



# LaB<sub>6</sub> CATHODES

## SINGLE-CRYSTAL LANTHANUM HEXABORIDE

Ladd Research  
(802) 658-4961  
https://www.laddresearch.com/

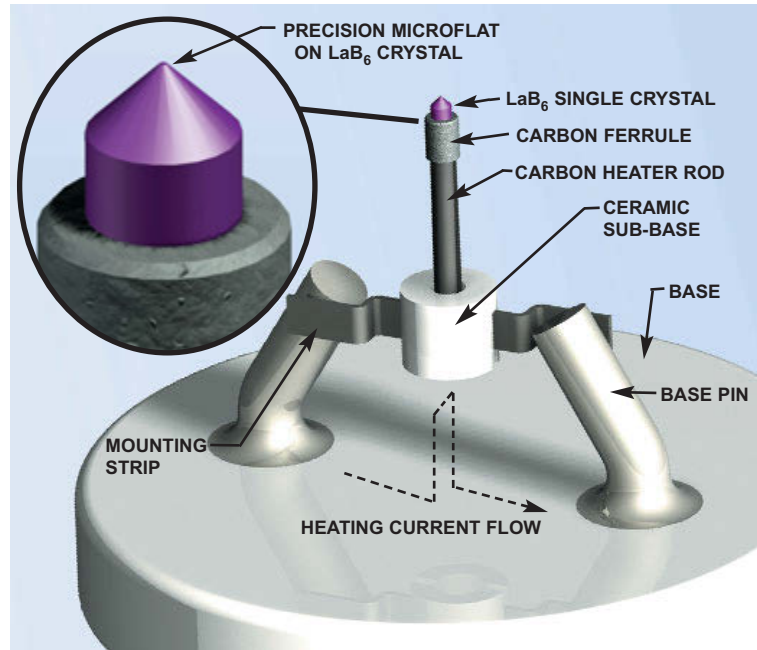
### ES-423E (Extended Life) LaB<sub>6</sub> Crystal

#### FOR USE IN:

- SCANNING ELECTRON MICROSCOPES
- TRANSMISSION ELECTRON MICROSCOPES
- ELECTRON LITHOGRAPHY SYSTEMS
- ELECTRON ACCELERATORS
- X-RAY SOURCES
- FREE ELECTRON LASERS
- CUSTOM APPLICATIONS

#### FEATURES / OPTIONS:

- EXTENDED LIFETIME
- GUARANTEED LIFETIME
- THOUSANDS OF HOURS IN CLEAN VACUUM (MEASURED IN SURFACE LOSS)
- GUARANTEED AGAINST MOUNTING STRUCTURE FAILURE
- EXCEPTIONAL STABILITY
- THERMAL / CHEMICAL / MECHANICAL / ELECTRICAL
- PRECISION MACHINED CARBON MOUNTING
- HIGH OVER-TEMPERATURE TOLERANCE
- HIGH BRIGHTNESS / LOW ENERGY SPREAD
- <100> ORIENTED SINGLE-CRYSTAL
- BEST QUALITY / HIGH PURITY MATERIAL
- ACCURATE MICROFLATS
- SUPERIOR OPTICS / CONTROLLED SOURCE SIZE
- STANDARD DIAMETERS AVAILABLE



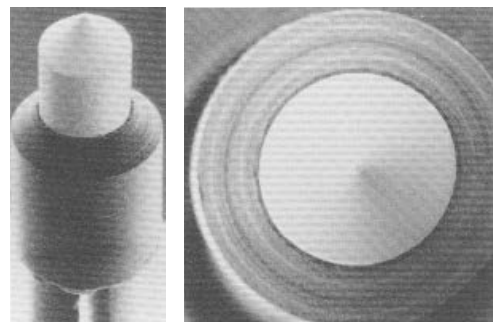
*LaB<sub>6</sub> single crystal cathode mounting (10 X)*

