ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY

FT-IR

1. Syllabus

Qualification for FT-IR operation

1. FT-IR self-user training

1) Theory class (FT-IR manager Mi Sun Cho, 4034)

2) Operation class (FT-IR manager Mi Sun Cho, 4034)

2. Practice FT-IR yourself

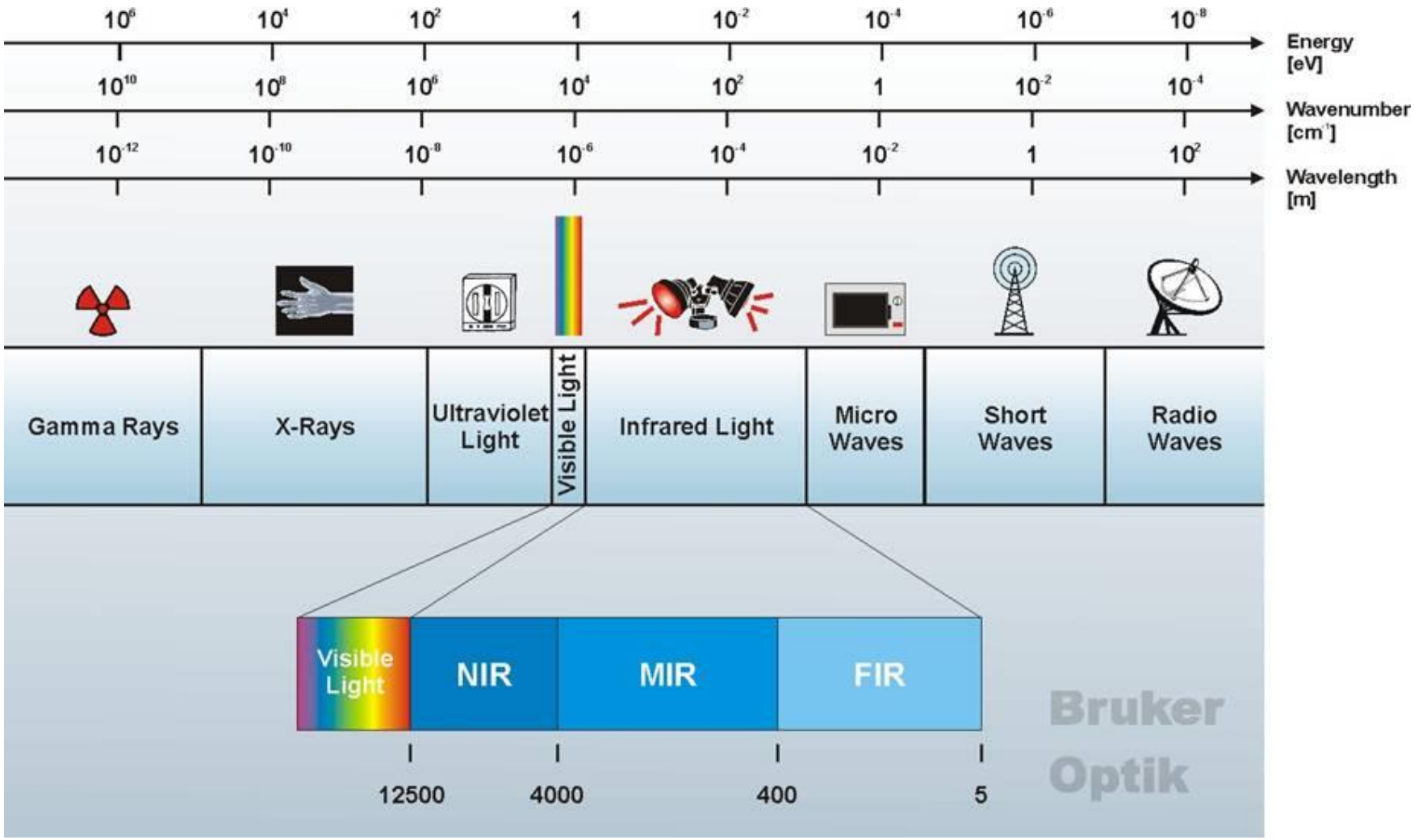
- Each person practice with manager 3 times.
- Please contact manager and make an appointment.

3. Attend the FT-IR test

- 20 min.test
- Explain about IR and measurement methods.
- Sample measurement with ATR or other accessories.

2. Basic Principles

Electromagnetic radiation



Spectral range

NIR : **12500 – 4000** cm^{-1} (0.8 – 2.5 μm , 1.55 – 0.5 eV)

- Overtones and combination vibrations
- low absorption coefficient ⇔ high sample concentrations
- Advantage : Quartz is transparent → fiber optics, in glass vials
- Source : tungsten lamp
- Optical material : Quartz
- Detector : Ge, InGaAs

MIR : **4000 – 400** cm^{-1} (2.5 – 25 μm , 0.5 – 0.05 eV)

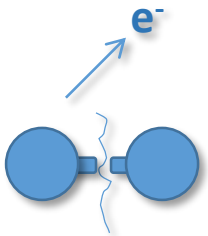
- Fundamental molecular vibrations : stretch and deformation vibrations
- high absorption coefficient ⇔ low sample concentrations
- Source : Globar
- Optical material : KBr, ZnSe
- Detector : DTGS, MCT

FIR : **400 – 5** cm^{-1} (25 – 1000 μm , 0.05 – 0.0012 eV)

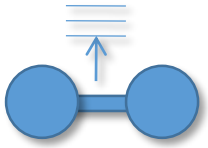
- Backbone vibration of large molecules, molecules with heavy atoms
- low absorption coefficient, strong water vapor absorption → vacuum spectrometer
- Source : Globar, Hg lamp
- Optical material : PE, CsI
- Detector : DTGS, Bolometer

Molecular processes

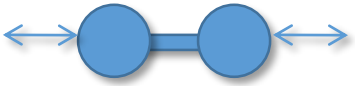
Bond breaking and ionization



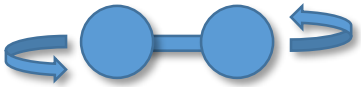
Electronic excitation

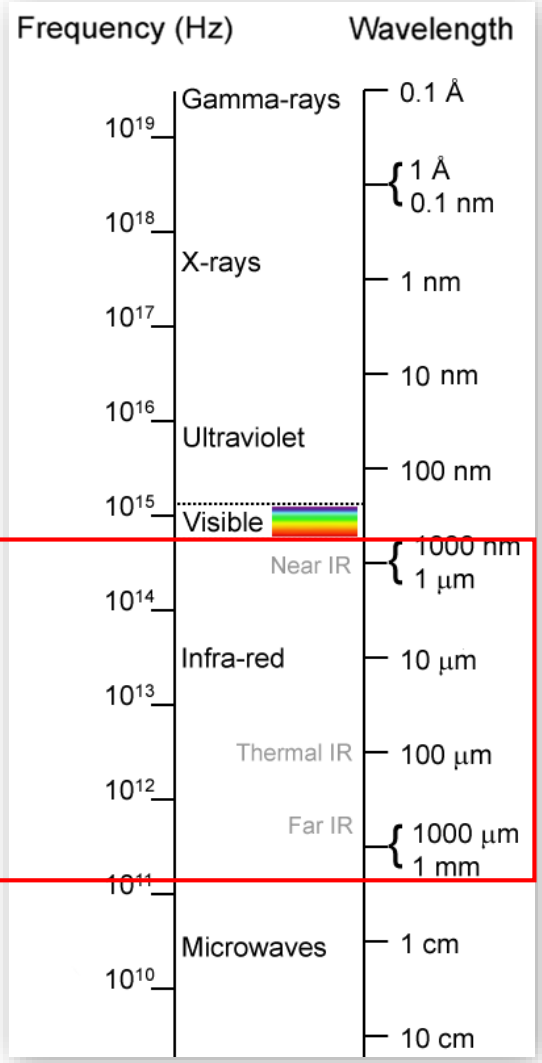


Vibration



Rotation

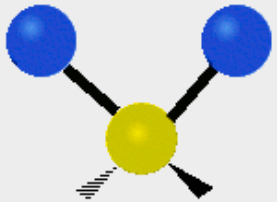
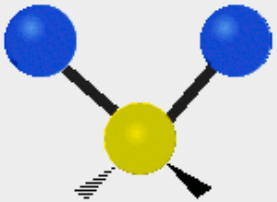
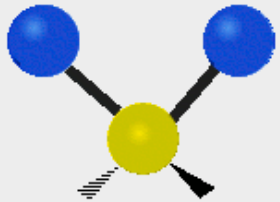
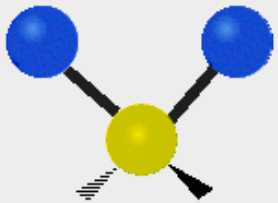
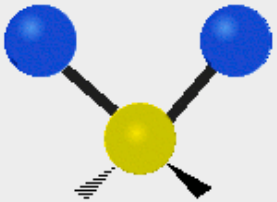
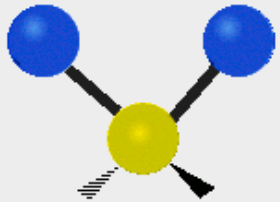


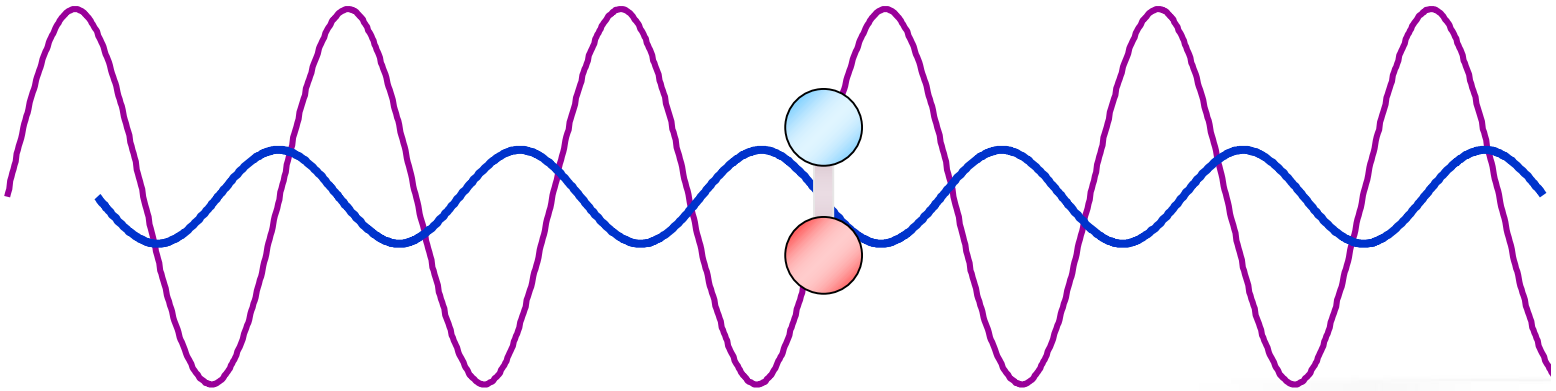


http://upload.wikimedia.org/wikipedia/en/8/8a/Electromagnetic-Spectrum.png

Molecular vibrations

https://en.wikipedia.org/wiki/Infrared_spectroscopy

Symmetric stretching	Asymmetric stretching	Scissoring(in-plane)
		
Rocking(in-plane)	**Wagging(out-plane)**	**Twisting(out-plane)**
		



Molecular vibrations

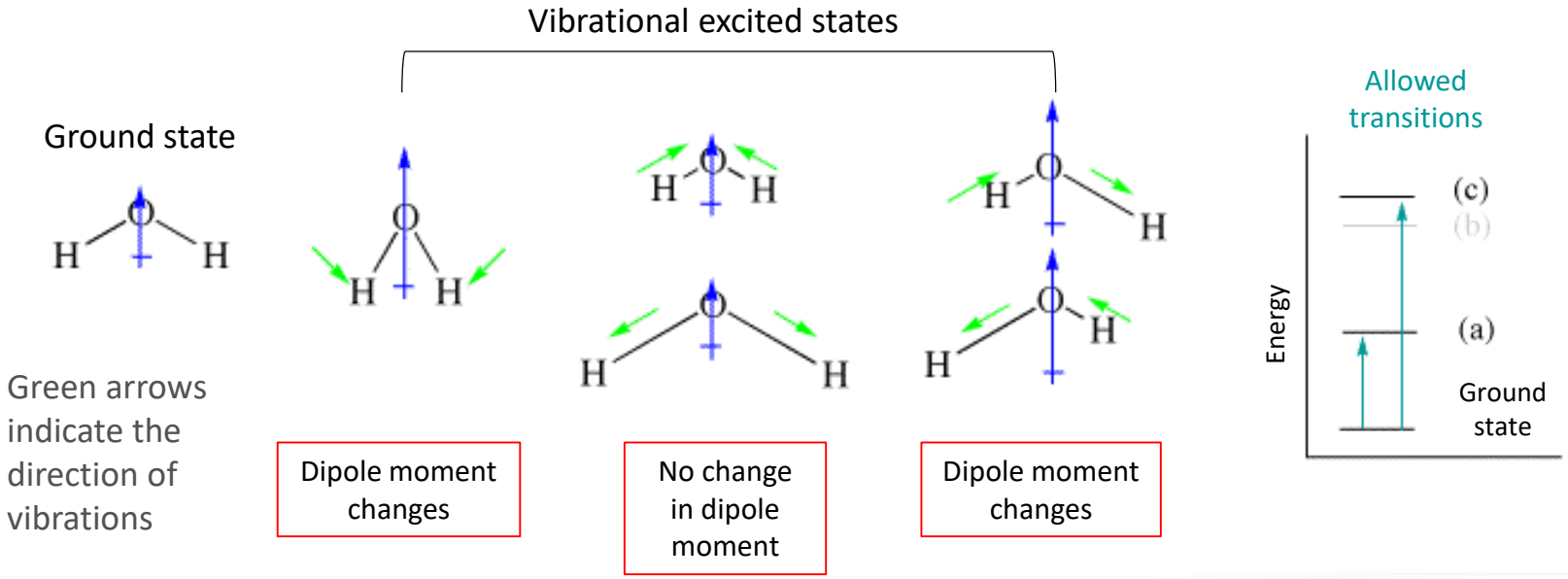
❖ Selection Rules

A molecule will absorb infrared radiation if the change in vibrational states is associated with a change in the **dipole moment (μ)** of the molecule.

Dipole moment (μ)
A dipole moment is a quantity that describes two opposite charges separated by a distance.

$$\mu = q \times r$$

q: separated charge(positive and negative charge)
r: distance between center of charges



Vibration theory

For a harmonic oscillator it is possible to calculate the vibrational frequency of a diatomic molecule as follows.

$$\nu = \frac{1}{2\pi c}\sqrt{\frac{k}{\mu}} = \frac{1}{2\pi c}\sqrt{\frac{k(Mx+My)}{M_x \cdot My}}$$

$$\mu = \frac{M_x \cdot M_y}{M_x + My}$$

ν = vibration frequency(cm^{-1})

c = Speed of light constant

K = Force constant of bond(dynes/cm)

M_x and M_y = Mass of each

Single bond $K \cong 5 \times 10^5\ dyne/cm$

$c = 19.8 \times 10^{-24} g,\ H = 1.64 \times 10^{-24} g$

$\nu_{CH} = 3040\ (obs) 2960 - 2850$

Bonding	Force constant f(dyne/cm)	Absorbance range (cm^{-1})	
		Calculation	Measurement
C — O	5.0 X 10^5	1113	1300 — 800
C — C	4.5 X 10^5	1128	1300 — 800
C — N	4.9 X 10^5	1135	1250 — 1000
C = C	9.7 X 10^5	1657	1900 — 1500
C = O	12.1 X 10^5	1731	1850 — 1600
C ≡ C	15.6 X 10^5	2101	2150 — 2100
C — D	5.0 X 10^5	2225	2250 — 2080
C — H	5.0 X 10^5	3032	3000 — 2850
O — H	7.0 X 10^5	3553	3800 — 2700

Vibration theory

C = C bond

$$\overline{v} = \frac{1}{2\pi c}\sqrt{\frac{K}{M_x M_y / M_x + M_y}}$$

$$K = 10 \times 10^5\ dynes/cm$$

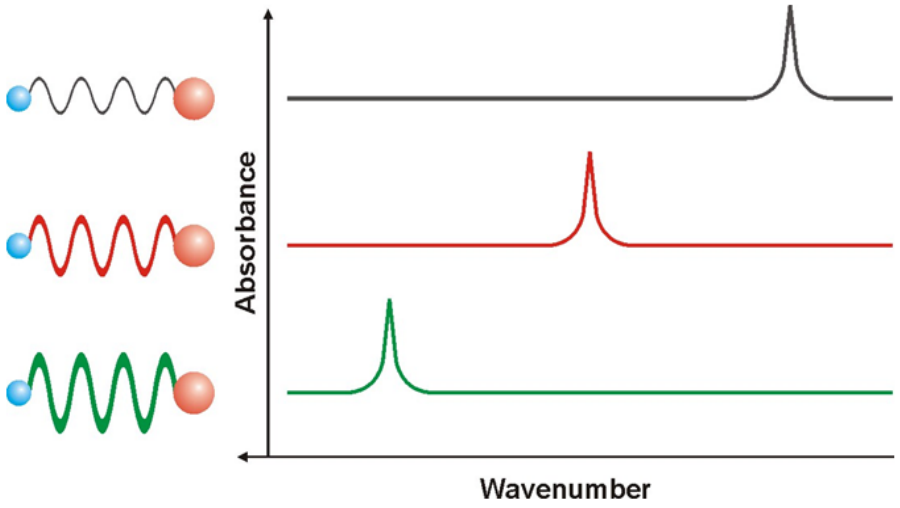
$$\mu = \frac{M_x M_y}{M_x + M_y} = \frac{(12)(12)/(6.023\text{X}1023)^2}{12 + 12/6.023\text{X}1023} = \frac{6}{6.023\text{X}1023}$$

$$\overline{v} = \frac{1}{2\text{X}3.14\text{X}3\text{X}10^{10}}\sqrt{\frac{10 \times 10^5}{6/6.023\text{X}1023}} = 1682\ cm^{-1}(calculated)$$

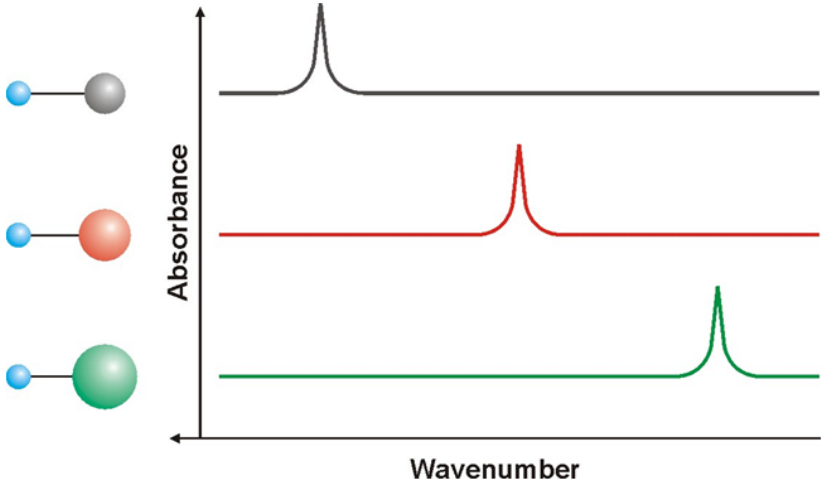
$$\overline{v} = 1650\ cm^{-1}\ (experimental)$$

Vibration theory

1) The higher the force constant (k , the bond strength), the higher the vibrational frequency (wavenumber).

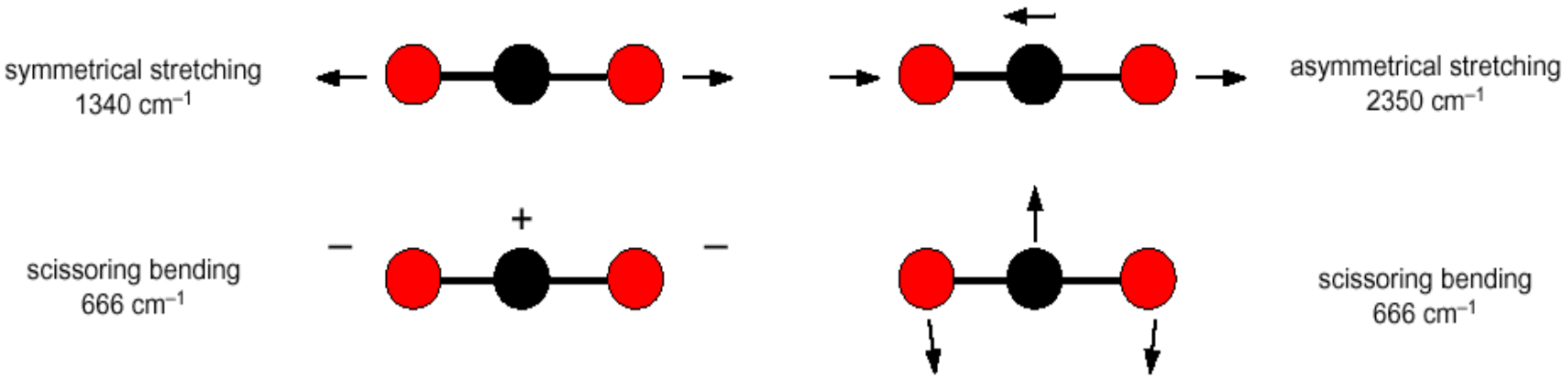


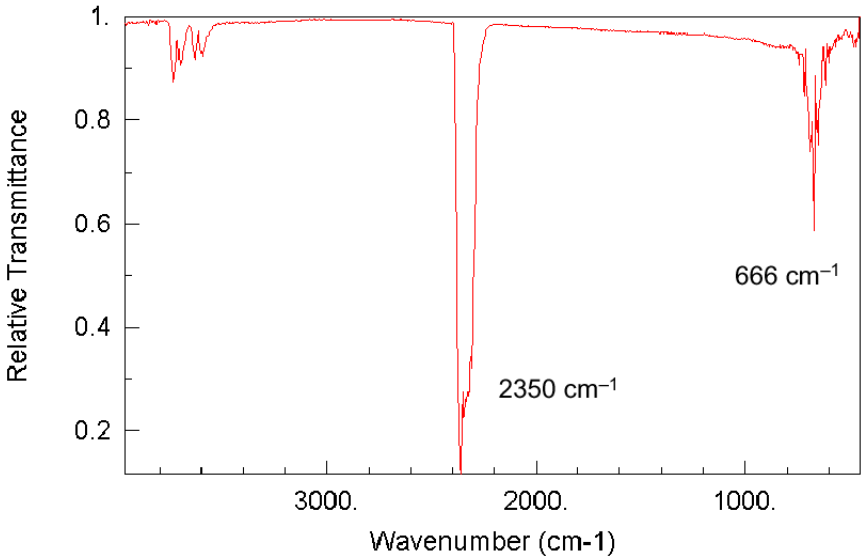
2) The larger the vibrating atomic mass, the lower the vibrational frequency.



Vibration theory

Example: CO_2





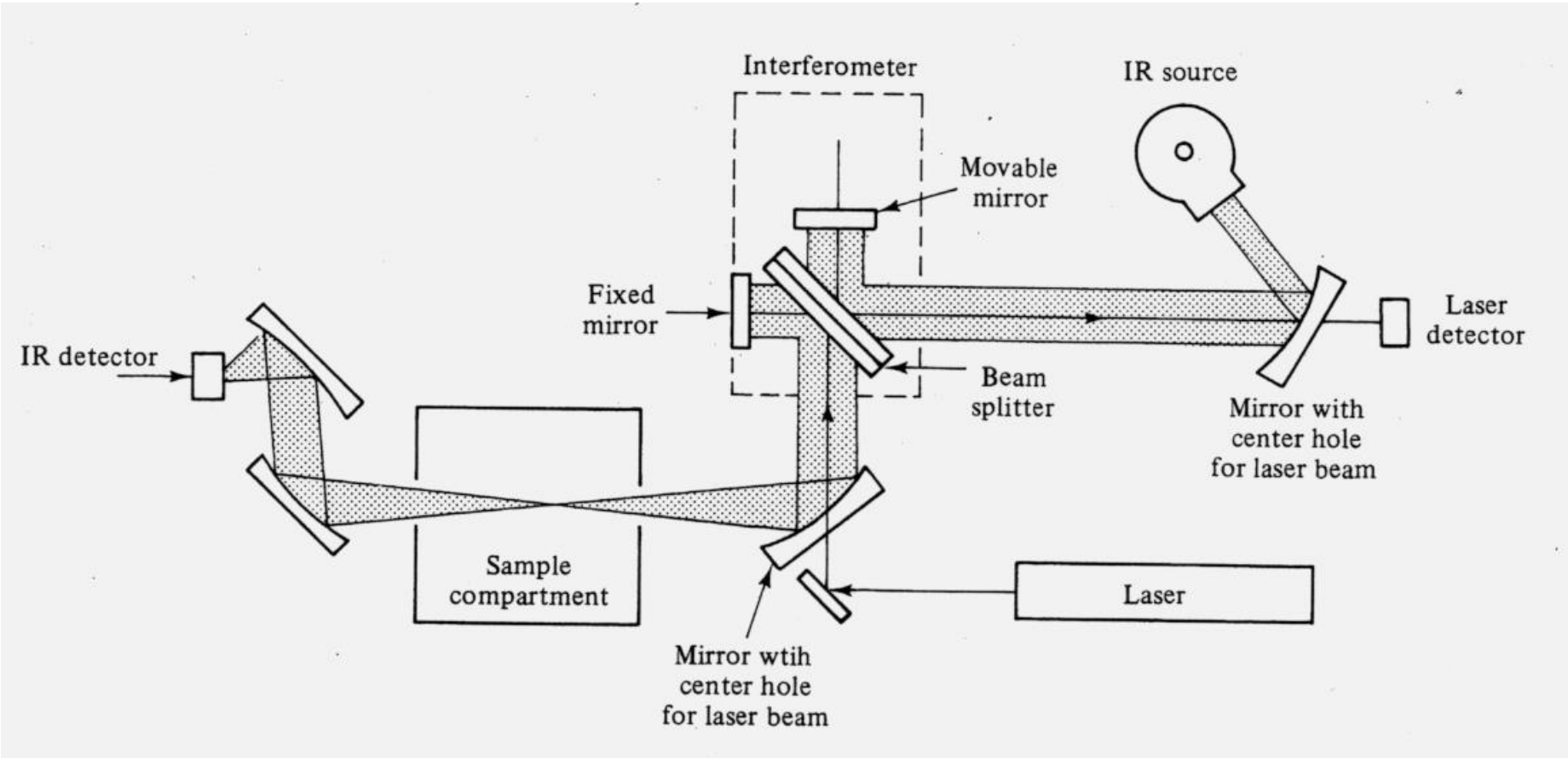
The theoretical number of fundamental vibrations (absorption frequencies) will seldom be observed.

The overtones (multiples of a given frequency), combination (sum of two other vibrations) or difference (the difference of two other vibrations) tones increase the number of bands.

3. Hardware

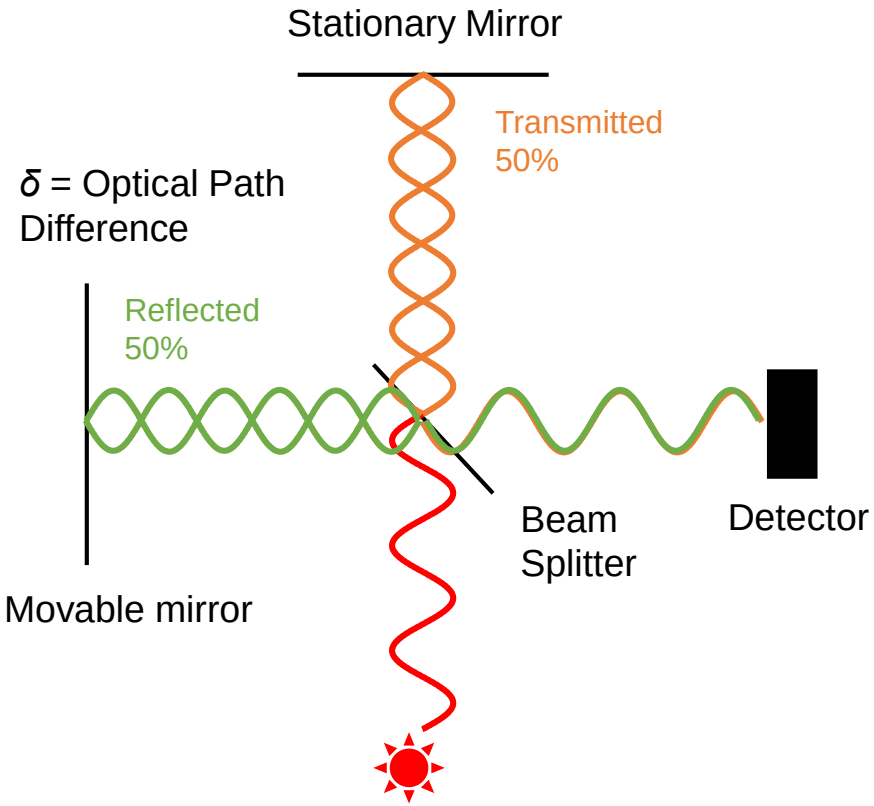
Fourier Transform Infrared Spectrometer (FT-IR)

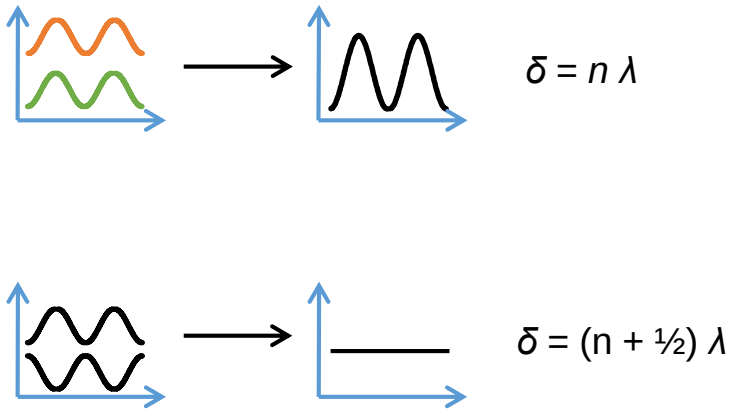
Single-beam FTIR Spectrometer



Fourier Transform Infrared Spectrometer (FT-IR)

- 광원에서 조사된 빛이 빔 스플리터에 닿으면 절반은 투과되어 고정 거울로 진행하고, 절반은 이동 거울로 진행함.
- 각각의 거울에서 다시 반사되어 광원으로 오는 빛을 제외하고 검출기로 들어가게 되는데, 투과파와 반사파의 위상이 같으면 보강 간섭이 일어나고, 1/4 λ만큼의 위상 차이로 인해 상쇄간섭이 발생함.





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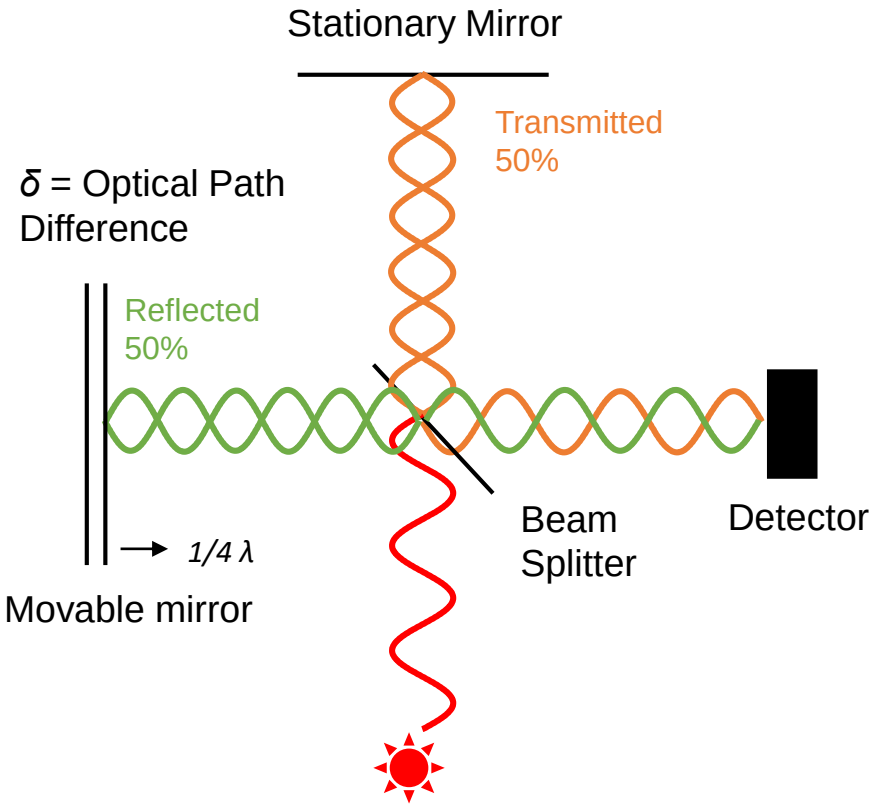
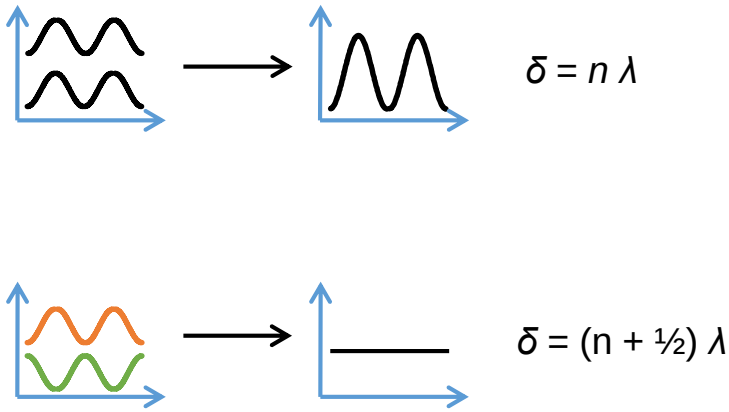
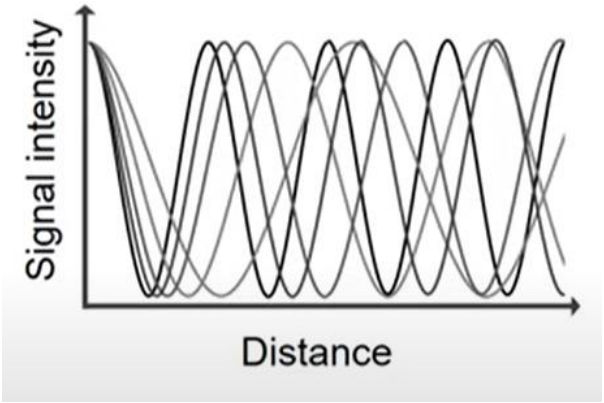
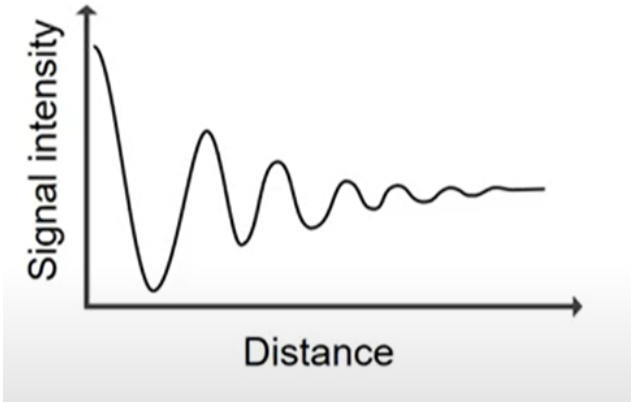


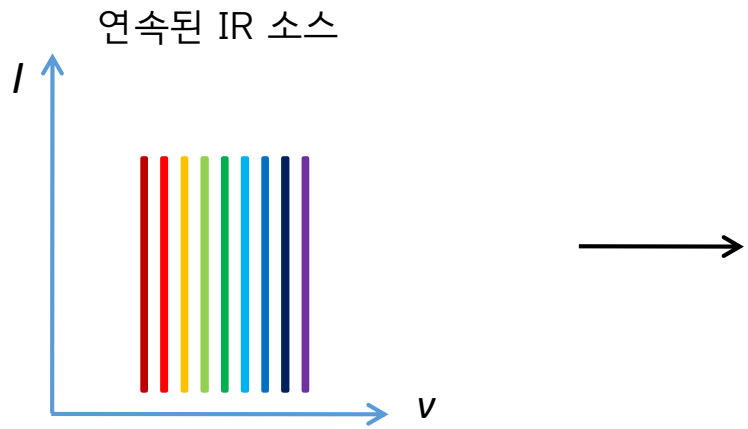


Fourier Transform Infrared Spectrometer (FT-IR)

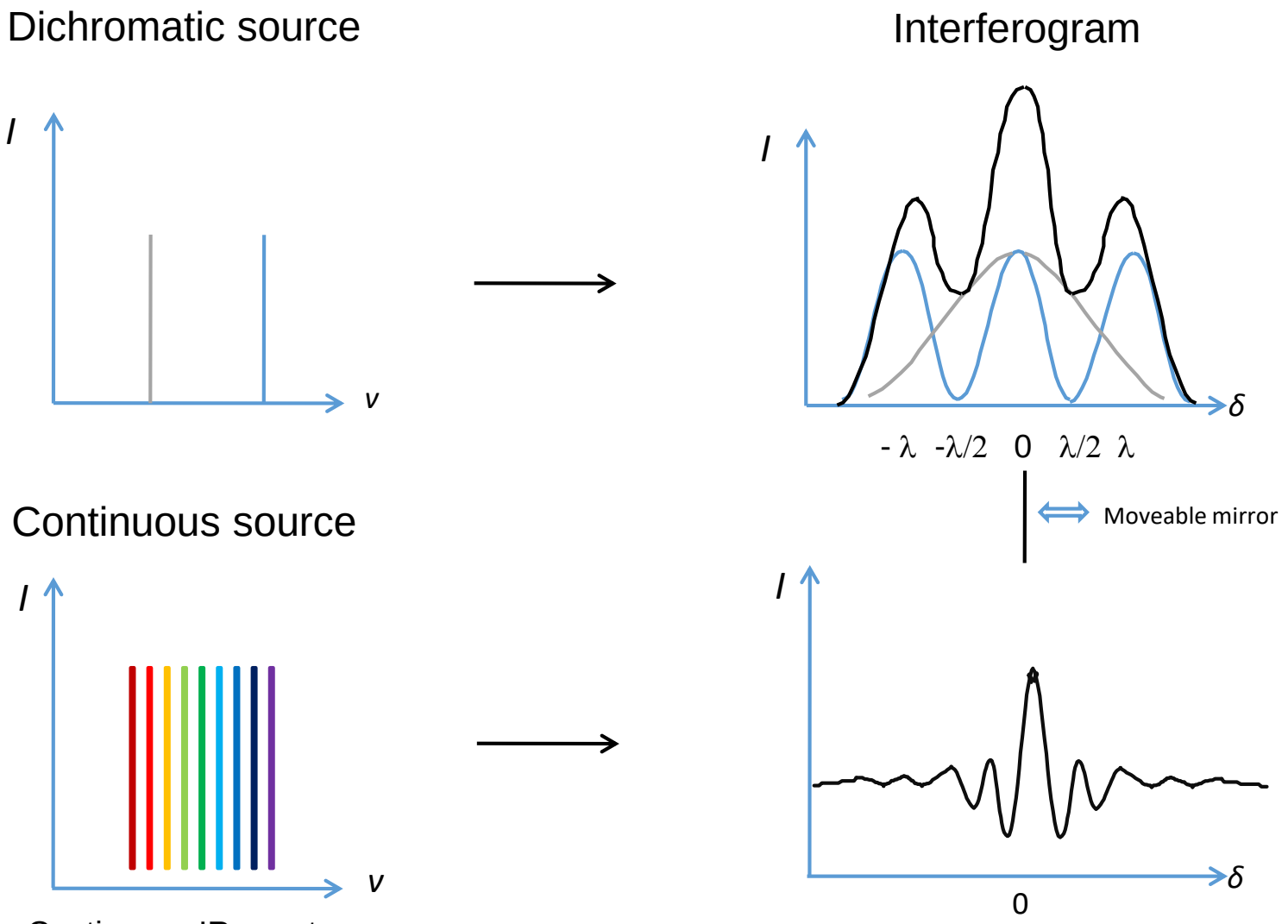
- 빛의 간섭 현상에 따른 적외선 시그널의 변화를 나타낸 것으로 광원에서 나오는 모든 파장에 대한 세기 정보를 포함.



