Electron Sources

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USPAS 08

U. of Maryland, College Park

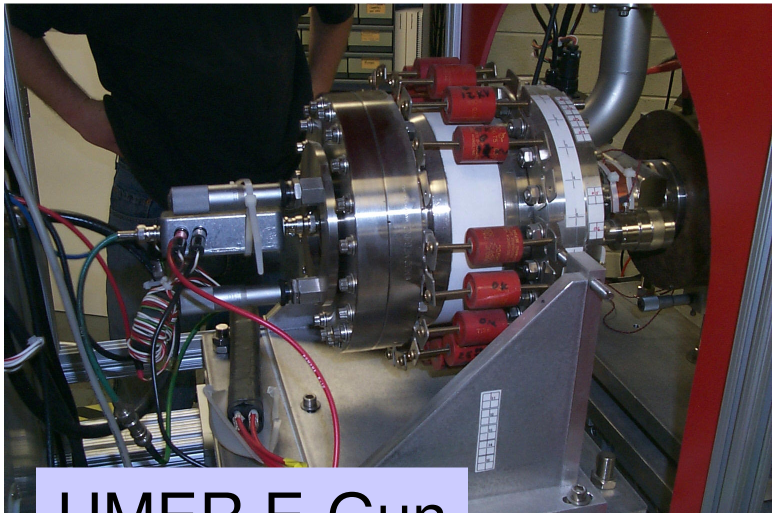
Electron Sources in General

TYPE & Max. Current Density	PHYSICS	TYPICAL CONFIG.	APPLICATIONS
Thermionic Up to 1 A/cm²	Richardson-Dushman, Child-Langmuir	Cathode + Electron Gun	Microwave tubes, Incoherent X-Ray sources, etc.
Photoemiss. >> 1 A/cm²	Photoelectric effect	RF Photocathode	Many accelerators, FELs, etc.
Field-Emission >>> 1 A/cm²	Fowler-Nordheim	Cold-cathode, Needle	Discharge tubes, Field-Effect Microscopes
Other: Plasma, multipactor, nano-tube, laser cooled, etc	Laser cooling, nano-physics, etc.	Plasma Ion source, cavity, optical trap, etc.	Most under R&D

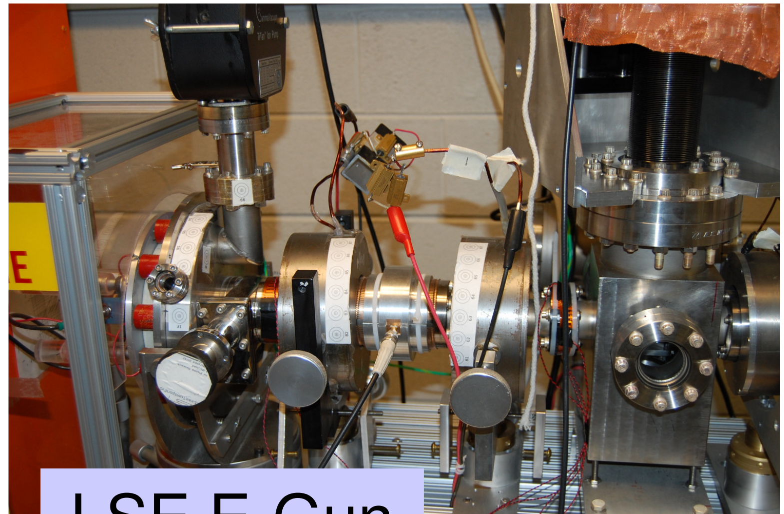
Electron Sources in UMER Lab

SOURCE	Max. Energy, Current, pulse	TYPE	DESCRIPTION
Hughes Gun r_C=12.7 mm	8 keV, 200 mA, 1μs	Pierce Geom., Convergent, diode	Scaled-down replica of SLAC PEP gun
LSE Gun r_C= 4 mm	5 keV, 120 mA 100 ns	Pierce Geom., triode	Cathode-driven, Variable A/K gap
UMER Gun r_C= 4 mm	10 keV, 100 mA, 100 ns	Pierce Geom., triode	Cathode-driven, Variable A/K gap

