ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY

Zeta-Sizer

Nano ZS

(Malvern)

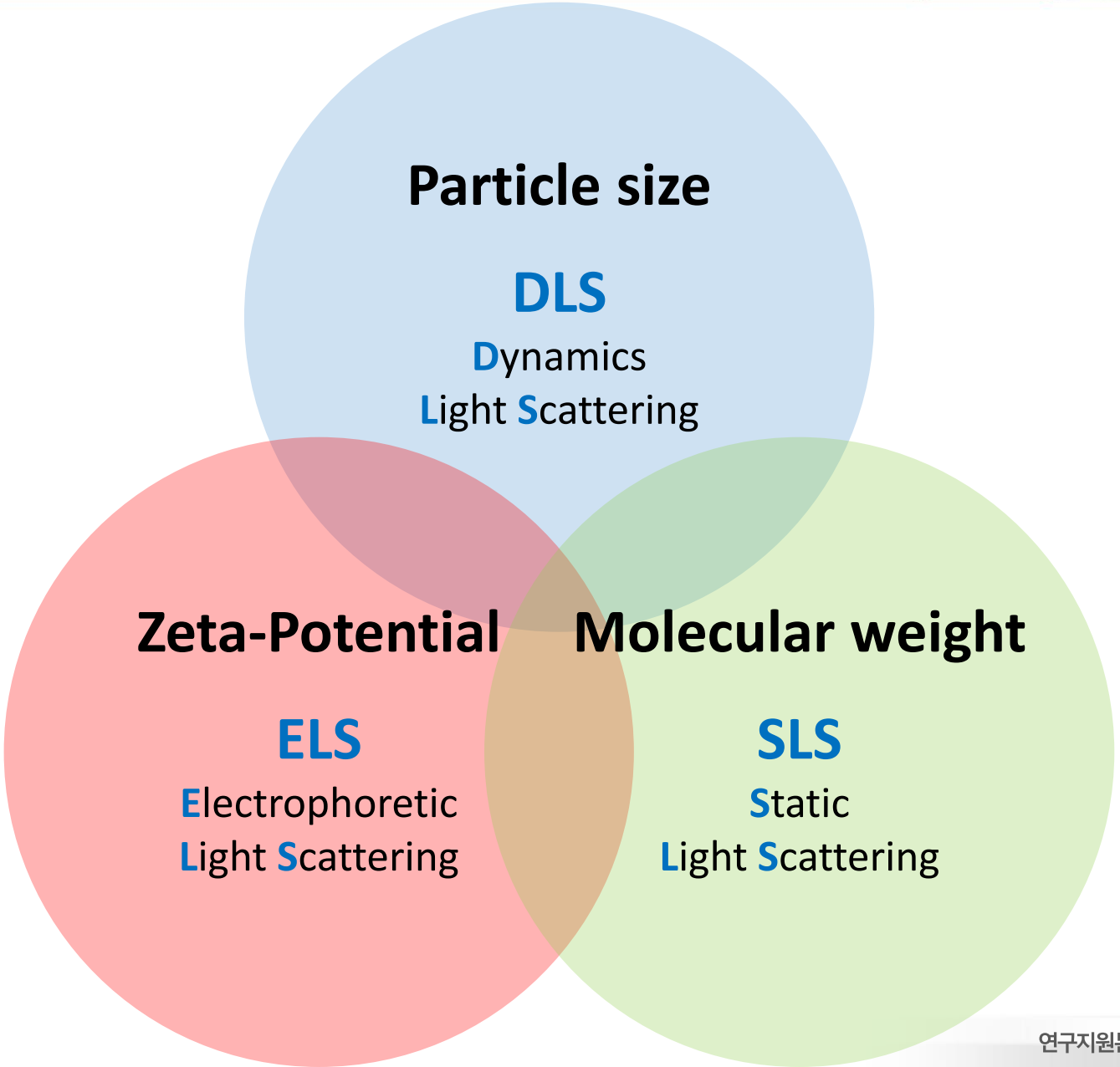
1. Basic Principles

Size Theory (DLS)

Zeta-Potential Theory (ELS)

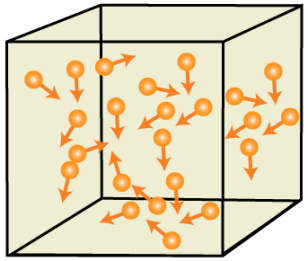
Molecular Weight Theory (SLS)

Measurement mode



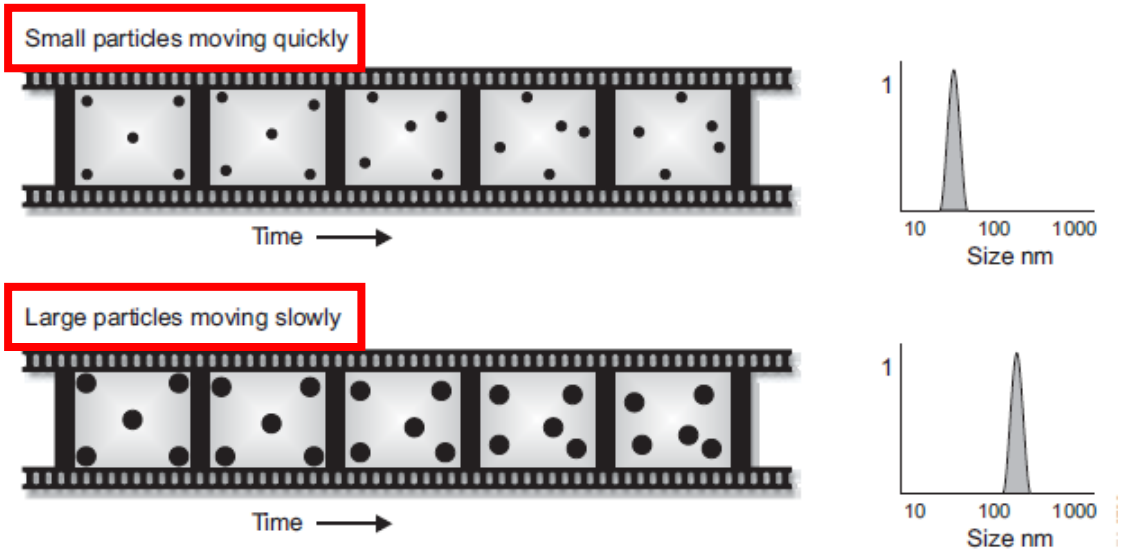
DLS (Dynamics Light Scattering)

▪ Brownian Motion



"The random movement of particles in a liquid due to the bombardment by the molecules that surround them."

The particle size can be determined by measuring **Brownian motion** of particles in a sample using **Dynamic Light Scattering (DLS)**.

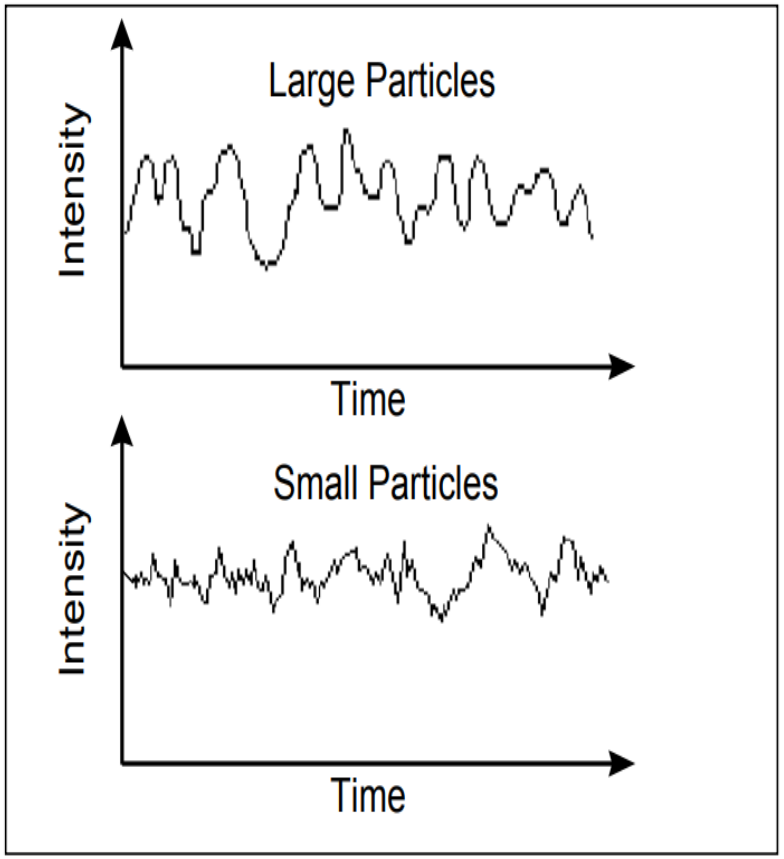


The particles in a liquid move about randomly and their speed of movement is used to determine the size of the particle.
➔ Using this knowledge and the relationship between **diffusion speed and size**, the size can be determined.

DLS (Dynamics Light Scattering)

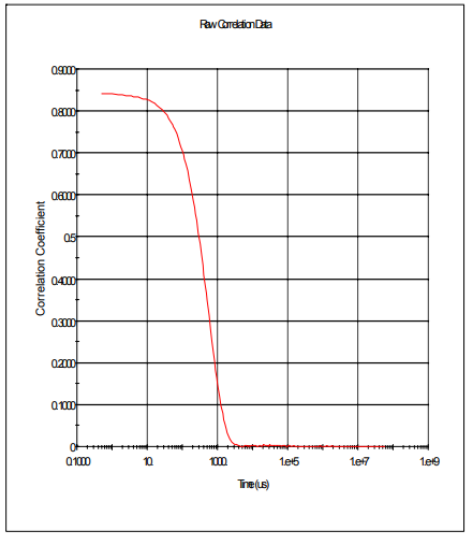
- **Particle size**

<Intensity fluctuations>

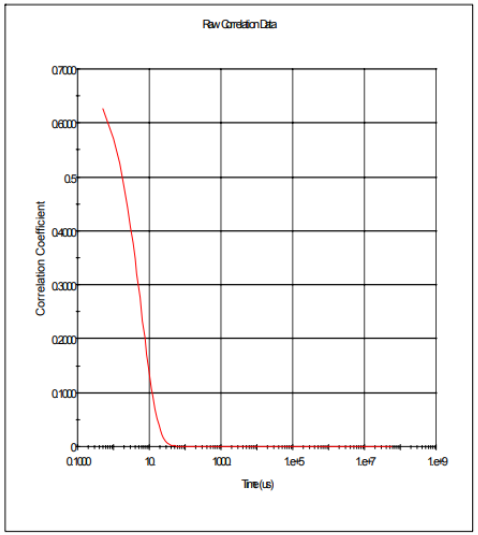


<Correlogram>

Large Particles

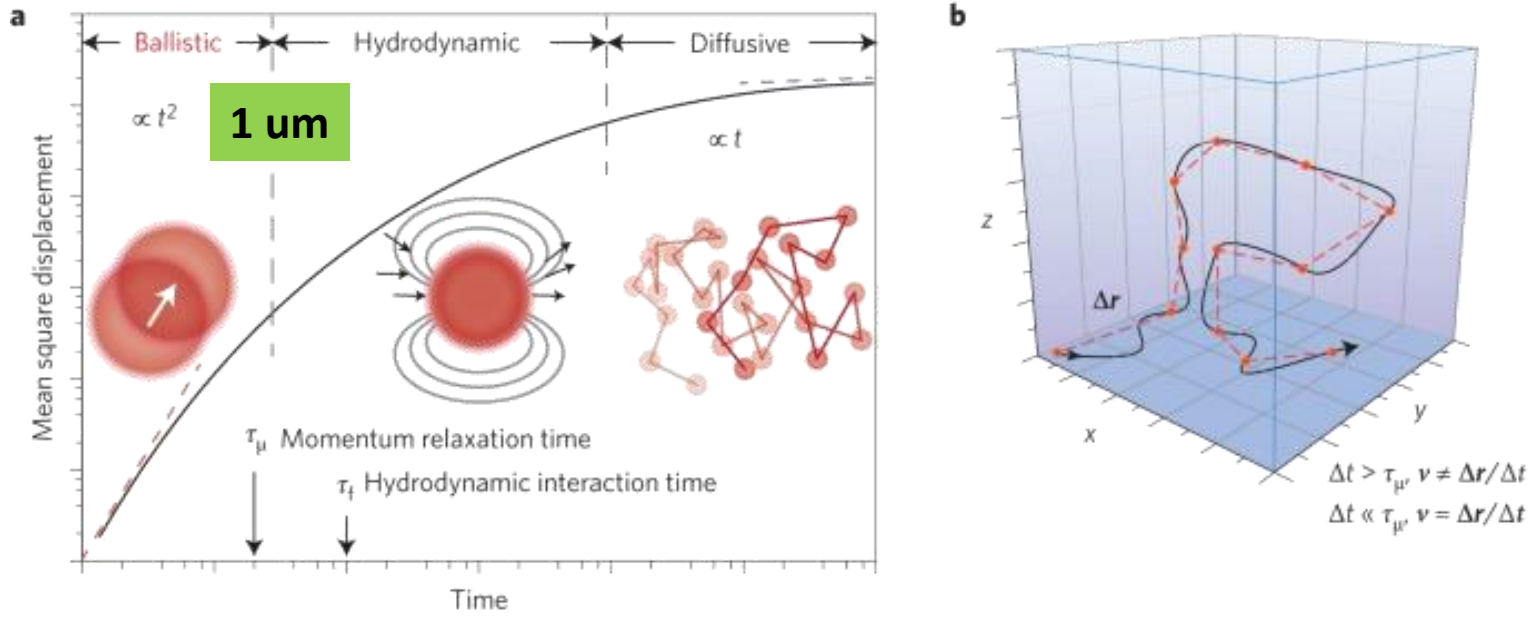


Small Particles



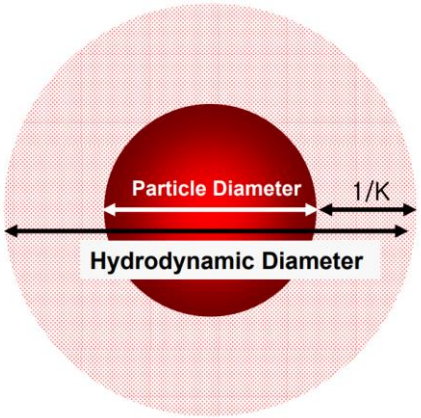
DLS (Dynamics Light Scattering)

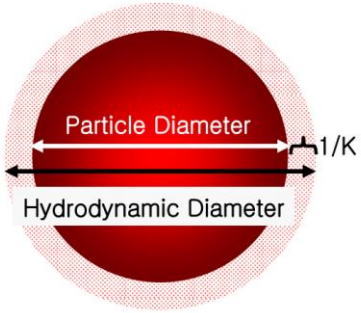
- **Brownian motion vs Ballistic motion**

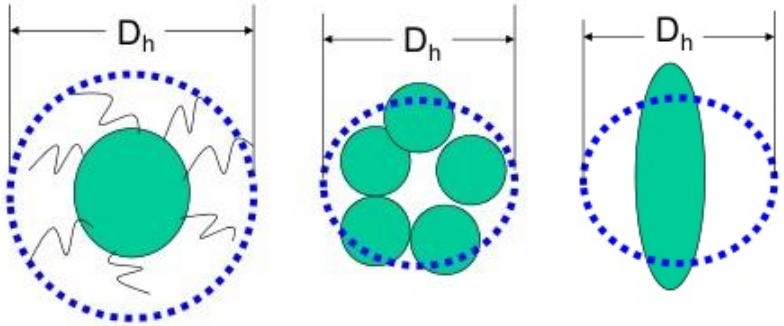


- **Hydrodynamic Diameter**

1/k (Debye length) = Thickness of electrical double layer







DLS (Dynamics Light Scattering)

Stokes-Einstein Equation

$$d_H = \frac{kT}{3\pi\eta D}$$

ISO: Z-average, PDI
RSD < 5 %

d_H = hydrodynamic diameter (m) → Calculation value

k = Boltzmann constant (J/K=kg·m2/s2·K) → Constant (1.3806504 * 10^-23)

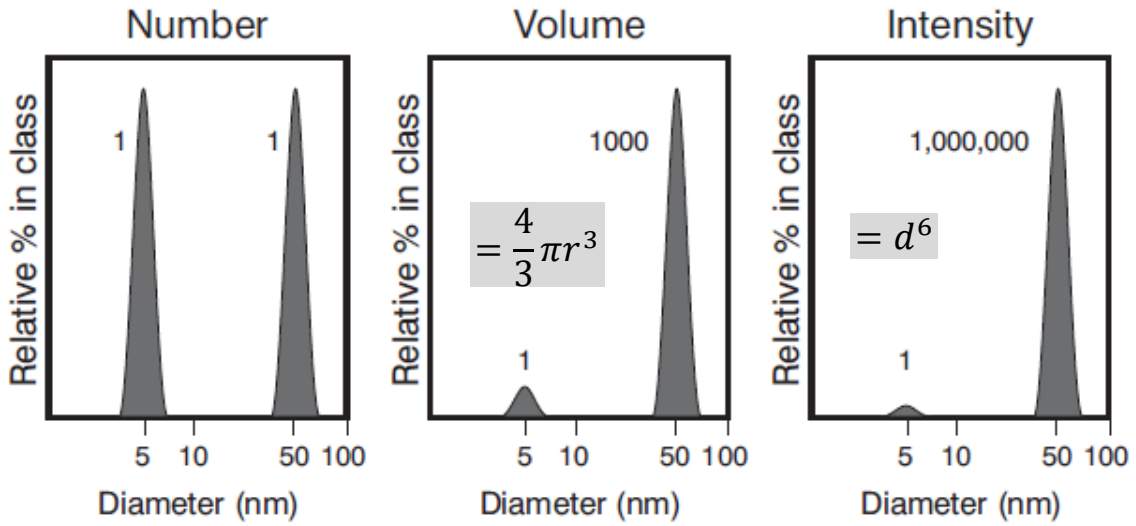
T = temperature (K) → 298.15 K (25 C)

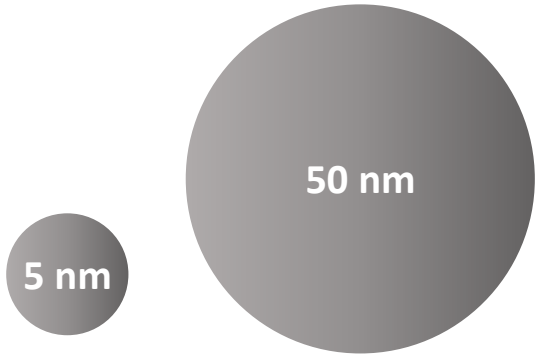
η = solvent viscosity (kg/m·s) → Insertion value

D = diffusion coefficient (m^2/s) → Measurement value (Total scattering rate)

DLS (Dynamics Light Scattering)

- **Intensity, volume and number distributions**





Same amount of two particles

Number PSD ***X 1***

As expected the two peaks are of the same size (1:1) as there are equal number of particles.

