JES-X3 series
JES-X310 / JES-X320 / JES-X330

Electron Spin Resonance Spectrometer

JEOL RESONANCE
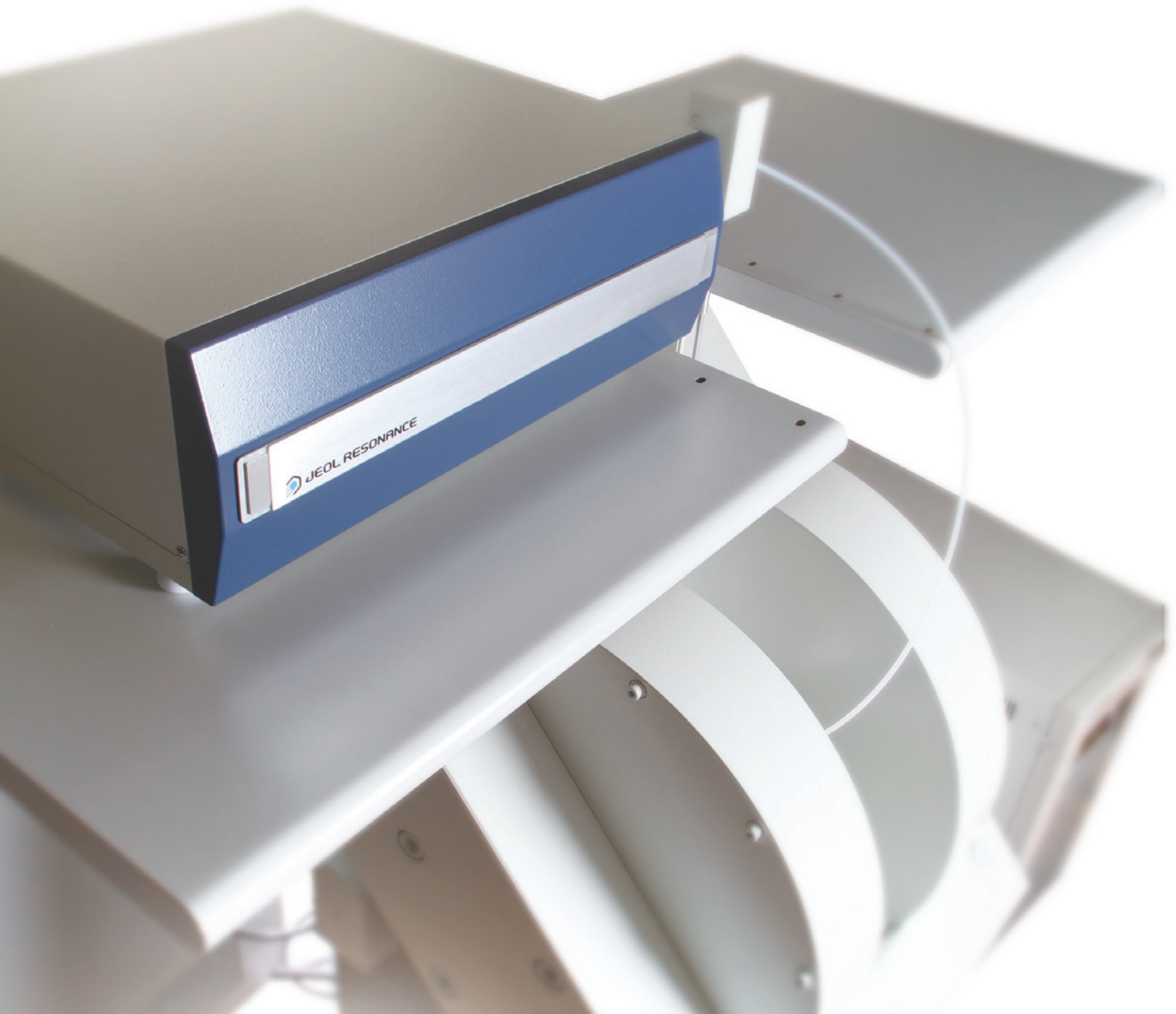
JEOL Ltd.

ESR Spectrometer **JES-**

The ESR Spectrometer JES-X3 series has an improved low-noise Gunn oscillator
sensitivity compared to previous models.
ESR is the only instrument for directly detecting paramagnetic species.
This supports a variety of applications in research, development, inspection and

High sensitivity

The standard configuration includes a Gunn oscillator as the stable,
low-noise microwave oscillation source, and a cylindrical (TE_{011}) cavity
with an internal modulation method providing modulation with good
uniformity and a high Q value, enabling high-sensitivity measurements.
The data is the ESR signals for 1 μM TEMPOL/benzene solution.

Signal : Power 1 mW

Noise : Power 200 mW
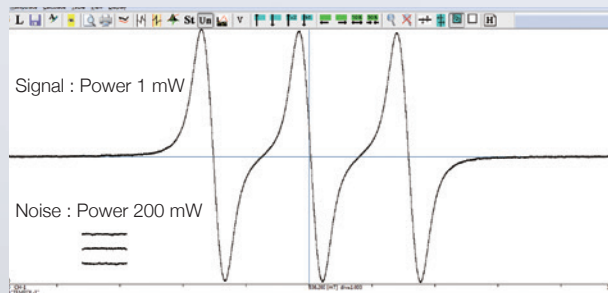
Magnetic field linearity

This figure shows the 6 ESR lines derived from Mn^{2+} measured
by changing the center field by 20 mT for each spectrum. The
coincidence of each peak position, even under different field setting,
indicates the excellent field linearity of the magnet field.
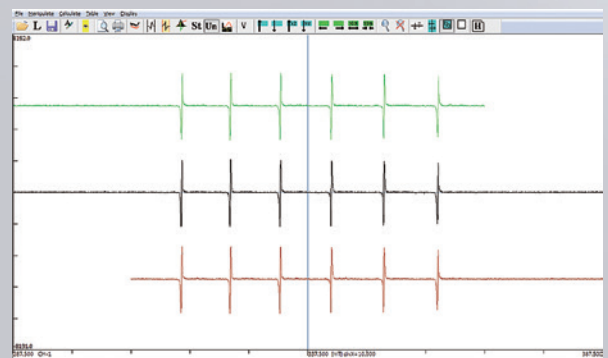
X3 series

providing a 30% improvement in

evaluation.