*Heating current path through precision-machined, single-piece carbon rod and mounting strips; sub-base provides rigidity and easier mounting.*

The Kimball Physics ES-423E (Extended Life) Lanthanum Hexaboride Cathode is a high performance, resistively heated, thermionic electron source. It is currently employed in many brightness-limited electron optical systems: SEM's, TEM's, probes, electron lithography systems, etc. It is based on a well-proven heater structure, which has recently been further refined with features that include improved reliability of the heater circuit, improved stability of the LaB<sub>6</sub> crystal, and less exposure of LaB<sub>6</sub> to reduce Wehnelt aperture contamination. Lifetimes in excess of 6 months of continuous operation are regularly achieved in commercial SEM's and TEM's with suitable gun vacuum. Continuous operation at the full operating temperature improves the thermal stability of the gun and hence beam current stability. It is no longer necessary to wait hours for stable beam conditions in order to perform quantitative EEL or EDX measurements.

The emitter is a 15 μm-diameter (standard), <100> oriented-single-crystal, surface (standard), mounted on the end of a single-piece, stress-free, carbon heater rod, held in place by a carbon ferrule. The rod has been precision machined with a 100 μm slot cut along the axis, such that the heating current goes up one side and down the other. The small area of the heating current loop keeps the unwanted heater-current magnetic field low. Because the rod is one single piece, no heating current passes through the crystal; there are no high-temperature current-carrying joints. A high degree of axial symmetry keeps mechanical motions small. The small physical size fits most Wehnelts with ease. In the ES-423E, the crystal can be completely evaporated away without affecting the heating circuit. The very tight tolerances, and the enclosed structure prevent the loss of LaB<sub>6</sub> in the mounting region throughout the entire crystal life. Reduced material loss also means less Wehnelt contamination. Emitter dimensions are machined to a 2 μm tolerance, (standard, 2 μm to 16 μm for microflats up to 320 μm) with a tilt tolerance of 0.5°. Microflat alignment to the instrument base can be provided to a tolerance of 13 μm for x, y and 76 μm for z, the height above the base (less than 70 μm on request). A high angular tolerance is maintained on the perpendicularity of the oriented single-crystal emission plane to the electron optical axis. All cathodes receive a stabilizing run-up prior to shipment.

With electron-gun oxidizing-gas partial pressures kept below 10<sup>-7</sup> torr, many instruments can achieve thousands of hours of stable cathode operation. In SEM type instruments, lifetimes up to 3000 to 4000 hours may be achieved at operating temperatures of 1850 K (corresponding to material surface loss rates in the 0.025 micron/hour range), with full brightness and excellent stability. With somewhat reduced brightnesses, as required by typical TEM instruments, lifetimes can be even longer. The ES-423E mounting structure will last more than 10,000 hours. Moreover, neither the electrical heating circuit drive impedance nor the thermal properties will drift perceptibly over that period. Chemical reactivity and mechanical drift problems have been eliminated.



*LaB<sub>6</sub> crystal mounted on carbon heater rod, and held in place by precision carbon ferrule; note roundness and smoothness of microflat.*