Volume PSD ***X 1,000***

The ratio of the peak area – 1 : 1,000 (5 mn : 50 nm)

The volume of a 50nm particle is 1,000 times larger than the 5nm particle.

Intensity PSD ***X 1,000,000***

The ratio of the peak area – 1 : 1,000,000 (5 mn : 50 nm)

Large particles have much more light scattered than small particles.

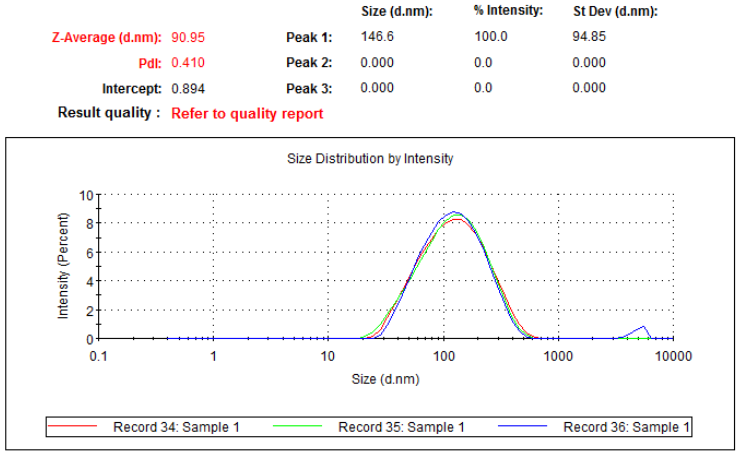
DLS (Dynamics Light Scattering)

PDI (PolyDispersity Index)

PDI	Example	Possible DLS
0 to 0.05	Latex standards or monodisperse particles	
0.05 to 0.08	Nearly monodisperse sample	
0.08 to 0.7	Mid-range polydisperse	
Greater than 0.7	Very polydisperse = Sedimentation	Bad sample

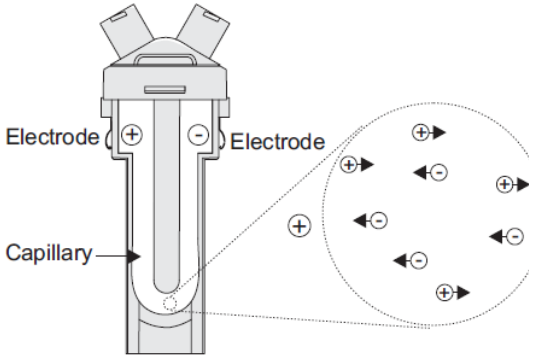
표 2. Definition of Particle Diameter Averages

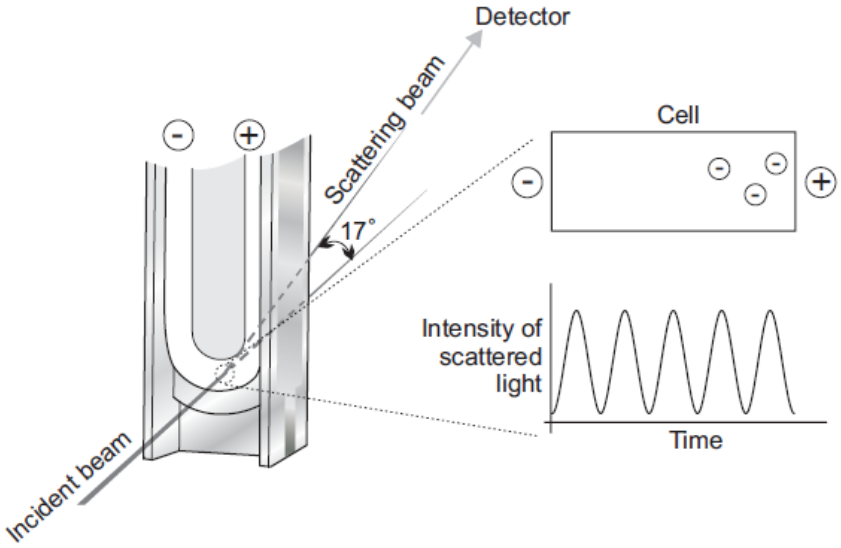
Average Diameter	Symbol	Number Basis	Weight Basis
Number average	D_n	$\frac{\sum n_i D_i}{\sum n_i}$	$\sum\left(\frac{w_i}{D_i^2}\right)/\sum\left(\frac{w_i}{D_i^3}\right)$
Z average	D_z	$\frac{\sum n_i D_i^5}{\sum n_i D_i^4}$	$\frac{\sum w_i D_i^2}{\sum w_i D_i}$



ELS (Electrophoretic Light Scattering)

- **Electrophoretic Light Scattering (ELS)**





Particles move towards the electrode of opposite charge, their velocity is measured and expressed in unit field strength as their mobility.

- **Henry equation**

Dielectric constant : Polar > 20 > Non-polar

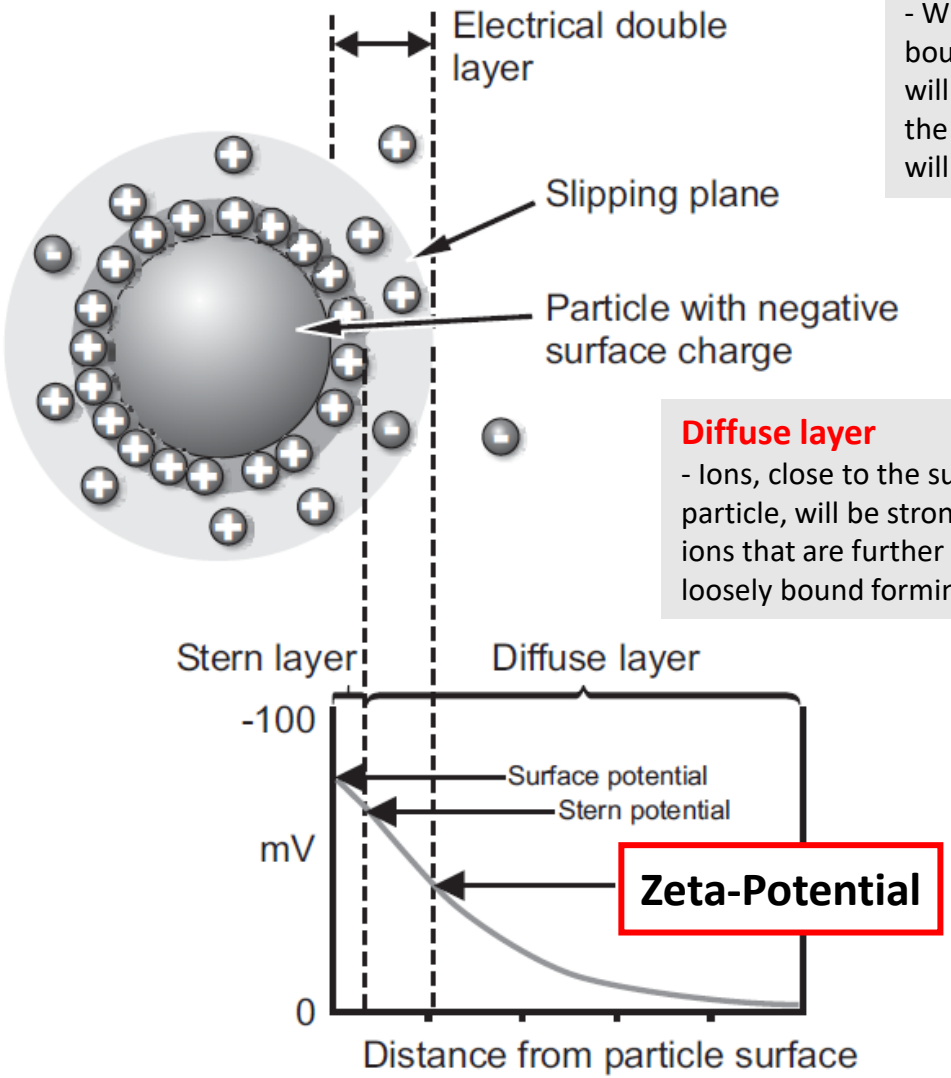
Zeta potential is related to the **electrophoretic mobility** by the Henry equation.

$$U_E = \frac{2\varepsilon z f(ka)}{3\eta}$$

z	=	Zeta potential	→ Calculation value
U_E	=	Electrophoretic mobility	→ Measurement value
ε	=	Dielectric constant	→ Sample by sample
η	=	Viscosity	→ Sample by sample
f(ka)	=	Henry's function (1.5 or 1.0)	→ Polar = 1.5 (Smoluchowski)
1/k	=	Length of electrical double layer	Non-polar = 1.0 (Huckel)
a	=	Particle diameter	

ELS (Electrophoretic Light Scattering)

- **Zeta-Potential on Electrical double layer**



Slipping plane
- Within the diffuse layer there is a notional boundary and any ions within this boundary will move with the particle when it moves in the liquid; but any ions outside the boundary will stay where they are.

Diffuse layer
- Ions, close to the surface of the particle, will be strongly bound while ions that are further away will be loosely bound forming.

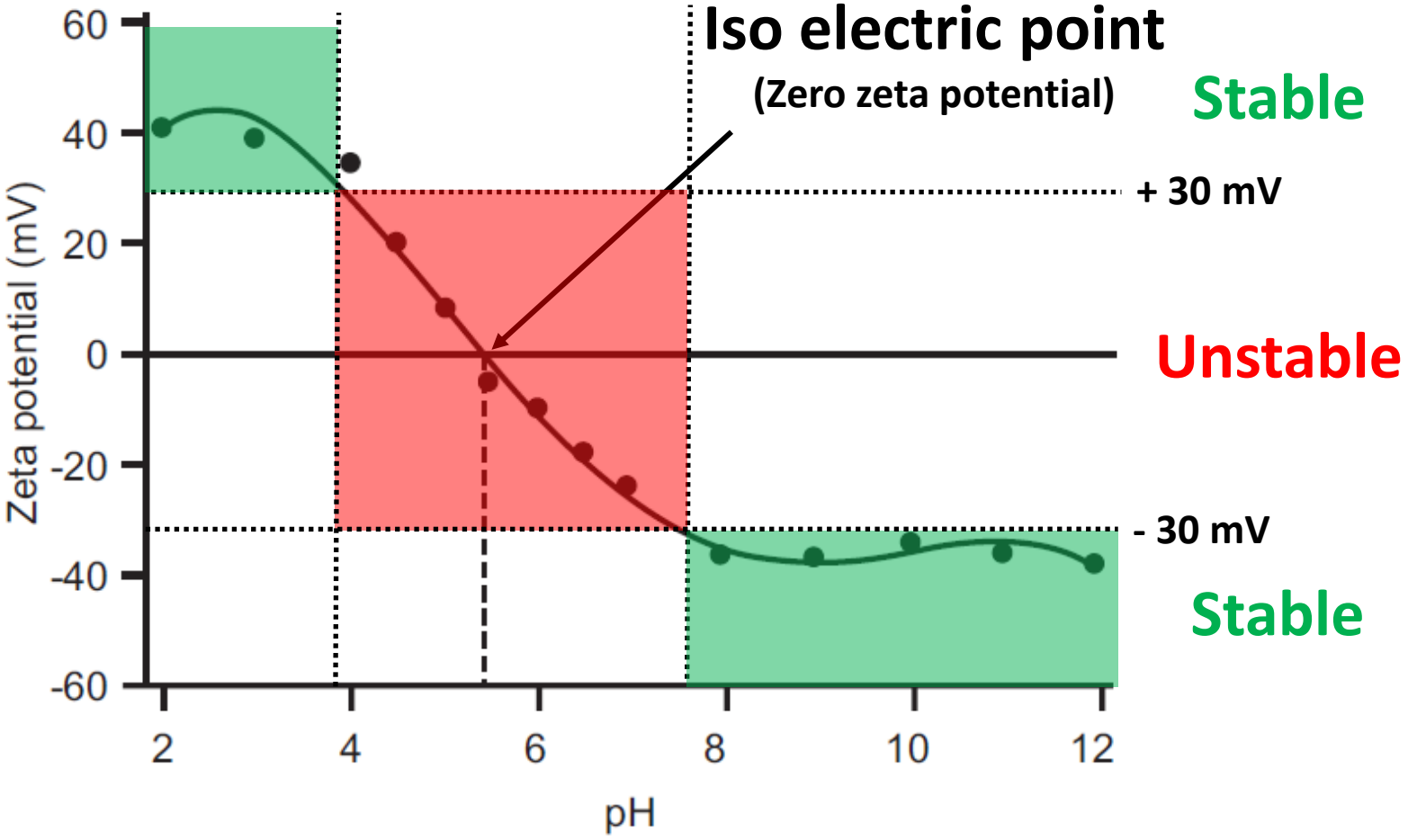
Particles with zeta potentials *more positive than +30mV or more negative than -30mV* are normally considered *stable*.

ELS (Electrophoretic Light Scattering)

- **Zeta Potential = Stability of Colloidal system**

Normally the point where
the colloidal system is least stable.

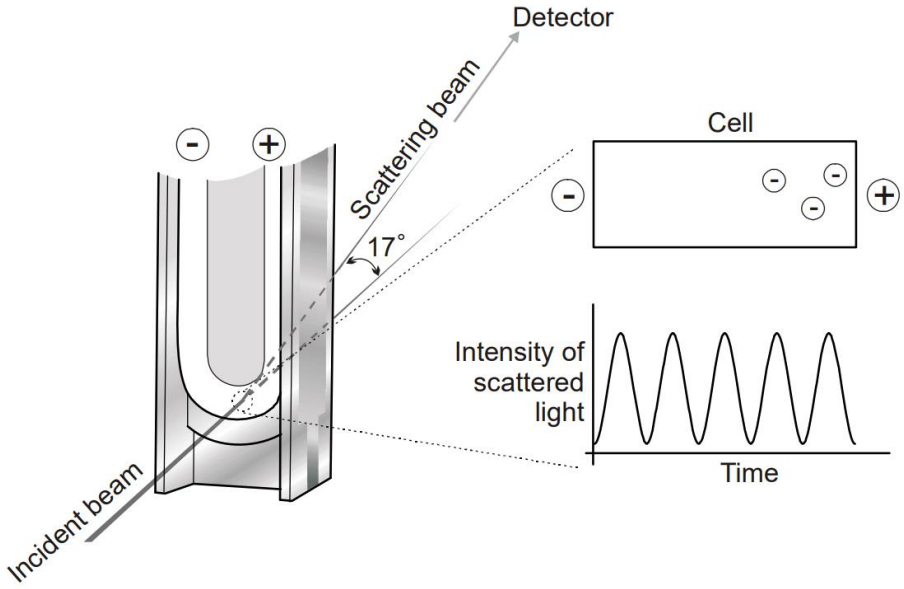
More positive charge ← Add acid

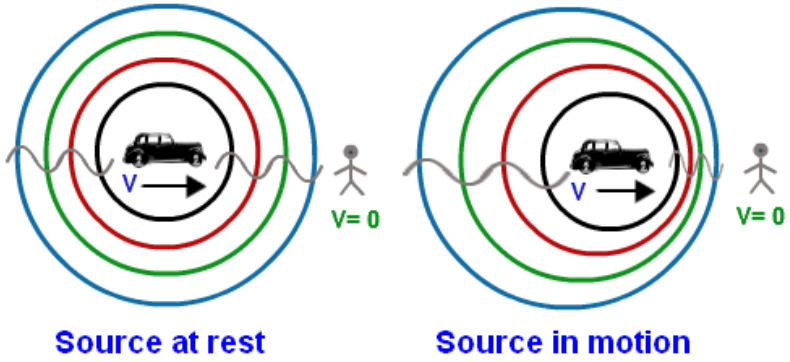


Add alkali → more negative charge

ELS (Electrophoretic Light Scattering)

- **LDV (Laser Doppler Velocity)**





Electrokinetic effects

Electrophoresis

Electroosmosis

Streaming potential

Sedimentation potential

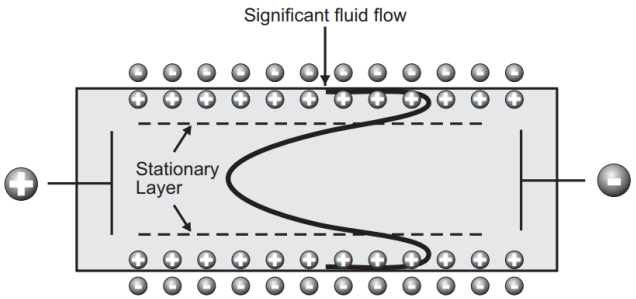
ELS (Electrophoretic Light Scattering)

- **M3**

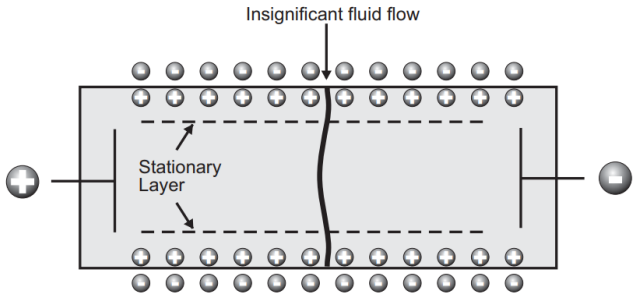
The M3 technique

'Mixed Mode Measurement'

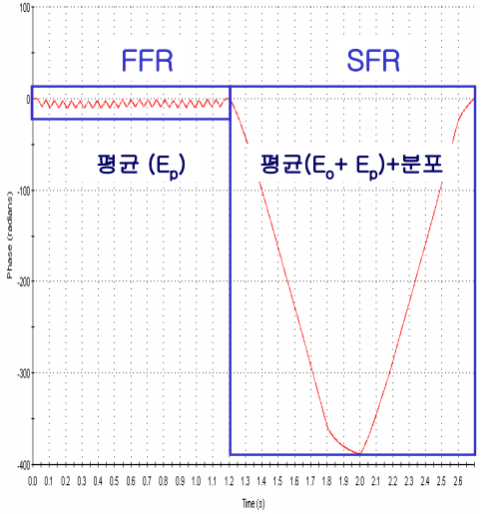
Slow Field Reversal (SFR)



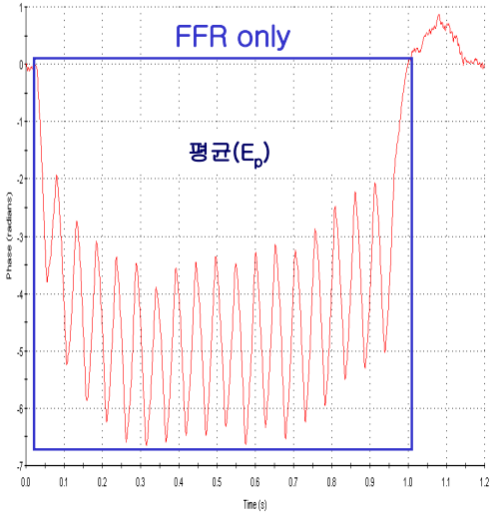
Fast Field Reversal (FFR)