- Improved sensitivity with the ultra-low noise Gunn oscillator
- Built-in microwave frequency counter
- Intuitive user interface
- Various automatic measurement modes
- 3 types of magnets to suit the application
- Zero cross-field sweep function
- Wide variety of attachments

High resolution

High-purity materials are used for the magnet pole pieces and precisely engineered to provide a magnetic field with superior uniformity. The addition of ring shims to the pole piece surface makes it possible to obtain excellent uniformity over a wide range.
The separation of the t-butyl group (4.7 μT) showing the smallest division of the galvinoxyl radical can be obtained.
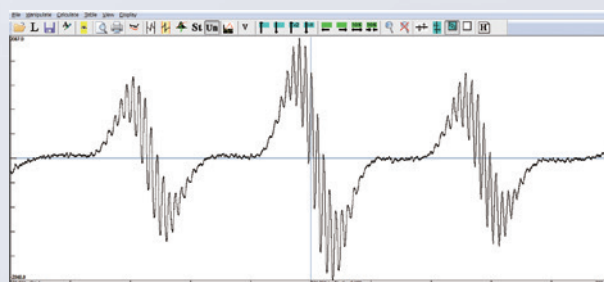
Magnetic field stability

Data acquired near the center of the ESR signal for the perylene cation radical. Even with a signal exhibiting fine splitting, there is no spreading, demonstrating the exceptional stability of the magnetic field.

1 scan

50 scans

100 scans
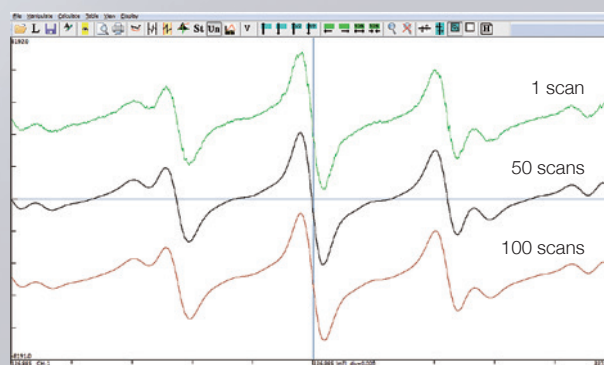
Intuitive User Interface (ESR measurements)

All the functions needed for ESR measurements are presented in 1 window that can be operated intuitively.
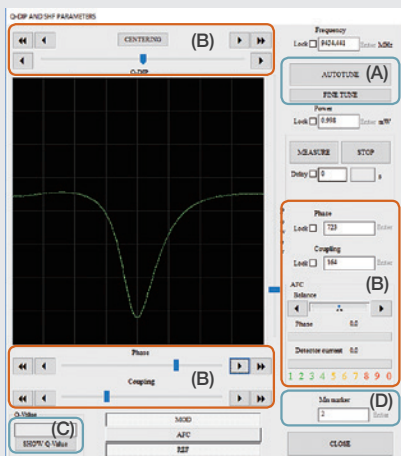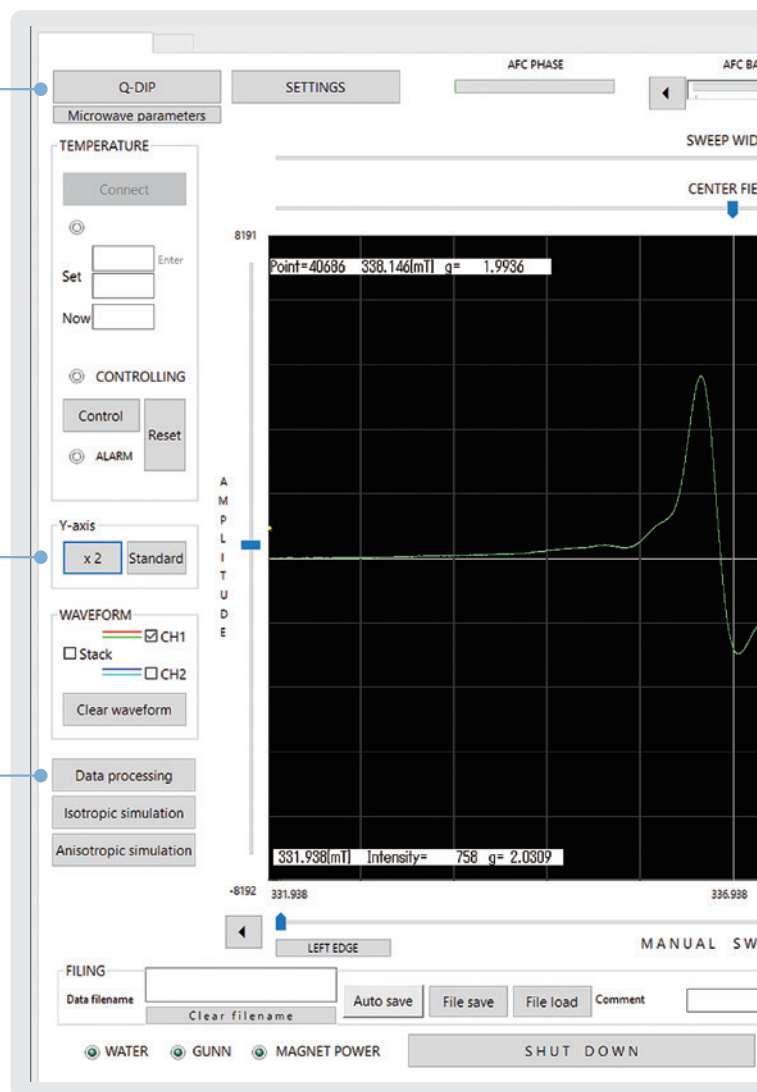Start the ESR system, adjust the microwaves from the Q-DIP window, set the acquisition conditions and

Q-DIP
Easily perform microwave adjustment.

Dynamic range
Switch between 5 settings.

Software for ESR analysis (P5)

■ **Microwave adjustment functions**

Microwave adjustment can be performed automatically using AUTOTUNE, or manually using various buttons.