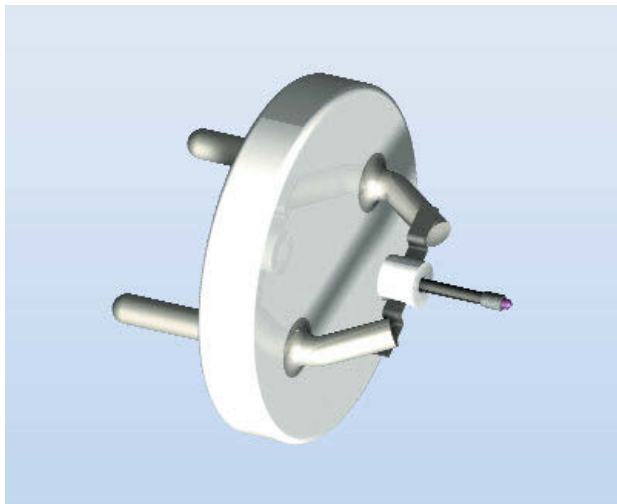


# LaB<sub>6</sub> CATHODES

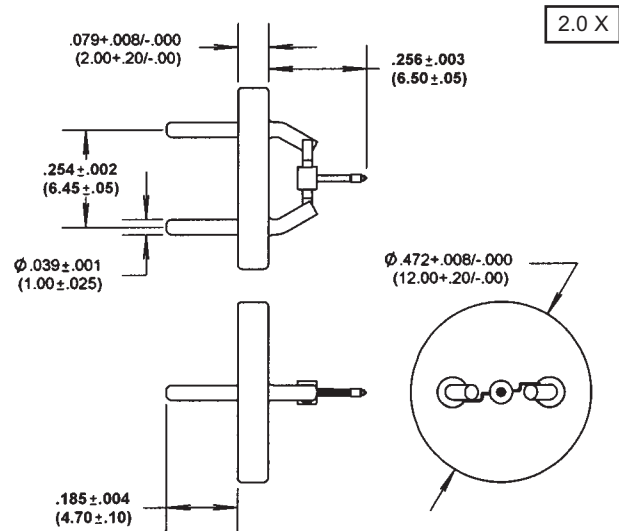
The real figure of merit of a thermionic electron emitter is the number of coulombs of electrons which may be boiled off per kilogram of cathode surface evaporated away. LaB<sub>6</sub> is an order of magnitude superior to the refractory metals in this key parameter. Any failure of a cathode mounting structure, before the LaB<sub>6</sub> cathode itself has been used up, represents a waste of cathode life. The ES-423E single-piece stress-free ultra-stable carbon mount is unique. Unlike other designs which operate near the temperatures where chemical instabilities will set in, the ES-423E carbon mount is almost impossible to destroy by accidental over-temperature. The melting point of Lanthanum Hexaboride itself is somewhat over 2800 K; there have been examples of crystals being melted (extreme over-temperature), in which the ES-423E carbon mount survived. The Kimball Physics mount is guaranteed.

The ability to run over-temperature may also be utilized to clean a contaminated crystal, and reduces the risks associated with less experienced operating personnel.

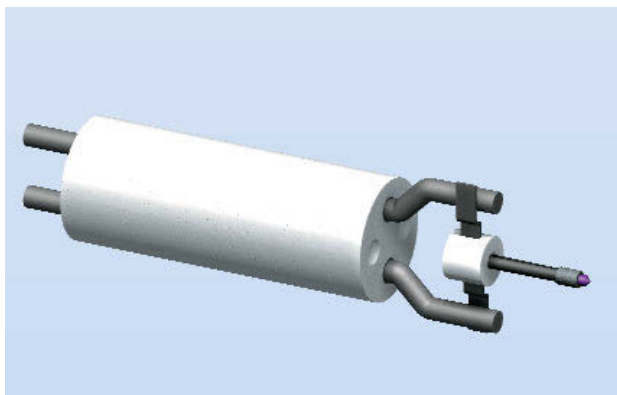
This small source size fits most Wehnelts with ease. In excellent vacuum with low material loss rates, the size of the cathode does not limit lifetimes. The Kimball Physics ES-423E Long Life Lanthanum Hexaboride Cathode is the most recent improved version of the IR 100 Award Winning design which has been used in many instruments types for many years. Kimball Physics invented the Directly Replaceable Lanthanum Hexaboride Cathode. Take advantage of the most experience in the business.



