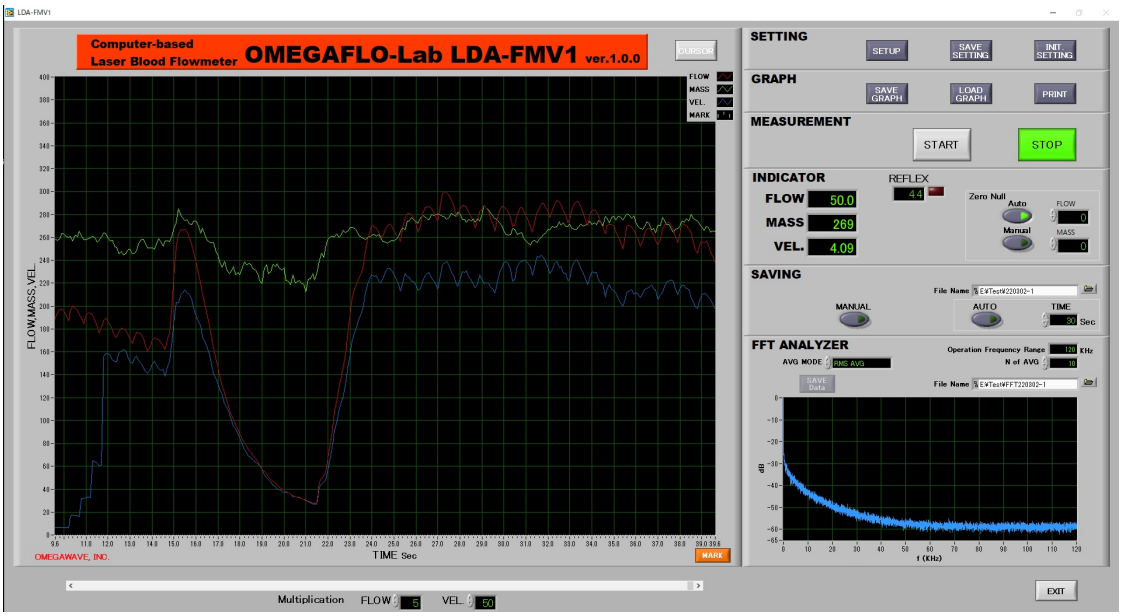
240805

Computer-based
Laser Blood Flowmeter
OMEGAFLO-Lab
User's Manual
(LDF-C1 + LDA-FMV1 ver. 2.0)



CONTENTS

CAUTION

1. Do not turn on the power switch of the computer before connecting the power cable of the laser unit box.

2. Check if there is enough capacity in the HDD for storing data before measuring. Data cannot be stored if there is not enough capacity.

3. Do not see the laser light through a lens or an optical instrument.

4. Do not update Windows and the other software automatically. The function may interrupt the software of this instrument.

5. Do not use this instrument as a conventional computer.

6. The computer has not any anti-virus software. Be careful when the computer is connected to the internet. Also, be careful when the data is transferred from USB memories and CDs.

SUMMARY

This laser tissue blood flowmeter, OMEGAFLOLAB, FLO-Lab, is a useful instrument for measuring tissue blood flow in skin, brain, internal organs, etc. for animals.

FLO-Lab can measure blood flow continuously and non-invasively, compared to H2 and Xe clearance method, and is used widely from in fundamental research to in clinical applications.

This system consists of a laser unit box and a computer-based signal processor with an A/D converter. An opt-electric circuit inside the laser box outputs analog signals of the scattered laser light from tissue. The A/D converter converts the analog signals to digital signals.

The computer-based signal processor receives the digital signals, and blood flow values are calculated, displayed and stored by the software, LDA-FMV1.

The power for the laser unit box is supplied through a USB connector, and AC power is only needed for the computer-based image processor.

The suitable frequency range for the calculation can be set by users, and FLO-Lab can be used from slow speed blood flow to faster speed blood flow.

FLO-Lab uses a semiconductor laser-diode hardly affected by the difference of absorption due to oxy- and deoxy- hemoglobin.

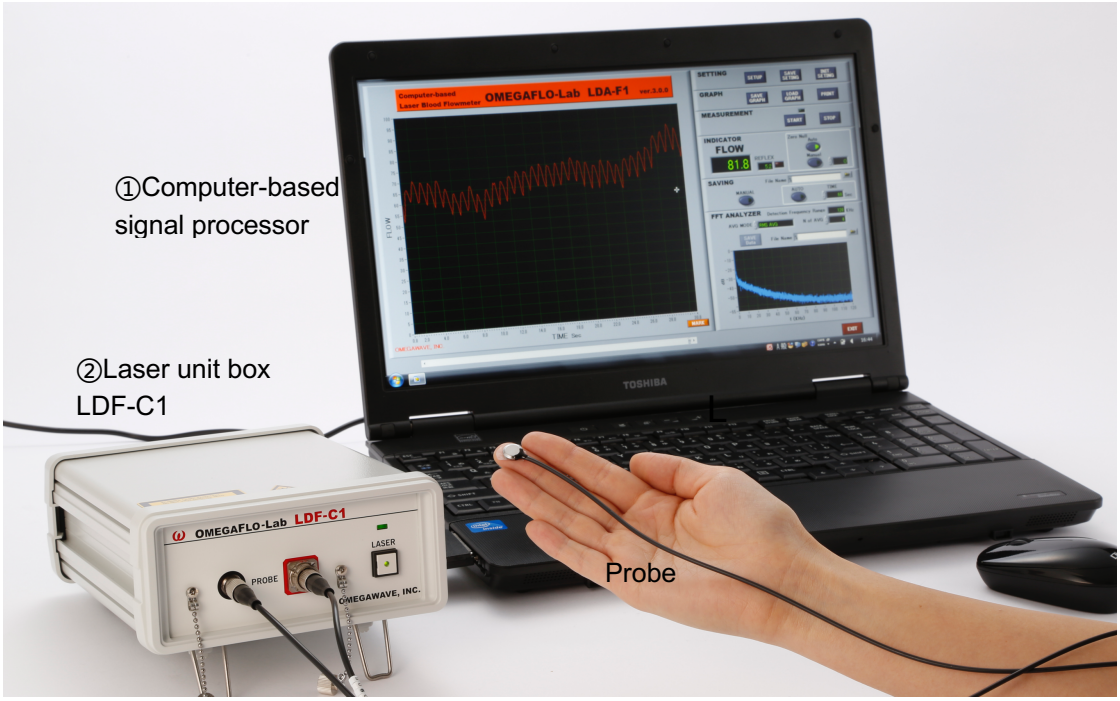
The measurement depth is about 1 mm from a surface of tissue in case of using standard probes.

This FMV version software measures tissue blood flow (FLOW), tissue blood volume (MASS) and blood flow velocity (VEL.). Therefore, the detail of tissue hemodynamics can be observed.

