

## CONTROLLED DEGRADATION BY OXYGEN EXPOSURE IN THE PERFORMANCE OF AN AG (100) SINGLE-CRYSTAL PHOTOCATHODE

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The search for high performance photocathode electron sources is a priority in the accelerator science community. The surface characteristics of a photocathode define many important factors of the photoemission including the work function, the intrinsic emittance and the quantum efficiency of the photocathode. These factors in turn define the ultimate electron beam performance which is measurable as normalised emittance, brightness and energy spread [1]. Strategies for improving these parameters vary, but understanding and influencing the relevant cathode surface physics which underpin these attributes is a primary focus for the electron source community [2].

The discovery of metal photocathodes in the 1800s showed two main classes of interest: caesium-coated metals and pure metal, however due to the background pressure required, caesium-coated cathodes were not practical for accelerator structures [3]. While pure metal photocathodes are unable to achieve the same level of quantum efficiency (QE) as semiconductor photocathodes, they are robust and their performance at UV wave-lengths is of interest as there are many machines that use pure metals such as at the LCLS at SLAC and CLARA at Daresbury.

We present performance data for a Ag (100) single-crystal photocathode under illumination at 266 nm wave-length, with known levels of surface roughness, using our Transverse Energy Spread Spectrometer (TESS) [4] both at room and cryogenic temperatures. Crucially our data shows the effect of progressive degradation in the photo-cathode performance as a consequence of exposure to controlled levels of oxygen.

Transverse energy distribution curve (TEDC) measurements were, as described in previous publications [5,6], under illumination at a wavelength of 266 nm, with the cathode biased at -60 V at the source with the grid and MCP front biased at 60V.