(A) AUTOTUNE
Automatically optimizes the phase, coupling and detection of the resonance frequency of the microwaves.

(B) MANUAL TUNE
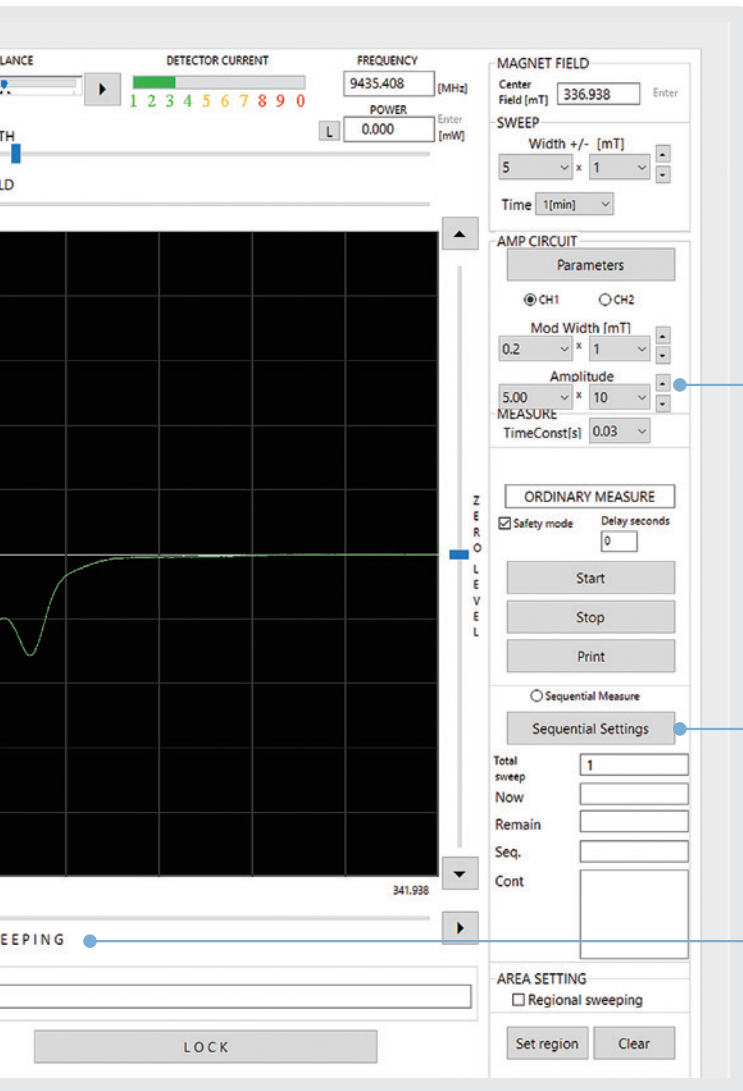Manually adjust the phase and coupling while observing the Q-DIP waveform.

(C) Show Q-value
Displays the approximate Q value.

(D) Mn Marker
The insertion amount (0 to 1000) of the Mn marker can be adjusted.

start measurements.

ESR measurement

The interface shows:

- BALANCE
- DETECTOR CURRENT: 1 2 3 4 5 6 7 8 9 0
- FREQUENCY: 9435.408 [MHz]
- POWER: L 0.000 [mW] Enter
- TH
- LD

MAGNET FIELD
- Center Field [mT]: 336.938 Enter

SWEEP
- Width +/- [mT]: 5 × 1
- Time: 1[min]

AMP CIRCUIT
- Parameters
- ● CH1 ○ CH2
- Mod Width [mT]: 0.2 × 1
- Amplitude: 5.00 × 10
- MEASURE
- TimeConst[s]: 0.03

- ORDINARY MEASURE
- ☑ Safety mode   Delay seconds: 0
- Start
- Stop
- Print

- ○ Sequential Measure
- Sequential Settings
- Total sweep: 1
- Now
- Remain
- Seq.
- Cont

AREA SETTING
- ☐ Regional sweeping
- Set region   Clear

341.938

EEPING ●

LOCK

ZERO LEVEL

Sequential measurement
Automatic continuous measurement can be set.

Manual sweep
Check for presence of an ESR signal before measurement and set start position manually.

■ Sequential Measurement Mode

Various 2-dimensional measurements can be obtained by sequentially varying the ESR measurement parameters automatically.

Example of sequential measurement parameters
- ○ Temperature
- ○ Microwave power (saturation)
- ○ Modulation width
- ○ Detection phase
- ○ Crystal axis (anisotropic tensor)
- ○ Amplification

Parameter change increment
- Arithmatic sequence
- Geometric sequence
- User-defined sequence

Other functions
- Interval time
- Repeat measurement
- Integration
- Data auto-save
- Save/Load parameter settings

Liquid Phase

Solid Phase
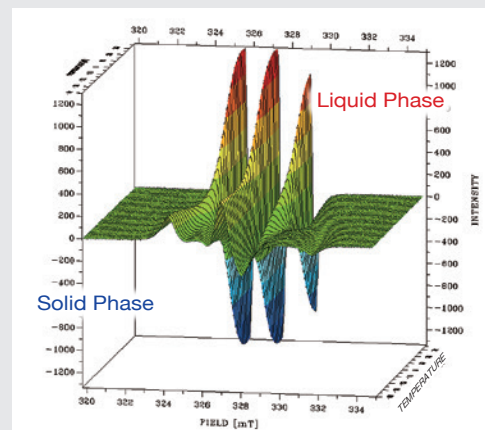
ESR signal of the TEMPOL radical in glycerol
Temperature varied in 2 °C steps from − 35 °C to + 37 °C

Data Processing for ESR Signal Analysis

The system is equipped with the tools required to obtain the information needed for ESR analysis (g-factor, A value, spin, linewidth, etc.) from the acquired measurement data.

