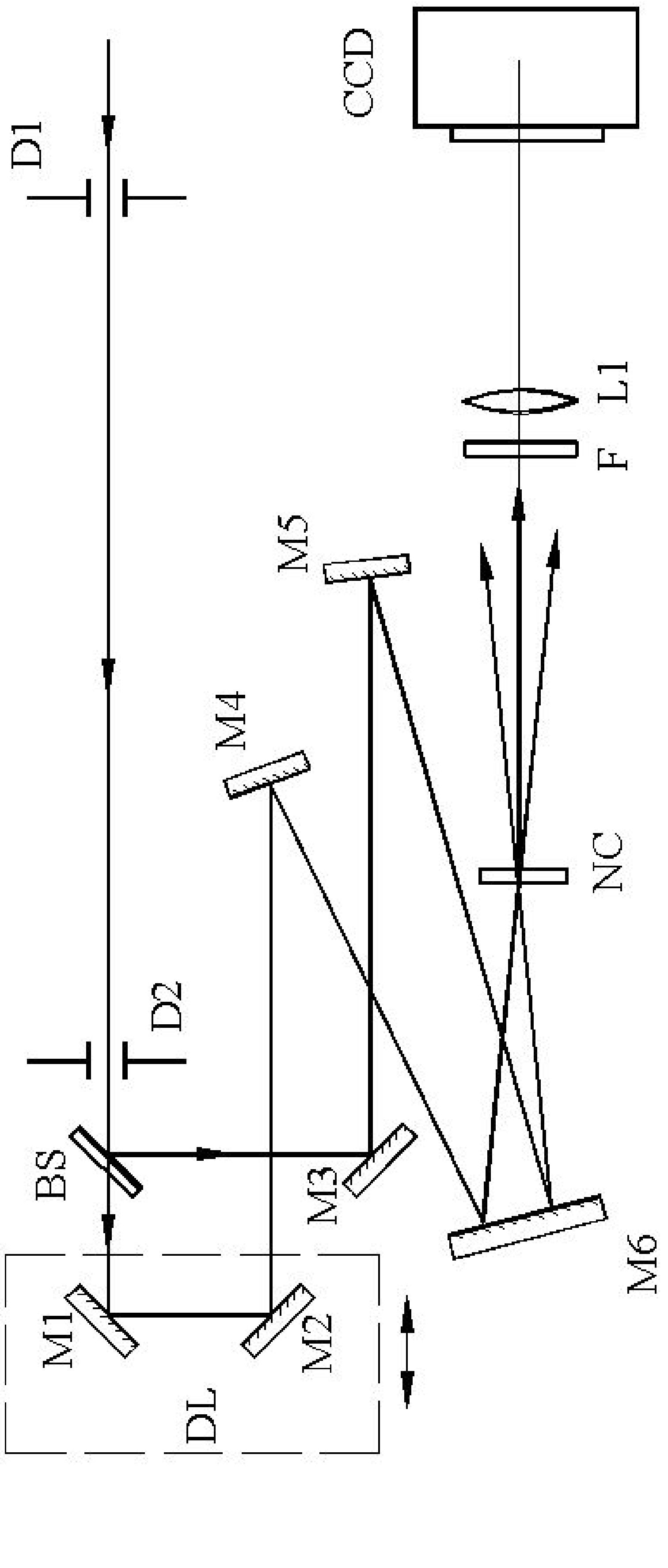

Fig. 2

Fig.3

Fig.4

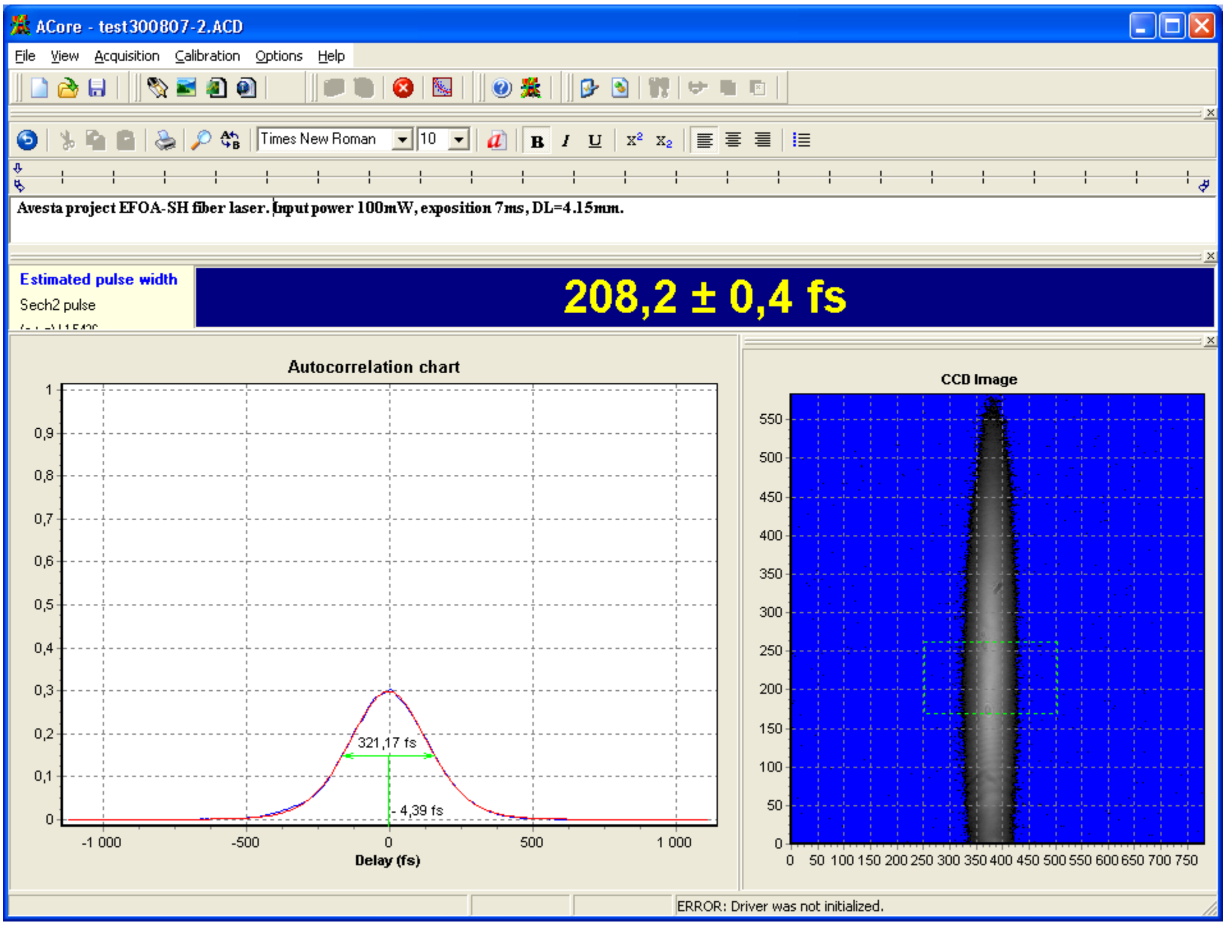
ACore - test300807-2.ACD
File View Acquisition Calibration Options Help
Times New Roman 10
Avesta project EFOA-SH fiber laser. Input power 100mW, exposition 7ms, DL=4.15mm.
Estimated pulse width
Sech2 pulse
208,2 ± 0,4 fs
Autocorrelation chart
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
321,17 fs
- 4,39 fs
-1 000
-500
0
500
1 000
Delay (fs)
CCD Image
550
500
450
400
350
300
250
200
150
100
50
0
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750
ERROR: Driver was not initialized.

Fig.5