KPI

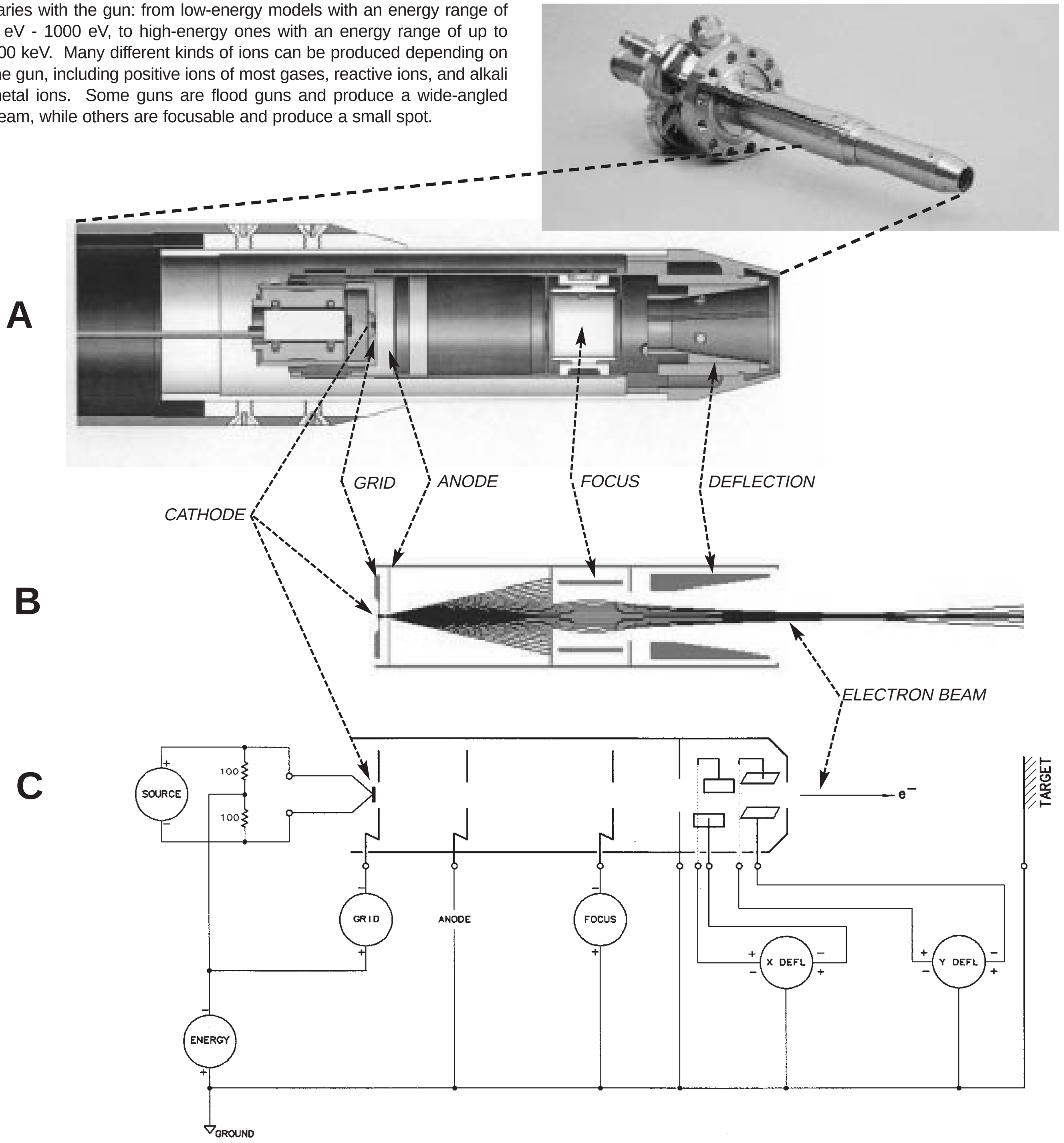
PRELIMINARY

AN INTRODUCTION TO ELECTRON AND ION GUNS

WHAT IS AN ELECTRON OR ION GUN?

An electron or ion gun is a scientific instrument that generates either electrons or ions, and forms them into a usable beam. The electron and ion guns built by Kimball Physics are used in a wide variety of basic research and industrial applications: from microscopic surface physics studies and semiconductor processing to large spacecraft testing. The guns range in size from about a centimeter to over half a meter long. The energy of the electrons produced also varies with the gun: from low-energy models with an energy range of 5 eV - 1000 eV, to high-energy ones with an energy range of up to 100 keV. Many different kinds of ions can be produced depending on the gun, including positive ions of most gases, reactive ions, and alkali metal ions. Some guns are flood guns and produce a wide-angled beam, while others are focusable and produce a small spot.

