# Field Enhancement with Plasmonic Nano Antennas on Silicon-based Waveguides

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Plasmonic nano antennas like dimers, have been investigated for their capability to provide a strong near-field enhancement when illuminated by external light. Traditionally these nano antennas, isolated or arrayed, are placed on a substrate and used in spectroscopy techniques. Surfaces made of such plasmonic nano antennas have been very useful for applications like surface enhanced Raman scattering in which it provides various orders of magnitude of enhanced sensitivity. These instruments however are not economic and are often not mobile since surfaces require an external beam illumination and the Raman scattering is detected by a large aperture microscope. The goal of this paper is to combine nano antennas made of gold dimers with integrated waveguide to make a spectrometer which has low cost and volume in comparison with the structure mentioned above. A technique in which optical plasmonic nano antennas are located in proximity of silicon nitride waveguide is proposed that is useful both for illumination and detection channels. The waveguide evanescent field, which is decaying outside of the waveguide, excites the dimer and causes it to resonate which results in a very strong electric field enhancement of approximately 25 times in the antenna gap. Also the coupling effect of dimer resonance on waveguide modes is investigated. To show the efficiency of the proposed structure, full wave analysis has been done and its results are compared with the multilayer structure case. The simulation results demonstrate that this structure can be designed and fabricated for the purpose of spectroscopy application.

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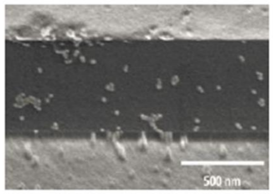
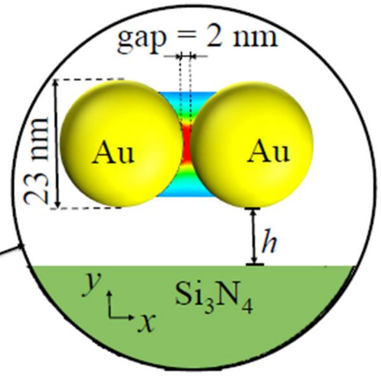
## 1 Introduction

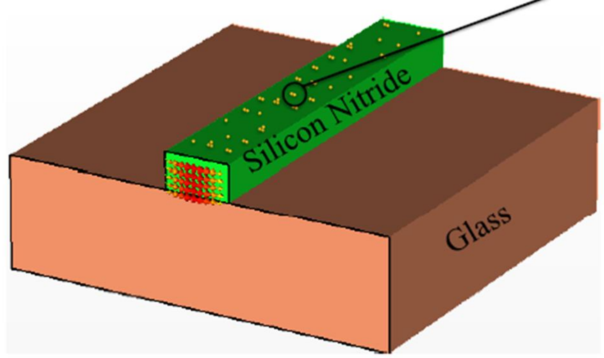
- Goal:
  - ✓ Integrate chemically assembled nanoparticles with integrated waveguide technology
  - ✓ Reduce size and cost and improve repeatability
  - ✓ Increase portability of future spectroscopy based sensors
- Why plasmonics nano antennas:
  - ✓ Strong near-field local field enhancement
  - ✓ Being placed on surfaces to apply in spectroscopy techniques [1]
  - ✓ Strong Surface Enhanced Raman Scattering (SERS) intensities [2]
- Why integrated dielectric waveguides:
  - ✓ Low loss [3]
  - ✓ Ability to use readily available silicon-based infrastructure
  - ✓ Integration with electronics [4]

## 2 Waveguide Structure and nano antenna geometry

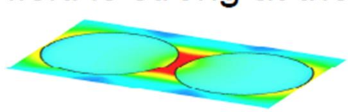


SEM image with gold nanospheres on top of silicon nitride waveguide [5]

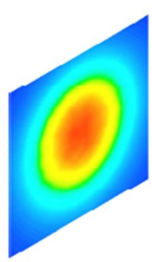


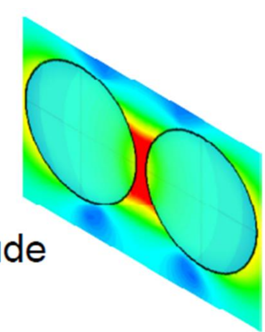

Nano antennas on top of silicon nitride waveguide are excited by the first guided mode in waveguide. Electric field is strong at the gap.