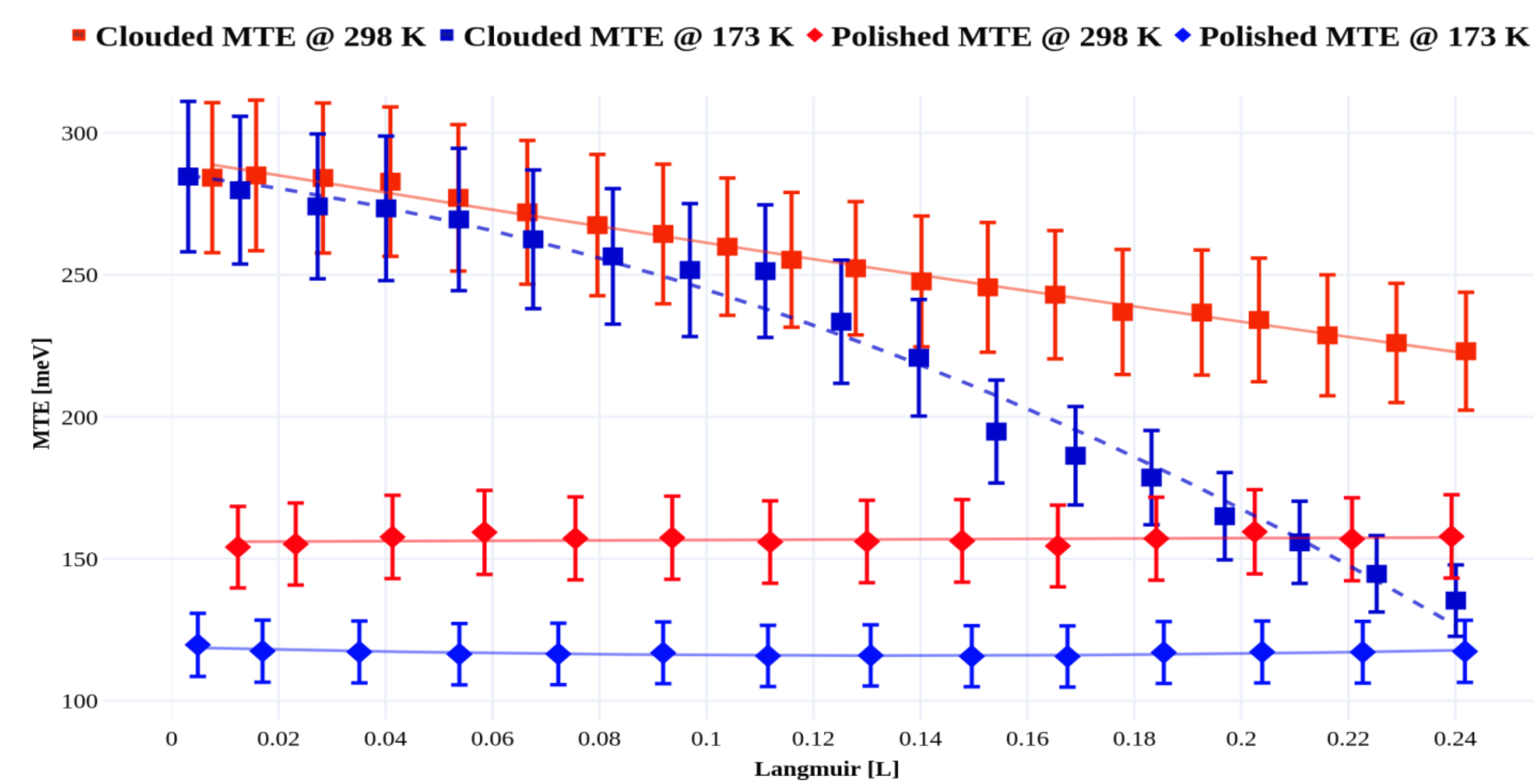


Figure 1: MTE of a Ag (100) cathode under illumination at 266 nm at a temperature of 298 K and 173 K as a function of progressive oxygen exposure, measured in 2 different positions on the sample surface.

Figure 1 shows the MTE data collected on the Ag (100) surface at two positions. The first set of measurements shown in red were taken at 298 K with the absolute pressure of the TESS chamber rising from a base of 2.0E-11 mbar to a maximum pressure of 1.5E-10 mbar during degradation, with the second set of measurements shown in blue taken at a base pressure of 2.3E-11 mbar to a maximum pressure of 1.5E-10 mbar.