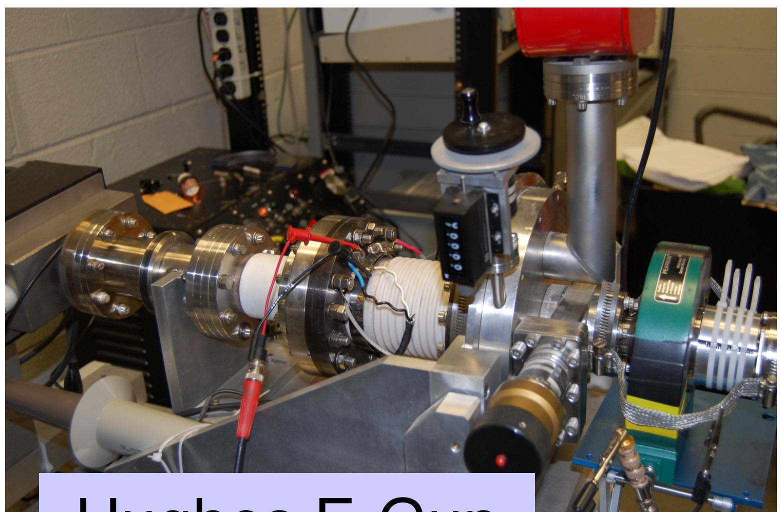
Electron Sources in UMER Lab



UMER E-Gun



LSE E-Gun



Hughes E-Gun

Physics of Thermionic Emiss. and Diode E-Guns

Richardson-Dushman Equation[1]:

$$j_{CM} = AT_C^{\,2}\exp\left(-\frac{qW}{k_B T_C}\right),$$

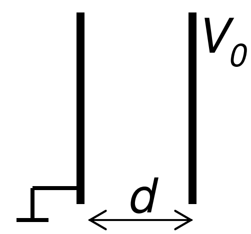
$$T_C = 1373\,\mathrm{K},\ A = 1.2\times10^{6}\,\frac{\mathrm{Amp}}{\mathrm{m^2K^2}},\ W = 2.1\,\mathrm{V}.$$

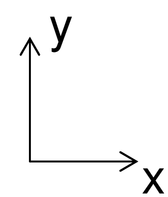
Child-Langmuir[2]:

$$j_{CL} = \frac{4}{9}\varepsilon_0\left(\frac{2q}{M}\right)^{1/2}\frac{V_0^{\,3/2}}{d^2},$$

1-D diode w/o space charge:

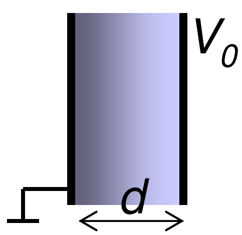
$$\phi(x) = V_0\left(\frac{x}{d}\right).$$





1-D diode with space charge:

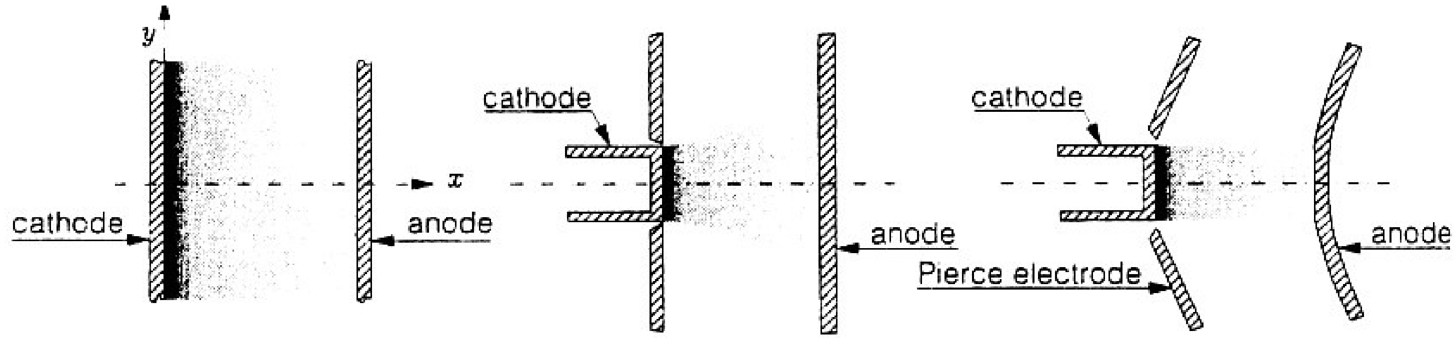
$$\phi(x) = V_0\left(\frac{x}{d}\right)^{4/3}.$$