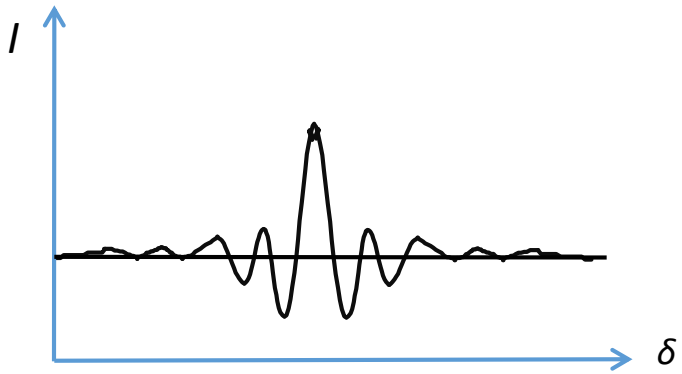




Fourier Transform Infrared Spectrometer (FT-IR)



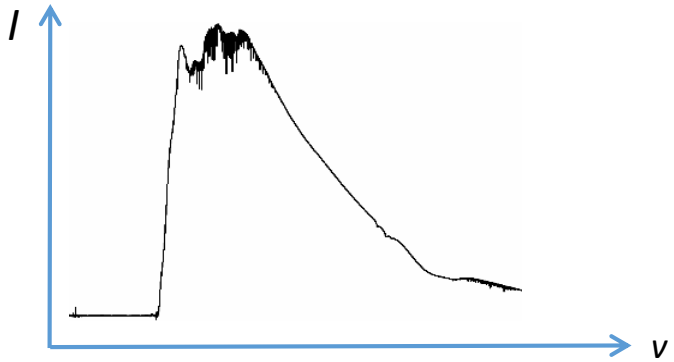
Fourier Transform Infrared Spectrometer (FT-IR)



Time domain: I vs. δ

$$I(\delta) = \int_{-\infty}^{\infty} B(\nu)\cos(2\pi\nu\delta)d\nu$$

FT



Frequency domain: I vs. ν

$$B(\nu) = \int_{-\infty}^{\infty} I(\delta)\cos(2\pi\nu\delta)d\delta$$

❖ Advantages of FT-IR

Throughput Advantage_Circular aperture, high signal intensity → high signal to noise ratio

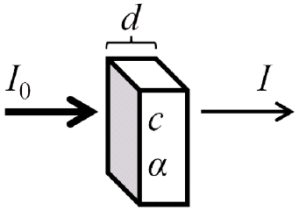
Multiplex Advantage_All frequencies are measured at the same time

Precision Advantage_Internal laser control the scanner – built in calibration

IR spectrum

y axis is %T or A

x axis is wavenumber (or wavelength)



$T = I/I_o$

$\%T = 100\ I/I_o$

T transmission / transmittance

$A = -\log T$

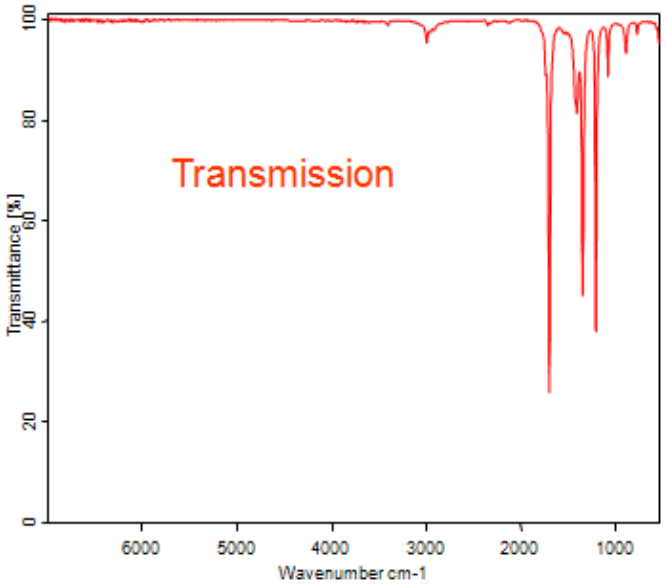
A absorbance (no units) $= cd\alpha$

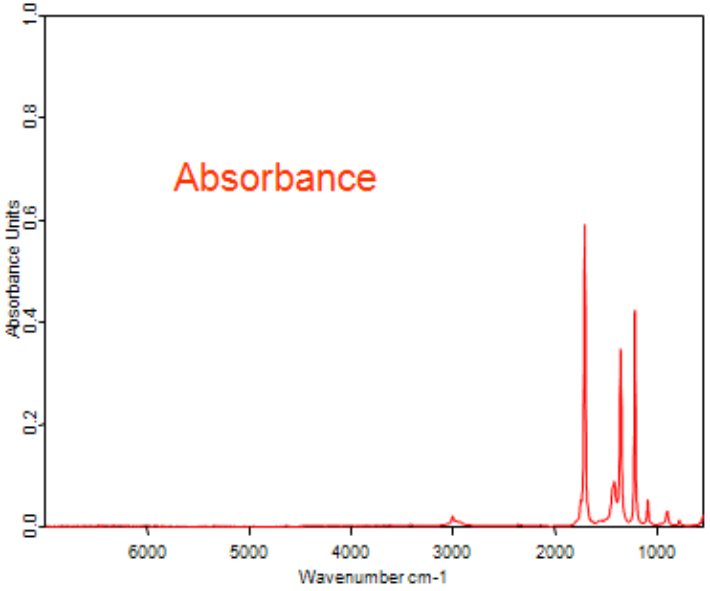
(Note A (but not T) $\propto$ concentration)

d = sample thickness

c = absorbant concentration

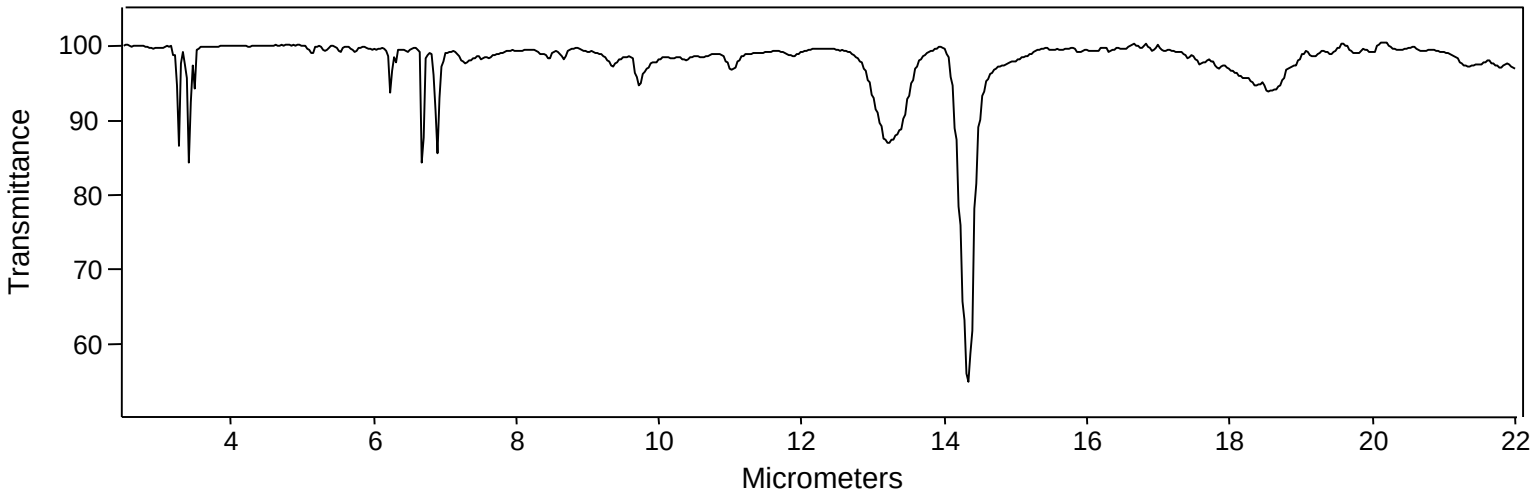
α= absorption coefficient



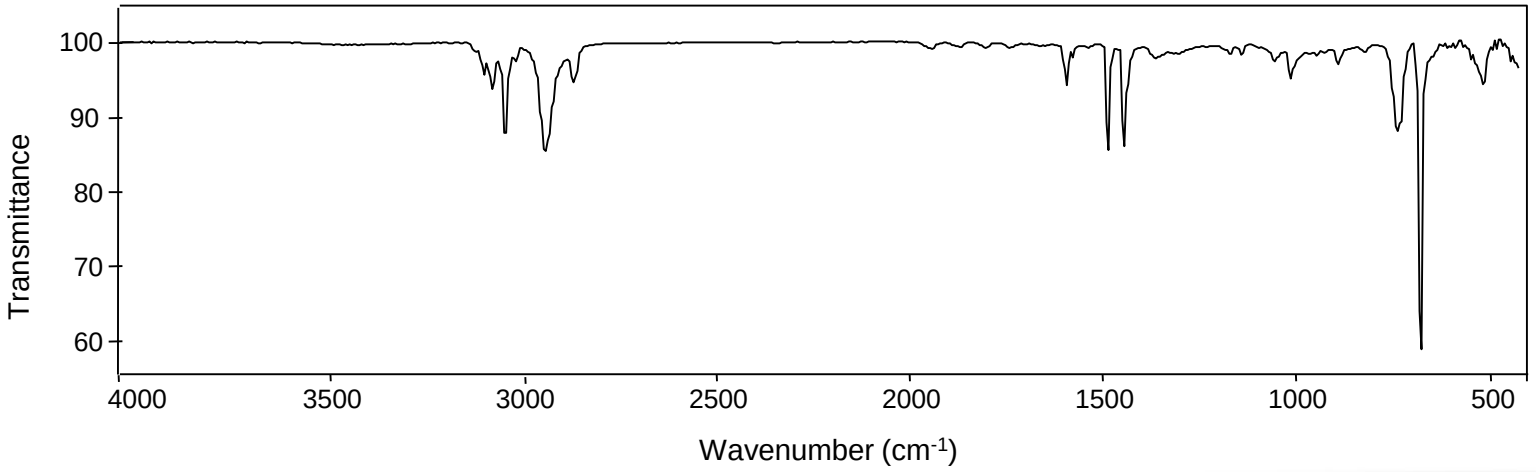


IR spectrum

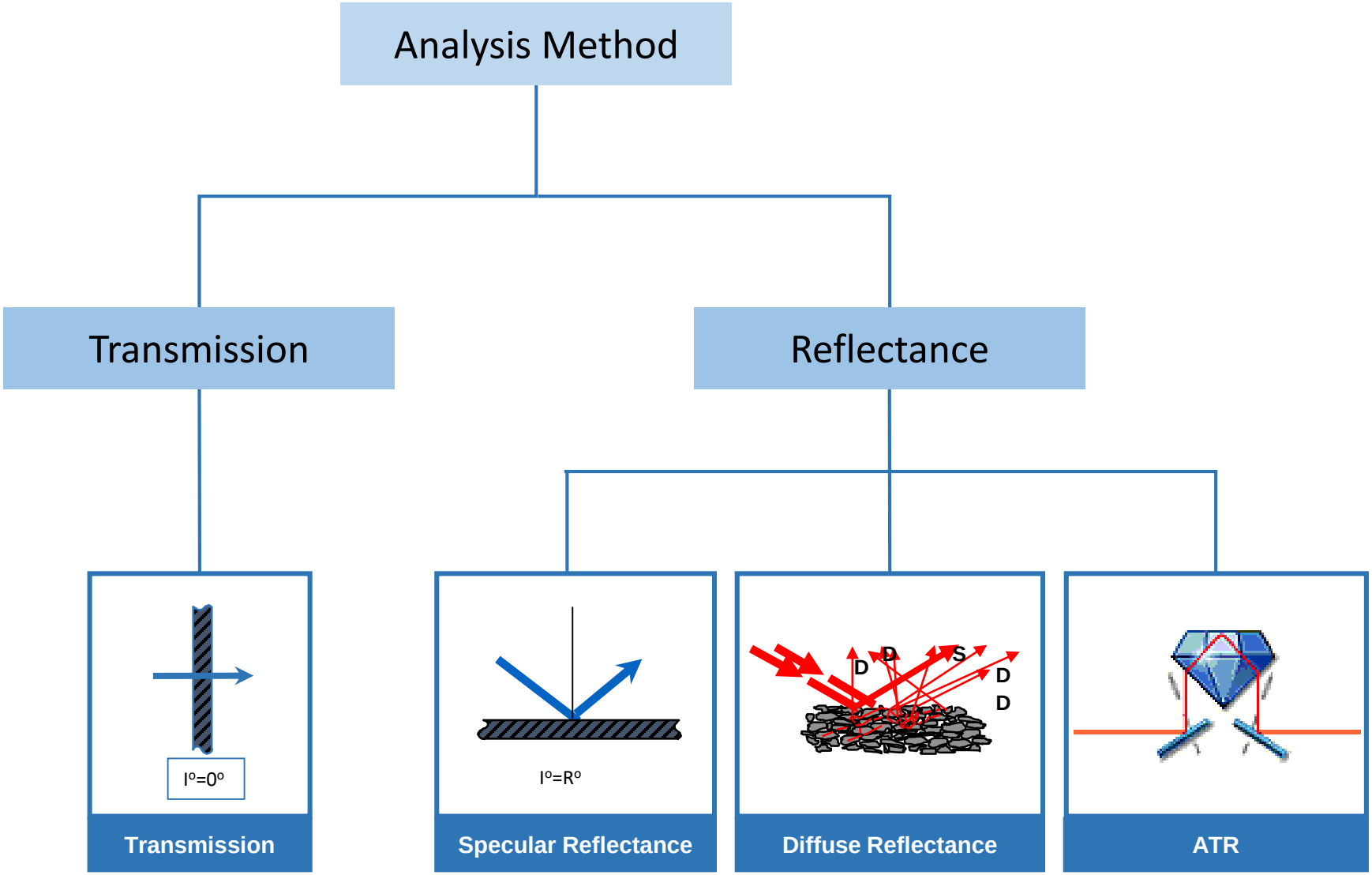
IR Spectrum in Wavelength (μm)



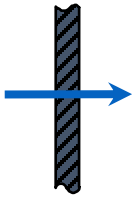
IR Spectrum in Wavenumber (cm^{-1})



FT-IR measurement



FT-IR measurement



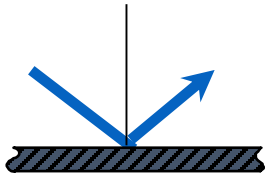
$I^o=0^o$

Transmission

(Powder, Drugs-KBr pellet/Films, Coatings, Paints-film holder/Liquid-window cell)

Absolute reference measurement

Sample preparation can be difficult and time consuming



$I^o=R^o$

Specular Reflectance

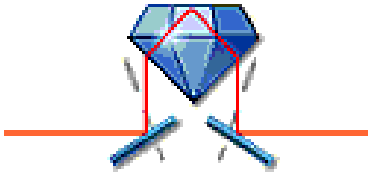
Sample must have a back reflective layer or must be on a mirror

(layer thickness = single molecule)

Diffuse Reflectance

Solids and powders, diluted in a matrix of KBr or KCl

Analysis of non-reflective materials



ATR (Attenuated Total Reflectance)

(Powder, Drugs, Films, Coatings, Paints, Liquid, Rubber)

The infrared beam is focused into a crystal

Creating an evanescent wave about 1 – 2 microns deep

No sample preparation

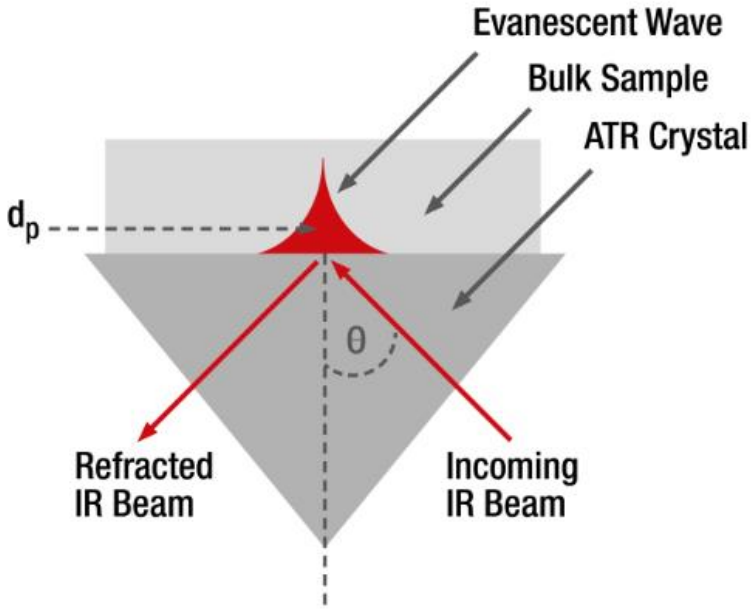
FT-IR measurement

ATR (Attenuated Total Reflectance)

- ATR spectroscopy utilizes the phenomenon of total internal reflection

- A beam of radiation entering a crystal sill undergo total internal reflection when the angle of incidence at the interface between the sample and crystal is greater than critical angle

- In this way, an evanescent wave penetrates into the sample in contact with the crystal, producing a spectrum of the sample



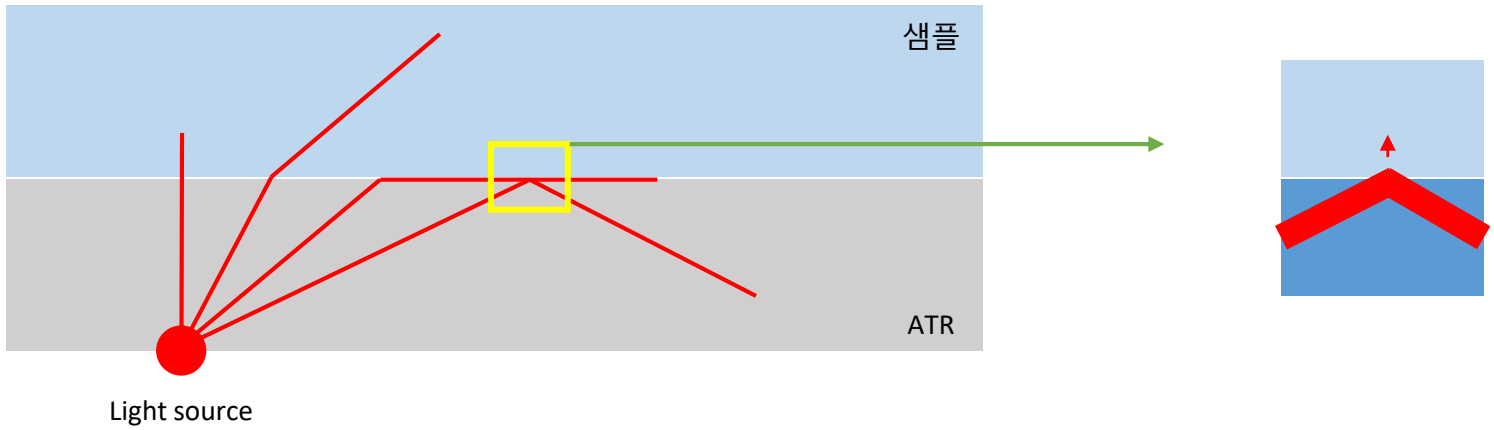
- Evanescent wave resulting from total internal reflection

FT-IR measurement

Total internal reflection

When a infrared light beam hits the surface between two optical media which are characterized by two different refractive indices at a certain angle of incidence, the light is totally reflected.

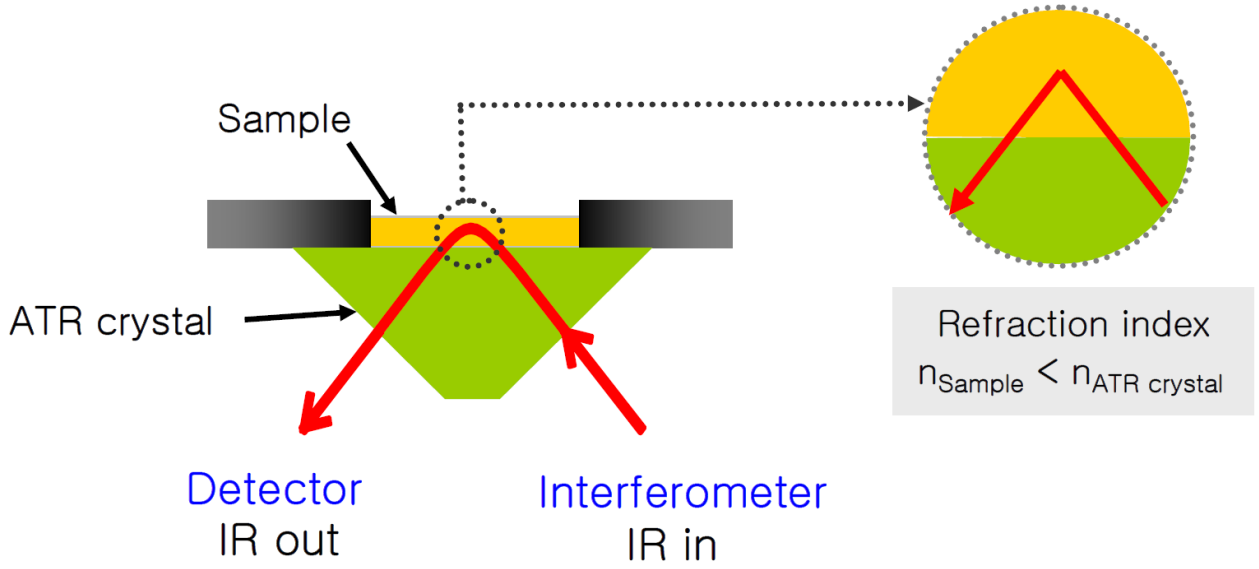
This angle is called the critical angle and can be calculated using Snell's law.



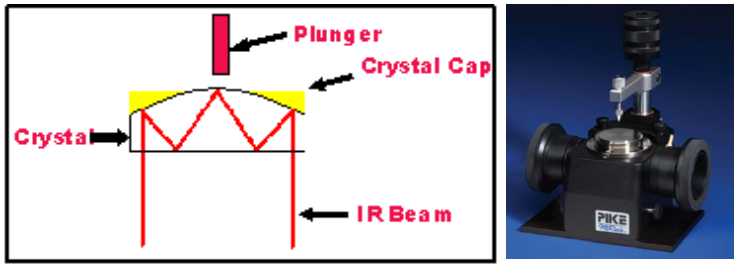
- Light is perpendicular to the material: no refraction
- Incident angle < Critical angle : refraction
- Incident angle = Critical angle : the angle of refraction is 90 degrees
- Incident angle > Critical angle : **total internal reflection**

FT-IR measurement

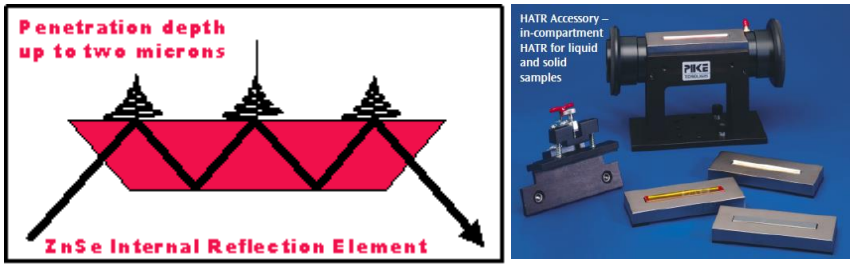
ATR (Attenuated Total Reflectance)



< *ATR system*>



Single-bounce ATR



Multi-bounce ATR

FT-IR measurement

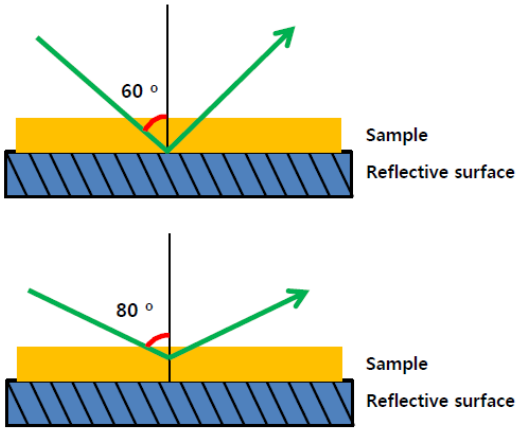
ATR crystal

Material	ATR Spectral Range (cm^{-1})	Refractive Index	Depth of Penetration (μ) (at 45º & 1000 cm^{-1})	Uses
Germanium	5,500 - 675	4	0.66	Good for most samples, especially strong absorbing samples, such as dark polymers
Silicon	8,900 - 1,500 & 360-120	3.4	0.85	Resistant to basic solutions
AMTIR	11,000 - 725	2.5	1.77	Very resistant to acidic solutions
ZnSe	15,000 - 650	2.4	2.01	General use
Diamond	25,000 - 100	2.4	2.01	Good for most samples. Extremely caustic or hard samples

FT-IR measurement

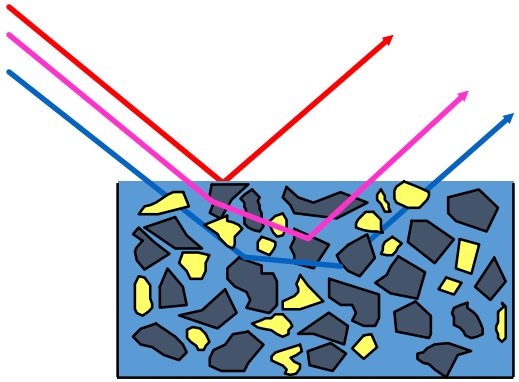
Reflectance method

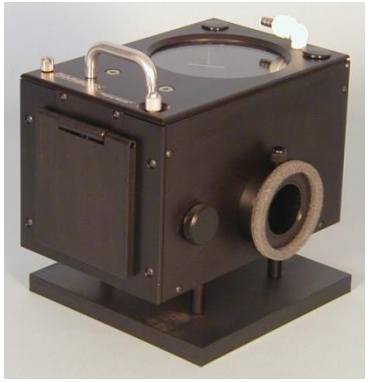
Specular reflectance



Seagull

Diffuse reflectance (DRIFTS)





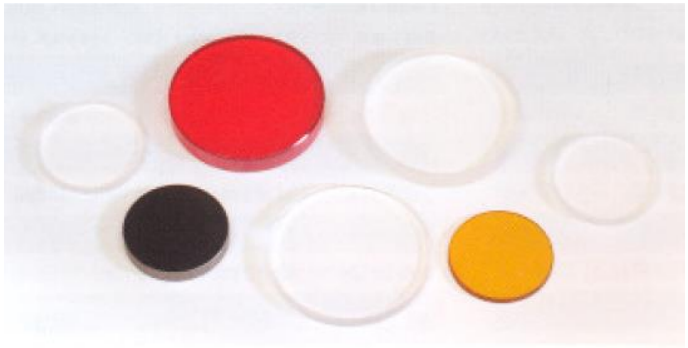
Praying Mantis

FT-IR measurement

Transmission_Powder, Drugs, Film

Pellet sample (13 mm die) and film sample

Transmission_Liquid sample (window material)

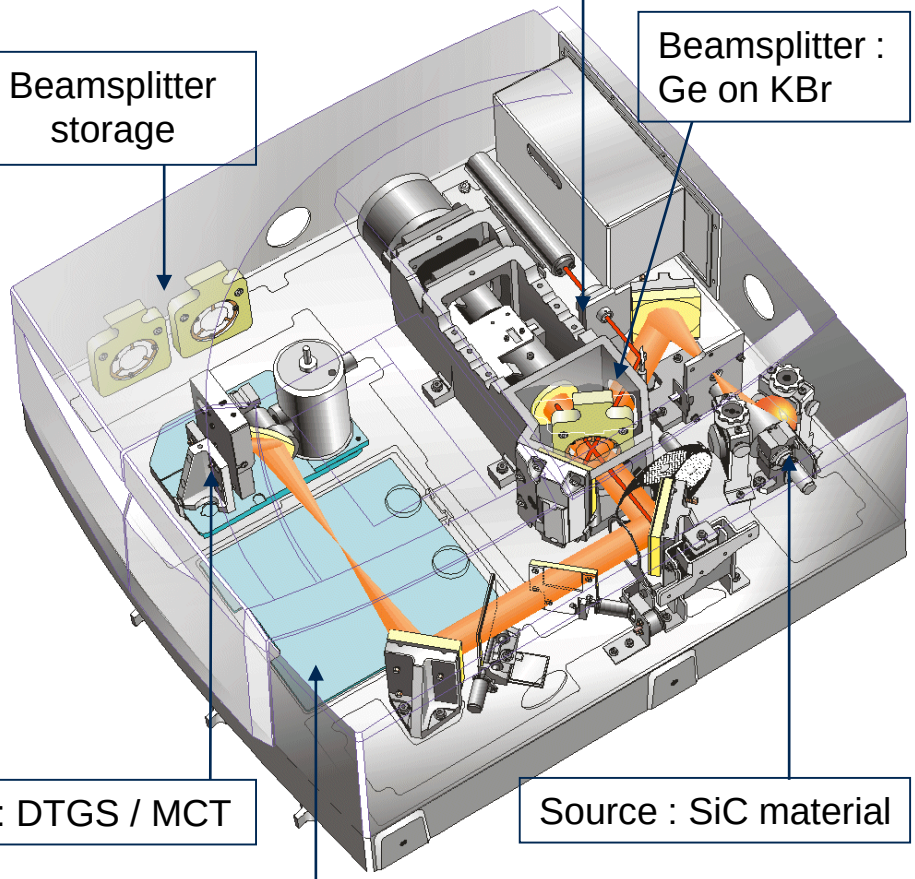


FT-IR measurement

Type of window materials for liquid sample

Material	Comments	Max. Temp. in air (℃)	Transmission Range (cm^{-1})	pH Range	Solvents which attack material
AgCl	Silver Chloride	200	25000-360	N/A	Complexing agents
Al_2O_3	Sapphire	1700	20000-1780	1-14	acids, alkalies
AMTIR	SeAsGe glass, brittle	300	1100-593	1-9	alkalies
BaF_2	Barium Fluoride	500	65000-700	5-8	NH_4^+, salts, acids
CaF_2	Calcium Fluoride	900	70000-1100	1-9	NH_4^+, salts, acids
CsI	Cesium Iodide	200	40000-200	N/A	Lower alcohols “wet” solvents
Diamond	Diamond	750	40000-2500 & 1667-33	1-14	$K_2Cr_2O_7$, H_2SO_4
Ge	Germanium	270	5500-625	1-14	H_2SO_4 aqua regia
KBr	Potassium Bromide	300	40000-400	N/A	Lower alcohols “wet” solvents
KRS-5	Thallium Bromide/Thallium Iodide, extremely toxic!	200	17900-204	5-8	Complexing agents
NaCl	Sodium Chloride	400	40000-625	N/A	Lower alcohols “wet” solvents
Si	Silicon, strong IR absorbance between 624-590 cm^{-1}	300	8900-624	1-12	HF, HNO_3
SiO_2	Silicon Dioxide (Quartz)	1200	40000-2500	1-14	HF, some hot acids and bases
ZnS	Zinc Sulfide	300	17000-690	5-12	acids
ZnSe	Zinc Selenide	300	20000-454	5-9	Acid, strong alkalies

670 FT-IR Systems

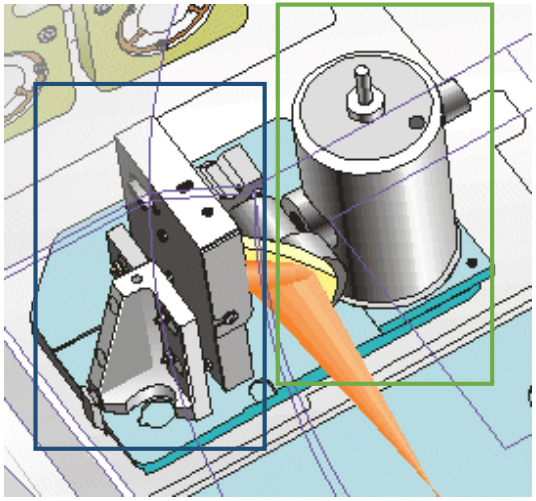


Source and Detector

❖ Source

Nernst Glower	heated rare earth oxide rod (~1500 K)	1-50 μm (mid- to far-IR)
Globar	heated SiC rod (~1500 K)	1-50 μm (mid- to far-IR)
W filament lamp	1100 K	0.78-2.5 μm (Near-IR)
Hg arc lamp	plasma	50 - 300 μm (far-IR)
CO2 laser	stimulated emission lines	9-11 μm

❖ Detector



- **DLaTGS (Deuterated, L-alanine doped TriGlycine Sulfate)**
  Pyroelectric detector (mid IR)
  DLaTGS detector provides linear response over a very wide range of FT-IR throughput, which is beneficial in qualitative and quantitative FT-IR sampling.

- **MCT (Mercuric Cadmium Telluride)**
  Quantum detector
  High MCT sensitivity will produce a large signal in a low-flux measurement. It demonstrates a relatively constant signal versus data-collection speed.