The figures below represent the overall structure of a typical, electron gun in three different ways. The first figure, **A,** is a three-dimensional drawing showing a cross-section of the gun. **B** is a plot of the electrons' paths in the gun due to the fields set up by different potentials on the gun elements; this illustrates how electron optics is similar to light optics. The third figure, **C**, is a schematic block diagram showing the power supplies (represented as circles) that apply voltages to the parts of the gun to produce and control the electron beam.



A typical mounted Electron Gun with electrostatic focusing and deflection (EFG-7, size 0.2 X), shown with
(A) a three-dimensional cross-section drawing of the electron gun, not including the mounting section,
(B) a plot of the paths the electrons will take in the gun when a given set of voltages is applied to the gun elements, and
(C) a block diagram with the electrical connections of the power supplies and gun elements.

WHAT DO THE PARTS OF THE GUN DO?

Triode

The electron gun is a descendent of the early vacuum tube, and some of the parts still use the same names although they are different in structure. Electron guns function in ultra high vacuum (UHV). As in the vacuum tubes, the cathode generates free electrons, the grid provides control of the electrons, and the anode attracts the electrons. This three-part structure (the triode) is the basis of many guns (see Figure A).

The cathode is heated to very high temperatures by the supply labeled Source, and electrons are given off from the surface of the cathode. The path that the electrons take from the cathode through the gun can be visualized from the field plot (Figure C). The energy that the electrons finally attain is determined by the difference between the initial potential set by the Energy supply and the final potential (ground) where they exit the gun.

The various elements in the gun, usually tubes or plates with an aperture (a hole), can act as lenses to control and focus the beam, similar to the lenses in light optics. The grid provides the first control of the electron beam, usually focusing it to a cross-over point. If the grid is sufficiently negative, it can also cut-off (stop) the electron beam. In many guns, the anode is at ground potential so the potential difference between the cathode and anode determines the overall energy of the electron beam.

Focus and Deflection

In a focusable gun, additional elements in the gun further control the size of the beam. In the gun illustrated on the previous page, the focus consists of three elements which together form a converging lens called an Einzel or single lens; the potential on the middle element is controlled by the Focus power supply. Some guns have more complicated lens systems, such as the zoom lens, for focusing and accelerating or decelerating the electrons. Many guns have additional elements that move the beam on the target for deflection or rastering. Instead of electrostatic lenses, some guns use magnetic coils that produce electric fields to control the beam; however, the effects are similar.

Ion Guns

Ion guns (also called Ion Sources in some cases) are quite similar in principle to the electron guns. The general structure of the gun and the control elements are similar to that described above. However, instead of a cathode, there is an ion source that generates the ions either directly from an alkali metal, or indirectly by generating electrons which then ionize a gas. With positive ions, the voltages applied to the gun elements are the opposite of those for electrons, but the focusing and control of the beam work in the same way.

HOW ARE ELECTRONS GENERATED?

Cathode

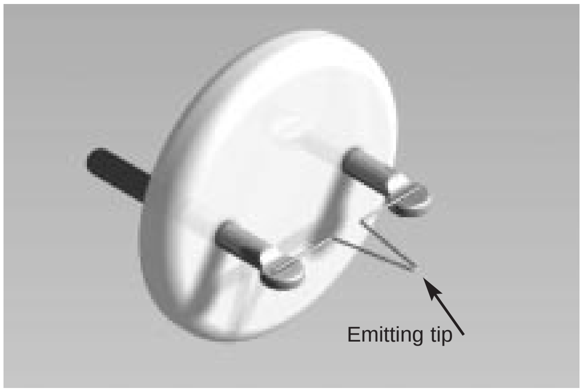
The standard cathode used in Kimball Physics electron guns is a refractory metal thermionic emitter. When a wire bent into a hairpin is heated to very high temperatures, it will emit heat, light and electrons, similar to the filament in a light bulb. In many cathodes, a disk attached to the bend of the wire is heated by the wire, and the electrons are emitted from this disk. A power supply (labeled Source in the block diagram) provides the current to the wire, which heats up because of its resistance. When an electron near the surface of the disk has received enough thermal energy, it can break free of the metal atoms surrounding it and move into the space near the disk; this process is called thermionic emission.