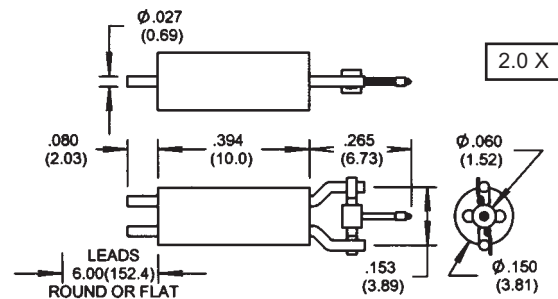
ES-423 LaB<sub>6</sub> Cathode  
(single cone-shaped crystal with microflat emitting surface)  
mounted on standard AEI base (4 X)



ES-423E Single cone-shaped crystal LaB<sub>6</sub> cathode  
mounted on an AEI Base



ES-423 LaB<sub>6</sub> Cathode  
(single cone-shaped crystal with microflat emitting surface)  
mounted on a Kimball Physics CB-104 ceramic base (4 X)



ES-423E Single cone-shaped crystal LaB<sub>6</sub> cathode  
mounted on a CB-104 ceramic base

ALL DIMENSIONS ARE IN INCHES  
(MILLIMETERS IN PARENTHESES)

Heater Voltage and Current vs Temperature; Electrical Characteristics vary only a few percent from Cathode to Cathode, thus insuring predictable operation.



# LaB<sub>6</sub> CATHODES

ELECTRON GUNS

ION GUNS

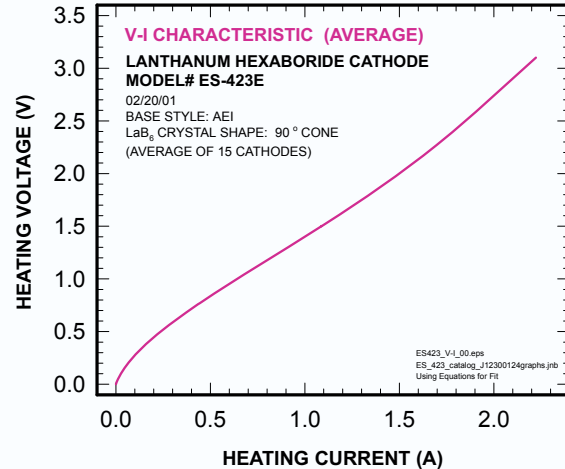
EMITTERS

DETECTORS

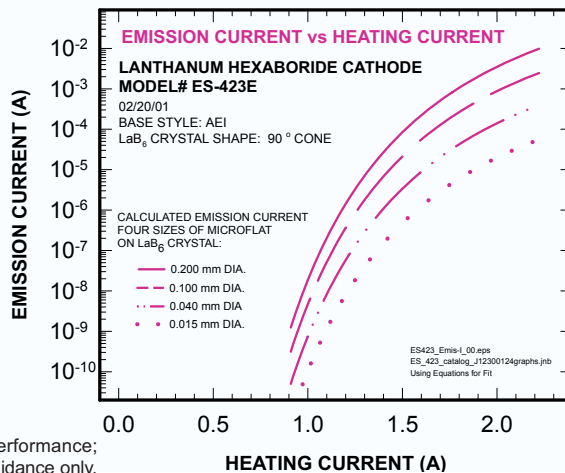
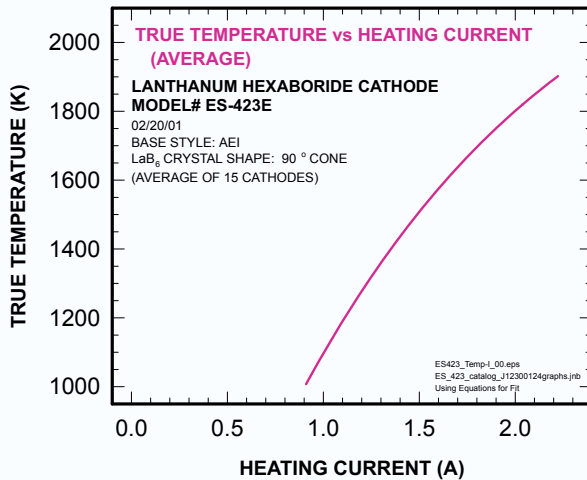
COMPONENTS

