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Surface Plasmon Enhanced Fluorescence on Nanostructured Metal Surfaces

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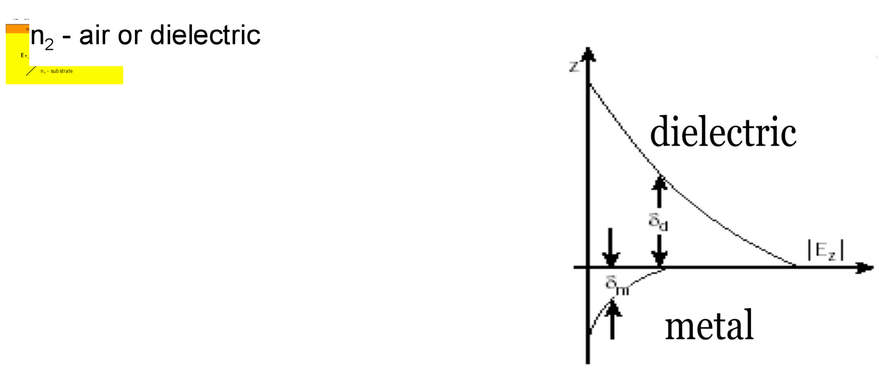
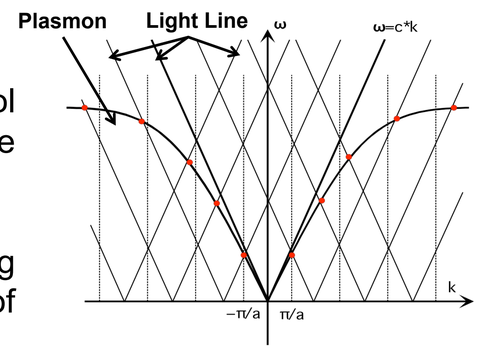
- Fluorescent materials have found widespread use in applications for biological and chemical sensing as well as detectors and optical sources.
- For many of these applications we would like to control where fluorescence occurs as well as increasing the amount of fluorescent signal.
- Surface plasmon polaritons generated by using grating coupled excitation can provide strong enhancement of fluorescence in combination with precise position control.
- It is well known that fluorescence from particles near a metal surface depends strongly on the balance between fluorescent emission and quenching due to the proximity of the metal.
- Our goal is to explore the behavior of position sensitive fluorescence enhancement by grating coupled surface plasmons and examine, in detail, the role that grating parameters play in this effect.

Surface Plasmon Polaritons



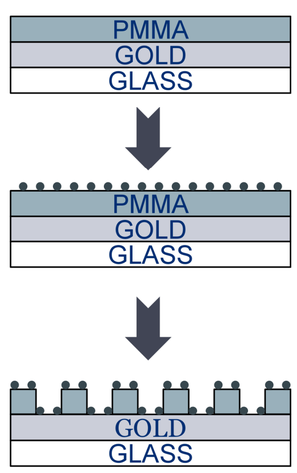
Surface plasmon polaritons are electromagnetic waves which propagate on the boundary of a metal and dielectric. They possess greatly enhanced fields near the surface which an be used to strongly excite materials close to the surface. Unfortunately these surface waves cannot be excited directly by illuminating the metal surface with light. In order to generate them we must use an additional setup to provide coupling.

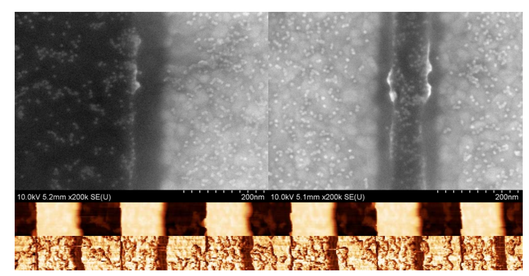
Grating Coupling



Patterning the surface with grating structures allows light to couple with surface plasmons. Coupling can occur for points where the curved plasmon dispersion relation intersects with light hitting the grating (red dots).

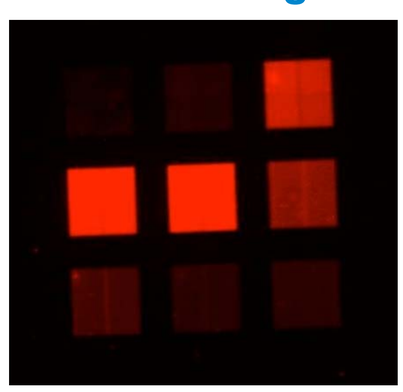
Our Experiment





- For our experiment we use gold coated glass slides.
- We then coat these slides with the polymer PMMA.
- CdSe/ZnS quantum dots, which glow red when illuminated with light, are deposited by spincoating.
- Finally, we use electron beam lithography to make gratings on the surface of the metal.

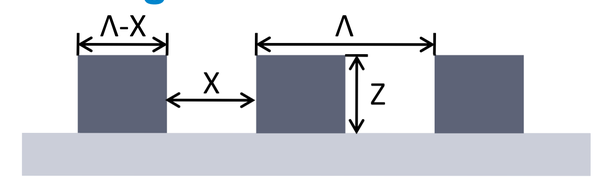
What do we get from all this?



- Highly enhanced fluorescence for some areas where we have patterns.
- Enhancement is confined to regions containing grating patterns.
- Measured enhancements range up to 150 times greater than background.
- A clearly discernible difference in response when we change the grating periodicity i.e. different patches
- Question: What kind of a role does geometry of the grating play here???

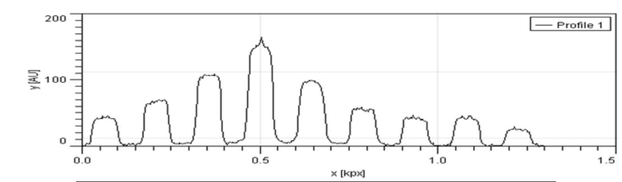
Research supported by BAE Systems

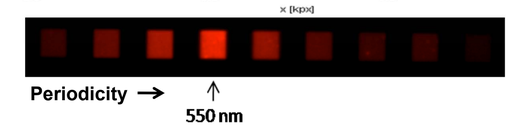
Grating Parameters



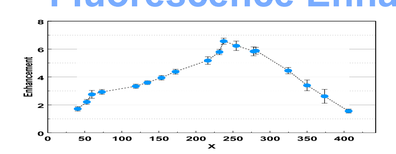
We are interested in three parameters:

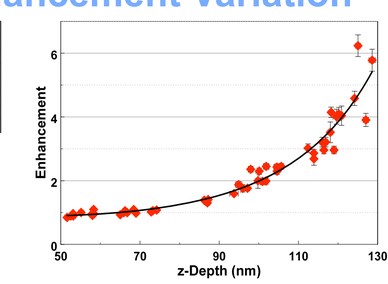
1. Periodicity Λ
2. Spacing/Duty Cycle X
3. Grating Height Z





Fluorescence Enhancement Variation





Results:

1. Enhancement is highest for periodicities near the illumination wavelength.
2. Optimal enhancement occurs near a duty cycle of approximately 50%.
3. Thickness dependence exhibits a lower thickness bound of approx. 75nm below which there is no enhancement.
4. Above this point the enhancement increases exponentially in thickness and continues increasing beyond the range depicted here.

Conclusions

We have performed a thorough study of the relationship between grating geometry and fluorescence enhancement by grating coupled surface plasmon polaritons. In particular we have been able to demonstrate precisely how the separation between the particle and metal surface affects the fluorescence enhancement effect. The development of a detailed understanding of how materials interact with surfaces and surface modes is crucial for the application of these techniques in any applications from biological and chemical sensing to detectors and optical sources.