Hardware

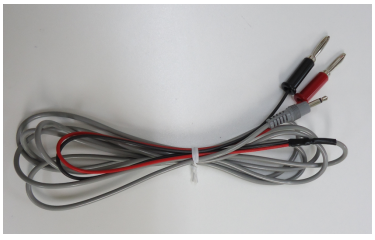
1. Component names and Functions

1) Component names



③ USB Signal cable

④ USB Power cable



⑤ Analog output cable

Fig. 1 Components of OMEGAFLO-Lab

2) Functions

① Computer-based signal processor

The raw signal of blood flow from the laser unit box, LDF-C1, is input to this computer-based signal processor through the A/D convertor inside LDF-C1. The value of blood flow, FLOW, and the time course of FLOW are shown on the display.

The OS of the computer-based signal processor is Windows. OS, the blood flow measurement software, LDA-F1, and other software are installed in the C drive. Blood flow data is stored in the E drive for safety. This computer-based signal processor has only one hard disk drive, but it is separated to two sections, C and E.

② Laser unit box LDF-C1

Laser light is output from the laser unit inside LDF-C1 and irradiated on tissue through a fiber optic probe. A portion of the scattered laser light inside the tissue is received through the paired optical fiber in the probe. The received laser light is converted to an electric signal by an opt-electric circuit, and the signal is output to the A/D converter from the rear panel.

There is no power switch on LDF-C1. The Power LED is turned on when 5V DC is supplied from a USB connector of the computer-based signal processor.

The laser switch is for ON/OFF of the laser light. The green LED on the switch is turned on when the laser light is output.

The optical connectors on the front panel are for connecting a fiber optic probe. The red connector is of laser output, and the black connector is of receiving. Conventional optic fiber probes have no polar. When the optic fiber probe having the color of red and black is used, connect to the optical connectors having the same color.

Fig.2 Front panel of Laser unit

Also, the red connector has the function of adjusting the output laser power at the probe end.

The output laser power can be lower by turning the front ring turning to CW direction. There are the base, the fixing ring for the optical power adjusting ring (FR) and the optical power adjusting ring (PR) on the optical connector for laser light. The FR is fixed when OMEGAFLO-Lab was shipped. The PR can be turned when the two red marks are on the same position. When they are in misaligned, the PR cannot be turned.

Adjust the detected light intensity by turning this ring when the detected light intensity is too strong. The detected light intensity is shown on the display at the left side of FLOW indicator. Set the intensity level in the green light zone.

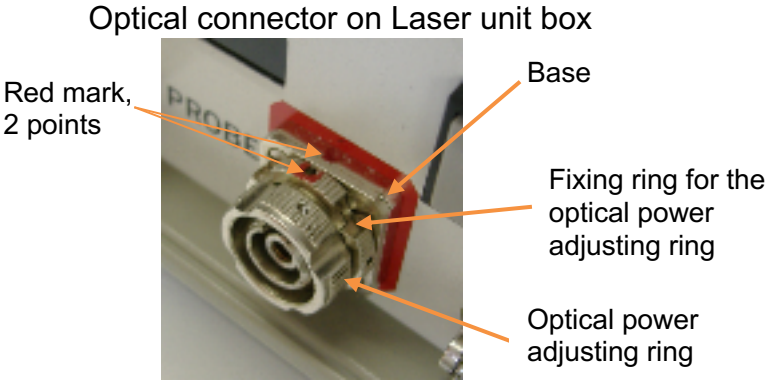


Fig.3 Laser power output adjustment ring

There is the USB signal output connector, the power input and the analog signal of blood flow output on the rear panel. Connect the USB signal cable ③ between the signal output and an USB port of the computer-based signal processor.

Fig. 4 Rear panel of Laser unit

Connect the USB cables before powering the computer ON.

The USB port is assigned by the software of the A/D converter, and connect to the USB port with a green label.

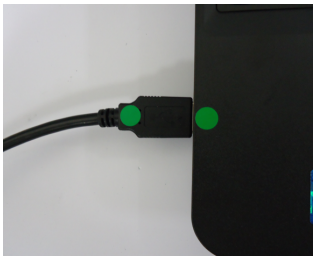


Fig. 5 Port for USB signal cable

The 5V power of is supplied from the computer-based signal processor through the USB power cable ④. This power port is not assigned.

The analog output outputs analog voltage of FLOW or VEL. in MAX 10V. Use the cable ⑤. The conversion of FLOW or VEL. / V can be set on SETUP function.

3) Probe connection

(1) Insert the plugs of an optic fiber probe into the optical connectors of FLO-Lab and screw the coupling of the plugs holding the black rubber boots by the fingers of the other hand not to turn the plug itself. Insert the plugs slowly and in a straight line. Do not insert the plugs slantwise by force.

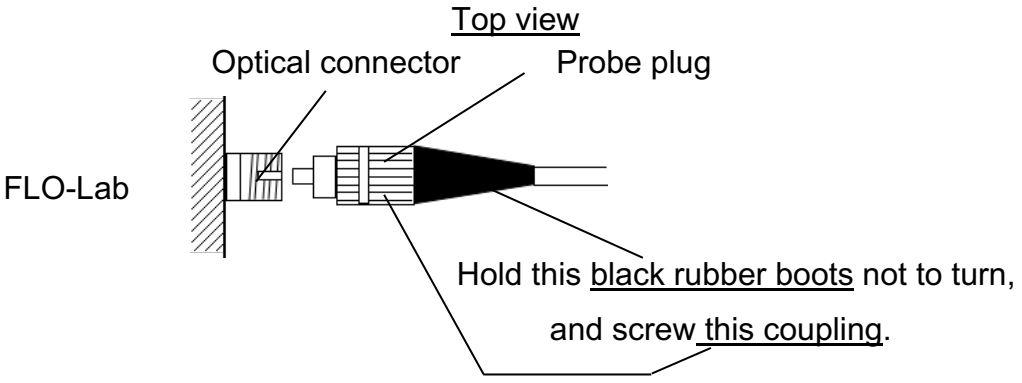


Fig. 6 Connection of Optical fiber probe

FLO-Lab has the laser incidence and receiving optical connectors. Insert the red plug of the probe into the red mark connector, and the black plug into the black connector if the probe has color tubes. The probe not being colored has no side. Both plugs of the probe can be inserted into either side of the optical connectors.

LDA Software

（LDA-FMV1）

1. Start

Switch the computer-based signal processor on. The display such as the chart below appears.

Fig.7 Initial display of Computer

Click the icon of “ LDA-FMV1 “.　The program starts.

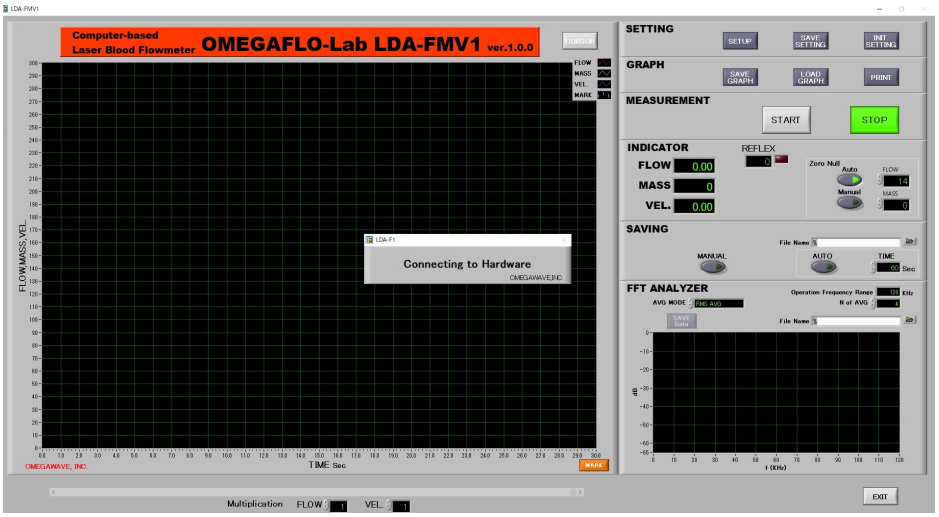


Fig. 8 LDA software display

The program checks the connected hardware, FLO-Lab, and it is displayed. The program quits when FLO-Lab is not connected or broken.