■ g-factor information

When a line is set on the ESR signal, the g-factor information can be extracted and a table of g-factors can be generated. The g-factor table can be saved in text format and processed using spreadsheet software. Highly-precise g-factors can be obtained by performing correction of the magnetic field using the Mn markers as a reference.
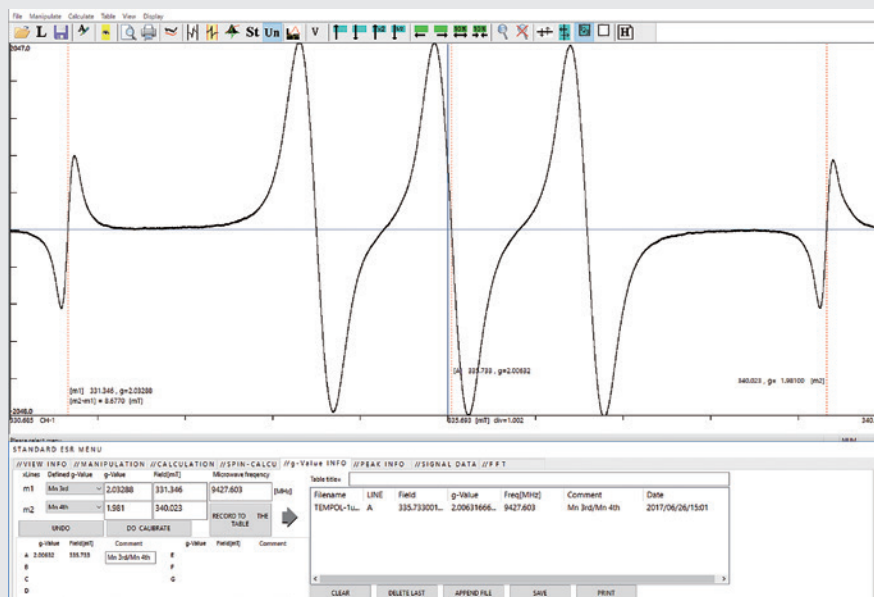

■ Spin calculation

The number of spins (radical concentration) can be calculated with the results presented in a list. The number of spins is proportional to the doubly-integrated value (area) of the ESR signal. The number of spins for an unknown sample can be determined by comparing the doubly-integrated value obtained for unknown samples with the value for a standard sample, e.g. TEMPOL, with a known concentration. Sensitivity correction is applicable by doubly-integrating Mn^{2+} signal as well.
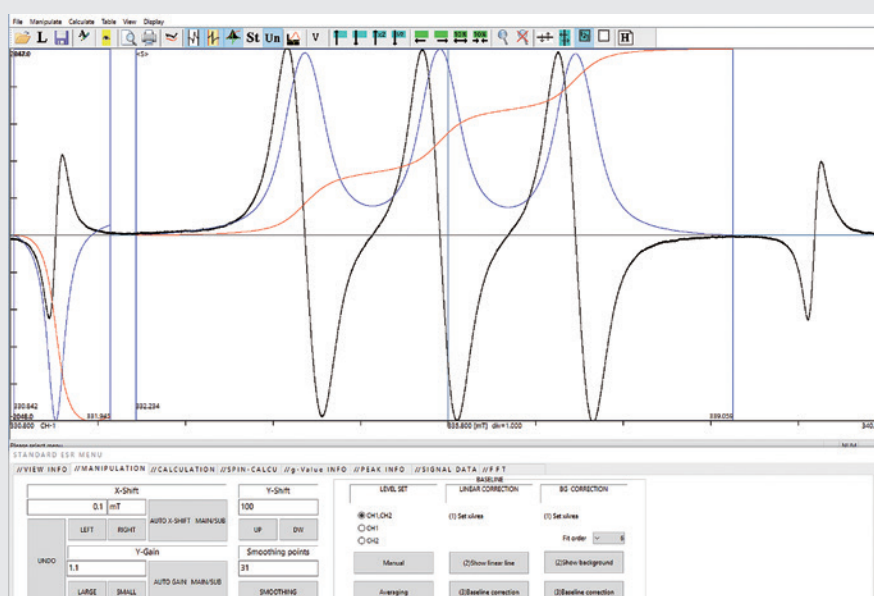
■ Waveform Processing

Available processing includes arithmetic operations on the signal, conversion to exponential and logarithmic forms, differentiation and integration, adjusting size and position for fitting signal, and baseline correction.

● Arithmetic operations
  Arithmetic operations on waveforms.

● Differentiation and integration
  Differential and integral processing of waveforms.

● Spectrum separation
  If the conditions are matched, spectrum separation may be possible using subtraction.

● Background elimination
  When there are known substances mixed into the sample, or when paramagnetic impurities are found in the sample tube, the arithmetic functions can be used to eliminate the background signal from the impurities.


① Sample including impurities

② Impurities

① - ② (Background elimination)
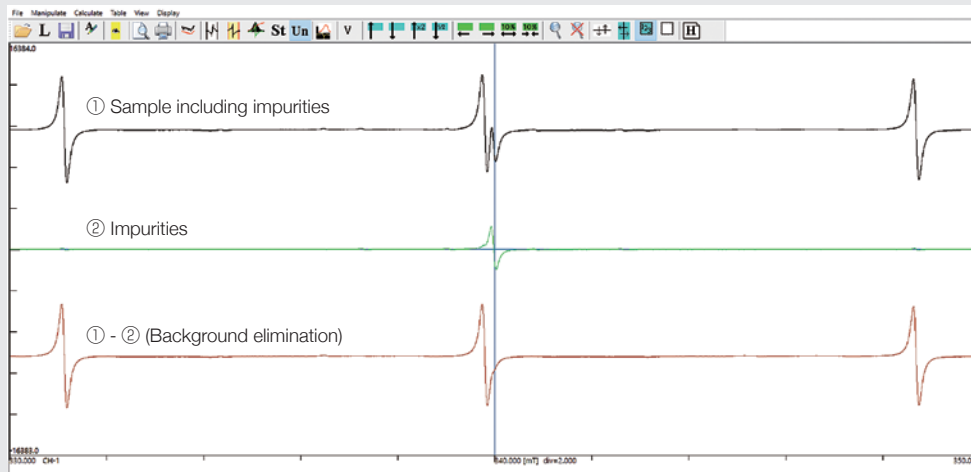
● AUTO SHIFT · AUTO GAIN
  Signal position and intensity can be adjusted automatically.

