

XM-10110

LaB₆ ELECTRON GUN

For the proper use of the instrument, be sure to read this instruction manual. Even after you read it, please keep the manual on hand so that you can consult it whenever necessary.

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XM-10110

LaB₆ ELECTRON GUN

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NOTATIONAL CONVENTIONS AND GLOSSARY

■ General notations

-  **WARNING :** A potentially hazardous situation which, if not avoided, could result in death or serious injury.
-  **CAUTION :** A potentially hazardous situation which, if not avoided, could result in minor injury or material damage.
Material damage includes, but is not limited to, damage to related devices and facilities, and to acquired data.
- CAUTION – :** Points where great care and attention is required when operating the device to avoid damage to the device itself.
-  **:** Additional points to be remembered regarding the operation.
-  **:** A reference to another section, chapter or manual.
- 1, 2, 3 :** Numbers indicate a series of operations that achieve a task.
-  **:** A diamond indicates a single operation that achieves a task.

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SAFETY PRECAUTIONS

For the proper use of the instrument, be sure to read the following safety precautions prior to starting operation or maintenance. They contain important information related to safety. Contact your JEOL service office whenever you are unclear about an operation or maintenance.

The safety definitions and their meanings used in our company's operation manuals are as follows:

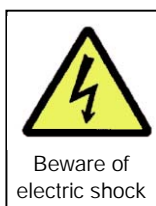
⚠ WARNING: A potentially hazardous situation which, if not avoided, could result in death or serious injury.

⚠ CAUTION: A potentially hazardous situation which, if not avoided, may result in minor injury or material damage.

Material damage includes, but is not limited to, damage to related devices and facilities, and acquired data.

Parts of this instrument where safety precautions are required are labeled with illustration signs as shown below.

Do not touch the parts labeled with these signs:



We request that you use the instrument in a proper manner and in the scope of the purposes and usage described in the brochures and operation manuals. Never make modifications such as removing protective parts, exchanging component parts and defeating safety measures.

The safety precautions for the optional attachments of this instrument are given in the individual instruction manuals as required.

CAUTIONS

- Never touch the high voltage terminals and connectors. There is a danger that you may get an electric shock.

1 GENERAL

The XM-10110 consists of a thermionic electron gun with a LaB₆ (lanthanum hexaboride) single crystal cathode and an ion pumping system.

A LaB₆ electron gun provides a higher brightness and a smaller energy-spread electron beam than a conventional tungsten cathode gun. Therefore, it provides higher quality secondary electron images than a conventional gun at a given resolution image; with the same image quality, higher resolution is attainable. The LaB₆ gun also provides a probe current several times higher than the conventional gun at a given probe diameter. At the same probe current, the probe diameter of the LaB₆ gun is half that of the conventional gun. Therefore, the LaB₆ gun is very useful for micro-area analysis and trace element analysis.

The electron gun chamber is independently evacuated by an ion pump and kept under high vacuum, resulting in a LaB₆ cathode lifetime that is much longer than that of the conventional gun cathode. The LaB₆ cathode can be easily changed to a W cathode.

2 SPECIFICATIONS

Resolution of secondary electron image:	5 nm (with a special specimen holder)
Brightness of electron gun:	About five times brighter than the W cathode gun
Probe current range:	10 ⁻¹² to 10 ⁻⁵ A
Probe current stability:	3 × 10 ⁻² /h
Ultimate pressure in electron gun chamber:	9 × 10 ⁻⁵ Pa
Pressure monitoring:	Displayed on the computer by converting the ion current of the ion pump to pressure value.
Pumping:	Automated
Applicable instrument:	JXA-8100, JXA-8200

3 COMPOSITION

Electron gun chamber evacuation pipe.....	1 set
Wehnelt unit	1 set
Single crystal LaB ₆ cathode.....	1 set
Cables	1 set
Ion pump and power supply	1 set
Special specimen holder	1 set

4 MOVEMENT

4.1 W/LBG switch

By this switch on the main panel of the JXA-8100/8200, you can select evacuation sequence for a W cathode and that for a LaB₆ cathode and control power supply to the ion pump.

- W/LBG switch

W: Set the W/LBG switch to W when a W cathode is in use. The ion pump does not operate.

LBG: Set the W/LBG switch to LBG when a LaB₆ cathode is in use. The V3B will not open so long as the electron gun chamber is kept under high vacuum during day and night operation of the ion pump.

