GENERATING EFFICIENT INCANDESCENT FILAMENTS WITH STOCHASTIC AND DETERMINISTIC OPTIMIZATION ALGORITHMS

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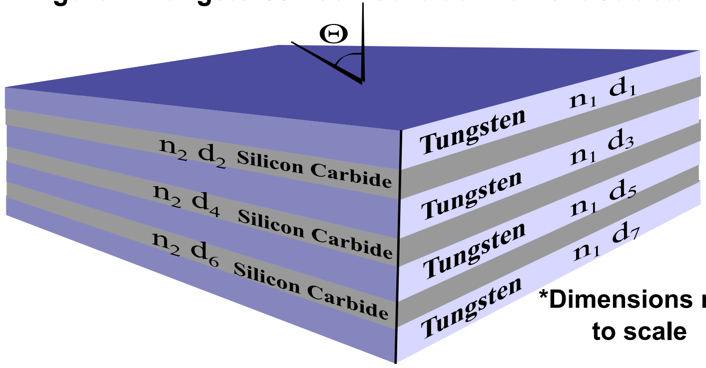
Introduction

Traditional Tungsten Filaments [fig. 3]:
- Used in incandescent bulbs
- Heated by electric current to 2800-3000 K
- Emit primarily infrared electromagnetic radiation

Ideal Improved Filament [fig. 1]:
- Peak emittance over the visible spectrum (390-700 nanometers (nm))
- Peak emittance over most angles from filament surface
- High melting point (over 2800 K)
- Low environmental impact unlike fluorescent bulbs
- Economical compared to Light-Emitting Diodes (LED's)
- Layered Structures: simplifies manufacturing

Figure 1: Tungsten/Silicon Carbide Filament Structure



*Dimensions not to scale

Emittance Calculations

Kirchoff's Law for Thermal Equilibrium[5]:

$$E = A = 1 - R - T$$

- Emittance determined from reflection and transmission coefficients
- *E* is emittance, *A* is absorbance, *R* is reflectance, and *T* is transmittance

The Transfer-Matrix Method[5]:

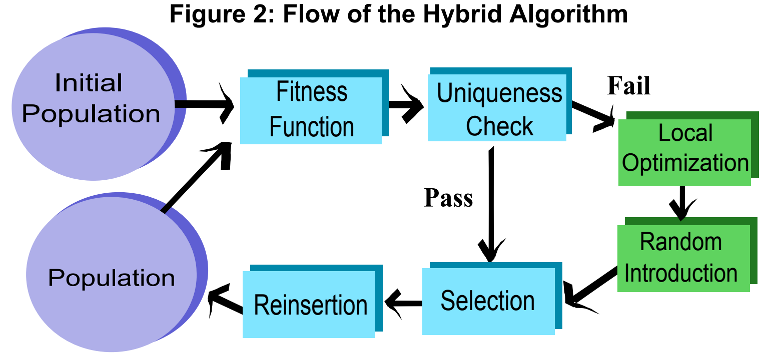
$$M = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix}; \quad R = \frac{1}{|M_{11}|^2}; \quad T = \left|\frac{M_{21}}{M_{11}}\right|^2$$

- Elements of the transfer matrix (*M*) help calculate *R* and *T*
- Transfer matrix found by multiplication of propagation and boundary matrices

Hybrid Optimization Algorithm

The Hybrid Optimization Algorithm [fig. 2]:
- Combines **global** and **local** optimization algorithms
- Optimizes filament-layer dimensions
- Calculates emittance
- **Global** Algorithm: Stochastic Genetic
  1) Initial filaments are generated randomly
  2) Fitness function assigns emittance values
  3) Best structure passes to new generation
  4) Remaining random filament structures are "mated" and also pass to new generation
  5) Repeat 2-4
- **Local** Algorithm: Deterministic
  1) Initiates when population fills with similar filaments
  2) Changes filament layer dimensions directly
  3) Passes best structure to new generation

Figure 2: Flow of the Hybrid Algorithm



Results and Conclusions

Resulting Structure [fig.4]:
- 3-layered tungsten and silicon carbide structure
- 92% emittance over the visible range
- Peak emittance from 400 to 650 nanometers and 0 to 70 degrees
- 1-800 nanometer layer widths

Conclusions:
- Structure can operate at 2900 K
- Tungsten melting point: 3400 K
- Silicon Carbide melting point: 3000 K
- Emission doubled in the visible spectrum compared to traditional filaments

Filament Emittance Plots

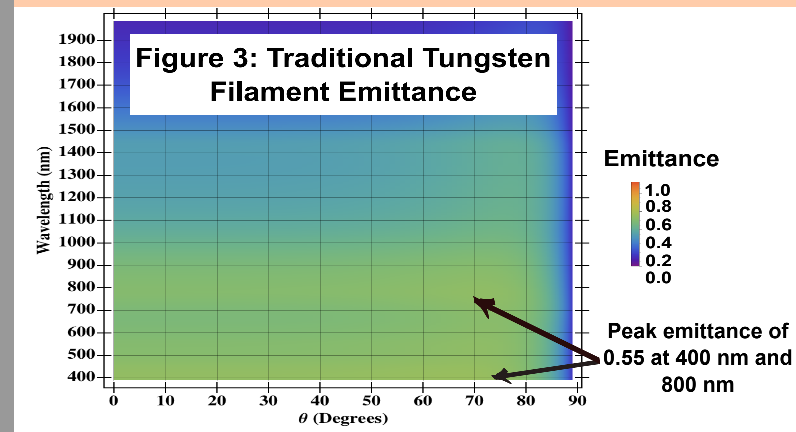


Figure 3: Traditional Tungsten Filament Emittance

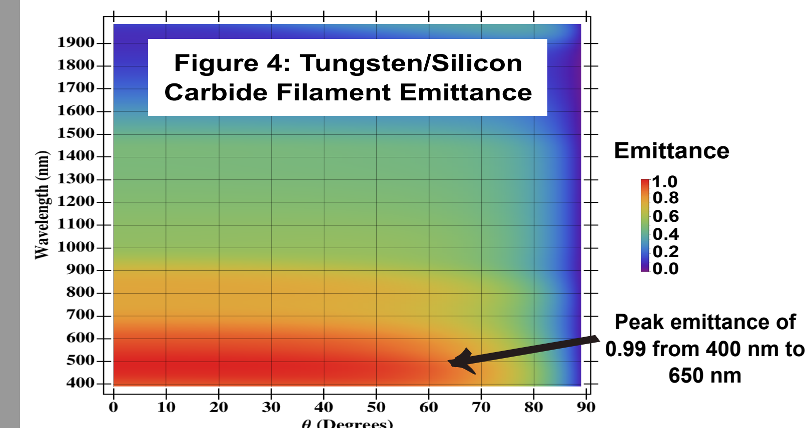


Figure 4: Tungsten/Silicon Carbide Filament Emittance

Future Research

Current/Planned Research:
- Continued optimization of the emitted spectrum
- Rewrite of FORTRAN 77/90 code to C++
- Parallelization of the Transfer-Matrix Method

Institutions/Acknowledgments

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[2] School of Electrical Engineering and Computer Science , Louisiana State University
[3] Center for Computation and Technology (CCT), Louisiana State University
[4] Hearne Institute for Theoretical Physics at Louisiana State University

[5] Cornelius, C.M., Dowling, J. P., 1999, Modification of Plank Blackbody Radiation by Photonic Band-gap Structures, Physical Review A, v.59, p.4736-4746.

-This material is based upon work supported by the National Science Foundation (NSF) #OCI-1263236 and #OCI-1254934