

Heat Transfer for Thermal Properties

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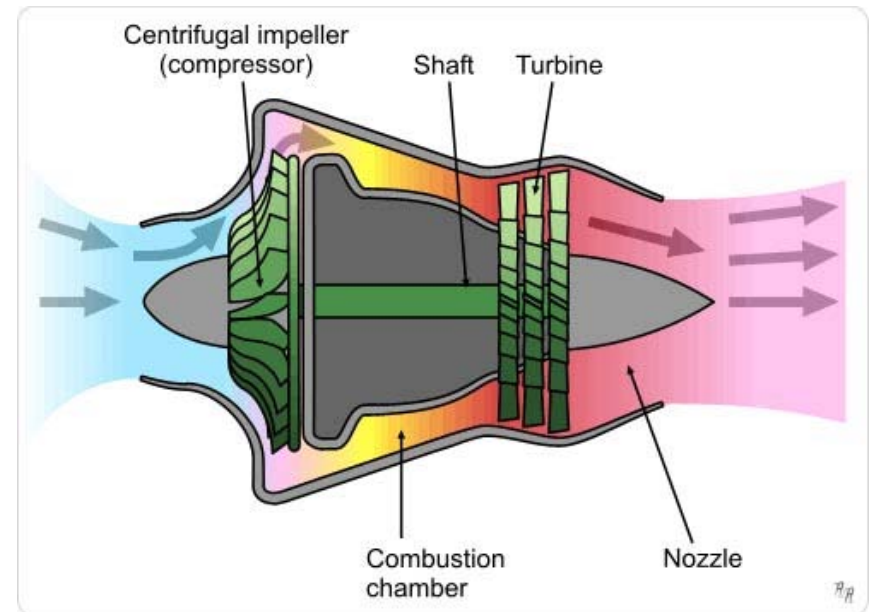
The Problem

Power Plant



Nd.edu

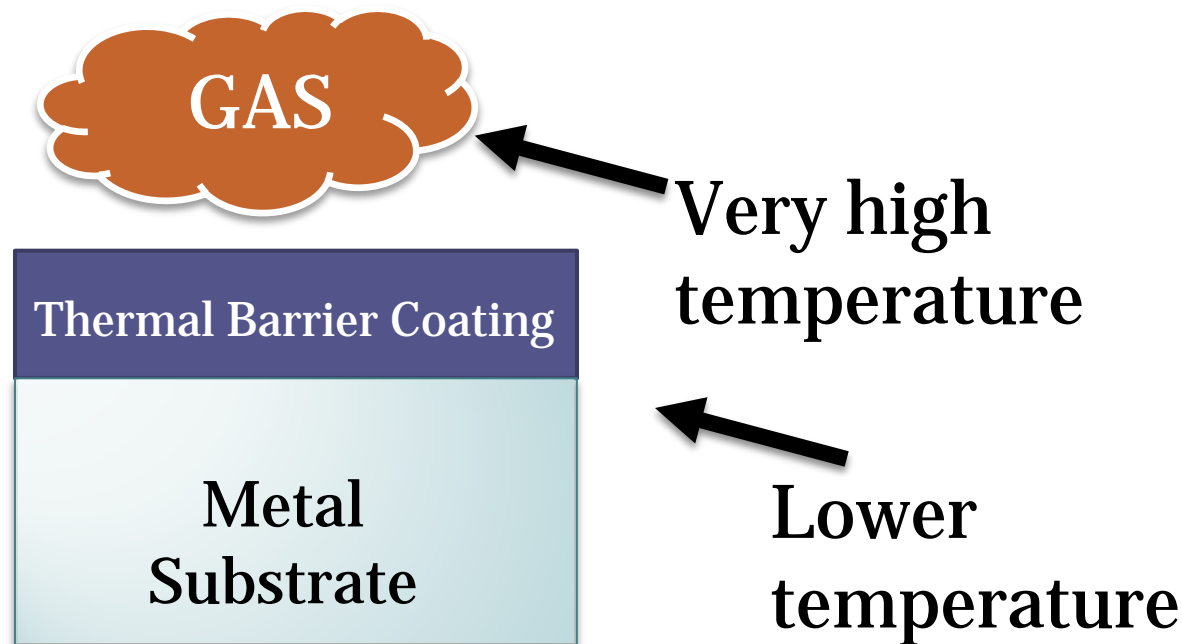
Jet Engine



hubpages.com

Solution: Thermal Barrier Coatings

- Protect components **in high temperature environments** from thermal damage, increasing efficiency



