Kimball Physics Cathodes (Electron Emitters)

Kimball Physics is a high-tech manufacturer of scientific instruments with over 50 years of experience in ultra-high-vacuum electron and ion optics. The company specializes in high stability electron emitters, precision electrostatic and magnetostatic optics, along with state-of-the-art vacuum chambers and fittings.

Table of Contents:

FOR USE IN:

- Scanning Electron Microscopes
- Transmission Electron Microscopes
- Electron Lithography Systems
- Electron Accelerators
- X-ray Sources
- Free Electron Lasers
- Electron Source (Gun) Systems
- Replacement, OEM, Custom Applications

FEATURES / OPTIONS:

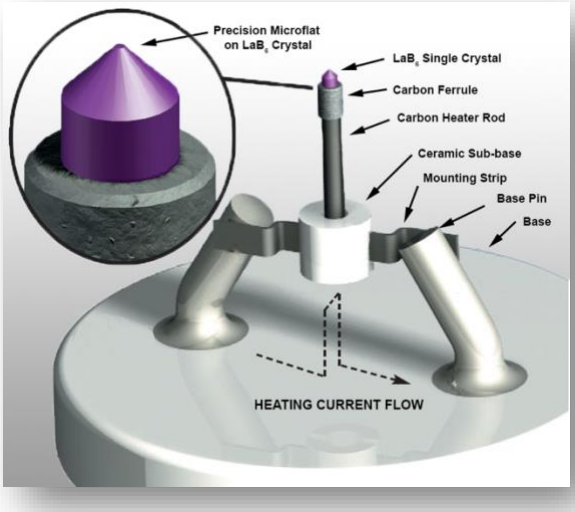
- **Lanthanum Hexaboride (LaB_6)**
  - Exceptional Stability
  - Precision machined carbon mounting
  - Superior Optics, Controlled Source Size
  - High-Brightness, Low Energy Spread
- **Tantalum (Ta) Disc**
  - High Quality General Purpose
- **Barium Oxide (BaO) Coated Disc**
  - Low Temperature, Low Light
- **Yttria(Y_2O_3) Coated Iridium Disc**
  - Rugged cathode with less ideal vacuum and usage conditions.

Introduction and Overview

The creation and spatial manipulation of an electron beam provides an exciting opportunity for humankind to interact with our sub-micron world. This beam of electrons gives us the ability to 1) observe morphological features that are orders of magnitudes beyond our innate senses, 2) probe/query information about the structure's properties, and 3) freeze a moment in time of very rapidly vibrating or moving structures. And beyond visualizing and measuring our nanoscopic world, a spatially and temporally controlled electron beam also allows us to manipulate, process, and micro-machine sub-micron structures with precision.

The sources of the electrons used in these negatively charged particle beams are commonly referred to by several names including electron emitters, cathodes, hot cathodes or electron sources.

Kimball Physics has a long history (over 50 years and has won the prestigious I.R 100 Award for our LaB_6 cathode design) of providing precise and reliable thermionic sources of electrons for use in a variety of scientific,



Electron Emitter Example: LaB_6 single crystal cathode mounting. Heating current path through precision-machined, single-piece carbon rod and mounting strips; sub-base provides rigidity and easier mounting.

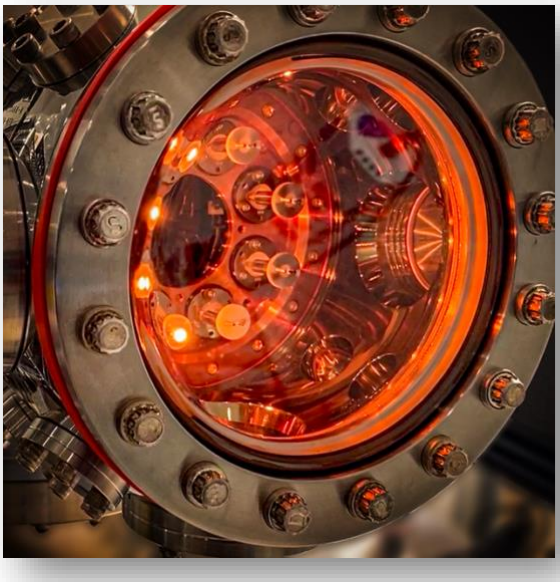
manufacturing and clinical applications that include scanning and transmission microscopy, lithography, x-ray generation, free electron lasers, and electron accelerators including our own electron sources (guns) that also include world-class electron optics.