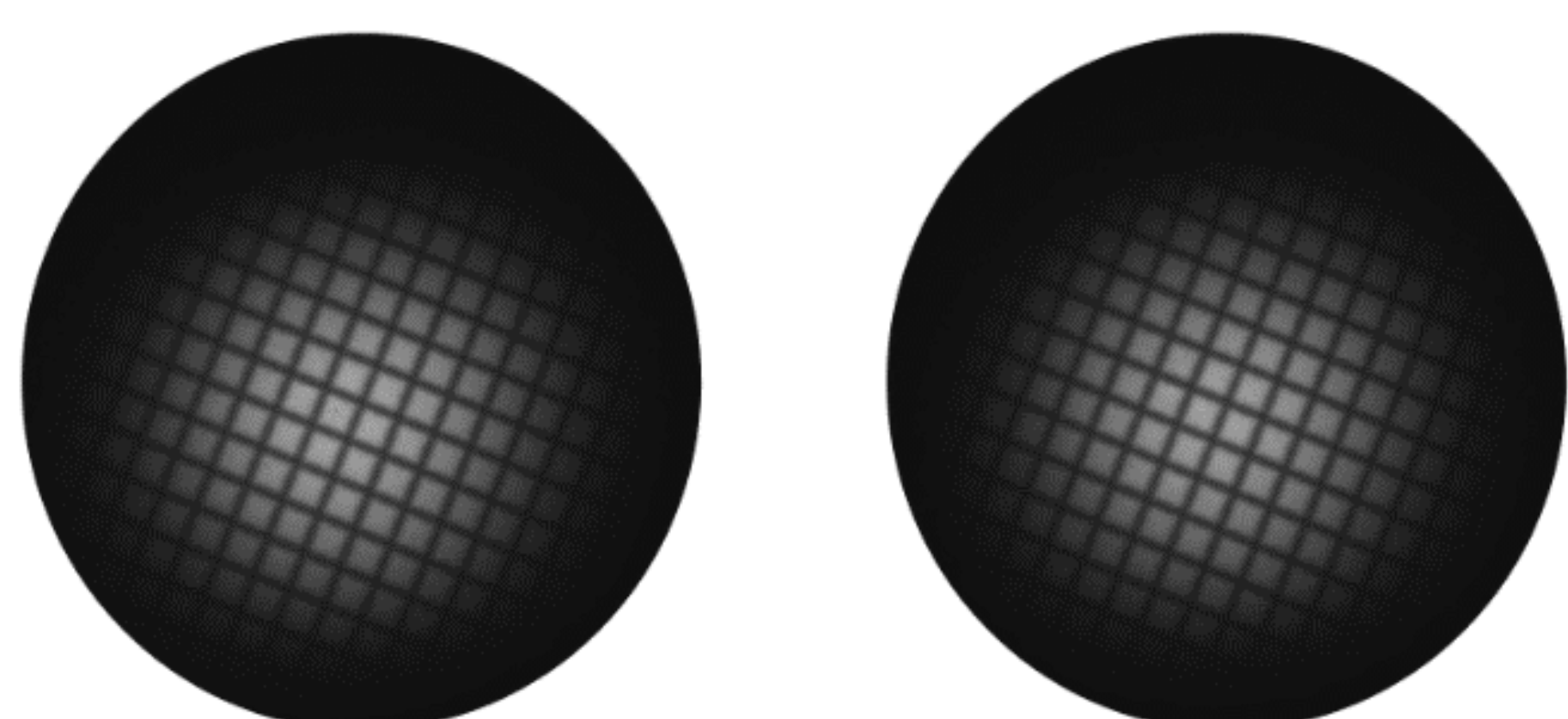


Figure 2: Photoemission footprint of the data image at 298 K before and after oxygen exposure. The images have a total image intensity of 4.96E+8 [au] and 4.65E+8 [au] on the left and right, respectively.