Challenges with Thermal Barrier Coatings

The image illustrates various challenges associated with Thermal Barrier Coatings (TBCs) through a series of micrographs and a photograph of a coated component.

- Foreign material:** A cross-sectional SEM image shows a dark, porous TBC layer on a substrate. A white oval highlights a region containing dark, irregular particles, labeled "Foreign material".
- Cracks:** A white oval highlights a network of fine, dark lines within the TBC layer, labeled "Cracks".
- Depth gradation:** A blue trapezoidal shape on the left indicates a change in material properties or structure across the thickness of the coating.
- microstructure coarsening:** A vertical arrow on the left points upwards, indicating the evolution of the microstructure from the substrate towards the surface.
- Delamination:** A cross-sectional SEM image shows a clear gap between the TBC layer and the substrate, labeled "Delamination". A scale bar of 150 μm is visible.
- Sintering:** A cross-sectional SEM image shows a dense, crystalline structure with large grains, labeled "Sintering". A scale bar of 33 μm is visible.
- Geometry:** A photograph of a rectangular, light-colored TBC-coated component, labeled "Geometry", showing the overall shape and the location of the coating.

Our Goals

- Gain familiarity with heat transfer equations to better understand Thermal Barrier Coatings
- Determine the thermal conductivity of:
 - Brass
 - Aluminum
 - Steel