General Purpose



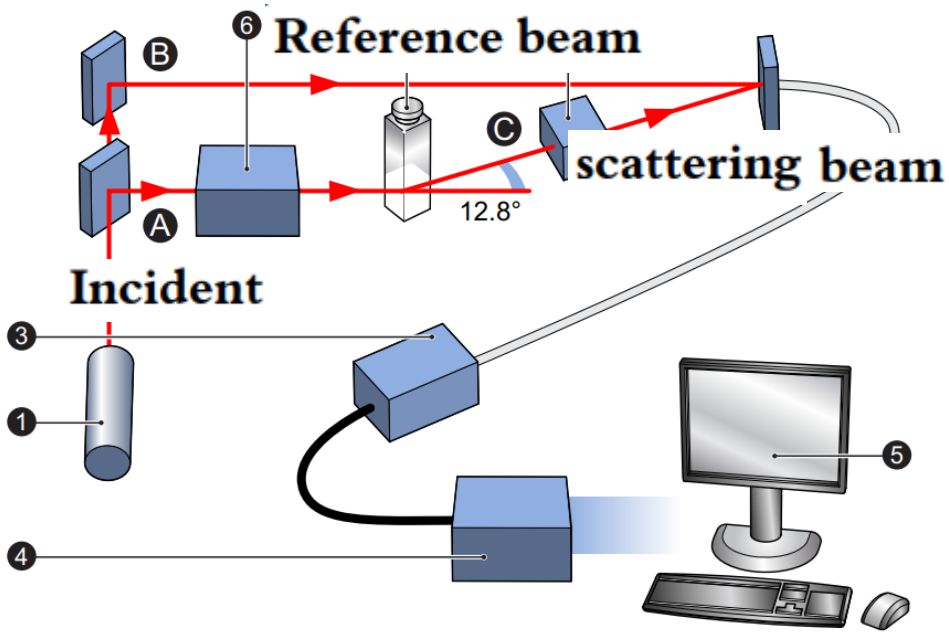
Monomodal

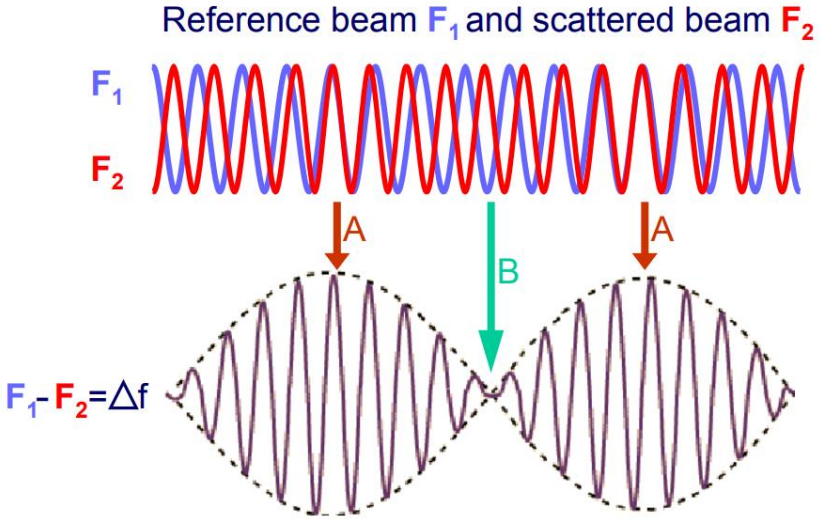


ELS (Electrophoretic Light Scattering)

- **PALS**

PALS (Phase Analysis Light Scattering)





Factors of Zeta potential measurement

1. Effect factors

-> pH

-> Conductivity (Concentration and/or Type of salt)

-> Concentration of an additive (ionic surfactant, polymer)

2. Closed to IEP (Iso Electric Point) -> More unstable

3. Conductivity -> Related to Electrical double layer thickness

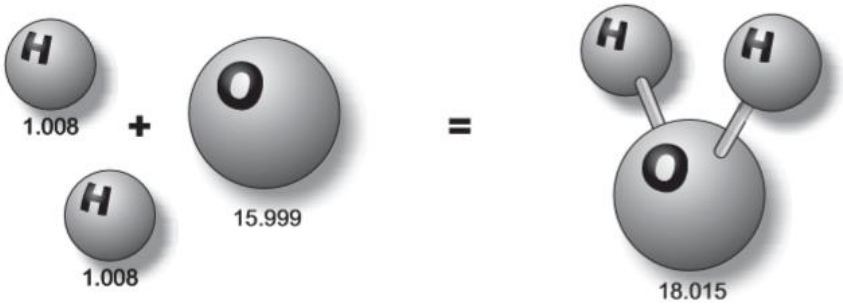
- High ionic strength -> Thin electrical double layer
- Effectivity : $Al^{3+} > Na^{+}$

SLS (Static Light Scattering)

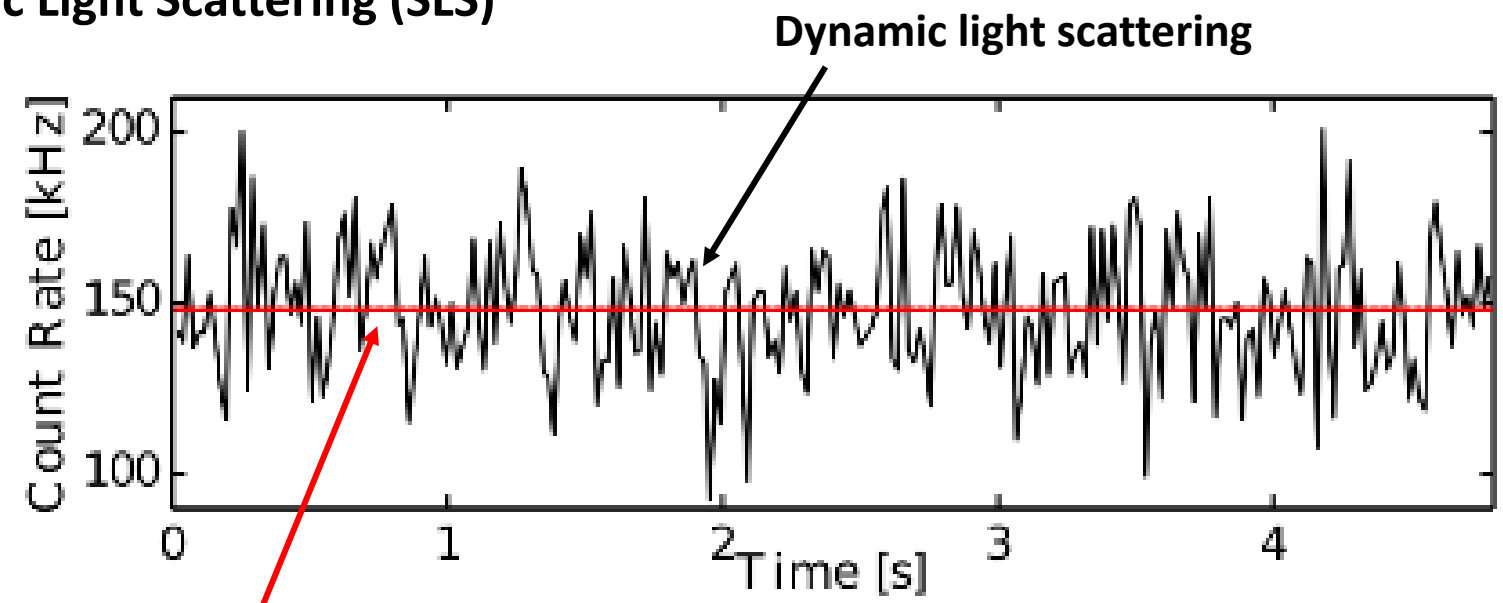
- **Molecular weight**

Atomic mass units (amu)

- Mathematically the molecular weight can be calculated from the molecular formula of the substance.
- **The sum of the atomic weights of all the atoms making up the molecule.**



- **Static Light Scattering (SLS)**



Static light scattering makes use of the **time-averaged intensity** of scattered light instead.

SLS (Static Light Scattering)

- **Static Light Scattering (SLS)**

The molecular weight is determined by measuring the sample at different concentrations and applying the **Rayleigh equation**.

Rayleigh equation : $$\frac{KC}{R_\theta} = \left(\frac{1}{M_W} + 2A_2C\right)P(\theta)$$

R_Θ : The Rayleigh ratio
– the ratio of scattered light to incident light of the sample.
M : **Sample molecular weight**
A_2 : 2nd Virial coefficient
C : Concentration
P_Θ : Angular dependence of the sample scattering intensity.
Please refer to the Rayleigh scattering section.

The Rayleigh ratio
from **a toluene standard**

$$R_\theta = \frac{I_A n_o^2}{I_T n_T^2} R_T$$

I_A : Residual scattering intensity of the analyte (i.e. the sample intensity – solvent intensity).
I_T : Toluene scattering intensity.
n_o : Solvent refractive index.
n_T : Toluene refractive index.
R_T : Rayleigh ratio of toluene.

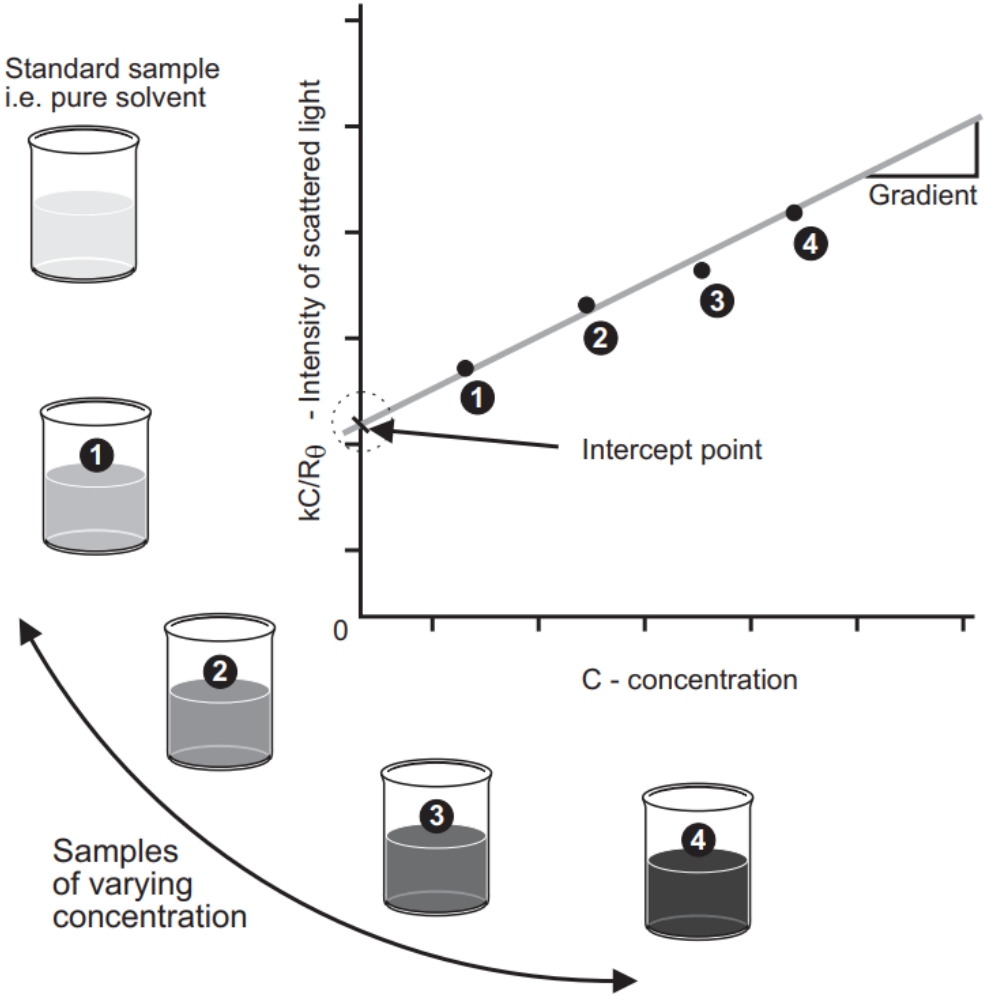
K : Optical constant as defined below.
N_A : Avogadro`s constant
λ_0 : Laser wavelength
n_0 : Solvent refractive index
dn/dc : The differential refractive index increment

$$K = \frac{4\pi^2}{\lambda_o^4 N_A}\left(n_o \frac{dn}{dc}\right)^2$$

SLS (Static Light Scattering)

- **The Debye plot**

▼ **Intensity of scattered light** (**KC/R_Θ**) of various **concentrations** (**C**) of sample at **one** angle;



$$\lim_{\theta \to 0} \frac{Kc}{\Delta R_\theta} = \frac{1}{M_w} + 2A_2c$$

KC / R_Θ = 1 / Mw

Mw is expressed in Daltons (or g/mol)

2nd Virial Coefficient (A_2)

Intercept at zero concentration will be **1/M**

A2 = Gradient

C = Concentration

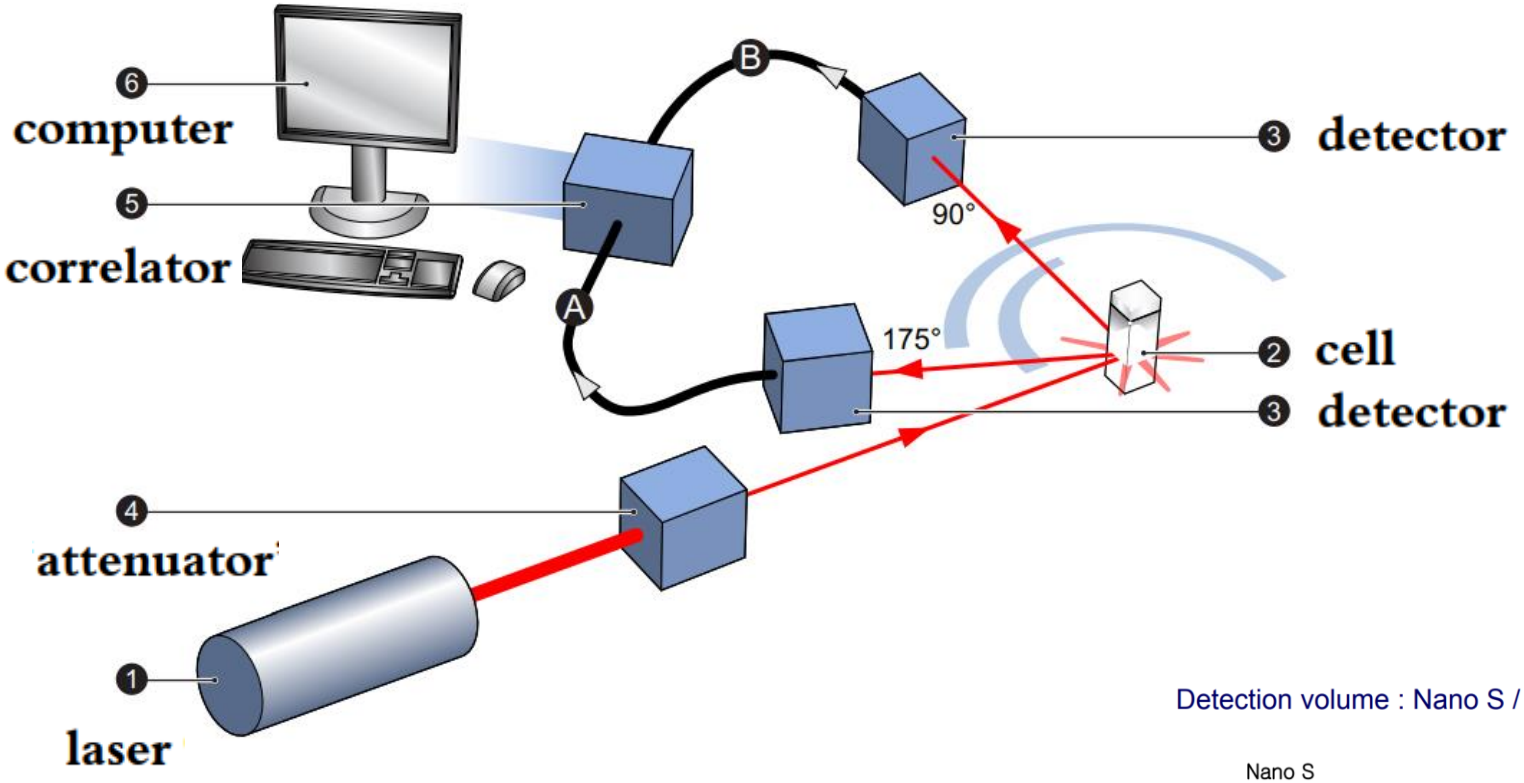
2. Hardware

Zeta-Sizer (Nano ZS)

- **Nano ZS (Malvern)**

Parameter	Specification
Particle size - Concentration range	0.3 nm ~ 10 µm (About 1 µm) *0.1 mg/ml lysozyme to 40 wt/vol%*
Zeta potential - Minimum sample vol.	3.8 nm ~ 100 µm 0.75 ml
Molecular weight range - Minimum sample vol.	342 ~ $2x10^7$ Daltons 12µl
Laser - Attenuation	He-Ne, 4.0mW, **633nm** *Automatic, transmission 100% to 0.0003%*
Condensation control	Purge facility using dry air
Temperature range	2 ~ 90 ℃

Diagram of Zeta sizer



Zetasizer	Optical Arrangement	Detection path (above)
Nano S / ZS	175°	Ⓐ
Nano S90 / ZS90	90°	Ⓑ

