NANOSTRUCTURED SURFACE-PLASMON ENHANCED COPPER PHOTOCATHODE

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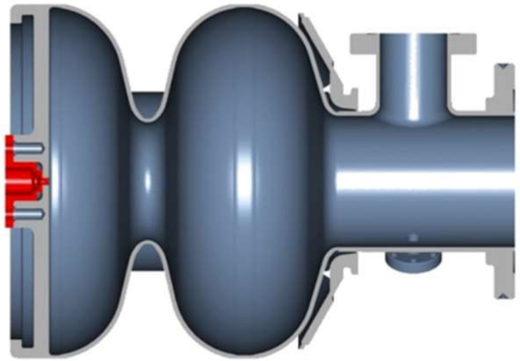
WHY PLASMONIC CATHODE?

Semiconductors	Metals
High Quantum Efficiency	Low Quantum Efficiency
Chemically reactive	Less chemically reactive
Expensive	Cheaper



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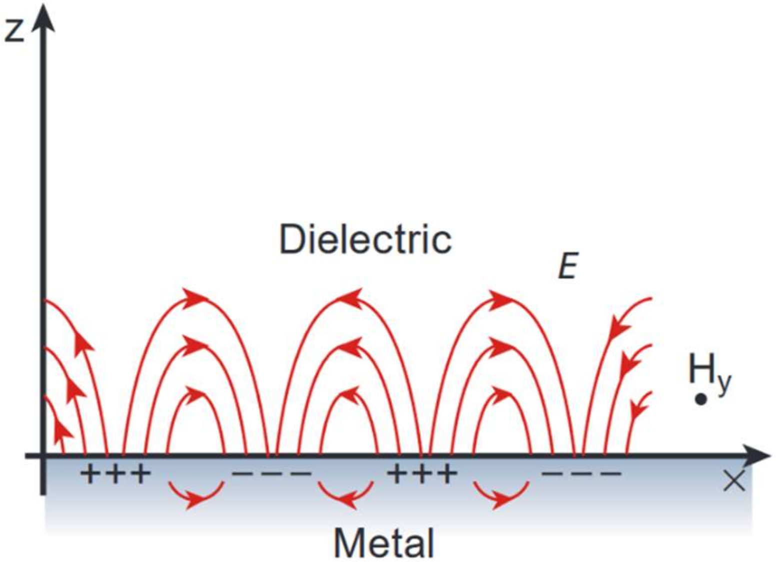
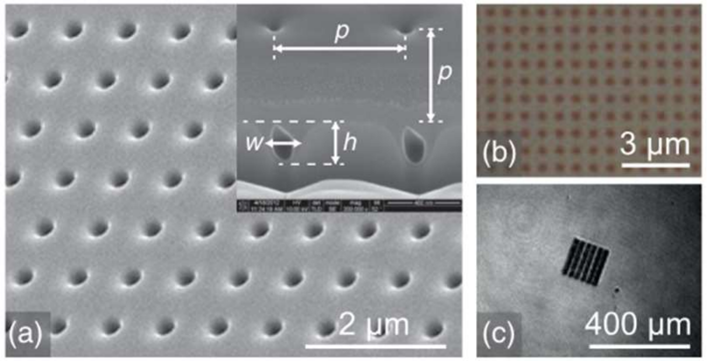
SHORT THEORY OF PLASMONICS

- Surface plasmons (SPs) are electromagnetic excitations that propagate along the interface between a metal and a dielectric.

- In order to get plasmons, it is necessary to couple light into the SP modes. The coupling can be achieved using a **periodic structure**.





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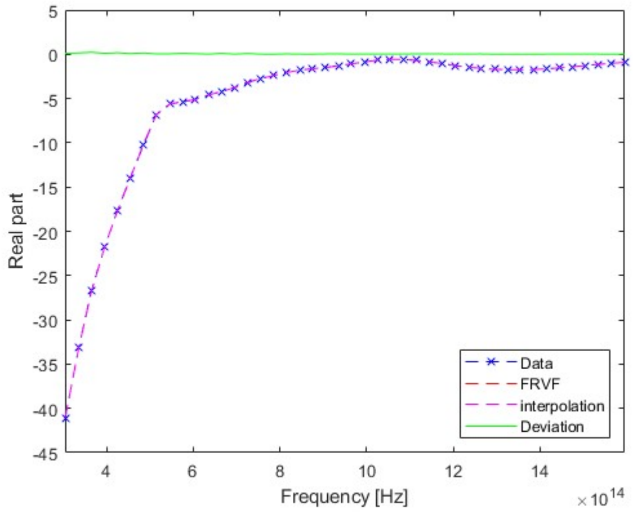
DISPERSION MODEL