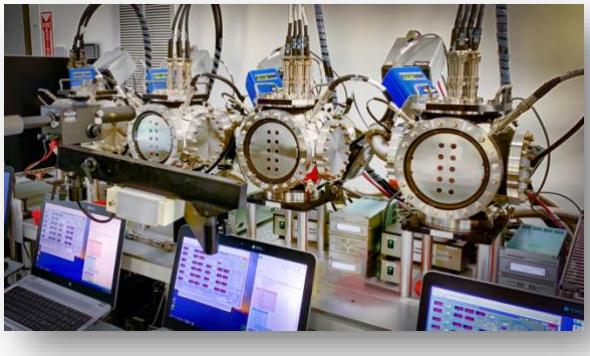
Based on the requirements of the application, which typically include parameters such as beam current, emission current density (cathode loading) and brightness, the eventual spot size, energy spread, and the environment (stability and degree of vacuum), the appropriate electron emitter can be selected from our various configurations and materials for your specific application (see table below).

Kimball Physics has several cathode options including extended lifetime, stable, high brightness single-crystal <100> Lanthanum Hexaboride (LaB_6) that is available in 60 and 90 degree conical geometries with microflats ranging 6 to 360 microns. A guard ring option is also available to optimize emission from the preferred microflat surface. Lifetimes more than 6 months of continuous operation are regularly achieved in commercial SEM's and TEM's with suitable vacuum.

We have LaB_6 Cathodes available for most electron microscope bases used in the industry. Please check out our *Electron Microscope* section, tables, and product list.

The LaB_6 crystal is 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





Cathode Testing Laboratory: Cathodes are individually evaluated to be within specified tolerances and receive a stabilizing run-up prior to shipment. The upper image shows a close-up of selected cathodes at temperature in a MCF vacuum chamber. The middle image shows one section of a large fleet of systems used for cathode testing. The lower panel shows the classic optical pyrometer used for measuring cathode temperatures.

the heating current loop keeps the unwanted heater current magnetic field low. Because the carbon rod is one single piece with a unique geometry at the crystal interface, no heating current passes through the crystal and thereby allows precise and stable heating of the system; there are no high temperature current-carrying joints as there are found in other mounting systems. A high degree of axial symmetry keeps mechanical motions minimized. 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_6 in the mounting region throughout the entire crystal life. Reduced material loss also means less Wehnelt contamination.

The LaB_6 is also available in planer surface configurations with diameters up to 1.78 mm for high brightness, high-current applications.

Kimball Physics also has a high-quality line of precision disc cathodes with several emission surface diameters available that either utilize Tantalum (Ta) for general purpose applications, Barium Oxide (BaO) coated disc for low temperature, low light environments and Yttria coated Iridium disc when a more rugged cathode is needed with less ideal vacuum and usage conditions.

The electron emitters are available on standardized AEI bases, along with most electron microscopic system bases (LaB_6 cathodes) used throughout the industry. Custom bases can also be designed and fabricated based on the customer's needs.

All cathodes are 1) individually evaluated to be within specified tolerances 2) receive a stabilizing run-up prior to shipment and 3) are mounted and shipped vacuum clean and ready to install in high quality protective containers.

Many of the emitters/cathodes provided by Kimball Physics have been innovated, designed, and manufactured for the customized specifications of our customers. If you do not see the configuration and parameters in an electron emitter that you need, please reach out to Kimball Physics to engage our physicists, engineers, and micro-fabrication specialists. Also, please inquire about options for replacement or OEM applications.

Cathode transporter with anodized aluminum base and sealable clear cover to protect the cathode during storage and transport. This example shows cathode ES-423E, a LaB_6 single crystal mounted on the end of a single piece of carbon heater rod, with a carbon ferrule to secure the LaB_6.