● X-Shift · Y-Shift
  Data can be freely manipulated, including moving the signal longitudinally or vertically, and varying the intensity.

● Smoothing
  When power cannot be applied because the sample is easily saturated, or the concentration is low, a sufficient S/N might not be obtained. In such cases, smoothing can be used to reduce the noise components.

● BASELINE correction
  Baseline correction can be performed by approximating the baseline components using a regression curve.
  · Linear approximation   · Regression curve (2nd to 11th order curve)

Before baseline correction

After baseline correction
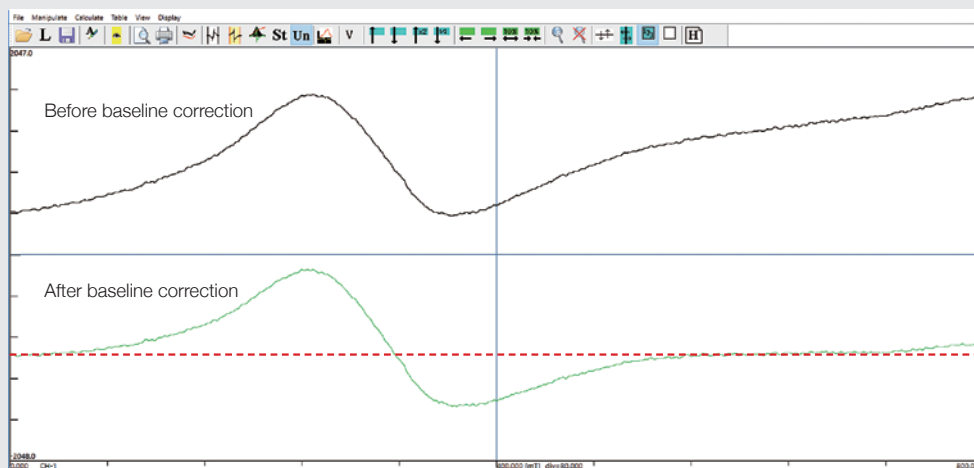
■ Various 2-Dimensional Displays

The display range can be set for signals and 2D data, and 2D data can be edited and created.
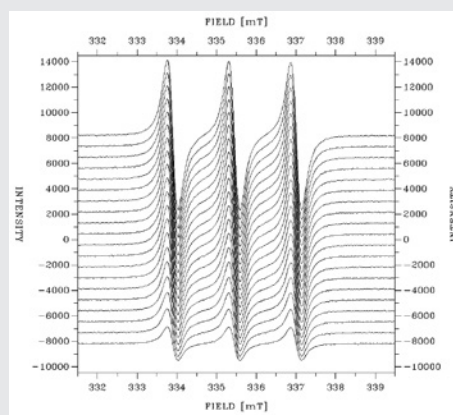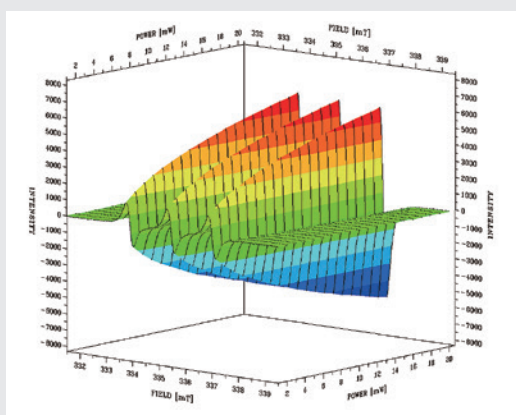
TEMPOL radical ESR signal
The microwave power range is varied in 1 mW steps from 1 to 20 mW

■ Peak information

By specifying an area on the ESR signal, it is possible to extract peak information (intensity, linewidth, intensity relative to the Mn marker) and generate a peak table. The peak table can be saved in text format and processed using spreadsheet software.

■ Other functions

● Partial signal zoom
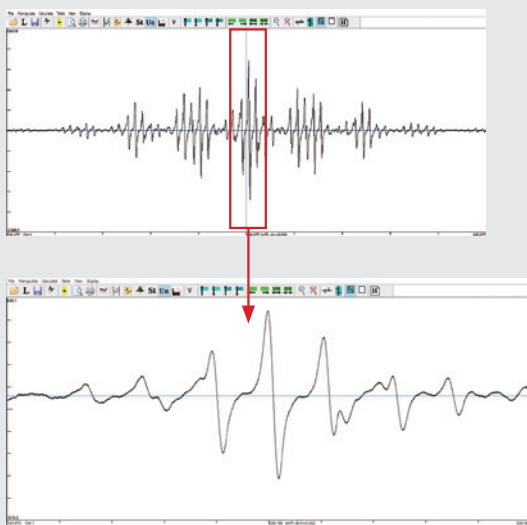
● Batch conversion of multiple files into text format
The original spectrum data is a 64 K point binary format; but, it is possible to compress the number of points and convert the files into text format. All the data files contained in a folder can be converted into text files at one time.


XY axis data in text format

Simulation Assisting ESR Signal Analysis

■ Simulation software

Simulation of Isotropic and Anisotropic ESR signals is included in the standard configuration. In the simulation for an ESR signal for which the radical types can be estimated, the waveform is calculated from the signal-specific information, such as the splitting width, g-factor, and linewidth, in addition to the actual measurement conditions like resonance frequency, center magnetic field and sweep width.
For the anisotropic simulation, the anisotropic parameters (g-factor anisotropy, A-value anisotropy, linewidth anisotropy) are used to calculate the waveform. Axial symmetry as well as rhombic anisotropy can be handled.