To recognize FLO-C1, refer to “ 4. Recognition of Hardware ” on p20.

2. Display of Measurement

The measurement display is the figure below.

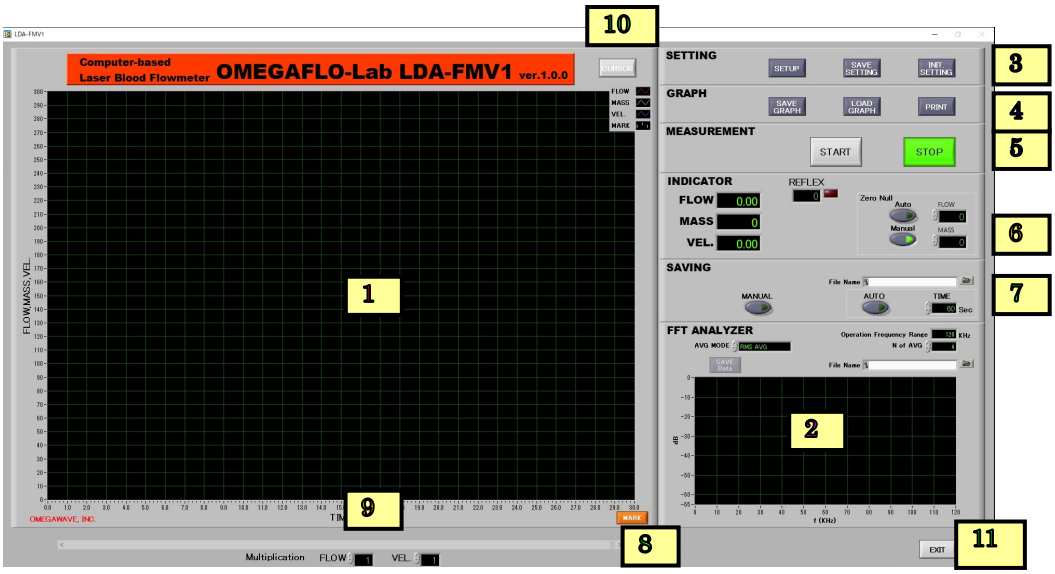


Fig. 9 Measurement display

1) Graph of FLOW, MASS and Velocity (FMV) graph

Time course wave forms of FMV are shown. X and Y axes can be changed directly or on the Setup function. The direct change of the X and Y axes are not saved when the program quits.

2) FFT graph

The frequency characteristic obtained by FFT of the raw signal from the laser unit box is shown. It shows the frequency range from 0 to 120 kHz at 20 Hz pitch. The operation frequency range for calculating FLOW value should be set based on this FFT frequency characteristic. The operation frequency range can be set on Setup function described below.

The operation frequency range is set in ” Frequency Range ” .

“ AVG MODE “ is for selection of Averaging or Non-Averaging of the graph. The FLOW value is calculated from the averaged FFT. When an averaged FLOW is required, use this function and assign the number of averaging.

" NON AVG " shows a real time FFT graph of 0.1 sec interval.

" RMS AVG " shows an averaged FFT graph assigned by " N of AVG ".

The FFT graph data is saved by “ SAVE Data “ button. The data file is saved in the folder shown in “ File Name “. The data is not saved when a folder and a file is not assigned.

3) SETTING Section

(1) SETUP BUTTON

SETUP display is shown by pushing the “ SETUP “ button.

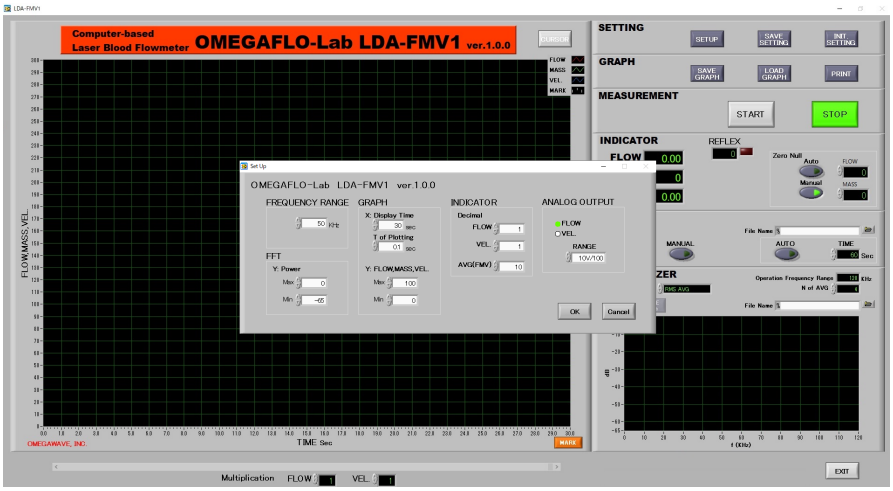


Fig. 10 SETUP display

FREQUENCY RANGE

The upper limit of the operation frequency range is set by ***Frequency Range.*** The lower limit frequency is 20 Hz and it is fixed. The upper limit can be set from 5 kHz to 120 kHz every 5 kHz pitch. Refer the FFT graph to set the upper limit frequency.

FFT

The ***Y : Power*** in ***FFT*** is used to determine the Y scale of FFT graph.

FLOW

The scales of X and Y axes of the graph are set in ***GRAPH.***
The “ Display Time “ is for the X axis, and “ FLOW, MASS, Vel. “ is for the Y axis.

FLOW INDICATOR,

a) The decimal point is set by ***Decimal*** .
It is recommended to enter “ 0 “ for a wider operation frequency range like 50 kHz or 100 kHz, and to enter “ 2 “ for a lower operation frequency range like 5 KHz or 10 KHz. Use “ 1 “ for a middle operation frequency range.

b) The value showed in FLOW in INDICATOR frame can be averaged by ***AVG*** . Set the number bigger to stabilize the value to read the value easily. The FLOW wave is not affected by this function.

ANLOG OUT RANGE

This is used to set the analog output voltage ratio for FLOW or VEL. value. It is shown as " Output Voltage / FLOW or VEL. value " .
The selections are 10V/10, 10V/100 and 10V/1000.

(2) SAVE SETTING BUTTON

This button is to save the measurement condition set up by SETUP display, the selection of " Zero Null ", and " AVG MODE " for FFT. "

(3) INIT. SETTING

A measurement condition is initialized by pushing this button.