4.2 Vacuum System

The diagram of the vacuum system is shown in Fig. 4.1 and the valve condition is in Table 4.1.

In the normal condition the V3B valve is closed and the electron gun chamber is evacuated only by the ion pump.

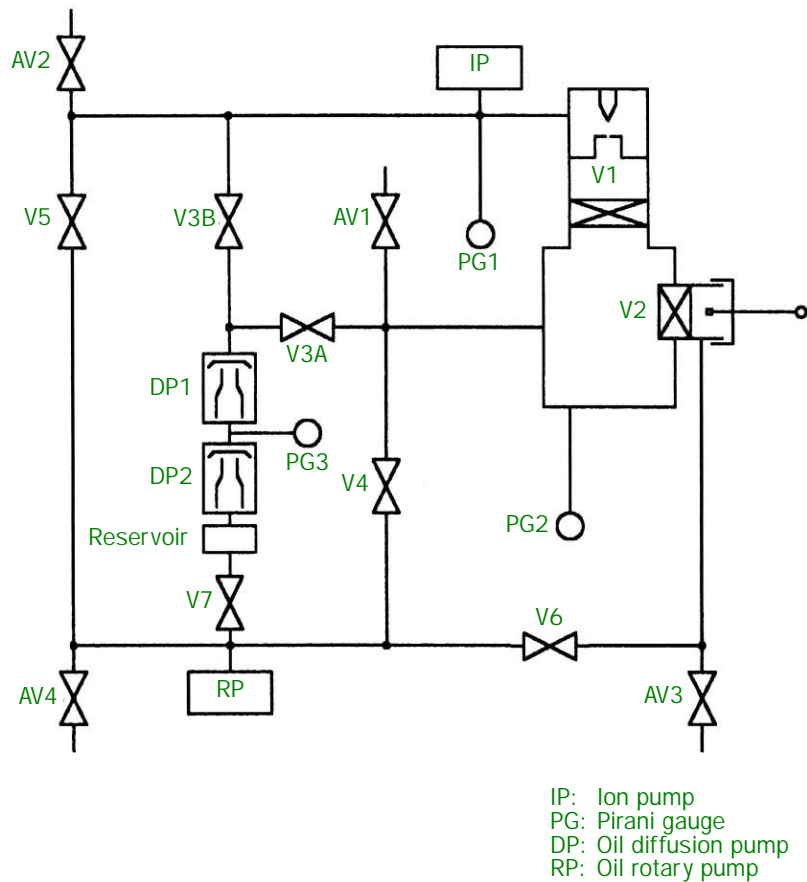


Fig. 4.1 Vacuum system

Table 4.1 Valving of XM-10110

		V1	V2	V3A	V3B	V4	V5	V6	V7	AV1	AV2	AV3	AV4
When the system shuts down		×	×	×	×	×	×	×	×	×	×	×	○
Startup (before rough pumping)	30 seconds after setting the POWER key to START	×	×	×	×	×	×	×	○	×	×	×	×
Final state	W/LBG switch	Ion pump											
	LaB ₆	* In operation											
	W	Not operated											
Specimen exchange	Rough pumping of specimen exchange chamber	○	×	○	×	×	×	○	×	×	×	×	×
	Withdrawing or inserting of specimen	○	○	○	×	×	×	×	○	×	×	×	×
	Re-exposing specimen exchange chamber to atmospheric pressure	○	×	○	×	×	×	×	○	×	×	○	×
Filament exchange	With GUN VENT button pushed	×	×	○	×	×	×	×	○	×	○	×	×
	Rough pumping of electron gun chamber	×	×	○	×	×	○	×	×	×	×	×	×
	Final pumping of electron gun chamber	×	×	○	○	×	×	×	○	×	×	×	×
	After operating pressure is reached	○	×	○	○	×	×	×	○	×	×	×	×
* Stage drawout	With VENT button pushed	×	×	×	×	×	×	×	○	○	×	×	×
	Rough pumping of specimen chamber	×	×	×	×	○	×	×	×	×	×	×	×
	Start of final pumping of specimen chamber	×	×	○	×	×	×	×	○	×	×	×	×
	After operating pressure is reached	○	×	○	×	×	×	×	○	×	×	×	×
Column maintenance, etc.	With VENT and GUN VENT buttons simultaneously pushed	×	×	×	×	×	×	×	○	○	○	×	×
	Rough pumping of column	×	×	×	×	×	×	×	×	×	×	×	×
	Start of final pumping of column	×	×	○	○	○	○	×	○	×	×	×	×
	About 10 minutes after operating pressure is reached	○	×	○	○	×	×	×	○	×	×	×	×
* Until final operating pressure is reached following startup of ion pump		○	×	○	○	×	×	×	○	×	×	×	×
* Evacuation of electron gun chamber by ion pump		○	×	○	×	×	×	×	○	×	×	×	×