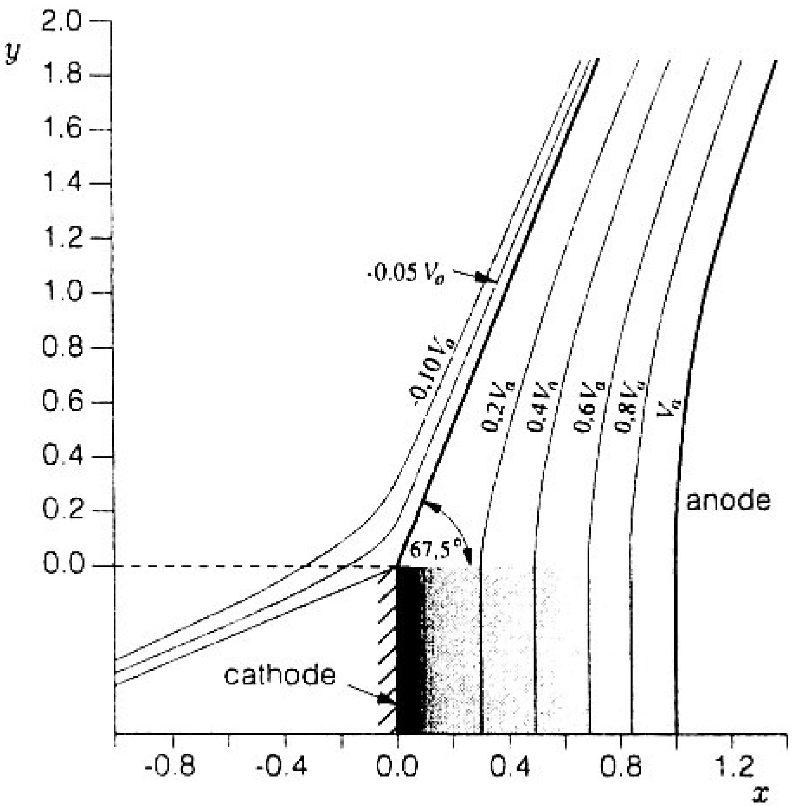
[1]See, for example, Leighton, Principles of Modern Physics, McGraw-Hill, 1959, p.355-56

[2]See Martin Reiser, Theory and Design of Charged Particle Beams, Sec. 2.5.2.

Pierce Electrode Geometry*



"Infinite" Diode   "finite" Diode   Pierce Diode



Assume $V(x) \propto x^{4/3}$, outside beam for finite (in y-direction) diode.

Use complex formalism $x \rightarrow re^{i\varphi} = \varsigma + i\xi$, $V \rightarrow W = V_R + iV_R$.

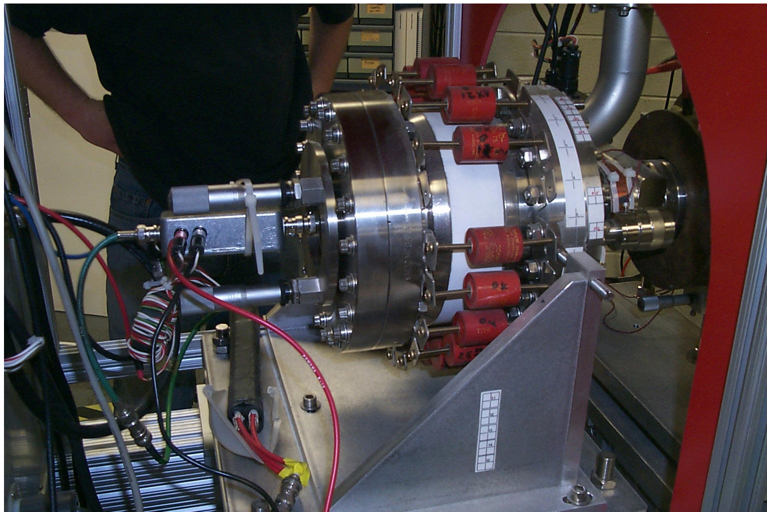
Then $V_R \propto r^{2/3} \cos[(4/3)\arctan(\varsigma/\xi)]$.