Heat Transfer Equation: Fourier's Law

$$q'' = -k \frac{\Delta T}{\Delta x}$$



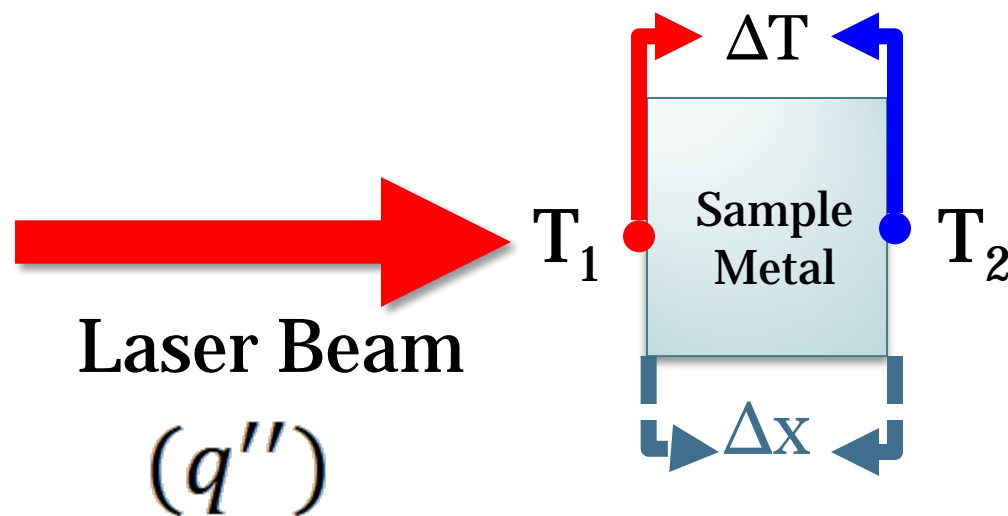
Heat Flux Rate

Thermal Conductivity

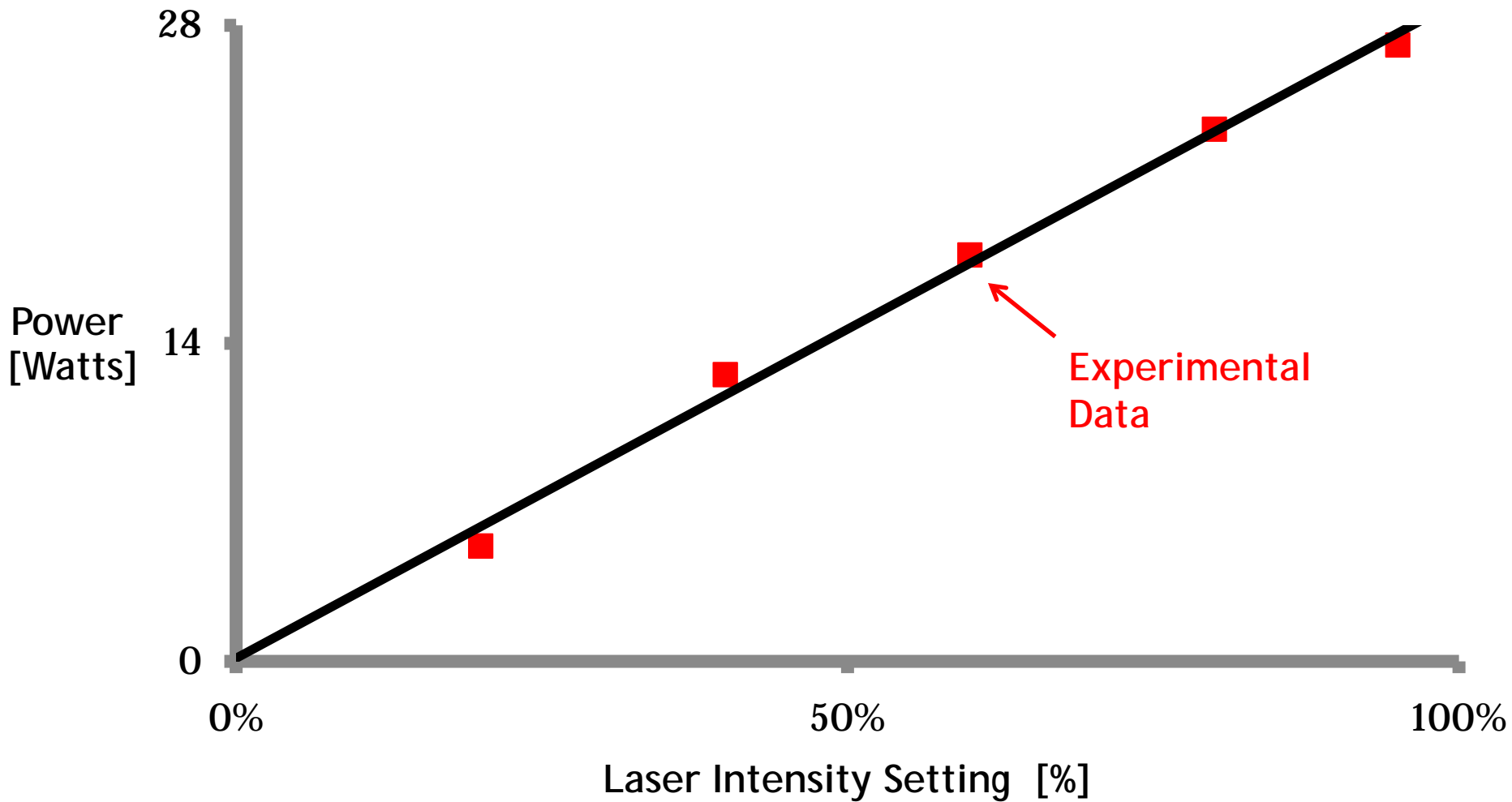
Temperature