INDEX / INFORMATION

ES-423E	
CATHODE MATERIAL	Lanthanum Hexaboride (LaB <sub>6</sub> ) single crystal
CATHODE SHAPE	Cone with 90° sides and microflat tip
MICROFLAT SIZE	Standard: 0.015 mm dia., larger or smaller available
HEATER	Single piece carbon rod
EMISSION AREA	1.7x10 <sup>-6</sup> cm <sup>2</sup> standard microflat, excluding sides
HEATING CURRENT	1.7A to 2.1A
CATHODE LOADING	20-30A/cm <sup>2</sup> recommended High loadings result in reduced lifetime
WORK FUNCTION	2.69 eV
OPERATING TEMP	approx. 1700-1900K
ENERGY SPREAD	approx. 0.4 eV
LIFETIME	Thousand plus hours with medium currents, good vacuum
VACUUM LEVEL	10 <sup>-7</sup> torr or better, recommended
POWER SUPPLY CAPABILITY	Voltage regulated power supply recommended, 4 V, 3 A



Standard microscopy styles include: 90-15, 90-20, 60-06



Typical performance; data for guidance only.

## Instrument Conditions for LaB<sub>6</sub> Cathodes

While the cathodes can be fitted to virtually any instrument, there are several requirements needed for achieving quality results. The most important requirement is for clean vacuum, with partial pressures of oxidizing gases being kept below 10<sup>-7</sup> torr in the electron gun. Many instruments achieve adequate vacuums as a matter of course; however many others do not. A major problem is instruments in which the pressure measurement takes place outside the gun itself (as in the measurement of an ion pump current). The actual pressure inside the gun, where outgassing is frequently high, may be much worse than the operator is led to believe. The condition of the cathode itself, along with that of the Wehnelt aperture, may often be used to verify the partial pressures in the gun. It is a waste of money to put good cathodes into poor vacuum.

A second requirement is that it must be possible to accurately and correctly position the cathode behind the Wehnelt. Some guns do not have adequate adjustment systems. Another requirement is for controllable bias resistors, which can reach adequately high values; some instruments are limited by values which are too low. While not a requirement, it is desirable to have the capability for independent bias. It is also desirable to have accurate heater circuit voltage and current meters. Most of these problems can be solved in most instruments, however significant efforts may be required. Note that the higher the brightness level desired, the lower the tolerance to tip recession. The electron optically allowed tip recession, and the acceptable contamination on the Wehnelt (before gun instabilities set in), are in fact the life-limiting parameters for current state-of-the-art cathodes. More information on all these topics may be found in the Kimball Physics Technical Bulletins.

For more information on LaB<sub>6</sub> operation in TEM's and SEM's you may download detailed technical bulletins from the website cathode support page.

- # LaB<sub>6</sub>-01 General Guidelines for Operating LaB<sub>6</sub> Cathodes.
- # LaB<sub>6</sub>-02 The Relationship Between LaB<sub>6</sub> and Cathode Life and Gun Vacuum
- # LaB<sub>6</sub>-03 Emission Drift—LaB<sub>6</sub> and Gun Stability.
- # LaB<sub>6</sub>-04 Oxygen Activation of LaB<sub>6</sub> Cathodes—The Double Saturation Effect
- # LaB<sub>6</sub>-05 Kimball Physics ES-423E LaB<sub>6</sub> Cathode Style 60-06 (60° Included Cone Angle, 6μm Diameter Flat)
- # LaB<sub>6</sub>-06 Kimball Physics ES-423E LaB<sub>6</sub> Cathode Operating Instructions for LEICA/Cambridge Stereoscan Series SEM's
- # LaB<sub>6</sub>-07 Recovery of Emission From ES-423E LaB<sub>6</sub> Cathodes Following a Vacuum Dump