

## 7 GLOSSARY FOR ELECTRON AND ION GUNS

**Alignment:** (1) Positioning of the physical elements of the electron/ion gun so that the charged particles travel in the optimal path through the gun.

(2) **Mechanical beam alignment:** A mechanical adjustment of the gun that changes the orientation of elements of the gun with respect to other elements or with respect to the target; use of a device to line up gun with the target, for example, using a Port Aligner which consists of two rotating angled disks.

(3) **Magnetic compensation alignment:** Displacement of the electron/ion beam in a plane (X-Y) perpendicular to the line of travel (Z) of the beam, by means of the magnetic fields produced by electric coils (X+,X- and Y+,Y-) arranged around the beam; used to position the beam on the target and improve beam current and beam uniformity.

**Analog meter:** A meter with a dial and pointer which displays current or voltage.

**Anode:** (also **G-2**) (1) The second electrostatic lens element in the gun, which usually provides the potential difference that accelerates the electrons; the third element of the triode; usually a tube with an aperture (hole); often grounded, but may be referenced to Energy and have a varied voltage.

(2) The power supply that applies voltage to the anode element in some guns. Also, the potentiometer that controls this power supply.

**Aperture:** A small hole that the electron/ion beam goes through, which can control the path and/or diameter of the beam.

**Barium oxide (BaO):** A coating applied to a cathode that reduces the work function enabling electron emission at lower temperatures, thus reducing light output.

**Bake out:** Heating the electron/ion gun while in vacuum to remove and pump away contaminants.

**Beam blanking:** Deflecting the electron/ion beam to one side of the gun tube to interrupt the flow of particles to the target without actually turning off the beam; can be used to pulse the final beam current repeatedly on and off, controlled by a TTL signal input.

**Beam current:** The electron/ion current exiting the gun, usually measured by a Faraday cup at the end of the gun (in mA,  $\mu$ A, or nA); not identical to emission current.

**Beam current density:** The beam current per unit area reaching the target (typically in  $\mu$ A/cm<sup>2</sup>).

**Beam current distribution:** The variation in beam current density at different positions in the spot at the target.

**Beam divergence:** The angular spread of the electron/ion beam as it exits the gun (in degrees  $^{\circ}$ ).

**Beam pulsing:** See Pulsing.

**Beam uniformity:** A qualitative statement about the beam current distribution, usually Gaussian-like.

**Cartridge:** (1) **Firing unit cartridge:** For electron Guns: An assembly containing cathode and grid which is part of a larger firing unit of some guns and can be replaced separately.

(2) **Ion source cartridge or alkali metal cartridge:** For Ion Guns: A cup containing a solid that is heated to produce alkali metal ions directly by a solid-solid chemical reaction, part of the ion source firing unit.

**Cathode:** The structure in the electron gun that emits electrons; the first element of the triode; may consist of a sharply-bent wire (hairpin) or of a heating wire and an emitting disc or other configuration.

**Centering:** See Deflection.

**Charged particle:** An electron or ion.

**CF, ConFlat:** A type of vacuum flange with a knife edge on the sealing surface; sized by the approximate diameter:

1 $\frac{1}{2}$  CF ~1.33 inch ~34 mm,

2 $\frac{3}{4}$  CF ~2.75 inch ~70 mm,

4 $\frac{1}{2}$  CF ~4.5 inch ~117 mm.

(The ConFlat flange was invented by Bill Wheeler at Varian; ConFlat is a registered trademark of Varian Associates.)

**Cut off (also Grid cut off):** (1) Shutting off the flow of electrons/ions to the target; for electrons, by making the grid voltage sufficiently negative that the electrons from the cathode are repelled and do not go through the grid, or similarly for positive ions, by making the grid sufficiently positive that the ions in the source region are repelled.

(2) The minimum grid voltage that reduces the beam current to zero.

**D-sub:** A multi-pin cable connector used on power supplies for computer input/output, such as an RS-232 serial port, trapezoid-shaped like the letter D.

**DAQ:** Data acquisition (1) Communication between a computer program, such as a LabVIEW™ executable program, and a physical system, such as an electron or ion gun power supply.

(2) Also refers to computer boards and cables used to transfer data and control signals to and from the equipment.

## 7 GLOSSARY for ELECTRON and ION GUNS cont.

**Deflection, X and Y Deflection:** (1) Electrostatic or electromagnetic displacement of the electron/ion beam in a plane (X-Y) perpendicular to the line of travel (Z) of the beam, by means of voltages applied to two pairs of plates (X+,X- and Y+,Y-), or by currents applied to deflection coils, arranged around the beam; used to position the beam on the target, generally without affecting the focus and energy of the beam.

