# The influence of gun design on Coulomb-interactions in a field emission gun

T. Verduin, P. Kruit and B. Cook
*Delft University of Technology*
*Lorentzweg 1*
*2628 CJ Delft, the Netherlands*
*T.Verduin@tudelft.nl*

Among the various parameters of an electron gun, the brightness is a key-parameter. Brightness is usually conserved, but with stochastic electron-electron interactions included, the size of a focused spot may increase and thus the brightness may decrease.. We already demonstrated the importance of stochastic Coulomb-interactions in the source region for the brightness[1]. This effect is calculated by projecting the displaced beam trajectories back to the virtual source plane. The reduction of the brightness is obtained by adding the broadening to the size of the virtual source. For our purpose, it suffices to approximate the trajectory displacement by cutting the beam in slices and sum the individual contributions[2].

We model the gun as given by figure 1, with a needle that ends in a spherical tip. The radius of curvature in the present example is 10 nm with a cone-angle of 7.5°, as illustrated in the inset. We introduce a block to the gun design. This could either be a plane from which the tip protrudes, or a shielding electrode. The distance from the end of the tip to this block is defined as *x*. There are four calculations involved: the electric-field, the quantum mechanical calculation of the emission current, the electron trajectories and finally the trajectory displacement by Jansen's equations[2]. We have amalgamated all four calculations to one simulator. This allows us to simulate in one-run the effect on brightness, while varying the distance *x* and extractor voltage. The range of extractor voltages is chosen such that the maximum brightness for each distance *x* is found. The results are given in figure 2.

From figure 2, we observe that the further the block is from the tip, the lower the maximum brightness. Also, the brightness peak is narrower. When the distance *x* is large, the extractor voltage at a given electric-field – and with that an intrinsic brightness – is lower. Due to the lower extraction voltage, the Coulomb-effects become more significant. This explains the sharper curve with a lower maximum. We conclude that choosing a smaller distance *x* results in higher maximum brightness and less sensitivity to the extractor voltage. We have shown that gun design should be taken into consideration for achieving the highest possible brightness electron sources.

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1 B. Cook, T. Verduin, C.W. Hagen & P. Kruit, *Brightness limitations of cold field emitters caused by Coulomb-interactions*, Journal of Vacuum Science & Technology B , vol. 28, issue 6, 2010

2 G.H. Jansen & P. Kruit, *Handbook of Charged Particle Optics*, chap. 7, Orloff CRC Press, 2009

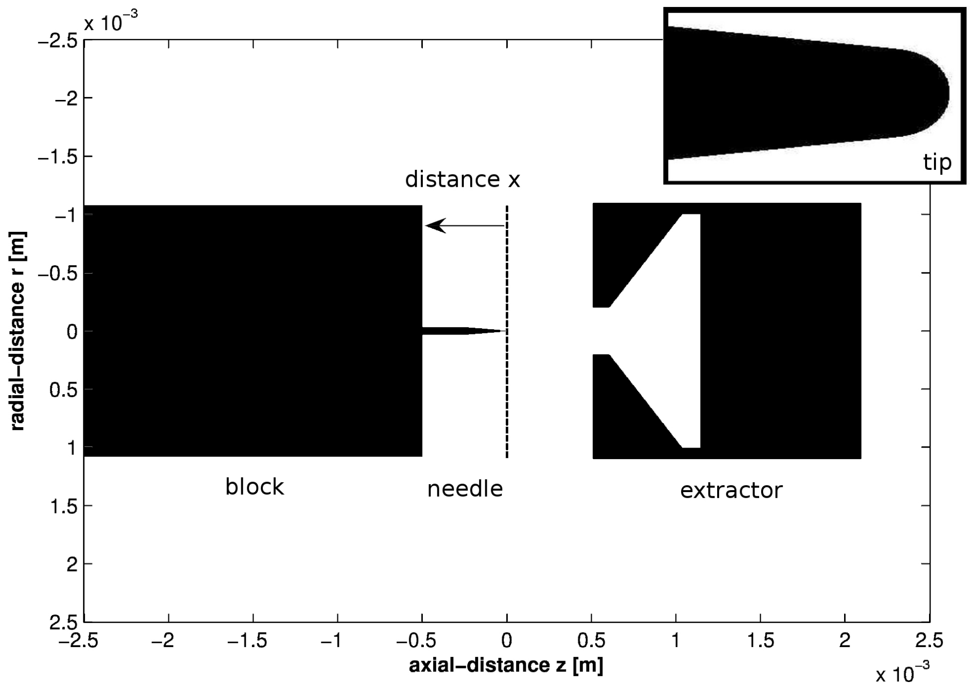


Figure 1: The configuration used for calculating the brightness. The configuration of the tip is given in the inset. For each calculation, only the distance *x* and the extractor voltage are scaled. Detailed specifications are in the abstract.

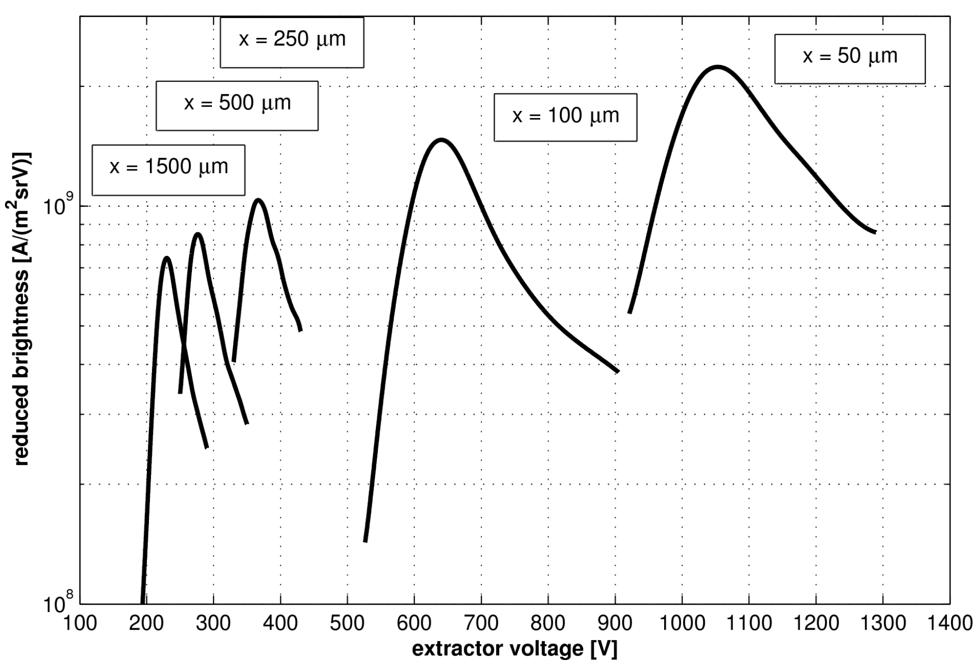


Figure 2: The brightness, limited by stochastic Coulomb-interactions, as a function of extractor voltage. Each curve corresponds to a particular distance *x*.