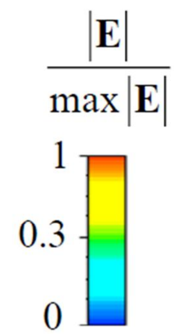
*x-z* plane



*y-z* plane



*x-y* plane



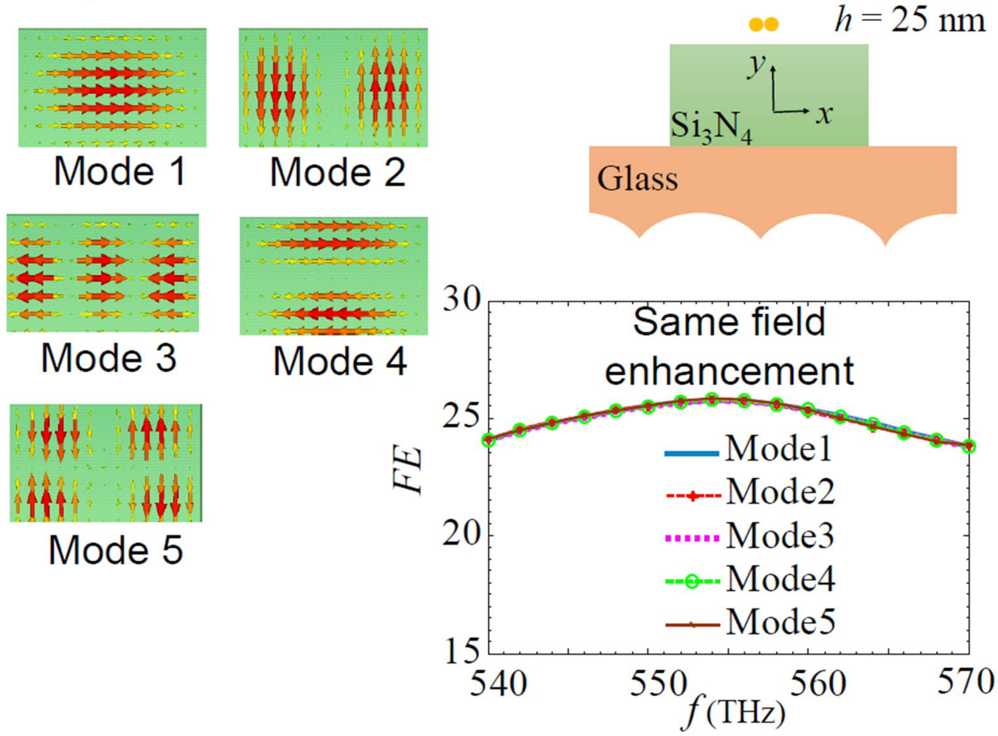

Normalized electric field magnitude at 554 THz

## 3 Mode independent field enhancement

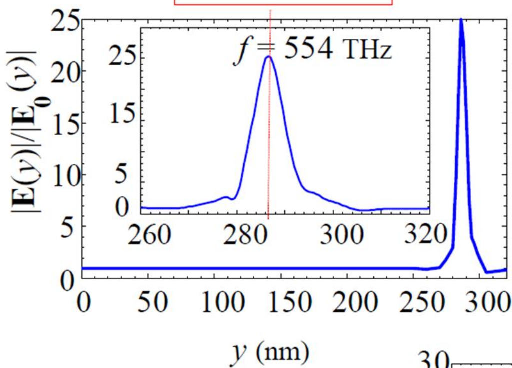
$|\mathbf{E}|$ Electric field magnitude at the center of gold dimer

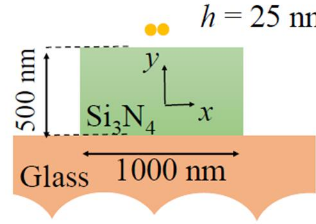
$|\mathbf{E_0}|$ Electric field magnitude at the same position in absence of nano antenna

