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Managing Thermal Emission: Subwavelength Diffractive Optics Technology in Support of SOF

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NNSA National Nuclear Security Administration

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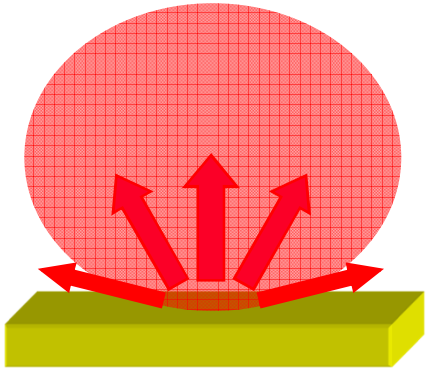
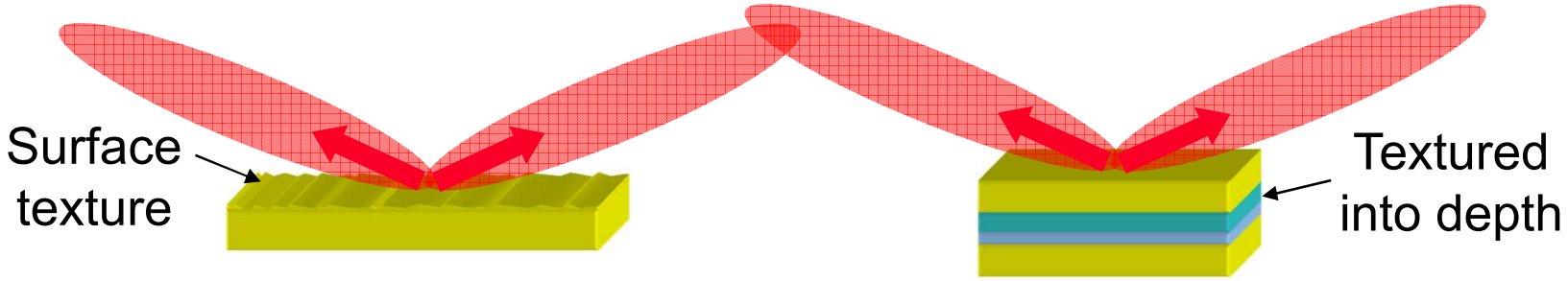
Coherent Thermal Emission Through Photonics/Plasmonics

A uniform surface has emission that is Lambertian: light is emitted in all directions



Adding texture to a surface can lead to coherent, and consequently, directed emission with wavelength selectivity



Combination of the two effects is currently unexplored

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Why Do Sandia National Laboratories Care?

Applications:

- Thermal emission mitigation
- Microsystem passive heat sinking/sourcing management

New science:

- Quantify and Optimize Plasmon/Photon coupling through materials and configurations
- Capitalize on emerging technology through Sandia's world-class fabrication facility and numerical capabilities

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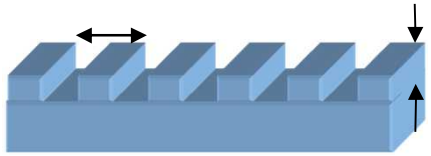
Hypothesis

Coherent thermal emission can occur if we have at least these two conditions:

- A material can support a surface-plasmon polariton (for metals) or a surface-phonon polariton excitation (for polar materials).
- There is a mechanism (a grating) to couple the surface plasmons to photons.