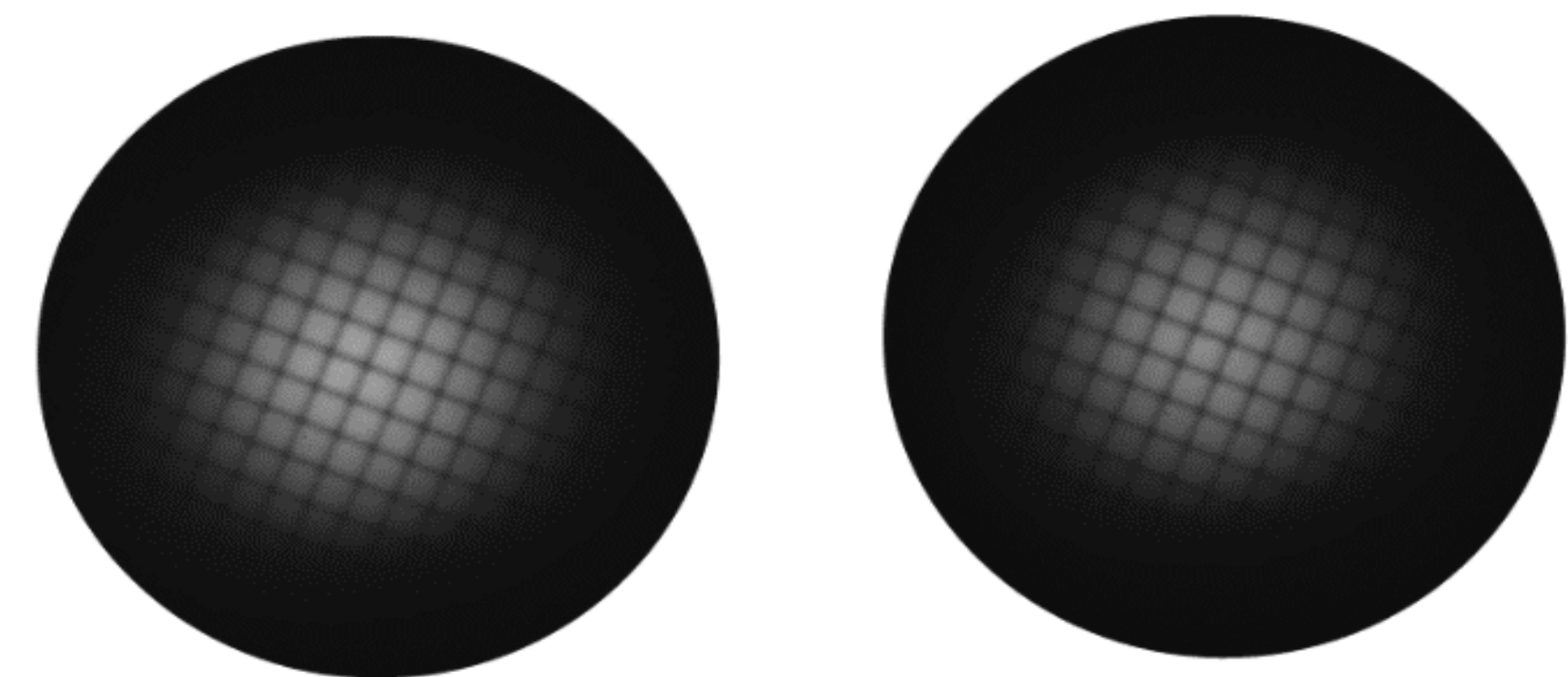


Figure 3: Photoemission footprint of the data image at 173 K before and after oxygen exposure. The images have a total image intensity of 4.87E+8 [au] and 3.69E+8 on the left and right, respectively.

Figure 4 shows very clearly the effect of cooling a photocathode on the QE degradation, where the final integrated intensities of the photoemission footprints at around 0.24 L have a large difference between them. The two positions measured for Figures 1 and 4 show differences in both MTE and QE degradation, this is due to the sample preparation where the 'polished' position maintained its surface finish, and the 'clouded' position was altered due to the sample preparation, showing the robustness of the polished Ag (100) over the clouded surface.