Also sometimes called **centering or X-Y centering**.

(2) The two power supplies that apply voltage to the deflection plates. Also the potentiometers that control the deflection power supplies.

**Differential Pumping:** Maintaining a different vacuum pressure in the electron or ion gun and the main vacuum chamber by connecting separate vacuum pumps to the two areas, usually using a Compact Tee differential pumping connector on the gun.

**D.V.M., Digital volt meter:** A meter that displays in numbers the amount of volts or kilovolts output from a given power supply.

**ECC:** (1) **Emission Current Control** For Electron Guns: Feedback circuitry that regulates the source power supply that heats the filament; used to maintain a constant emission current from the cathode.

(2) **Emission Current Control** For Alkali metal Ion Guns: Feedback circuitry that regulates the source power supply that heats the alkali metal cartridge; used to maintain a constant ion emission current from the ion source.

(3) **Electron Current Control** For Gas Ion Guns: Feedback circuitry that regulates the source power supply that heats the filament in the ion source, so that a constant flow of electrons is given off; only indirectly controls the production of ions by the ion source.

(4) Also the potentiometer and switch that control the ECC circuitry.

**Emission current:** (1) For Electron Guns: The total electron current that leaves the cathode and goes to ground (in mA or  $\mu$ A); equivalent to all the current that exits the gun (beam current) plus all the current that lands on grounded elements within the gun.

(2) For Ion Guns: The total ion current produced by the ion source that goes to ground (in mA or  $\mu$ A), directly measured in only some gun; not identical to the electron emission current which causes gas ionization or to the ion beam current which exits from the gun; equivalent to all the current that exits the gun (beam current) plus all the current that lands on grounded elements within the gun.

**Encoder Wheel:** A disc-shaped rotary switch (thumb wheel) on power supplies with FlexPanel control that adjusts the programming signal of a selected supply or menu item. The rate of increase/ decrease varies with the speed of rotation.

**Energy** (1) Kinetic energy of a charged particle emitted from the gun; equal to  $\frac{1}{2}mv^2$ , where  $m$  is the particle mass and  $v$  is the particle velocity; this energy is achieved by applying accelerating voltages to elements of the gun. 1 eV is equivalent to the energy obtained by a particle with unit electronic charge ( $1.6021 \times 10^{-19}$  coulombs) accelerated by a 1 volt potential difference and is equal to  $1.6021 \times 10^{-19}$  joules.

(2) The energy power supply that provides the electron/ion accelerating voltage; other power supplies can be referenced to this power supply. Also, the potentiometer and switch that control the energy power supply.

(3) For Ion Guns: also called Ion Energy.

**Extract (also G-2)** (1) The second electrostatic lens element in the ion gun, which provides the potential difference that extracts the ions from the ion source region and accelerates them; usually a tube with an aperture (hole); often grounded, but may be referenced to Energy and have a variable voltage.

(2) The power supply that applies voltage to the extract element in some ion guns. Also, the potentiometer that controls this power supply.

(3) For Ion Guns: also called **Ion Energy**

**Faraday cup** A particle-collecting device consisting of a shielded cup and output wire; usually used with an ammeter in series to ground to measure beam current.

**Feedthrough:** Electrical, gas, mechanical and other connections (wires, tubing, insulators etc.), usually from vacuum to non-vacuum parts of a system.

**Filament, Fil+, Fil-:** (1) The wire heating part of the standard cathode or ion source.

(2) Also the positive and negative leads to the cathode or ion source.

**Firing Unit:** (1). For Electron Guns: The part of the gun that emits the electrons; the assembly that can be replaced as a unit, usually consisting of the complete triode (cathode, grid and anode) or just the cathode and grid; in some guns, only a part of the firing unit called the firing unit cartridge needs to be replaced.

(2) For Ion Guns: The part of the gun that produces the ions; the assembly that can be replaced as a unit, usually consisting of the gas ion source or alkali metal ion cartridge, the grid and sometimes extract elements.

**Flange Multiplexer:** A vacuum component with one flange surface (usually  $2\frac{3}{4}$  CF) to connect to a vacuum port and five smaller flanges (usually  $1\frac{1}{2}$  CFs) for various feedthrough and cable connections; used as the mounting system on many electron/ion guns.

## 7 GLOSSARY for ELECTRON and ION GUNS cont.

**FlexPanel:** (1) A Kimball Physics power supply control panel design featuring a digital screen, selector buttons and a single variable control (encoder wheel).

(2) More specifically, the set of digital interface controller boards designed by Kimball Physics, used in power supplies for programmed control of supplies, metering, and display on a digital vacuum fluorescent screen. Power supplies with this controller are considered FlexPanel units even if they are "black box" style with no manual controls or display screen.