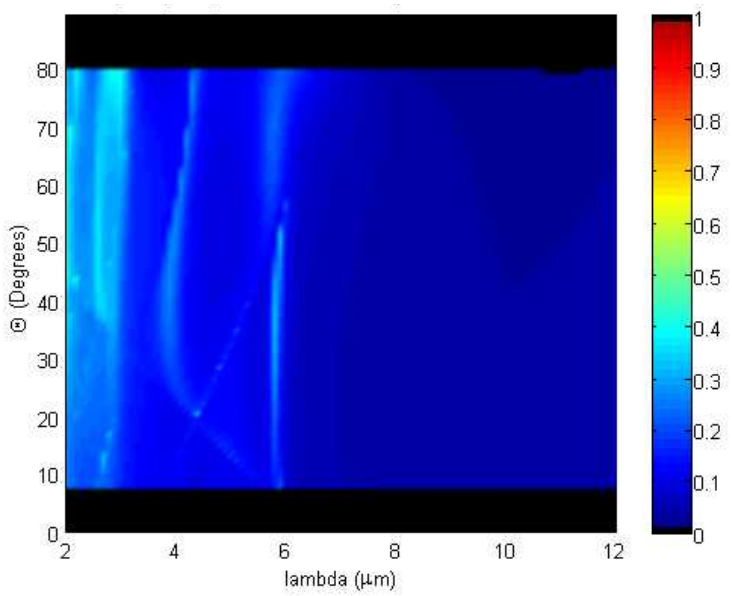


Process

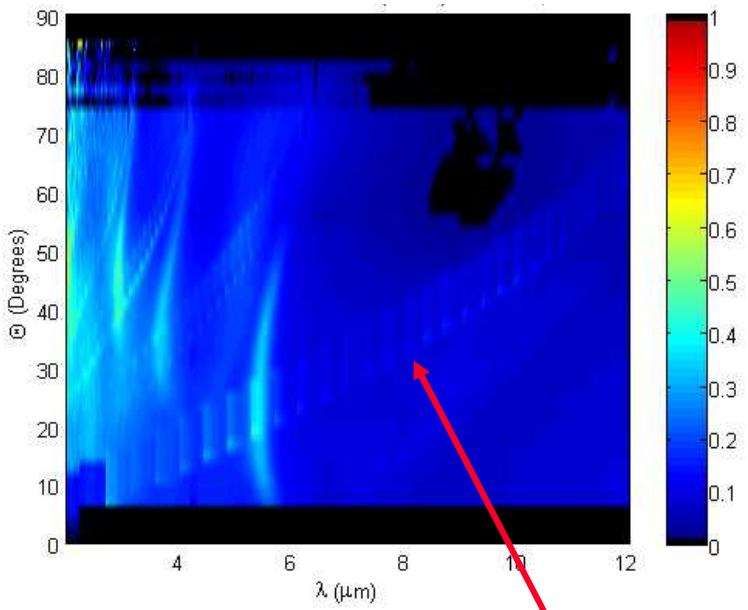
1. Thermal energy excites plasmons in the applied materials.
2. A grating in the material provides a phased-coupling mechanism between the plasmons and emitted photons
3. The grating parameters determine the angular and wavelength "shape" of emission.

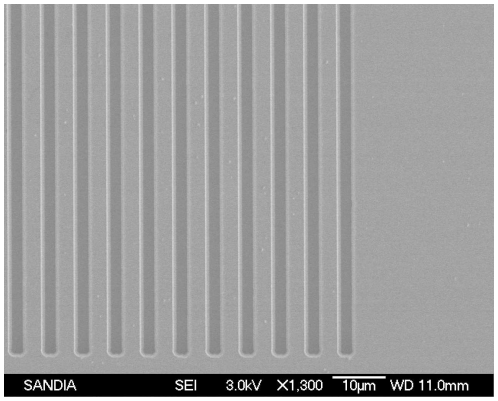
Simulation and Measurement : Nickel with Grating