* Indicates that the ion pump is in operation.

○: Open; ×: Closed

4.3 Vacuum Pressure Monitoring

- **Monitoring vacuum pressure on the operation observation system**

Selecting **Maint. – Maintenance** displays the Maintenance window and also the pressure value converted from the ion current of the ion pump. This value is displayed only when the W/LBG switch is set to LBG.

- **Monitoring vacuum pressure on EWS**

Selecting **JEOL – Vacuum Monitor** displays the Vacuum Monitor window and then checking Vacuum display displays the same value mentioned above.




5 OPERATION

In this section operational procedure on the electron optics system is described in the way using the operation observation system. You can operate the same procedure on EWS.

 For details, refer to the instruction manual of JXA-8100/8200.

5.1 Startup


Start the instrument as follows.

1. Set the W/LBG switch on the main panel to LBG (upper side).
2. Start the instrument according to the instruction manual of JXA-8100/8200.
 -  The ion pump power supply and the gate valve are automatically controlled. When the pump pressure reaches approx. 2.9×10^{-4} Pa, the HV READY lamp on the JXA-8100/8200 basic unit lights to indicate that accelerating voltage application and filament heating are enabled.
 -  The PR gas for a gas flow proportional counter must start flowing after V3B is closed (the electron gun chamber is evacuated only by the ion pump). The PR gas may cause a temporary vacuum deterioration due to Ar instability or shorten the lifetime of the ion pump.
 -  When the V3B valve is not closed even after three hours have passed since the ion pump started, or vacuum pressure remains deteriorated or the ion pump stops, refer to Section 6.6 “Checking the Electron Gun Vacuum”.
3. Wait until the vacuum pressure reaches 2.3×10^{-4} Pa or less.

5.2 Obtaining Electron Probe and Emission Pattern

The cathode monitor incorporated in the instrument displays an emission pattern of the electron gun. Since the emission pattern accurately reflects the electron gun setting for even a very small electron source, it is conveniently used to set electron gun brightness to the optimum level and to maintain stable electron emissions.

