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Benchmarking the Performance of a New Photoelectron Source

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When performing low voltage imaging in a spherical aberration corrected microscope, chromatic aberration can dominate and degrade the resolution of the image [1]. This can be an issue when imaging nanoparticles and 2D materials which may be damaged at higher voltages [2]. Decreasing the energy spread of the electron source is one promising solution to reducing the chromatic defocus blur and hence increasing the resolution of low voltage imaging. A lower electron energy spread also improves energy resolution in electron energy loss spectroscopy (EELS) and increases the sensitivity of elemental identification.

Decreasing the energy spread of an instrument's beam could involve upgrading your electron gun to a lower energy spread electron source such as a cold field emission gun or investing in an expensive electron monochromator. **Figure 1** is an graph adapted from [3] on the approximate cost of electron monochromators and different electron guns versus their electron energy spread. We see that there is a general trend that the lower the electron energy spread required the more expensive the equipment needed. This is perhaps unsurprising with the need to introduce extra optical elements or higher-performance pumping systems. However, we propose that there is a way to deviate from this trend by using a low-cost retrofittable photoelectron source.

The proposed photoelectron source operates by using a laser to strike a material with a low workfunction (such as Lanthanum Hexaboride (LaB_6)) causing low energy spread electrons to be emitted. Previous work from Sawa et. al. has shown electrons with an energy spread as low as ΔE=0.11eV can be produced through photoemission from a LaB_6 [4]. With advances in blue-ray DVD player technology, UV laser diodes are now increasingly economical and widely available, while LaB_6 crystals are commonly found in thermionic electron guns. Therefore, using 3D printed components, UV laser diodes and the photoelectron effect a retrofittable photoelectron source can be produced which has an energy spread three times less than a cold FEG and a fraction of the price of electron monochromators.

A prototype of such a photoelectron source, equipped to an SEM, was recently demonstrated in our group and preliminary results obtained. A discussion into the performance of this retrofittable photoelectron gun will be presented including both theoretical predictions and experimental results. This will include an analysis of how light sources of different wavelengths can affect the energy spread of the emitted photoelectrons and how the power of the laser can impact the photoelectron current produced as shown in **Figure 2**. Given the relationship between photocurrent and wattage in **Figure 2** the laser could potentially be used to modulate the strength of the electron beam to control dose. An investigation into the percentage of photocurrent versus thermionic current as a function of temperature will also be outlined. The results of this investigation describe the possibility of operating the photoelectron source in a low energy spread mode when the crystal in cold or in a high current mode when the crystal is hot when both photoelectrons and thermionic electrons are being emitted.

By benchmarking the performance of this photoelectron gun, we evaluate how it compares to other technologies and how its retrofittable design may increase the functionality and resolution of current electron microscopes. This could open new avenues in future instrument design or offer a sustainable means of increasing the lifetime and use of existing microscopes.

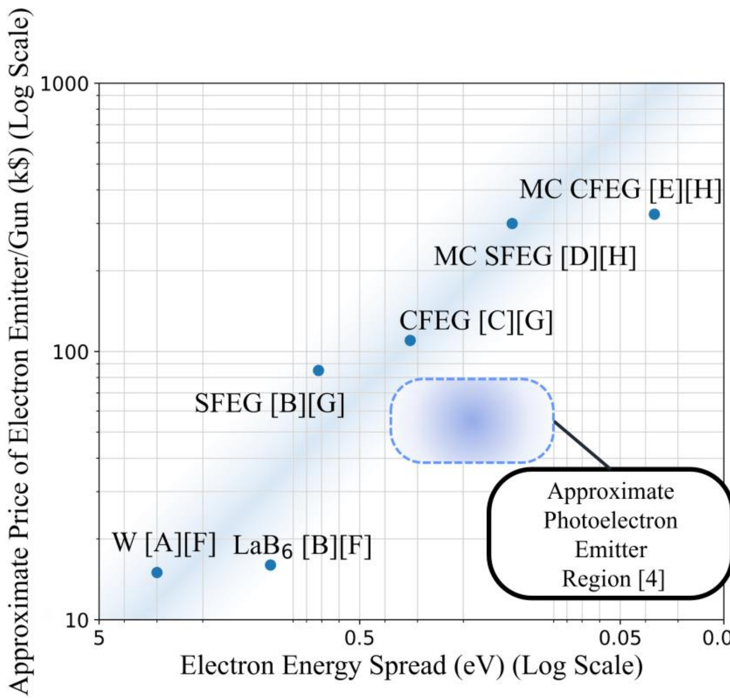

Figure 1. A representation of the general trend in the price/performance trade-off of a variety of electron guns and monochromators. Further details for all emitters are found in [3]. Information on the energy spread of the photoelectron gun can found in [4].

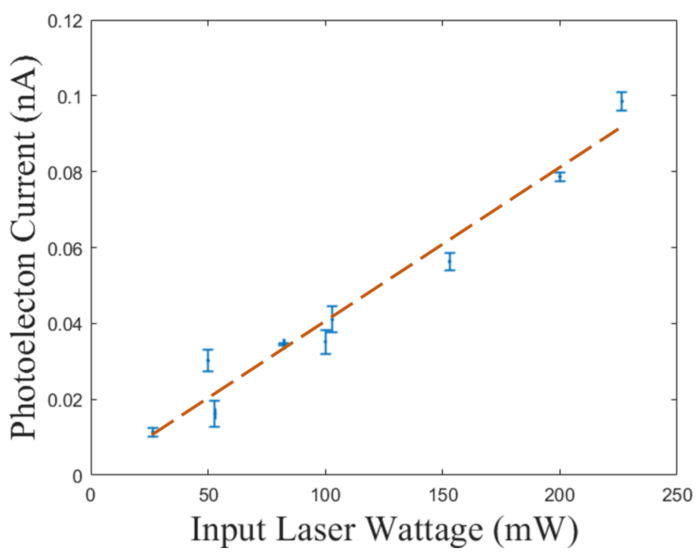

Figure 2. Experimentally measured results from our prototype system of the photoelectron current produced via photoemission from LaB_6 versus the input laser wattage (wavelength = 405nm).

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