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Abstract
During this project the first task was to gain a basic understanding of the experimental set-up used for electron shadow-imaging and deflectionmetry, and the two-temperature model (TTM). Gradually, a C++ program which would be able to calculate heat transfer described by the model for the case of a thin gold film was developed. This was done in several steps including: the creation of a program based on a simplified version of TTM, refining to a second more realistic version, revising the program again to increase precision of the calculation. Currently, there is no experimental evidence regarding TTM for sample temperature near and above one eV, only inferential data and theoretical work.

Background: Laser Pump and Probe
A high-powered laser passes through a beam splitter. One line of the light, containing 90% of the laser’s power, called the pump line is directed to an ultra-high vacuum (UHV) chamber where it is incident normally upon the front surface of a sample. The other beam, the remaining 10% of the laser’s power, called the probe line (is frequency tripled and converted to an electron pulse via a photomultiplier tube in the UHV (electron gun)) this stream of electrons then passes parallel to the sample surface (perpendicular to the pump line). The pump line rapidly heats the sample, causing electrons to jump off the surface into the plasma. These electron-shadow images are converted to light images by way of a phosphor screen. The images are intensified before being recorded by a CCD camera.

Simulating TTM: Writing a C++ Routine
In writing the code to simulate TTM, the first step was to create a C++ program which could perform a simplified version of the calculation which does not account for the laser heat source (S, t) or for electron transport (neglected because the film is so thin). Quantitatively, the functions describing the temperatures of the electrons and the lattice are as follows:

In this simplified case where the power of the laser is relatively low, G is the electron-phonon coupling ‘constant’ (approximately constant and equal to 3x10^6 W/m²K²). C is the specific heat of the lattice and equals 3.5x10^7 J/m²K. The parameter t is simply the time. The specific heat of the electrons, C_e, depends upon T_e, such that:

\[ C_e = G T_e \]

Where G is a constant equal to 7.5x10⁶ K².

The two functions were used in conjunction with Euler’s equations in order to calculate the temperatures of electrons and lattice over time given some smaller time interval h (in this case h=5s). Euler’s equations follow:

\[ \begin{align*}
\frac{Y_{e+1}}{Y_{e}} &= \frac{Y_{T_{e+1}}}{Y_{T_{e}}} = \exp \left( -\frac{-2\pi \psi}{h} t \right) \\
\end{align*} \]

The final step in writing the program was to consider that the electron-phonon coupling ‘constant’ is not in fact a constant at higher laser power and therefore higher temperatures. Therefore, data from the University of Virginia regarding this value (G) and also the value of C_e, which does not follow the simple proportion (shown above) at higher temperatures, with respect to temperature was saved in two files. Gnpulot generated graphs of these data are shown.

The program utilizes the initial electron temperature and converts it to an index in order to look-up these two values. Originally, if no exact value was found, a linear interpolation method between the two closest points was assumed. Later, this method was exchanged for a Hermite cubic-spline interpolation which is a more precise estimate of the two desired parameters G and C_e. The next two values of T_e and T_l are then calculated using Euler’s equations and the process is repeated until a given maximum time is reached. The final expressions for the functions f and g used in the program follow (next column).

The following shows the final C++ script of Euler’s equations used for calculating the temperatures of electrons and lattice respectively.

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\[ f(t, T_e, T_l) = \left( \frac{T_e}{T_l} \right)^{\frac{1}{2}} \exp \left( -\frac{-2\pi \psi}{h} t \right) \]

Finally, I would like to thank Dr. Blessing and my peers and friends in the Women in Math Science and Engineering (WIMSE) group at Florida State University.

References

Acknowledgements
I would like to thank my mentoring professor, Jim Cao as well as his group members Jun Zhou and Dong Li, and the RET participant, Marci Savoy, who I worked alongside. Credit and great thanks to Ryan Laem for the Hermite cubic-spline interpolation routine. Thanks to Jose Sanchez and the Center for Integrating Research and Learning (CIRL), and to the National Science Foundation (NSF). This program is paid for by NSF Grant DMR-0654118. Finally, I would like to thank Dr. Blessing and my peers and friends in the Women in Math Science and Engineering (WIMSE) group at Florida State University.