1. Set the following items according to the JXA-8100/8200 manual.

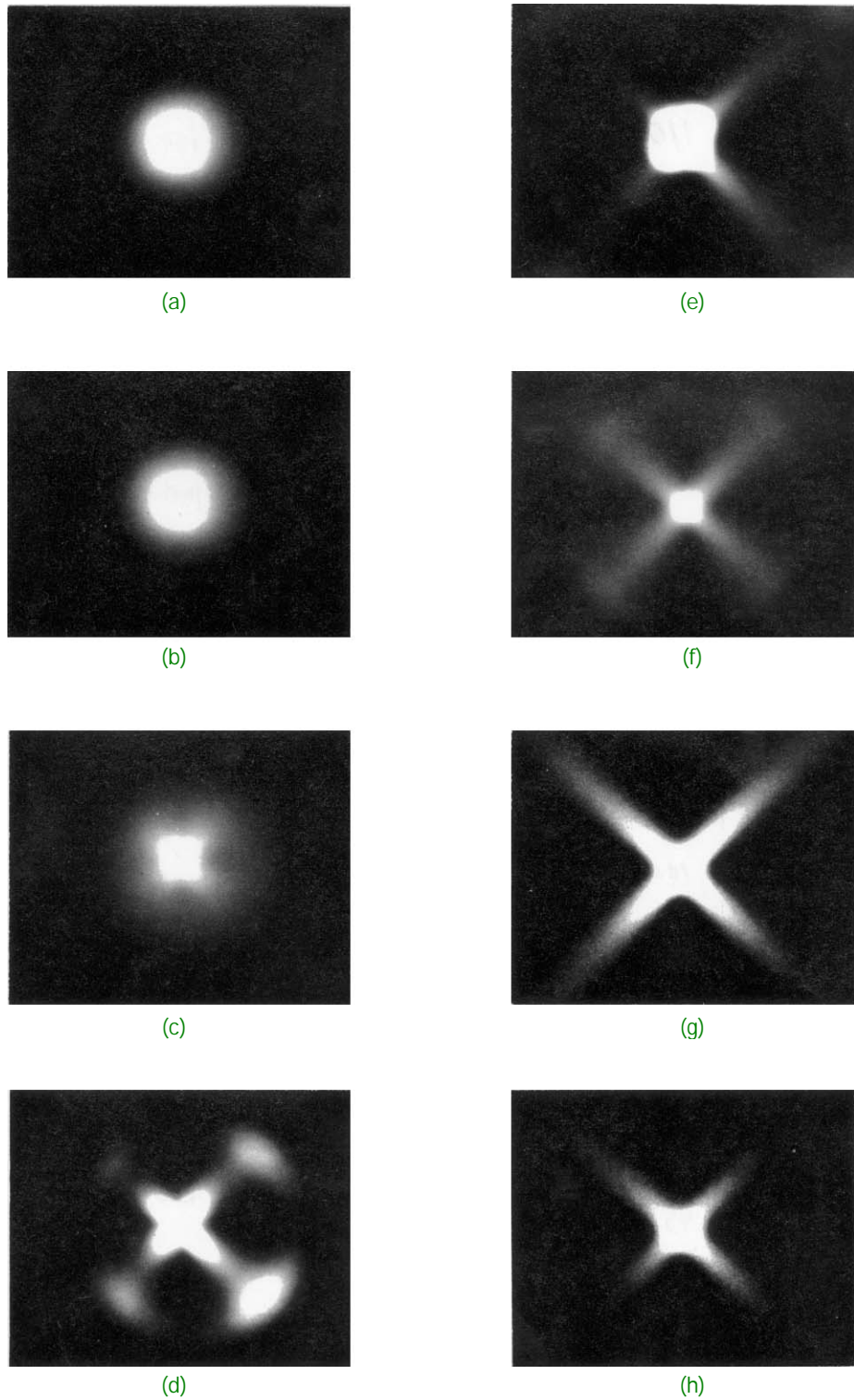
Accelerating voltage:	Desired value
Filament heat code:	0
Image selector:	SEI
Column Mode:	EMP
HT button:	OFF (blue)
PCD icon:	ON (orange)
2. Set COARSE of the Probe Current in the Control window to around 43. Objective aperture selection must be 1 – 2 in this operation.
3. Turn the HT button on (green) and PCD off.
4. Gradually increase the filament current with taking one step for about 3 seconds in the Control window and find a position where the emission pattern changes little (saturation position, for example, (b) in Fig. 5.1)
 -  It is for protection of LaB₆ tip to increase the filament current gradually. Otherwise lifetime of the filament shortens.

- ✍ If the center of the emission pattern is not at the center of observation display, push the FINE VIEW button on the operation panel (scan speed around No. 7) and adjust GUN Alignment Tilt so as to align the emission pattern to be at the center of the CRT screen.
 - ✍ Adjust the PROBE CURRENT and the CONTRAST to obtain a clear emission pattern when the emission pattern comes into view.
 - ✍ Fig. 5.1 shows an example of the emission pattern at 25 kV accelerating voltage. At lower accelerating voltages, the emission pattern broadens.
 - ✍ If the emission pattern symmetry is poor under the condition of Fig. 5.1 (e) or 5.1 (f), reset the LaB₆ cathode as instructed in Chap. 6, “Maintenance”.
 - ✍ Pressure becomes higher along with the increase of filament current. If the pressure is higher than 2.9×10^{-4} Pa, decrease the filament current once and then again increase it so as not to exceed the pressure 2.9×10^{-4} Pa.
 - ✍ Table 5.1 lists the LaB₆ cathode electron gun operating conditions at available accelerating voltages.
- If you put the lifetime of the LaB₆ cathode above the brightness of the electron gun, you'd better choose less emission current than that in the Table.