Emission and Beam Current

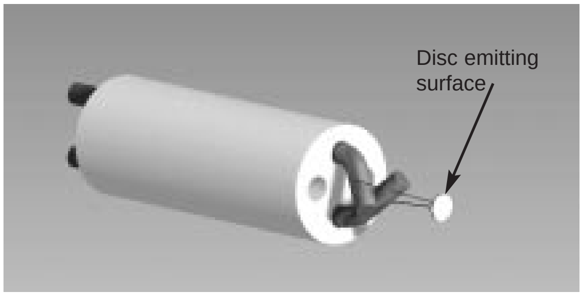
Where the electron goes once emitted depends on its energy and the electrical fields in the space around the cathode. If the electron does not have enough energy or if the space around it has too much negative charge (called space-charge limited), the electron will return to the cathode. The electrons that leave the cathode can then be focused into the electron beam. The emission current is all the electron current that leaves the cathode and goes to ground. This emission current depends on both the cathode temperature and the electron beam energy set by the Energy power supply. However, not all the electrons emitted from the cathode will finally exit the gun; some may land on other elements in the gun column. Thus the final beam current at the target may be less than the initial emission current.

Special Cathodes

Instead of the standard refractory metal cathode, various other cathodes are employed in some Kimball Physics electron guns for specific purposes. For example, a barium oxide (BaO) low- light cathode may be used in applications where the bright light emitted from the standard cathode is a problem, however, the BaO cathode requires a better vacuum. Another coating material, thorium oxide (ThO2) has a lower work function than uncoated refractory metals, which means that more electrons will be emitted from the thorium. Because iridium is a chemically unreactive metal, a thorium oxide-coated iridium cathode is more rugged and is needed in some environments. A cathode that is quite different from the metal ones described above is the lanthanum hexaboride (LaB_6) cathode. It is formed from a single crystal of LaB_6 cut into a cone shape with a flattened point. This unique cathode generates a small beam of electrons that can be focused to a very small spot (about 10 microns). A variety of cathodes, which are available from Kimball Physics separate from the gun system, are described more fully in the EMITTERS SECTION (the magenta-colored section) of this catalog.



Simple hairpin filament cathode
mounted on standard glass base (size 3 X)



Coated refractory metal disc cathode
mounted on Kimball Physics ceramic base (size 3 X)

HOW ARE IONS GENERATED?

There are three different basic processes by which ions are generated in different Kimball Physics ion guns: electron impact gas ionization, microwave gas ionization, and alkali metal solid surface ionization.

Gas Ionization

This type of ion source has a filament which emits electrons when heated by the Source power supply. An inert or a reactive gas, such as argon or oxygen, is introduced from an external tank via a gas feedthrough into the region inside the ion gun near the filament. The electrons emitted from the filament are accelerated into the gas region and collide with the neutral gas molecules. If the impact is of sufficient energy, an electron will be removed from the neutral gas molecule, resulting in a positive ion. Usually the ion will be singly charged. Depending on the energies involved, the primary and the secondary (released) electrons may go on to collide with other gas molecules and cause further ionization. The electrons finally land on a positive structure called the ion cage.

The number of ions produced by electron impact ionization depends mainly on the number of electrons emitted, their energy, the type of gas and the number of gas molecules present to be ionized. The ionization potential of each gas species determines the minimum energy the bombarding electrons must have to remove an outer electron. Within a normal range, the pressure of the gas introduced into the gun is linearly related to the ion beam current produced.

Plasma

The microwave ion source is similar to the electron impact ion source in that it generates ions from a gas introduced into the gun. However, instead of electron bombardment, it uses microwave power, which is transmitted from an external generator to a helical antenna in the ionization chamber, to heat the gas and create a plasma, a highly-energized state in which the gas molecules are disassociated into ions and free electrons. The plasma can be seen as a glowing gas in the chamber, similar to a fluorescent light tube. After the ions are extracted by several apertures, they pass through an ExB filter that consists of a region with an electrical field (E) perpendicular to a magnetic field (B). This ExB filter separates the ions based on their mass; by varying the electric field, ions of different masses can be selected as in a mass spectrometer. The electrical field is adjusted so that only ions of the type desired (based on their mass) can pass through, while other ions and molecules are deflected. Further lenses control the energy, focus and deflection of the selected ions.

Solid Ionization

In other ion guns, ions of alkali metals such as Cs+, Li+, or K+, are generated directly by solid surface ionization. Instead of having a filament, this type of ion source has a cartridge containing solid compounds of the alkali metal. When heated by the source voltage, these compounds undergo a solid-solid chemical reaction that releases the alkali metal ions at the surface. These positive ions are then accelerated and focused into a beam as in other guns.