Detection volume : Nano S / Nano S90

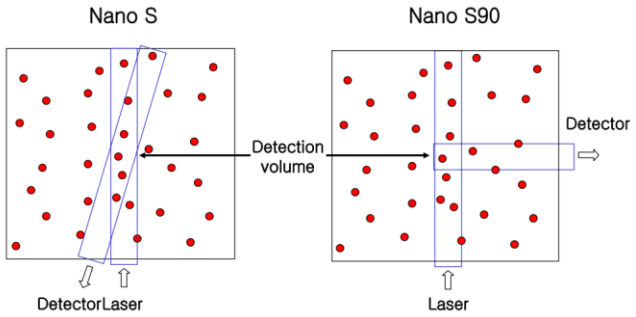
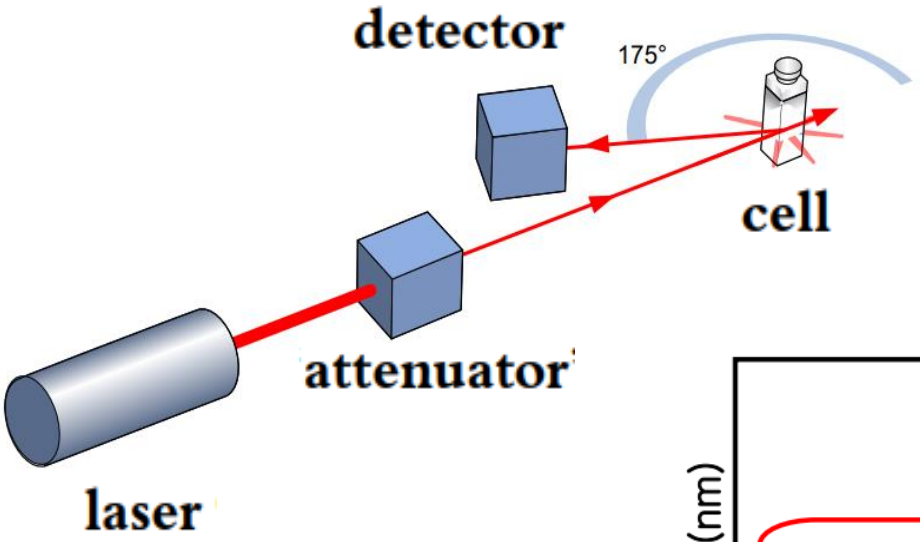
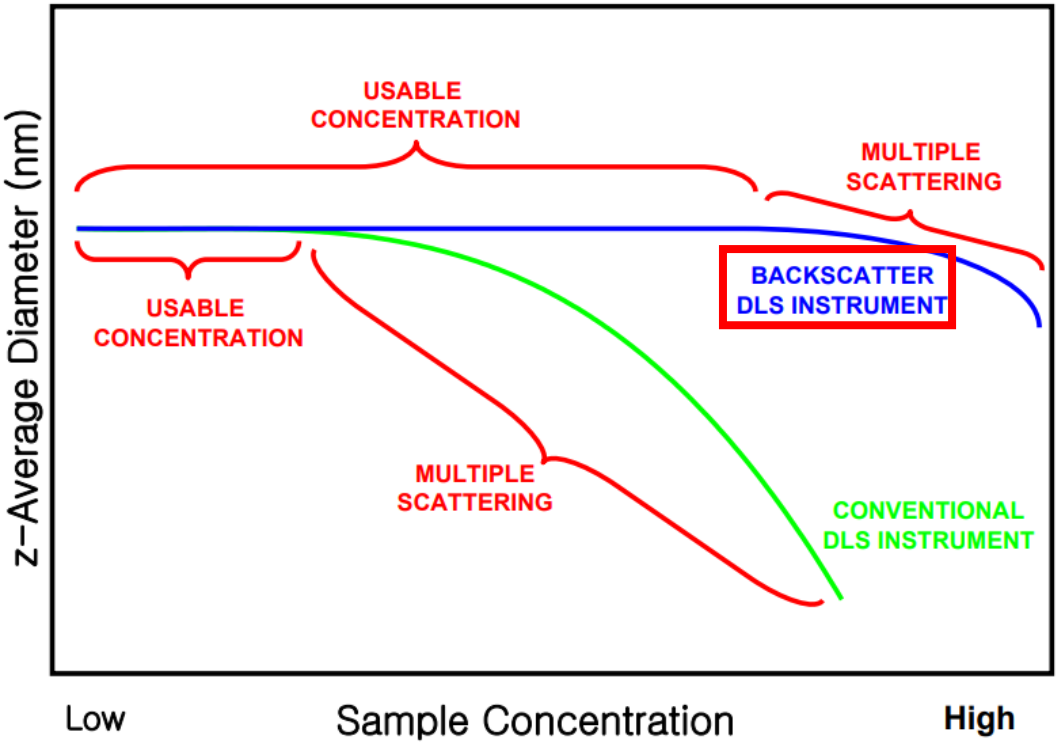


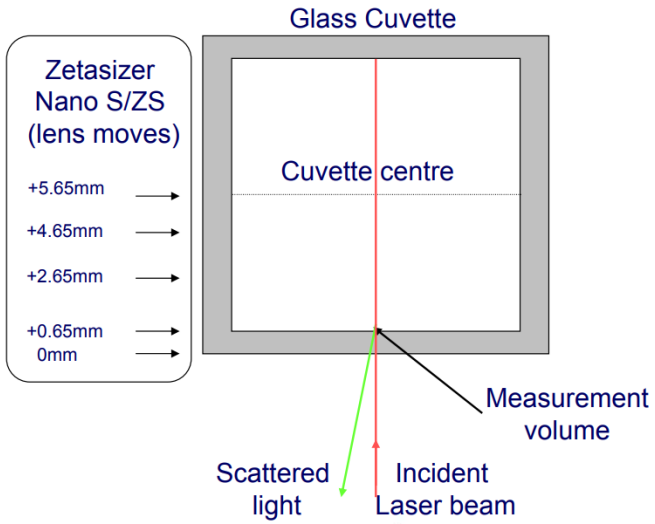
Diagram of Nano ZS





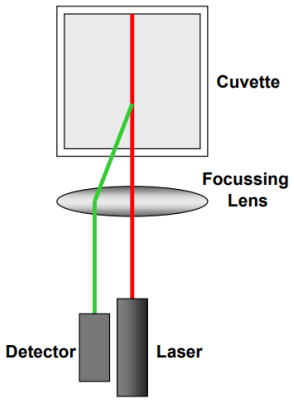
Measurement position

입도 측정 위치(Measurement Position)

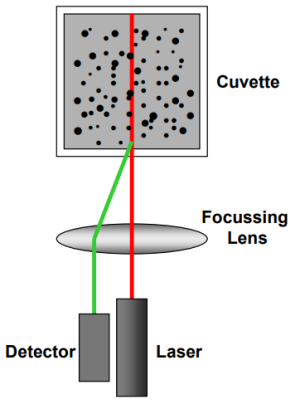


Non Invasive Back Scatter: NIBS

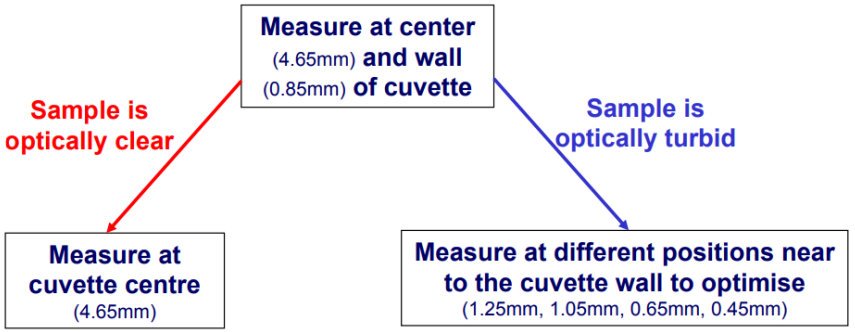
작은 입자 / 희석 시료



고농도



Cell Positioning Factor (CPF)



- CPF : Intercept value, Count rate, Attenuator value
  - 가장 높은 CPF value = 가장 높은 Intercept value
    (Signal to noise ratio)

3. Sample Preparation

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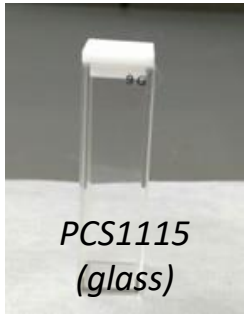
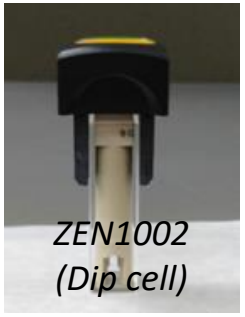
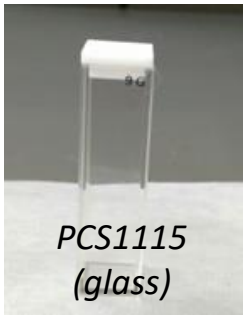
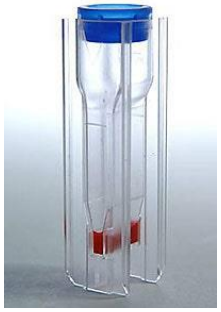
Sample Preparation

- Choosing the correct cell

Particle Size (DLS)	 *DTS1070*	 *DTS0012*	*Water, Water/alcohol*	 *PCS1115 (glass)*	*Water, Organic solvents*
Zeta potential (ELS)	 *ZEN1002 (Dip cell)*	*Water, Organic solvents*	 *DTS1070*	*Water, Water/alcohol*	
Molecular weight (SLS)	 *PCS1115 (glass)*	*Water, Organic solvents*		*Organic solvents*	

Sample Preparation

- DLS (Dynamics Light Scattering)

(1) Particle size

Concentration

Particle size	Min. Concentration (Recommended)	Max. Concentration (Recommended)
< 10nm	0.5mg/ml	Only limited by the sample material interaction, aggregation, gelation, etc
10nm to 100nm	0.1mg/ml	5% mass (assuming a density of 1g/cm^3)
100nm to 1μm	0.01mg/ml (10^{-3} % mass)	1% mass (assuming a density of 1g/cm^3)
> 1μm	0.1mg/ml (10^{-2} % mass)	1% mass (assuming a density of 1g/cm^3)

Filtration

1. Aqueous dispersants = 0.2 μm
2. Non-polar dispersants = 0.02 μm

Using ultrasonic

1. Remove air bubbles
2. Breakup agglomerates
3. ex) 광물시료 (TiO2), Carbon black 등에 적합

Sample Preparation

- ELS (Electrophoretic Light Scattering)

(2) Zeta potential

Many samples will require dilution and this procedure is absolutely critical in determining the final value measured. For meaningful measurements the dilution medium is crucially important. **(lower than 0.5 w/v%)**

Too low concentration = **a low sample count rate**
Too low concentration or bubble in cell = **low sample concentration**

Aqueous/Polar systems (dielectric constant > 20)

Disposable folded capillary cell (DTS1070)

Preserve the existing state of the surface during the process of dilution;
pH, total ionic concentration, concentration of any surfactants or polymers using buffer solution

Non-polar systems (dielectric constant < 20)

Dip cell (ZEN1002)

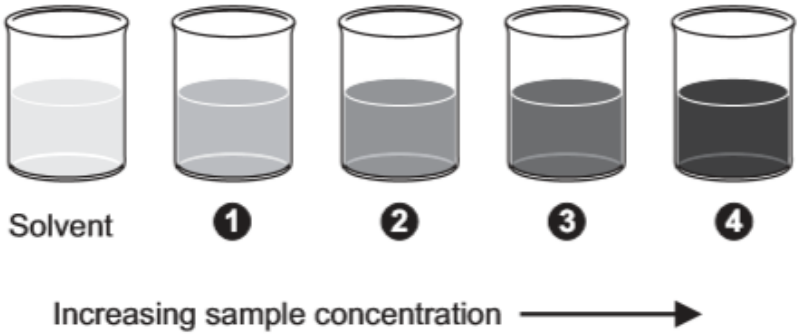
Equilibration of the sample after dilution is the time dependent step, equilibration can take in excess of 24 hours.

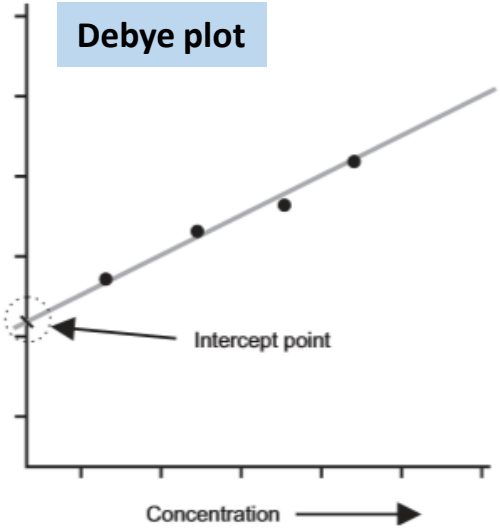
Sample Preparation

- SLS (Static Light Scattering)

  (3) Molecular weight

The technique is very sensitive to dirt or dust in the sample and therefore great care is required in sample preparation.

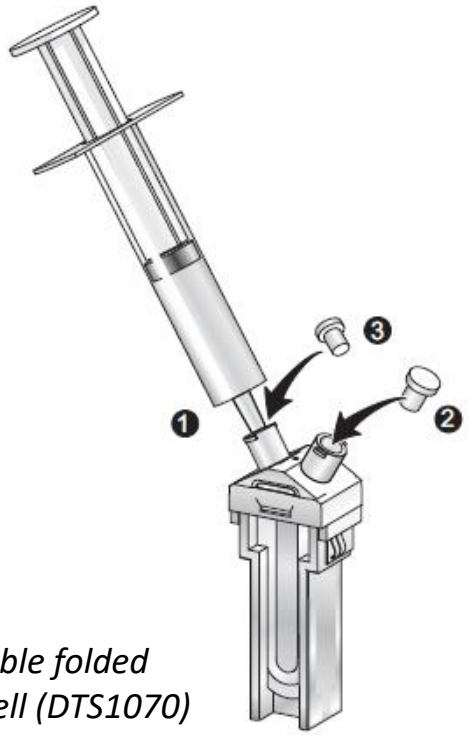




A number of concentrations of the sample must be prepared (**typically 0.25 to 1 g/L**). The polymer must be fully soluble and dust must be excluded.

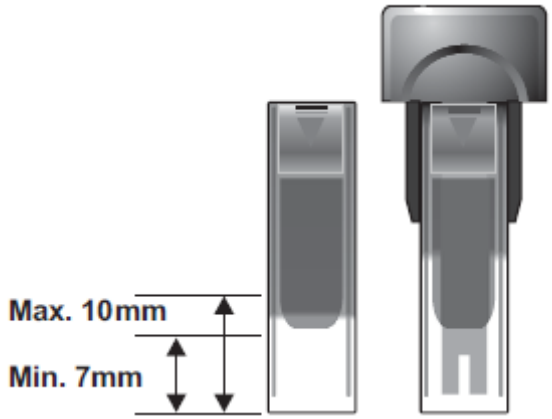
Sample Preparation

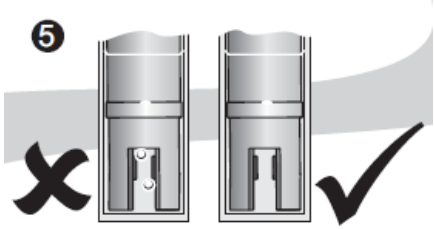
- Filling the cell



Disposable folded capillary cell (DTS1070)

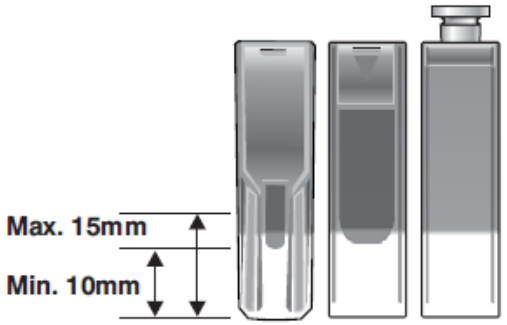
Zeta-potential





ZEN1002 (Dip cell)

Size and Molecular weight



DTS0012 (Polystyrene)

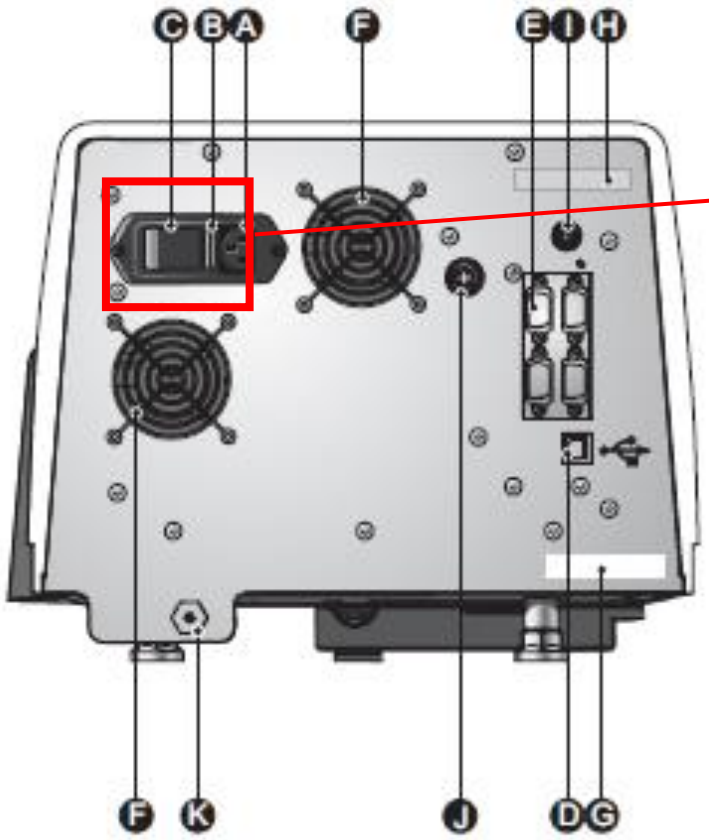
PCS1115 (glass)

4. Operation

- DLS and ELS
- SLS

Operation

1. Switch on (warm up for at least **10 min** / **recommend 30 min**)

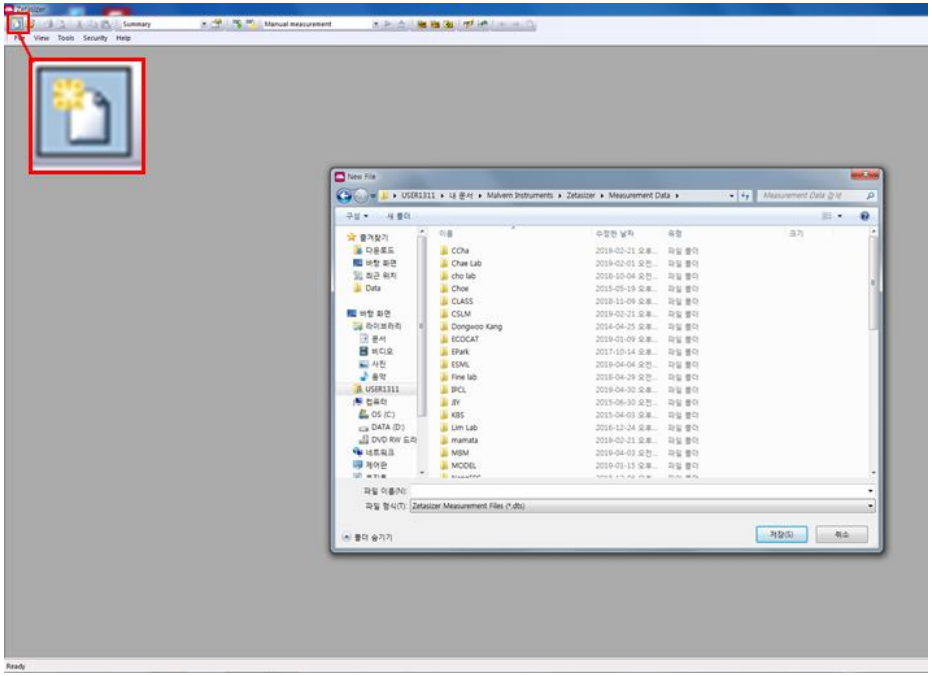


2. click ‘Zeta sizer Software’