Table 5.1 LaB₆ gun operation conditions (example standard)

HT (kV)	Wehnelt cap (counterclockwise turn)	Emission current (μA)
0.2 – 1.0	1/2 turn	10 – 30
1.1 – 3.5		20 – 60
4.0 – 12.5		30 – 60
13.0 – 30.0		40 – 70

5. Click the NOR button in the Control window and cancel the EMP mode.
6. Align the electron gun as directed in the JXA-8100/8200 manual.
7. Obtain the desired probe diameter and probe current for observation or analysis as indicated in the JXA-8100/8200 manual.
 - ✍ Use the instrument with the pump pressure at 2.9×10^{-4} Pa or less. If it is above the said value, reduce the filament current temporarily with operation in the Filament window.
 - ✍ When LBG is used, you can not operate Auto-saturation and Auto-alignment functions on the host-computer system.



Accelerating voltage: 25 kV
 Wehnelt cap: Level the filament tip to Wehnelt cap,
 then turn the cap back 1/2 a turn.

**Fig. 5.1 Emission patterns (Angular distribution of emission)
 (example standard)**

5.3 Specimen Exchange

1. Turn the accelerating voltage and filament current off with setting the HT button to OFF.
 - ✎ At a specimen exchange, pressure may get higher temporarily. Then turn HT off in order to prevent the LaB₆ cathode from damage.
2. Verify that V3B is closed (lamp is lit off).
 - ✎ If V3B is open, the ion pump may stop when opening airlock valve V8.
3. Exchange specimens as indicated in the JXA-8100/8200 manual.
 - ✎ Use of airlock
Opening airlock valve V2 may increase the pressure in the electron gun chamber temporarily.
 - ✎ Stage drawout (☞ see Sect. 5.5, “Venting and Re-evacuating Specimen Chamber Only”)
 - Closing V1 (by pushing SPEC VENT button) may temporarily increase the pressure in the electron gun chamber.
 - Opening V1 may increase the pressure in the electron gun chamber, depending on the pressure in the specimen chamber, etc. at the time.
4. Turn the HT button on, after confirming the filament heat code is zero. Then increase the filament current to the value previously input; increase it taking about five minutes in order to protect the LaB₆ cathode.

5.4 Venting and Re-evacuating Electron Gun Chamber

This operation is carried out for LaB₆ cathode replacement, etc.

5.4.1 Venting the electron gun chamber

1. Turn the accelerating voltage and filament current off with setting the HT button to OFF.
2. Stop supplying PR gas.
3. Wait about 10 minutes for the LaB₆ gun to cool down.
4. Push the GUN VENT button on the main panel.
 - Vent valve AV2 will open to vent the electron gun chamber.**

5.4.2 Re-evacuating the electron gun chamber


1. Verify that the electron gun chamber is closed.
2. Evacuate the electron gun chamber by pushing the GUN VENT button again.
 - ☞ For vacuum deterioration and a halt of the ion pump, refer to 6.6, “Checking the Electron Gun Vacuum”.
3. Let the PR gas start flowing after V3B is closed.

5.5 Venting and Re-evacuating Specimen Chamber Only

The instrument allows specimen exchanges by stage drawout with the electron gun chamber under high vacuum.

5.5.1 Venting the specimen chamber

1. Turn the accelerating voltage and filament current off with setting the HT button to OFF.
2. Turn the high voltage of secondary electron detector off with setting SE Detector on the Control window to OFF.
3. Verify that the ion pump is operating and that V3B is closed.
4. Push the SPEC VENT button on the main panel.

 The above operation vents the specimen chamber only. Do not push the GUN VENT button or set the W/LBG switch to W. Moreover, do not turn the ion pump off. If you desire to vent the electron gun chamber successively, first re-evacuate the specimen chamber according to the procedure in Sect. 5.5.2, "Re-evacuating the specimen chamber". After completing final pumping of the chamber, proceed to Sect. 5.6, "Venting and Re-evacuating Column".

5.5.2 Re-evacuating the specimen chamber

1. Verify that the related valves are closed.
2. Re-evacuate the specimen chamber by pushing again the SPEC VENT button.

5.6 Venting and Re-evacuating Column

The following procedure is used for column maintenance, etc.

5.6.1 Venting the column

1. Turn the accelerating voltage and filament current off with setting the HT button to OFF.
2. Stop supplying PR gas.
3. Wait about 10 minutes for the LaB₆ gun to cool down.
4. Turn the high voltage of secondary electron detector off with setting SE Detector on the Control window to OFF.
5. Press the GUN VENT button and the SPEC VENT button simultaneously.

