Statistical Coulomb Forces in Photo-Field Emitters for Ultrafast Microscopy

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As the electron microscopy community becomes increasingly interested in ultra-fast processes we must understand the nature of the ultra-fast electron source. Brightness is still a key parameter determining the imaging current available. Ultra fast microscopes operating in stroboscopic mode use, on average only one electron per pulse[1]. To have one electron within the correct emmittance may mean producing many electrons at the source and later aperturing. However we have shown in[2] that due to electron-electron interactions there is already significant brightness reduction at the source before aperturing can take place.

The most promising ultra-fast electron source is the photofield or optical field emitter[3]. For a continuous photofield emitter we have calculated the maximum brightness as a function of tip radius and find similar results to the cold field emitter of in reference [2] , see fig(1). We expect that these results are also valid for pulses, where the pulse length is much greater than the propagation length, and in this paper will extend the work to consider ultra-fast (femtosecond) pulsed photofield emitters using Monte-Carlo simulations. Thus we can find for what range of values our continuous approximation is valid.

We expect that only at the level of one electron per pulse there is a significant gain in the brightness, due to the lack of Coulomb interactions. Also to have one electron in a pulse, at the maximum brightness, requires a short enough laser pulse. Based on the size of the photo field emitter, and the information/parameters in fig(1) we can determine the maximum pulse length at the maximum brightness with one electron in it, This is shown in fig(2).

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[1] VA. Lobastov, R Srinivasan, and A H. Zewail, PNAS **102**, 20 (2005)
[2] B. Cook, T. Verduin P. Kruit, J. Vac. Sci. Technol. B **28,** 6(2010)
[3] P. Hommelhoff, et al, Phys. Rev. Lett. **96,** 7 (2006)

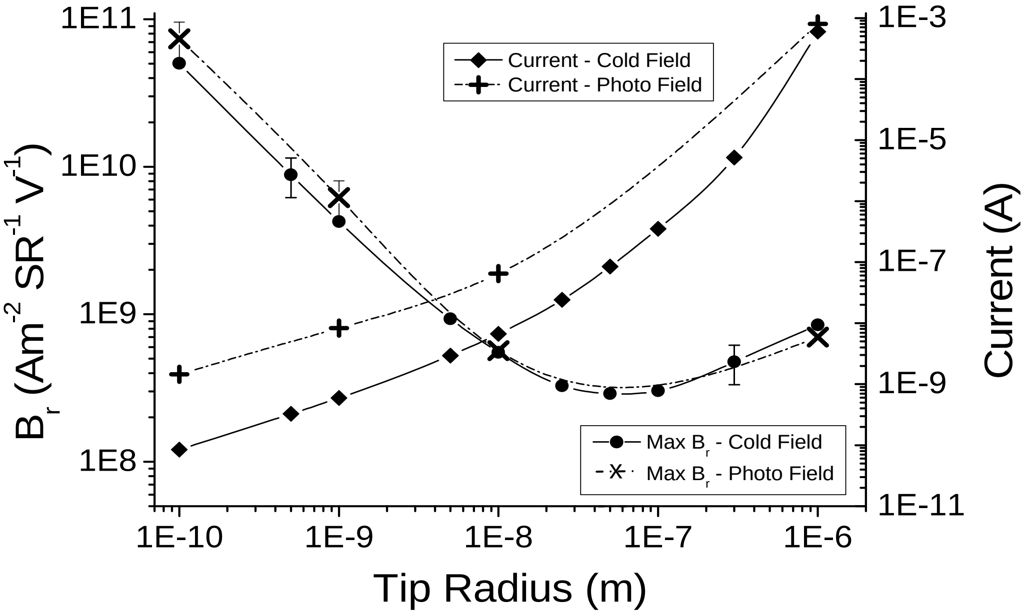

Figure 1: The upper graph shows the maximum brightness for a cold field emitter when Coulomb interactions are also calculated (see [1]) we now add the same calculation for a CW photofield emitter. On the right axis is the current at the maximum brightness for that tip radius. Three error bars are shown to give an indication of the total error of the method without disturbing the visibility of the lines. We used a laser intensity of 0.1GW/m2, and photon energy of 1.55eV, and scattering/reflection parameters for tungsten.

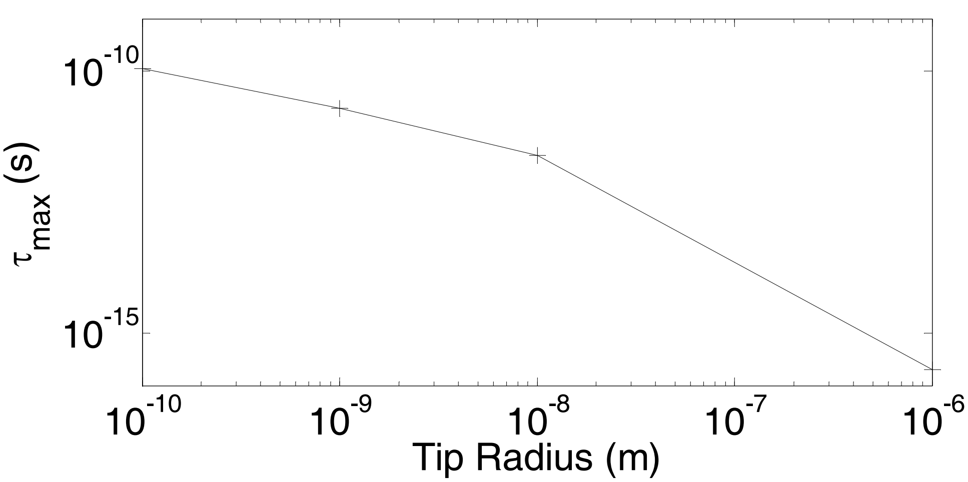

Figure 2: The maximum allowed pulsed length to achieve a single electron per pulse at the maximum brightness as a function of the tip radius. Parameters are the same as in fig (1)