Kimball Physics Cathode Comparison Table

Cathode Material	Lanthanum Hexaboride (LaB_6)	Lanthanum Hexaboride (LaB_6)	Tantalum (Ta)	Barium Oxide (BaO)	Yttrium oxide (Y_2O_3)
Cathode Configuration	-Conical config. with microflat (ES-423E) -Guard Ring over conical config. with microflat(ES-423GR)	Single Crystal Planer Disc (ES-440)	Planer Disc	Planer Disc	Planer Disc
Description / Features / Options	-High brightness single crystal -very small diameter microflats - Long lifetime and reliability -Guard ring option	-High brightness single crystal - Long lifetime and reliability -Planer disc <100> -High beam currents	-General purpose planer disc -Sturdy, stable uniform electron emission	BaO coated disc -Low light -Low operating temperature	Yttria coated iridium disc -Rugged -Chemically resistant -Higher operating pressures
Work Function	2.69 eV(<100>)	2.69 eV(<100>)	4.1 eV	1.0 – 1.8 eV	2.6 eV
Energy Spread	0.4 eV	0.4 eV	0.6 eV	0.3 eV	0.6 eV
Operating Temperature	1700-1900 K	1700-1900 K	2200 K	1150 K	1800 K
Emission Current	i.e. 0.51 mA (15 micron microflat dimension)	0.5 A	1-5 mA	5 µA to 2 mA	1 – 10 mA
Cathode Loading (Emission Current Density)	20 – 30 A/cm^2	Up to 20 A/cm^2	0.25 A/cm^2	0.1 A/cm^2	0.5 A/cm^2
Brightness ($A/cm^2/sr$)	$>10^6$	$>10^6$			
Vacuum Conditions	$<10^{-7}$ torr	$<10^{-7}$ torr	$<10^{-5}$ torr	$< 10^{-7}$ torr	$<10^{-4}$ torr Iridium heater $<10^{-5}$ Tungsten heater
Melting Point	2480 K	2480 K	3290 K	2196 K	2698 K
Resorption Rate	~0.025 microns/hour ~2.2 x 10-9 $g/cm^2 \cdot sec$	~0.025 microns/hour ~2.2 x 10-9 $g/cm^2 \cdot sec$			
Richardson Constant**	29 A/m^2K^2	29 A/m^2K^2			
Applications					
Electron Sources (Guns)	•	•	•	•	•
SEM)	•				
TEM	•				
EPMA	•				
X-Ray Sources	•				
Electron Lithography	•				
Product Details					
Bases Available	AEI, CB-104, custom *Electron Microscopes (see list below)-	AEI, custom	AEI, CB-104, CB-105	AEI, CB-104	AEI, CB-104, CB-105
Microflat dimensions (microns) available (if applicable)	6, 15, 20, 300, 330 ***Electron Microscopes- 6, 15, 20 microns				
Conical Angles (if applicable)	60, 90 degrees.(flat-180 also available)				
Planer Disc Dimensions (if applicable)	N/A	Dia. 1.78 mm (standard)	Dia. 0.033"(~0.84 mm) Dia. 0.048"(~1.22 mm) Dia. 0.062"(~1.58 mm)	Dia. 0.033"(~0.84 mm) Dia. 0.048"(~1.22 mm) Dia. 0.062"(~1.58 mm)	Dia. 0.033"(~0.84 mm) Dia. 0.048"(~1.22 mm) Dia. 0.062"(~1.58 mm)

*Electron Microscope Bases Available: Zeiss, VG-AEI replacement, VG, Philips, Perkin Elmer/ ETEC, Leica-AEI, JEOL-K, JEOL-GC (JSM, JEOL-E, ISI 2-pin, Hitachi S, ETEC, Electroscan-AEI, Camscan-AEI, Cameca-AEI, BioRad-AEI, Amray, AEI

* Configurations Available: Code (Cone angle – microflat size(microns): 60-06, 90-15, 90-20

Note- not all combinations are available (Cone angle, microflat dimension, with/without GR and base style, or Disc dimension and base). However, custom options are often available.

** Richardson constant (A/m^2K^2) LaB_6 = 29, Other materials for reference CeB_6 = 3.6

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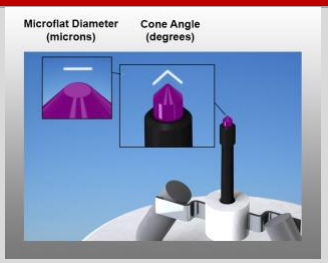
Kimball Physics Cathode /Electron Emitters Product Lists

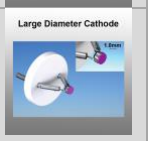
Lanthanum Hexaboride (LaB_6) Cathodes

Lanthanium Hexaboride (LaB_6)

FEATURES

-Single Crystal <100>
-High Current
-High Brightness
-Emission Current Densities to 30 A/cm^2
-Long Lifetime
-Operating Pressures $<10^{-7}$ torr