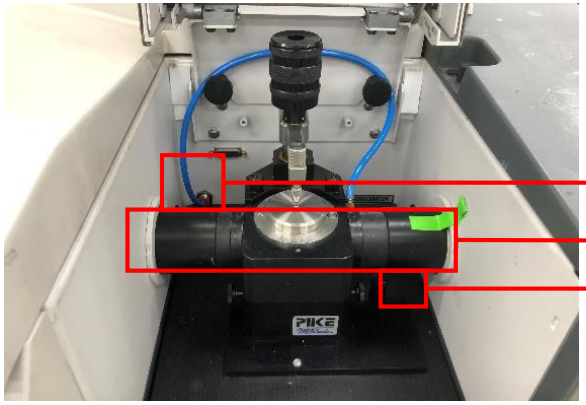
4. FT-IR Operation

ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY

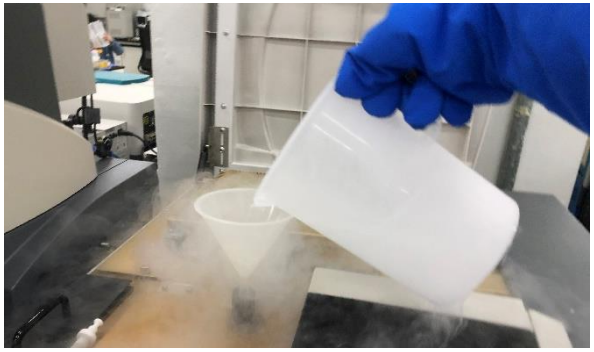
Before FT-IR Measurement

❖ before using the equipment

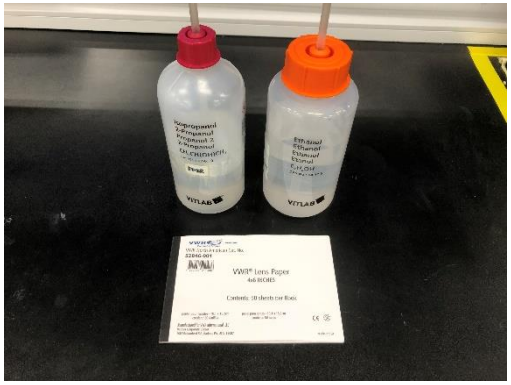
① Check 3 items

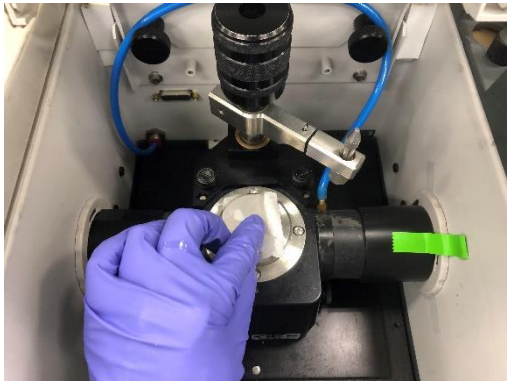


② Fill the LN_2 in the LN_2 Tank
(If you use MCT detector)



③ Clean ATR using lens paper with two kinds of solvent(isopropanol, ethanol)

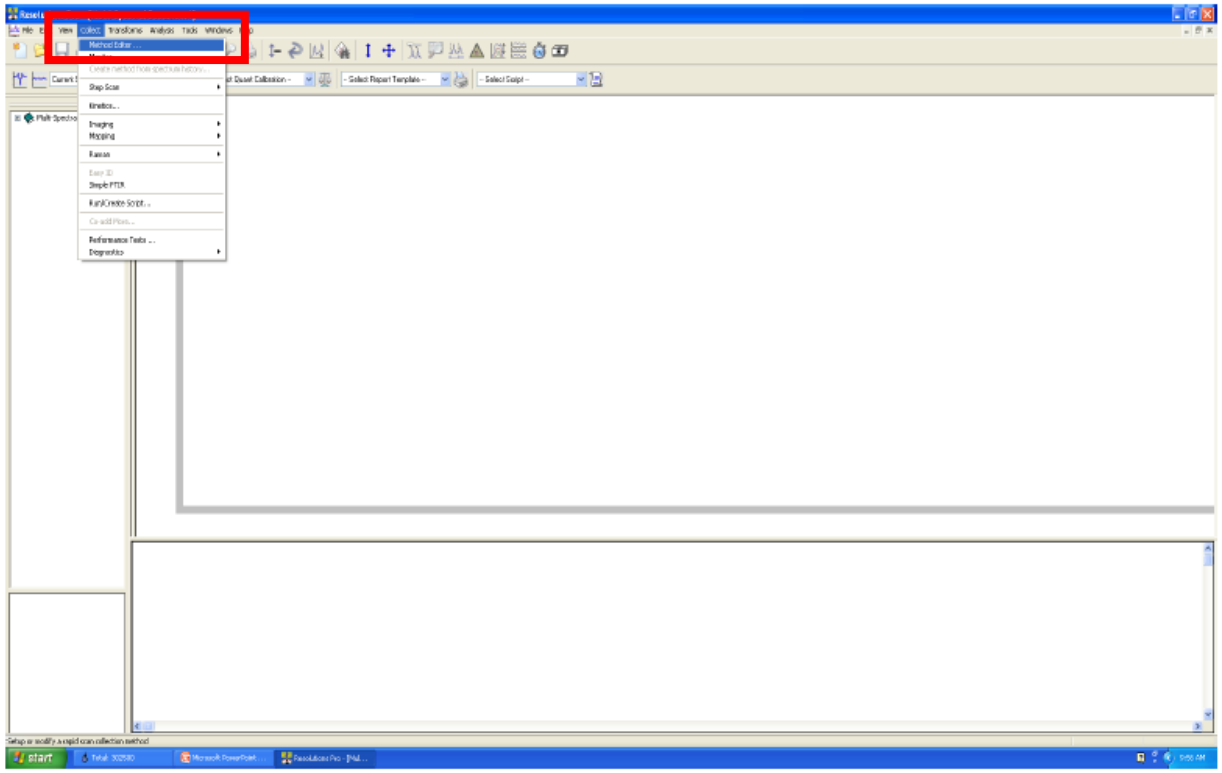




FT-IR Measurement

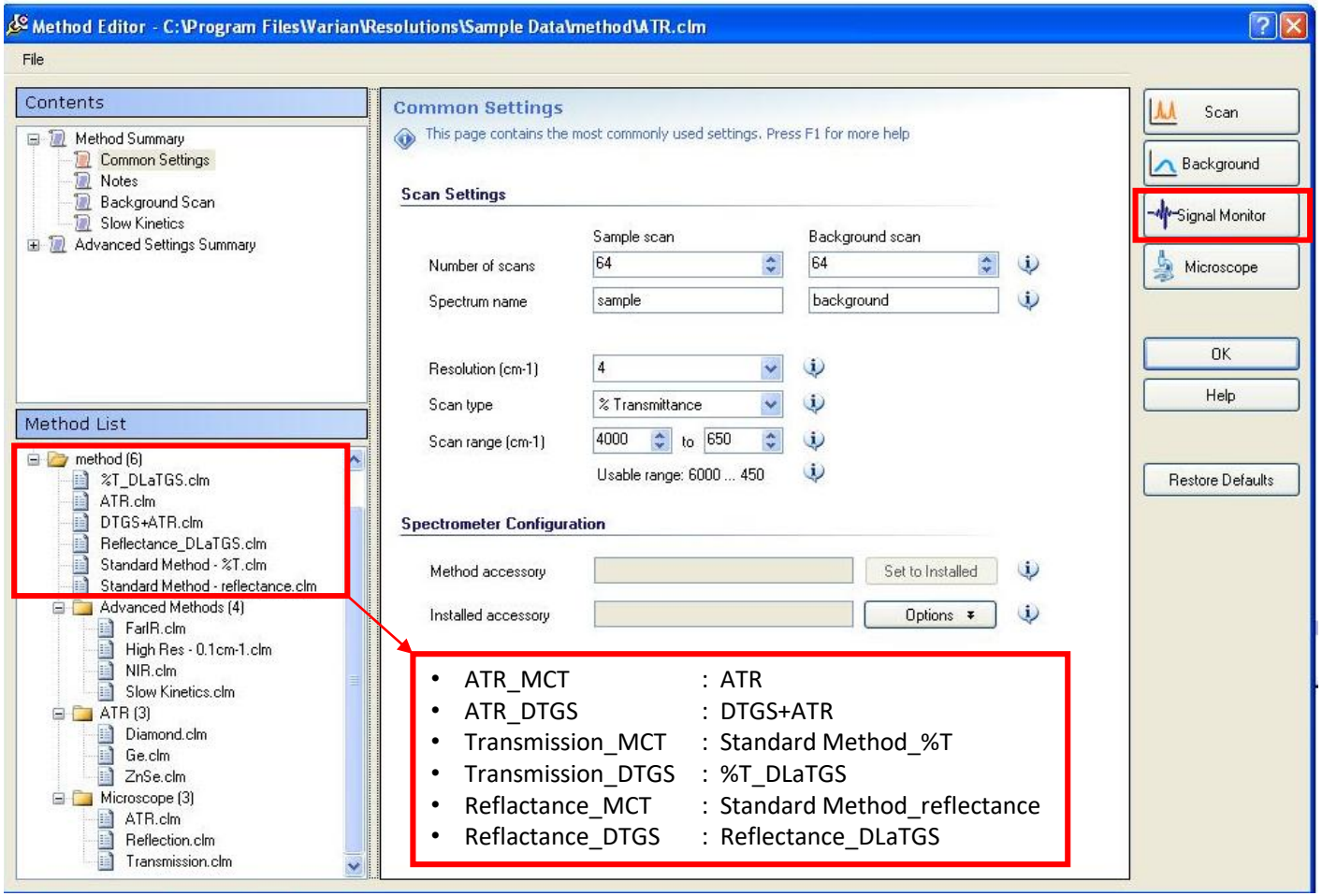
1. Agilent Resolution Pro. START
(Check the knob at the bottom of the equipment, gas line, and the ATR screws.)

2. Collect → Method Editor



FT-IR Measurement

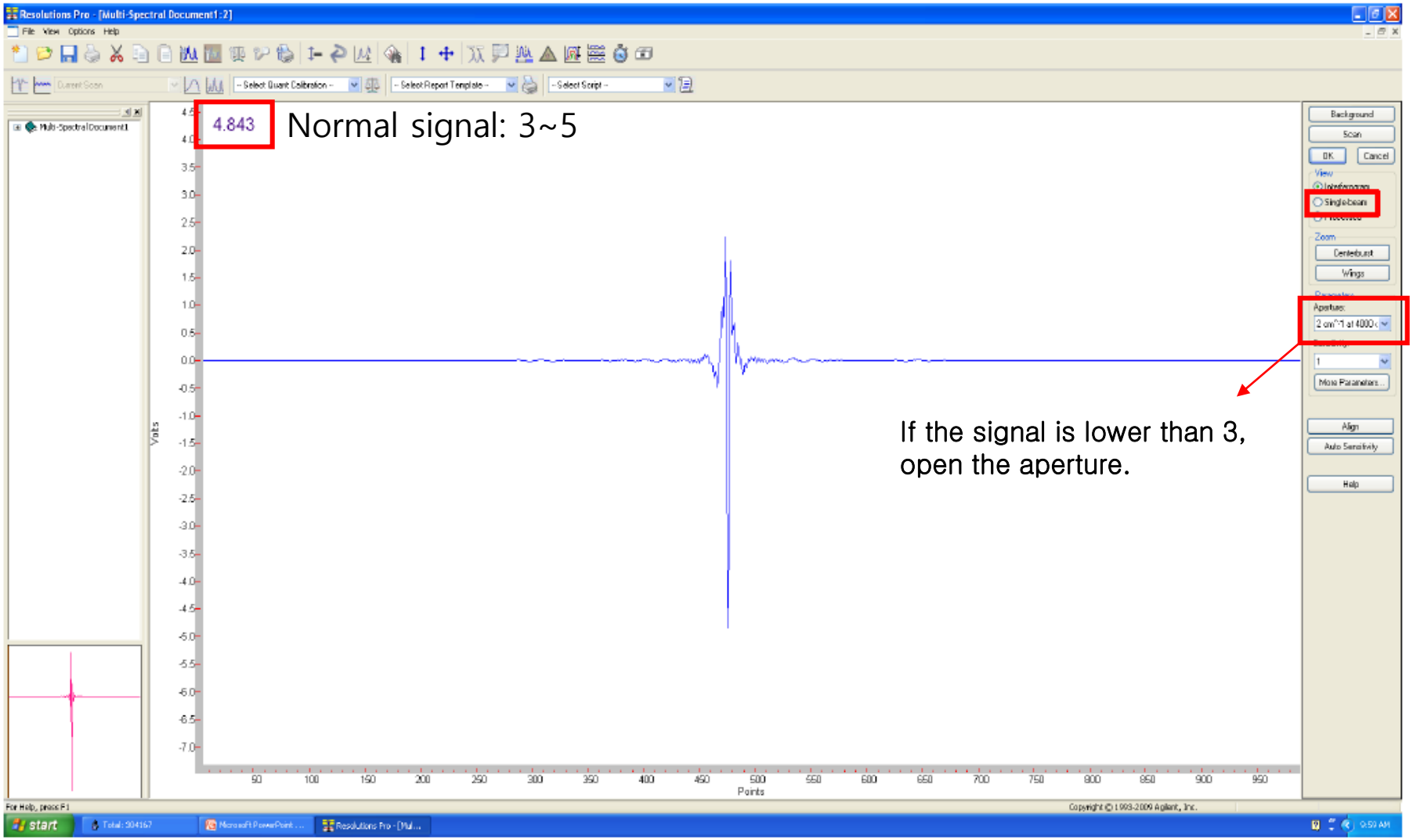
3. Method List → select method(check the scan range)



4. Signal Monitor click

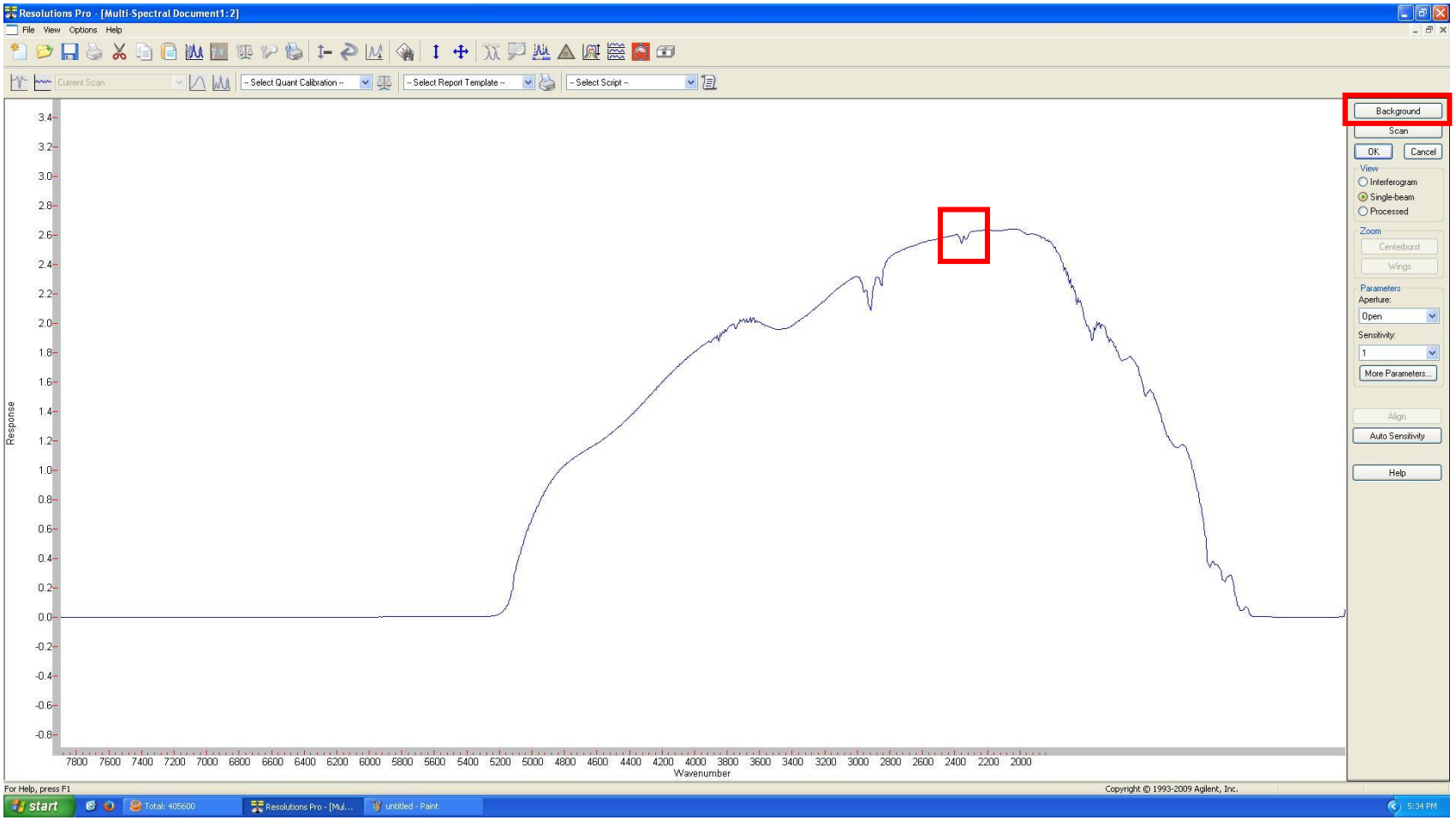
FT-IR Measurement

5. Check the signal click single beam



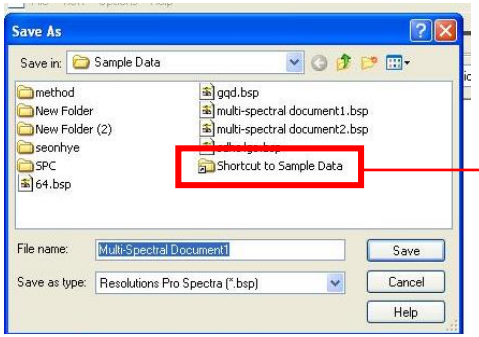
FT-IR Measurement

6. Check the CO_2 peak(2350cm−1) → Click background



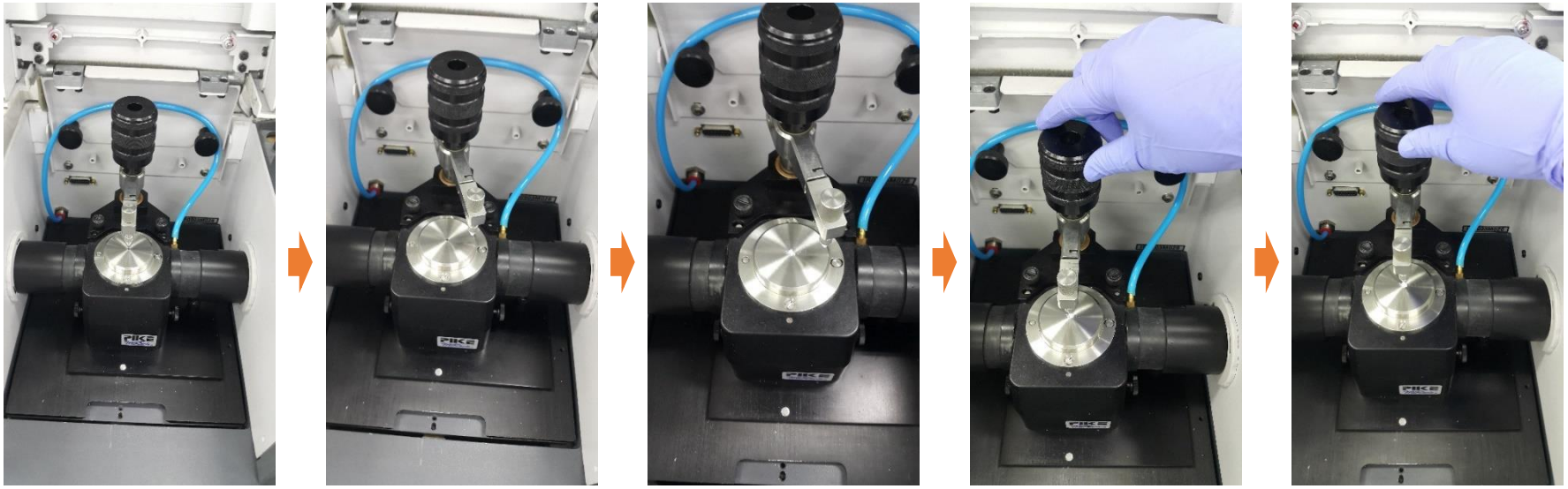
FT-IR Measurement

7. Save the file



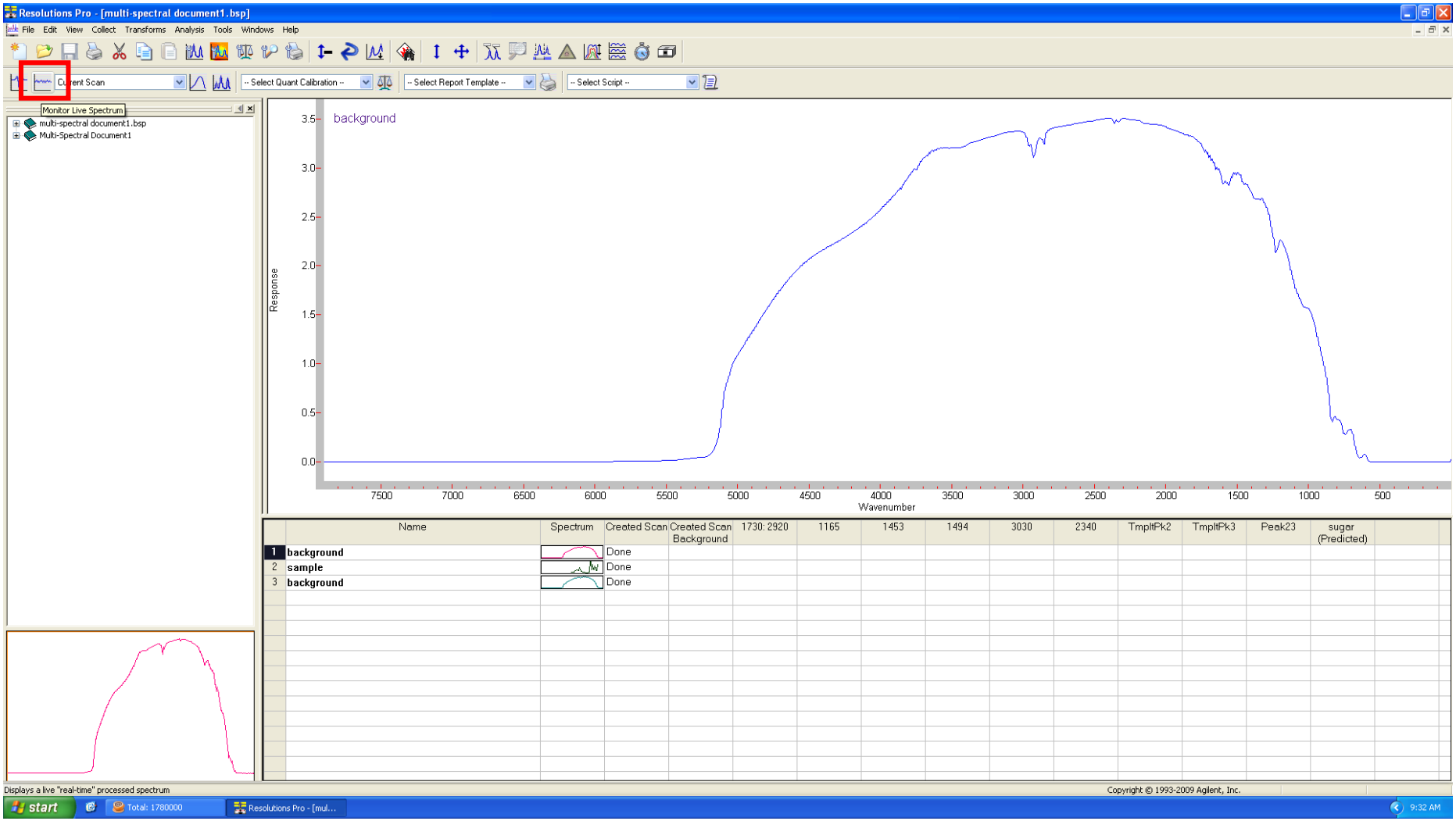
Shortcut to sample data(Desk top) →
Lab/Professor name → user name → date

8. Load the sample and press



FT-IR Measurement

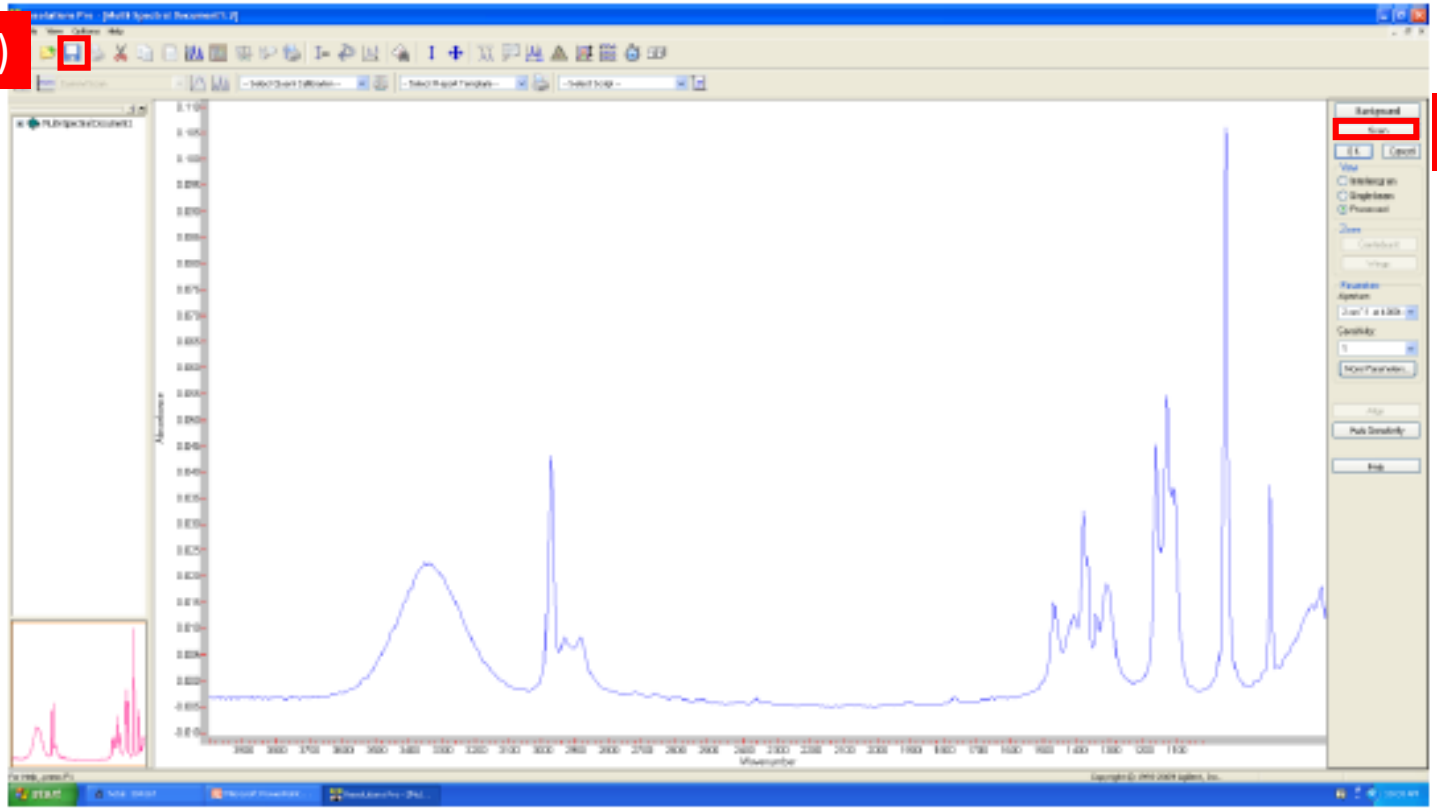
9. Monitor live spectrum click



FT-IR Measurement

10. Click Scan → Change the sample name → Click on save icon

(3)



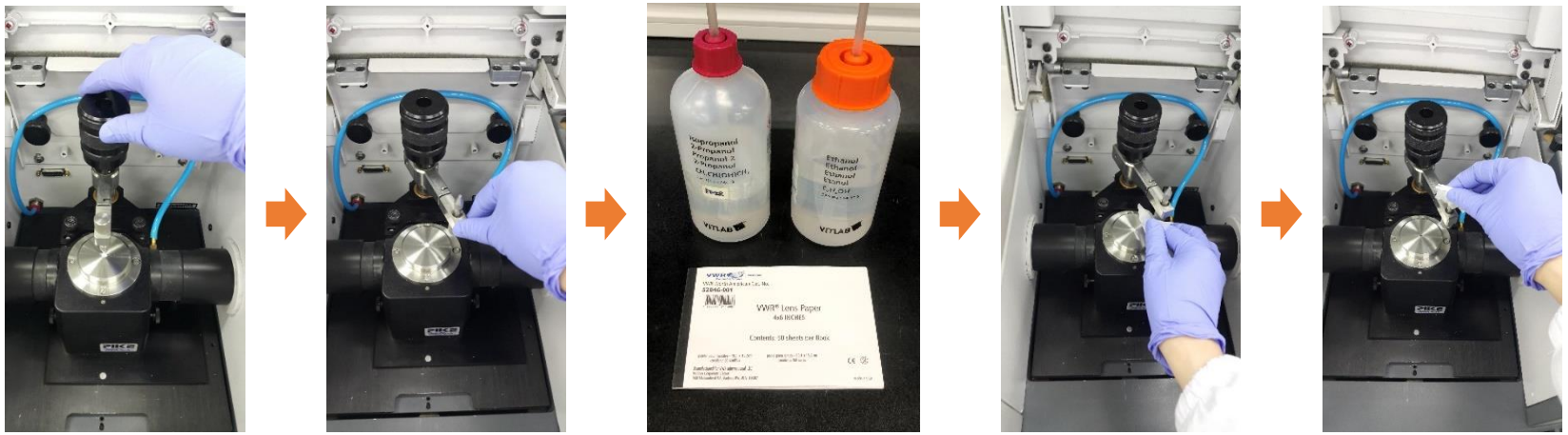
(1)

(2)

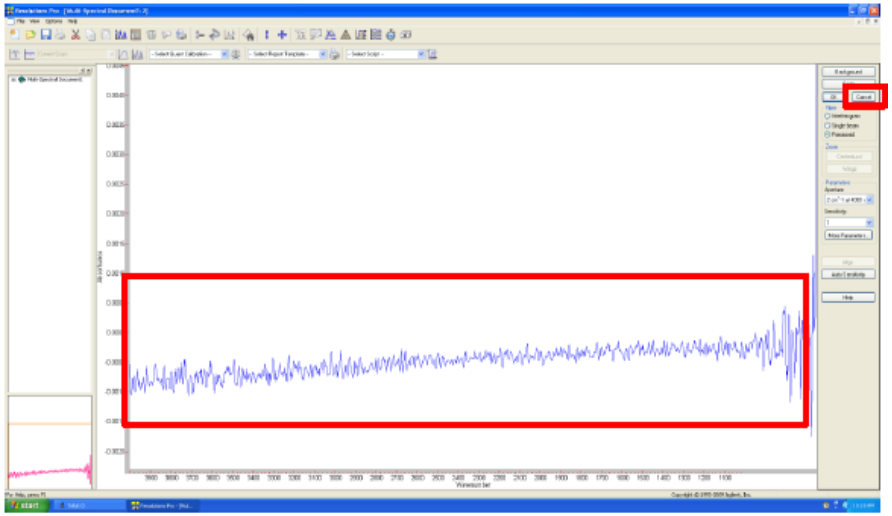
	Name	Spectrum	1730: 2920	1165	1453	1494	3030	2340	TmpItPk2	TmpItPk3	Peak23	sugar (Predicted)	TmpItPk1	Created Scan	Created Scan Background	Interferogram
1	KCM													Done		
2	CM													Done		
3	background													Done		

FT-IR Measurement

11. Clean the ATR using two kinds of solvent



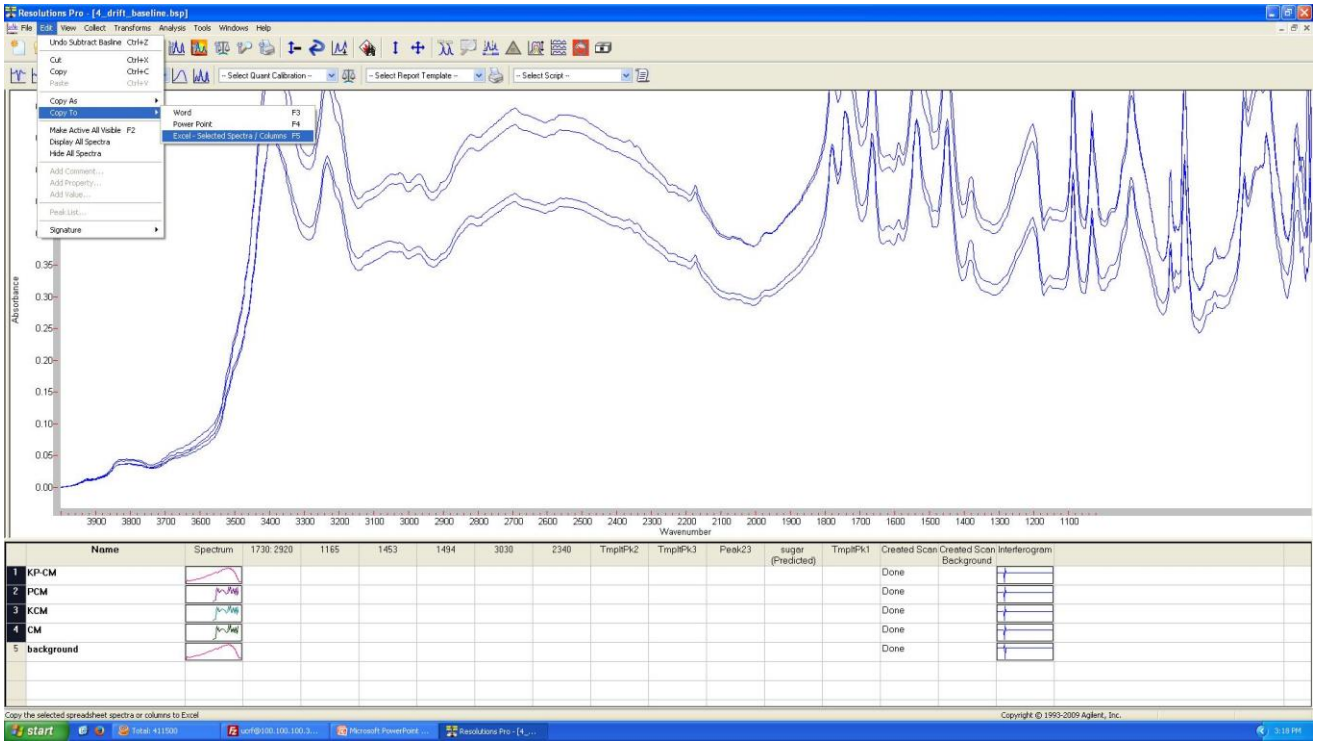
12. Click the remaining sample



(Click monitor live spectrum →
If there is no peak, click cancel)

FT-IR Measurement

13. Select all sample spectrum(Shift + click) → edit → copy to → excel → save



14. Program off
15. Data translation(NAS server)

Cautions

Shutter close
- Signal detection off

Shutter open
- Signal detection on

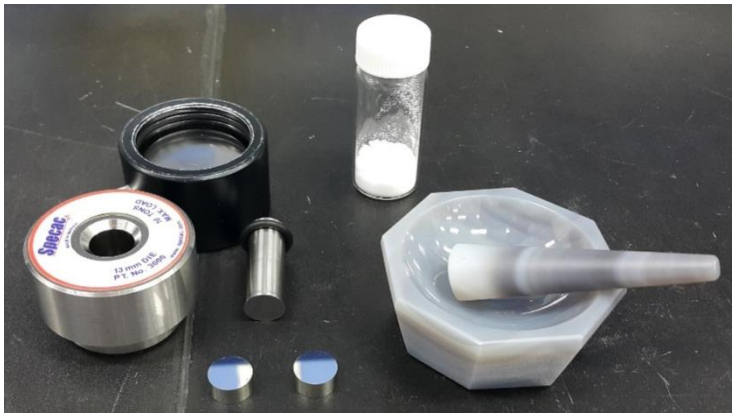
5. Pre-treatment(Use ACC)

-시료 준비

-전처리

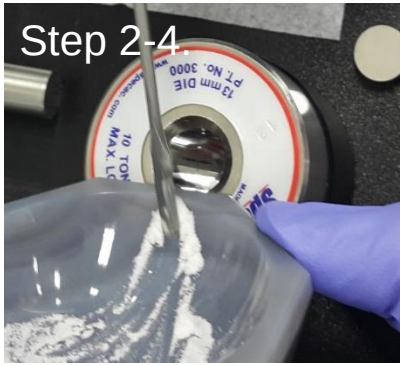
Transmission_powder sample

Preparing KBr Pellets



Step 1. The powder sample and KBr must be ground to reduce the particle size to less than 5 mm in diameter. Otherwise, large particles scatter the infrared beam and cause a slope baseline of spectrum.

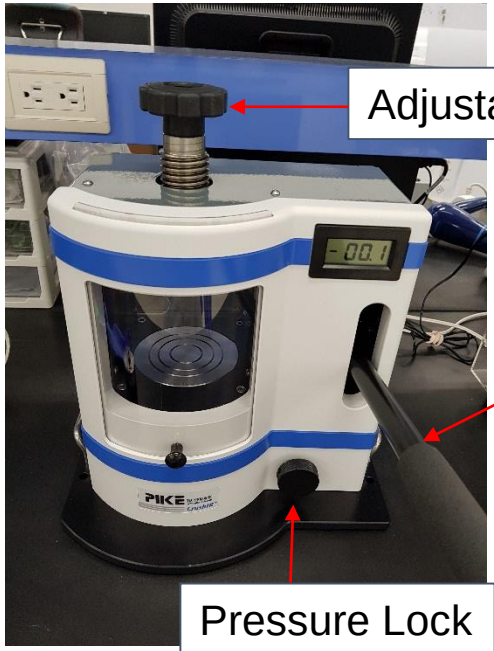
Step 2. Take two stainless steel disks. Place a piece of the precut cardboard on top of one disk and fill the cutout hole with the finely ground mixture.
Put the second stainless steel disk on top.
(Fill the ground sample on more smooth side of disk.)



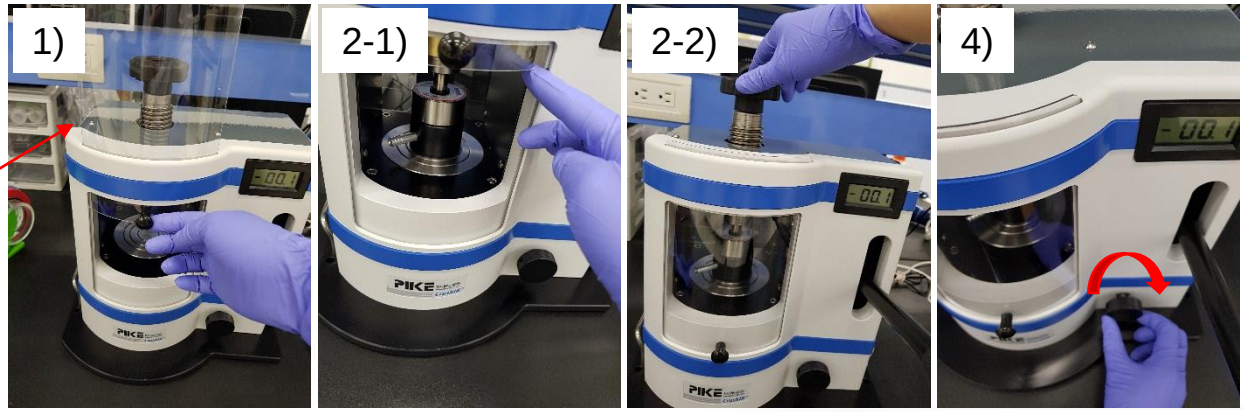
Transmission_powder sample

Preparing KBr Pellets_Pressing pellet

Step 3. Pressing pellet



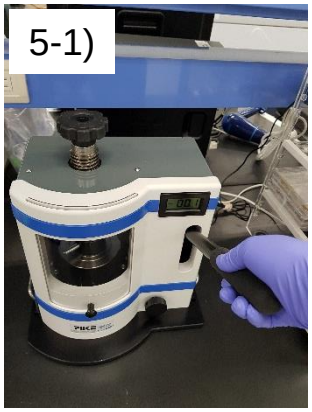
1) Place your pellet press into the CrushIR adjusting the die stop as needed to provide a comfortable amount of clearance.
2) Position the pellet press so that it's top and bottom are centered relative to the die stop and the hydraulic ram.
3) Close the protective shield.
4) Turn the pressure lock/release knob fully clockwise to close.