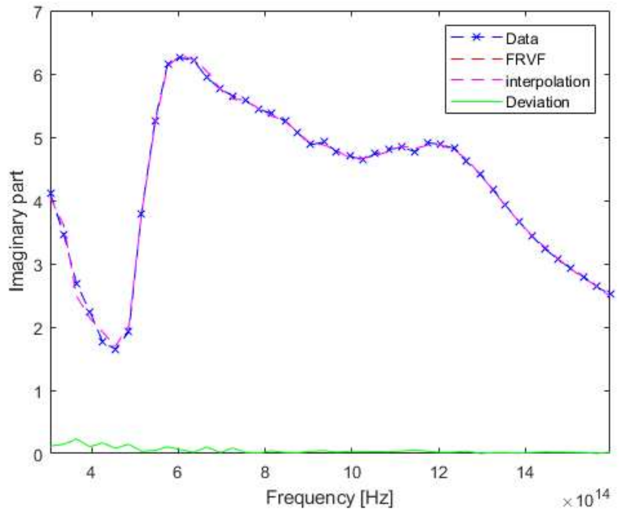
Existing models

- Different models available (e.g. Drude, partial fraction, Lorentz model)
- The results are not consistent

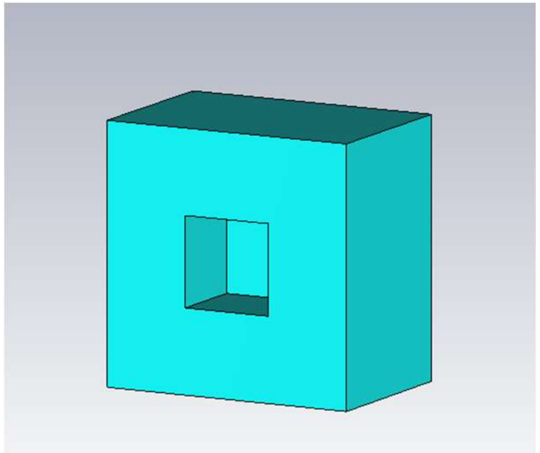


Our approach

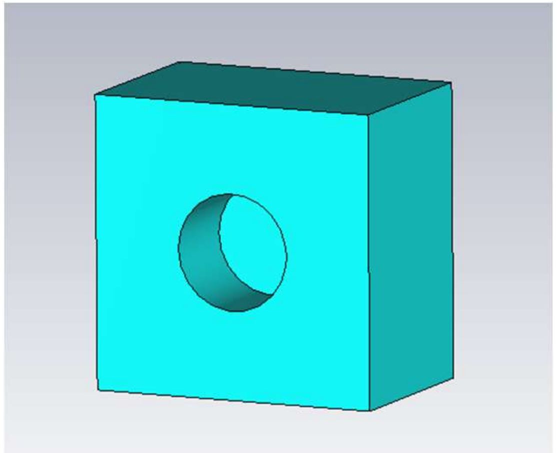
- Own fitting based on data from Johnson & Christy
- Johnson and Christy data: 44 data points (180-984 nm)
- The fitting: 1000 interpolated data points