Gradient

Determining thermal conductivity

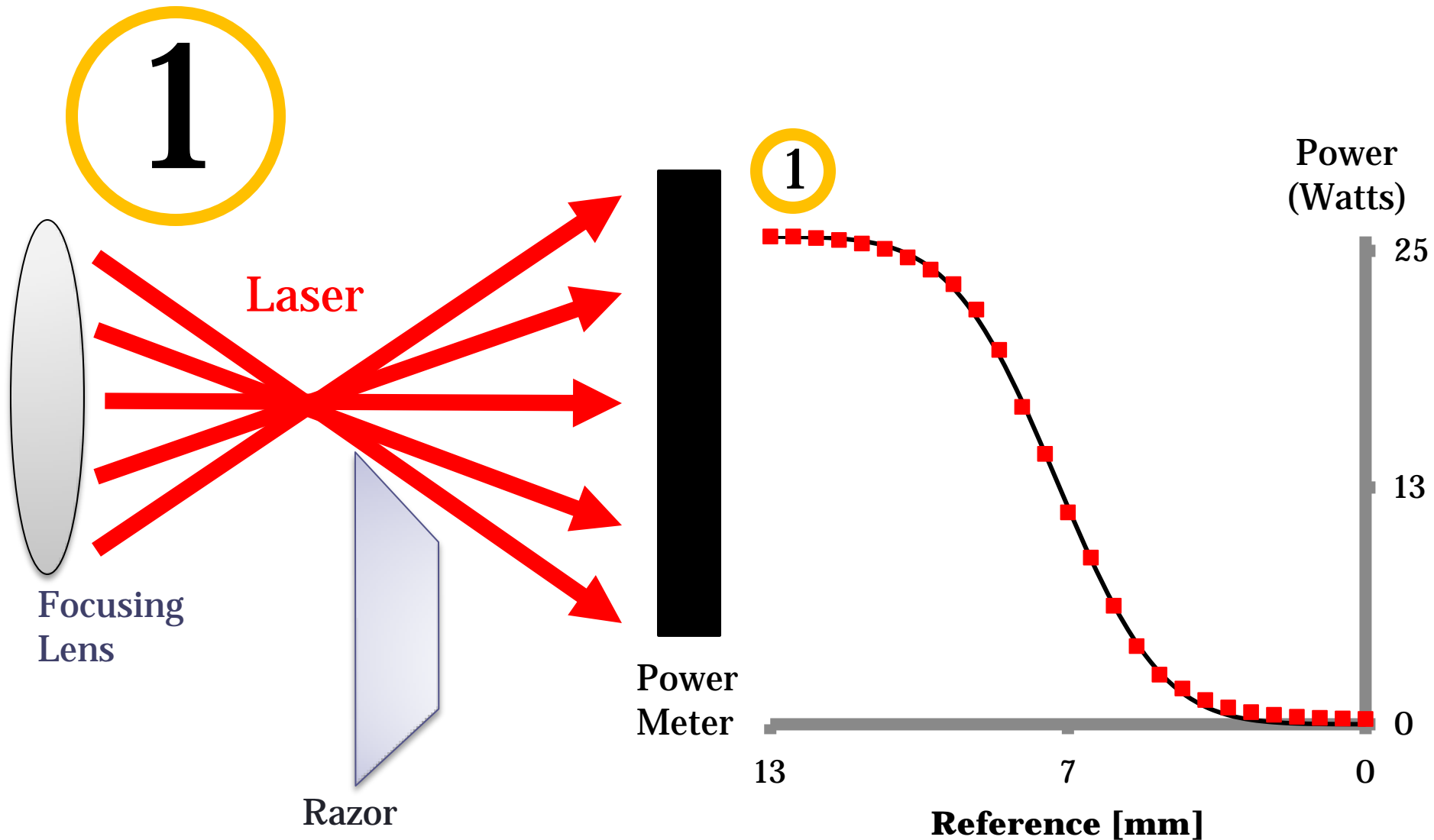
$$q'' = -k \frac{\Delta T}{\Delta x} \quad \longrightarrow \quad k = -q'' / \left(\frac{\Delta T}{\Delta x} \right)$$



