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Thermionic Emission from the Advanced LIGO Ring Heaters

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1 Introduction

Advanced LIGO will employ nichrome ring heaters for thermal correction of the radii of curvature of the ETM HR surfaces. This document analyzes the rate of thermionic emission from the ring heater material and the amount of charge deposited onto the ETM as a result.

2 Thermionic emission from metals

Thermionic emission is governed by the Richardson-Dushman Law:

$$J = A^* T^2 \exp\left(-\frac{W}{k_B T}\right)$$

Where J is the thermionic current density in A/m^2, $A^* = 4\pi m k_B^2 e / h^3$ is Richardson's constant, T is the temperature, and W is the work function of the electron source. In practice, the value of A^* is much less than the theoretical value, due to solid-state effects in the emitting material, so the Richardson-Dushman Law gives a reasonable upper bound to the thermionic emission rate.

I have not found data for the work function of nichrome; however, the work functions for both nickel and chromium, the chief components of nichrome, are both about 4.6 eV, which is a typical value for metals.

The ring heater will have an emissive area of approximately .03 m^2, and a temperature of about 400 K, so the net thermionic current is of order I = 10^{-48} A. This is less than one electron per Hubble time. Given the assumptions above, it is extremely unlikely that thermionic emission will cause any charging of the Advanced LIGO test masses.

3 Future studies

There is the possibility that the work function of nichrome is significantly less than the 4.6 eV assumed. If data are available for this parameter this calculation can be refined. Otherwise, if the risk of charging is still deemed significant, a sample ring heater could be operated at much higher temperature in order to generate a measurable thermionic current, and the magnitude of this current vs. temperature could be used to determine the work function of nichrome. Finally, any thermionic current would tend to be collected by the grounded metallic shield around the ring heater, and if needed a small positive potential of the heater relative to the shield could be applied to suppress emission.