5.6.2 Re-evacuating the column


1. Evacuate the electron gun chamber and specimen chamber by pushing the GUN VENT button and the SPEC VENT button simultaneously again.
2. Let the PR gas start flowing after V3B is closed.

5.7 Operating the LaB₆ Gun Overnight

The LaB₆ cathode requires that the electron gun chamber is under high vacuum. Operate the following two items according to the case you desire. The ion pump cannot be continuously operated independently.

5.7.1 Continuous day-and-night operation of ion pump and vacuum system

Carry out this operation when the specimen chamber vacuum or pumping system vacuum is not high enough (e.g., during instrument installation or maintenance).

1. Verify that the ion pump pressure is 2.9×10^{-4} Pa or less.
2. Close all windows, then set the OPE PWR/OFF switch of the main panel to OFF. This cuts off the power supply to the operation and display system.
 -  The power of EWS does not cut off but it cannot communicate with the JXA-8100/8200 basic unit.


5.7.2 Continuous day-and-night operation of the entire instrument

To preheat the LaB₆ cathode or to process data overnight, the JXA-8100/8200 need be operated continuously day and night.

- ◆ Verify that the ion pump pressure is 2.9×10^{-4} Pa or less.

5.8 Shutting Down

To shut down the entire instrument and the ion pump, proceed as follows:

1. Turn the accelerating voltage and filament current off with setting the HT button to OFF.
2. Shut down the instrument as indicated in the operation manual.
 -  Do not forget to turn off the switchboard.

6 MAINTENANCE

6.1 Conditions Required for Stable and Prolonged Operation of the LaB₆ Electron Gun

- The inner surface of the Wehnelt cap must be free from contamination.
- The LaB₆ tip must be well-centered.
- Emission pattern is not over saturated with not worse than a pattern of (a) shown in Fig. 5.1.
- GUN-ALIGNMENT should be well-adjusted.
- Objective aperture should be well-centered.
- The pressure in the electron gun chamber should be less than 2×10^{-4} Pa.

6.2 Cleaning the Wehnelt Cap

Clean the Wehnelt cap in the following cases.

- When the electron gun chamber is vented after long-time use of LaB₆ electron gun.
- When the electron beam is stable in the W cathode but not in the LaB₆ cathode (unstable beam position, change of brightness, unstable emission current or the like).
- After more than 100 hours' operation with the LaB₆ electron gun.

6.2.1 Removing and disassembling the Wehnelt unit

1. Vent the electron gun chamber (☞ see Sect. 5.4, "Venting and Re-evacuating Electron Gun Chamber").
2. Open the hinged top of the electron gun, cover the exposed gun chamber with aluminum foil for protection against dust, and wait for the Wehnelt unit to cool until it can be touched by hand.
✍ It takes about 30 minutes for the unit to cool down.
3. Remove the Wehnelt unit with the Wehnelt unit removal tool (Fig. 6.1).

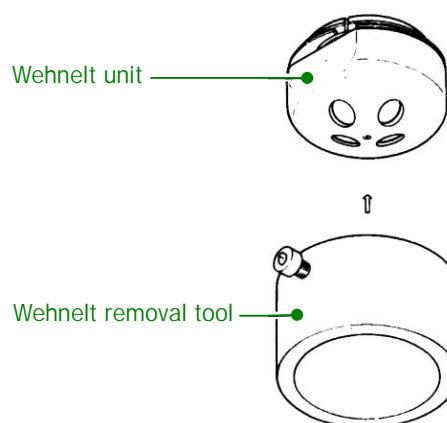


Fig. 6.1

4. After turning the Wehnelt cap about one-turn counterclockwise, remove the LaB₆ cathode by loosening the cathode holding screws (Fig. 6.2).
✍ Do not touch the LaB₆ tip with anything.