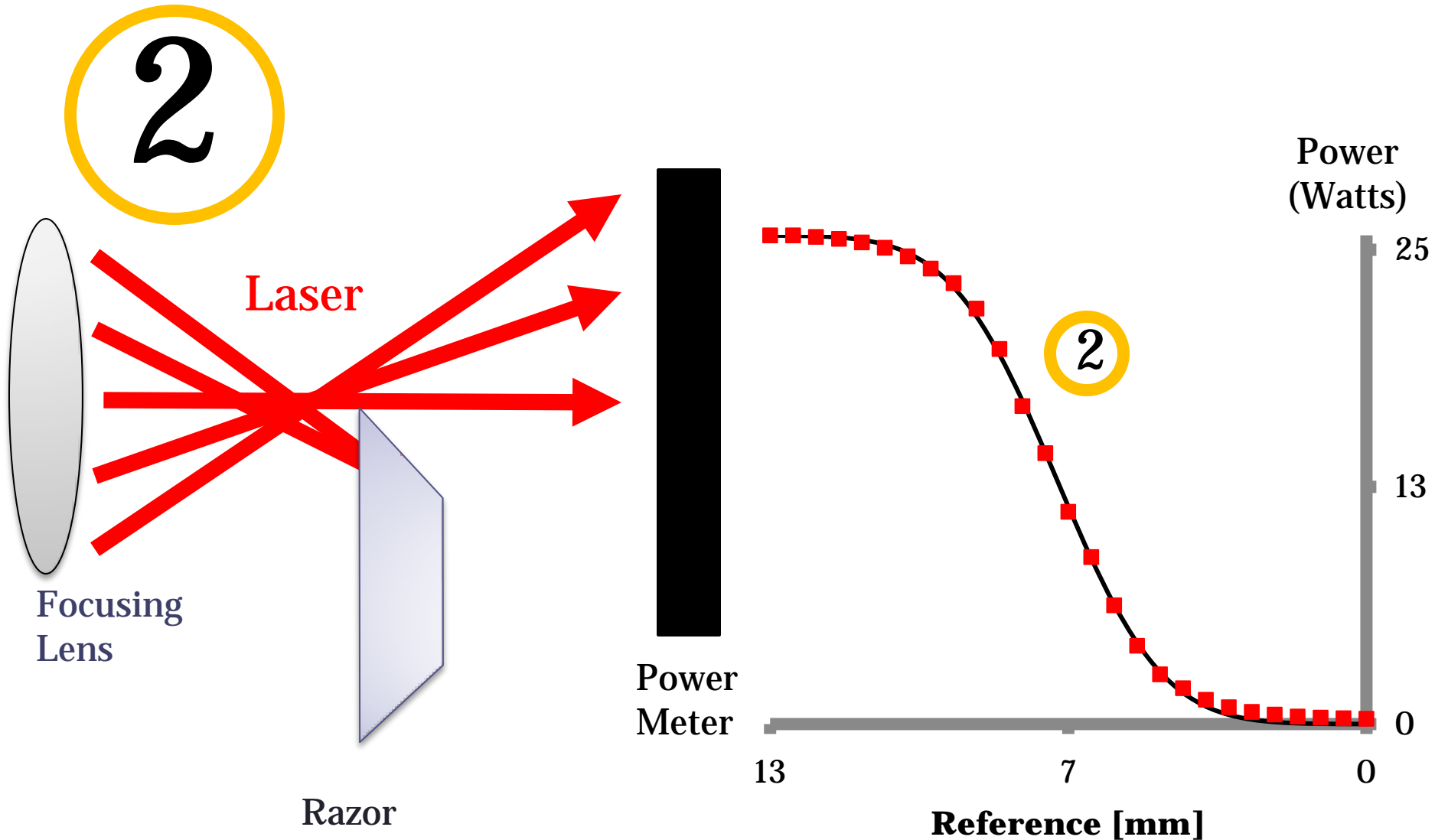
Laser Power vs. Intensity Setting



Laser Beam Characterization (q'')

