Plasma Energy Measurement with an Open-Cell Metal Foam

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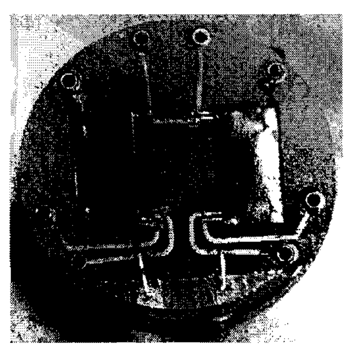
Abstract:

Metal foams were researched to possibly replace current tantalum calorimeter foils. Different foam properties were characterized using SEM scans and spectrophotometer readings. Fluffy gold was also developed to possibly be coated on current foils or foams to improve UV absorption and reflectance properties. Fluffy gold samples were also characterized using SEM scans and spectrophotometer readings.

Performing routine maintenance of the plasma calorimeters in the OMEGA laser system can often be a tedious task. A new mounting system for the window assembly utilizing magnets was developed. The use of magnets allows for the calorimeter window to easily be aligned to the calorimeter foils and reinstalled in the OMEGA target chamber. Ultra bright LED's which produced 5,500 mcd each were interfaced with Labview computer software to bench test the calorimeter system. This allows for a complete test of a calorimeter before installation.

Introduction to Plasma Calorimeters:



The plasma calorimeters used in OMEGA serve the main function of recording how much plasma energy is expelled during the irradiation phase of laser fusion. The calorimeter uses two 25 μm thick Tantalum foils to absorb energy. One foil is exposed to all energy while the other is only exposed to light, this allows for plasma energy to be determined (all energy – light energy = plasma energy). A small Quartz window that transmits only light energy is placed in front of one of the foils. A small reference pad is unexposed to any energy and is used as a zero temperature reference for data collection.

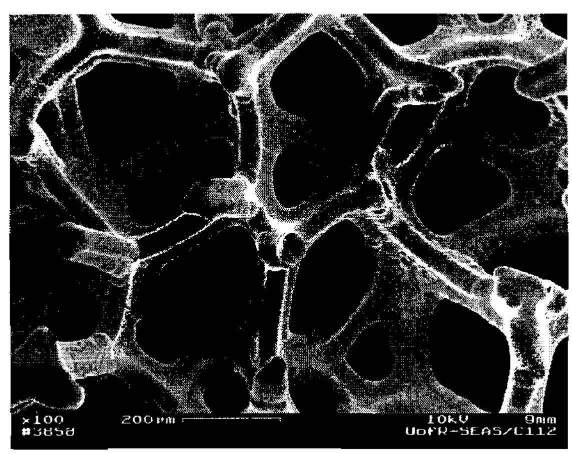
When energy is absorbed into the calorimeter foils they heat up. This change in temperature is read by small thermocouples located at different points on the foils and reference pad. Very sensitive and precise thermocouples are used so small changes in heat intensity over small amounts of time can be read and analyzed.

The main physical property that we were interested in improving was the reflectance characteristics of the Tantalum foils on the calorimeters. The metal foam would theoretically have a much lower reflectance than the tantalum foil, thus decreasing the sensitivity of the measurement to scattered laser radiation. Each tantalum foil reflects a unique amount of energy (depending on the amount of imperfections on the foil itself), the less energy that is reflected means more energy gets absorbed into the foil and read.

Foam Absorber Testing:

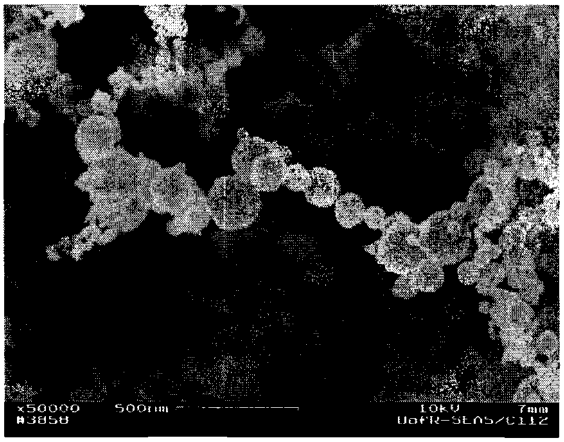
One aspect of my work was testing different foam materials to possibly replace the current tantalum foils on the calorimeters. Two instruments were used to determine characteristics of metal foams and Au smoke (fluffy gold). A scanning electron microscope (SEM) was used to investigate the structures of the materials, as well as take different size dimensions of the pores on the metal foam and the spherical diameters of the fluffy gold. A Spectrophotometer was used to test reflectance as well as transmission properties of the materials.

Nickel foam with 100 pores per inch (PPI) was tested to replace the Ta foils with metal foam. At 350 nm the foam had a reflectance of 9.8%, about half of the original Ta foil. One of the worries with a open cell foam would be that a large amount of light would simply pass through the foam. Spectrophotometer scans showed that only 0.15% of light passed through the foam at 350 nm. The image to the right shows the SEM scan of

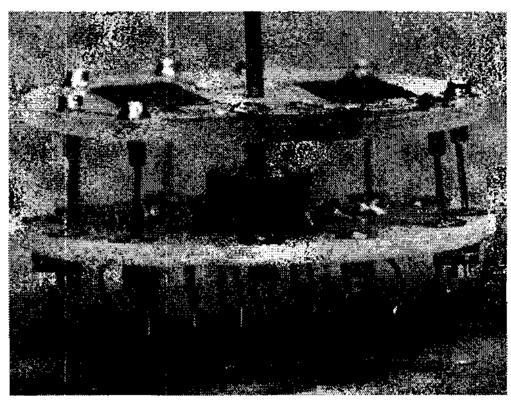


nickel foam. The foam had very large pores with diameters between 450 to 500 μm. The structure of the foam was uniform over the whole surface.