**Focus (also Lens):** (1) One or more electrostatic or magnetic lens elements in the electron/ion gun that control the beam spread; usually controls spot size at the target; in some guns, may control beam divergence at points internal to the gun.

(2) The power supply that applies voltage or current to the focus/lens element(s). Also, the potentiometer that controls this power supply.

**Gaussian:** A normal distribution curve; even if a beam current distribution is not strictly Gaussian, this term is used to describe distributions that are brightest in the center of the spot and fade off at the edges.

**G-1, G-2, G-3, G-4:** The series of apertures and electrostatic lens elements in the electron/ion gun labeled by their position (first, second, third, fourth) instead of by common names.

**Grid (also G-1):** (1) The first electrostatic lens element in the electron/ion gun; the second element of the triode in electron guns; provides the first control and usually focuses the beam to a crossover; usually a tube with an aperture (hole), but may be a mesh (like a screen); can be used to cut-off the beam in most guns.

(2) The power suppl(ies) that apply voltage to the grid element. Also the potentiometer that controls the grid power supply.

**H.V.:** High Voltage, sometimes used as a label on the Energy switch or to refer to an additional Power Supply unit needed for a high current electron gun.

**Insertion length:** The length of the gun that is in vacuum, from the vacuum sealing surface to the beam-exit end of the gun.

**Ion cage:** The part of the ion source where the gas is ionized in some ion guns, consisting of a wire coil that accelerates the ionizing electrons.

**Ion emission current:** The total ion current produced by the ion source (in mA or  $\mu$ A); not identical to the electron emission current which causes ionization or to the ion beam current which exits from the gun.

**Ion source:** (1) The structure in the ion gun that produces ions; for gas ions, usually consists of an electron-emitting filament, shields and an ion cage; for alkali metal ions, consists of a chemical cartridge and its heating filament.  
(2) Another term for a complete ion gun; the entire unit made up of the ion source which creates the ions, and the electrostatic lens system that controls and focuses the ions to produce the final ion beam.

**Ionization:** (1). The production of a charged particle (ion) from a neutral atom or molecule by either the loss of one or more electrons (positive ion), or gain of one or more electrons (negative ion).

(2) **Electron impact ionization** Ionization by bombarding a gas with electrons, which collide with and remove electrons from the neutral gas molecules producing positive ions.

(3) **Surface ionization** Ionization by heating a solid alkali metal compound so that ions are produced in a solid-solid chemical reaction.

**LaB<sub>6</sub>, lanthanum hexaboride:** A cathode material with low work function and long lifetime; a single crystal structure cut and mounted on a heating rod; used as a cathode in some electron guns to produce electrons that can be focused to a small spot.

**LabVIEW™:** A National Instruments Inc. software used by Kimball Physics to develop programs to control the electron or ion gun power supply; allows the system to be operated remotely via a virtual instrument panel on a computer screen: also allows automated collection of data.

**Lens (also Focus):** (1) One or more electrostatic or magnetic lens elements in the electron/ion gun that control the beam spread; usually controls spot size at the target; in some guns, may control beam divergence at points internal to the gun.

(2) The power supply that applies voltage or current to the focus/lens element(s). Also, the potentiometer that controls this power supply.

**MCDU, MCDU-4C, Manual Control Deflection Unit:** The group of power supplies, circuitry and controls contained in the main power supply unit that produces and controls the voltages needed for deflection of the beam.

**Potentiometer:** A dial control knob, usually with numbers 0-10 on the ring, that regulates the output of a given power supply proportionally, typically by a 0 to 10 V signal input.

**Plasma:** A state of matter in which outer electrons are not held to the rest of the atoms or molecules, so there are free electrons and free ions in a gas-like cloud; used as a source for ions in some guns.

**Power Supply:** (1) The 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/ion gun.

(2) An individual group of electronic circuits, contained in the larger unit, that produces voltage/current applied to a specific element in the electron/ion gun.

## 7 GLOSSARY for ELECTRON and ION GUNS cont.

**Pulsing** (also **Beam pulsing**): Rapidly stopping and starting the flow of electrons/ions, with a variable width (time on/off) and variable repetition rate; usually accomplished by rapidly switching the grid voltage to the cut-off potential; can be controlled in one of several ways: manual control with the grid potentiometer, remote computer control, dual grid power supplies with a TTL switching signal, capacitive pulsing with a pulse junction box and an external pulse generator.

**Pulse junction box**: A capacitor-containing device that combines input from an external pulse generator and the voltage from the grid power supply to vary the voltage applied to the grid; used to turn the beam current on and off rapidly; can be a separate box or part of a Grid Pulsing Cable.