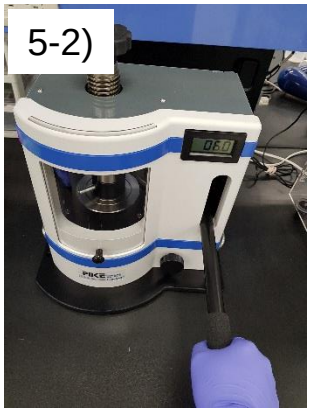


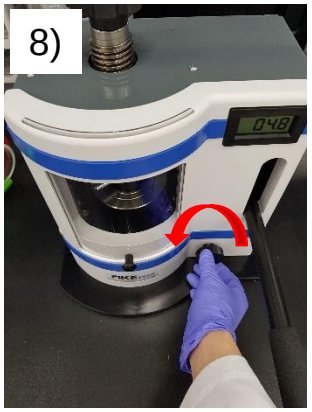
Transmission_powder sample

Preparing KBr Pellets_Pressing pellet

Step 3. Pressing pellet







5) Apply force to the pellet press by pumping the press arm up and down.
6) Continue applying force to the pellet press until you reach its maximum rating.

In the case of the PIKE Evacuable Pellet Press, the maximum load is 10 US tons.
WARNING - Never exceed the maximum force rating of the pellet press.

7) Allow the force to stay at the maximum value for about 1 minute.
8) Then release the force by turning the pressure lock/release knob counterclockwise.
9) Open the protective shield and remove the pellet press to extract the pellet.

NOTE: KBR POWDER IS SOFT AND COMPRESSIBLE. WHEN MAXIMUM FORCE IS APPLIED TO THE POWDER IT IS NORMAL FOR THE DIGITAL READING TO DROP INITIALLY BEFORE IT SETTLES AND REACHES A STEADY-STATE READING.

Transmission_powder sample

Preparing KBr Pellets_Pressing pellet

Step 4. Disassemble the die set and put the pellet onto the sample holder.

Step 5. Please clean the die after you finish your experiment.

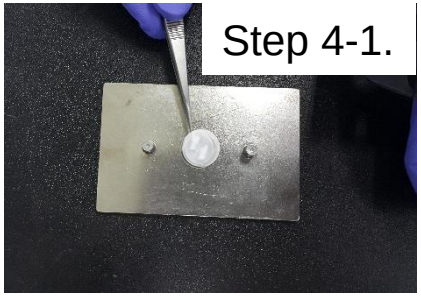
Step 6. Measurement background spectrum.

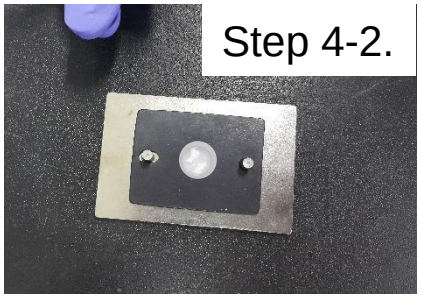
Step 7. Take a small amount of powder sample (about of 0.1-1% of the KBr amount) mix with the KBr powder. Subsequently grind the mixture for 3-5 minutes.

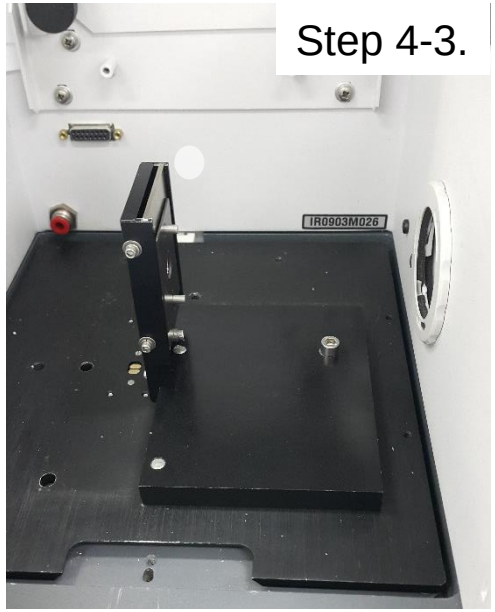
Step 2~6.

Step 8. Measurement sample spectrum.

- ✓ A good KBr pellet is thin and transparent. Opaque pellets give poor spectra and white spots in a pellet indicate that the powder is not ground well enough, or is not dispersed properly in the pellets.







Transmission_liquid sample

Step 1. Choice the window material.(ZnSe or CaF_2)

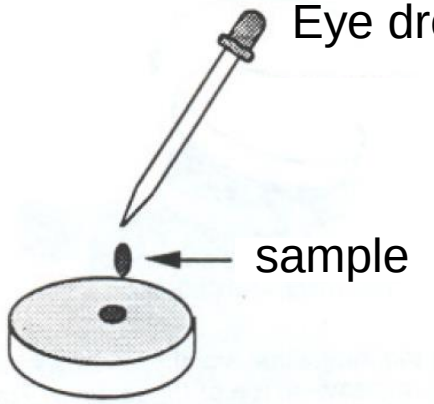
Step 2. Measurement background spectrum with window material.

Step 3. Place a small amount of sample onto the window using the eye dropper or spatula.

Step 4. Once enough sample is deposited on the window, place the other infrared window on top of the sample.

Step 4. Twist the windows together in opposite directions to get rid of air bubbles and to decrease the pathlength.

Step 5. Measurement sample spectrum with sample and window material.

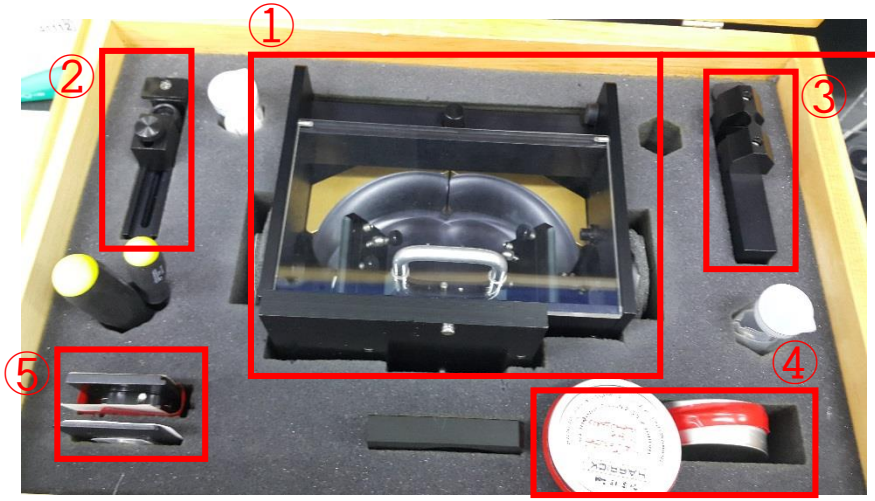


Apply pressure and twist top window

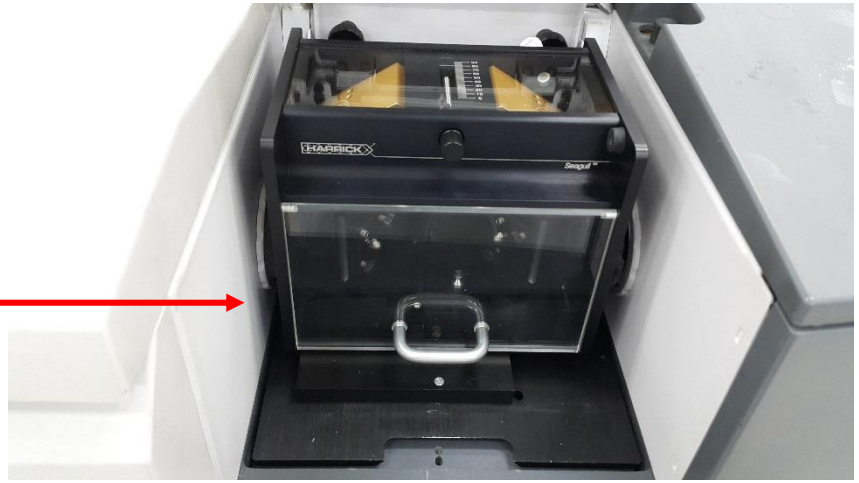
Apply pressure and twist bottom window

Specular Reflectance

PREPARATION OF SEAGULL



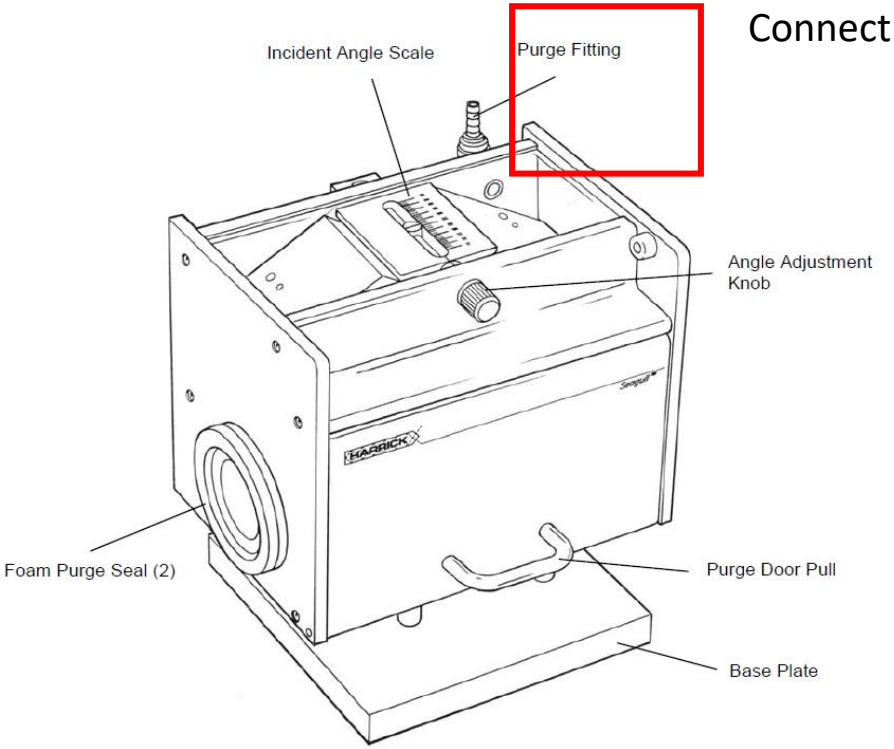
Place Seagull part to FT-IR main body.



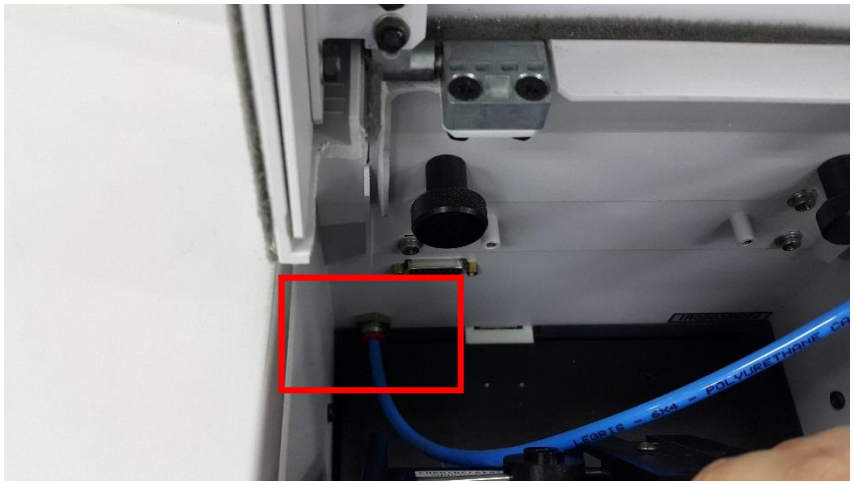
① Seagull part
② Sample holder
③ ATR sample holder
④ ATR crystal(Ge and ZnSe)
⑤ Polarizer

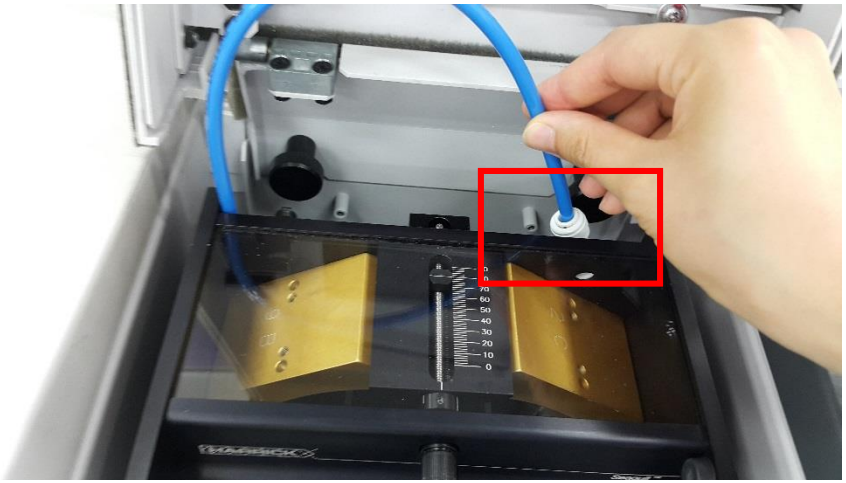
Specular Reflectance

PREPARATION OF SEAGULL



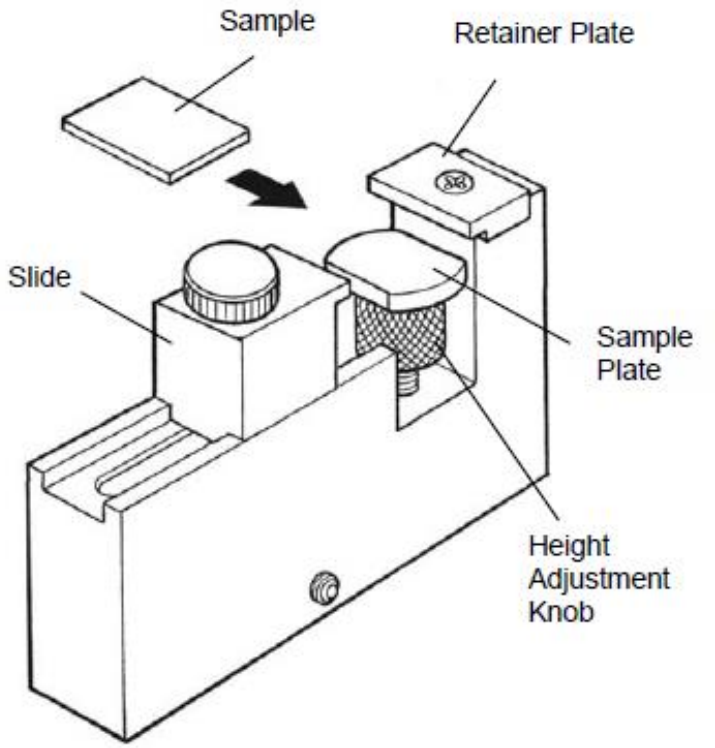
Connect and additional purge line to the fitting on the Seagull.



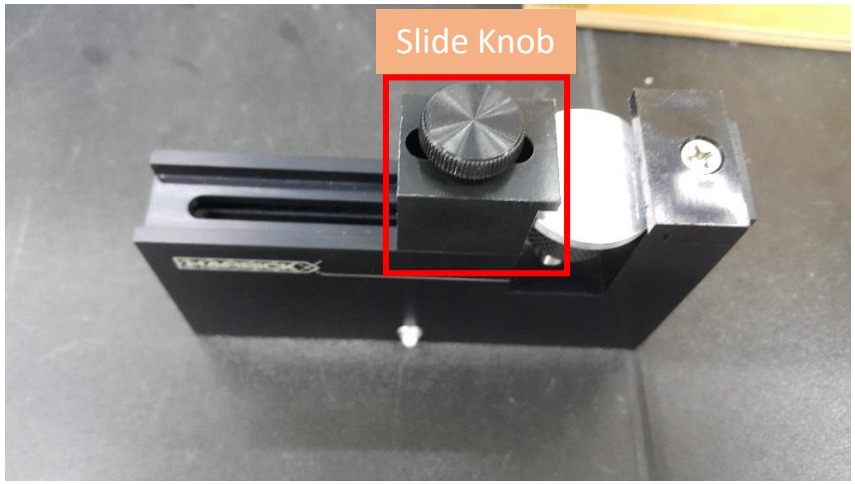


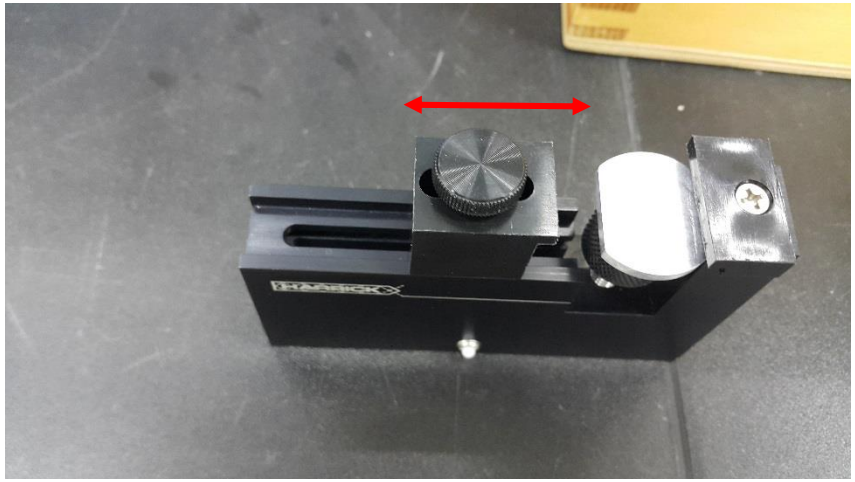
Specular Reflectance

PREPARATION OF THE SAMPLE HOLDER



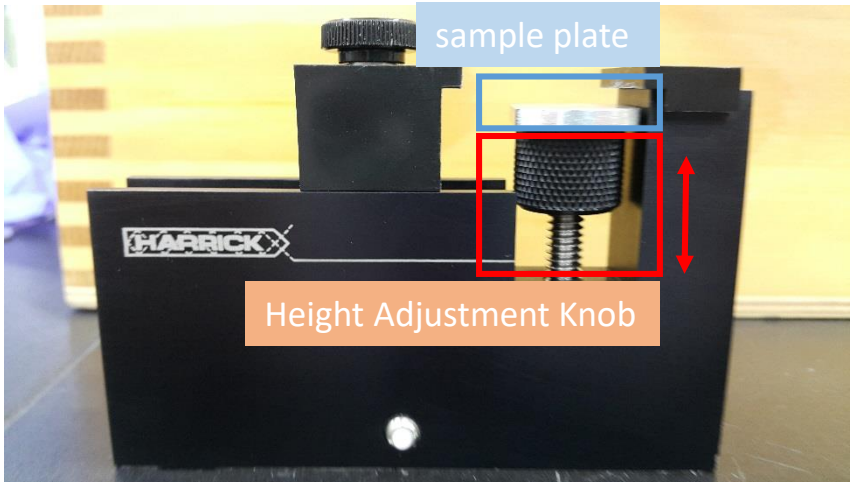
1) Turn the slide knob on the external reflection sample holder clockwise (Figure) until the slide is free to move.





Specular Reflectance

PREPARATION OF THE SAMPLE HOLDER



2) Lower the height adjustment knob by rotating it clockwise.

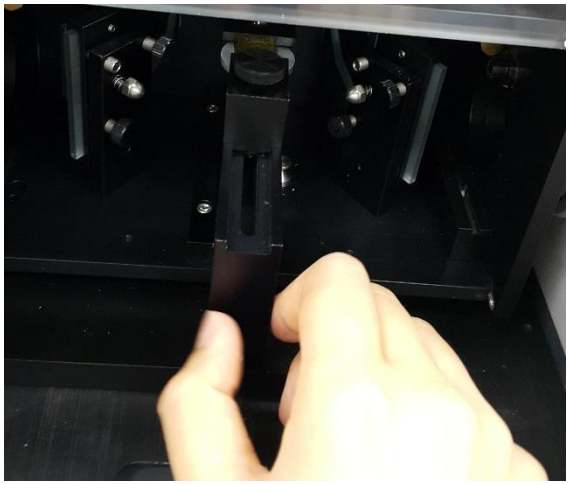
3) Locate the sample plate on the height adjustment knob.

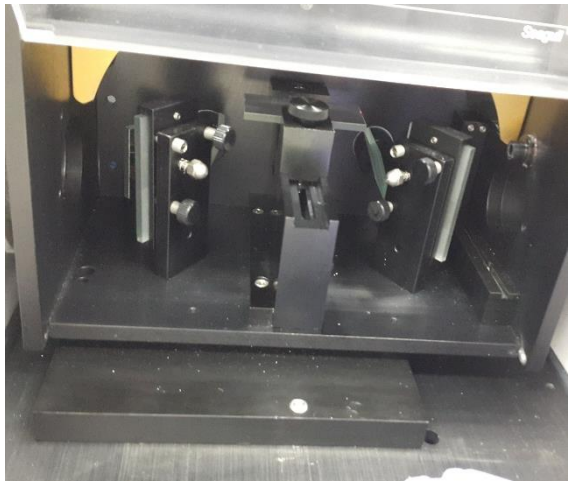
4) Place the reference face up on the sample plate and move the slide so it lightly touches the reference.

5) Secure the slide by turning the slide knob clockwise.

6) Elevate the reference by rotating the height adjustment knob counterclockwise until the mirror is held in place against the retainer plate and slide.

7) Open the purge door and slide the sample holder into the Seagull™.

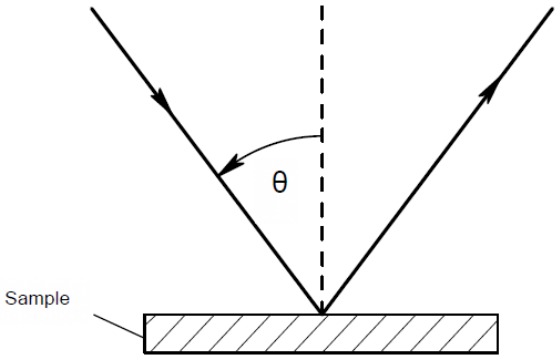


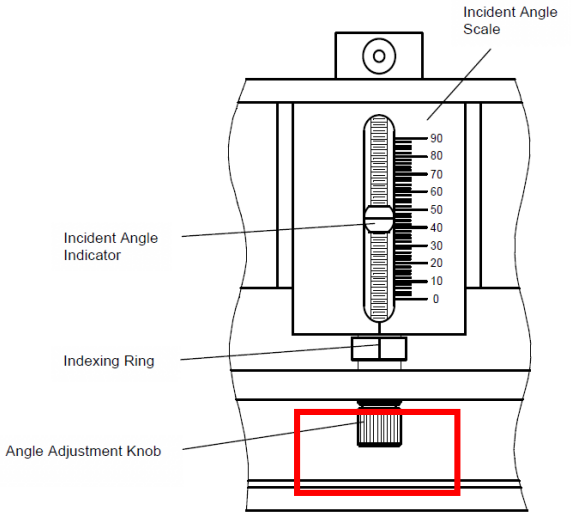


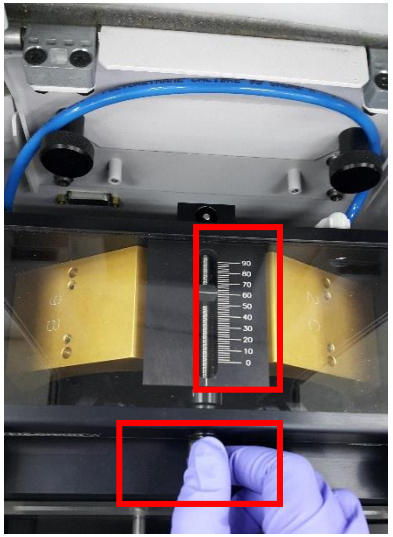
Specular Reflectance

INCIDENCE ANGLE AND REFLECTANCE OPERATION

The incident angle θ (Figure 5) is read from the scale on top of the Seagull.







8) Set the incident angle.

9) Collect the background spectrum.

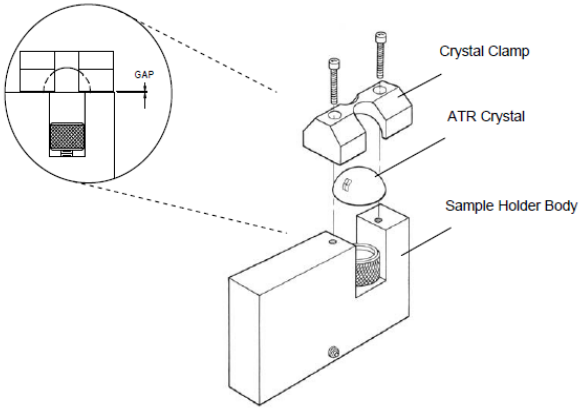
10) Replace the reference with the sample.

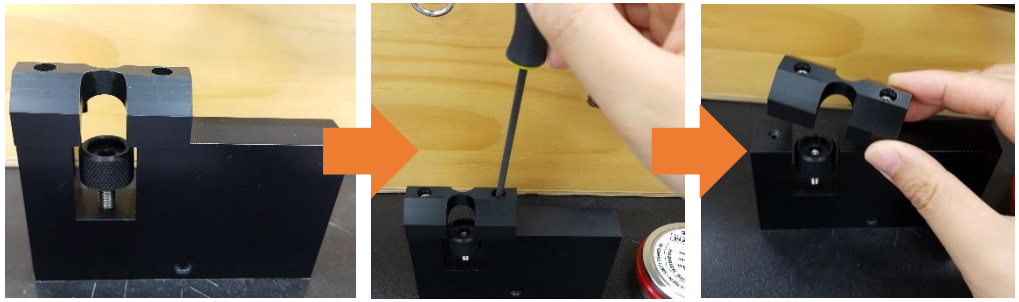
11) Collect the sample spectrum.

Specular Reflectance

ATR SAMPLE HOLDER

The ATR sample holder is used for ATR operation.





MOUNTING THE ATR CRYSTAL

1) Mount the ATR crystal into the ATR sample holder using a 7/64” ball driver undo the two screws on the crystal clamp of the ATR sample holder.

2) Remove the crystal clamp.

3) Carefully place the crystal on the ATR sample holder body as shown in Figure.

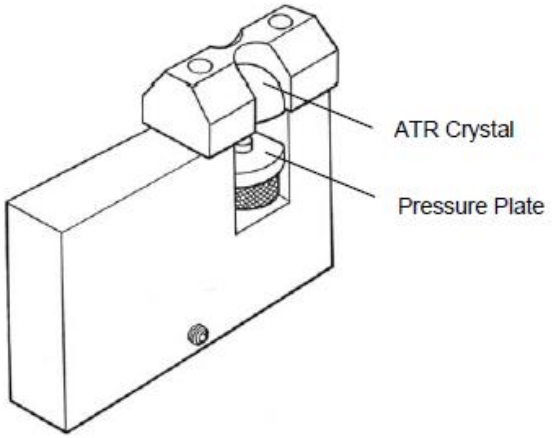
4) Carefully replace the crystal clamp and tighten the screws evenly so the crystal clamp is seated with equal gaps on both ends.

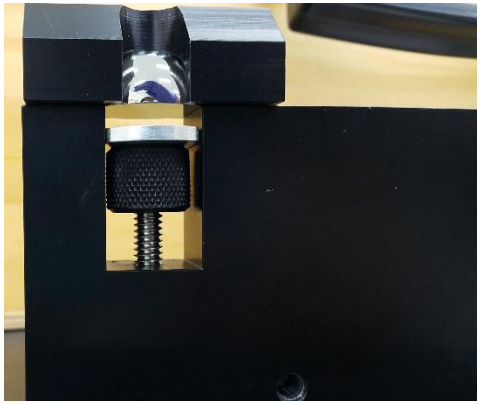
CAUTION:

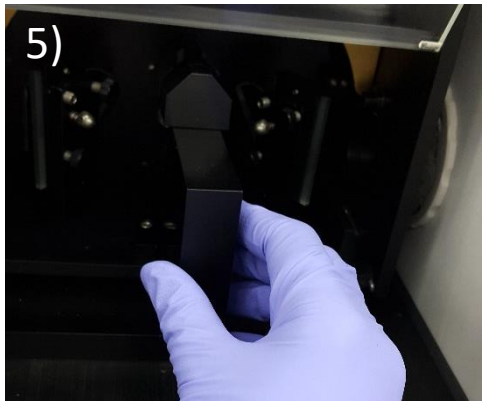
The ATR crystal scratches easily so it should be handled with care. Wipe only with damp lens tissue or cotton swabs.

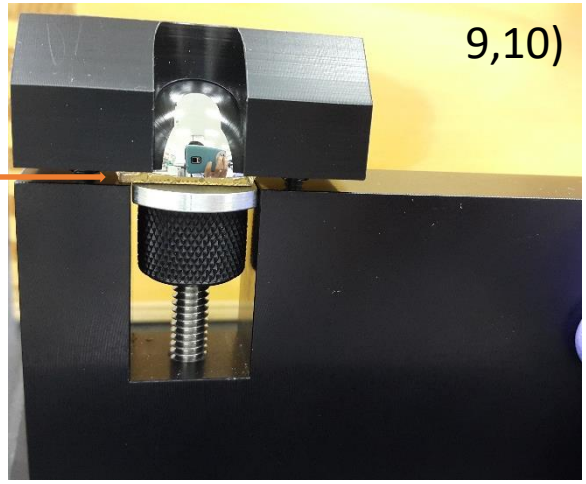
Specular Reflectance

ATR SAMPLE HOLDER







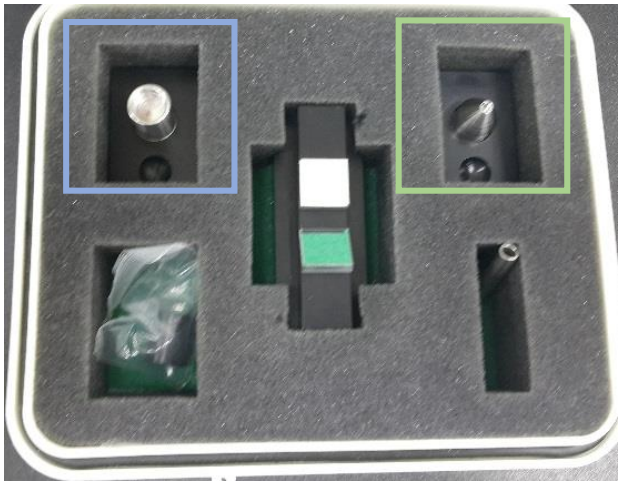


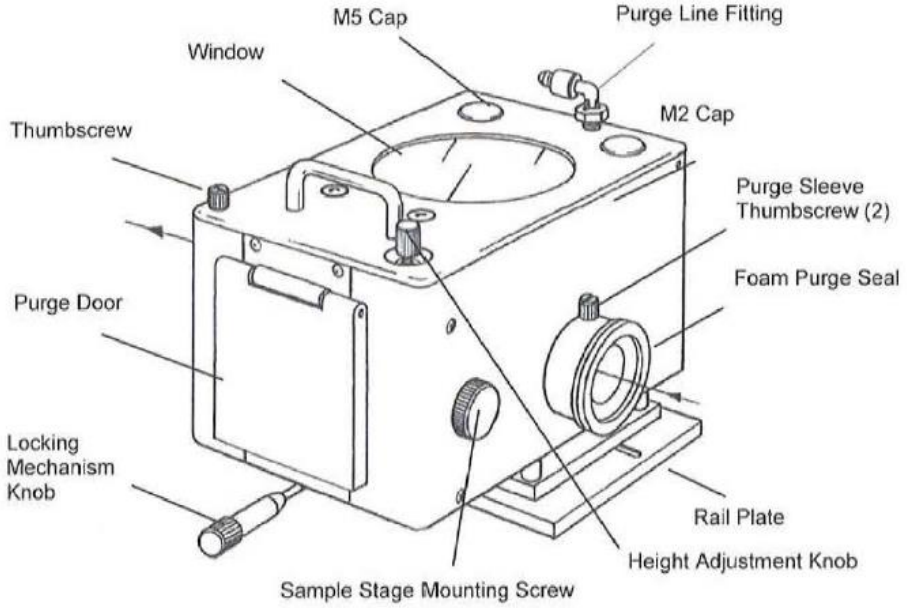
To use the ATR sample holder:

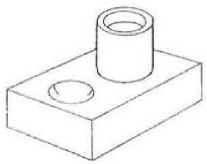
5) Install the ATR sample holder into the Seagull™.
6) Set the desired incident angle.
7) Collect the background spectrum.
8) Locate the pressure plate on the height adjustment knob of the ATR sample holder.
9) Place the sample on the pressure plate.
10) Raise the pressure plate to make contact between the crystal and the sample.
11) Collect the sample spectrum.
12) Clean the crystal with lens paper and IPA.

Diffuse Reflectance

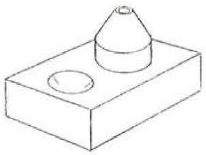
DRIFT(Diffuse Reflectance Infrared Fourier Transform)_Praying Mantis







Standard Sampling Cup
10mm diameter (0.25ml)



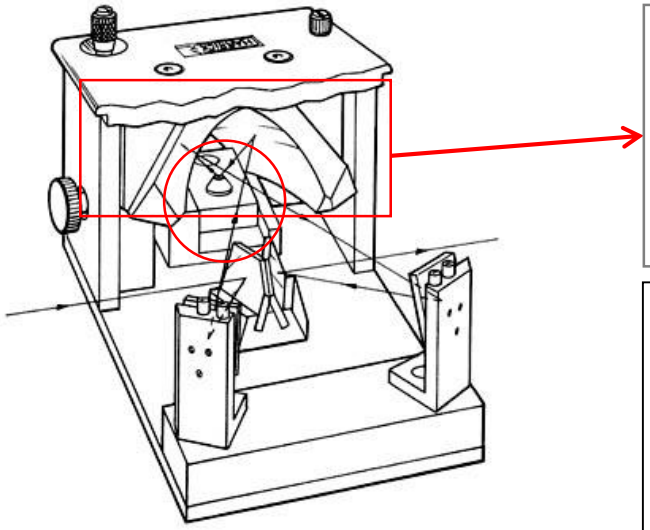
Microsampling Cup
3mm diameter(0.03ml)

Diffuse Reflectance

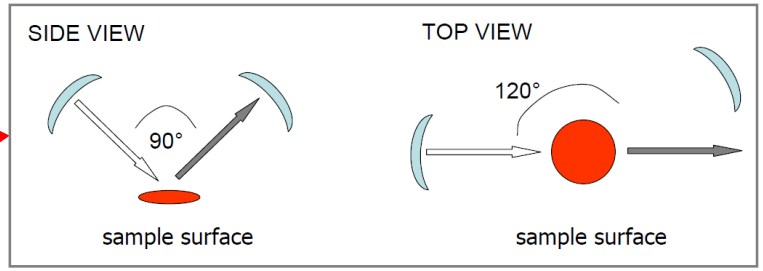
DRIFT(Diffuse Reflectance Infrared Fourier Transform)

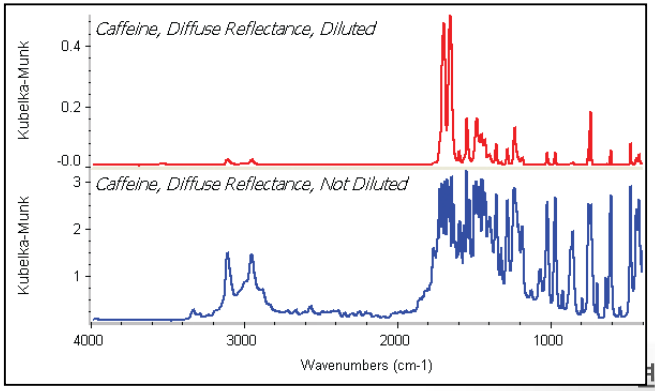
- Factors for high quality DRIFT

Particle Size	Refractive Index	Packing
Samller particles (≤10 μm) improve the quality of spectra.	**Sample dilution** reduce the distorted spectra by Specular reflectance component.	**Loosely packing** maximize IR beam penetration and minimize spectral distortions.