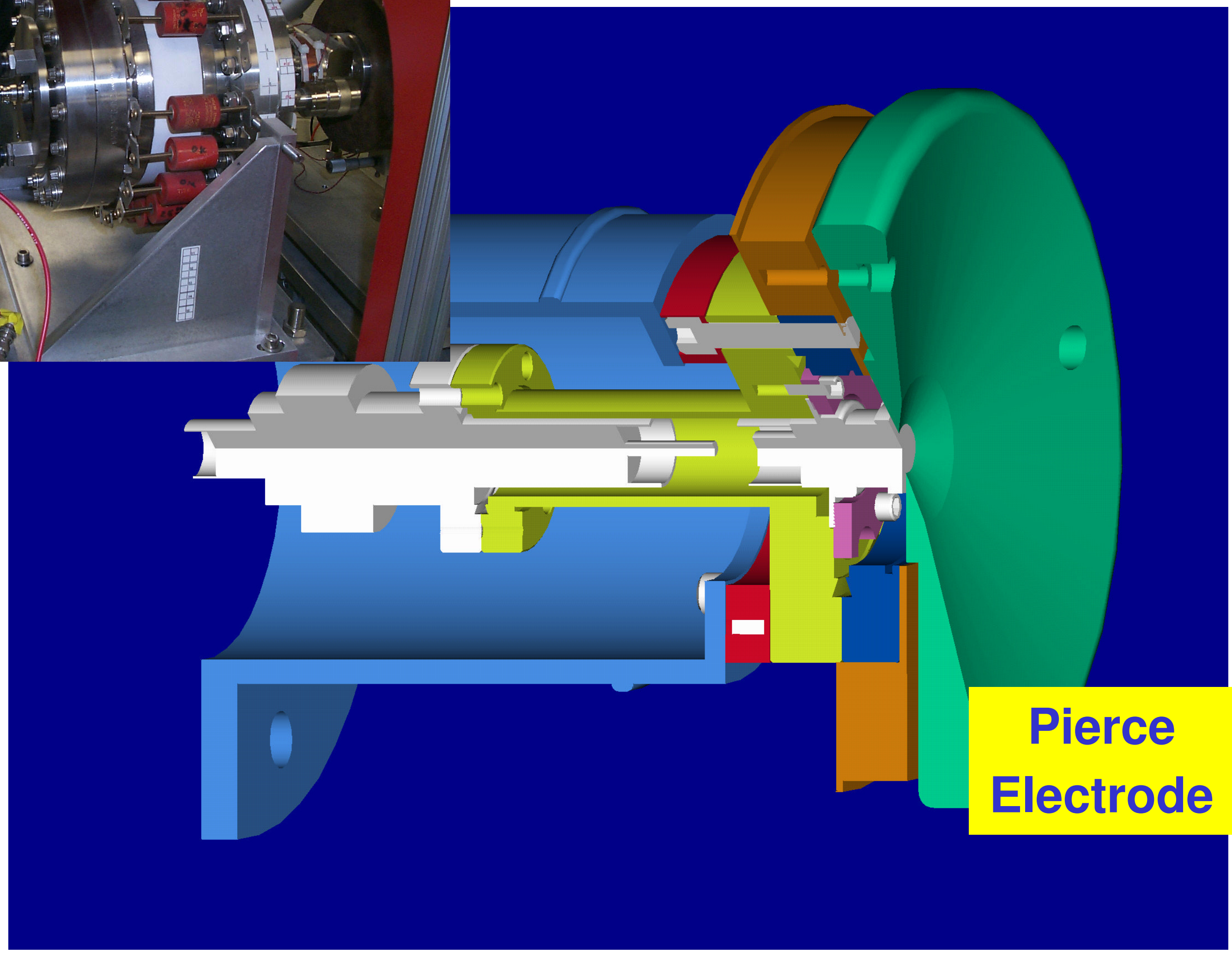
Since cathode is grounded, $V_R = 0$, so we need
$(4/3)\arctan(\varsigma/\xi)] = \pi/2$, or slope at x=0 is

$(3/4)\ \pi/2 = 67.5^0$

*Miroslav Sedlacek, Electron Physics of Vacuum and Gaseous Devices, Sec. 6.2 (1996).