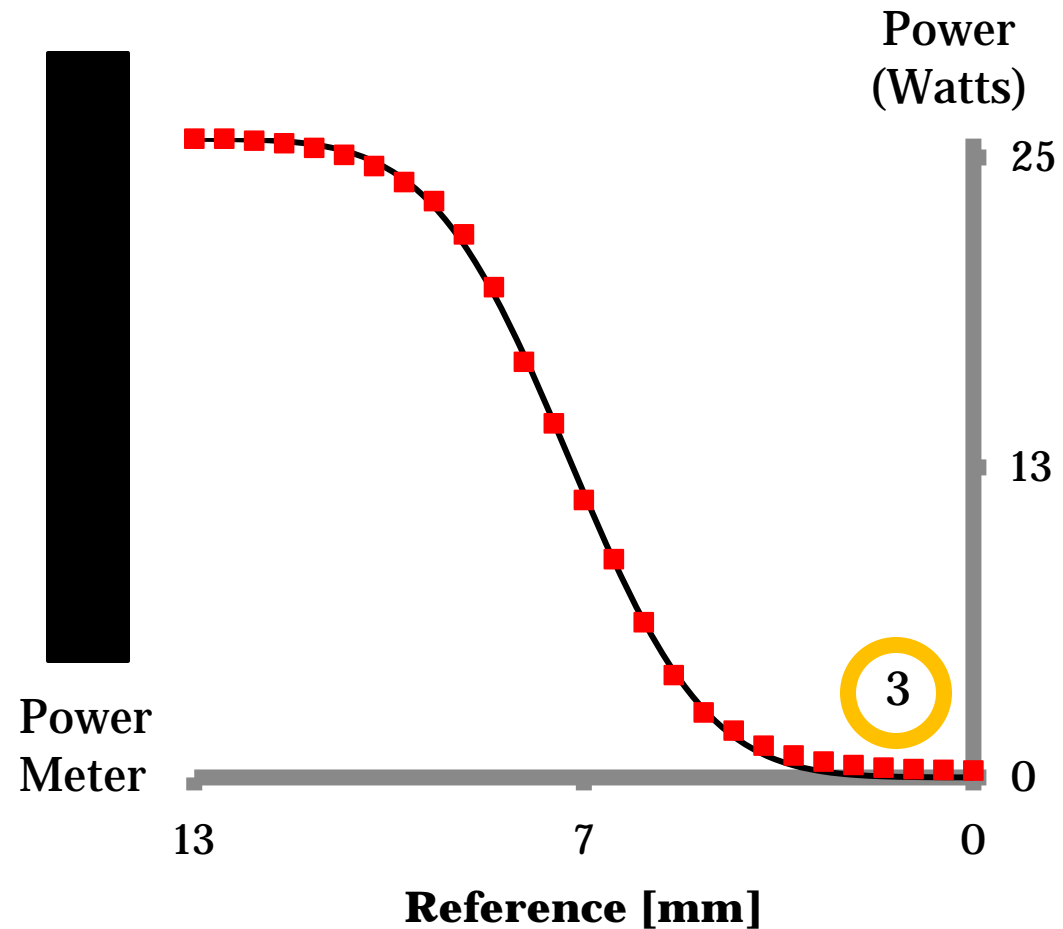
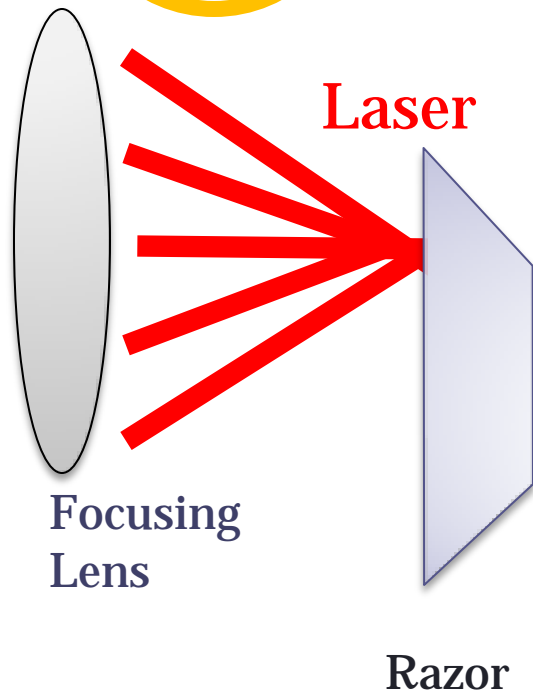


