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Retrofitting a Photoelectron Source: Improving Resolution & Functionality

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Low voltage transmission electron microscopy (≤80kV) has many applications in imaging 2D materials, which would be damaged at higher voltages. Once spherical aberration has been corrected for in a Transmission Electron Microscope (TEM), chromatic aberration may dominate and limit the ultimate resolution of the microscope [1]. The chromatic (defocus) blur can be reduced by decreasing the energy spread of the primary electrons. This usually involves an upgrade to a lower energy spread electron gun such as a cold FEG ($\Delta E \approx 0.3$eV) or installing an expensive electron monochromator which is not feasible for many global research laboratories [2].

This work proposes to exploit the photoelectric effect, where UV light can stimulate the direct emission of electrons from a material, to develop a low-cost and retrofittable electron gun. By using a laser and a material with an intrinsically narrow and low work function (such as Lanthanum Hexaboride (LaB_6)) the electrons emitted (the photoelectrons) would have near monochromatic energy and be an ideal low energy-spread electron source for an electron microscope. The underlying concept was previously demonstrated by Sawa et. al. where electrons with an energy spread $\Delta E = 0.11$eV were produced [3].

Recent advances in low-cost, compact UV lasers used in blue ray DVD players have made similar UV laser diodes increasingly available and economical, and LaB_6 crystals are already found in many thermionic electron guns. This research capitalizes on these low-cost UV laser diodes, 3D printed components and the photoelectric effect to create a compact, cost-effective photoelectron source that can be retrofitted into current electron microscope technology. Therefore, this source would not only increase low voltage image resolution but produce more precise elemental identification during Electron Energy Loss Spectroscopy (EELS) if deployed in a TEM.

We will present the design and construction of our photoelectron emitter as retrofitted onto an existing LaB_6 thermionic electron gun in a ZEISS EVO Scanning Electron Microscope (SEM) **(Figure 1)**. **Figure 1c)** shows the set up with the laser on, but in operation this is covered by a light-tight enclosure. This retrofitted emitter has successfully produced images using photoelectrons as shown in **Figure 2**. It should be noted that in this experiment the photocathode was warmed to 990K to reduce the rate of potential carbon contamination leading to a small but negligible number of thermionic electrons in the lower half of the image when the laser was turned off. While currently installed in a SEM, it is hoped that this prototype will be the foundation of a photoelectron gun that could have an energy spread three times smaller than present cold FEG systems costing a small fraction of the cost of a monochromator to manufacture. It would therefore be beneficial in opening high resolution microscopy to institutes that would not have been able to previously afford electron monochromator technologies. It is hoped that this approach may also increase the sustainability of existing microscopes, extending their lifetime by increasing their resolution and functionality. [4].

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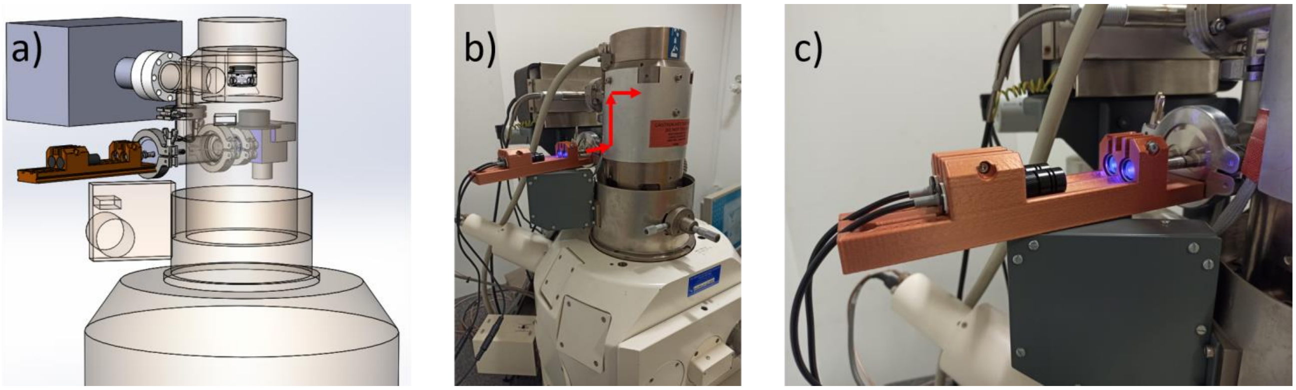

Figure 1. a) A technical drawing of the photoelectron system retrofitted on a Zeiss EVO SEM, b) and c) show the final retrofitted system where a 3D printed holder supports the lasers so that they are directed at the collimators and the vacuum fiber optic feedthroughs that are fed up to the LaB_6 source.

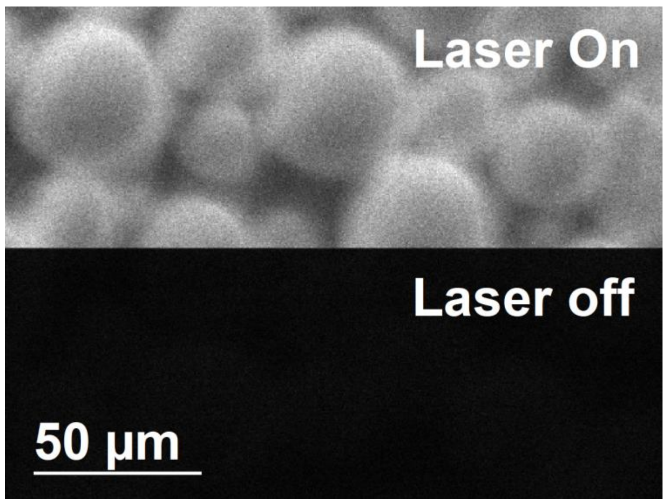

Figure 2. Titanium balls imaged in the SEM using photoelectrons. The top half of the image was taken when the laser was turned on and photoelectrons were emitted from the LaB_6 source. The bottom half of the image was taken when the laser was turned off and only some small instrumental noise is visible. The LaB_6 crystal was at approximately 990K throughout the duration of the experiment to keep the crystal free from contamination.

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