4) GRAPH Section

(1) SAVE GRAPH

This button is to save displayed FMV graphs. Enter the file name of a saving graph after pushing this button.
The saved graph can be loaded by the button of " LOAD GRAPH ".

(2) LOAD GRAPH

This button is to load the graph saved by " SAVE GRAPH ". Select a file after pushing this button.

(3) PRINT

This button is to print the graph.

5) MEASUREMENT Section

(1) START

Push this button and measurement starts.

(2) STOP

Push this button to stop measurement. This button does not work during data is saved.

6) INDICATOR Section

(1) FLOW(Tissue Blood Flow), MASS (Tissue Blood Volume) and VEL.(Blood Flow Velocity)

FLOW, MASS and VEL. values are shown in the frames. The decimal point can be set on SETUP function.

(2) REFLEX

Detected light intensity is shown in this frame. When the intensity is too low (<1) or too high (>9.5), it is not possible to calculate the blood flow value and the red LED is turned on. The state of low intensity implies the probe used is

broken. When the intensity is too high, adjust the intensity level by turning the ring of the right sided optical connector in red.

(3) ZERO NULL

The noise caused by the electronic circuit and the laser shot noise are eliminated by this function.

When " Auto " is turned on, the noise is automatically eliminated by the program. When " Manual " is selected, FLOW and MASS values showed in INDICATORs are subtracted. To select " Manual " turn " Auto " off, and select " Manual ".

7) SAVING Section

This section is for saving data. Assign a folder and a file name before measurement. Without entering the file name, this function does not work. Data is saved in EXCEL file.

(1) MANUAL

This button is for saving data manually. Pushing this button starts saving data and turn the LED on. The data is saved until the next pushing.

(2) AUTO

Data is saved automatically for the time assigned by " TIME ".

8) MARK

This button is used to make a white line on the graph. The time is saved in EXCEL file with the data.

9) Multiplication

The values of FLOW, MASS and VEL. are usually different. MASS shows about 200 -500, FLOW about 10-100, and VEL. about 0.2 – 2.0. Therefore, it is not easy to see all values on one graph. This function changes the values of FLOW and VEL. on the graph to make it easier to see. This function does not affect the real values themselves, but just on the graph.

10) CURSOR

This button is used to know the MAX, MIN and AVG(average) FLOW between the two cursors, T1 and T2. The cursors can be moved manually.

11) EXIT

To quit the program, push this button.

This button works when measurement is stopped.

3. Operation of LDA-F1

1) Assignment of Folder and File name

Assign the folder for saving data of FLOW and FFT data, and enter the file name.

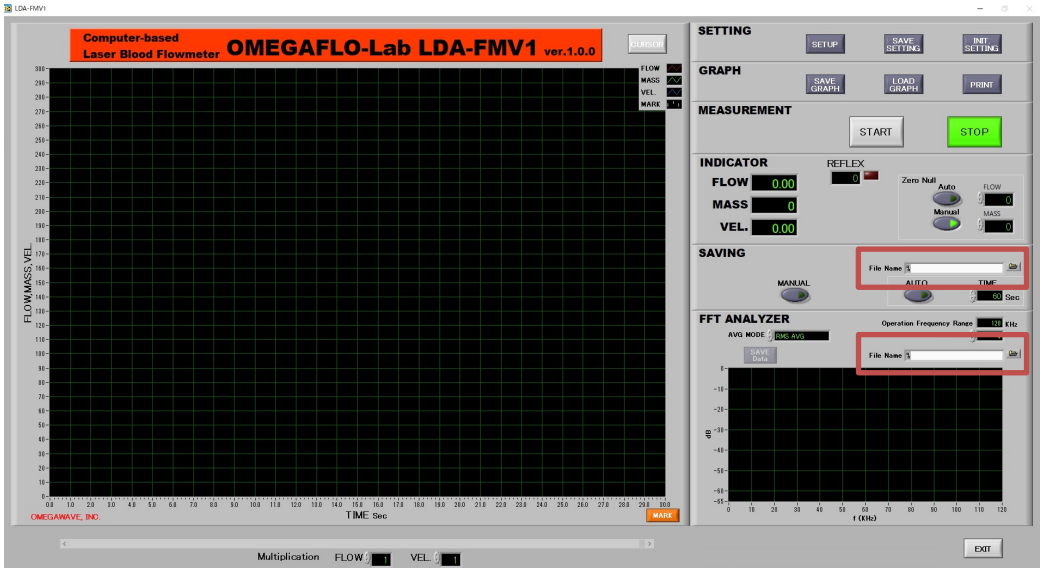


Fig. 11 Assignment of Folder and Filename

Click the figures of folders in red square marks. It is initially assigned that data is save in “ E “ drive “ in the hard disk/ SSD , and its window opens automatically.

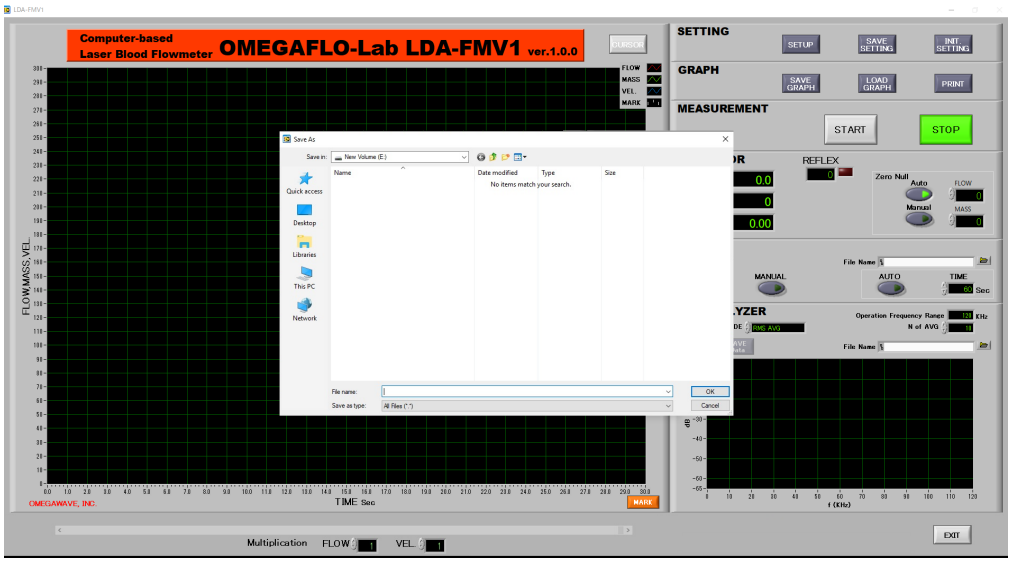


Fig. 12 Contents in E Drive

“Test Measurement“ folder is created in “ E “ drive.