Operation

- Size and Zeta-potential

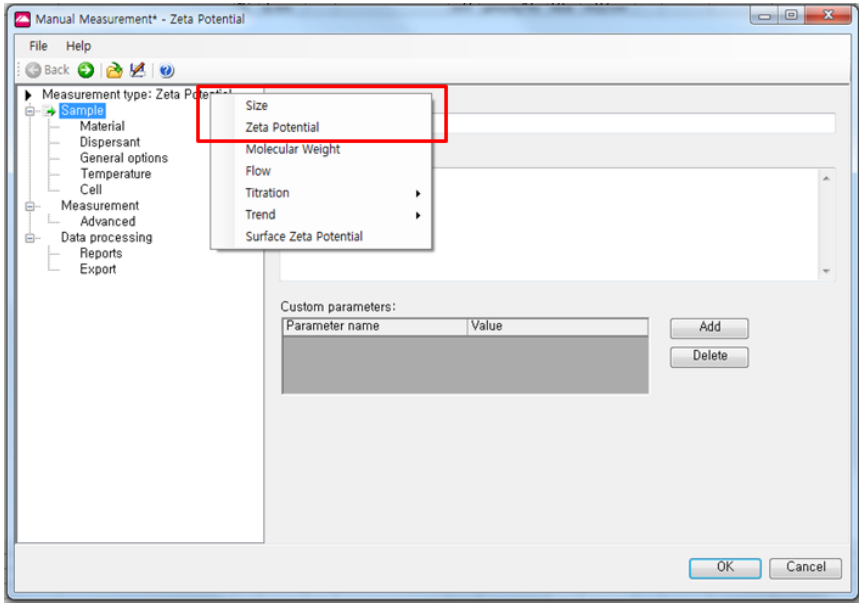
3. Click '**NEW**' icon – set the file to save (Workspace setting – size or zeta)



4. [**Measure**] - [**Manual**]

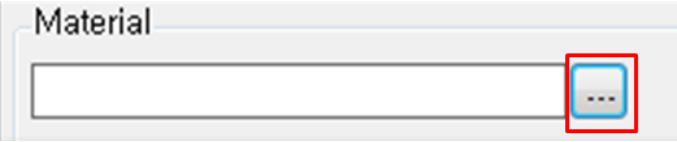
5. Select '**Measurement Type**'
   - Size, Zeta potential or Molecular weight

   Write '**Sample name**'

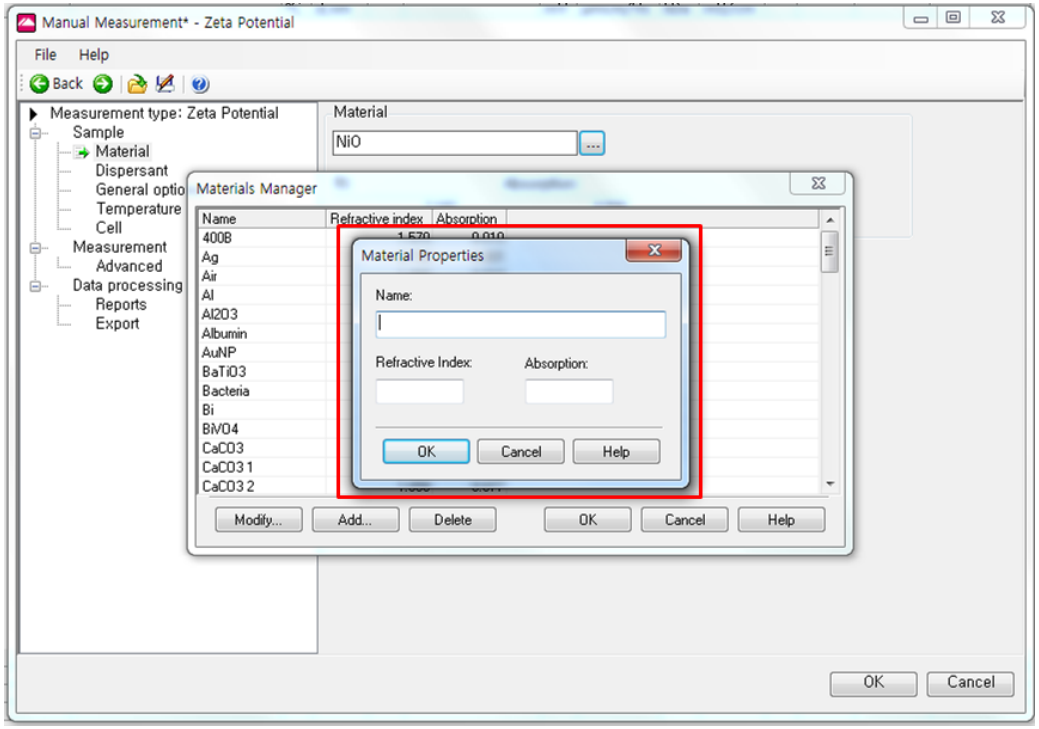


- Size and Zeta-potential

6. Select '**Material**' (solute)



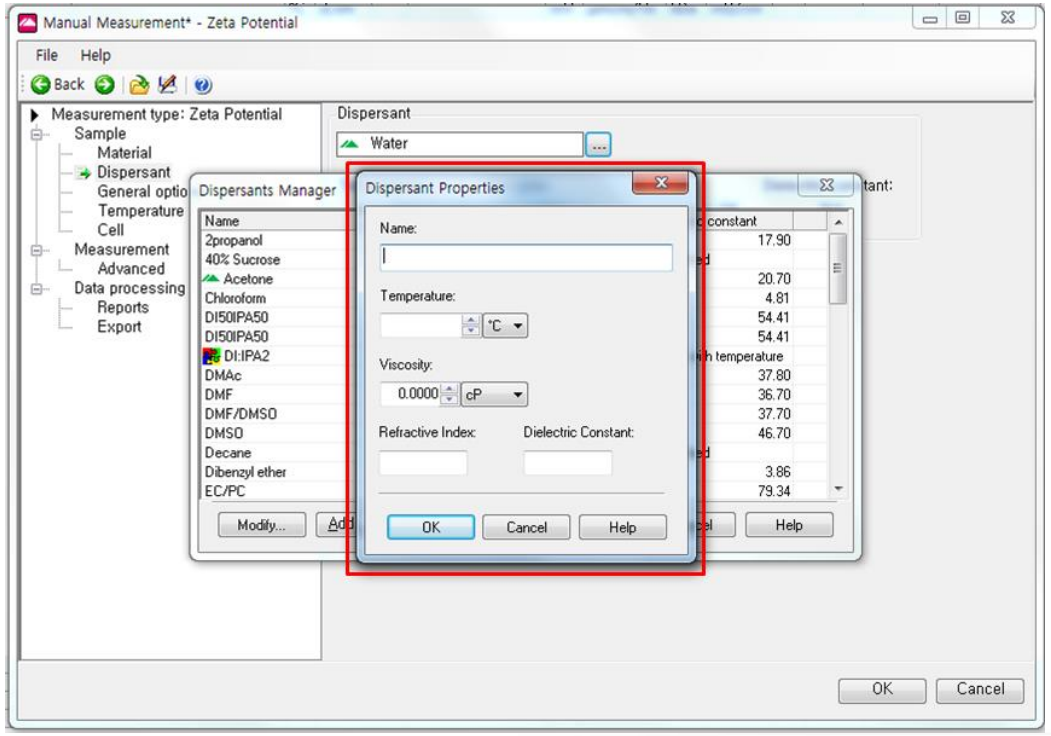
▶ If the material that you want to measure is not in the library, click 'Add' and save 'Material Properties' such as Refractive Index, Absorption.
▶ If you don't know Refractive index of your sample, you can calculate this parameter.



- Size and Zeta-potential

7. '**Dispersant**' - choose solvent
If solvent in your sample is not in the library,
click 'Add' and save 'Dispersant Properties'
such as Viscosity (at 25 °C), Refractive Index, Dielectric Constant.
Viscosity is very important factor.

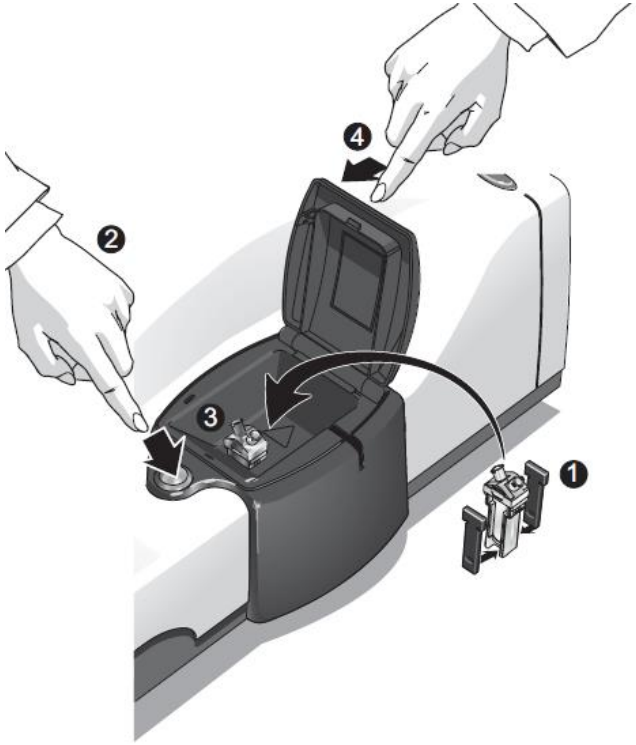
8. '**Cell**' - Choose the type of cell to use.



Operation

- Size and Zeta-potential

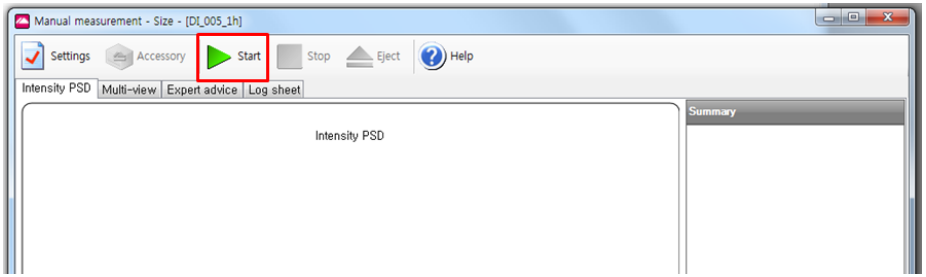
9. Push the **button** and **load your sample**.



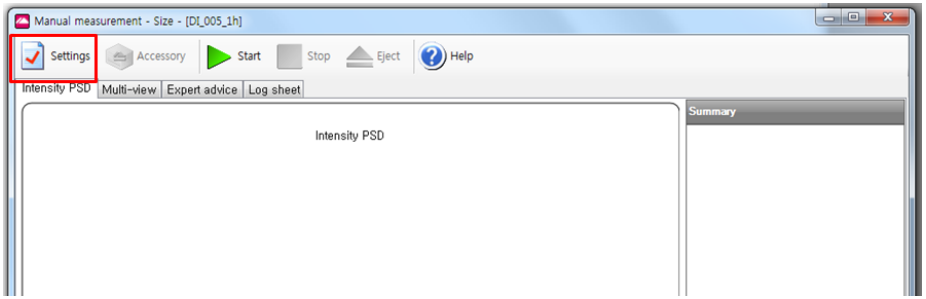
Operation

- Size and Zeta-potential

10. Click ‘**Start**’



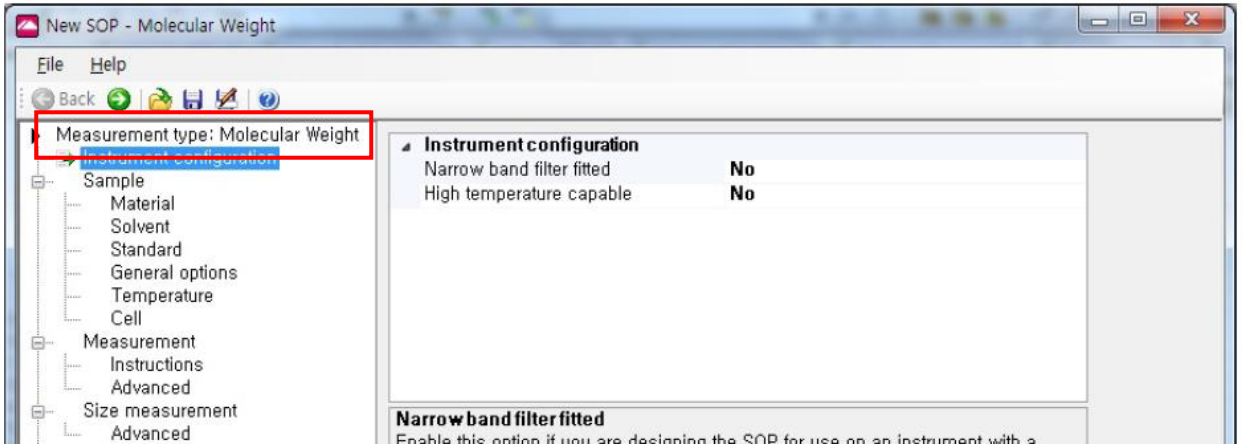
11. Load the next sample and click ‘**Settings**’



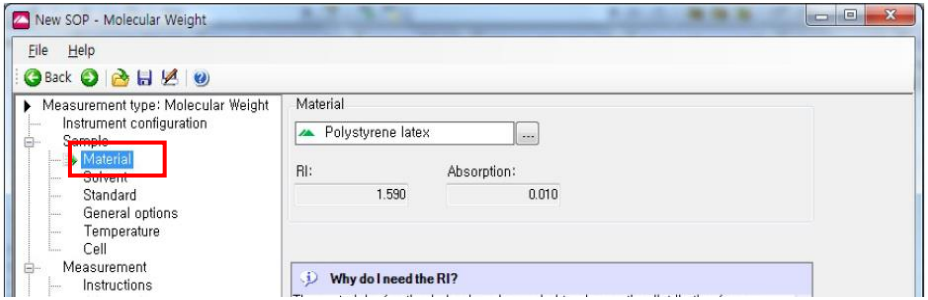
12. Put parameters of the next sample and click ‘OK’
13. When measurement is finished, Just close the program.
(Data is saved automatically when each samples are measured.)
14. Data transfer using Filezilla.
    Download ‘Zetasizer Software’(at coreFTP) on your PC.
15. Turn off the machine and log off True Café.

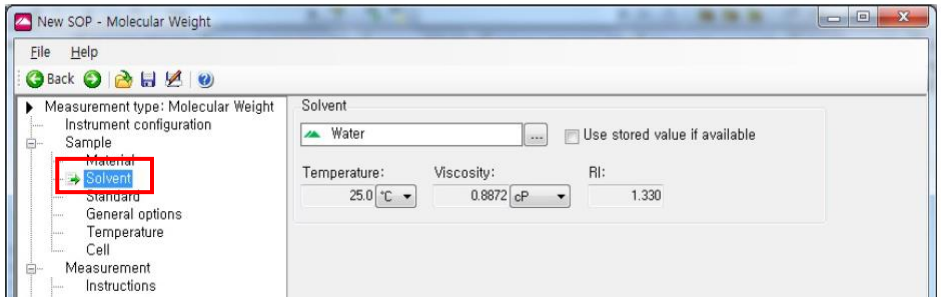
- Molecular weight

1. Select '**Measurement Type**'
   -> Molecular weight



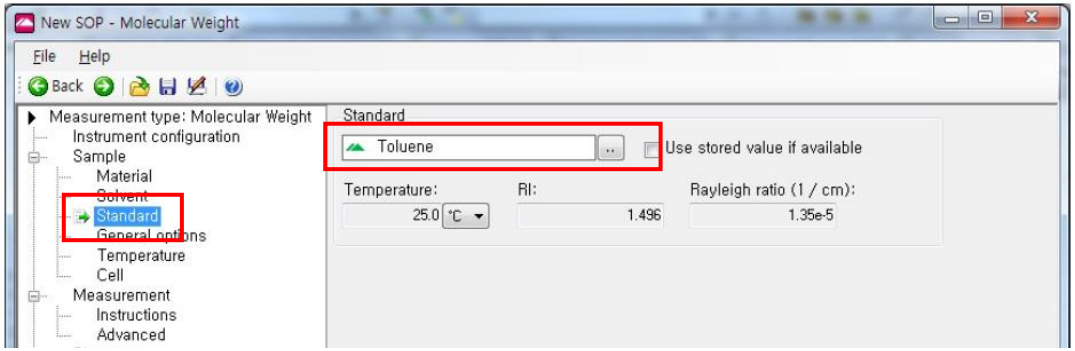
2. Select '**Material**' (solute) and '**Dispersant**' (solvent)
   as in Size and Zeta potential



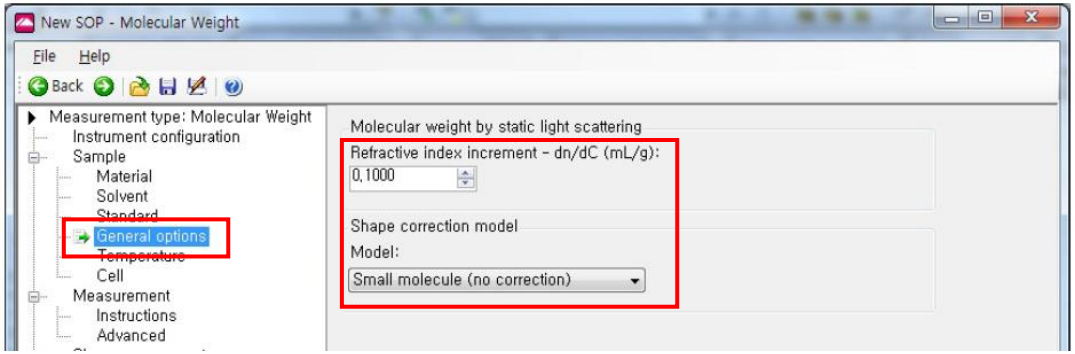


- Molecular weight

3. '**Standard**' – 'Toluene'



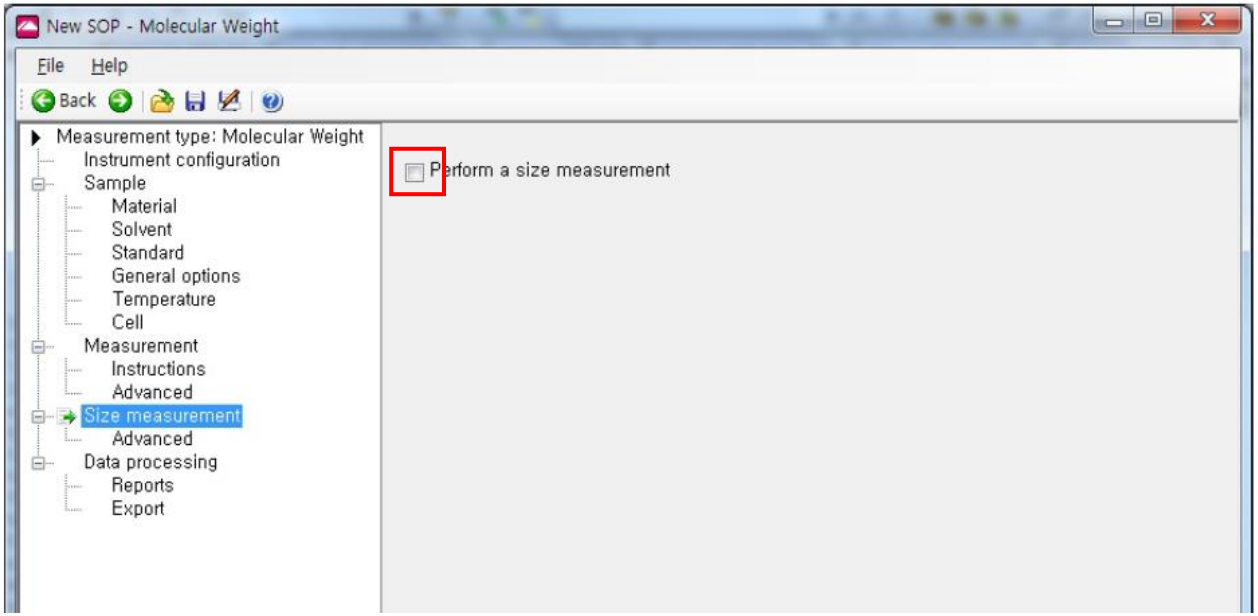
4. 'General options' – Enter '**dn/dC**' of your sample and select 'Shape correction model' (normally 'small molecule')



- Molecular weight

5. '**Cell**' - Choose the type of cell to use. (Glass)

6. If you want to measure size of your sample, Select '**Size measurement**'.



7. '**Data processing**' – 'General purpose'

Operation

- Molecular weight

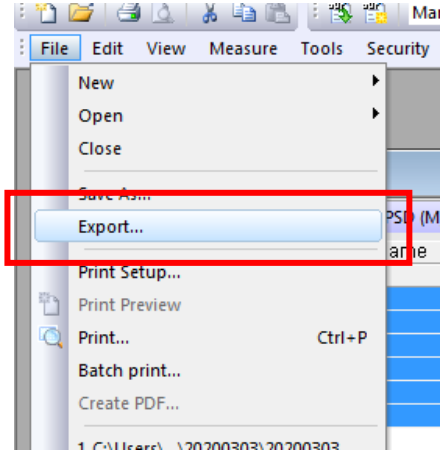
7. Measure dark scattering **nothing on cell holder**.