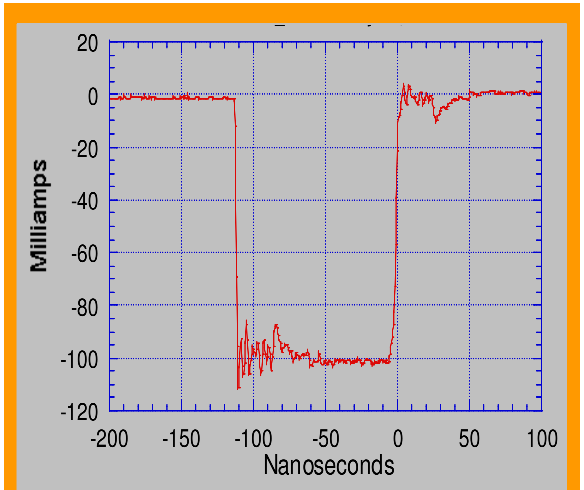
UMER Electron Gun

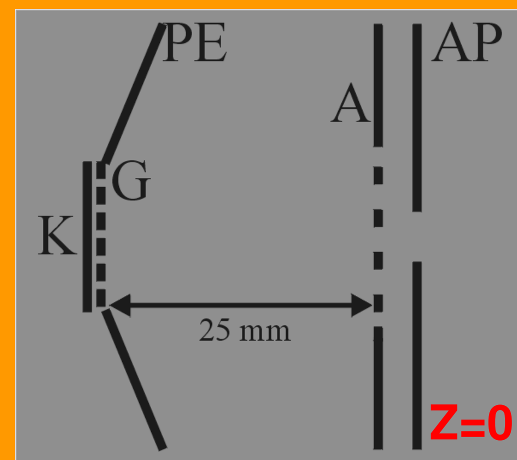




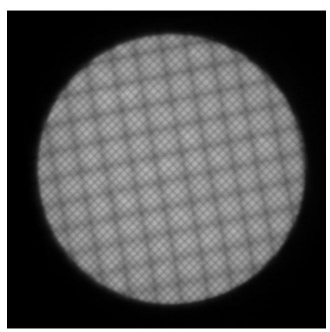
UMER Electron Gun

TRIODE ELECTRON GUN: CATHODE DRIVEN, PIERCE TYPE

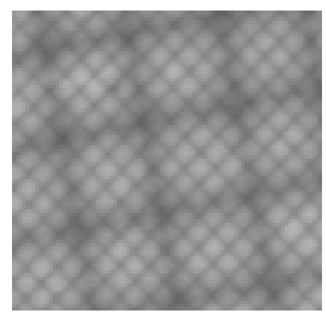




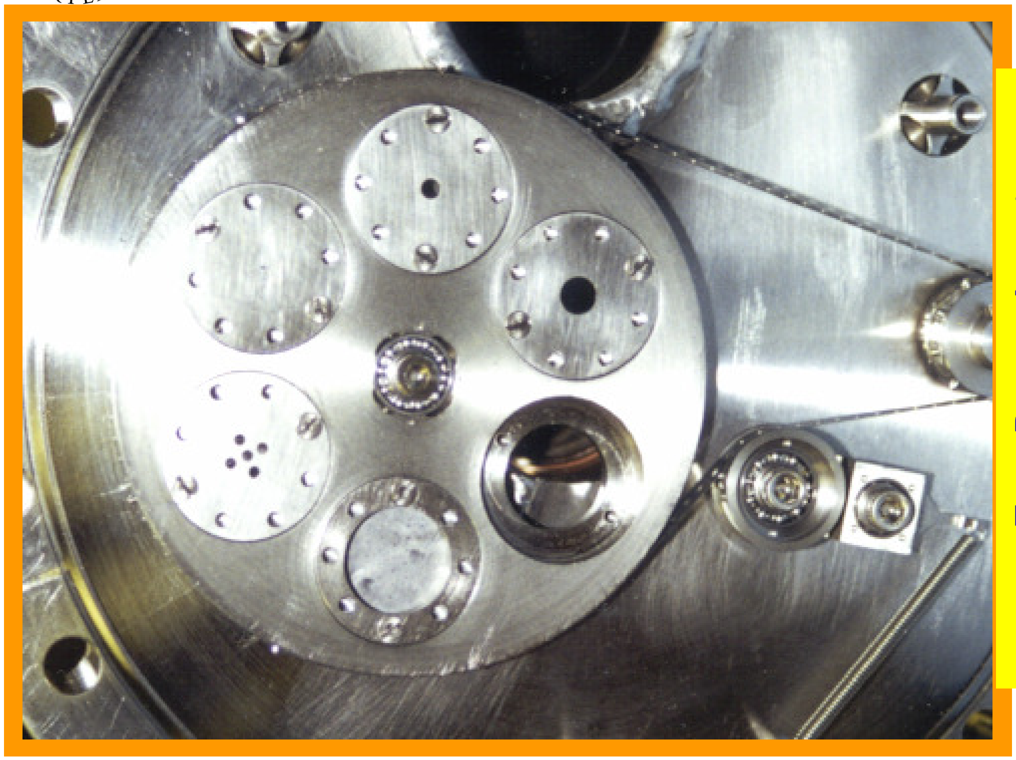