Ion Beam

The ions generated by the ion source are then formed into the ion beam. A gun element called the extract aperture, which has a negative voltage relative to the ion energy, accelerates and extracts the positive ions from the region of electron bombardment; this is similar to the function of the anode in the electron gun triode. The grid element, with its potential controlled by the Grid power supply, also helps extract and focus the ions. Depending on the gun, additional elements may be present to accelerate, decelerate, focus and deflect the beam.

HOW IS THE ELECTRON OR ION BEAM OBSERVED?

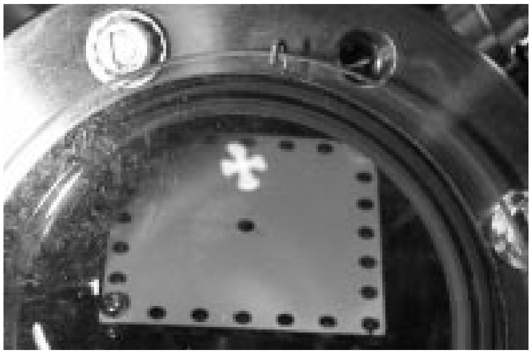
Because an electron or ion beam is invisible, it must be observed by its effects, by employing some type of detector. Two common types of detectors are phosphor screens, which emit light when struck by the electrons/ions, and Faraday cups, which collect the electrons/ions and allow current measurement. A variety of phosphor screens and Faraday cups available from Kimball Physics are described in the DETECTORS SECTION (purple section) of this catalog.

Phosphor Screen

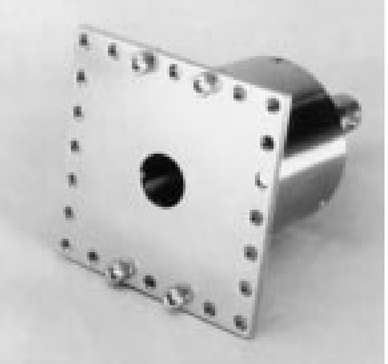
A grounded phosphor screen in the target position allows visual, real-time observation of the spot produced by the beam. The phosphor screen emits light (photons) when bombarded by high-energy particles, either electrons or ions; the light color, typically blue or green, depends on the phosphor material. On the screen, the electron/ion beam usually appears as a small, solid circle (the spot); if the beam has not been focused, the spot may be much larger, or have fuzzy edges, or be made up of many dots (beamlets), or even (with an LaB_6 cathode) have an unusual cross shape. As the position, size and shape of the spot can be easily observed, the screen is useful for alignment and setting the proper operating parameters for the gun.

Faraday Cup

A Faraday cup can be used to detect and measure the actual beam current emitted from the electron/ion gun. The Faraday cup consists of a shielded cup with an aperture, which collects the electrons or ions, and an output wire, which is connected to an ammeter. The Faraday cup can be completely separate from the gun, or it can be part of an assembly mounted to the end of the electron/ion gun and manipulated remotely. Some Faraday cup assemblies include a phosphor screen as well. An array of small Faraday cups or a Faraday cup on mounted on a linear manipulator can be used to measure the distribution of the beam current across the spot; this shows the beam uniformity.



Maltese-cross shaped spot from an unfocused LaB_6 cathode seen on a phosphor screen inside the vacuum chamber



Unmounted Faraday cup

WHAT ARE THE CHARACTERISTICS OF AN ELECTRON OR ION BEAM?

Beam Energy

One of the most important characteristics of the beam is the kinetic energy of the electrons or ions. The beam energy is determined by overall potential difference that accelerates the electrons/ions as they travel from the cathode/ ion source to the final aperture of the gun. This energy, measured in electron volts (eV or keV), is controlled by the Energy power supply and can range from 5 eV to 100 keV depending on the gun. The energy spread is a measure of the variation in energies (typically less than half an eV), as not all particles will exit with exactly the same energy.

Beam Current

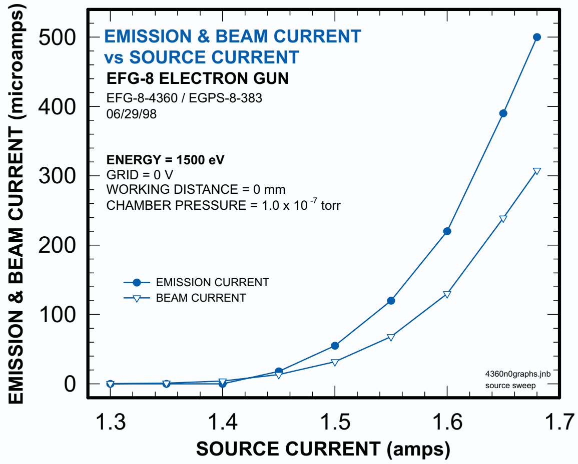
Beam current is the total electron/ion current exiting the gun and can be measured by a Faraday cup at the end of the gun (in mA, µA, or nA). As discussed above under electron generation, beam current is not identical to emission current, which is the total current that leaves the cathode/ion source and goes to ground, because in the process of traveling down the gun and being focused some of the electrons/ions will land on various gun elements. Thus the final beam current at the target may be less than the initial emission current.