● Isotropic simulation
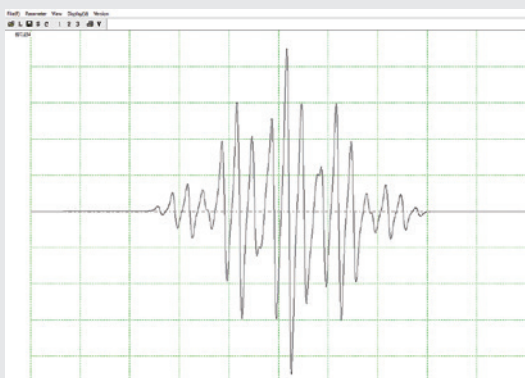
Simulation of ESR signal of the Anthraquinone radical anion

● Anisotropic simulation
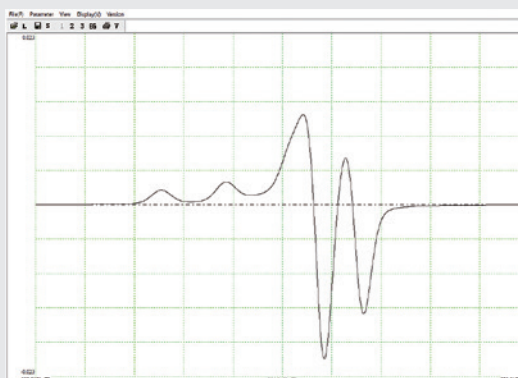
Simulation of ESR signal for copper

Sample Tubes

Sample tubes have an outer diameter of 2 to 5 mm, with the measurement section made from high-purity synthetic quartz.
For samples with a large dielectric losses and liquid samples, sample tubes with a smaller diameter, capillary tubes or aqueous sample cells may be more suitable.

Unit:mm

● Quartz For X-band 5 φ

  270 Part No.：780225392
  100 Part No.：820374083
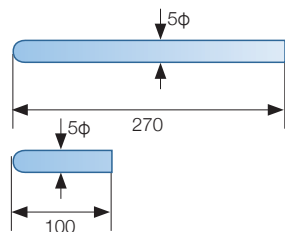
● For X-band (Quartz tip) 3 φ

Part No.：422000272
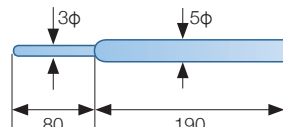
● Quartz For Q-band 2 φ

Part No.：620007125
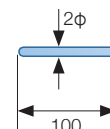
● For X-band (Quartz tip) 5 φ

Part No.：422000281
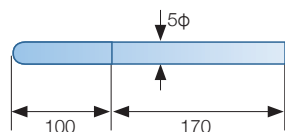
● For X-band (Quartz tip) 2 φ

Part No.：422000990
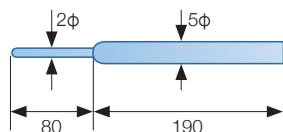
● For sample rotation device

A=5φ Part No.：800310641
  3φ Part No.：800310659
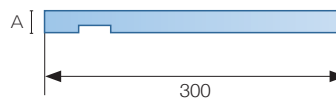
＊ The caps for sample tubes are sold separately.

■ **Variable Temperature Controller** (ES-13060DVT5)

● Features
· Variable temperature range:103 to 473 K
· Temperature stability : ± 0.5 K
· USB connection
· Temperature control : Auto PID
· Compressor flow : 17 L/min (air)
· Dewar volume : 10 L
  (30 L Dewar also available as option
  Variable temperature range : 113 to 473 K)

● Composition
· Temperature controller
· Heating tube
· Dewar adapter
· Metal Dewar
· Variable temperature adapter
· Compressor
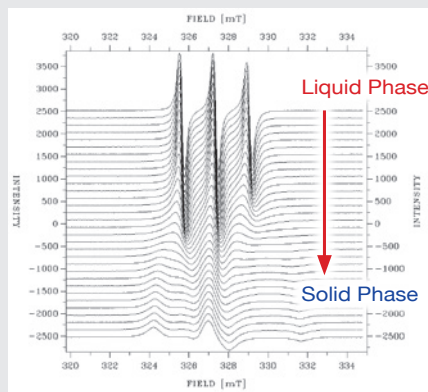
ESR signal of the TEMPOL radical in glycerol
Temperature varied in 2°C steps from -35 to +37 °C

10 L Dewar   30 L Dewar

* Separate consultation required for 400 °C VT.

■ **Liquid He Variable Temperature Controller** (ES-CT470)

● Features
· Variable temperature range : 2.5 to 470 K
· Easy set-up : Assembly time : about 20 min
· Rapid cooling : From room temperature to 4.2 K :15 min
· Temperature stability : ± 0.5 K
· Can use both UV radiation and Mn markers
· Easy sample exchange
· Control using liquid nitrogen available
  (Variable temperature range : 80 to 470 K)

* Additional rotary pump is needed for the experiments
  conducted below 4.2 K.

● Composition
· Cryostat
· Transfer line
· Dewar adapter and spacer
· Flow meter
· Temperature sensor
· Temperature controller
· Parts for assembly and spare parts
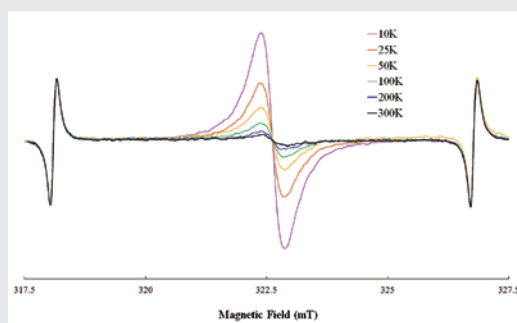
ESR signal of silicon dangling bond

■ Aqueous Sample Cells (ES-LC12)

● Features
· Flat cell structure makes it possible to minimize reduction of sensitivity.

● Specifications
· Volume：130 µL
· Sample tube outer shape (mm)：12 × 1.5
· Sample tube inner shape (mm)：10 × 0.25
· Permitted temperature range：Room temperature

50mm

Holder

Suction pump
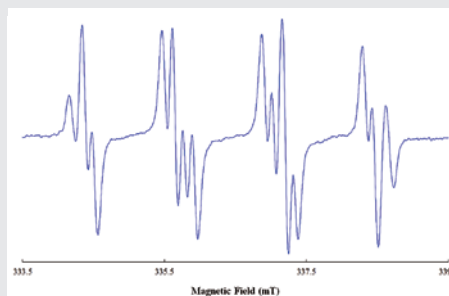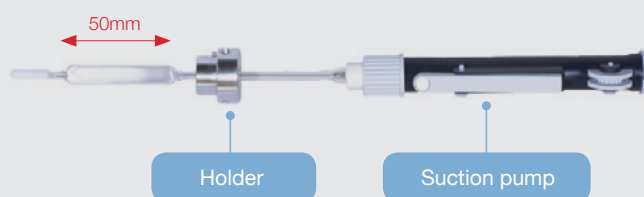
ESR signal of DMPO spin adducts of superoxide anion radical

■ Sample Angular Rotation Device (ES-12010)

● Features
· Angle setting resolution：0.06° (Rotation angle: 0 to 360°)
· Variable temperature controller (ES-13060DVT5) and the liquid helium variable temperature controller (ES-CT470)can be used concurrently.