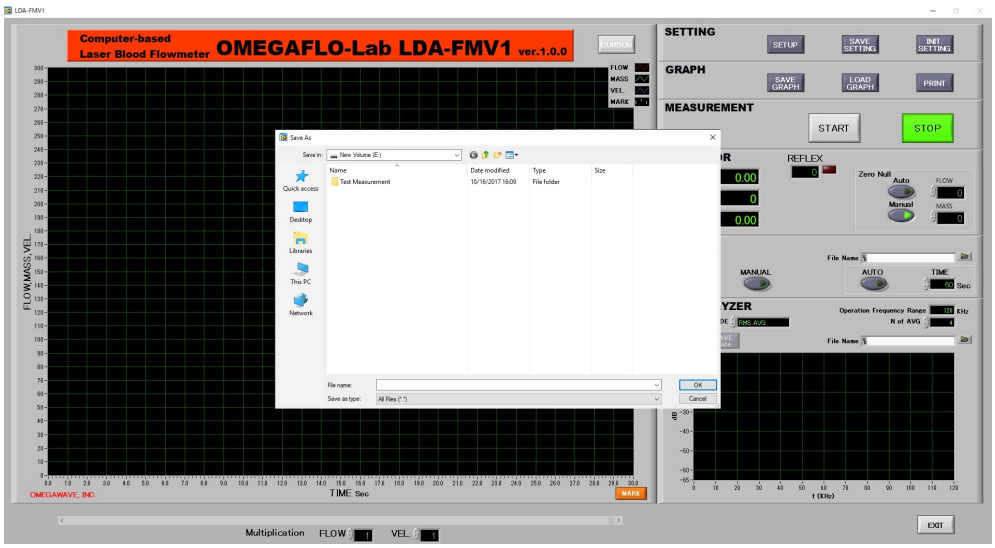


Fig. 13 Test Measurement folder in E Drive

Open the “ Test Measurement “ folder and enter the file name for saving a measurement data.

The name of “ Data -1“ is entered as an example. Click “ OK “ and the information is shown in the frame of File Name in SAVING Section.

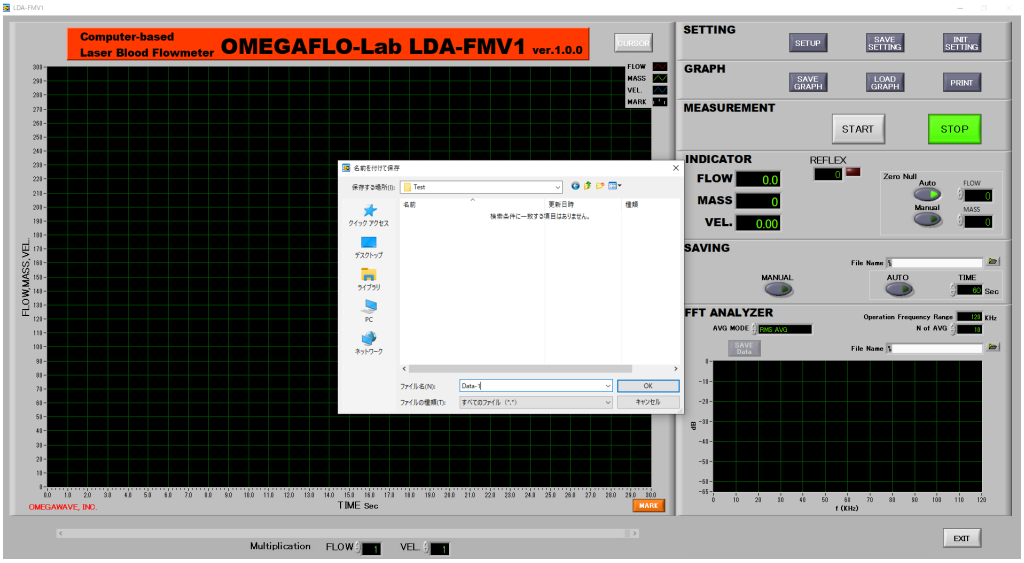


Fig. 14 The name of “Data-1“ is entered.

Also, enter the file name for FFT data. The file name of “FFT - 1“ in the “ Test Measurement “ as an example. Click “OK“, and this information is shown in the frame in FFT ANALYZER Section.

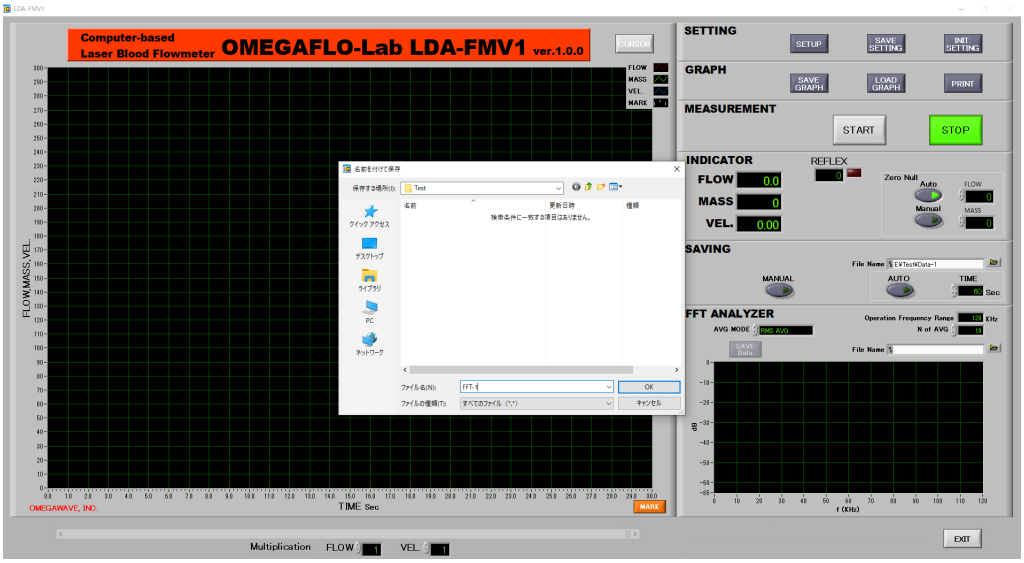


Fig. 15 The name of “FFT-1“ is entered.

2) Measurement

After entering the file names, push the button of “START“.
For saving data continuously, push the button of “MANUAL“ or “AUTO“.
For saving FFT data momentary, push “SAVE Data“ button.
An example of finger blood flow measurement is shown below.

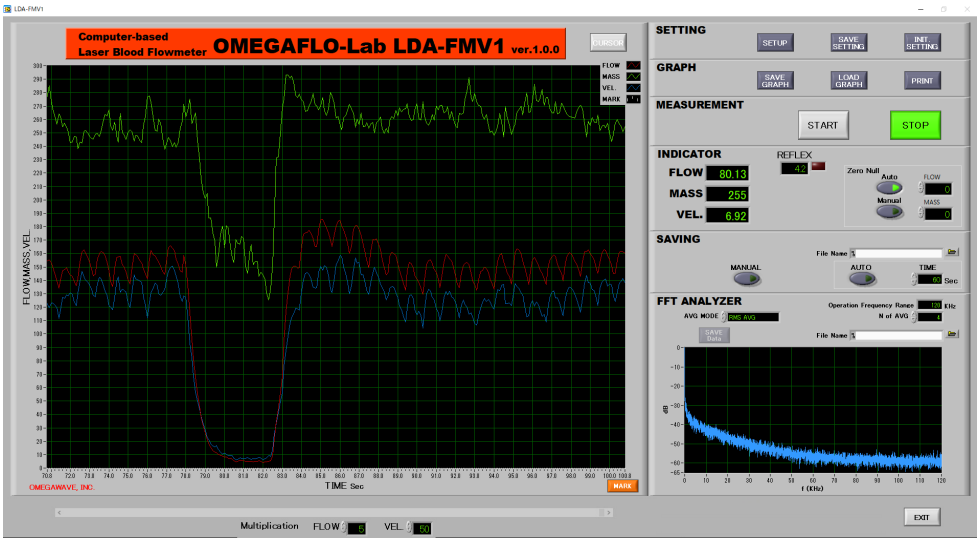


Fig. 16 Example of measurement

To show the maximum, minimum and averaged Flow between a certain time period, click " CURSOR ". The cursors, T1 and T2, can be freely moved manually.
Min : Minimum,
Max : Maximum
AVG : Average