8. Measure ‘Toluene’ – **Standard**

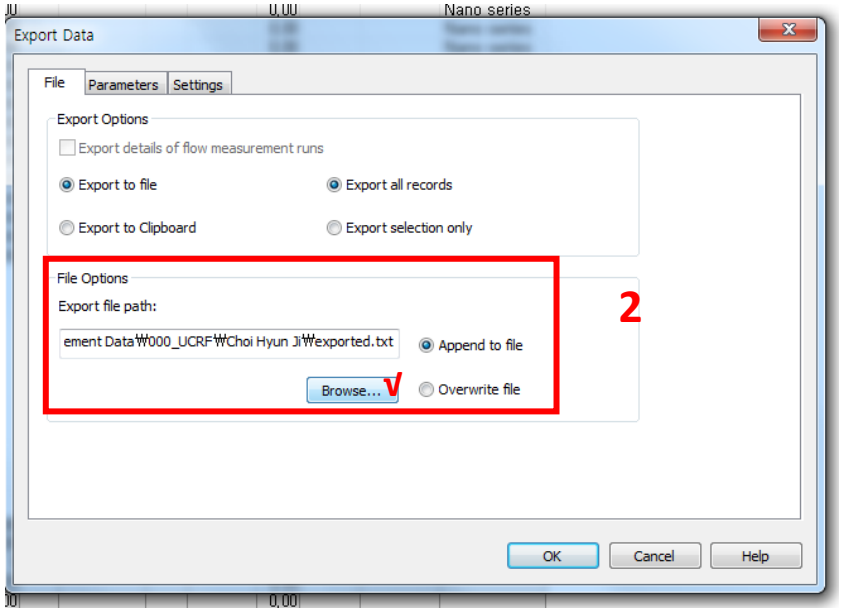
9. Measure ‘Solvent’

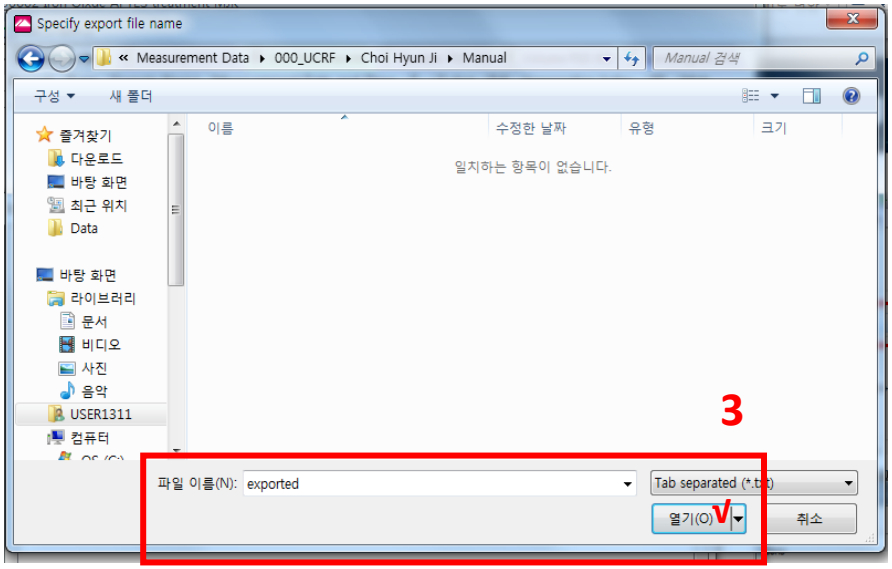
10. Measure ‘Samples’ in order from the low concentration.
(**Prepare three or more concentrations**.)

Export raw data

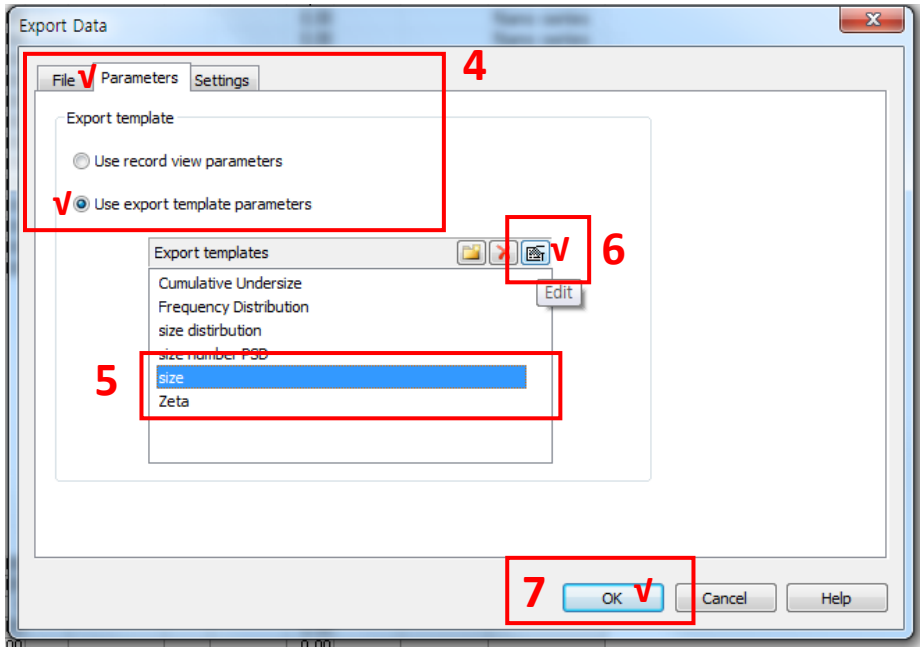


1. [File] – [Export]
2. [File Options] – [Browse..]
3. Find your folder and Do not change the file name.
   - Click [Open '열기']

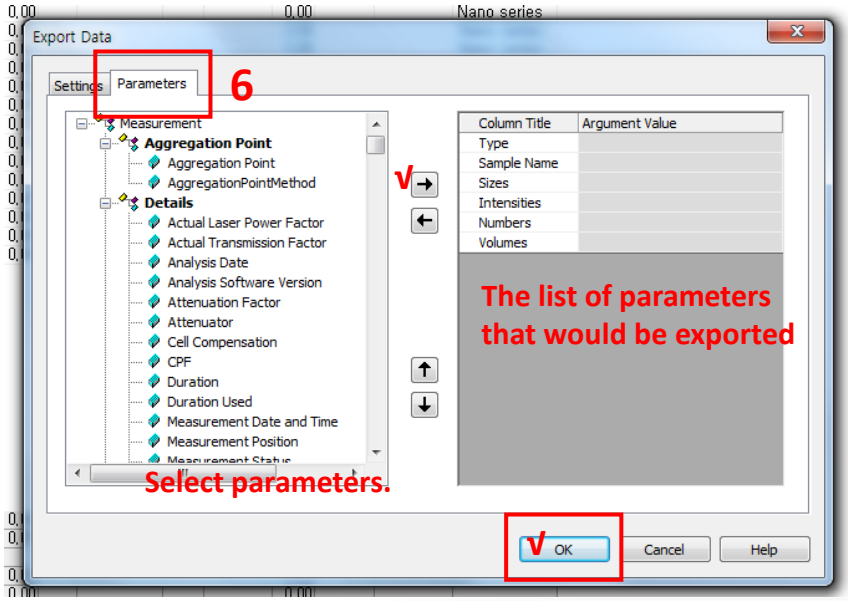




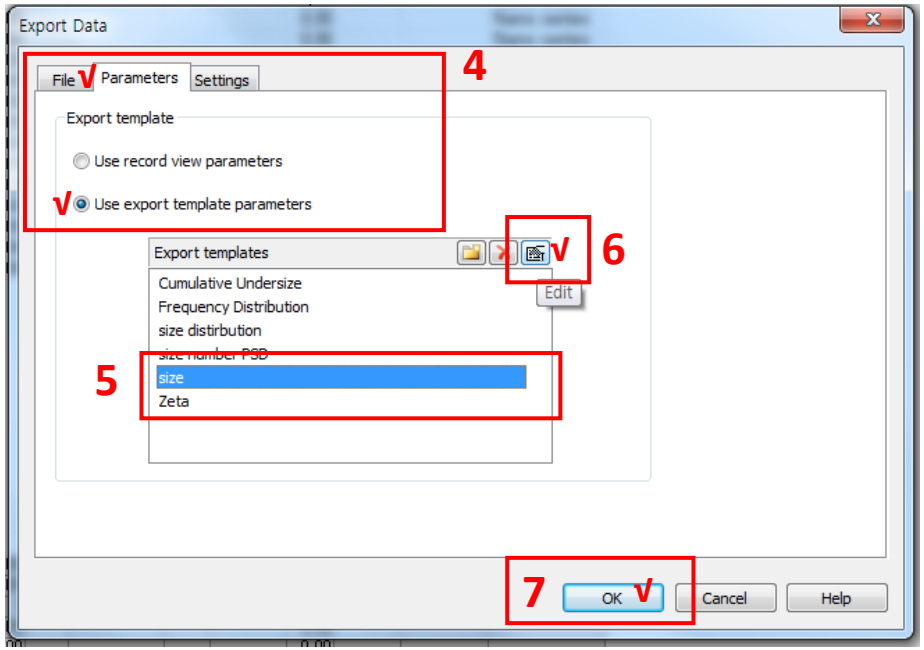
Export raw data



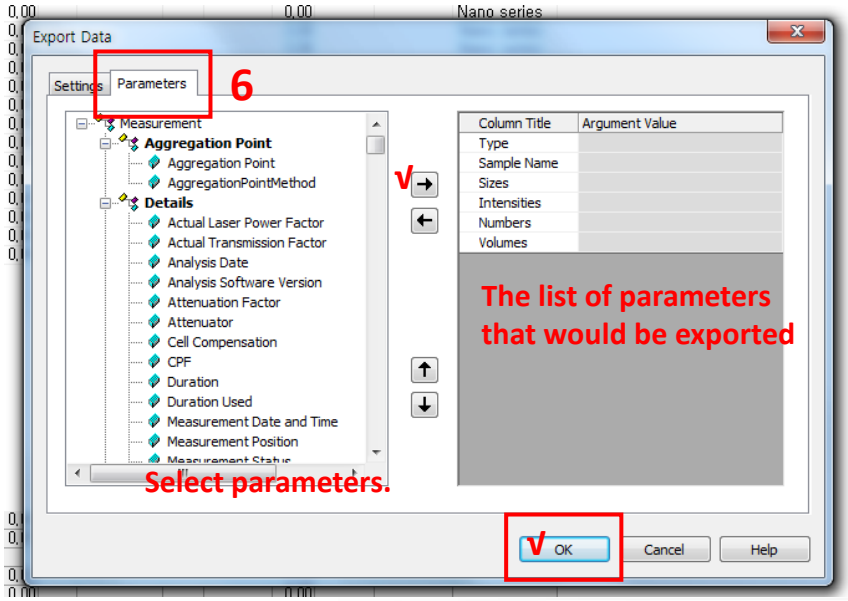
4. [Parameters] tab
   – select ‘Use export template parameters’
5. Select templates that you want to export data, sizes or zeta (zeta-potentials).
6. Click ‘Edit’ to select parameters. – [OK]
7. Click [OK]
8. Raw data is exported in ‘.txt’ form.



Export raw data



4. [Parameters] tab
   – select ‘Use export template parameters’
5. Select templates that you want to export data, sizes or zeta (zeta-potentials).
6. Click ‘Edit’ to select parameters. – [OK]
7. Click [OK]
8. Raw data is exported in ‘.txt’ form.

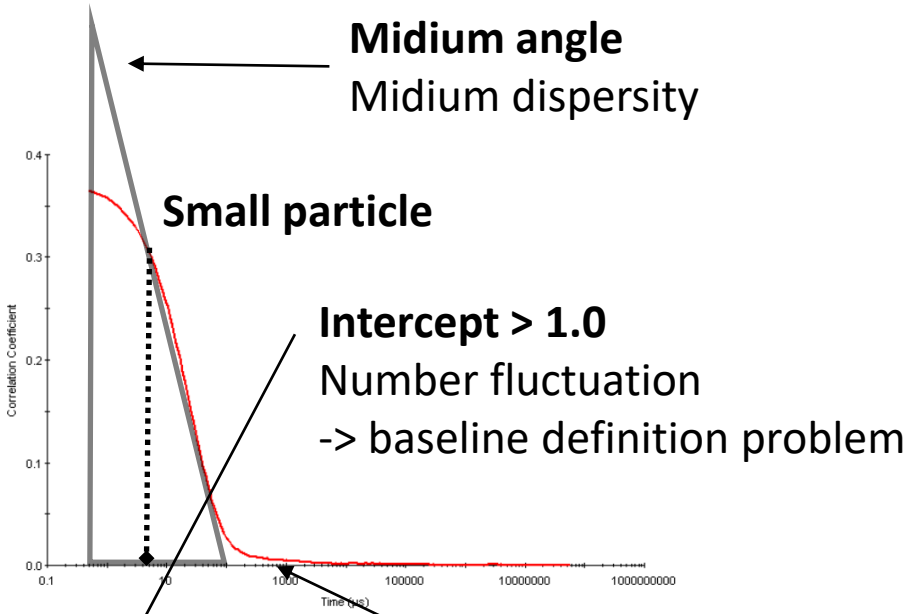


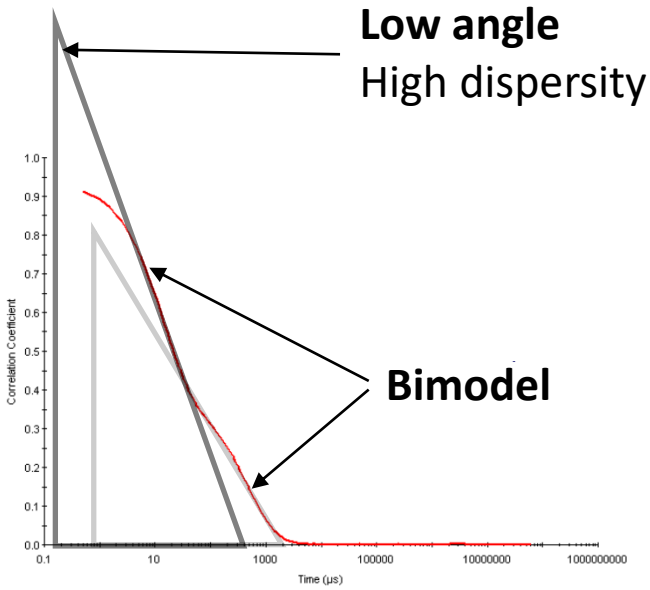
Data interpretation

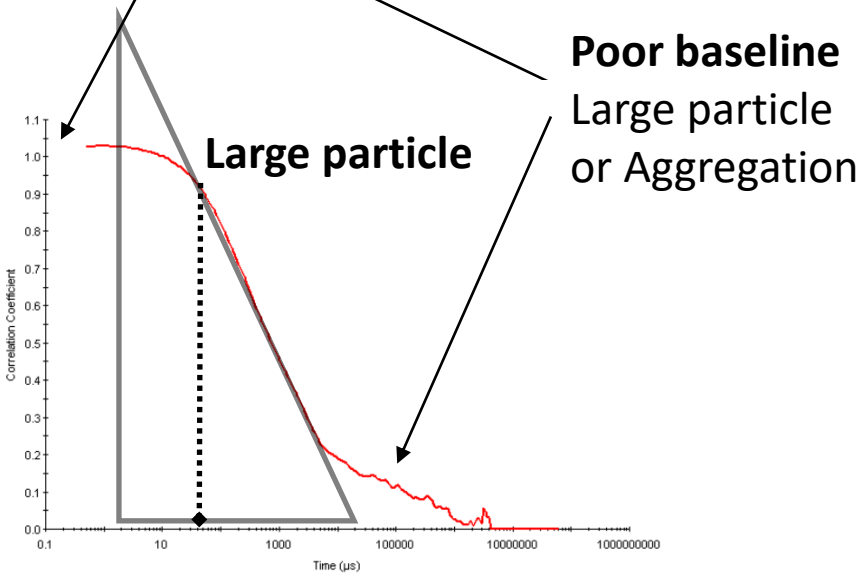
Measurement duration
(Measurement time)

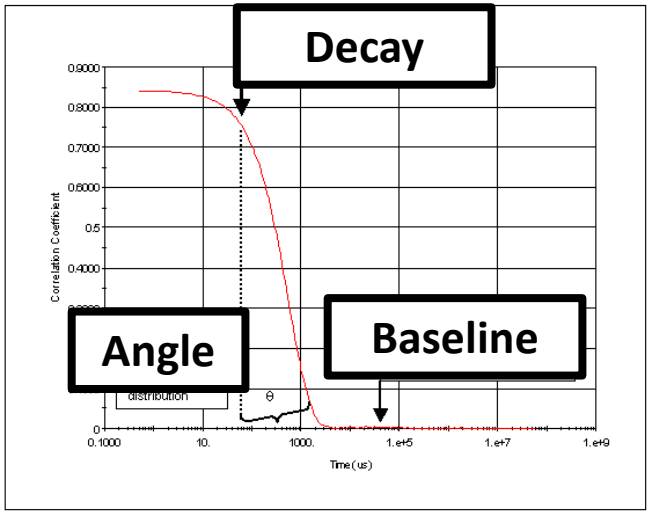
High count rate
= Long measurement time
= Unstable sample