CATHODE AND ANODE GRIDS

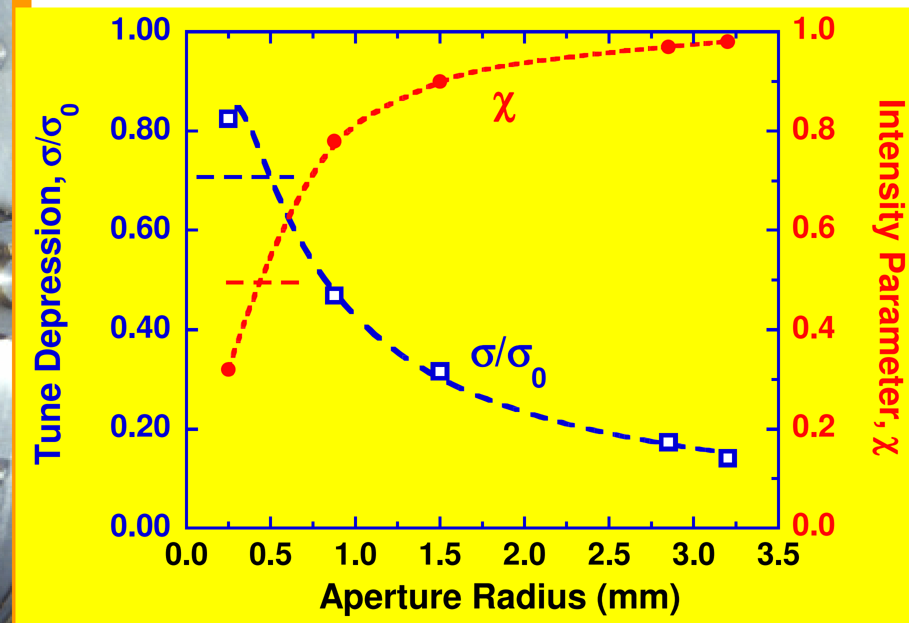


8 mm



UMER e-Gun Apertures

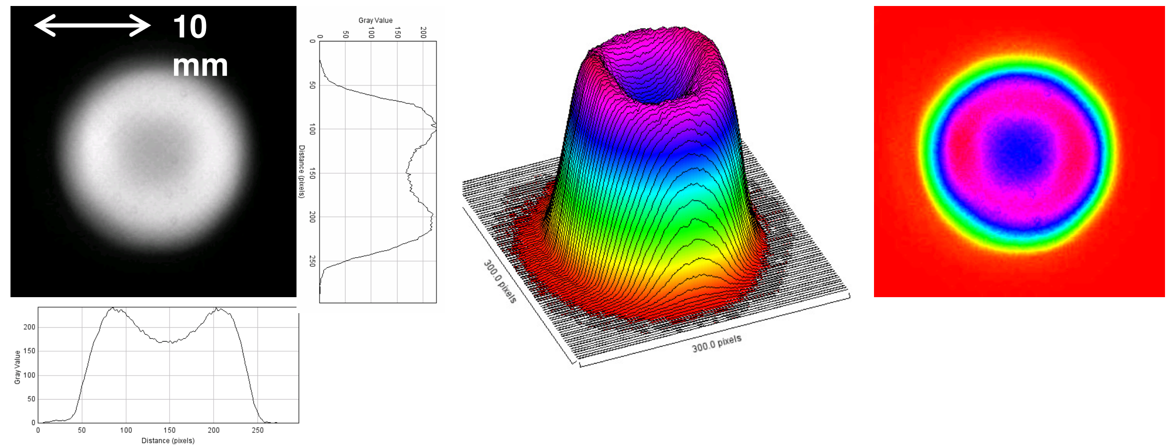




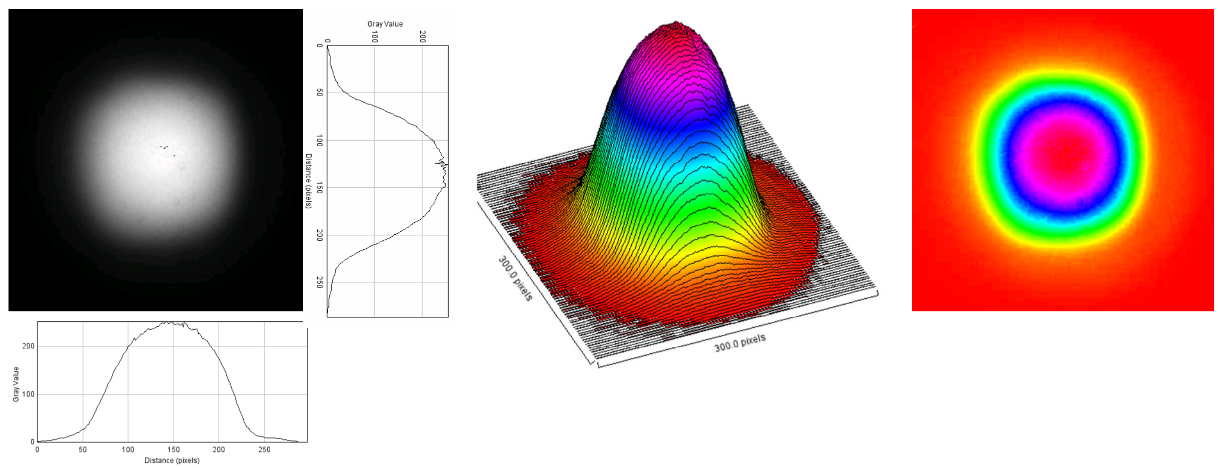
Aperture Radius	Beam Current	ϵ (μm) rms, norm.	χ
0.25 mm	0.55 mA	0.3±20%	0.28