Product	Emission Material	Cone Angle (Degrees)	Microflat (Microns)	Base Type	Price
ES-423E 60-06	LaB_6	60	6	AEI CB-104	Request quote
ES-423E 90-15	LaB_6	90	15	AEI CB-104	Request quote
ES-423E 90-20	LaB_6	90	20	AEI CB-104	Request quote
ES-423E 90-300	LaB_6	90	300	AEI CB-104	Request quote
ES-423E 90-XX	LaB_6	90	XX*	AEI CB-104	Request quote
ES-423E 90-	LaB_6	90	XXX*	AEI CB-104	Request quote
ES-423E 180-330	LaB_6	180 (Flat)	330	AEI	Request quote
Guard Ring Cathode					
ES-423E-GR025 AEI	LaB_6		25**	AEI	Request quote
Large Diameter Cathode					
ES-440 SG AEI	LaB_6	Flat	440	AEI	Request Quote

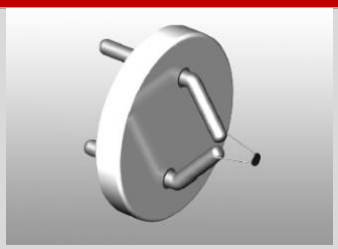
Notes:
1) PLEASE CHECK WEBSITE or CALL FOR MOST CURRENT PRICE
2) *Custom Microflat Configurations: Custom microflats XX*< 100 microns, XXX* >= 100 and < 330 microns
3) **Guard Ring Cathodes- custom microflat dimensions available
3) Custom mounting available all cathode designs
4) Electron Microscopes- most microscope bases available, please see separate table.

Tantalum (Ta) Disc Cathodes

Tantalum (Ta) Disc Cathode

FEATURES

-General Purpose Refractory Metal Planer Cathode
-Exceptional Stability
-Low Energy Spread
-Not harmed by Repeated Exposure to Atmosphere
-Accurately Pre-aligned
-Operating Pressures <10^{-5} torr or better



AEI Base

CB-104 Base

CB-105 Base

Product	Emission Material	Disc Size	Emission Area	Base Type	Price
ES-042	Ta	0.033 in dia. x .004 in thick (0.84 mm dia. x 0.1 mm thick)	5.52×10^{-3} cm^2	AEI CB-104	Request Quote
ES-044	Ta	0.048 in dia. x .004 in thick (1.22 mm dia. x 0.1 mm thick)	11.7×10^{-3} cm^2	AEI CB-105	Request Quote
ES-046	Ta	0.062 in dia. x .004 in thick (1.57 mm dia. x 0.1 mm thick)	19.5×10^{-3} cm^2	AEI CB-105	Request Quote

Notes:
1) PLEASE CHECK WEBSITE or CALL FOR MOST CURRENT PRICE
2) Please inquire about custom bases and disc sizes.

Barium Oxide (BaO) Disc Cathodes

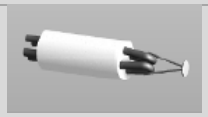
Barium Oxide (BaO) Coated Disc

FEATURES

-Oxide Planer Cathode
-Low Light / Low Temperature
-Excellent Stability
-Low Energy Spread
-Accurately Pre-Aligned
-Operating Pressures $<10^{-7}$ torr

AEI Base

CB-104 Base



CB-105 Base

Product	Emission Material	Disc Size	Emission Area	Base Type	Price
ES-015	BaO	0.033 in dia. x .004 in thick (0.84 mm dia. x 0.1 mm thick)	$5.52x10^{-3}$ cm^2	AEI CB-104	Request Quote
ES-064	BaO	0.048 in dia. x .004 in thick (1.22 mm dia. x 0.1 mm thick)	$11.7x10^{-3}$ cm^2	AEI CB-105	Request Quote
ES-066	BaO	0.062 in dia. x .004 in thick (1.57 mm dia. x 0.1 mm thick)	$19.5x10^{-3}$ cm^2	AEI CB-105	Request Quote

Notes:
1) PLEASE CHECK WEBSITE or CALL FOR MOST CURRENT PRICE
2) Custom mounting available all cathode designs

Yttrium (Y_2O_3)Coated Iridium Disc Cathodes

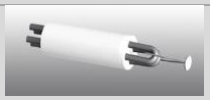
Yttria Coated Iridium Disc

FEATURES

-Yttrium Oxide (Y_2O_3) Coating
-Operation Poor Vacuum Conditions
-Iridium Planer Disc Cathode
-Resists Oxidation
-Exceptional Stability
-Low Energy Spread
-Operating Pressures $<10^{-7}$ torr