● Compatible cavity
· ES-UCX2/ES-MCX3B

● Sample rod
· 1 each of 5 φ, 3 φ are provided
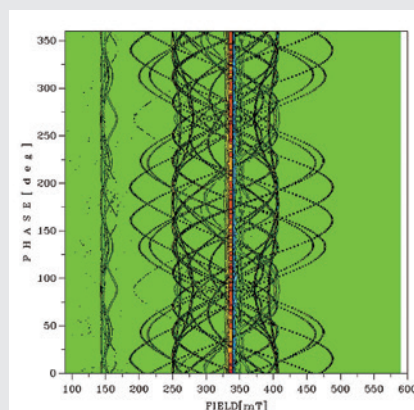
Angular rotation spectrum (1.2° increments) of diamond Ⅱ a monocrystal irradiated with an electron beam

■ Q-Band Microwave Unit (ES-SQ5)

● Features
· Temperature variation can be performed by attaching the temperature control adapter (ES-UTQ3) to the variable temperature unit (ES-13060DVT5) .
· High filling factor
· Only small sample volumes needed (a few µL)

● Composition
· Compatible ESR systems : JES-X320/JES-X330
· Q-Band cavity
· Q-Band microwave unit

● Sample tubes
· Q-Band dedicated sample tubes

(B) Q-band
v = 34.85 GHz
H_0 = 1248.8 mT
Mn^{2+}
Cr^{3+}

(A) X-band
v = 9.454 GHz
H_0 = 340.96 mT
Mn^{2+} (g =1.981)
Cr^{3+}

ESR signal for Mn^{2+} containing Cr^{3+} as impurities is shown around the center field H_0.
(A) X-band, (B) Q-band

Q-Band microwave unit configuration
(Left) Q-Band microwave unit
(Right) Q-Band cavity

Attachments Generating Radicals by External Stimulation

■ Ultraviolet Irradiation Apparatus (ES-USH500 / USH500H / UXL500 / UXL500H)

● Features
· Variable temperature controller (ES-13060DVT5) and the liquid helium variable temperature controller (ES-CT470)can be used concurrently.
· Can choose a high-voltage mercury lamp or a xenon lamp.
· 2 types of irradiation models for each light source.
· The ultraviolet irradiation accessory kit (ES-UVAT1) and condenser lens (ES-UVLL/UVLS) are required options.
· Selectable irradiation wavelength using colored glass filters.
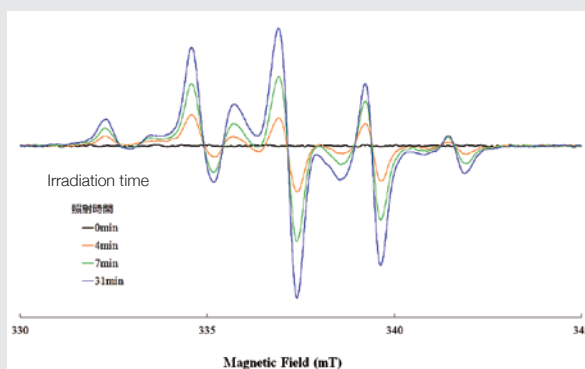
Variation in ESR signal intensity relative to the irradiation time of polymethacrylic resin (optical fiber)

∗ A cart for moving the ultraviolet irradiation apparatus is not included.
∗ Please inquire about irradiation apparatus using optical fiber if needed.

■ Time-Resolved ESR System (ES-CIDEP)

● Features
· Time resolution of several hundred ns

● Composition
· Wide-band pre-amplifier (ES-WBPA4)
· Digital oscilloscope
· Time-resolved ESR software
· Cables
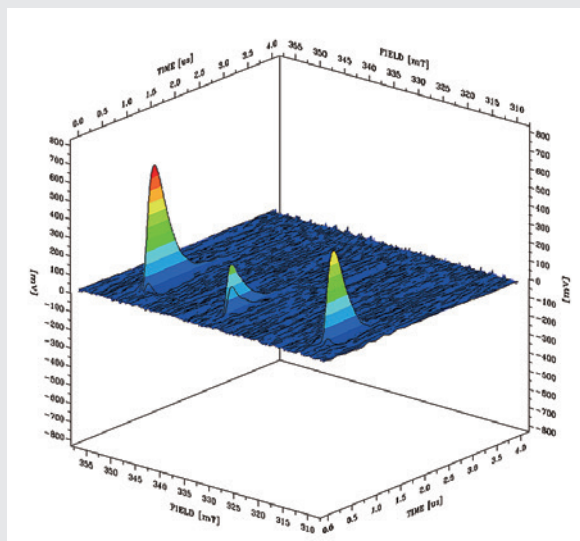
Sample：TMDPO / benzene solution
YAG laser: 355 nm (3rd harmonic)

∗ Laser light source and optical path not included.

■ Helix Electrode Electrolytic Cell (ES-EL30)

● Features

· Can use with the Variable temperature controller (ES-13060DVT5).
· Measurement possible for highly-polar organic solvents (DMSO, DMF, etc.) or with water as the solvent.