0.875	7.2	0.7	0.81
1.5	24	1.5	0.90
2.85	85	2.7	0.97
Full	107	3.0	0.98

Adjusting the E-Gun Control Grid Bias for Optimal Output

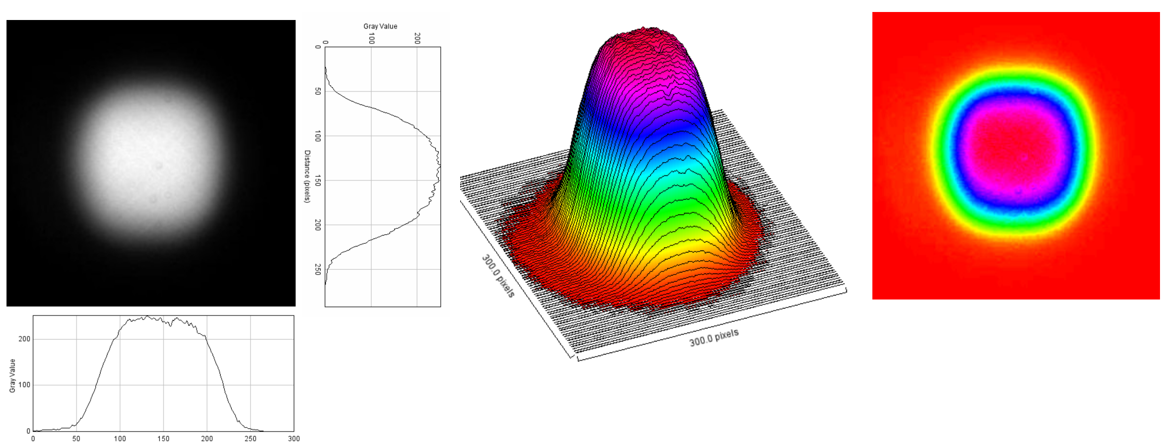
Ap=50
BV=30V
Sol=0
No Atten.



Ap=50
BV=45V
Sol=0
No Atten.



Ap=50
BV=42.2V
Sol=0
No Atten.



6.2 mA,
10 keV