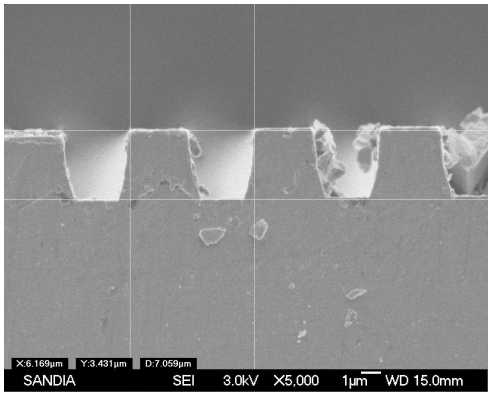
Simulation : 1 – Total Reflection



Measurement =1 – Total Reflection







Note: blurred measurement artifact

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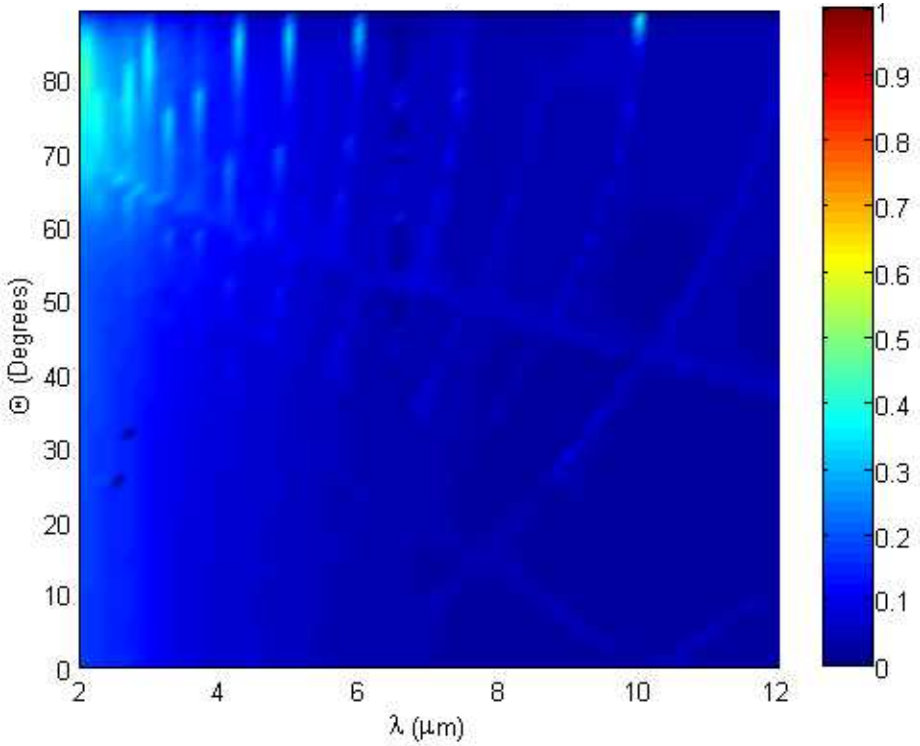
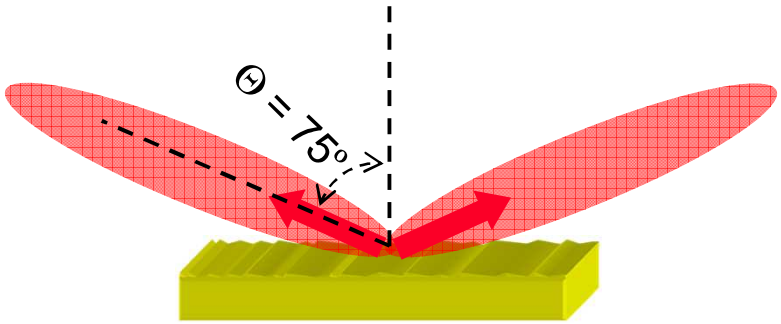
Next Component:
Nearly Planar, High-Angle Emission

Simulation of Λ=30μm on Ni





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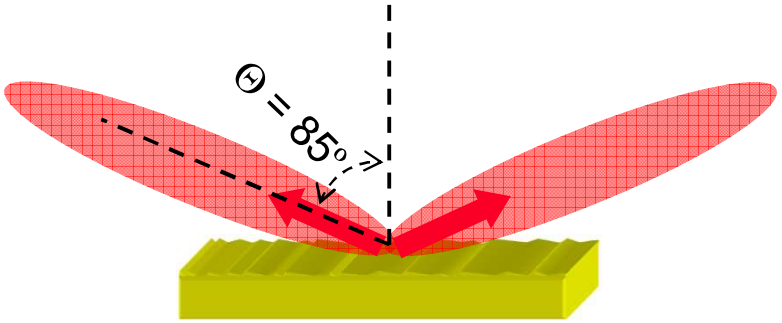
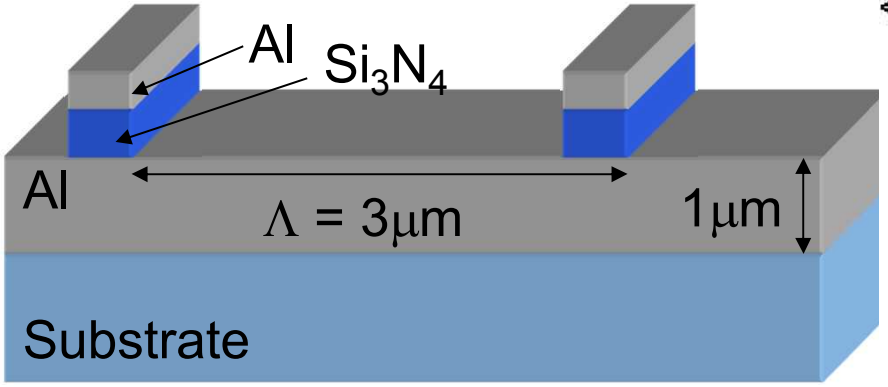
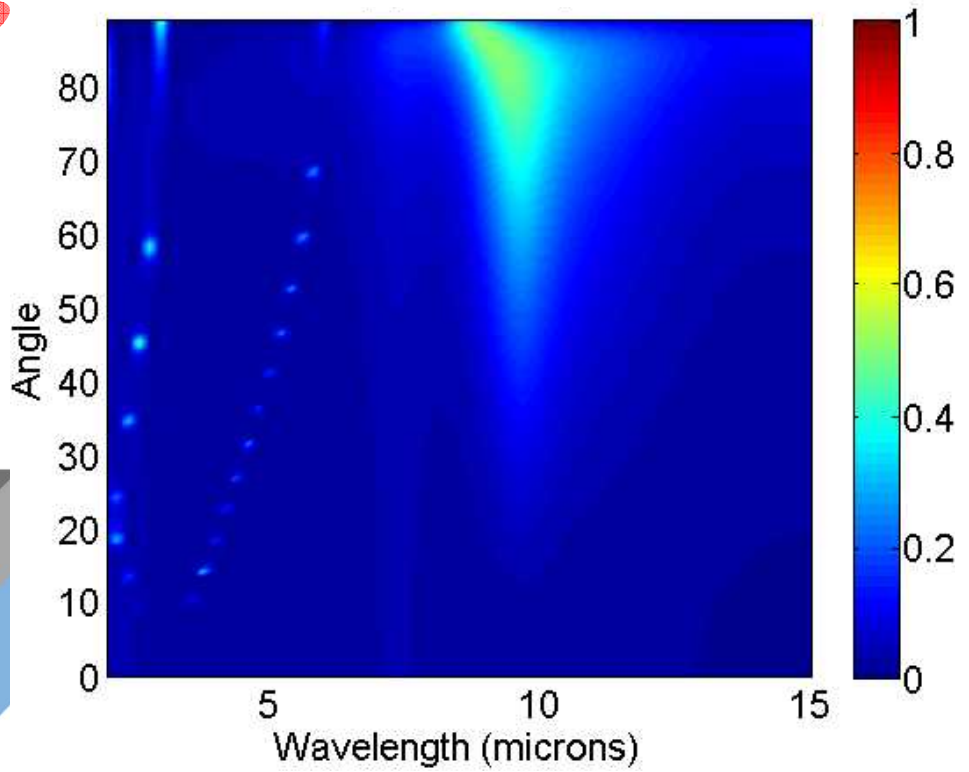
Following Component:
Nearly Planar, High-Angle Emission Component