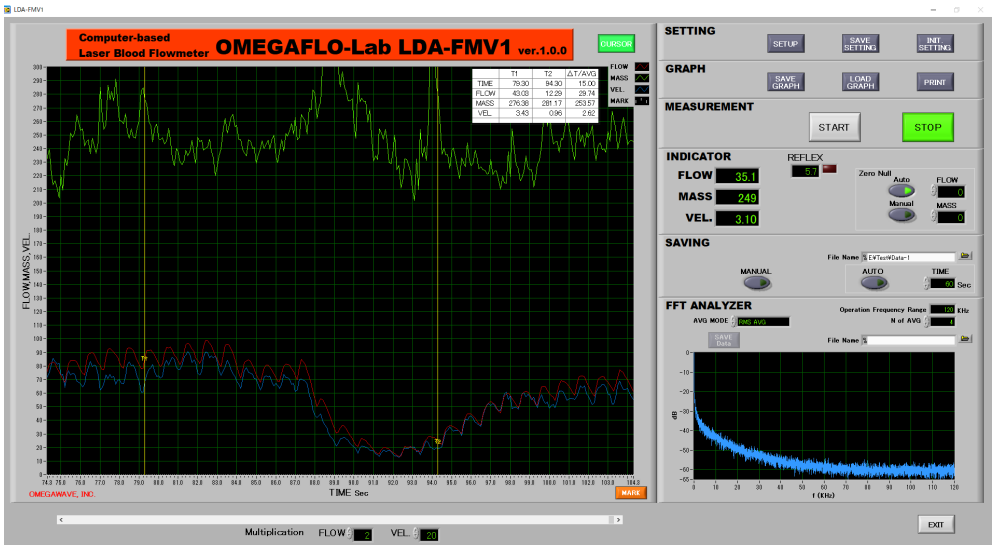


Fig. 17 Display with cursor

3) Saved data

Sequential FLOW and FFT data are automatically saved in “ E “ drive.
When the “ E “drive is opened, the folder named “ Test Measurement “ is shown.

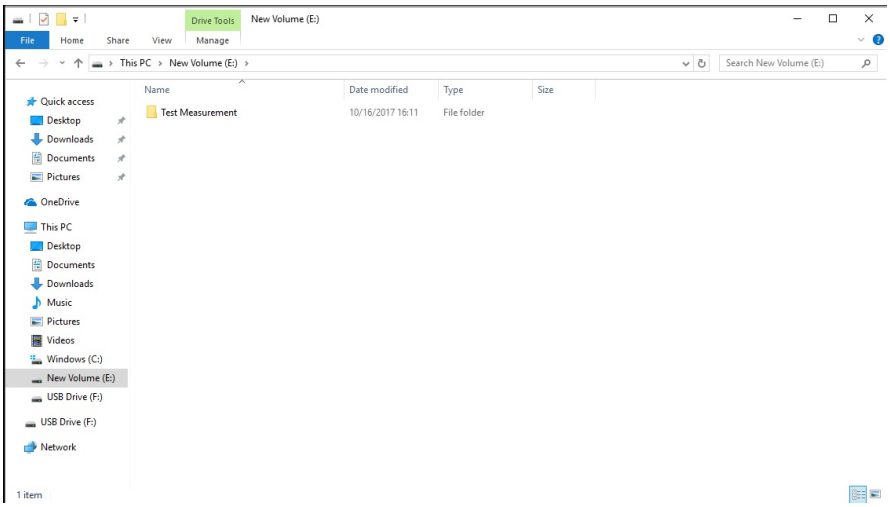


Fig. 18 Contents in E drive

There are files named as “Data-1“ and “FFT-1“ in this folder. Each file has sequential number at end as 11, 12, 13, etc.

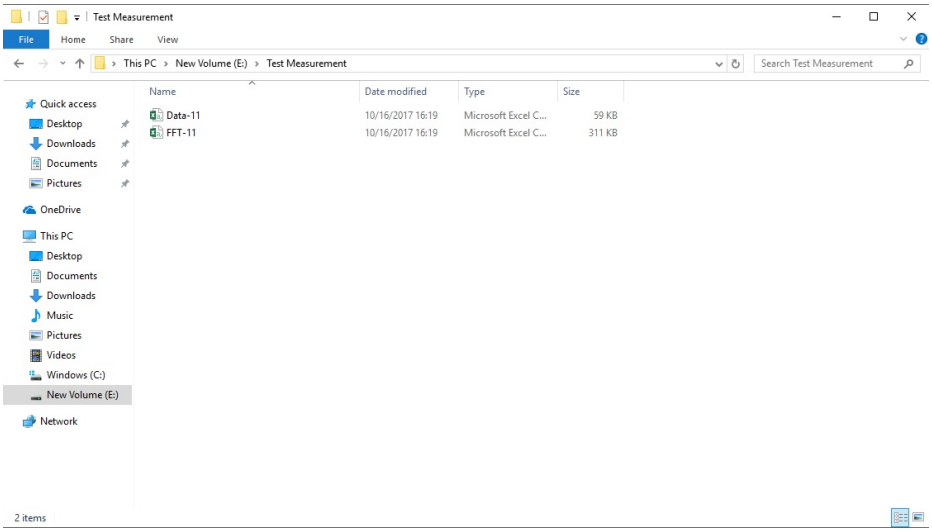


Fig. 19 Contents in “Test Measurement “ folder

An example files in EXCEL are shown below.

(1) FLOW file

Frequency Rage (KHz) : operation frequency range set in SET UP.

Average : N of AVG

TIME : measurement time from the start point

FLOW : blood flow value

Mark : the time MAKER was pushed. It is show as “ 2 “ on 22.2 sec in this file. This value “ 2 “ is automatically set.

ZERO NULL : zero null condition. Auto (A) or Manual (M).

	A	B	C	D	E	F	G	H	I	J	K	L
1	Frequency Range (KHz)	120	TIME	FLOW	MARK	ZERO NULL						
2	Averages	2	21.6	138.85	0	A						
3			21.7	132.78	0	A						
4			21.8	130.41	0	A						
5			21.9	127.69	0	A						
6			22	127.87	0	A						
7			22.1	119.88	0	A						
8			22.2	117.62	2	A						
9			22.3	113.48	0	A						
10			22.4	113.57	0	A						
11			22.5	125.83	0	A						
12			22.6	133.67	0	A						
13			22.7	131.34	0	A						
14			22.8	131.7	0	A						
15			22.9	129.03	0	A						
16			23	125.26	0	A						
17			23.1	124.39	0	A						

Fig. 20 Data in “Data-1“ Excel file

(2) FFT file

Average : N of AVG

TIME (sec) : the time FFT data was saved.