Spot Size

The spot size is the diameter (in cm, mm or µm) of the electron/ion beam at a given distance from the gun (working distance). This may range from 10 µm to several hundred mm, depending on the gun. The spot is measured either visually on a phosphor screen, or by a Faraday cup array; as the edge of the circle may not be clear cut, the full-width-half-max measurement (FWHM) is defined as the width that includes all beam current densities greater than half the maximum density. In a flood gun, which does not have focusing lenses, the size of the spot is mainly dependent on the working distance, on how far away the target is from the end of the gun, although other operating parameters have some effect as well. Beam divergence is the angular spread of the electron/ion beam from the final aperture of the gun (in degrees º) and so affects the spot size.

Beam Uniformity and Current Density

Beam uniformity describes the beam current within the spot. The beam current can be further characterized by measuring the beam current density, the beam current per unit area at the target (typically in µA/cm2). The variation of beam current density at different positions in the spot is called the beam current distribution. In most guns, this distribution is similar to a normal curve (called the Gaussian curve); the spot is brightest in the central area and fades off at the edges. A few guns have elements designed to produce a flatter, more uniform distribution across the entire spot.



Comparison of Emission Current and Beam Current

HOW IS THE BEAM TURNED ON AND OFF?

In most guns, the electron or ion beam may be turned off and on while the gun is running. The way this is accomplished depends on the particular gun design; often several methods are available for a gun.

Grid Cut Off

The grid, sometimes called G-1 or the Wehnelt, is the first electrostatic element in the gun that the electrons/ions come to after being emitted from the cathode/ion source. The grid provides the first control over the beam and usually can be used to shut off the beam. In an electron gun, if the grid voltage is sufficiently negative with respect to the cathode, it will suppress the emission of the electrons, first from the edge of the cathode and at higher (more negative) voltages from the entire cathode surface. Similarly, in some ion guns, a positive grid voltage can suppress the positive ions from the ion source. The minimum voltage required to completely shut off the flow of electrons/ions to the target is called the grid cut off. The grid voltage is controlled manually by a potentiometer knob on the power supply; thus, in most guns, the beam can be turned off while the gun is running by setting the grid to the cut off voltage.

Beam Pulsing

Pulsing, also called fast beam pulsing, is stopping and starting the flow of electrons or ions in a fast cycle. This pulsing is usually accomplished by rapidly switching the grid voltage to its cut off potential to stop the beam. The gird voltage can be controlled by several different methods (listed in order of speed):

1) Manual control with the dial potentiometer,
2) Remote control with computer input into power supply terminals,
3) Dual grid power supplies with a TTL signal input, and
4) Capacitive pulsing with a pulse junction box or cable and an external pulse generator.

The features of these four methods are compared in the table on the next page.

The simplest method of turning the beam off and on is just to cycle the grid voltage by hand with the control knob on the front of the power supply. Clearly, this would be slow and not reproducible. A more systematic method of controlling the grid is by an input signal into the remote terminals on the rear panel of the power supply. Remote control is a standard feature on all power supplies, so this method does not require any system options. However, it may not provide sufficiently fast pulsing.

With the dual grid pulsing option, there are two grid power supplies built into the main power supply. A pulsing TTL (transistor-transistor-logic) signal switches rapidly between the two supplies, pulsing the beam on and off. For most guns, the dual supplies are (1) the normal, variable control grid supply which is adjusted to allow the electron flow and (2) a fixed grid supply which is fixed at the cut-off grid voltage at the factory. For guns that usually have a positive grid, the dual supplies are (1) a variable positive grid supply which allows the electron flow, and (2) a variable negative grid supply which is adjusted to cut-off.

Grid pulsing cable for capacitative pulsing

HOW IS THE BEAM TURNED ON AND OFF?(cont..)

Beam Pulsing cont.

For the capacitive or fast pulsing option, many guns can be equipped with a capacitor-containing device (either a separate pulse junction box or a cable with a box) that receives signal from an external pulse generator. The grid power supply and pulse generator outputs are superimposed to produce the voltage at the grid aperture, as shown in the diagram below. The grid power supply is first set at the cut off voltage. As the grid voltage is negative with respect to the cathode, positive voltage pulses are required to pulse the gun on. The general pattern of the beam pulsing is a square wave with a variable width (time off and time on) and a variable repetition rate. Capacitive pulsing can provide the fastest rise/ fall time and shortest pulse length of the various methods. However, the capacitor does not permit long pulses or DC operation.