Data interpretation





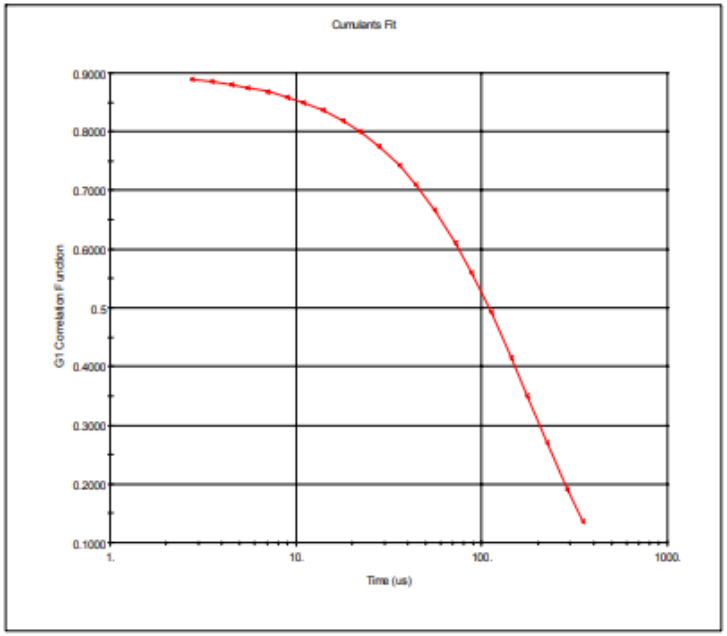




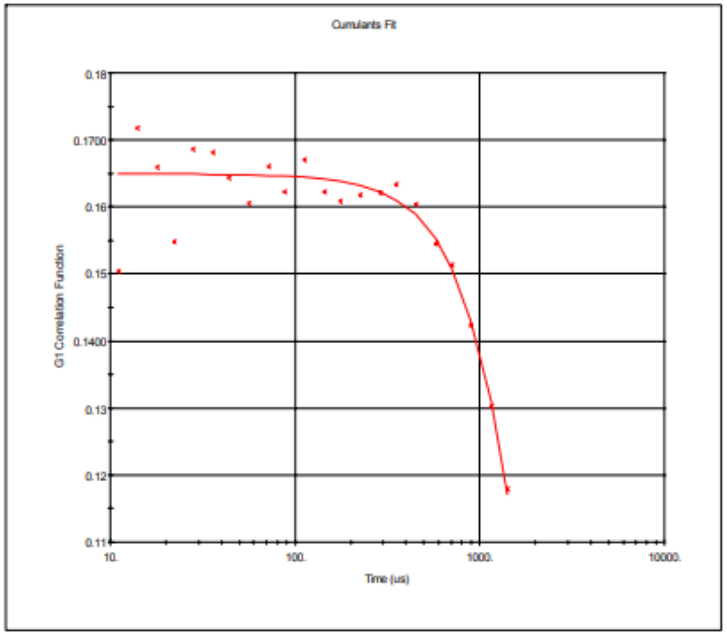
Cumulants / Distribution Fit

- Cumulants Fit : z-average diameter, PDI
- Distribution Fit : size distribution
- Fit errors : 0.005 이하

Good Fit errors : 0.00037



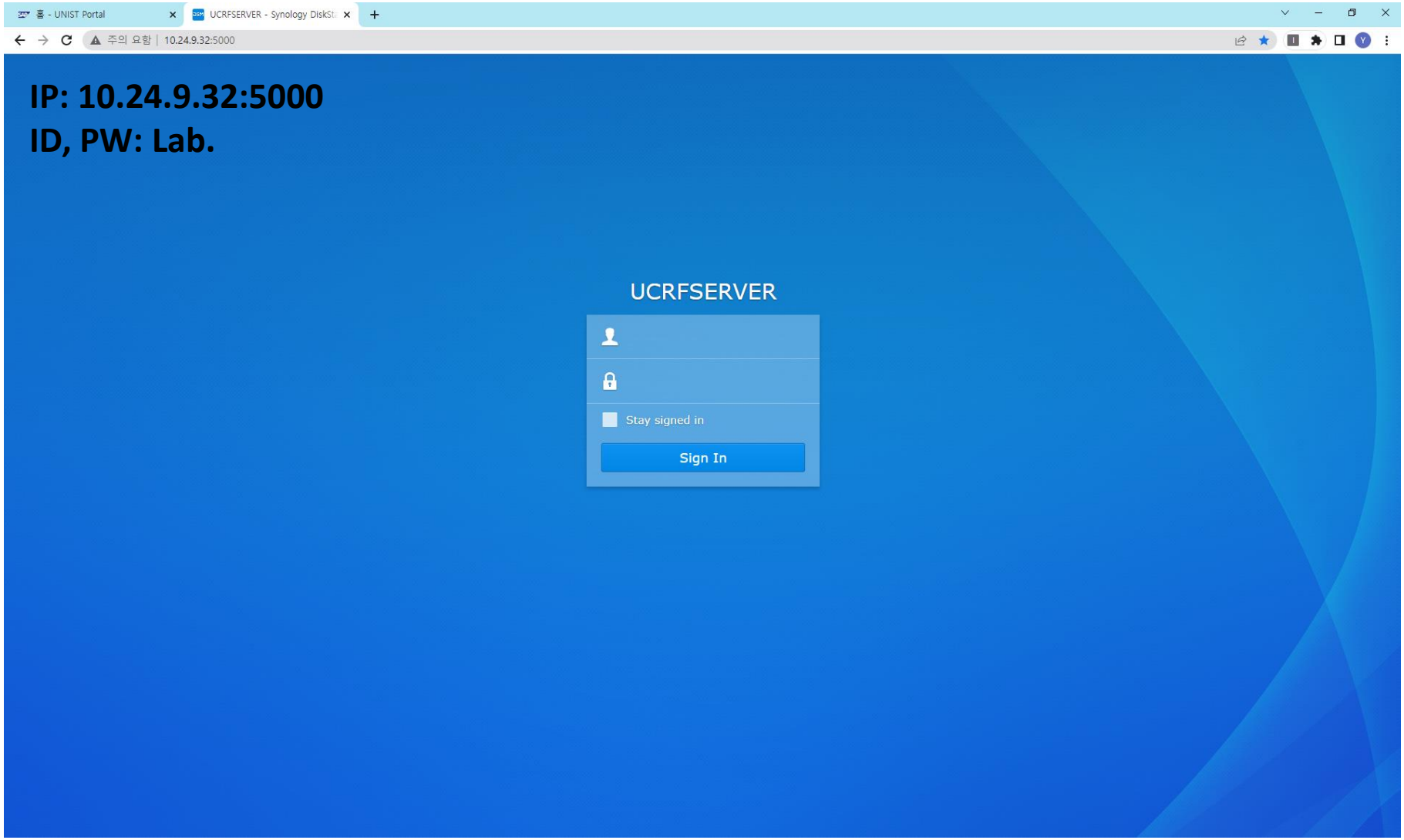
Bad Fit errors : 0.008



Size Quality Report

- 입도측정결과의 평가 : Result quality
- Good : “Result Meets Quality Criteria”
- Refer to quality report : 12 가지 가능한 원인
  - z-average is smaller than lower size analysis limit
  - z-average is larger than upper size analysis limit
  - Polydispersity index is very high
  - Cumulant fit error high
  - etc

NAS Server


홈 - UNIST Portal
UCRFSERVER - Synology DiskSt
주의 요함 | 10.24.9.32:5000
IP: 10.24.9.32:5000
ID, PW: Lab.
UCRFSERVER
Stay signed in
Sign In

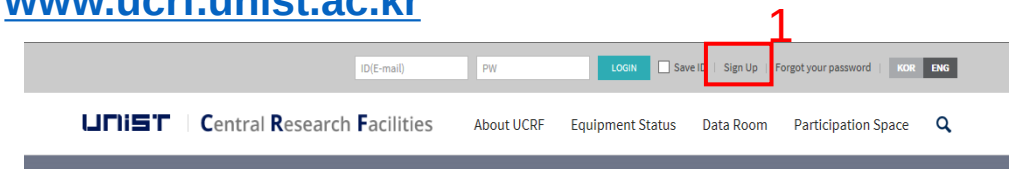
5. FAQ

- Reservation control information
- Request for self user
- Reservation, cancel and input result
- Guideline for the Operation of the UCRF
- Penalty Points and Sanction Criteria

ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY

Create Account

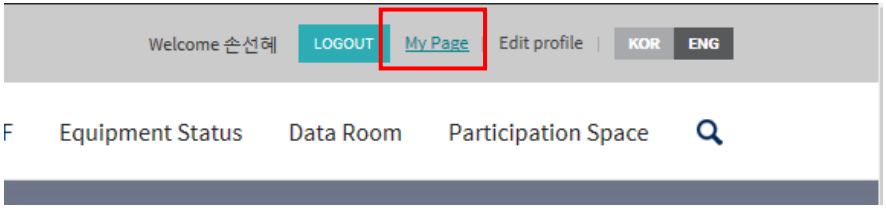
www.ucrf.unist.ac.kr

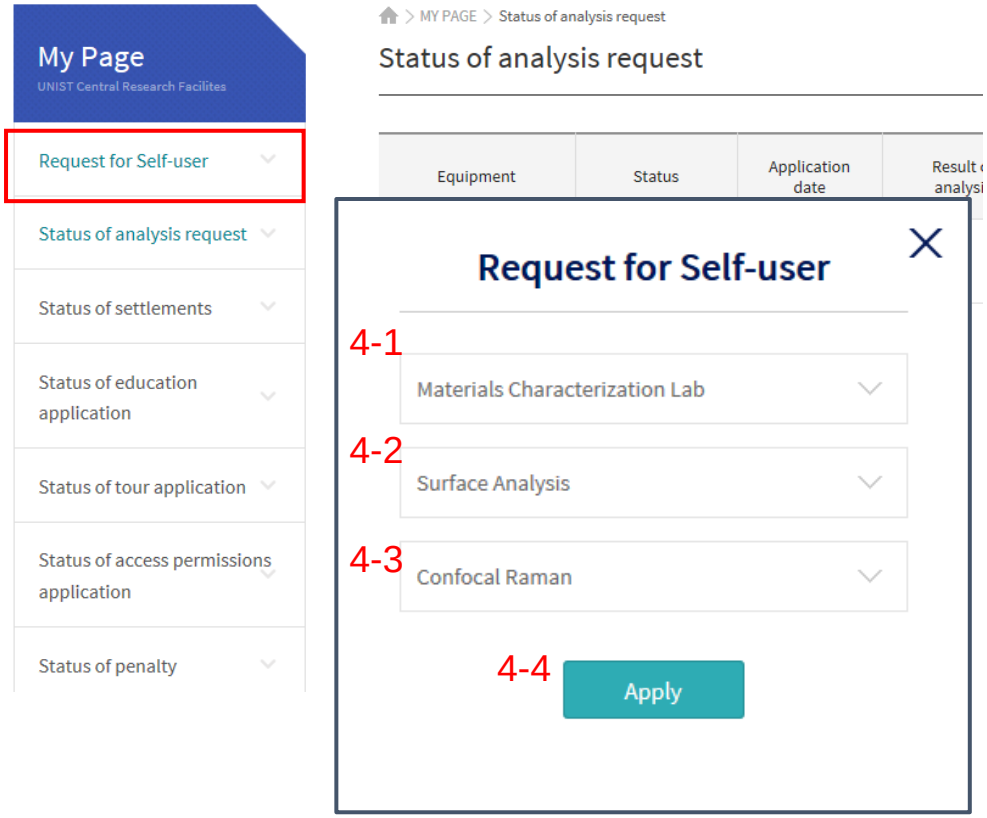


1. Click [Sign up].
2. Click [UNIST Member].
3. Input [Portal id/pw]_Click [Confirm].
   Please check your information.
4. Input professor name in [Principal investigation]
   _Click [Professor search]_Click professor name.
5. Click [Create Account].

Request for Self-user

www.ucrf.unist.ac.kr



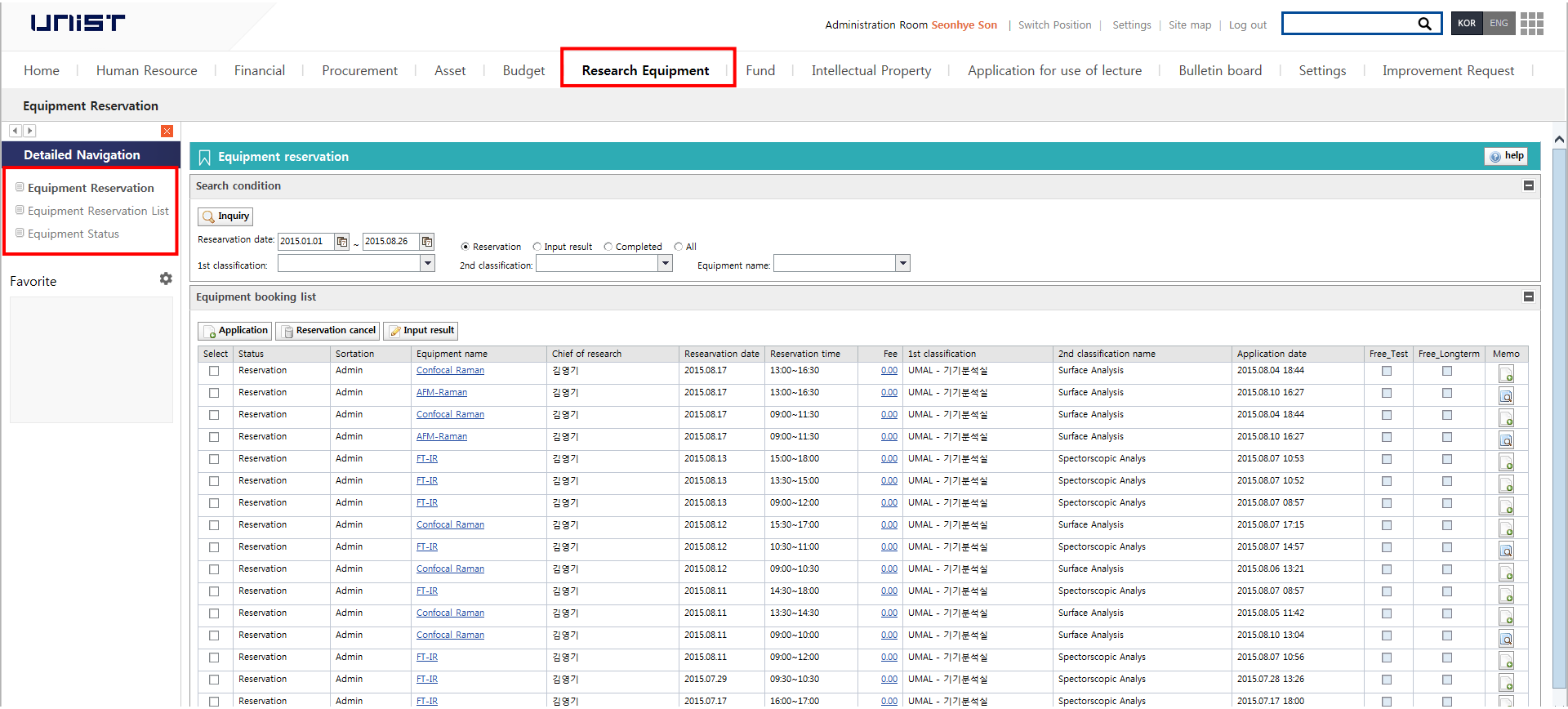


After pass the test,

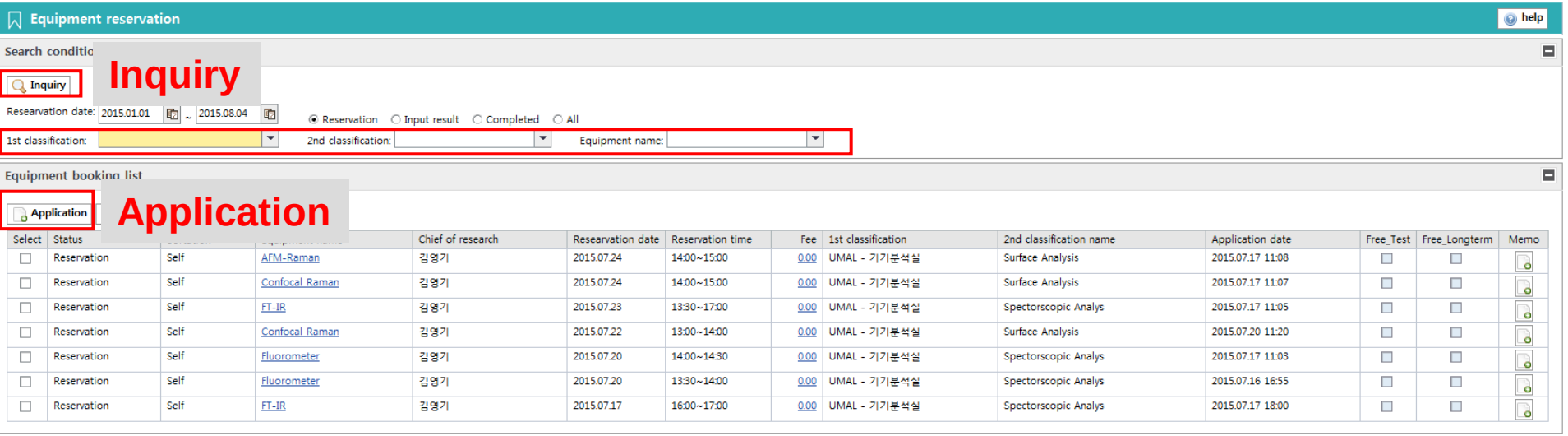
1. Login UCRF website.
2. Click [My Page].
3. Click [Request for Self user].
4. Select the equipment.
   1) Select [Materials Characterization Lab].
   2) Select [Spectroscopic analysis].
   3) Select [Zeta-Sizer].
   4) Click [Apply].