KHZ : frequency

dB : intensity of the power at each frequency in dB

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Power Spectrum		KHz	dB									
2	Average	2	0	12.69874									
3	TIME(Sec)	5.4	0.02	8.277246									
4			0.04	-22.3242									
5			0.06	-20.3844									
6			0.08	-23.2549									
7			0.1	-25.8853									
8			0.12	-24.9988									
9			0.14	-23.3472									
10			0.16	-23.6351									
11			0.18	-23.8977									
12			0.2	-22.0509									
13			0.22	-22.2135									
14			0.24	-21.6023									
15			0.26	-21.0399									
16			0.28	-25.971									

Fig. 21 Data in “FFT-1“ Excel file

4. Recognition of Hardware

An error message is shown when

1) The USB signal cable is not connected to the assigned USB port,
2) The USB signal cable is connected after the power of the computer-based signal processor was ON.

This error shows when a Laser unit box is not recognized.

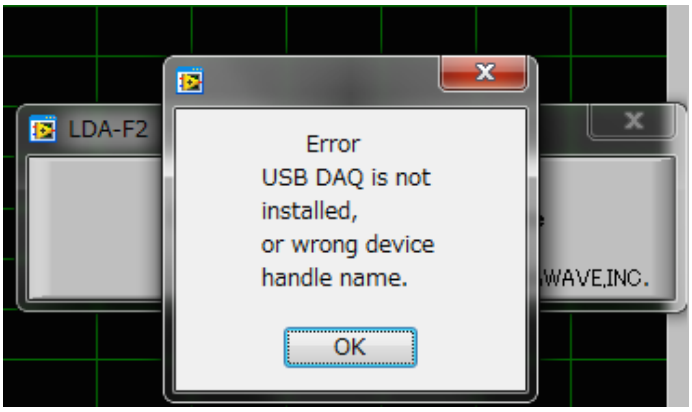


Fig. 22 Error message of the hardware unrecognition

To solve this error, let the computer-based signal processor recognize by the following procedures below.

1) Make the computer-based signal processor show “All programs” from “Start button”, and click “Instacal” in “ Measurement Computing ” folder.

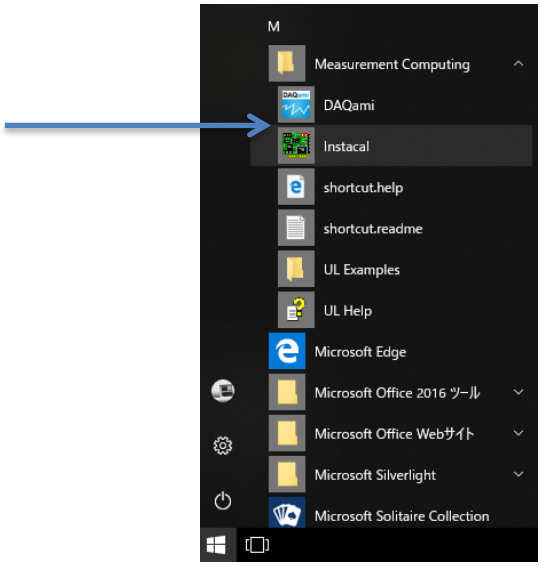


Fig. 23 “Instacal“ software in “Measurement Computing”

2) The type of DAQ (Data Acquisition) connected to the computer-based signal processor is shown.

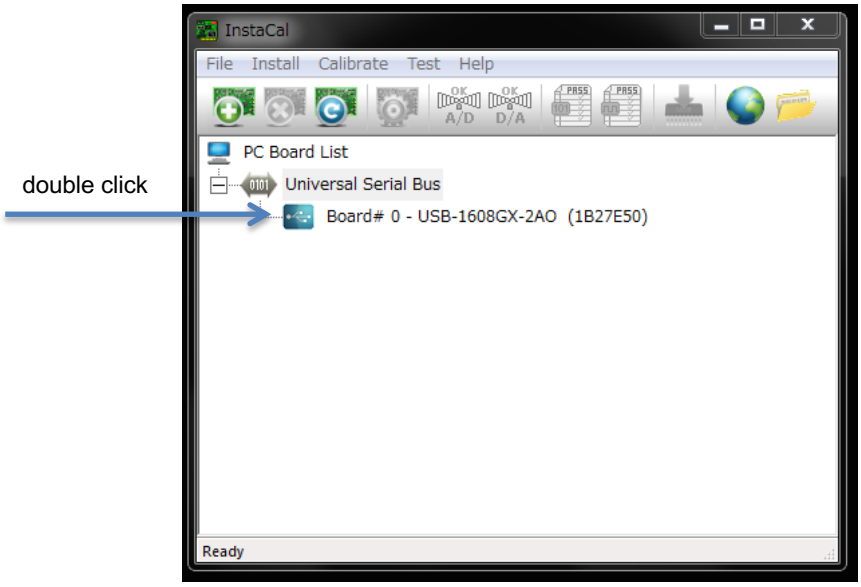


Fig. 24 Recognition of the connected board

3) Double click “Board #0 – USB-1608GX-2AO”.
4) Board Configuration is shown.
   Select “Single Ended (16bit)” in “ Input Mode ”.

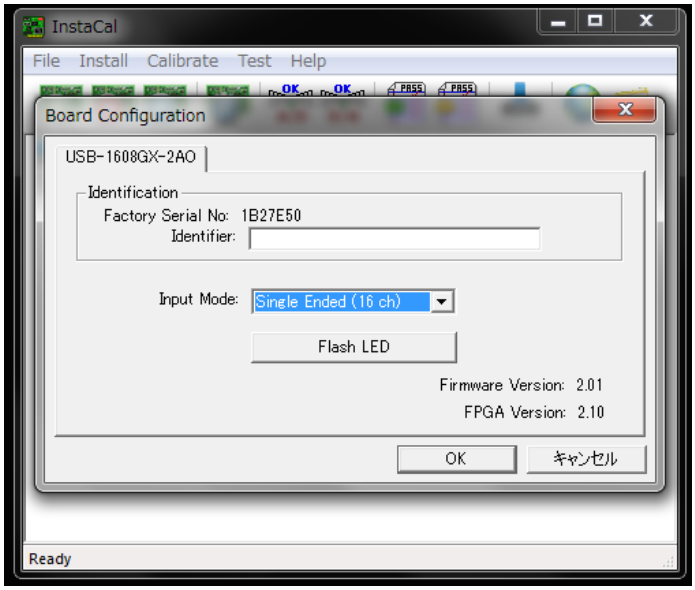


Fig. 25 Mode selection

5) Push “OK” button. The recognition is completed, and blood flow program works.

Theory of tissue blood flow measurement by Laser

When laser light illuminates tissue, the light is diffused by tissue and erythrocytes (red blood cells). Generally, the volume fraction of the erythrocytes in the tissue is small, therefore, most of the photons are only scattered by static tissue elements and, in the case of short optical path length, a small number of photons are scattered by the erythrocytes once, or at most a few times, during the scattering process. The light scattered from the static tissue elements does not shift in frequency, but the light scattered from the moving erythrocytes does shift in frequency, and is dependent on the flow velocity.