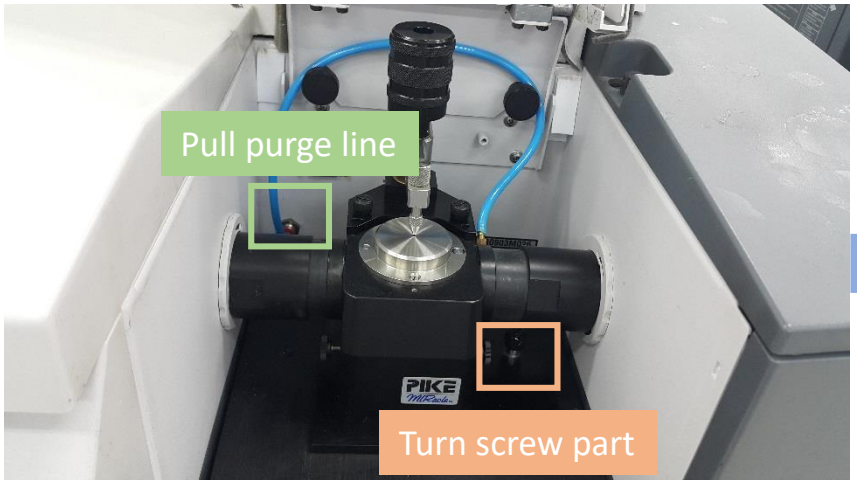
Interior View of the Praying Mantis

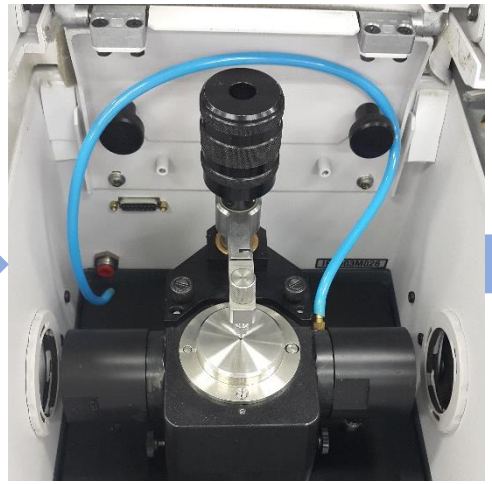




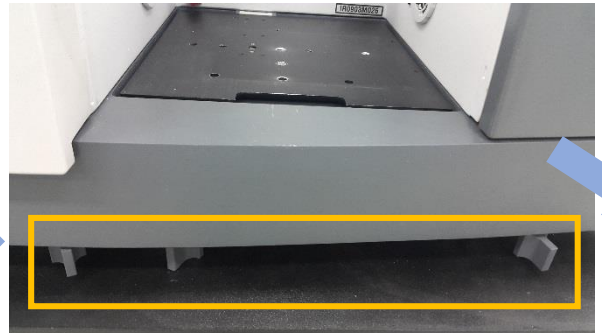
Diffuse Reflectance

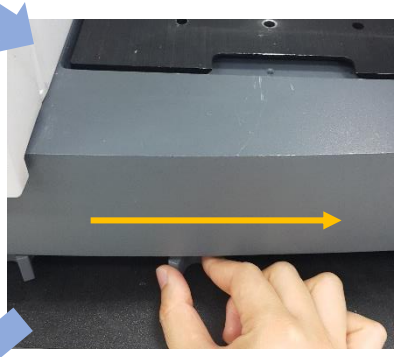
PREPARATION OF PRAYING MANTIS

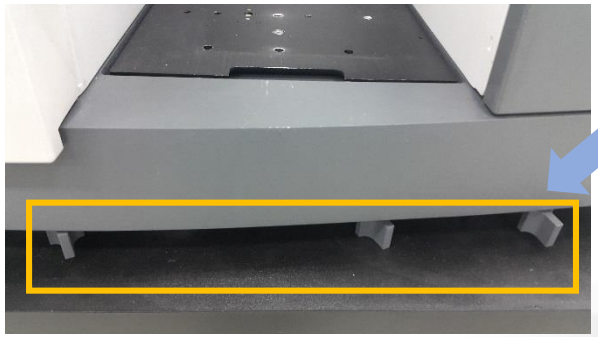




Remove ATR part







The plate can be removed from FT-IR main body when this lever move from the left to the right.

Diffuse Reflectance

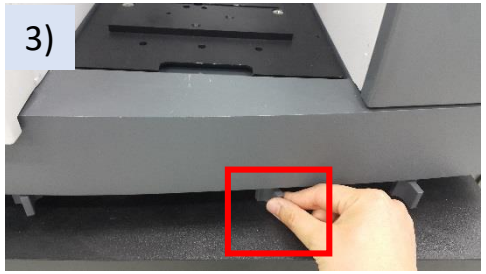
PREPARATION OF PRAYING MANTIS

1) Remove the plate.
2) Change to the rail plate.
3,4) Change the lever position to fix the rail plate.
5) Put the Praying Mantis on the rail plate.
6) Move the Praying Mantis along the rails until the spectrometer focal point is in the center of the attachment.
7) Lock the Praying Mantis in place by tightening the locking mechanism knob.
8~10) Extend the purge sleeves until they firmly contact the sides of the sample compartment. Lock the purge sleeves in place with the thumbscrews.

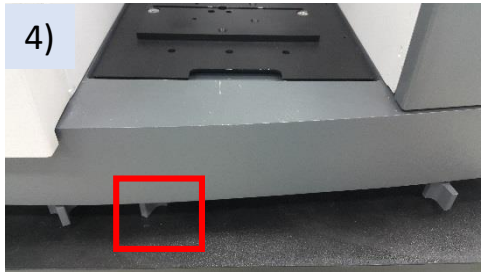
1)

2)

3)



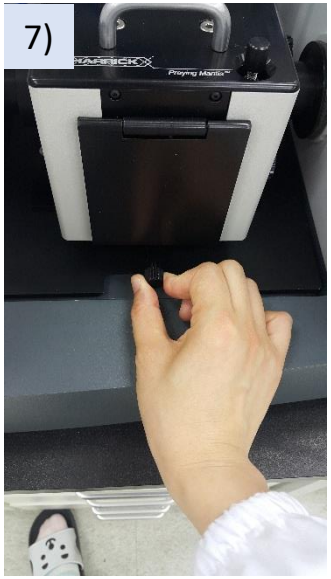
4)



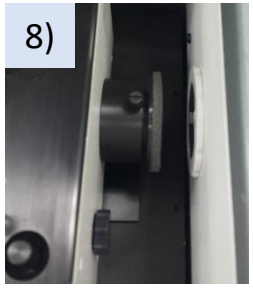
5)

6)

7)



8)



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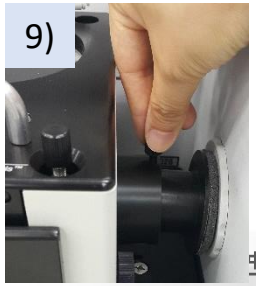

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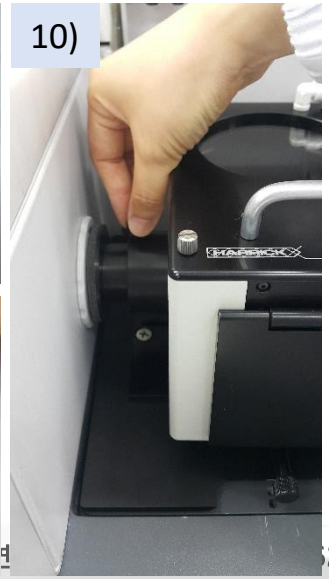
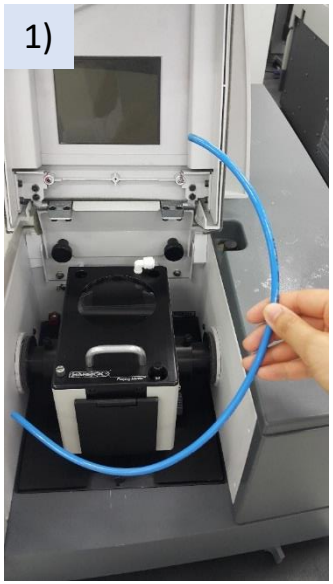


Diffuse Reflectance

PREPARATION OF PRAYING MANTIS

For quicker purging, connect an additional purge line to the fitting on the Praying Mantis.

1)



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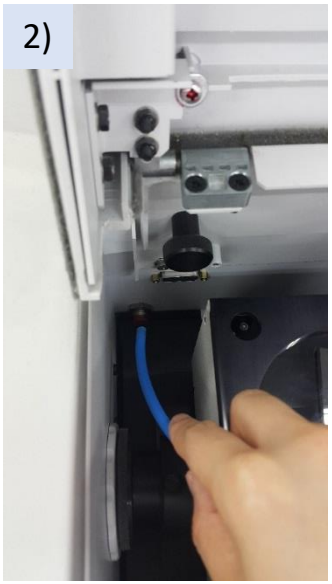
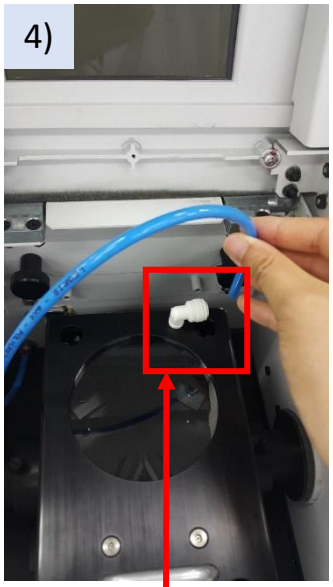


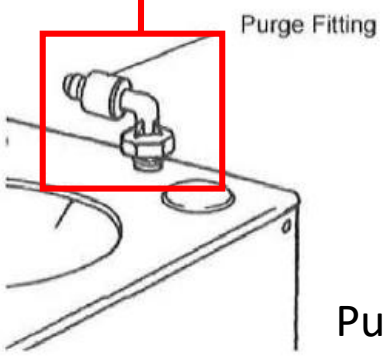
3)

4)



5)

1) Prepare additional line.
2,3) Connect the line to the main body.
4,5) Connect the line to the Praying Mantis part.

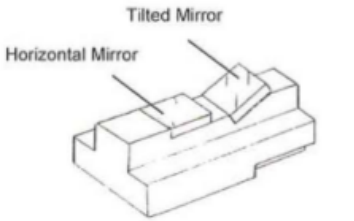


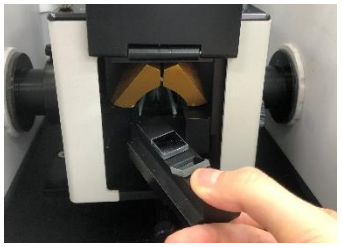
Purge line

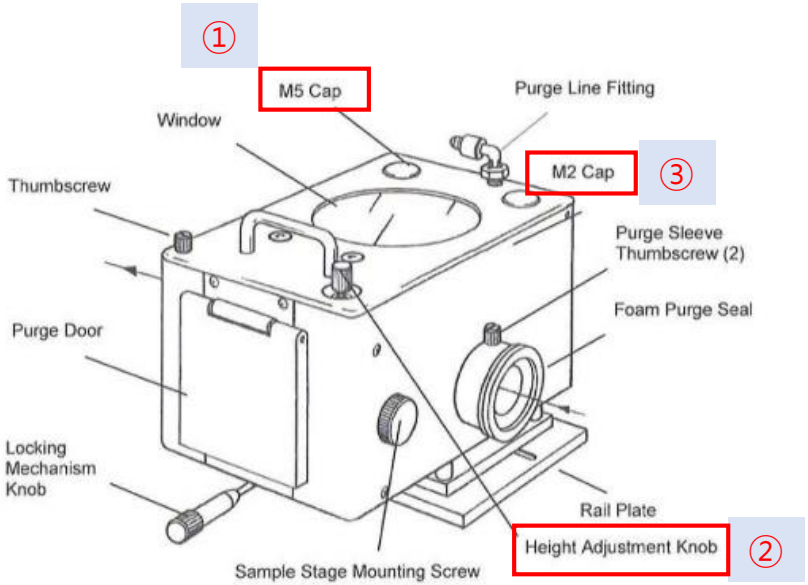
Diffuse Reflectance

PREPARATION OF PRAYING MANTIS

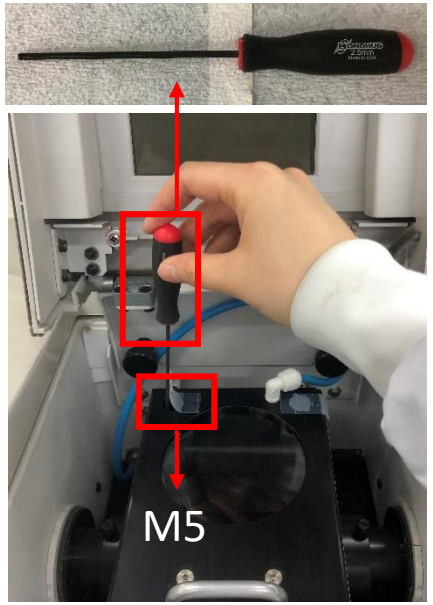
The Praying Manti has been pre-aligned prior to shipment.







2.5mm



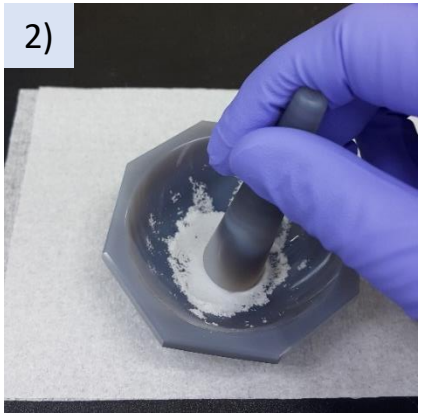
1) Open the door on the front of the attachment. Slide the alignment fixture into the Praying Mantis, with the horizontal mirror going in first. In this orientation, the tilted mirror is in the sampling position
2) Remove the plastic caps over mirrors M2 and M5.
3) Adjust the turn and tilt controls for M5(①) until the signal on the detector is maximized.
4) Adjust the height of the alignment fixture with the height adjustment knob(②) to maximize the signal.
5) Adjust the turn and tilt controls for M2(③). Repeat this sequence until there is no further increase in the signal on the detector.
6) Slide the sample holder. Adjust the height of the alignment fixture with the height adjustment knob(②) to maximize the signal.

Diffuse Reflectance

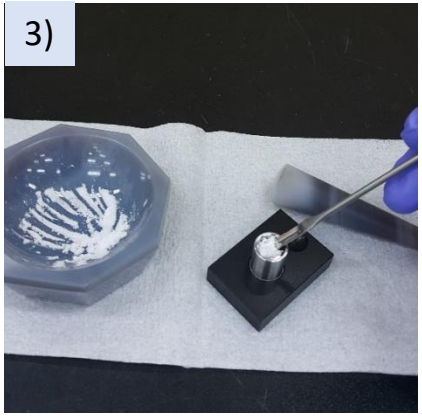
BACKGROUND SPECTRUM

1)

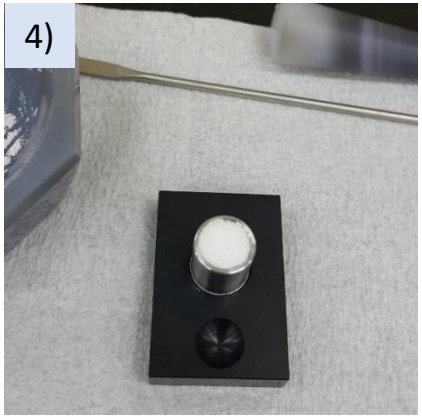
2)



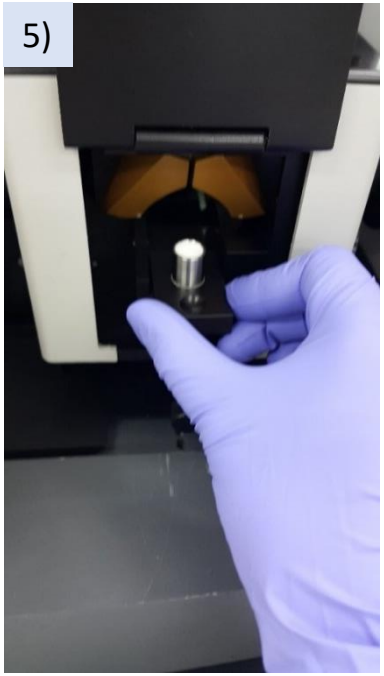
3)



4)



5)



6)

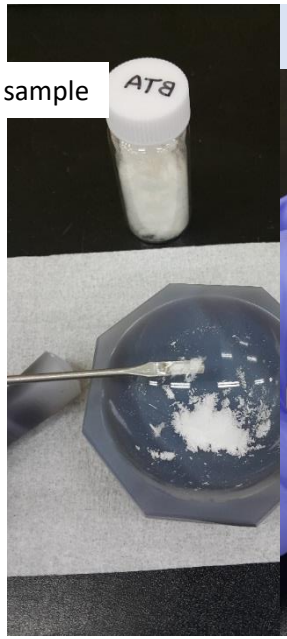
7)

1) Prepare reference material.
2) When the reference material is KBr, grind the powder with mortar and pestle.
The particle size should be smaller than 10 mm (i.e. not exceeding the wavelength of the incident radiation).
3) Overfill one of the sampling cups with the reference material (i.e. KBr).
4) Level off the surface using a flat blade.
5~6) Open the purge door and slide the sampling cup into the Praying Mantis, pushing it in against the stop.
7) Find the center of laser position on sample surface turning the Height adjustment knob.
8) Measure background spectrum.

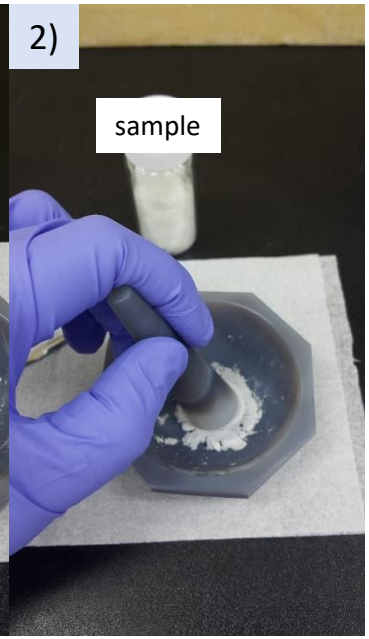
Diffuse Reflectance

SAMPLE SPECTRUM

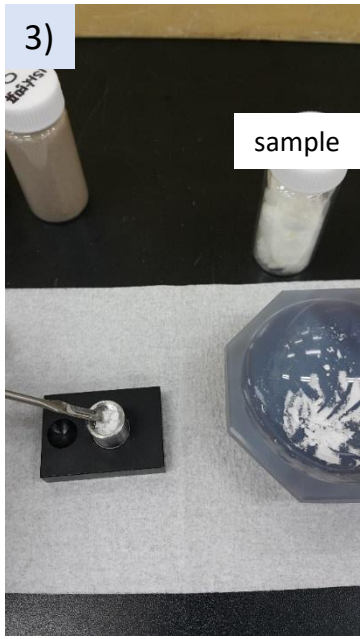
1)



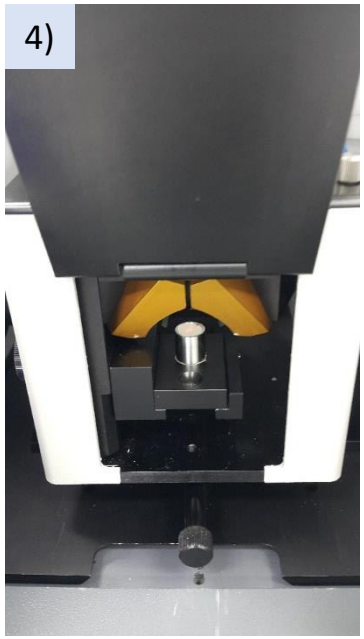
2)



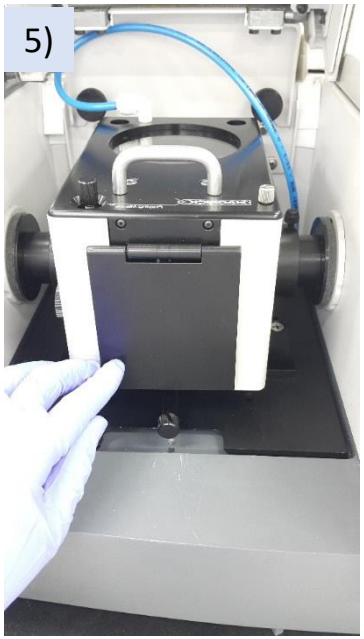
3)



4)



5)



1) Add sample to reference material(i.e. KBr).
2) Grind the sample with reference material.
If the sample Is a strong absorber it may need to be diluted (approximately 1~5%) In a nonabsorbent reference matrix.
3) Overfill one of the sampling cups with the sample and level off the surface using a flat blade.
4) Open the purge door and slide the sampling cup into the Praying Mantis, pushing it in against the stop.
5) Close the purge door.
6) Measure sample spectrum.

6. Microscope

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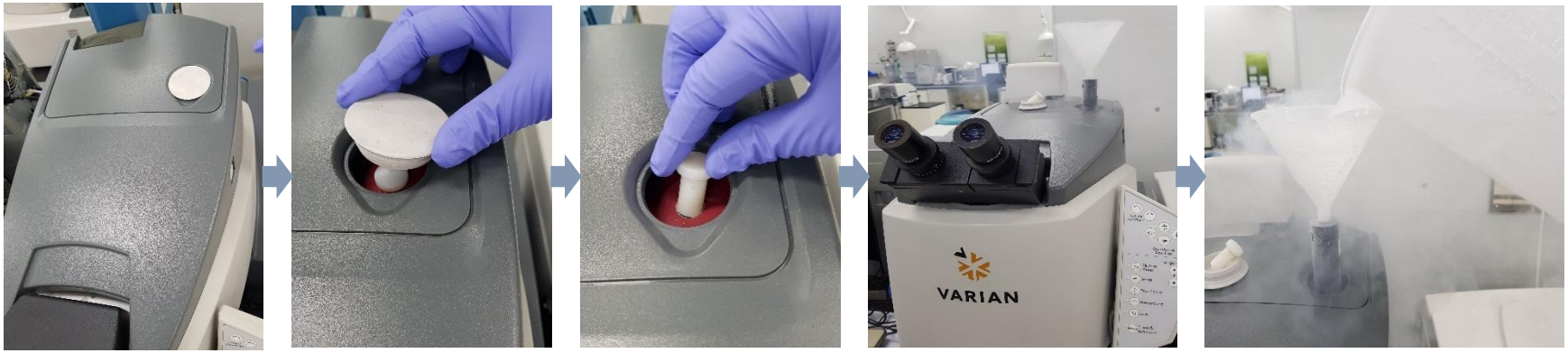
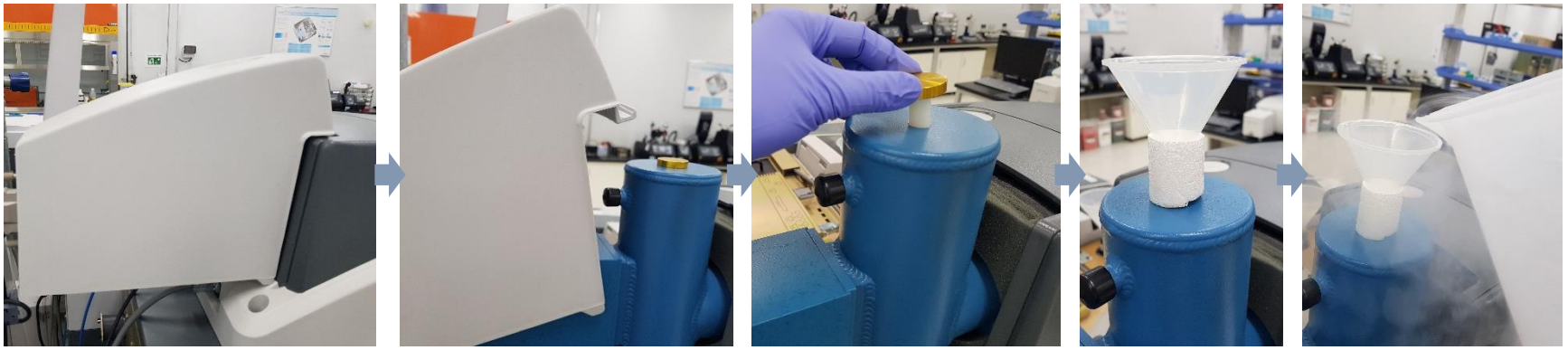
Measurement_FT-IR Microscope

- **Fill the detector with Liquid Nitrogen.**

1) Microscope MCT detector(for single spectrum) need about 500mL liquid nitrogen.



2) FPA detector(for image scan) need about 1L liquid nitrogen.

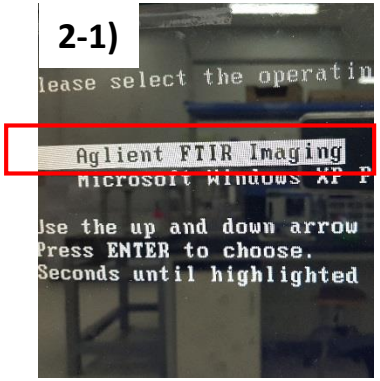


Measurement_FT-IR Microscope

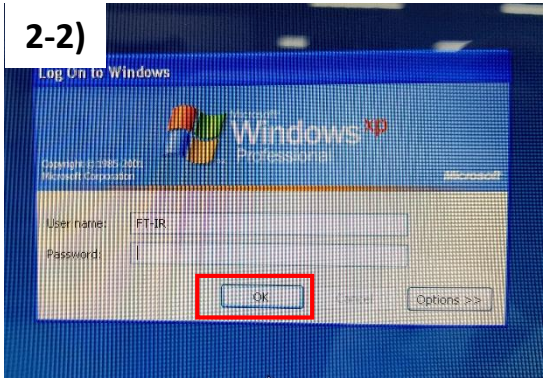
- **Restart the computer and Switch on the microscope part.**

1) Select Agilent FTIR Imaging.
2) Click OK on Long On to Windows.
3) Switch on the microscope part(backside of IR microscope).
4) Switch on the FPA detector(only for the IR image scan).
5) Switch on the Joy stick for the stage control.
6) Open the beam line between mainbody and microscope part.

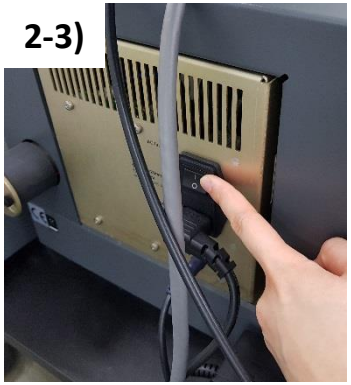
2-1)



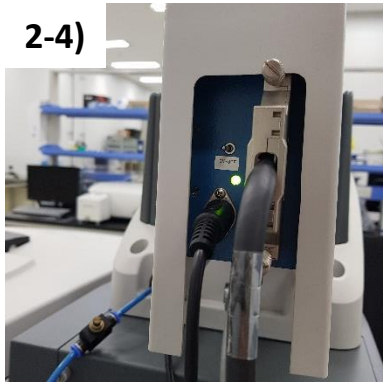
2-2)



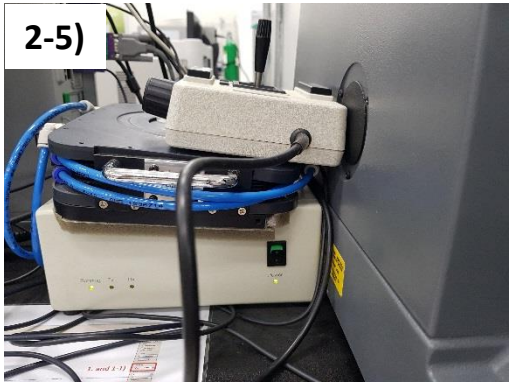
2-3)



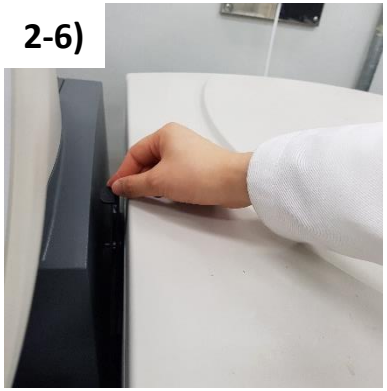
2-4)



2-5)



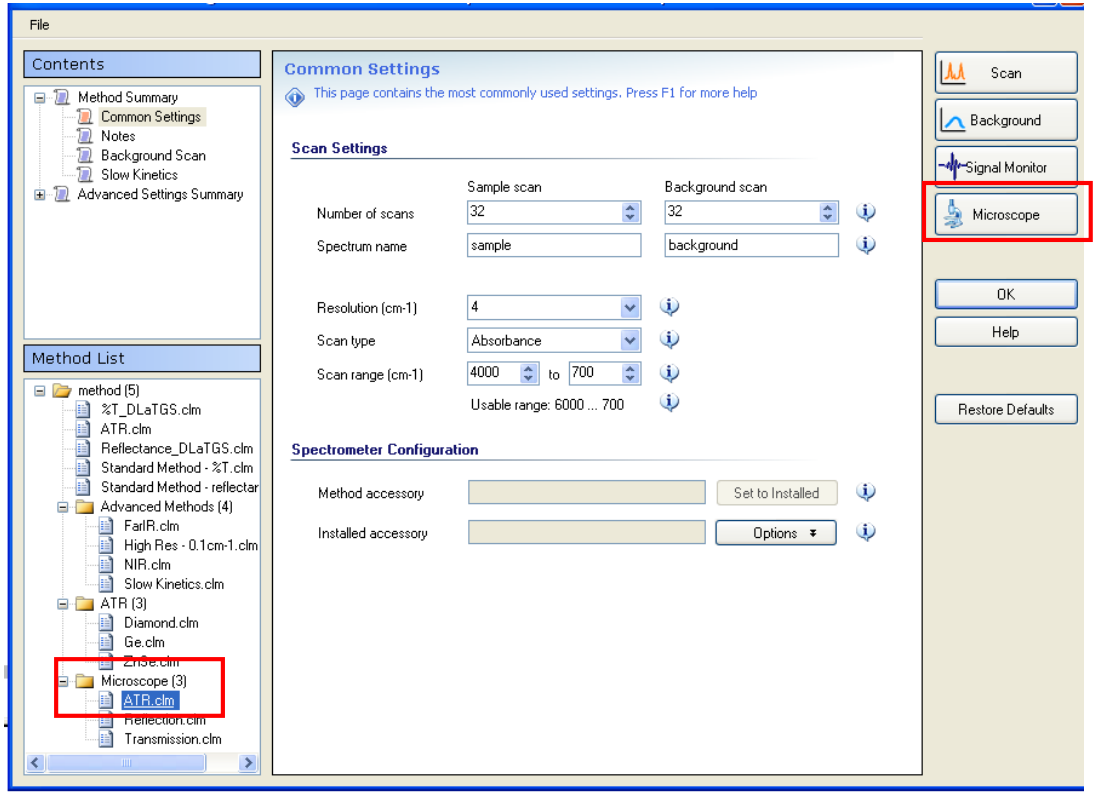
2-6)



Measurement_FT-IR Microscope

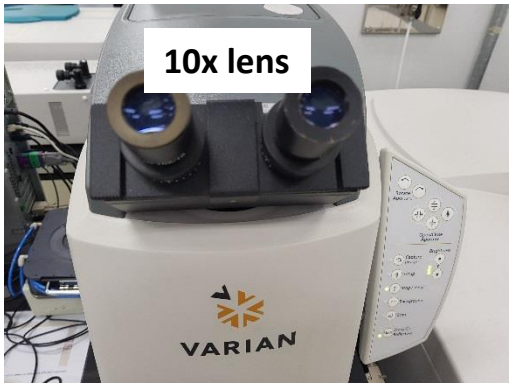
- **FT-IR Microscope_ATR**

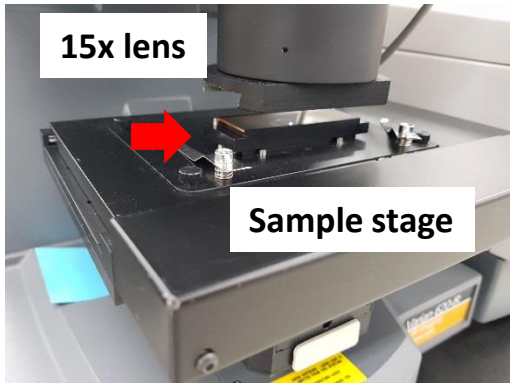
1. Open the Agilent Resolution Pro. Program.
2. Place the sample on the sample stage.
3. Method editor – Method List – Microscope.
4. Find focus and select the measurement point of sample changing the stage positon.

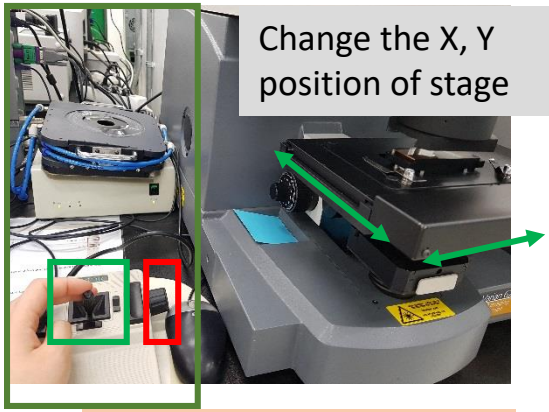


Measurement_FT-IR Microscope

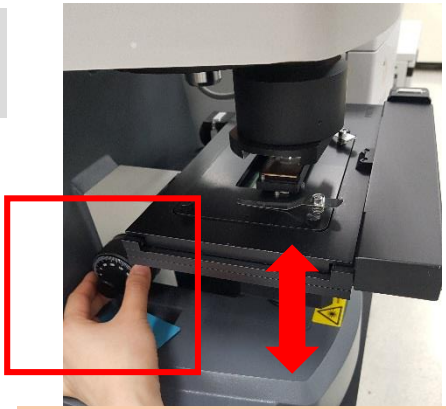
- **FT-IR Microscope_ATR**



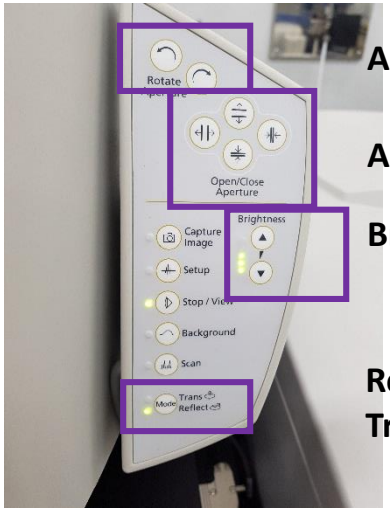




Turn **Right** – Stage **DOWN**
Turn **Left** – Stage **UP**



Turn **Right** – Stage **DOWN**
Turn **Left** – Stage **UP**



Aperture rotation

Aperture size

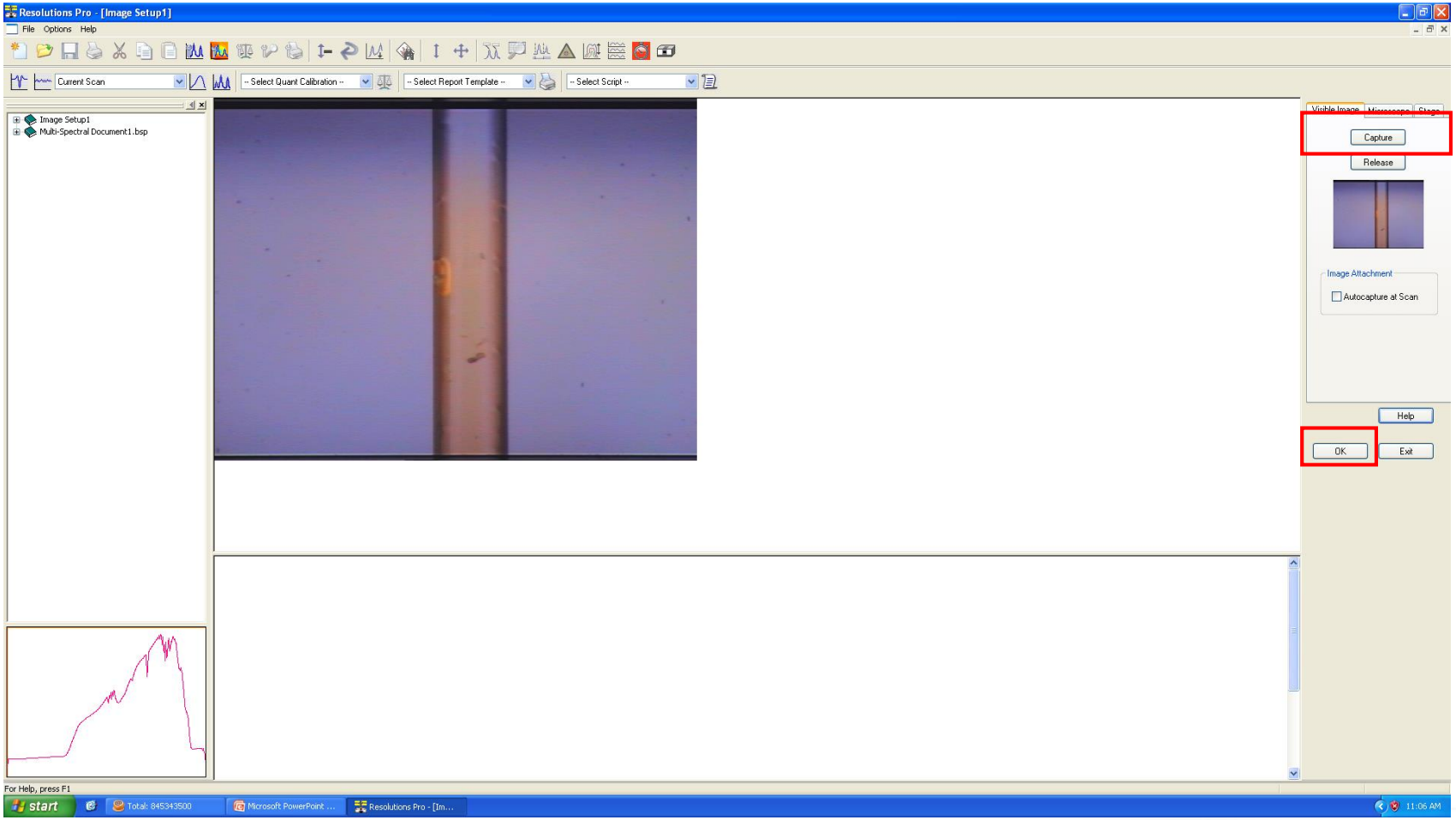
Brightness

Reflectance/ Transmittance mode

Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR**

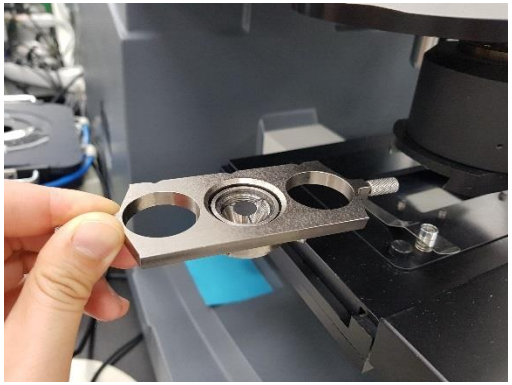
5. Click Capture.
6. Click OK.