Not all guns are designed to be pulsed. For example, a few electron guns have a positive grid, and some ion guns have a negative grid, in order to extract more electrons or ions, and so these guns do not have grid cut off. However, Kimball Physics can often customize a positive grid system to allow pulsing.

SUMMARY OF BEAM PULSING METHODS

1) MANUAL CONTROL

Features:
- Rise /fall ~ 0.5 s
- Pulse lenghts ~ 0.5s to DC possible
- Available on all guns that cut off
- Operator needs to control grid potentiometer

Drawbacks:
- Slow and irregular
- Not available on electron guns with positive grid or guns without cut off

2) REMOTE CONTROL

Features:
- Rise /fall ~ 1 ms
- Pulse lenghts ~ 1ms to DC possible
- Available on all guns that cut off
- 0 to 10 V control signal required (e.g. D/A converter, DAQ board with analog input)

Drawbacks:
- Not available on electron guns with positive grid or guns without cut off
- May not be sufficiently fast

3) DUAL GRID POWER SUPPLIES

Features:
- Rise /fall ~ 500 ns
- Pulse lenghts ~ 1 µs to DC possible
- Controlled by any TTL generator (computer or stand alone)
- Optional, built into main Power Supply, request at time of order

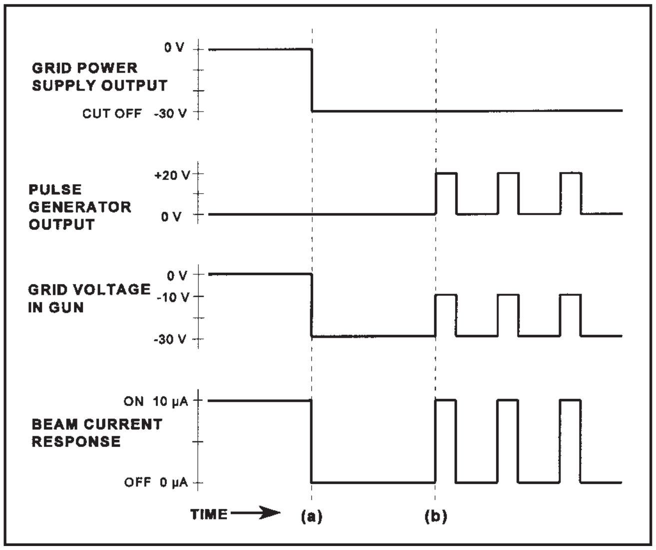
Drawbacks:
- May not be sufficiently fast

4) CAPACITATIVE PULSING

Features:
- Rise /fall ~ 10 ns
- Pulse lenghts ~ 20 ns to 100 µs
- Controlled by a external pulse generator with positive voltage at least equal to grid cut off value
- Removable pulse junction box or special cable (depends on gun)
- Can be added to existing system

Drawbacks:
- Long pulses not achievable
- Requires pulse generator with desired rise /fall
- Not available on electron guns with positive grid or guns without cut off

Beam Pulsing cont.

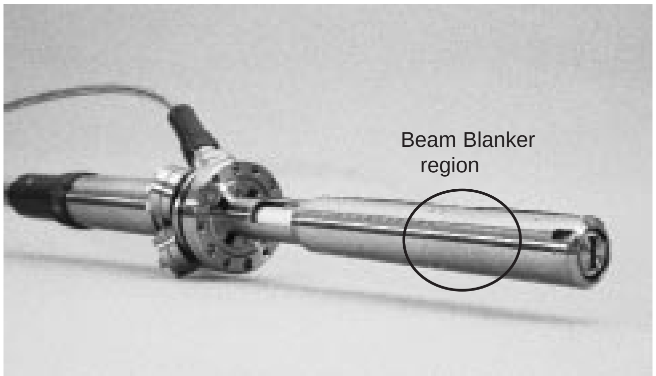


Capacitative Fast Beam Pulsing Diagram
The grid power supply and pulse generator outputs superimpose to produce the voltage at the grid aperture. This grid voltage then controls the beam current, pulsing it on and off. At time (a) the grid power supply is set to the cut off voltage, and at time (b) the pulse generator is started.

HOW IS THE BEAM TURNED ON AND OFF?(cont..)