As tissues are highly scattering materials in near infrared region, the photons are scattered many times by static tissue elements before colliding with the erythrocytes. Therefore, the incident directions of the photons with respect to the erythrocytes are random.

Also, vectors of flowing erythrocytes are not unity. Then, the electric output of an opt-electric circuit with a photo-diode has broad frequency characteristic. This broadening of frequency depends on the velocity and number density of the erythrocyte in the tissue. (Figure below)

From this spectral characteristics, tissue blood flow (FLOW) can be obtained by the next equation.

$$FLOW \propto \int \omega P(\omega)\, d\omega / \langle I \rangle^2$$

ω : angular frequency, ω = 2πf,
I : detected light intensity
P(ω) : power spectrum

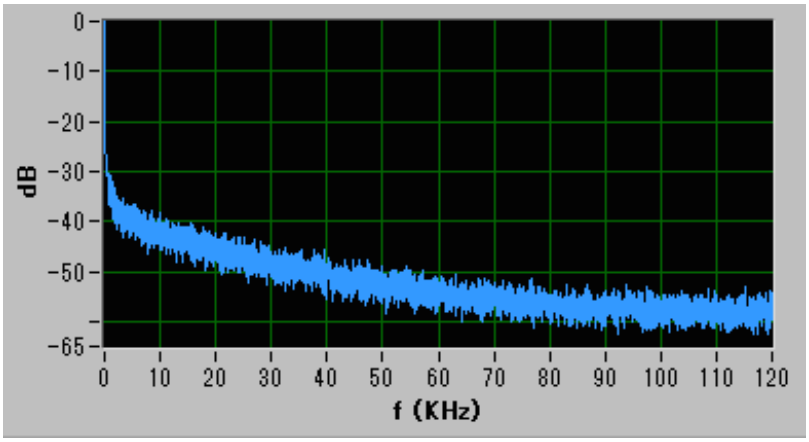


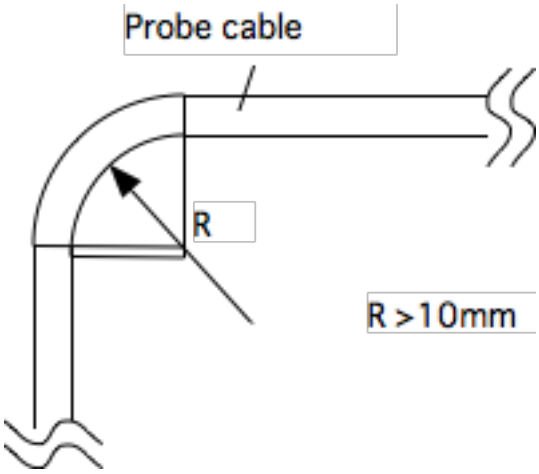
Fig. 26 Power spectrum of detected light intensity

Handling and Cautions

1) Pay attention to the next matters.
   (1) Keep FLO-Lab out of water.
   (2) Set FLO-Lab on the place where air pressure, temperature, humidity, wind, sunlight, dust, and air containing salt and sulfur do not cause bad condition.
   (3) Pay attention to inclination, vibration and shock.
   (4) Keep FLO-Lab out of a storeroom of chemicals and the place where gas generates.
   (5) Pay attention to the voltage and frequency of the power source FLO-Lab is connected to.

2) Pay attention to the next matters before using FLO-Lab
   (1) Examine switch workings and meters, and confirm FLO-Lab working.
   (2) Confirm all the cables being connected correctly and completely.
   (3) Pay attention to using other instruments together.

3) Pay attention to the next matters in use of FLO-Lab.
   (1) Do not use over the time for diagnosis and medical treatment.
   (2) Do not look at the laser light generated from FLO-Lab directly and through a lens.
   (6) Probes are made from glass fibers, and they are hardly repaired.
   Pay attention to the next matters for probes.
   ① Do not scrub the tip of probes.
   ② Do not bend into a circle of under 10 mm in radius.



③ Do not step on probes.

④ Keep the tip and plugs clean.

⑤ Do not insert and pull the plugs slantwise by force.

⑥ Use under 60℃ of sterilization.

4) Pay attention to the next matters after using FLO-Lab

(1) Turn off the power switch.

(2) Do not pull the cables by force.

(3) Pay attention to keeping.

① Keep FLO-Lab out of water.

② Set FLO-Lab on the place where air pressure, temperature, humidity, wind, sunlight, dust, and air containing salt and sulfur do not cause bad condition.

③ Pay attention to inclination, vibration and shock.

④ Keep FLO-Lab out of a storeroom of chemicals and the place gas generates.

(4) Put belongings, cables and probes in order after cleaning.

(5) Clean FLO-Lab for the next using.

5) When FLO-Lab is out of order, do not handle. Leave it to a specialist.

6) Do not remodel FLO-Lab.

7) Maintenance

(1) Inspect FLO-Lab regularly.

(2) Confirm FLO-Lab being in order before using it having not used for a long time.

Specification

Measurement terms

Measurement	1. Tissue blood flow (FLOW) 0 - 1000 (mL/min/100g corresponding) 2. Tissue blood volume (MASS) 0 -2000 (A. U.) 3. Tissue blood flow velocity (VEL.) 0-100.00 (AVG frequency : kHz)
Detection frequency range	0 Hz ～ 120 kHz
Operating frequency range	5KHz ～ 120KHz, 5kHz pitch
Plot interval	0.1, 0.2, 0.5, 1, 2, 5, 10 sec
FLOW display time	10 ～ 600 sec every 10 sec
Analog output	FLOW : 0 – 10 V
Measurement area	inside of about 1 mm circle
Measurement depth	about 0.5mm – 1mm from surface (depends on tissue)

Hardware

Computer-based signal processor & A/D converter	
Power	100～240 VAC, 50/60Hz、about 15W
Size	about 380 × 40 × 250 mm（W×H×D）
Weight (kg)	about 2.6
OS	Windows Windows11
CPU	Core i7
Memory	over 8GB
Hard disk drive or SSD	over 500GB
DVD drive	Multi (maybe external)
Display size	15.6 - 16 inch
Resolution	1920 X 1080
Laser unit box	
Laser	Wavelength : 780nm, semiconductor laser 3mW at Probe end, CLASS 1
Optical connector type	FC
Fiber optic probe	100/140 μm、Silica GI
A/D converter	16 bit, USB
Power	5V DC, 0.4A
Size (mm)	about 155 × 58 × 202（W×H×D）
Weight (kg)	about 1

Guarantee

1) FLO-Lab

Repairs are free within one year after the purchase of FLO-Lab except the next cases.

(1) Malfunction and damage due to incorrect using and inattention.

(2) Malfunction and damage due to a nature calamity and a fire.

2) Probes

Probes are treated as like consumption articles, and cost of repair are according to the table below at the first time.

after purchase	cost of repair
within 6 months	under 50% of the purchase price
within one year	under 70% of the purchase price
after one year	not provided

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