Laser Beam Characterization (q'')



Laser Beam Characterization (q'')

3

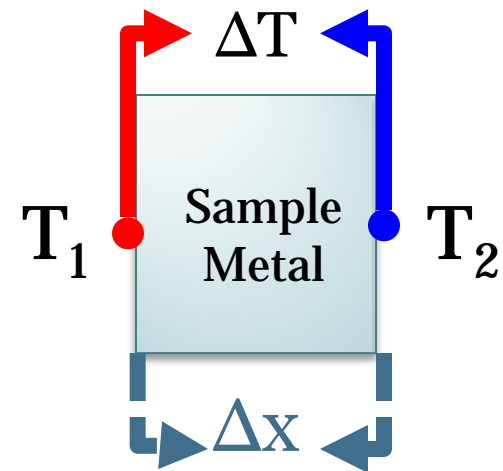


Determining Heat Flux Rate

$$k = \frac{-q''}{\left(\frac{\Delta T}{\Delta x}\right)}$$

Surface Area: 20.5 mm²

$$q'' = 1257 \text{ kW/m}^2$$



Results

Aluminum

$k = 191 \text{ W / m K}$

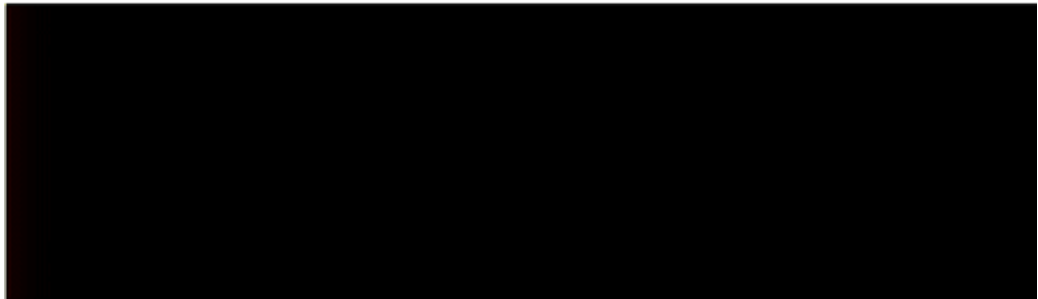
% Error = 18%



Brass

$k = 121 \text{ W / m K}$

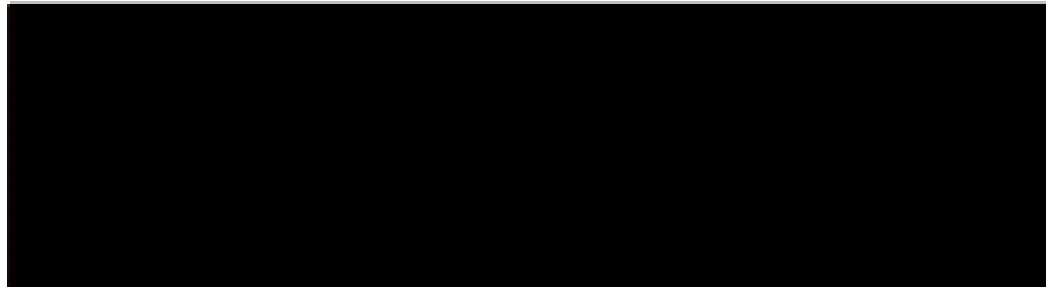
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Steel

$k = 43 \text{ W / m K}$

% Error = 65%



What We Learned

- **Thermal barrier coatings & their importance**
- **Fourier's Law & Its Implementation**

A Special Thank You To...

- Raymond Valdes
- Ted Bennet
- SIMS Staff & the RA's