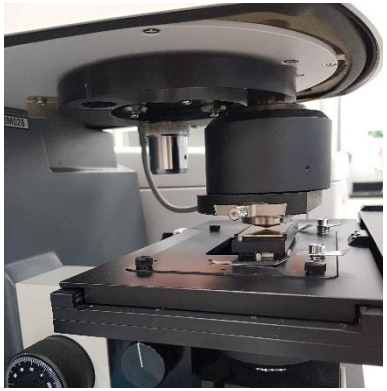


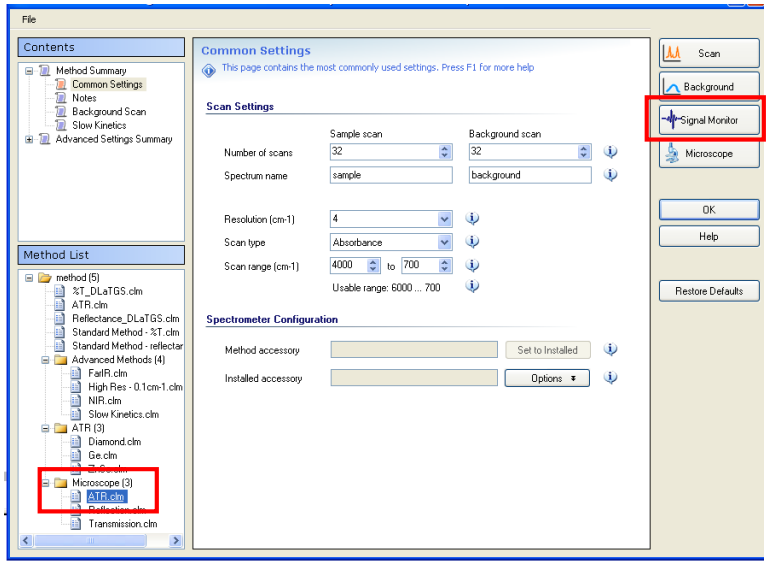
Measurement_FT-IR Microscope

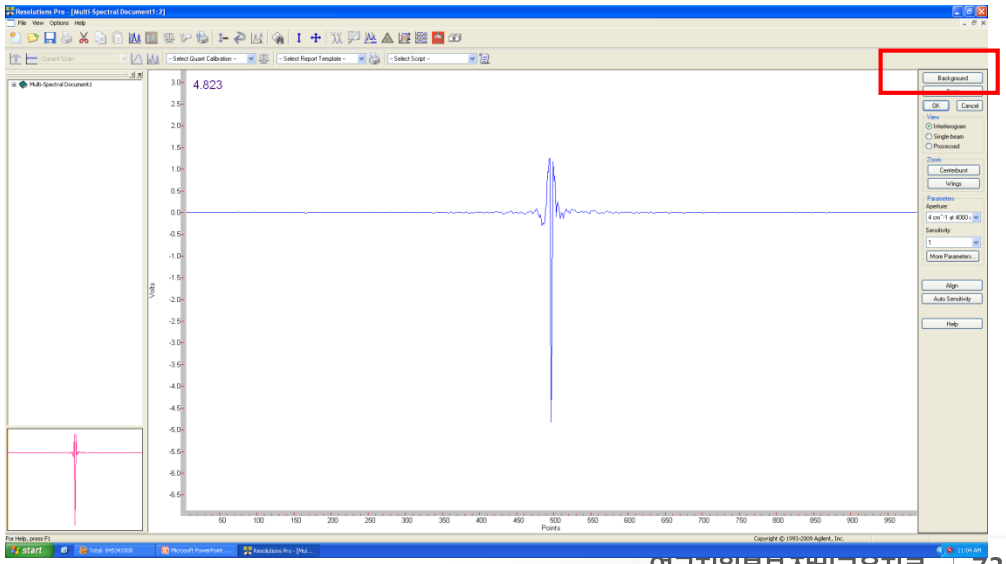
- **FT-IR Microscope_ATR**

7. Put the ATR slide to the lens part.
8. Method editor – Method List – Microscope – Reflectance – Signal monitor





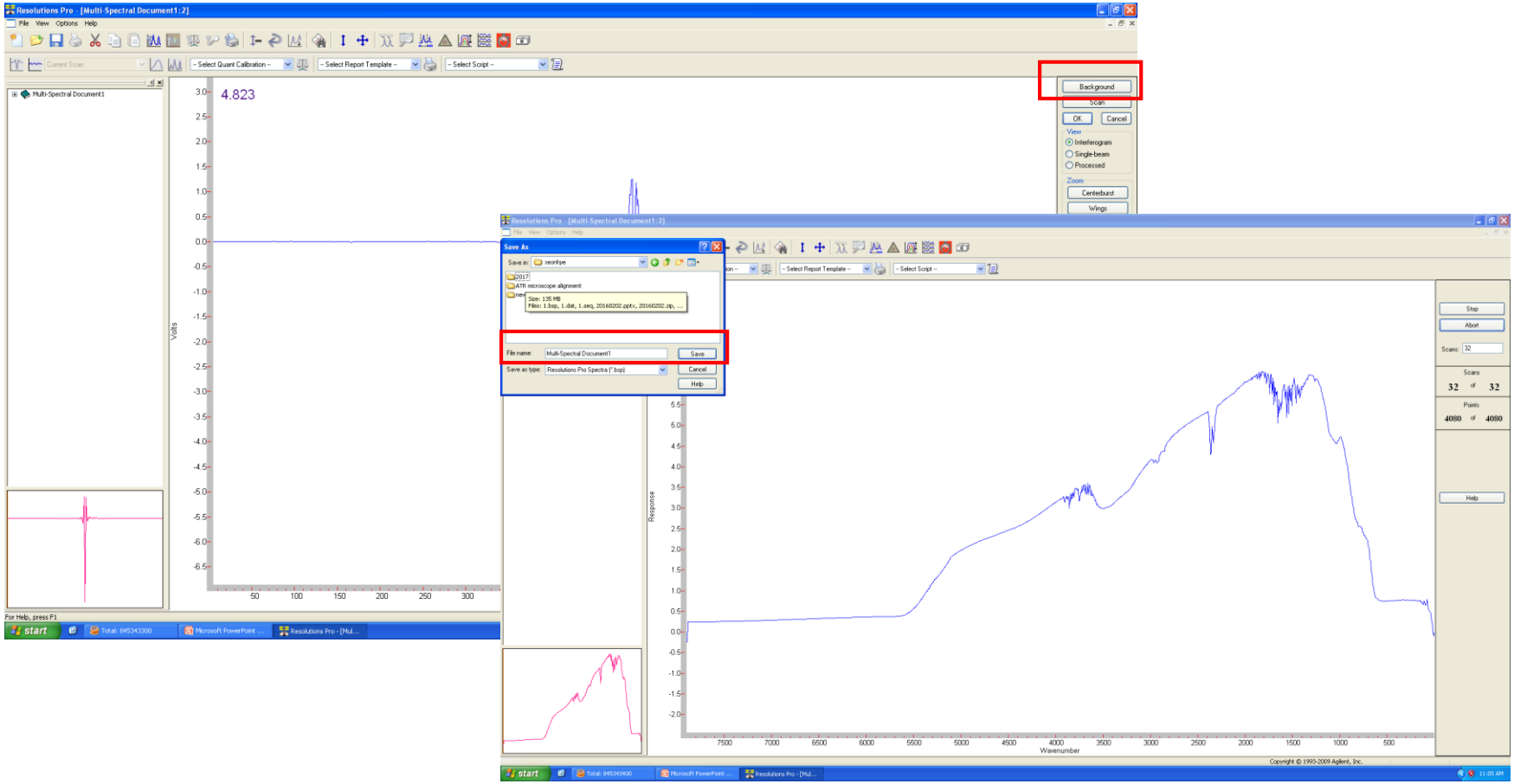




Measurement_FT-IR Microscope

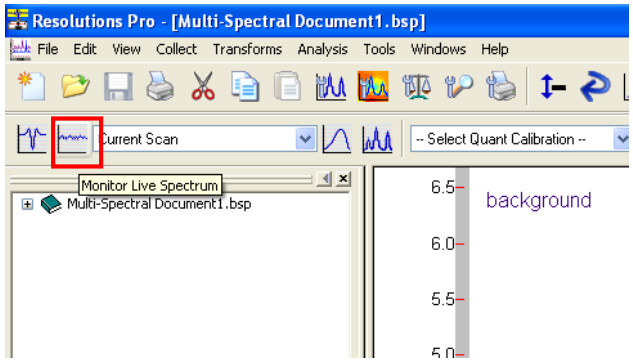
- **FT-IR Microscope_ATR**

9. Background – Save

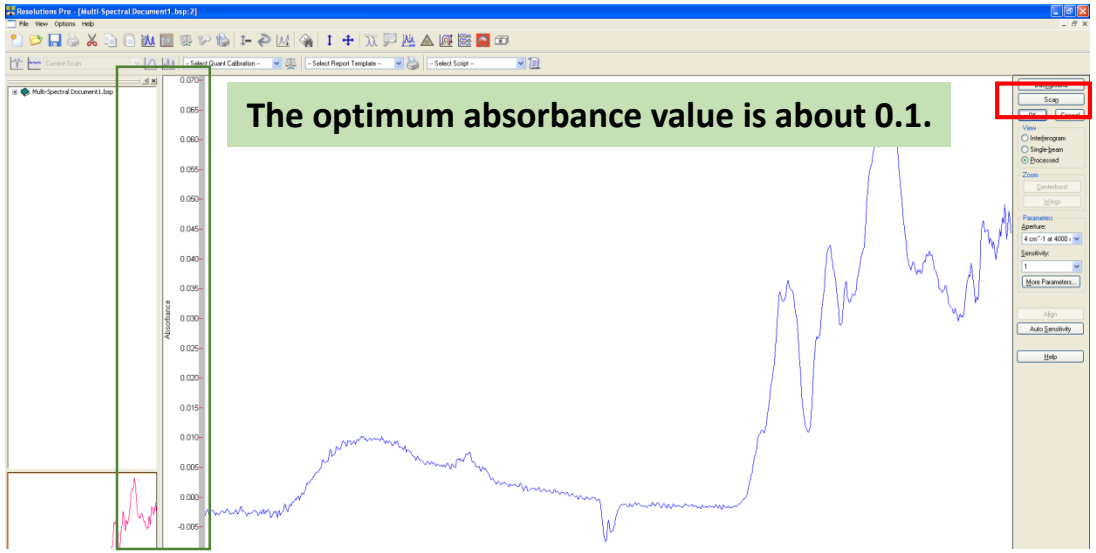


- **FT-IR Microscope_ATR**

10. Monitor Live Spectrum

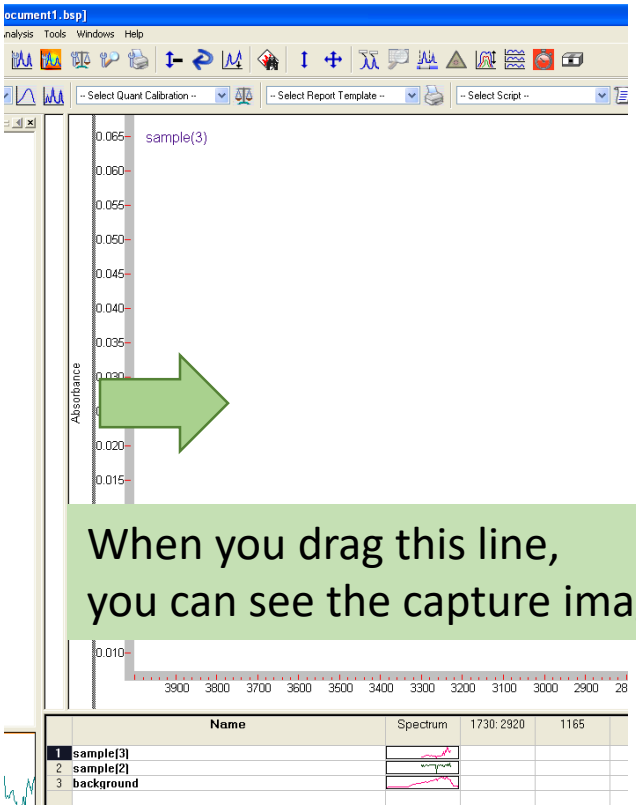


11. Move up the stage checking the IR signal through Monitor live spectrum.
12. Scan.

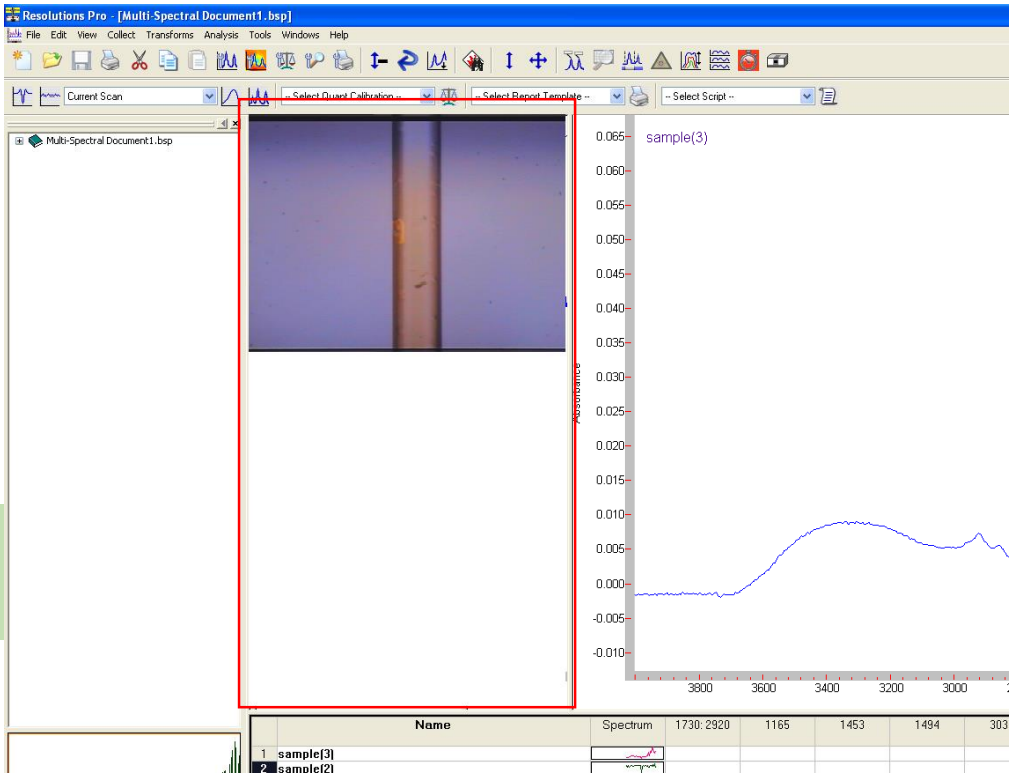


Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR**

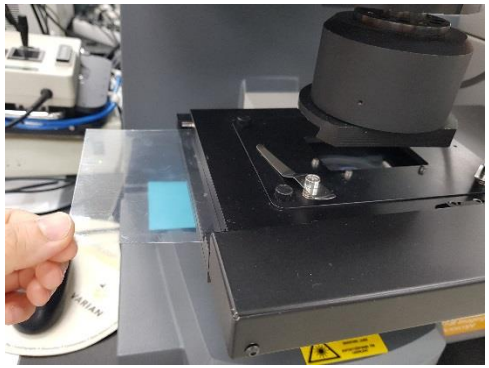


When you drag this line,
you can see the capture image.

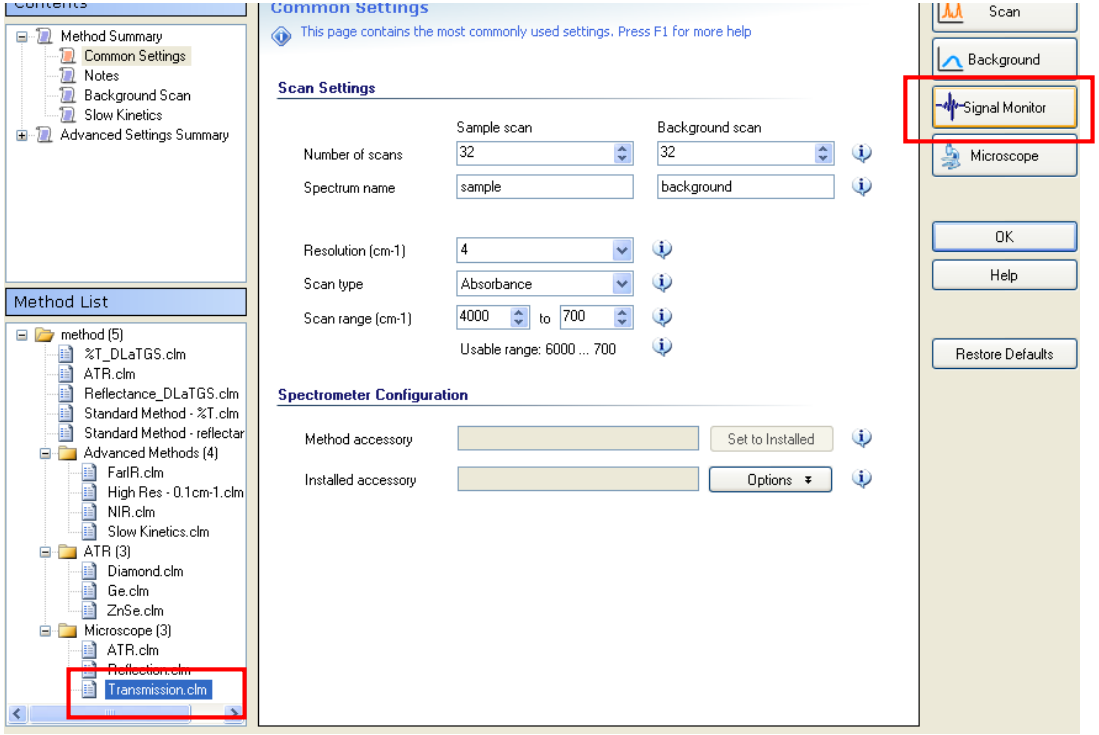


Measurement_FT-IR Microscope

- **FT-IR Microscope_Transmittance**



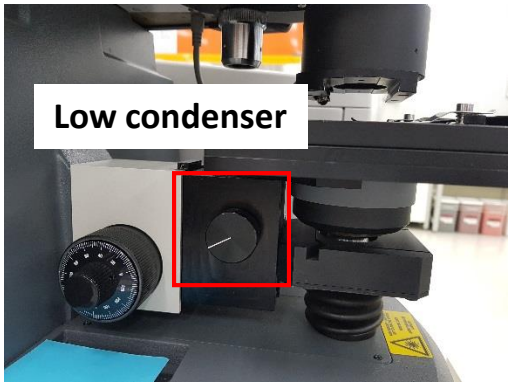
1. Remove the protective film in the stage.
2. Place the sample on the stage and find the focus.
3. Remove the sample from the stage.
4. Method editor – Method List – Microscope – Transmittance – Signal monitor

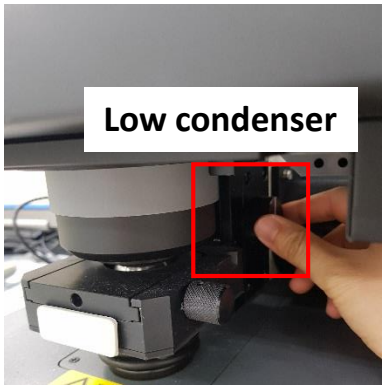


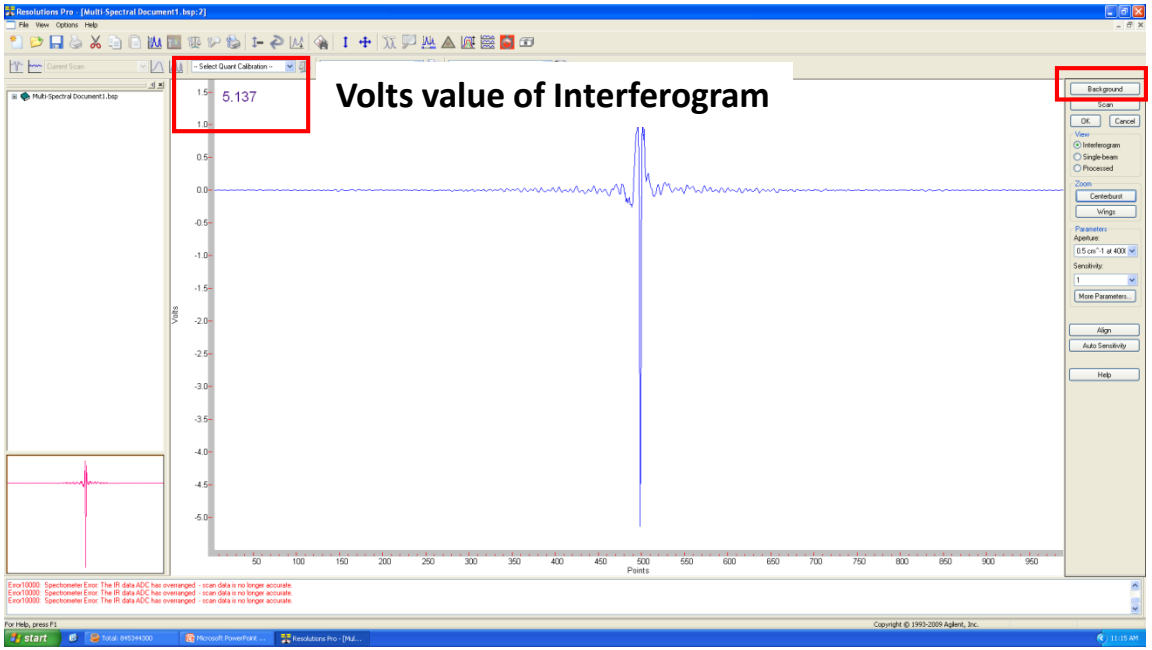
Measurement_FT-IR Microscope

- **FT-IR Microscope_Transmittance**

5. Adjust the maximum Interferogram volts value changing the low condenser.





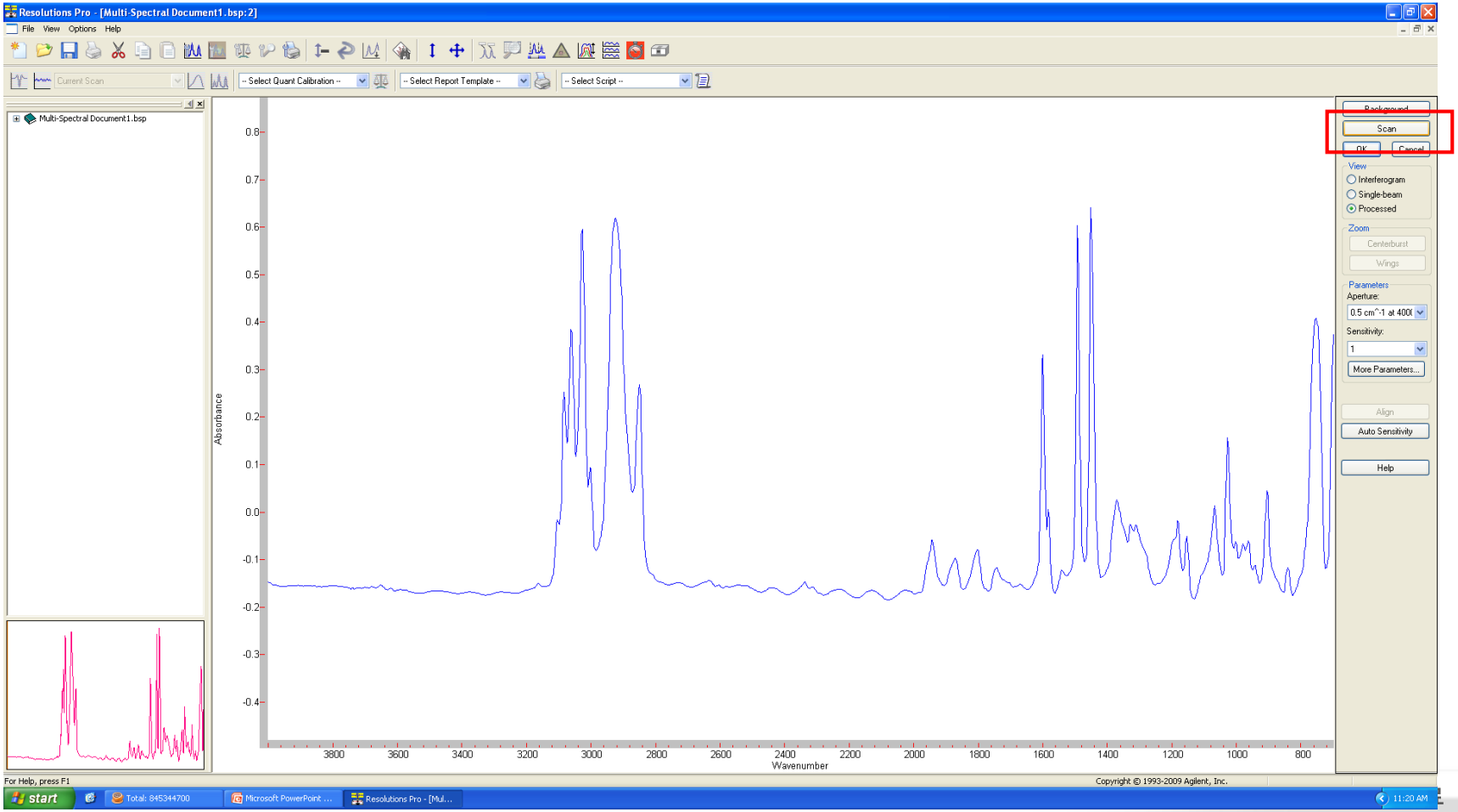


6. Collect Background.
7. Save.

Measurement_FT-IR Microscope

- **FT-IR Microscope_Transmittance**

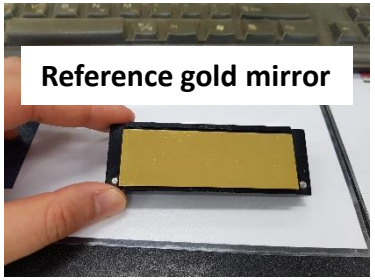
8. Place the sample on the stage and find the focus again.
9. Check the Monitor live spectrum.
10. Collect scan.

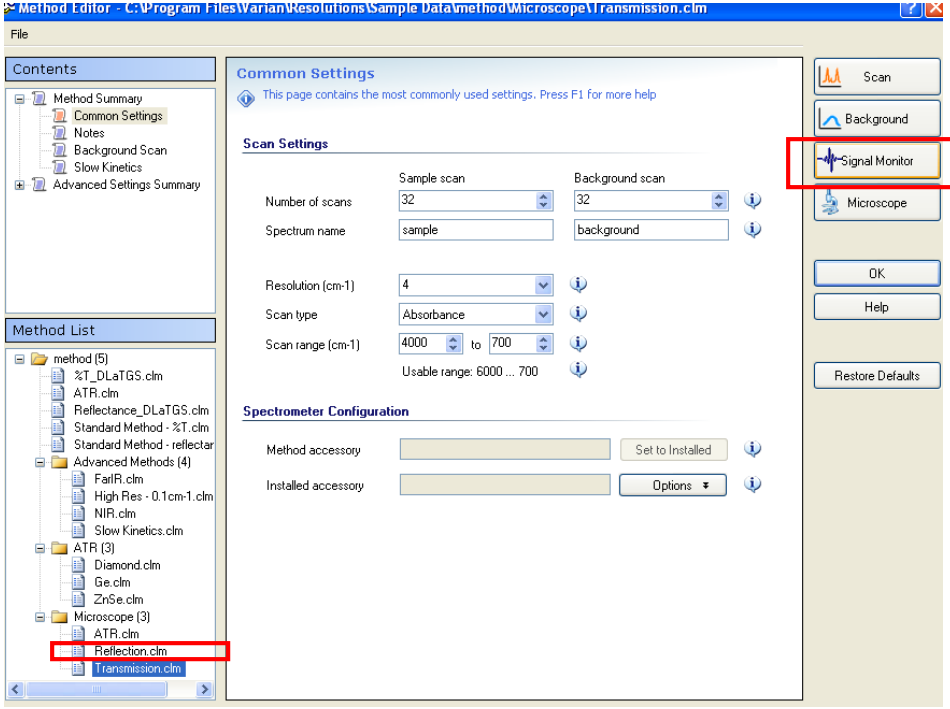


Measurement_FT-IR Microscope

- **FT-IR Microscope_Reflectance**

1. Place the reference gold mirror on the sample stage.
2. Find focus on surface of gold mirror.
   Aperture size should be same with sample size.
3. Method editor – Method List – Microscope – Reflectance – Signal monitor – Background – Save



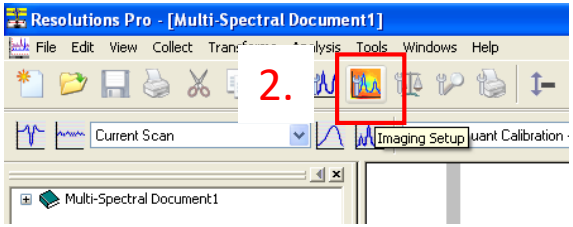


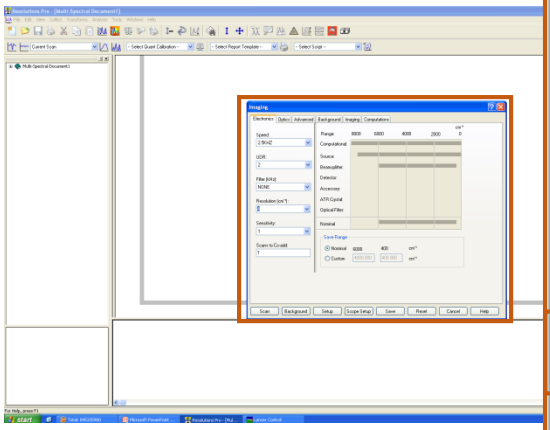
4. Place the sample on the stage.
5. Find the focus and select the measurement point.
6. Check the spectrum with Monitor live spectrum.
7. Scan.

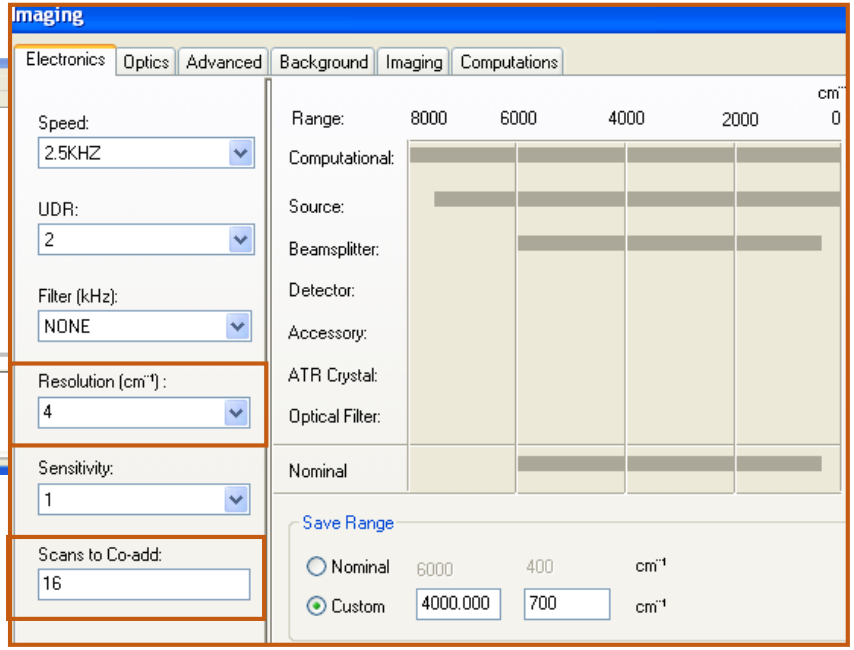
Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

1. Open the Agilent Resolution Pro. Program.
2. Click the Image Setup.
- You can change the Resolution, Sensitivity and Scan number.







Measurement_FT-IR Microscope

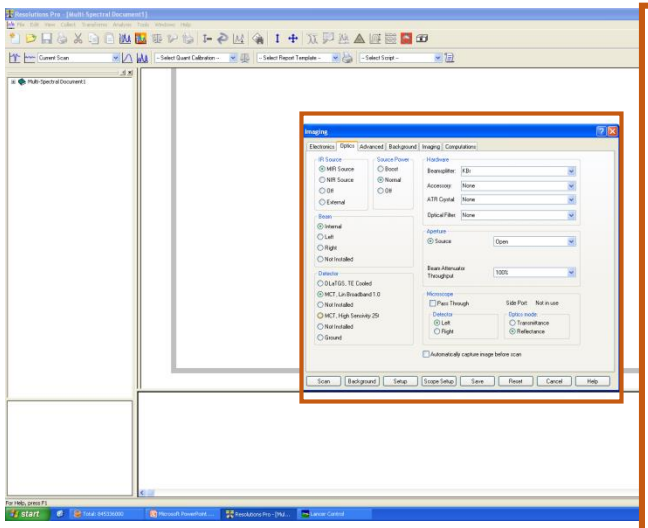
- **FT-IR Microscope_ATR image scan(mapping)**

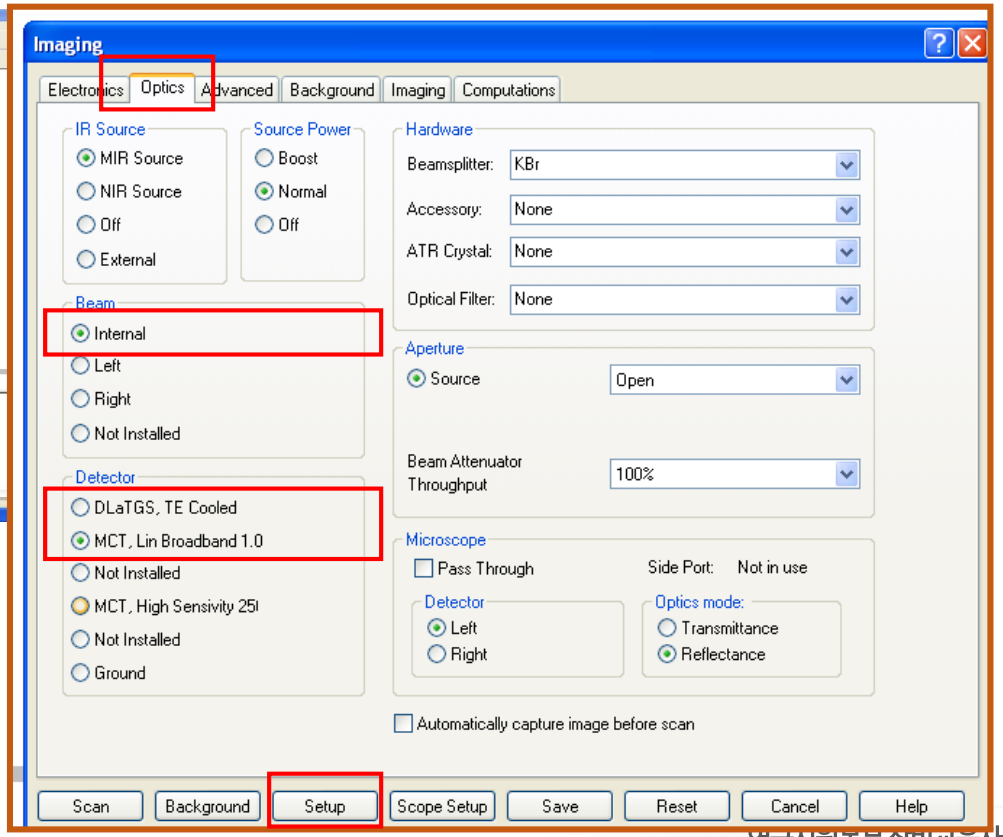
3. Find the beam line from the mainbody.

1) Select the Optics.

- Beam_Internal
- Detector_Mainbody detector(DLaTGS, TE Cooled or MCT, Lin Broadband 1.0)

2) Click Set up.