● Composition

· Electrolytic cell (glass vessel)
· Electrodes (Au),
  Reference electrode (Ag)
· Sample tube (quartz)
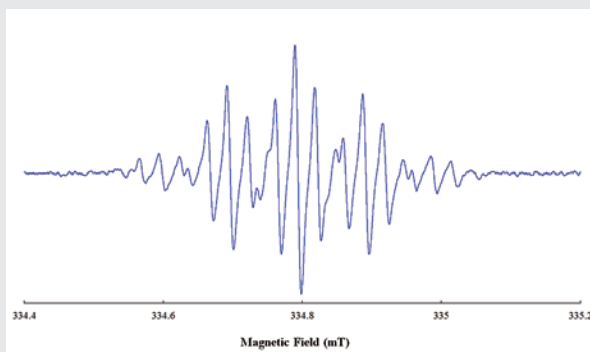
Anthraquinone anion radical ESR signal

Helix working electrode

Exhaust port

Counter-electrode terminal

Working electrode terminal

Reference electrode terminal
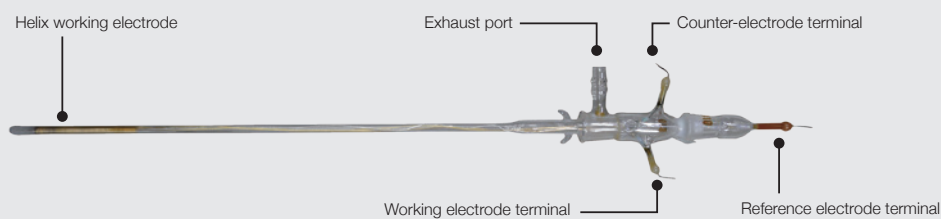
Please see the attachment brochure for other options, such as insertion type Dewar, ODMR, EDMR, ESRET, ENDOR, and so forth.

ESR Applications

Inspection/ Assessment

Analysis of biological REDOX reactions

Structural analysis

Materials development

ESR

Basic research and technology

Foods
Antioxidant function assessment
Irradiated food detection
Disinfection / Sterilization

Fossils & Rocks
Dating
Dosimetry
Source location estimates

Living organisms
Function analysis
Metabolism / Activity
REDOX status etc.

Inorganic materials
Defect locations & structure
Bonding state
Conductivity etc.

Gemstones

Medicine

Pharmaceuticals / Supplements

Organic materials
Deterioration mechanisms
Reaction mechanisms
Results of radiation / exposure to light
etc.

Resources

Electrical materials
Performance / Durability
Recombination rate
Withstand voltage characteristics etc.

Gases

Polymer materials
Photo/Thermal polymerization process
Shear effect
Molecular motion etc.

Combustion

Magnetic materials
Magnetic properties etc.

Complexes
Electron state etc.

Liquid crystals

Green tea Pepper · Quartz · Coral Shell · Barite · Ruby Pearl · Tooth Bone · Lipid peroxide · OH⁻ O₂·⁻ · Sugar Beer · Active oxygen · Catalyst Glass · Adsorbed molecules · Diamond · Active nitrogen · Biological membranes · DNA · Ceramics · Coal Carbon · Lubricants Petroleum · Capsules · Surfactants · Organic magnetic materials · Organic conductors · Superconductors Semiconductors · Methane hydrate · Crude drugs Saccharides · Clathrate compounds · Coating films · Conductive polymers · Conductors Thin metal film · Flame Gas · NO NO₂ · O₂ · Magnetic films · Ferromagnet Diamagnetic material · Solar cells · Photocatalyst · Methanol · Paramagnets · Magnetic polymers · Synthetic resins · Transition metals · Rare earths · CVD films · IGZO · Enzymes

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Installation Example

Unit:mm

JES-X310

AC100V Single phase 500VA
AC200V 3-phase 2kVA
Cooling water 12mm dia
Dewar for VT
800
Magnet
600
1180
1200
Spectrometer Data System
800
3600 or more
3000 or more

JES-X320

AC100V Single phase 500VA
AC200V 3-phase 13kVA
Cooling water 22mm dia
Dewar for VT
800
613
Power supply
683
Magnet
600
1400
1200
Spectrometer Data System
800
3800 or more
3200 or more

JES-X330

AC100V Single phase 500VA
AC200V 3-phase 20kVA
Cooling water 22mm dia
Dewar for VT
800
803
Power supply
703
Magnet
600
1600
1200
Spectrometer Data System
800
3800 or more
3200 or more

Main Specifications

	JES-X310	JES-X320	JES-X330
Electromagnet			
Maximum magnetic field (T)	~0.65	~1.3	~1.4
Sub-polepiece magnetic field (T)	-	~1.7	~2.0
Sweep width (mT)	±0.01 to 250	±0.01 to 500	
Magnetic field setting accuracy	±5μT or ±0.1% or less (whichever is larger)		
Long term stability	5×10^{-6}		
Pole diameter (root)/Effective gap(mm)	150 / 60	240 / 60	360 / 75
Microwave unit			
Frequency range (GHz)	8.750 to 9.650		
Frequency count display	7 digits (std)		
Microwave output (mW)	0.0001 to 200		
Microwave tuning	Auto		
Cavity			
Resonance mode / Q value (no load)	Cylindrical TE_{011} / 18000 or more		
Mn marker	Auto / Motor control		
Data system			
OS	Windows® 10		
Spectrum resolution (bit)	16		
Analysis software/ Simulation	Standard		

Dimentions and Weight

External dimensions = Width × Depth × Height

	JES-X310	JES-X320	JES-X330
Electromagnet (Including SHF table)			
Dimensions （mm)	1,180×710×1,105	1,400×803×1,190	1,600×990×1,190
Weight kg	520	1,060	2,300
Spectrometer			
Dimensions （mm)	300×602×602 / 35		
Excitation power supply			
Dimensions （mm)	Included in magnetic chassis	683×613×895	703×803×1,114
Weight kg	-	300	500
Power requirements			
Spectrometer	1φ 100 V, 500 VA		
Magnet （Breaker rating)	3 φ 200 V, 2 kV 30 A	3 φ 200 V, 13 kVA 60 A	3 φ 200 V, 20 kVA 100 A
Power supply fluctuation / grounding	± 5 % / Class D grounding		
Cooling water			
Water pressure (MPa)	0.05 to 0.2	0.15 to 0.3	
Flow rate (L/min) / Temperature (℃)	6 / 15 to 25	8 /15 to 16/25	16 /15 to 25
Faucet outer diameter (mm)	12	22	

✳ Appearance and specifications are subject to change without notice.
✳ The official name of Windows® is the "Microsoft Windows® Operating System".
✳ Microsoft and Windows® are registered trademarks of Microsoft Corporation in the USA and other countries.

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