Beam Blanking

Beam blanking is accomplished by deflecting the electron beam to interrupt the flow of electrons to the target while the gun is running. The electrons are absorbed by plates on the side of the gun instead of going to the target. Thus, beam blanking is different from standard pulsing in that the electron beam is not actually cut off and the grid is not involved. Blanking can be controlled by a pulsing TTL (transistor--transistor-logic) signal from an external TTL generator and is used to turn the beam at the target on and off rapidly. The rise/ fall time with blanking is approximately 500 ns.



EMG-12 Electron Gun with Beam Blanker installed

HOW IS THE BEAM MOVED ON THE TARGET?

Mechanical Alignment

Mechanical alignment is available with many gun mounting systems to aid in aiming the electron or ion beam at the target. A rotating flange or a device consisting of two rotating angled disks (a Port Aligner) can be used to mechanically change the position of the gun. Port Aligners are available from several manufacturers.

Deflection

Many Kimball Physics electron and ion guns have an electrostatic deflection system as an option. In the gun column following the focusing lenses, two pairs of plates (X+,X- and Y+, Y-) are arranged around the path of the beam. Voltages are applied to these plates by manually-controlled X and Y power supplies, and the resulting electrical field bends the path of the beam. This deflection is used to move the beam around in the plane of the target to position the beam. In a few guns, magnetic coils are optionally available to similarly deflect the beam for alignment.

Rastering

Rastering, which is related to deflection, is a continuous movement of the electron or ion beam over the target plane in order to uniformly cover an area over time. This rastering is similar to what occurs with a TV or CRT screen. Two synchronized, cyclically-varying voltages are applied to the X and Y deflection plates in the gun. This causes the beam to move in a synchronized pattern: sweeping back and forth (X direction) while simultaneously moving down more slowly (Y direction), then returning to the start position without sweeping back and forth (retrace). Visually, it appears that the beam covers a large square area, instead of a single small spot. Rastering is occasionally done in an unsynchronized mode.

Beam Rocking

Magnetic beam rocking, which is used in a few high-energy guns, is very similar to rastering. Instead of electrostatic deflection plates, currents in electromagnetic coils around the gun move the electron beam in an unsynchronized pattern over the target area. The effect is the same as rastering, to provide a more uniform coverage of a larger area.

HOW ARE THE POWER SUPPLIES CONTROLLED?

The power supply unit, which is part of the electron or ion gun system, is a complete unit containing electronic circuitry, meters and controls, that takes power input from the outside line and converts it to voltages and currents required to run the electron or ion gun. Individual power supplies within the power supply unit provide the voltage to particular gun elements. The output of a power supply is monitored by either an analog meter (one with a dial and pointer) or with a digital voltage meter (DVM).

Manual and Remote Control

These individual supplies can be controlled either manually by the potentiometers on the front of the power supply unit, or remotely by a signal into the remote controls on the rear of the power supply. The manual dial potentiometer controls a 0 to 10 V signal that directly controls the output of the individual power supply proportionally. By use of the remote control terminals , the supplies may be either voltage programmed or resistance programmed. The voltage signal can be obtained from any source, such as a computer with a digital to analog converter, or an analog supply. Resistance programming involves connecting a resistor to the remote terminals.

Feedback Control (ECC)

In addition to the usual manual or remote control, the source power supply can be controlled in a feedback-regulated mode, labeled ECC for Emission Current Control. In electron guns, this feedback circuitry regulates the source power supply, which heats the filament, so that a constant emission current is maintained from the cathode. Similarly, in alkali metal ion guns, the ECC regulates the heating of the ion cartridge and so maintains a constant ion emission current. In gas ion guns, the ECC feedback circuitry controls the electrons used for ionization, but this does not completely regulate the emission of ions from the ion source, as the ionization is also dependent on the gas pressure and other factors.

Kimball Physics Ion Gun Power Supply, shown with Ion Gun
This system includes the following supplies: Ion Energy, Source with ECC feedback control, Electron Energy, Extract, Grid, Focus, X Deflection, and Y Deflection
(Manual controls are on the front panel and remote control terminals on the rear panel)

HOW IS THE GUN CONNECTED TO THE VACUUM SYSTEM?