$$FE = \frac{|\mathbf{E}|}{|\mathbf{E_0}|}$$

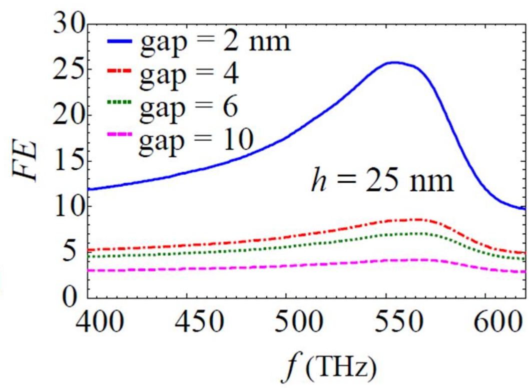


## 4 Field Enhancement



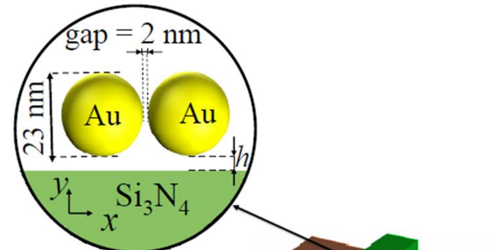

strong field enhancement within the nanoantenna gap

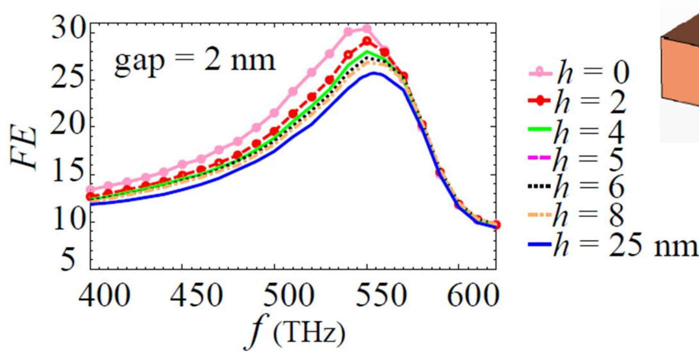



Gap size is a critical parameter

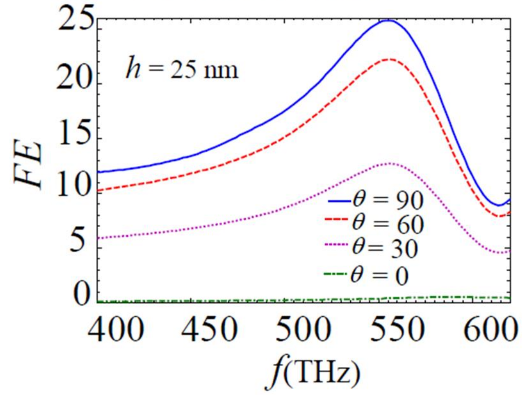
## 5 Dependence on height *h*

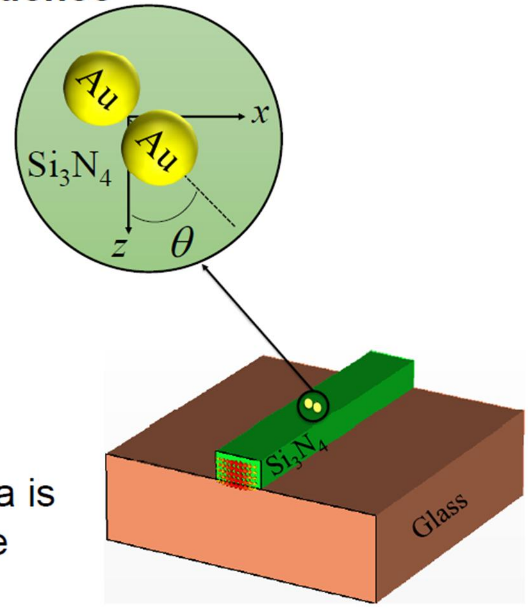
The FE does not strongly depend on height *h*



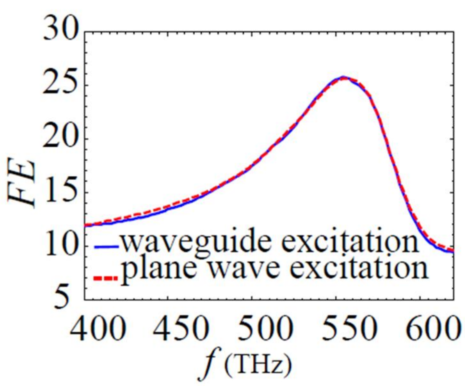
## 6 Enhancement dependence on orientation

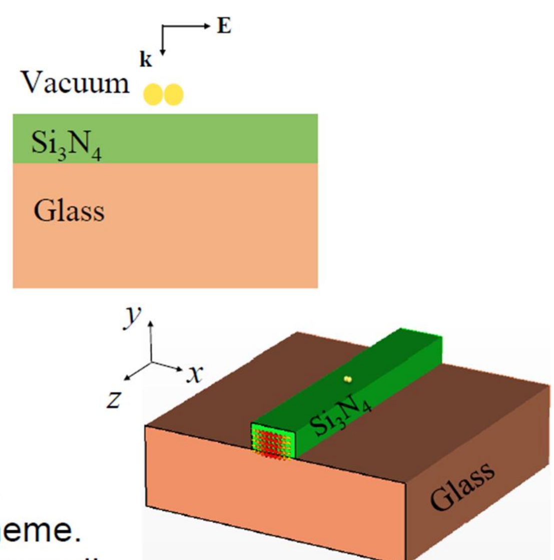



The excitation of the antenna is sensitive to orientation of the dimer

## 7 Comparison of plane wave Vs. waveguide excitation




The field enhancement is not sensitive to the excitation scheme. Waveguide excitation performs well

## 8 Conclusion

- Proposing a configuration with strong electric field enhancement
- Investigating FE for different dimer locations and orientations
- Demonstrating that a CMOS compatible waveguide geometry can yield strong field enhancement

## 9 References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