Reservation

portal.unist.ac.kr – Research Equipment– Equipment reservation/input result



Reservation

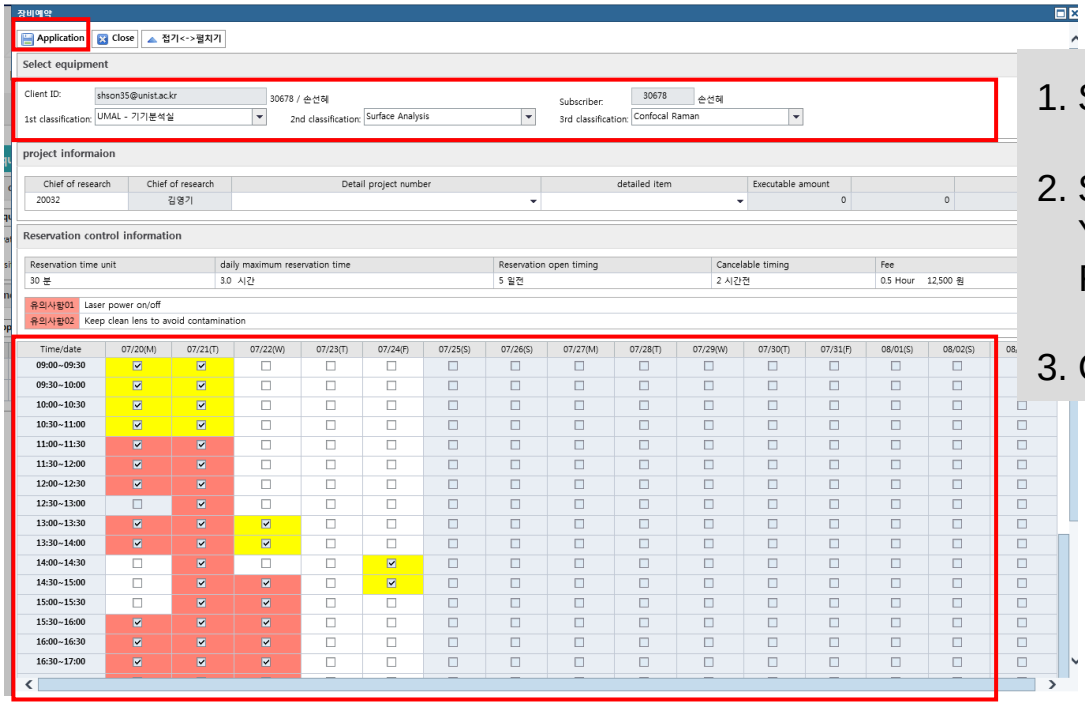


Select	Status			Chief of research	Reservation date	Reservation time	Fee	1st classification	2nd classification name	Application date	Free_Test	Free_Longterm	Memo
☐	Reservation	Self	AFM-Raman	김영기	2015.07.24	14:00~15:00	0.00	UMAL - 기기분석실	Surface Analysis	2015.07.17 11:08	☐	☐	
☐	Reservation	Self	Confocal Raman	김영기	2015.07.24	14:00~15:00	0.00	UMAL - 기기분석실	Surface Analysis	2015.07.17 11:07	☐	☐	
☐	Reservation	Self	FT-IR	김영기	2015.07.23	13:30~17:00	0.00	UMAL - 기기분석실	Spectorscopic Analys	2015.07.17 11:05	☐	☐	
☐	Reservation	Self	Confocal Raman	김영기	2015.07.22	13:00~14:00	0.00	UMAL - 기기분석실	Surface Analysis	2015.07.20 11:20	☐	☐	
☐	Reservation	Self	Fluorometer	김영기	2015.07.20	14:00~14:30	0.00	UMAL - 기기분석실	Spectorscopic Analys	2015.07.17 11:03	☐	☐	
☐	Reservation	Self	Fluorometer	김영기	2015.07.20	13:30~14:00	0.00	UMAL - 기기분석실	Spectorscopic Analys	2015.07.16 16:55	☐	☐	
☐	Reservation	Self	FT-IR	김영기	2015.07.17	16:00~17:00	0.00	UMAL - 기기분석실	Spectorscopic Analys	2015.07.17 18:00	☐	☐	

3

1

2

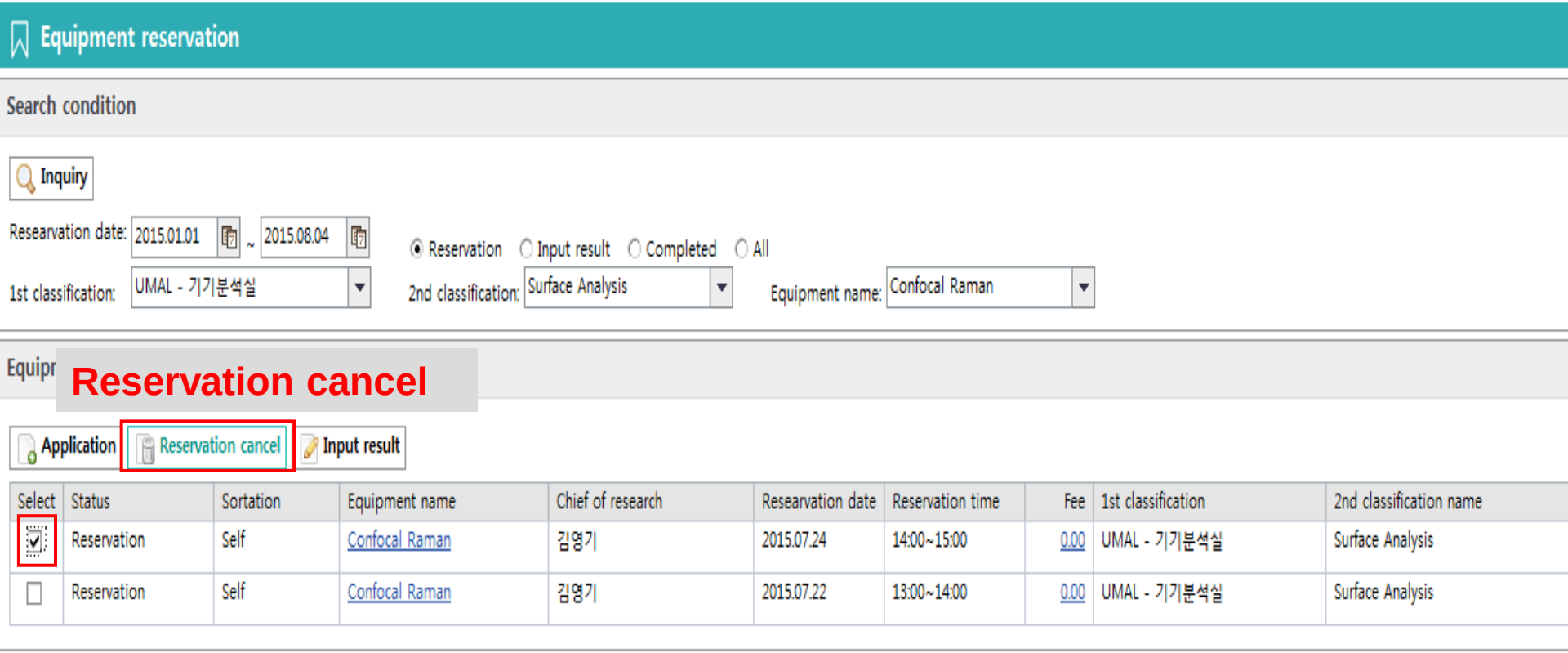


1. Select the classification and equipment

2. Select the time you want on white box.
   Yellow box : my reservation
   Red box : others reservation

3. Click [Application].

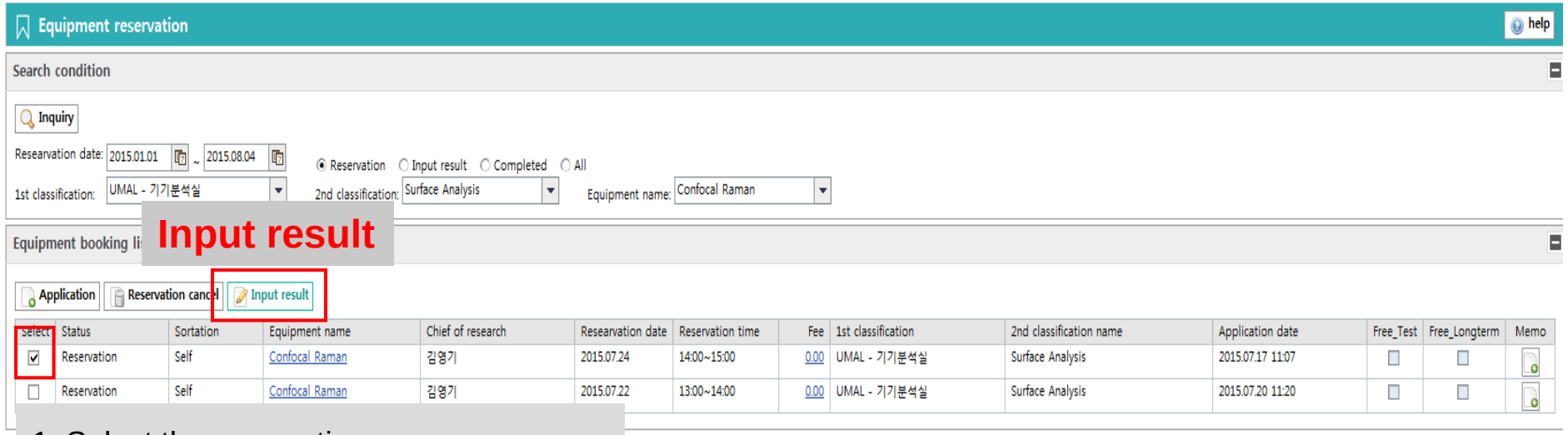
Reservation cancel



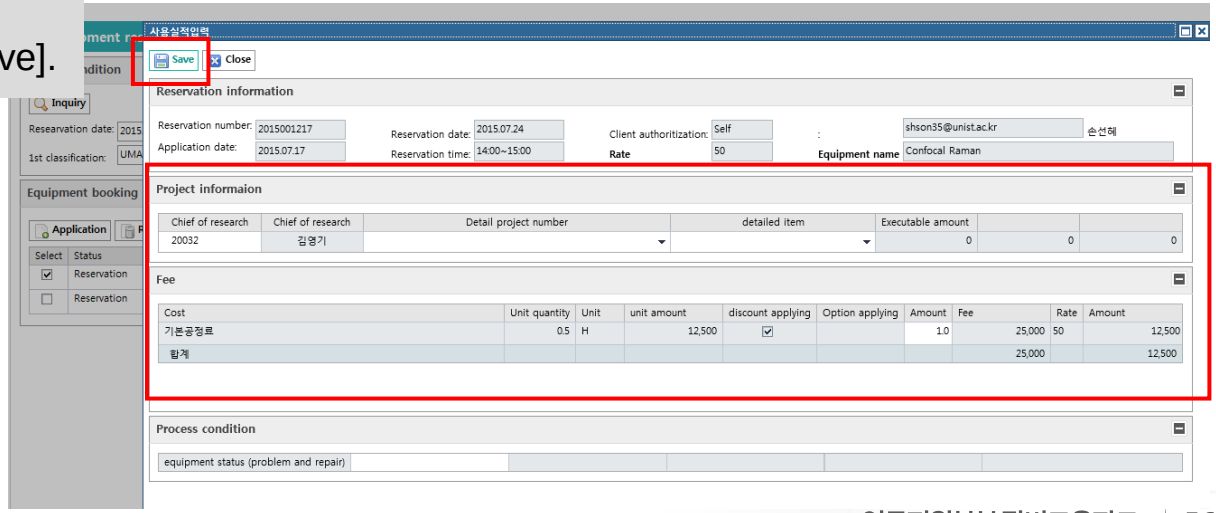
1. Select the reservation.
2. Click the [Reservation cancel].

Input result

After measurement, you have to input result instead of filling in log sheet



1. Select the reservation.
2. Click the [Input result].
3. Check the information and click [Save].



Guideline for the Operation of the UCRF

Article 1 (Purpose)
This guideline is intended to provide detailed requirements for operating the Central Research Facilities at Ulsan National Institute of Science and Technology (UNIST) (hereinafter referred to as “UCRF”) in accordance with Article 10, Operational Regulations of Central Research Facilities at UNIST.

Article 2 (Scope)
This guideline shall apply to faculty, graduate students, undergraduate students and researchers at UNIST, as well as external clients, who request services from UCRF, and equipment managers.

Article 3 (Definitions)
Terms used in this guideline shall be defined as follows:
“Autonomous use” means that UNIST faculty members or students use UCRF's equipment without any help from the equipment manager.
“Autonomous user” refers to users who have qualifications for the “autonomous use” of the equipment in paragraph 1 above, according to procedures set by UCRF.
“Request for analysis and processing” is a request to the equipment manager to perform a series of analyses and processes, so autonomous users can use UCRF's common equipment to obtain the results of a test analysis or process.

Article 4 (Access Management)
① If any personnel want authorized access to laboratories with restricted access, they must fill out an application form and receive approval from the supervising professor and Center manager to register their ID.
② If any personnel needs to access laboratories for equipment maintenance and repair, they must be accompanied by a competent manager or have the manager's approval to gain access to the labs.
③ For laboratories that require safety training for personnel with access, approval for access will be withheld until they complete prior training, as specified for each laboratory.

Article 5 (Requests for Analysis and Processing)
① If a client requests for analysis and processing that can be supported by UCRF, the client should discuss with the equipment manager beforehand.
② A client who requests analysis and processing shall cooperate with the equipment manager in identifying the necessary information needed to maintain the normal operations and safety of equipment or facilities.
③ Analysis and processing services will be available to clients on a first-come-first-serve basis. In any special circumstances such as equipment inspection and repair is needed, requests for such services may be reserved or cancelled at the equipment manager's discretion.

④ If there are no special requests from the client, each manager may discard any specimens that are seven days or older after the results-notice date, and may also discard the outcome or results data produced by the analysis and processing service three months from the day of said notice or later.

Article 6 (Qualifications for Autonomous Use)

① Authorized persons who qualify for autonomous use shall be limited to graduate students, researchers, professors and authorized undergraduate students (with the supervising professor's approval) at UNIST.
② Qualifications for autonomous use shall be granted to any persons who satisfy the requirements specified by each laboratory (e.g. safety training, equipment user training, evaluation, etc.).
③ A list of autonomous users shall be updated every 6 months and shall be published on the UCRF homepage.
④ An autonomous user's qualifications may be cancelled if the equipment manager deems it necessary, or if the user does not frequently use the equipment (less than the minimum limit of 10 times in the last 6 months). In such cases, users may discuss with the manager and go through a re-orientation process to be qualified for autonomous use again.

Article 7 (Responsibility of Autonomous Users)

① Autonomous users should follow the instructions for using the equipment as they learned during the orientation. If there is something significant to report, they must discuss with a competent manager and help operate and maintain the safety of the research equipment facilities.
② Autonomous users will be liable for any accidents, equipment damage, failure and loss incurred as a result of their negligence when using the equipment.
③ Equipment reservations should be made a day (24 hours) prior to when they need to use the equipment, and may be cancelled no later than 12 hours before the booked start time. If a user wants to cancel their reservation, they must inform the equipment manager via phone or e-mail during regular work hours (weekdays: 09:00 - 18:00) or via e-mail during off-hours.
④ Any reservations that are made less than 24 hours in advance may be cancelled before the booked start time. If users want to cancel their reservation, they must inform the equipment manager via phone or e-mail during regular work hours (weekdays: 09:00 - 18:00) or via e-mail during off-hours.
⑤ After using the equipment at night or during the equipment manager's off-hours, authorized users should make sure the laboratory is put back in order, the lights are turned OFF, and the entrance door is properly locked before leaving.

Guideline for the Operation of the UCRF

Article 8 (Restrictions for Autonomous Use)

① For the convenience of other users, a comfortable research environment, and to promote proper use of the equipment, UCRF may sanction users.

② Sanction criteria from the above paragraph 1 shall follow "Table 1. Penalty Points and Sanction Criteria for Users of Common Equipment."

Article 9 (Billing for Test Analysis Fees)

① Clients or autonomous users will receive bills for test analysis fees in the following month after the analysis and processing has ended, and may only pay for these bills to UCRF's bank accounts.

② Clients or autonomous users shall follow the specified procedures to pay bills charged under the standards of test analysis fees in accordance with Article 8, "Operational Regulations of Central Research Facilities at UNIST."

③ The standards of test analysis fees, as stipulated in Article 7, Operational Regulations of Central Research Facilities at UNIST, may be provided to clients or users before request or use.

④ If this is their first request or first time using the equipment, clients and users should submit copies of their business license and their bank book to UCRF's administrative offices.

⑤ When there is any change to the business license, they shall inform the administrative manager of the change and send a copy of the new business license to the manager.

⑥ Bills for test analysis fees shall be issued by UCRF's administrative office, and clients or users shall pay the bill to UCRF no later than 1 month after the bill is sent to them. If the payment is overdue, UCRF may stop supporting services for users and laboratories in arrears.

⑦ If more time is required for analysis and process due to negligence on the part of clients, additional test analysis fees may be charged.

Penalty Points and Sanction Criteria

	Behaviors subject to penalty points	Penalty pts
	[Eligibility to use equipment]	
1	Unauthorized use of equipment without permission	5
2	Use of equipment without a reservation	3
3	Someone other than the equipment lessee used the equipment	3
	[Reservations for using equipment]	
4	Reserved and used equipment outside of permitted hours	1
5	Use of equipment beyond the time reserved without making another reservation beforehand for extra time	1
6	Failed to use the equipment durng the reserved time and did not cancel reservation in advance	3
7	Cancelling reservations for equipment after the cancellation deadline, under Article 7, Guideline for the Operation of the UNIST Central Research Facilities (UCRF)	1
8	Use of any equipment without giving a prior notice to the equipment manager, after making a reservation	1
	[Careless behaviors]	
9	Using functions on the equipment that are not permitted	3
10	Failure to promptly notify the manager of any errors or failures detected during use	3
11	Negligence that resulted in damages or failure to the equipment	5
12	Negligence that resulted in loss or damage to an equipment component or part	5
13	Failure to record in the equipment usage log after using any equipment, or misrepresentation or partial representation of the facts	1
14	Failure to provide specimen information required by the equipment manager to ensure normal operations and safety of equipment or facilities, thus resulting in damage or failure to the equipment	3
15	[Careless behaviors]	3
16	Using functions on the equipment that are not permitted	5
17	Failure to promptly notify the manager of any errors or failures detected during use	5

Penalty Points and Sanction Criteria

Classification	Penalty pts.	Follow-up actions
(Individual users of equipment)		
Sum up penalty points imposed to individuals	≥ 5 points	Equipment manager will notify user(s) and their supervising professor by email of their penalty points total, and shall post the details of their penalty points on the bulletin board of the equipment room. Users with penalty points 8 points or higher may not use the relevant equipment for 3 months.
	≥ 8 points	Equipment manager will notify user(s) and their supervising professor by email that the user(s) may not use the relevant equipment for 3 months until they complete the re-orientation course; will also forward an official notice to their supervising professor; and will post details of their penalty points on the bulletin board of the equipment room.
(User's laboratory)		
Sum up penalty points imposed on the students in the laboratory for the same equipment in the same laboratory	≥ 12 points	Equipment manager will notify the user(s) and their supervising professor by email that user(s) with penalty points 15 points or higher may not use the relevant equipment in the laboratory for 3 months.
	≥ 15 points	Equipment manager will email the supervising professor to inform that the user(s) may not use the relevant equipment in the laboratory for 3 months; will also forward an official notice to their supervising professor; and will post the details of their penalty points on the bulletin board of the equipment room.
Sum up penalty points imposed on the students in the laboratory for all UCRF equipment in the same laboratory	≥ 20 points	UCRF will notify students and their supervising professor by email that the user(s) with 25 penalty points or higher may not use any UCRF equipment in the laboratory for 1 month.
	≥ 25 points	UCRF will notify students and their supervising professor by email that user(s) may not use any UCRF equipment in the laboratory for 1 month; will also forward official notice to their supervising professor; and will post details of their penalty points on the bulletin board of UCRF.