Mounted Guns

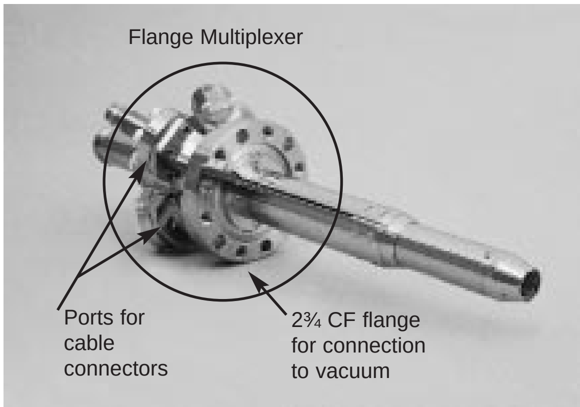
Most Kimball Physics electron and ion guns are designed in a mounted configuration, the gun being housed in a tube with a flange for connecting the vacuum system. The mounting system uses a standard type of vacuum flange (called a CFF or ConFlat flange) that has a knife edge on the sealing surface and comes in standard sizes according to its approximate diameter; for example, a 1⅓ CF flange has about a 1.33 inch or 34 mm diameter, a 2¾ CF flange about 2.75 inch or 70 mm, and a 6 CF about 6 inches or 152 mm. The mounted gun also includes cable connectors for the power supply and vacuum feedthroughs, which are insulated connections for the electrical wires and other tubes needed to connect the gun to the power supply cable and other external parts, such as a gas tank. A Kimball Physics Flange Multiplexer, which is used as the mounting system on many electron/ion guns, has a one (2¾ CF) flange surface to connect to a vacuum port and five smaller (1⅓CF) flanges for various feedthroughs and cable connectors.

Unmounted Guns

Some of the simpler guns are also available in an unmounted configuration, which allows the customer to design the housing, mounting system and vacuum connections.

Vacuum Fittings

A more complete discussion of the design of vacuum components and descriptions of the many vacuum parts available from Kimball Physics that can be used in building a vacuum system are given in the COMPONENTS SECTION (the green section) of this catalog.



Flange Multiplexer fitting
for attaching the gun to the vacuum system

Unmounted Electron Gun
Firing unit triode alone (cathode, grid, and anode)
with no CF flange or feedthrough (size 0.5 X)

WHAT HAZARDS ARE INVOLVED WITH ELECTRON AND ION GUNS?

Safety from possible hazards due to High Voltage or X-ray radiation must be a consideration in setting up and operating the entire system. The purchaser's safety officer should inspect the installation and shielding of the electron/ion gun prior to operation.

High Voltage

Proper High Voltage precautions and grounding techniques must be observed. In no event should the power supply be energized unless the electron/ion gun is bolted into a properly evacuated high vacuum chamber. Proper vacuums are better than 1 x 10^{-5} torr for refractory metal cathodes/ion sources, or better than 1 x 10^{-7} torr for LaB_6 and BaO cathodes. To energize the system without proper vacuum would cause the gun to be damaged by arc-overs, that expose the operator to a severe electric shock hazard. In no event should the safety interlocks on the high voltage cable, or in the power supply, be disconnected or bypassed. Due to possible high voltage hazards, Kimball Physics does not recommend that users construct their own power supply.

X-Ray Radiation

For a higher-powered electron gun (over 10 keV), X-ray radiation hazards are a concern. Since high-energy electrons striking targets or any other surface on the interior of the vacuum chamber may generate x-ray radiation, x-ray radiation shielding is recommended when using the electron/ion gun. This x-ray shielding is part of the host vacuum system. Therefore, the purchaser must observe proper radiation shielding procedures to protect personnel and/or property when designing the host vacuum system into which the gun is to be inserted. When observing the target area of a higher-powered electron gun (over 10 keV), it is necessary to cover standard glass viewports with leaded glass; failure to do so could increase the risk of exposure to x-rays. Unleaded viewports are transparent to x-rays, so direct viewing of the cathode or target area through normal glass viewports is a radiation health hazard.

HOW ARE THE GUNS TESTED?

Every new electron or ion gun and power supply built at Kimball Physics is individually tested by being run in our vacuum laboratory, and data on various gun parameters are collected. This ensures that each gun functions properly, is well aligned, and meets its specifications. Graphs are provided to the customer showing the results of this testing to aid in determining the operating conditions for the particular gun. Guns returned for rebuild or repair undergo similar, but less extensive, testing. (The only exceptions to this testing procedure are a few simple, firing unit models sold in large batches.)

Data

The data collected depends on the gun model and the needs of the customer. The following graphs are generally included: the V-I Characteristic (Source Current vs Source Voltage), which shows the performance of the particular cathode/ion source; Emission and Beam Current vs Source Current, which shows the overall gun performance, how much beam can be produced, and is used to set the source when running the gun; Emission Current vs Grid Voltage and Beam Current vs Grid Voltage at various Energies, which together show how the grid can be used to improve or to cut off the beam. Depending on the gun, graphs showing focusing parameters, spot size, beam current density, or other properties may also be provided. Additional custom-designed testing procedures can be performed as required by the customer.

Some representative graphs are shown in this catalog under the various gun models; data for electron guns are in the blue section, and for ion guns in the red section.