Fluffy gold showed the lowest reflectance of all measured materials. Fluffy gold was made in house, and intended as a coating for the current Ta foils or alternate metal foams to improve reflectance characteristics. Fluffy gold excelled in the area of reflectance, with only 2.5% of light reflected at 350 nm. SEM scans showed an interesting spherical shape to the deposited fluffy gold. The photo on the left was also taken with the SEM and shows the ultra-small spheres with diameters ranging from approximately 250 nm to 25 nm. The downside to the fluffy gold was how easy it was to remove from the surface it was deposited on. It was agreed that the fragile material would not fare well in OMEGA bay conditions, due to the fact that simple handling of the foam would remove it from its surface.



Calorimeter Window Mount Redesign:



The amount of time a scientist or technician spends in the laser bay is crucial. The less time spent adjusting instruments means the less time that the laser system could get contaminated. One issue with the plasma calorimeters that had to be remedied was the way that the UV window was attached to the target bay mount. The current mount uses tiny pins to line up and hold in the window mount. These pins (shown in photograph above) are also used to hold the calorimeter to the base. The main issue, besides tedious removal and installation, was the amount that dimensions could vary. The distance from the UV window to the calorimeter face could vary as much as 0.2 inches.

After investigating several different designs, I decided that the use of magnets would be the best solution. Small high intensity magnets replaced the pins and showed excellent results. The magnets eliminated the ability for the window to calorimeter distance to vary. The magnets also snapped the window into proper orientation, and due to the fact that three magnets were used, the window could only be placed one way. Time spent installing the window assembly to the calorimeter was greatly reduced. One thing that still needs to be investigated with the use of the magnets is stray magnetic fields that might be leaking into the bay.

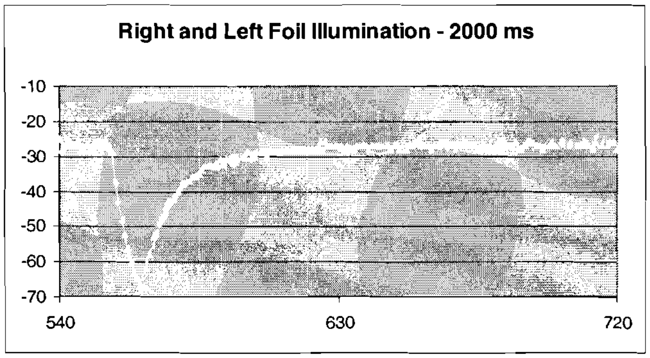
Ultra-bright LED Lab Testing System

The LED testing system was developed to recreate OMEGA style data collection curves on the calorimeters to ensure proper working order of a complete system while still in a lab setting. This would allow one to double check the calorimeters instead of having to install them in the laser bay and then find out they are not functioning correctly. Labview programs were developed along with electrical hardware to create accurate pulse widths and frequencies. Pulse widths and frequencies could be varied to test different data curves. A 4 LED array was set up so each foil could be tested independently (2 LED's per foil) or both at the same time. This would allow inconsistencies between foils to be found and compensated for. The LED's used are rated at 5,500 mcd each and are the first to be able to recreate an OMEGA style data curve.

Two electronic boxes were created to control the LED's. One was specifically designed to help the LED's interface with the computer, using an FET to trip a nine volt power source and light the LED's. This unit needed to be build due to the fact that the power output from the Labview interface was too low to light the LED's at full power. Another box was also created to switch between the LED's in the 4 LED array. It used two switches set up as an OR gate to chose between LED's.

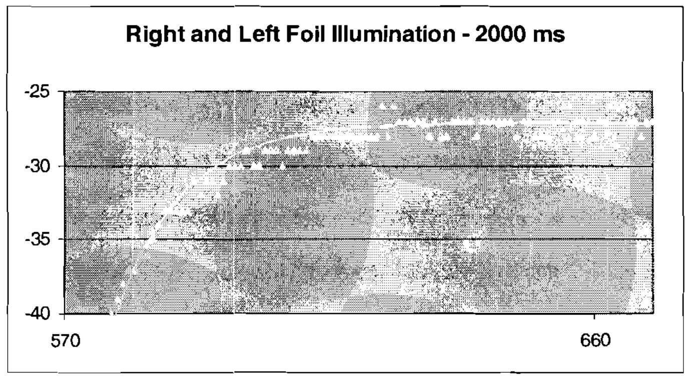
Data Modeling:

The calorimeter foil is modeled as a capacitor to better understand data. When the test data was collected in the Labview programs, it often had many inconsistencies due to equipment limitations. Modeling data curves allows them to be smoothed using mathematical equations. The equation also determines many variables so



the data can also be checked for consistency and accuracy. These models were created in Microsoft Excel.

The graph to the left shows a typical data output graphed in Microsoft Excel. The triangular dots are actual data points and the line is the mathematical model. The rising slope of the graph indicates the calorimeter foils "charging" with energy, while the decay of the slope shows the foils "releasing" the energy as they are no longer exposed to light. The foils charge and release energy much like that of a capacitor, and that is why we model it as such. The graph to the right better depicts how the mathematical formula "averages" data to give a smoother curve.



Conclusion:

The use of magnets to hold in the calorimeter window assembly proved to make removing and reassembling the calorimeter housing a lot easier. Microcellular metal foams are a better alternative to the current tantalum foils. Laboratory testing the calorimeters using ultrabright LED's created curves much like those seen in OMEGA. A capacitor model was used to average out data collected from laboratory testing as well as determine different variables to ensure test accuracy.