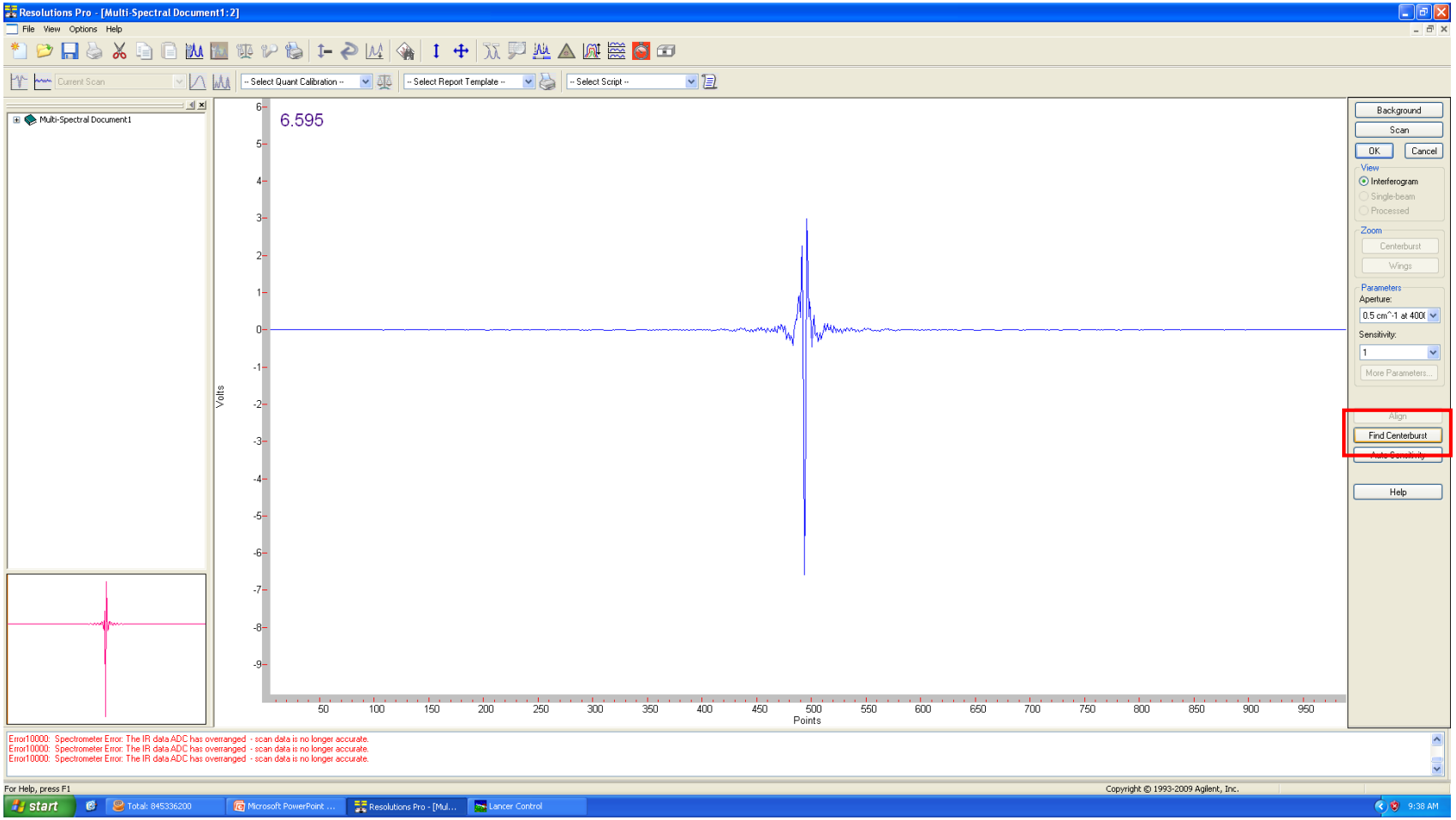




Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

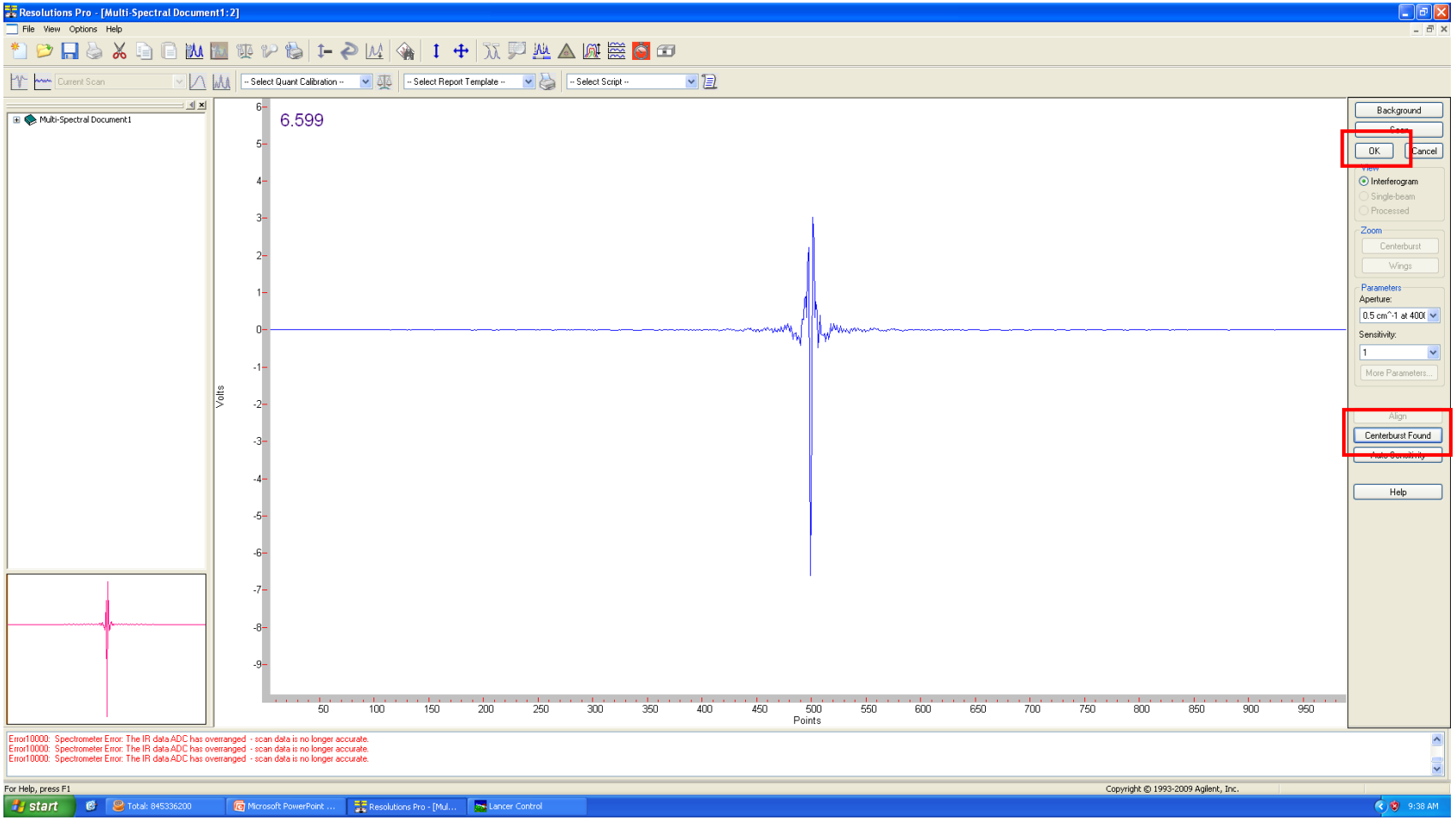
3) Click Find Centerburst.



Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

4) Check Centerburst Found.
5) Click OK.

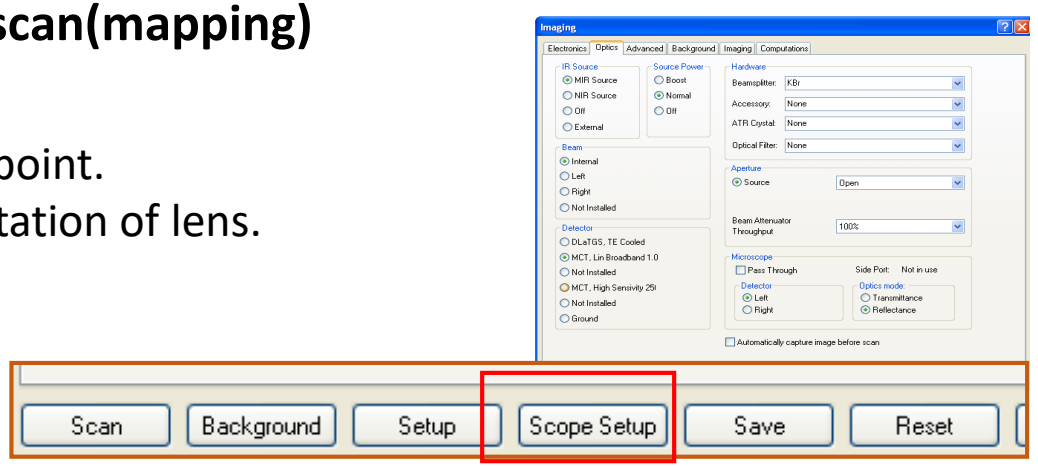


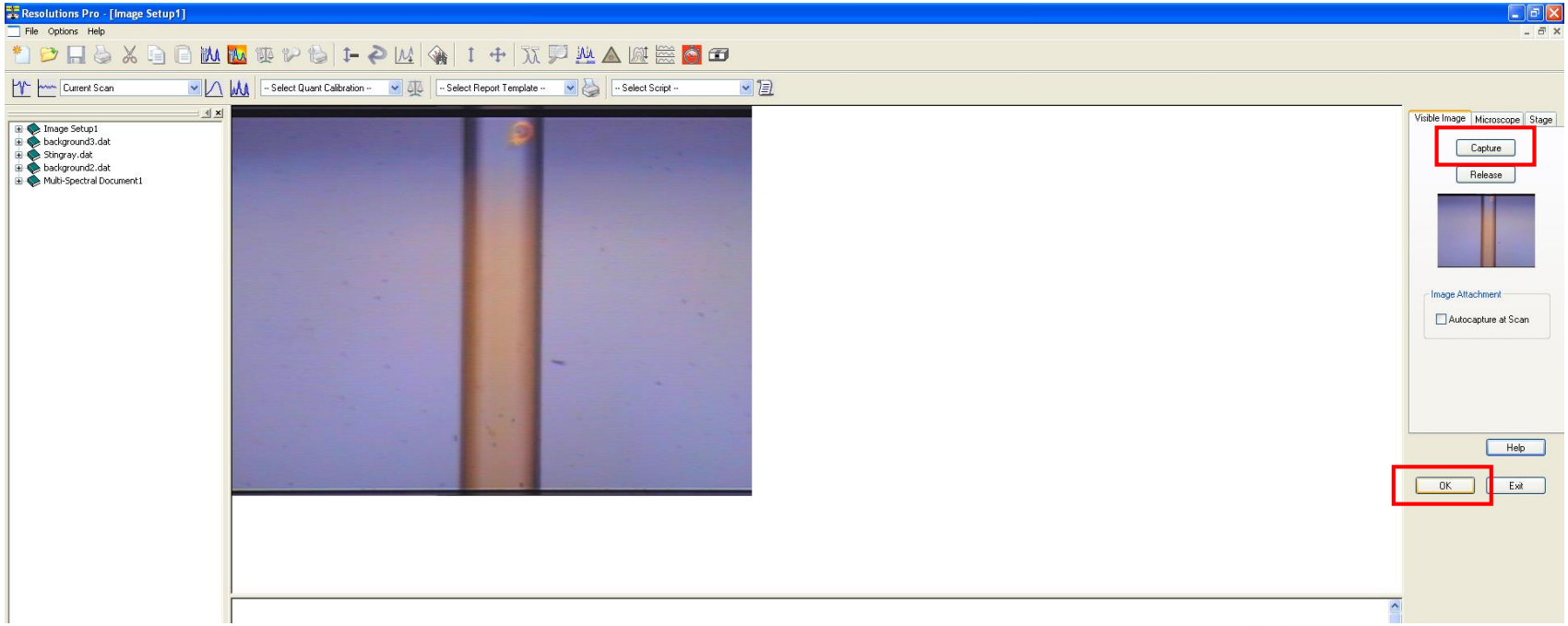
Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

4. Imaging – Scope Setup

1) Find the focus of measurement point.
2) Change the aperture size and rotation of lens.
3) Click capture.
4) Click OK.

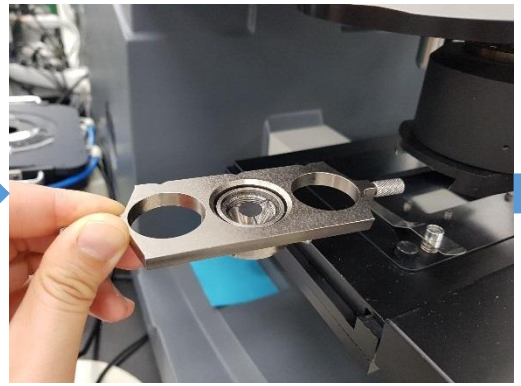
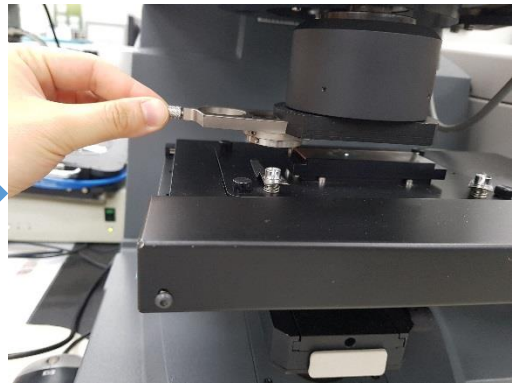




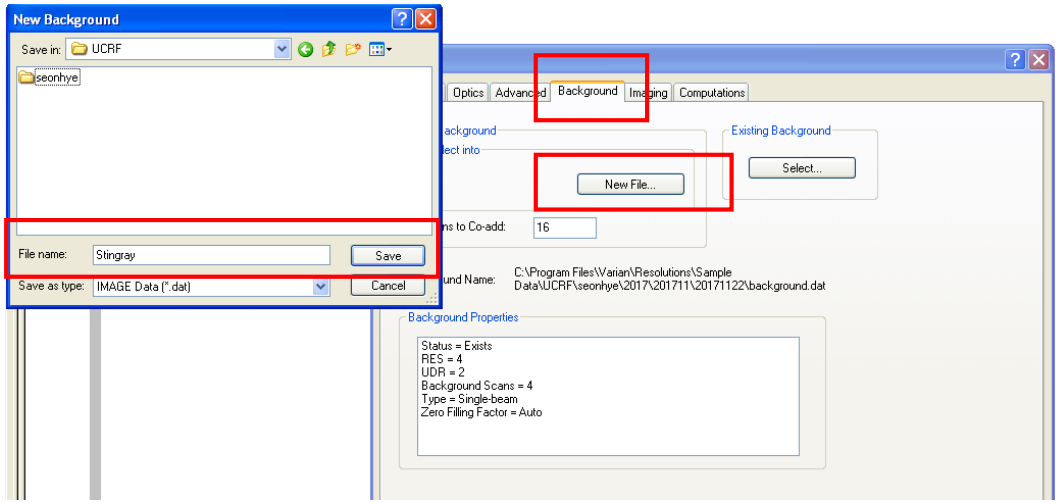
Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

5. Put the ATR slide to the lens part.

6. Set the background file name and save condition.
Imaging – Background – New File - Save



Measurement_FT-IR Microscope

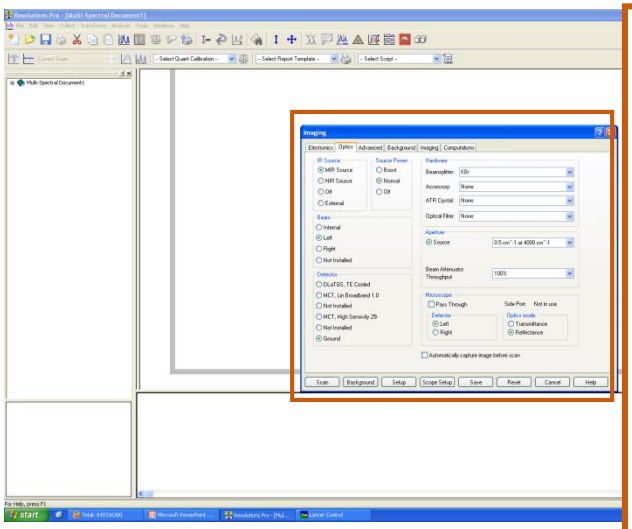
- **FT-IR Microscope_ATR image scan(mapping)**

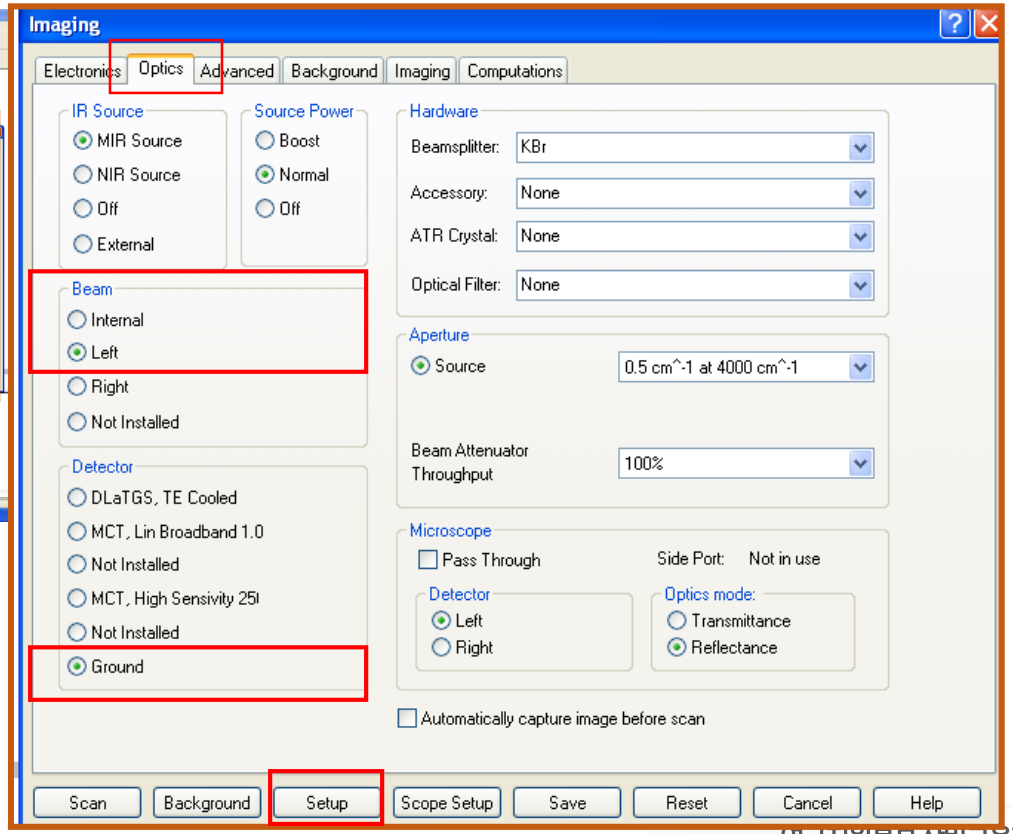
7. Imaging set up again.

1) Select the Optics.

- Beam_Left
- Detector_Ground

2) Click Set up.

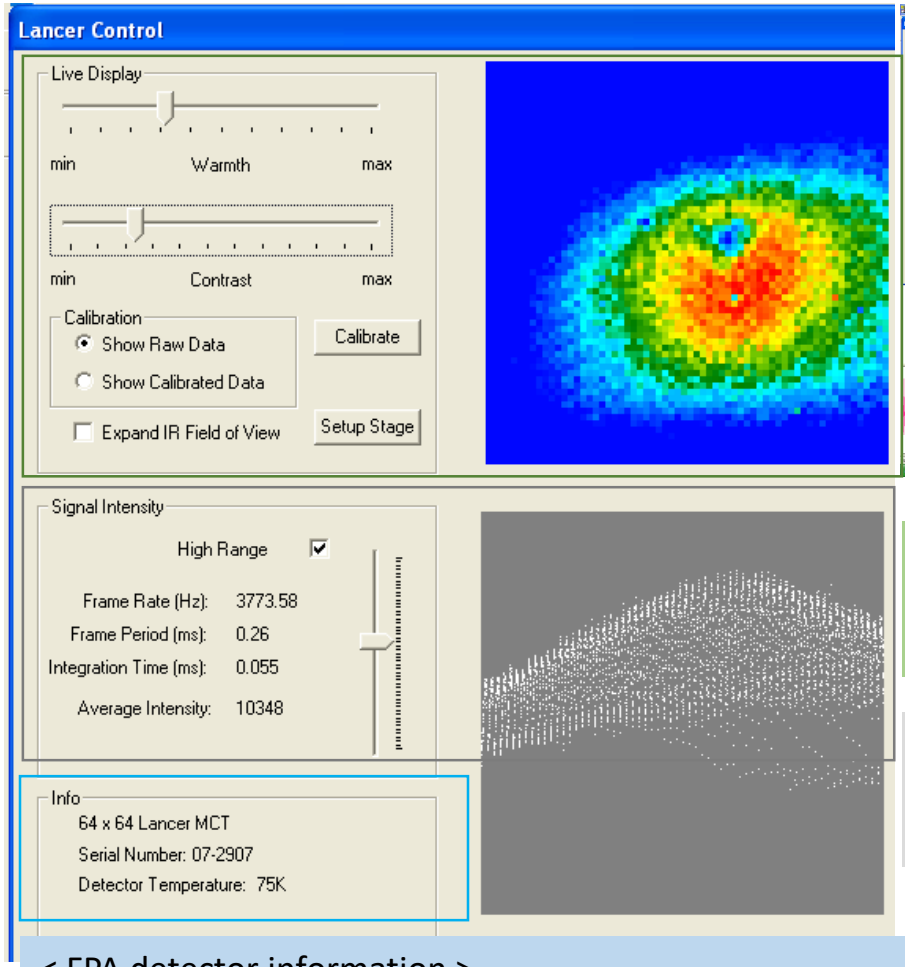


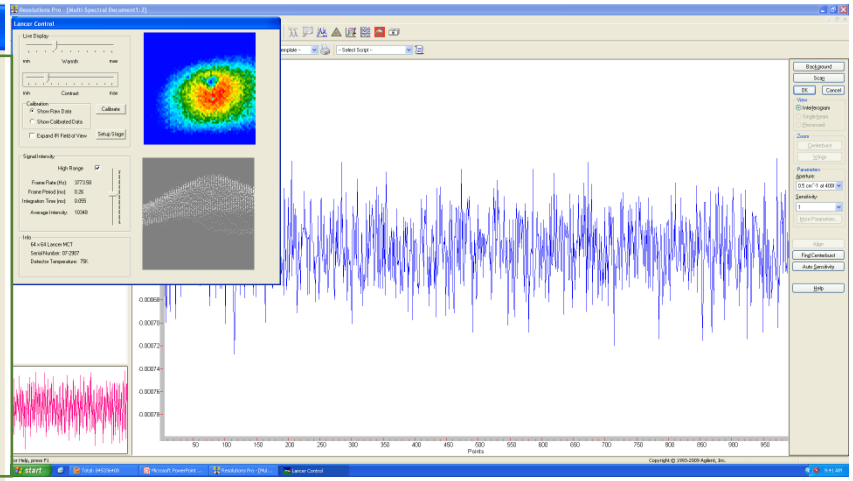


Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

8. Lancer Control





< Calibration >
- Click show Raw Data
- Change Warmth and Contrast checking right image.

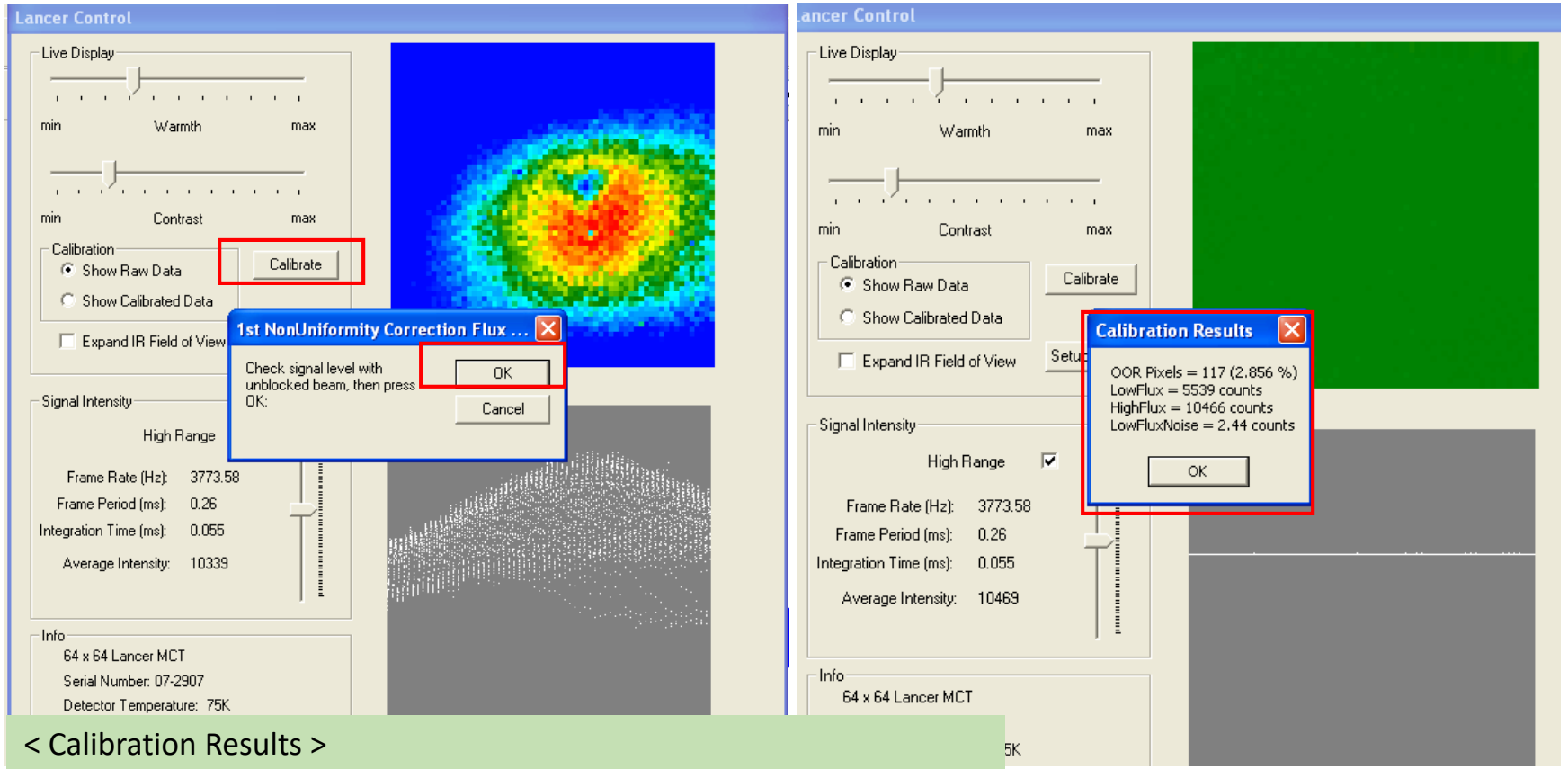
< Control Signal Intensity >
- Check the shape of mountain.
- Make the baseline one-third of box.

< FPA detector information >
You have to check the temperature.
When you see the red warning mark, please close the program and fill the liquid nitrogen again.

Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

9. Click Calibrate – OK – Check the calibration Results – OK



< Calibration Results >

- **OOR Pixels** have to be below than **7%**.
- The difference value between **LowFlux** and **HighFlux** is about **3000**.

✓ Value > 3000, Calibration again after decrease Average Intensity .

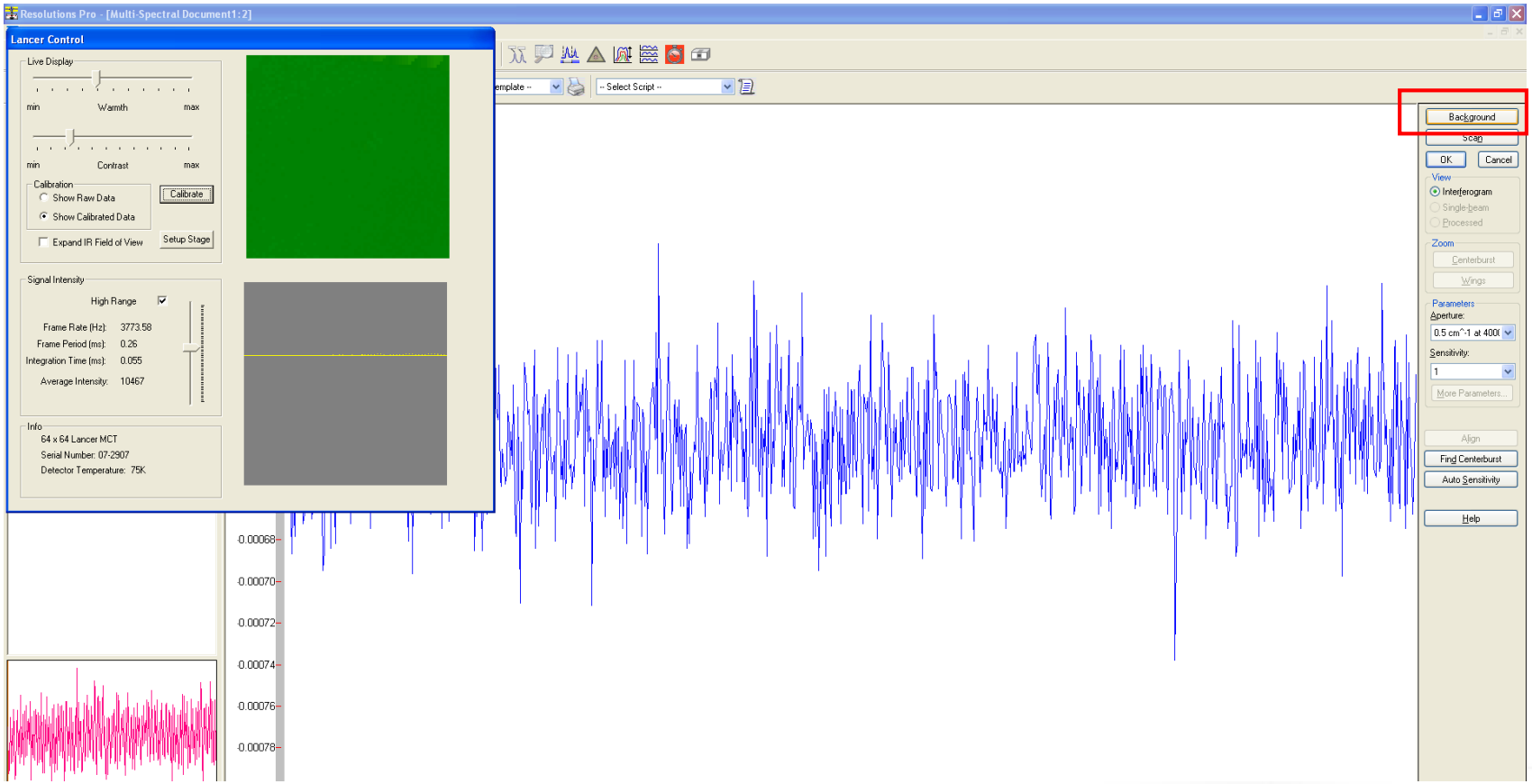
✓ Value < 3000, Calibration again after increase Average Intensity.

- **LowFluxNoise** have to be below than **5**.

Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

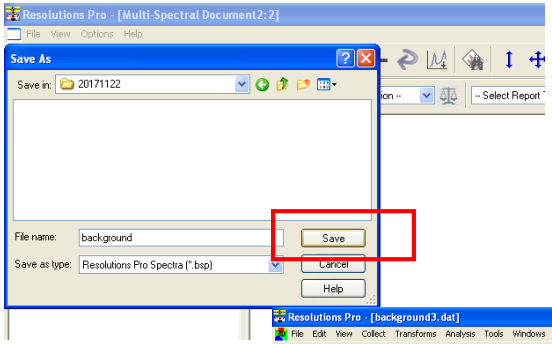
10. After calibration,
    you can see the green color window at upper box and yellow line at lower box.
    (uncalibrated data would be in white)
11. Click background.

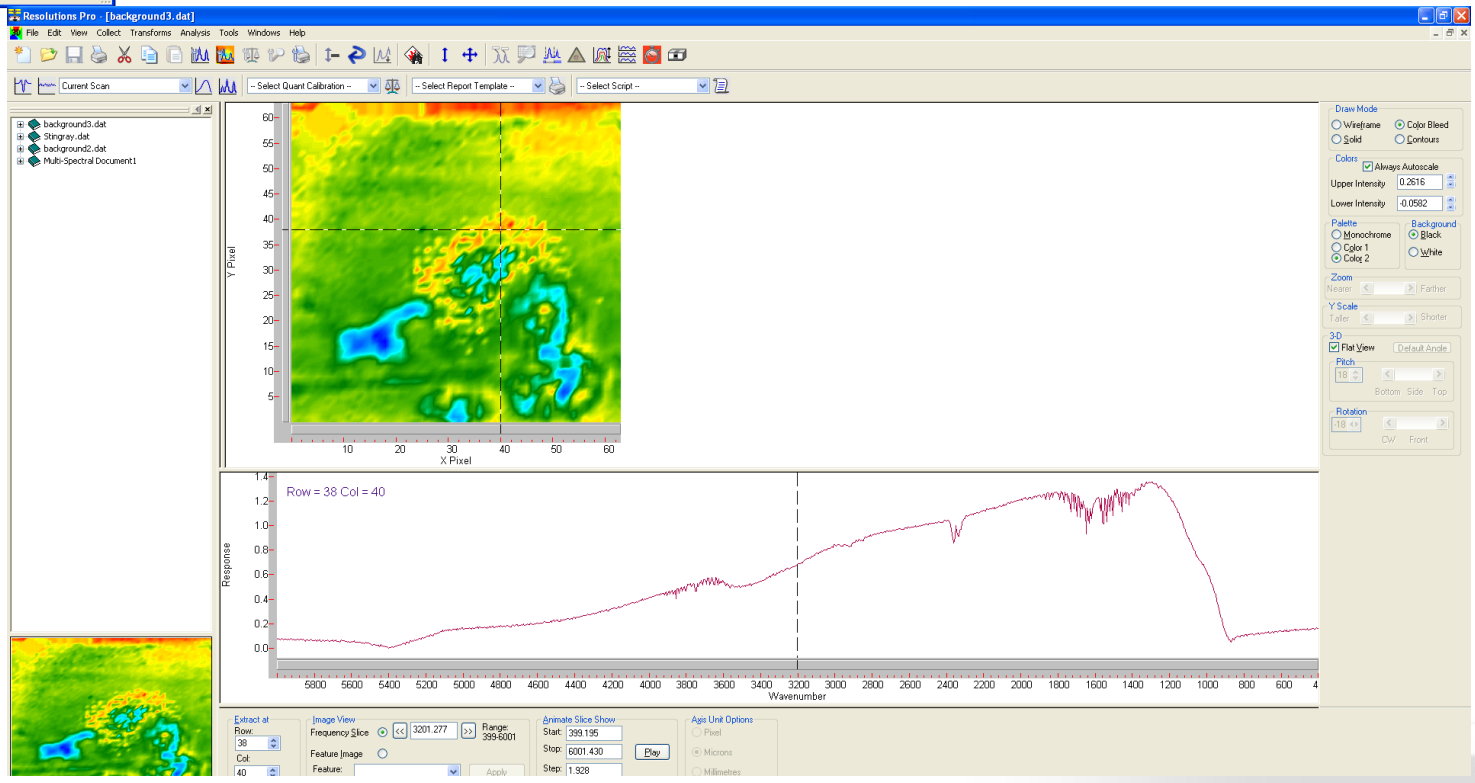


Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

12. Save the data

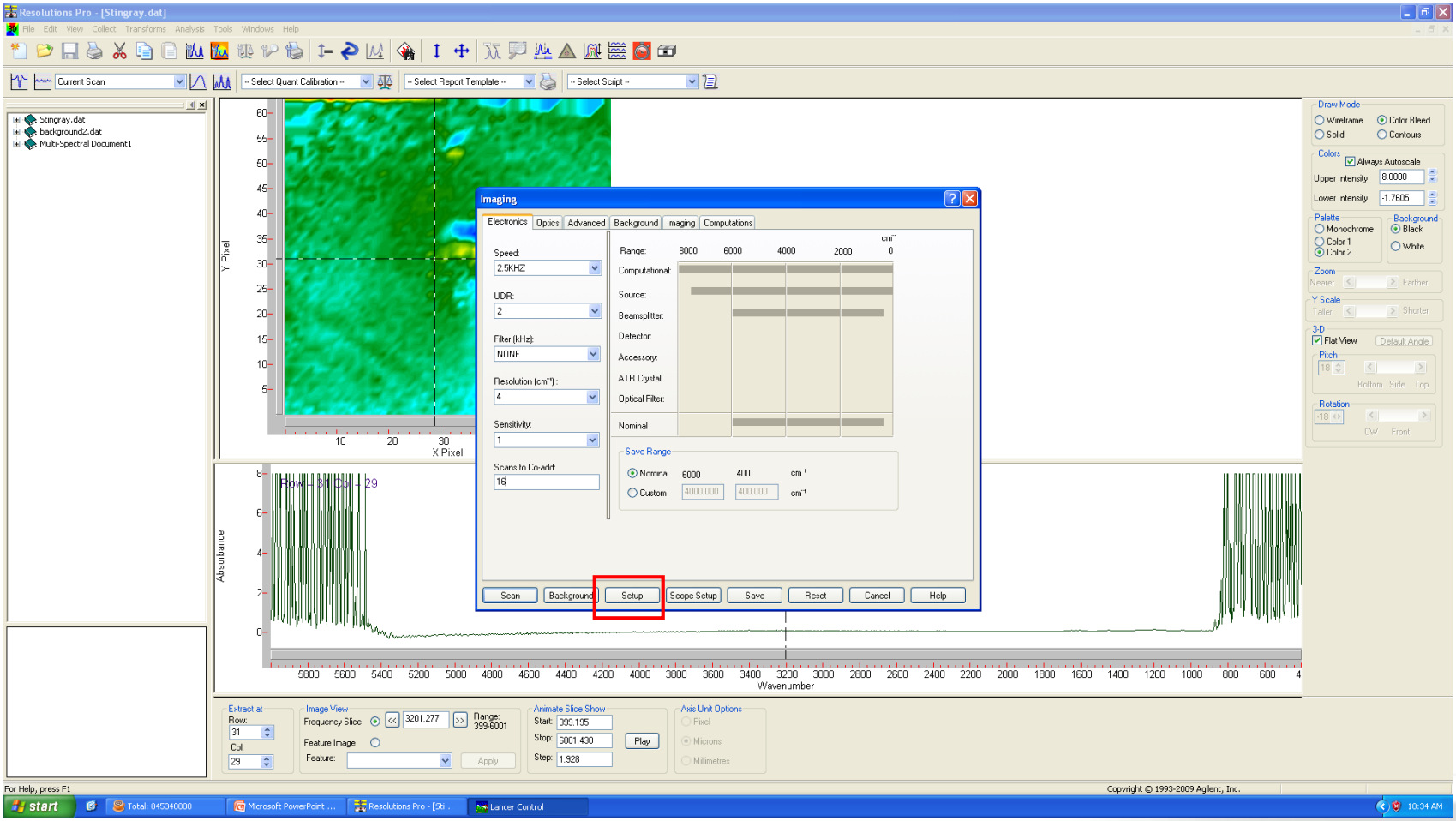




Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

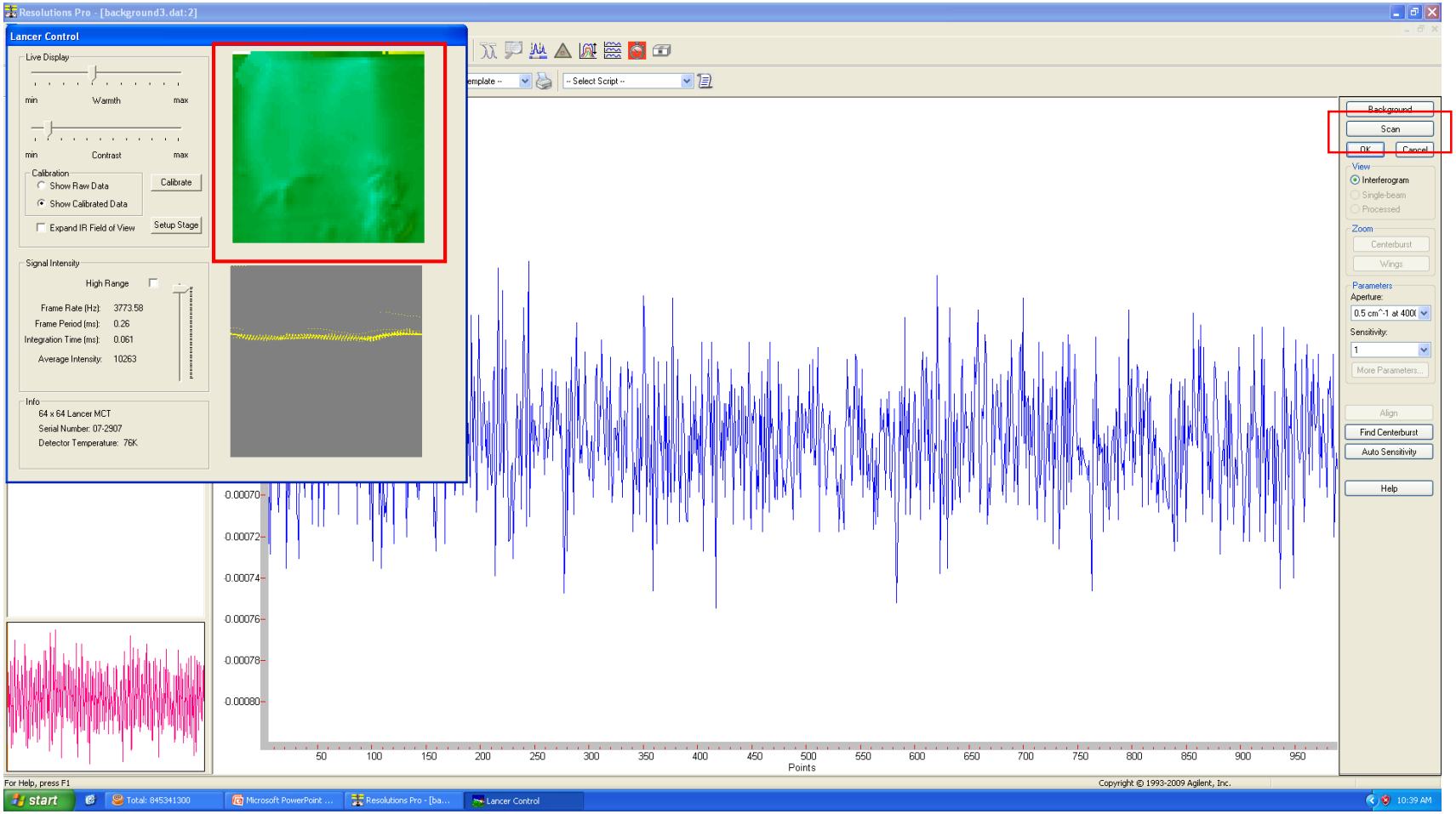
13. Place the sample on the stage and find the focus of measurement point.
14. Open Imaging Setup.
15. Click Setup.