Emission Simulation of
Λ=3μm on Al/Si_3N_4



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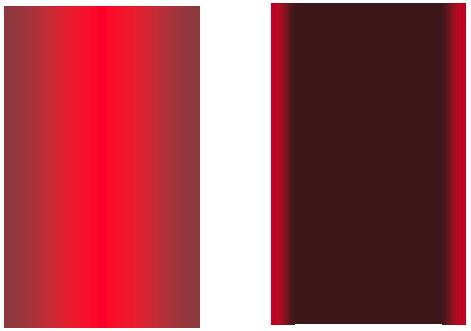
Implementation

How do we implement this technology?

The underlying physics gives us a practical, realistic answer.

- **The effect is based upon plasmons and their characteristic propagation length, which is small (~100 microns).**
- **The elements can be this size, like glitter.**
- **Dispersed in a liquid, the elements may be painted on and will conformally coat an object.**

Cylinder emission without plasmon paint



Cylinder emission with plasmon paint

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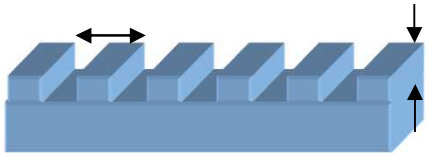
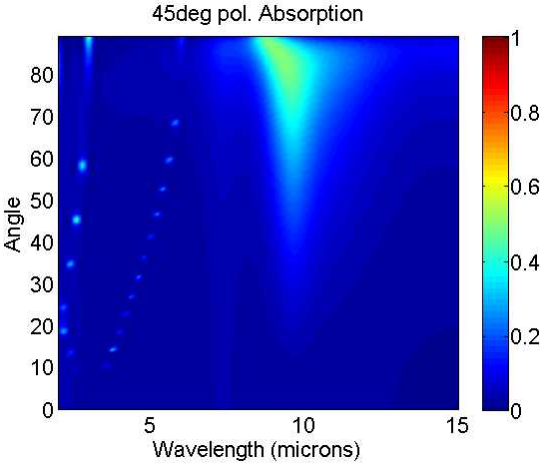
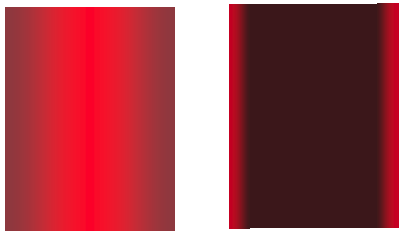
Summary

- We are designing, fabricating, and characterizing diffractive structures that couple plasmons to photons for emission management.
- We expect that if a high absorption location is near a plasmon mode and the mode propagates efficiently, the coherent emission will be significant in that wavelength regime.
- We plan to implement this technology as a conformal paint.







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