5. Remove the Wehnelt cap.

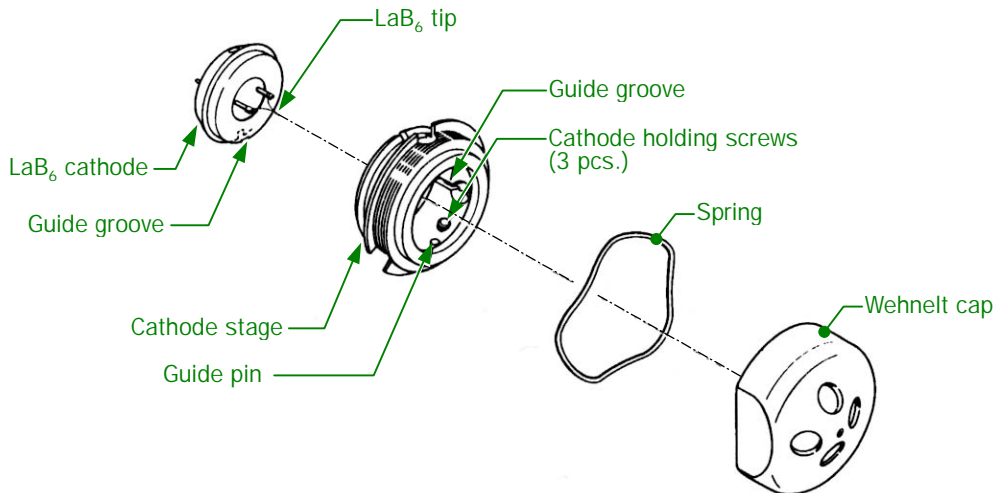


Fig. 6.2

6.2.2 Cleaning

1. Clean the inside and outside of the hole by rubbing it with cotton swabs, absorbent cotton, or gauze smeared with fine-grained metal polish.
~~✂~~ **Do not use metal polish on the threaded portions.**
2. Wipe off metal polish and stains from the cap with absorbent cotton or gauze dampened with a cleaning solution.
3. Clean the cap by immersing it in cleaning solution in a beaker or the like.
~~✂~~ **An ultrasonic cleaner may provide better results.**
4. Remove the cap from the cleaning solution and blow off the solution traces from inside and outside the cap.
5. Make sure there are no dust deposits on the inside or outside of the hole by using a stereo-microscope, etc.
6. When the anode in the electron gun chamber is stained, take it off by turning it counterclockwise. Then clean it.

6.2.3 Assembling and installing the Wehnelt unit

1. Give the Wehnelt unit one or two turns into the cathode stage.
2. Verify that the tip of LaB₆ cathode is free from dust or the like under the microscope.
3. Insert the LaB₆ cathode into the stage, after aligning its guide groove with the guide pin, and then secure it with cathode holding screws.
~~✂~~ **Do not let the LaB₆ come into contact with anything.**
4. Adjust the height of the Wehnelt cap and center the LaB₆ cathode (☞ see Fig. 6.3).
5. Return the Wehnelt unit onto the insulator of electron gun.
6. Verify that no dust is in the gun chamber, on the O-ring or on its seat, and that the O-ring is properly fitted in the groove. Then replace the hinged top of the gun.

7. Push the GUN VENT button (main panel).

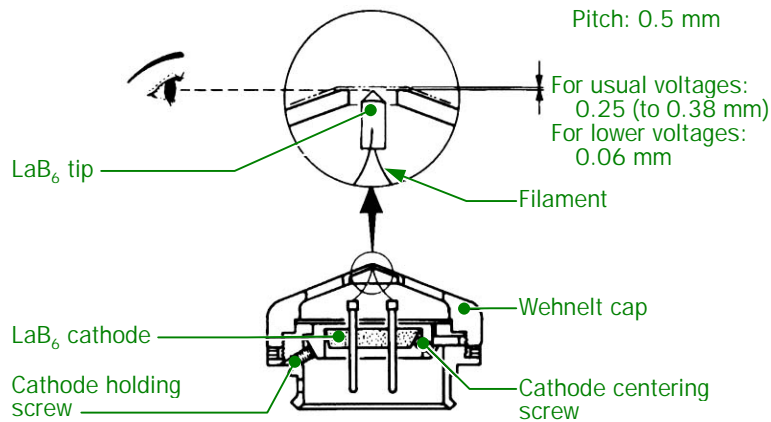


Fig. 6.3 LaB₆ cathode Wehnelt unit

6.3 Exchange of LaB₆ Cathodes

After long-time use, the LaB₆ cathode becomes worn and, in some cases, the tip-filament welding unstable. Exchange the LaB₆ cathode when the following phenomena appear only in the LaB₆ cathode but in W cathode.