**Rastering**: Movement of the electron/ion beam 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); used to cover an area of the target region fairly uniformly over time; produced by two synchronized cyclical voltages or currents applied to the X and Y deflection plates or deflection coils in the gun. Rastering may also be non-synchronized, in which case there is no retrace segment.

**RGDU, Raster Generator Deflection Unit**: A separate unit containing the power supplies, circuitry and controls that produce and control the voltages applied to the deflection plates for either rastering or deflection (centering) of the electron/ion beam.

**Rocking** (also **Beam rocking**): Movement of the electron/ion beam in an unsynchronized pattern sweeping back and forth (X direction), while simultaneously moving up and down more slowly (Y direction), with no retrace; used to cover an area of the target region fairly uniformly over time; produced by magnetic fields from varying currents in electrical coils around the beam in the gun.

**RS-232, RS-422, RS-485**: Types of command languages used to program power supplies based on industry-standard specifications for the hardware. RS-232 is ground-based, while RS-422 and RS-485 are differential and addressable.

**Sine wave driver board**: A removable electronic circuit board in the main power supply unit that controls the individual power supply outputs.

**Source**: (1) For Electron Guns: The power supply that produces the voltage and current that heats the cathode causing it to emit electrons. Also the potentiometer and switch that control the source power supply.

(2) For Ion Guns: The power supply that produces the voltage and current that heats the filament of the ion source, either causing the filament to emit electrons for gas ionization, or heating the alkali metal cartridge for solid ionization, depending on gun. The potentiometer and switch that control the source power supply.

(3) The cable and power supply connector that include the source (filament), grid and other leads, depending on the electron/ion gun; the H.V. Multiconductor Source Cable.

(4) **Ion source** See Ion Source above.

**Space charge**: The electric field resulting from the presence of a number of charged particles (electrons and ions) in a region of space; can limit the emission of more electrons from a cathode or limit the ions extracted from an ion source; can also affect the path of charged particles through a region.

**Spot**: The electron/ion beam at the target area; can be seen as a (usually circular) light area on a phosphor screen.

**Spot size**: The diameter (in mm or  $\mu\text{m}$ ) of a circle that contains most of the electron/ion beam at a given distance from the gun (working distance); measured either visually on a phosphor screen, or electrically by sampling beam current density across the spot with a Faraday cup; FWHM (full-width-half-max) measurement is the width that includes all beam current densities greater than half the maximum density.

**Tantalum**: A refractory metal commonly used as the electron emitting material in a cathode.

**Target**: The place (a plane) at which the electron/ion beam is aimed.

**Tetrode**: An electron extraction and acceleration unit used in some electron guns, consisting of four elements: cathode, grid, a variable first anode, and a grounded second anode.

**Thermionic emission**: Emission of electrons or ions from a metal or other coating material by heating the emitter in order to impart enough energy to overcome the work function of the emitting material.

**Thoria**: A common name for thorium oxide,  $\text{ThO}_2$ ; used as a coating on some cathodes or filaments, because of its relatively low work function.

**Triode**: The basic electron extraction and acceleration unit of most electron guns, similar to a vacuum tube, consisting of three elements: cathode, grid, and anode.

## 7 GLOSSARY for ELECTRON and ION GUNS cont.

**TTL, transistor-transistor logic:** Electronic circuitry that produces a repeated on-off (square wave) signal, usually +5 V and 0 V.

**Tungsten:** A refractory metal commonly used in cathodes, because of its high melting point, either as the electron emission surface or as the heater leg.

**Uniform beam distribution:** An even distribution of beam current density over the entire spot area; a flat step-like curve on a graph of beam current density ( $A/cm^2$ ) vs position in the spot.

**Wehnelt:** Another term for grid, from the physicist, A. Wehnelt.

**Work function:** A material-dependent measure of the work per unit charge needed to emit a charged particle (usually an electron) from the emitting material.

**Working distance:** The distance from the end of the gun where the electron/ion beam exits to the target plane.

**X axis, Y axis:** Arbitrarily-defined horizontal and vertical lines used as reference for motion of the beam in the target area for deflection, rastering, or alignment; correspond to the position of four deflection plates in the gun.

**Z axis:** A reference line through the exact center of the electron or ion gun, in the direction of electron or ion travel; the approximate beam line.

**Zener limit:** The upper limit on the source voltage in ECC mode, pre-set at the factory with a potentiometer and diode in the ECC circuitry.

**Zoom lens:** A series of electrostatic lens elements in the electron/ion gun (including anode or G-2, focus, and sometimes other lenses) that both focuses and accelerates / decelerates the beam; allows spot size and beam current to remain roughly constant as energy is varied.