Measurement_FT-IR Microscope

- **FT-IR Microscope_ATR image scan(mapping)**

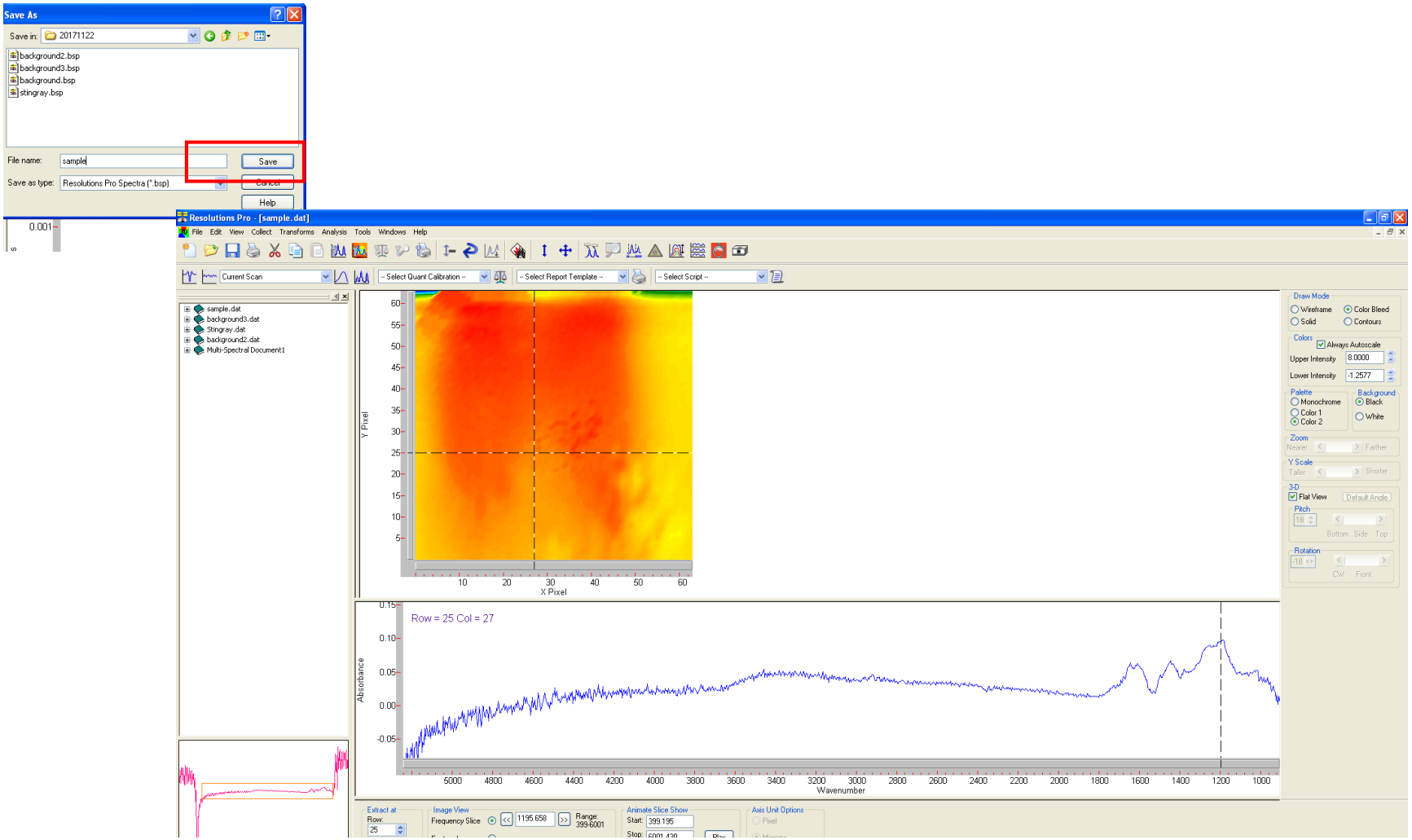
16. Move up the stage and check the Display image(green box) on Lancer Control.
17. Click **Scan** when you see the shape of sample surface.



Measurement_FT-IR Microscope

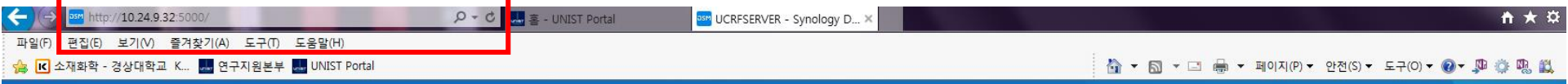
- **FT-IR Microscope_ATR image scan(mapping)**

18. Save.



Data translation

2)



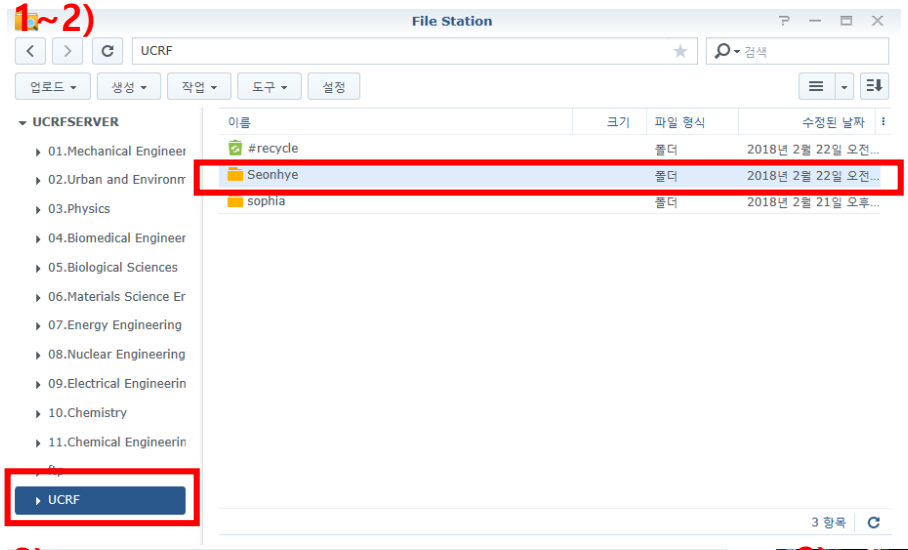
1) Connect to the Internet
2) Type the IP address

UCRF PC
100.100.100.30

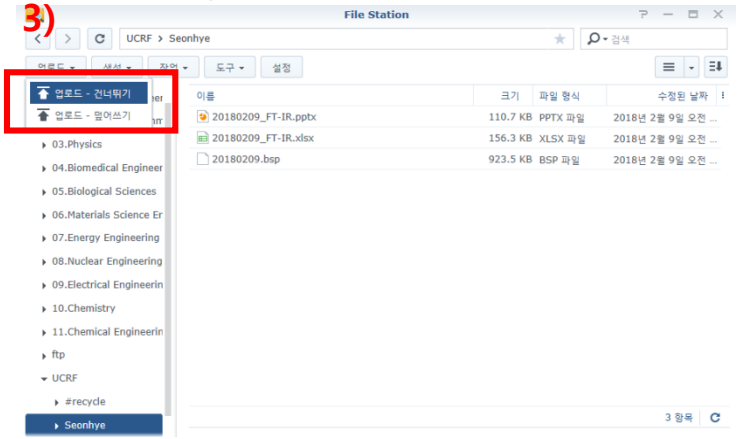
When you access from outside,
10.24.9.32

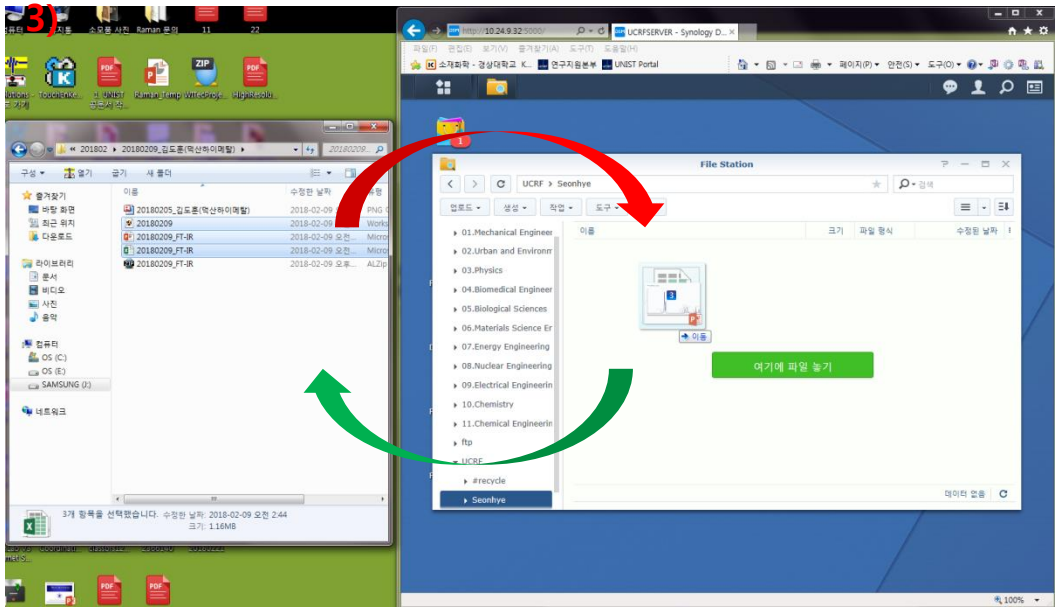
3) Sign in
ID(Professor name)/PW

Data translation



1) Open the File Station
2) Select your folder
3) Transfer your data
   - Use upload and download
   - Drag and drop





6. 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

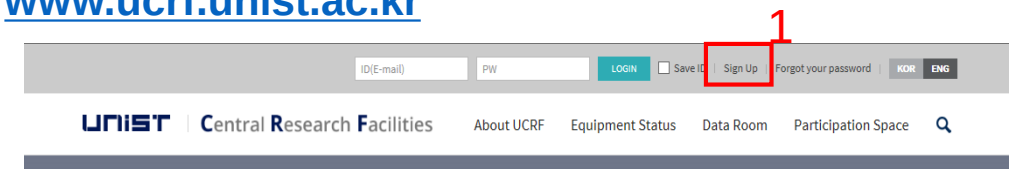
ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY

Reservation control information

Reservation time unit	Daily maximum reservation time	Cancelable timing	Fee (ATR)	
30 min.	3.0 hr	2.0 hr	Client	21,000/hr
			Self-user	15,000/hr

Create Account

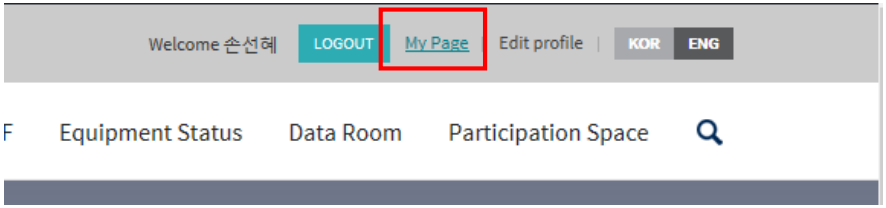
www.ucrf.unist.ac.kr

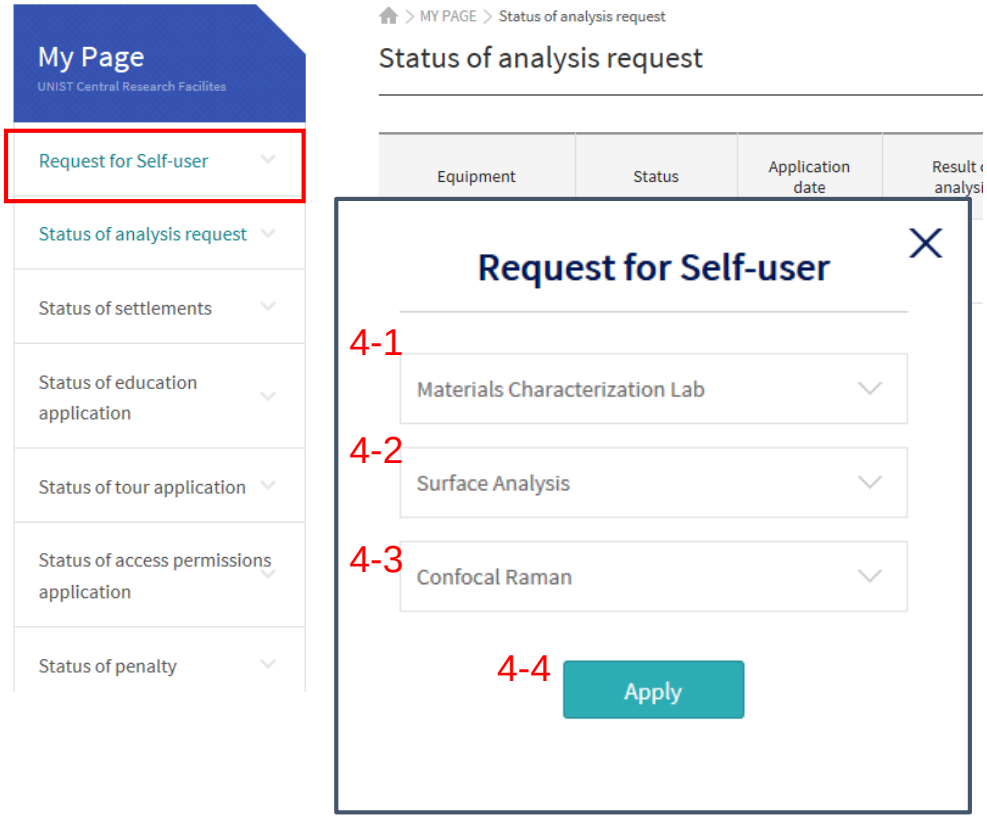


1. Click [Sign up].
2. Click [UNIST Member].
3. Input [Portal id/pw]_Click [Confirm].
   Please check your information.
4. Input professor name in [Principal investigation]
   _Click [Professor search]_Click professor name.
5. Click [Create Account].

Request for Self-user

www.ucrf.unist.ac.kr



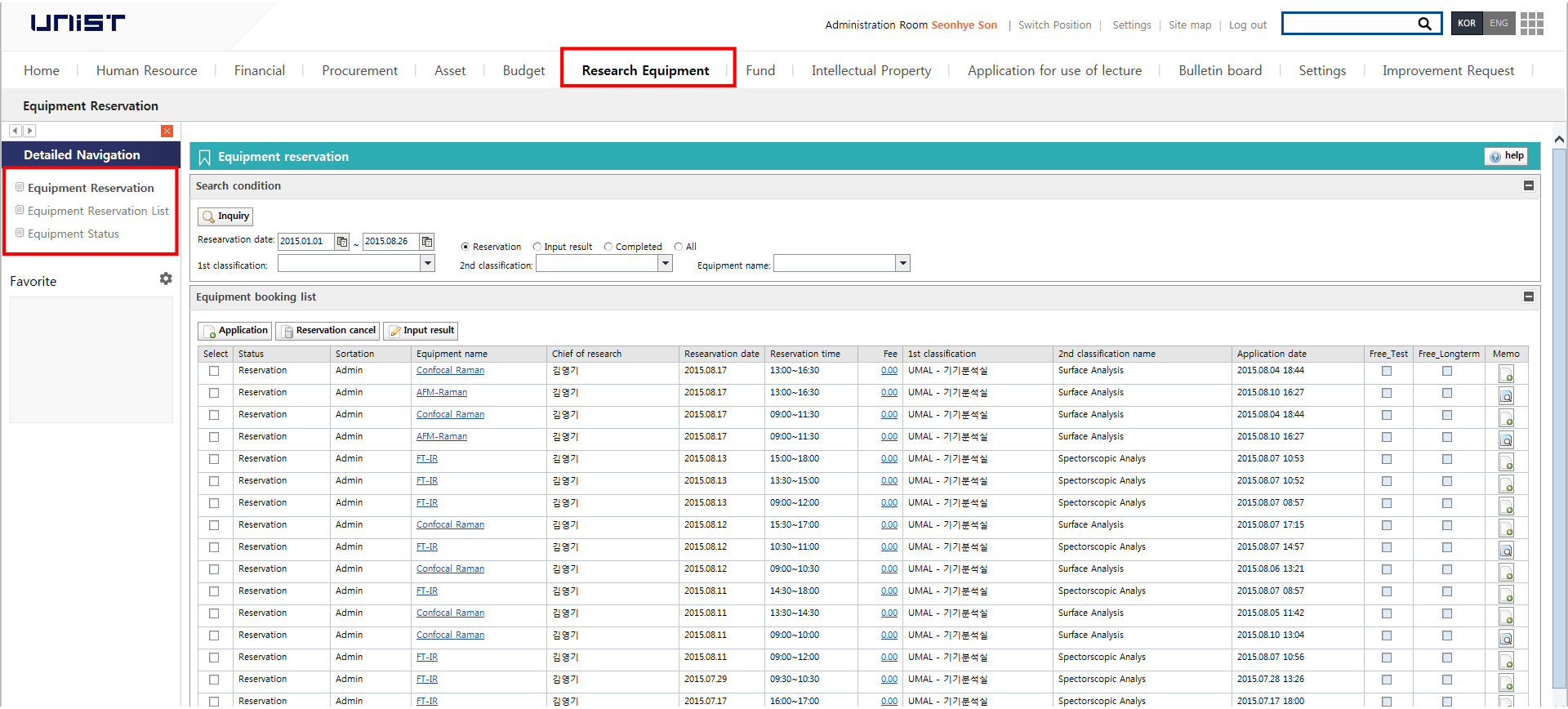


After pass the test,

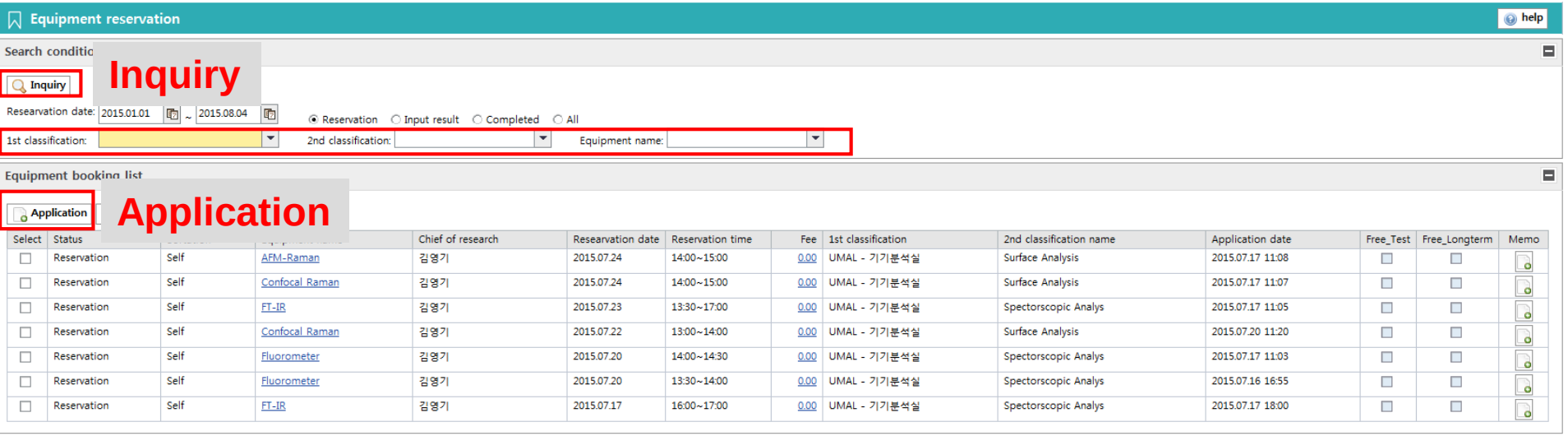
1. Login UCRF website.
2. Click [My Page].
3. Click [Request for Self user].
4. Select the equipment.
    1) Select [Materials Characterization Lab].
    2) Select [Surface Analysis].
    3) Select [Confocal Raman].
    4) Click [Apply].

Reservation

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



Reservation

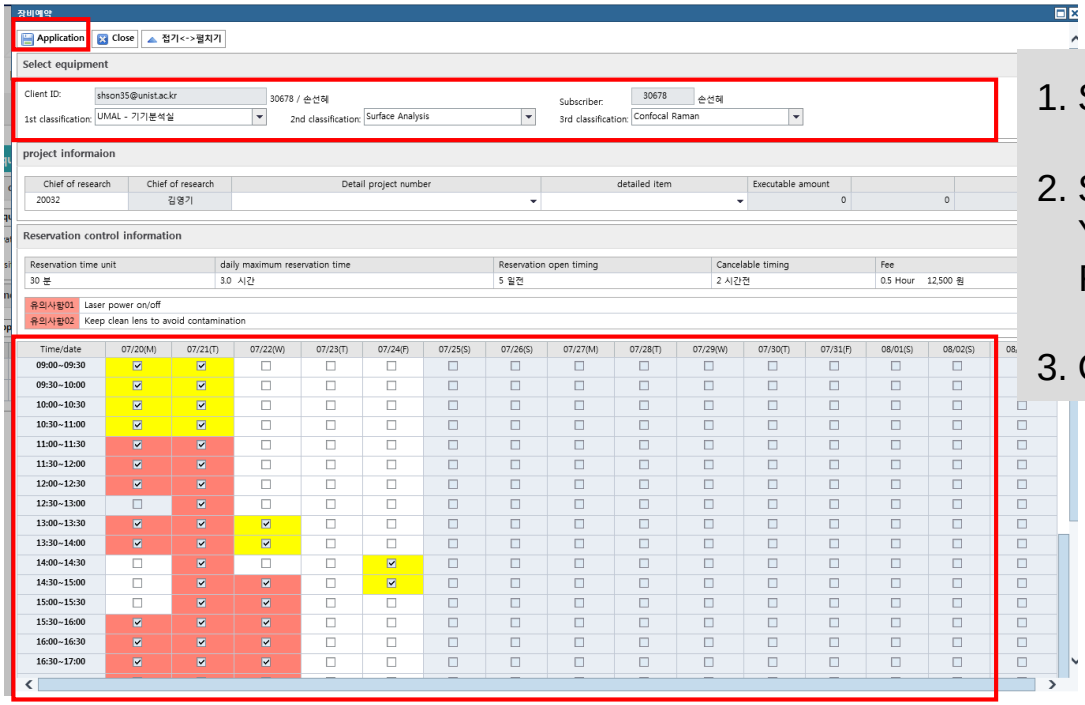


Select	Status			Chief of research	Reservation date	Reservation time	Fee	1st classification	2nd classification name	Application date	Free_Test	Free_Longterm	Memo
☐	Reservation	Self	AFM-Raman	김영기	2015.07.24	14:00~15:00	0.00	UMAL - 기기분석실	Surface Analysis	2015.07.17 11:08	☐	☐	
☐	Reservation	Self	Confocal 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

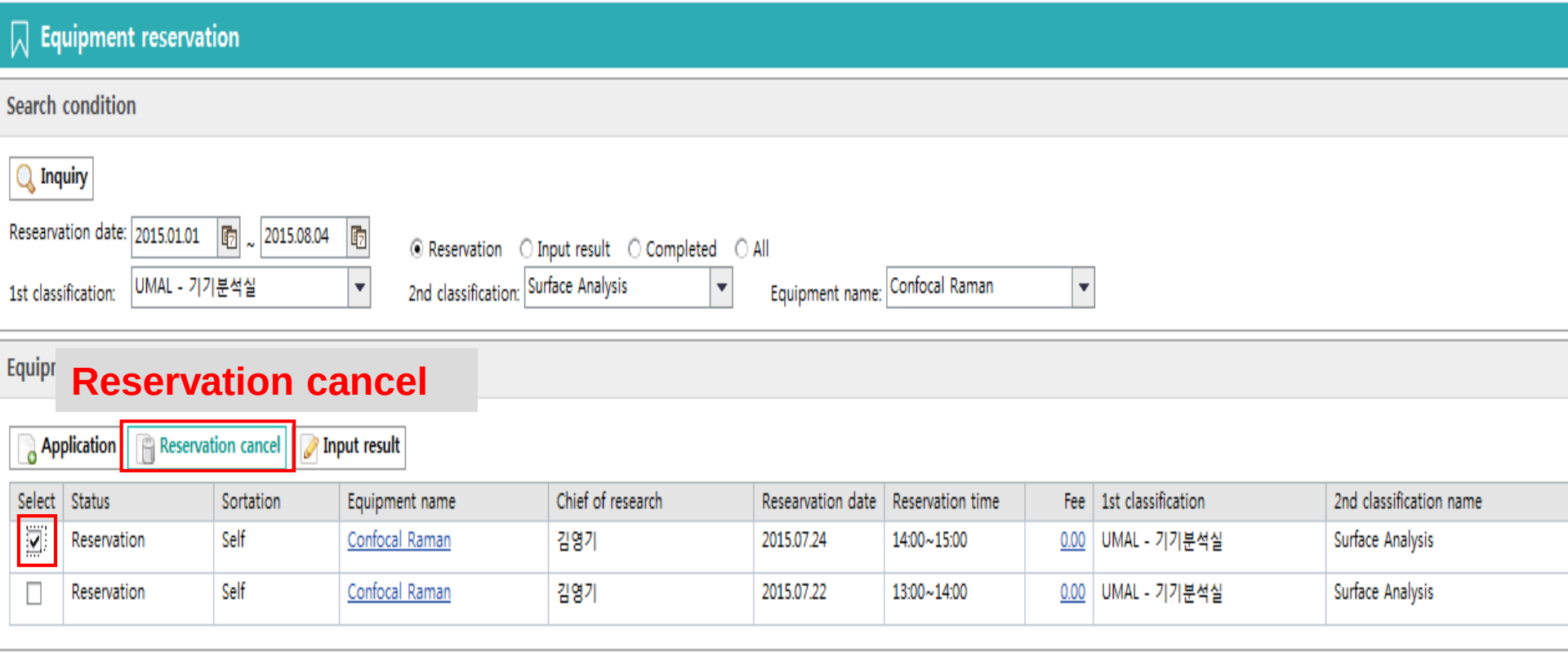


1. Select the classification and equipment

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

3. Click [Application].

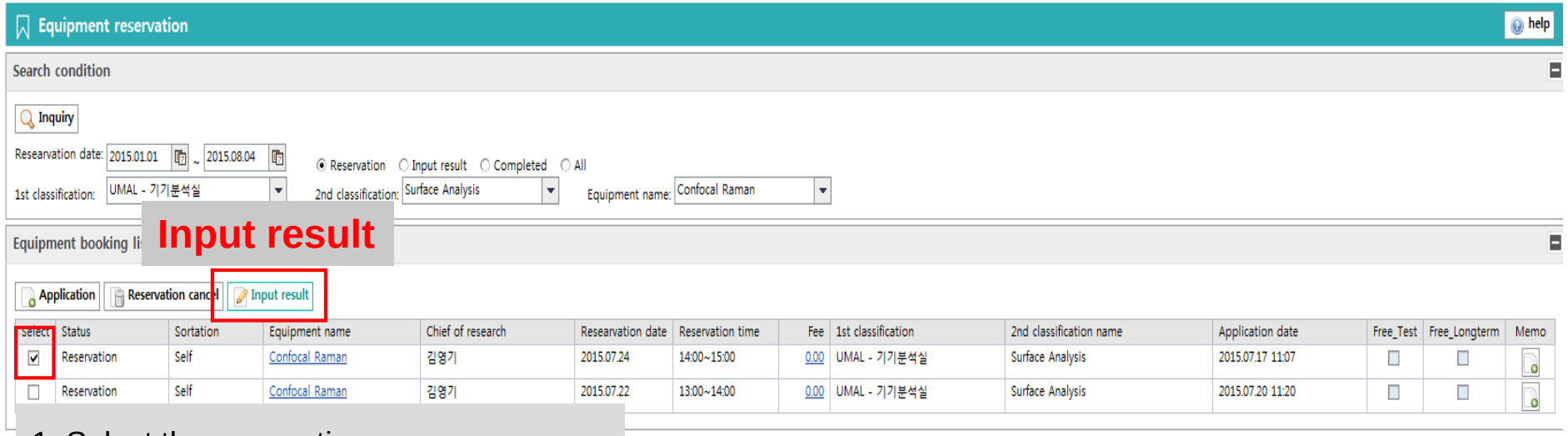
Reservation cancel



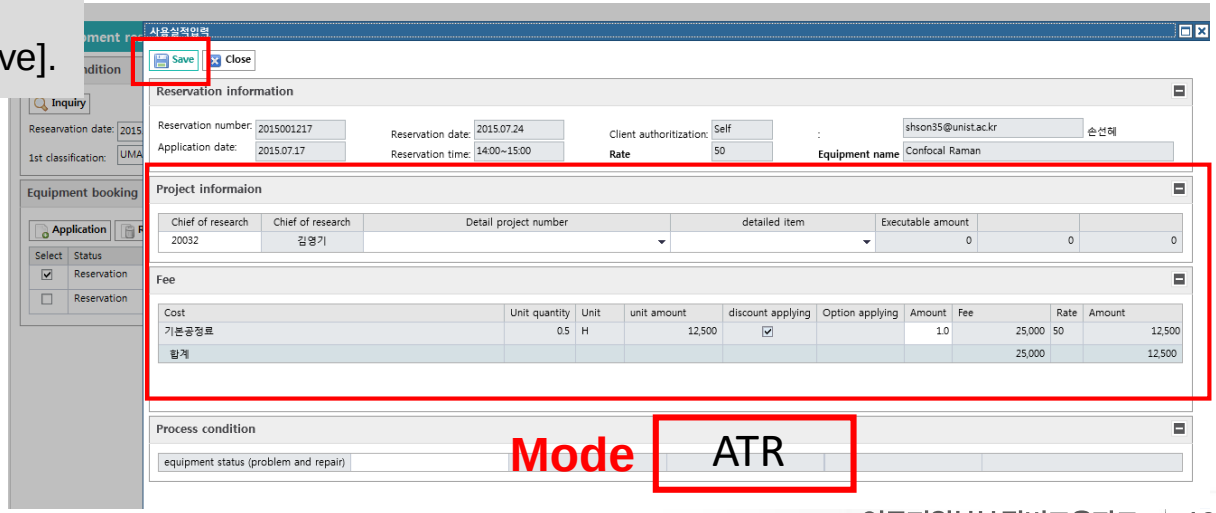
1. Select the reservation.
2. Click the [Reservation cancel].

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 for users of equipment

- 벌점 부과 기준

No.	벌점 부과 내용	벌점
[장비 사용 자격]		
1	해당 장비에 대하여 직접 사용이 허가 되지 않은 사용자가 기기를 사용	5
2	장비 예약하지 않고 장비 사용	3
3	장비 예약자 본인이 아닌 자가 장비를 사용	3
[장비 사용 예약]		
4	허용시간 이외의 시간에 장비 예약 및 사용	1
5	장비 예약시간을 초과하여, 예약시간 종료 전에 초과시간에 대한 예약없이 장비 사용	1
6	장비 예약 취소 사실 통보 없이 해당 시간에 장비 사용하지 않은 경우	3
7	「연구지원본부 운영지침」제7조의 내용을 기준으로, 장비 예약 취소 기한이 지나서 예약을 취소한 경우	1
8	예약 후 장비담당자에게 통보하지 않고 기기 사용	1
[부주의한 행동]		
9	장비 사용 중 허용되지 않은 기능 조작	3
10	장비 사용 중 장비의 이상이나 고장 발견 후 담당자에게 즉시 고지하지 않은 경우	3
11	사용자 부주의로 기기 손상 및 고장	5
12	사용자 부주의로 장비 부속품 분실 또는 파손	5
13	장비 사용 후 장비사용일지를 작성하지 않거나 허위 작성 또는 일부만 작성	1
14	담당자가 장비 또는 시설의 정상적인 작동과 안전을 유지하는 데에 반드시 파악해야할 시료의 정보를 제공하지 않아 장비 손상 및 고장을 초래	3
15	야간 또는 장비 담당자의 정규 근무시간이 아닌 때에 장비 사용 후 소등. 출입문단속. 주변 정리 등을 확인하지 않고 퇴실	3
16	유독 물질 및 가스의 누출 또는 화재 발생의 위험을 초래	5
17	타인의 개인물품(분석 및 공정 소모품 및 기자재)을 사전 동의 없이 사용하거나 훔치는 행위	5

Penalty points for users of equipment

- Penalty points criteria

No.	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	Leaving the laboratory without putting the laboratory back in order, without turning off the lights, or without properly locking the entrance door, after using equipment at nighttime or during the equipment manager's off-hours	3
16	Causing leakage of toxic substances, gases, or causing risk of fire	5
17	Using or stealing someone's personal items (e.g. supplies, equipment or materials for analysis and process) without prior consent	5

Penalty points for users of equipment

- Follow-up Actions after Imposing Penalty Points

구분	벌점	조치내용
[장비사용자 개인]		
개인에게 부과된 벌점 합산	≥ 5 points	장비 담당자가 사용자 및 지도교수에게 이메일로 통보(벌점 8점 이상일 시 장비 사용이 3개월간 금지됨을 공지)하고 해당 사용자의 벌점 내역을 기기실에 게시
	≥ 8 points	장비 담당자가 사용자 및 지도교수에게 사용자의 해당 장비 사용이 3개월간 금지되고 재교육 후 사용이 가능함을 이메일로 통보하고 지도교수에게 공문 발송, 해당 사용자의 벌점 내역을 기기실에 게시
(사용자 소속 연구실)		
동일 연구실에서 동일 장비에 대하여 연구실 소속 학생들에게 부과된 벌점 합산	≥ 12 points	장비 담당자가 지도교수와 해당 사용자에게 벌점 15점 이상일 시 해당 연구실의 해당 장비 사용이 3개월간 금지됨을 이메일로 통보
	≥ 15 points	장비 담당자가 지도교수에게 해당 연구실의 해당 장비 사용이 3개월간 금지됨을 이메일로 통보, 지도교수에게 공문 발송, 해당 사용자의 벌점 내역을 기기실에 게시
동일 연구실에서 연구지원본부 전체 장비에 대하여 연구실 소속 학생들에게 부과된 벌점 합산	≥ 20 points	연구지원본부에서 지도교수와 소속 학생에게 벌점 25점 이상일 시 해당 연구실의 연구지원본부 전체 장비 사용이 1개월간 금지됨을 이메일로 통보
	≥ 25 points	연구지원본부에서 지도교수와 소속 학생에게 해당 연구실의 연구지원본부 전체 장비 사용이 1개월간 금지됨을 이메일로 통보, 지도교수에게 공문 발송, 해당 벌점 내역을 연구지원본부 게시판에 게시

Penalty points for users of equipment

- Follow-up Actions after Imposing Penalty Points

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.