- Too much noise in the scanning images, or brightness changes
- No electron beam is emitted.

6.4 Adjustment of Wehnelt Cap Height and Centering of LaB₆ Cathode

Adjustment of the Wehnelt cap height and centering of the LaB₆ cathode are essential for that the LaB₆ cathode is to exhibit its superiority over the tungsten cathode. The LaB₆ cathode is precentered with an accuracy of 100 μm.

1. Verify that the LaB₆ tip, which is in the Wehnelt cap hole, is not stained or bent, using the microscope.
✍ **Slanted illumination may provide a better view.**
2. While observing the Wehnelt cap hole in the horizontal direction under a microscope, stereo-microscope or the like, make the LaB₆ tip flush with the top of the cap by turning the cap.
3. Turn the Wehnelt cap counterclockwise by 1/2 (– 1) turn.
✍ **Resetting of a sharp edged LaB₆ cathode may be required (for example, one turn) for saturation under high voltage operation.**
✍ **The pitch of the Wehnelt cap threads is 0.5 mm.**
4. Adjust the cathode centering screws (3 pcs.) so that the LaB₆ tip is centered within 50 μm of the center of the Wehnelt cap hole (Fig. 6.3).
5. Secure the LaB₆ cathode with holding screws and then check that the LaB₆ tip is within 50 μm of the center.

6.5 Replacing the LaB₆ Cathode with the W Cathode

The W cathode is used for column alignment, etc.

1. Mount a W cathode on the Wehnelt unit for W cathode (☞ refer to the JXA-8100/8200 MAINTENANCE manual).
2. Vent the electron gun chamber according to Sect. 5.4.
3. Exchange the Wehnelt units and replace the hinged top of the electron gun; then evacuate the electron gun chamber by pushing the GUN VENT button.
4. Set the W/LBG switch to W (lower side).
 - ✂ If the W/LBG switch is set at W, the instrument is evacuated according to the usual pumping sequence. The ion pump cannot be operated.
 - ✂ To maintain the electron gun vacuum by operating the ion pump for the W cathode, set the W/LBG switch to LBG and evacuate the gun as indicated in Sect. 5.4.
5. Select Initialize-HardConfig-Option from the EPMA menu and cancel the LBG setting.
6. Obtain an electron probe as indicated in the JXA-8100/8200 operation manual.

6.6 Checkig the Electron Gun Vacuum

If the pressure in the electron gun chamber is still higher than 2.9×10^{-4} Pa with keeping the electron gun for a long time in a condition that no accelerating voltage and filament current are applied, or if the ion pump current is fluctuating, take the following countermeasures.

- ① When the ion pump repeats on and off more than half a day, or when V3B has not been closed for more than three hours since the ion pump started to work, or when HV READY is not reached:
 - Check for leaks, dust, cotton fibers, or the like or scratches on the O-ring and O-ring seating in the electron gun chamber.
 - When the gas flow counter window in the spectrometer deteriorates and the pressure in the specimen chamber is higher than 6.7×10^{-3} Pa, the ion pump repeats on and off. Or even when the pressure is 2×10^{-5} Pa or higher, the ion pump operates continuously but V3B remains unclosed for more than three hours. In these cases check the gas flow counter window and replace it if necessary. (☞ Refer to the MAINTENANCE manual for details.)
- ② Fluctuating pump current:
 - Remove flakes/film from the pump by tapping it with a mallet, a screwdriver handle or the like.
- ③ Sudden stopping of the ion pump in the HV Ready status:

In normal operation, the ion pump is automatically turned on/off depending on the vacuum level. If the protecting circuit halts the ion pump while the SIP lamp on the main panel is lit, perform the following procedure.

 - When the trouble described in (1) causes the ion pump to halt, perform as indicated in (1).

- When the Ar instability* causes the ion pump to halt, stop supplying PR gas and turn off the POWER key switch of the JXA-8100/8200 basic unit once, and then restart it.

Let the PR gas start flowing after the V3B valve is closed.

If vacuum malfunction still remains even after measures above have been taken, contact the nearest service center.

* "Ar instability" occurs periodically when the ion pump temporarily cannot evacuate Ar gas permeated the column from the PR gas of detector. It is needed for you to stop the PR gas flow until V3B closes when the ion pump starts up.