AEI Base

CB-104 Base



CB-105 Base

Product	Emission Material	Disc Size	Emission Area	Base Type	Price
ES-535	Y_2O_3	0.033 in dia. x .004 in thick (0.84 mm dia. x 0.1 mm thick)	5.5 $x10^{-3}cm^2$	AEI	Request Quote
ES-535W	Y_2O_3	0.033 in dia. x .004 in thick (0.84 mm dia. x 0.1 mm thick)	5.5 $x10^{-3}$ cm^2	AEI CB-104	Request Quote
ES-526	Y_2O_3	0.048 in dia. x .004 in thick (1.22 mm dia..x 0.1 mm thick)	1.17 $x10^{-2}$ cm^2	AEI CB-105	Request Quote
ES-529	Y_2O_3	0.062 in dia. x .004 in thick (1.57 mm dia. x 0.1 mm thick)	1.95 $x10^{-2}$ cm^2	AEI CB-105	Request Quote

Notes:
1) PLEASE CHECK WEBSITE or CALL FOR MOST CURRENT PRICE
2) Custom mounting available all cathode designs

Kimball Physics LaB_6 Cathode Electron Microscope Bases

LaB_6 Cathode	ES-423E-90/15	ES-423E-90/20	ES-423E-60/6
Features	-Extended Lifetime -High Brightness -Low Energy Spread	-Extended Lifetime -High Brightness -Low Energy Spread	-Extended Lifetime -High Brightness -Low Energy Spread -High resolution
Application	SEM, TEM	Analytical SEM, Microprobe	TEM
Material	LaB_6	LaB_6	LaB_6
Cone Angle(degrees)	90	90	60
Microflat (microns)	15	20	6
Price	Request Quote	Request Quote	Request Quote
AEI (Standard)	•	•	•
Company Base			
Amary	•	•	•
BioRad (AEI)	•	•	•
Cameca (AEI)	•	•	•
CamScan (AEI)	•	•	•
ETEC / Perkins Elmer	•	•	•
Electroscan (AEI)	•	•	•
Hitachi S	•	•	•
ISI 2 Pin	•	•	•
JEOL E	•	•	•
JEOL GC (JSM)	•	•	•
JEOL K	•	•	•
Leica (AEI)	•	•	•
Philips	•	•	•
VG	•	•	•
VG- AEI Replacement	•	•	•
Zeiss	•	•	•

Notes:
1) PLEASE CHECK WEBSITE or CALL FOR MOST CURRENT PRICE
2) Custom mounting available all cathode designs
3) Please call Kimball Physics if your base in not listed in the table or for clarification.
4) (ABT, Topcon, see ISI) , (Tescan, LEO, see Zeiss), (FEI, see Philips)

References

For more information on Kimball Physics Cathodes and LaB_6 operation in TEM's and SEM's you may download additional detailed technical bulletins from the website resource page:

Technical Bulletins:

LaB_6-01 General Guidelines for Operating LaB6 Cathodes.
LaB_6-02 The Relationship Between LaB_6 and Cathode Life and Gun Vacuum
LaB_6-03 Emission Drift—LaB_6 and Gun Stability.
LaB_6-04 Oxygen Activation of LaB_6 Cathodes—The Double Saturation Effect
LaB_6-05 Kimball Physics ES-423E LaB_6 Cathode Style 60-06 (60° Included Cone Angle, 6μm Diameter Flat)
LaB_6-06 Kimball Physics ES-423E LaB_6 Cathode Operating Instructions for LEICA/Cambridge
LaB_6-07 Recovery of Emission From ES-423E LaB_6 Cathodes Following a Vacuum Dump

LaB_6 ES423-E
LaB6 Cathode (ES-423E) - Cathodes / Emitters- Extended Life LaB6 Cathode- Description and Specifications

LaB_6 ES423-GR
LaB6 Cathode (ES-423GR) - Cathodes / Emitters- Extended Life LaB6 Cathode- Description and Specifications

LaB_6 ES440
LaB6 Cathode (ES-440) - Cathodes / Emitters- Extended Life LaB6 Cathode- Description and Specifications

LaB_6 ES423-Microscopes

Barium Oxide Cathodes
Barium Oxide Cathodes / Emitters- Description and Specifications

Tantalum Cathodes
Tantalum (Ta) Cathodes / Emitters- Description and Specifications

Yttria Coated Cathodes
Yttria Coated Iridium Cathodes / Emitters- Description and Specifications

Notes:
1. Charts /graphs show typical performance, data is for guidance only
2. It is not necessarily possible to achieve all maximum specifications simultaneously.
3. Specifications Subject to Change Without Notice.
4. Refer to website or call for current pricing.
4. DE Altobelli, DT Taylor 2/28/2023

Document: KP_Cathode_Summary_2023_0229