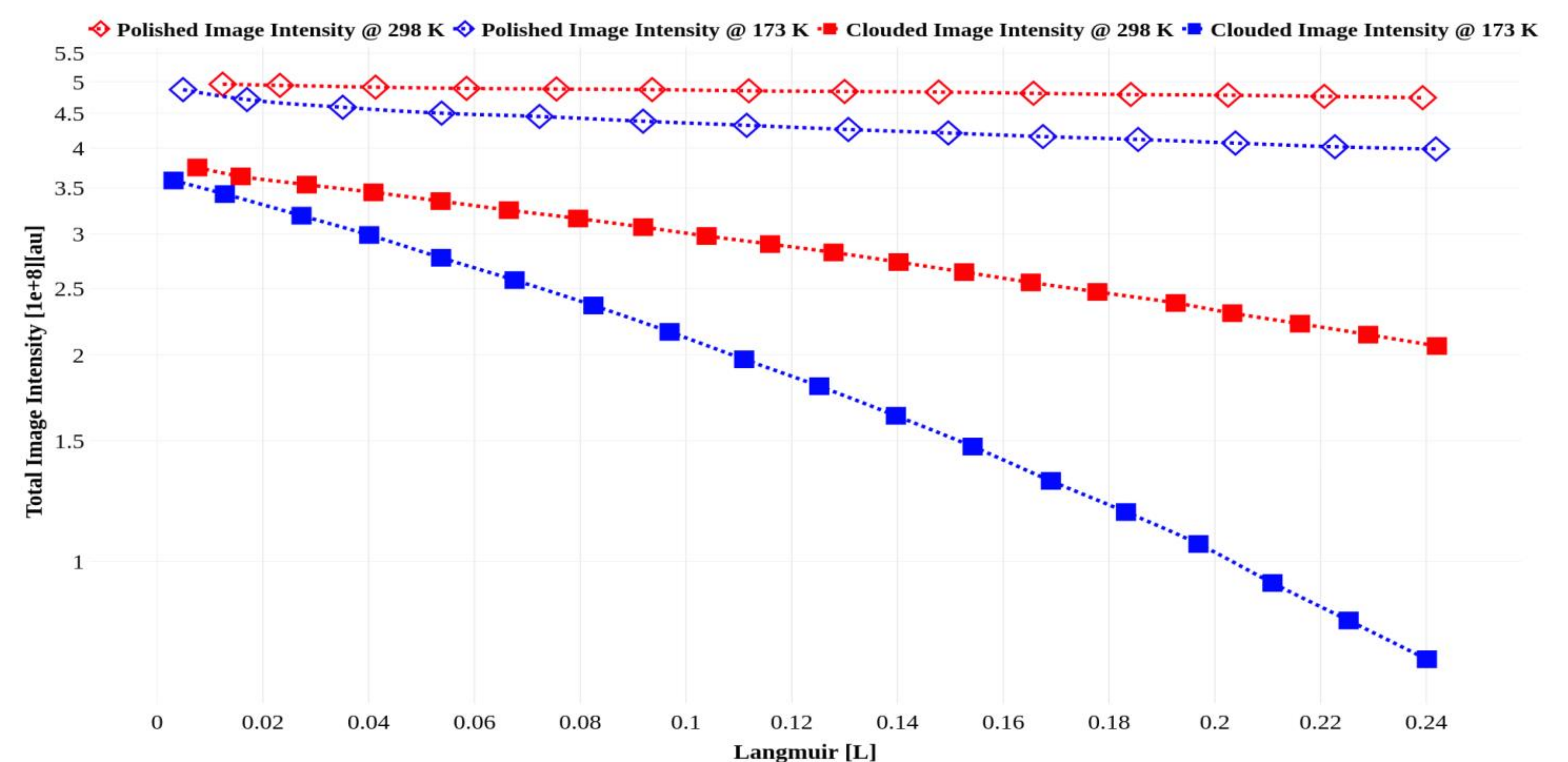


Figure 4: Total image intensity representing the change in quantum efficiency of a Ag (100) cathode under illumination at 266 nm at a temperature of 298 K and 173 K as a function of progressive oxygen exposure in 2 positions.

The main driving force behind the rate of degradation in the cathode presented is the temperature of the cathode surface, which affects the work function and the sticking coefficient for oxygen on the surface. However beyond this, the 'clouded' effect that we saw on the surface of the Ag (100) sample as a result of the sample preparation presents an interesting set of results, as even with surface characterisation stating the surface was clean alongside a clear LEED pattern to show for it, as we saw the MTE increase by almost a factor of 2, and for the QE to be affected a lot more readily by oxygen exposure with an up-to a factor of 8 decrease.

The measurements presented here on the degradation of Ag (100) confirm that the performance of a cathode is affected significantly under controlled degradation simulating exposure to the residual gas found in a vacuum system. Our results show that the QE changes as a function of oxygen exposure. With a total exposure of 0.24 L we witnessed the QE fall by 6.2 % in the room temperature measurements, and by 24.0 % in the cryogenic measurements at the polished position, and at the clouded position we saw a 45.1 % fall in QE at room temperature and an 87.5 % fall in QE at cryogenic temperatures.

### References:

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