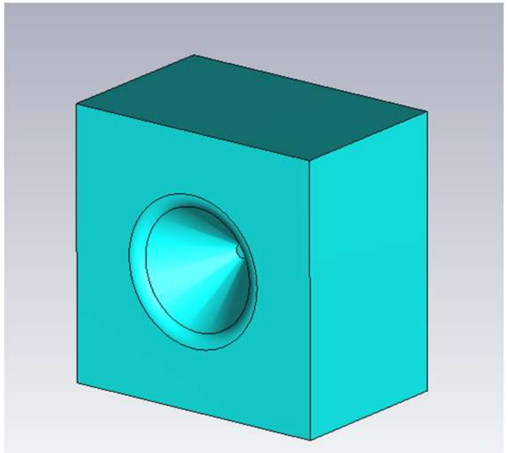
NANO-STRUCTURE GEOMETRIES



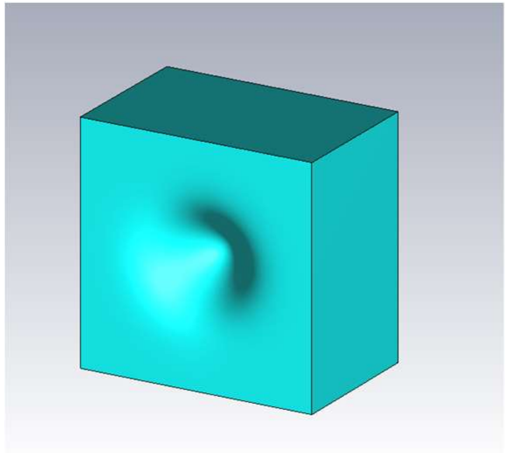
Square



Round



Cone



Gaussian

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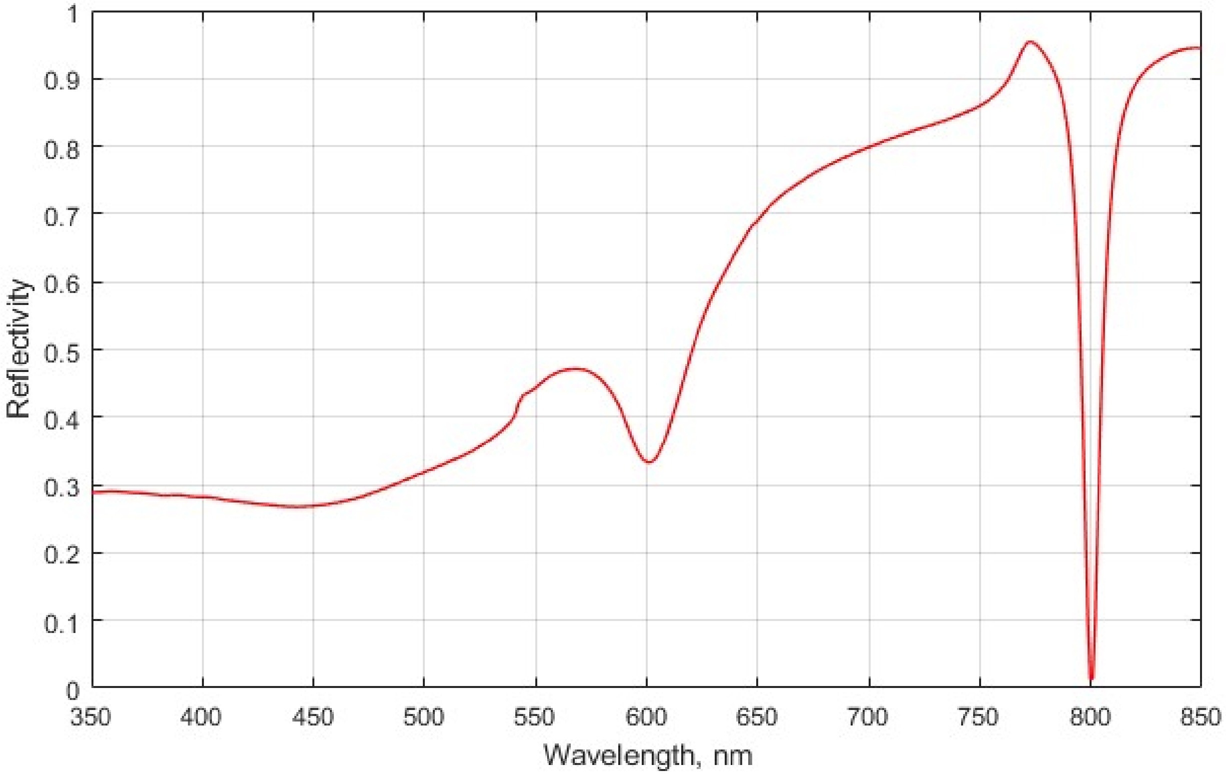
OPTIMIZATION OF IR-CATHODE WITH NANO-CONES (800 NM)



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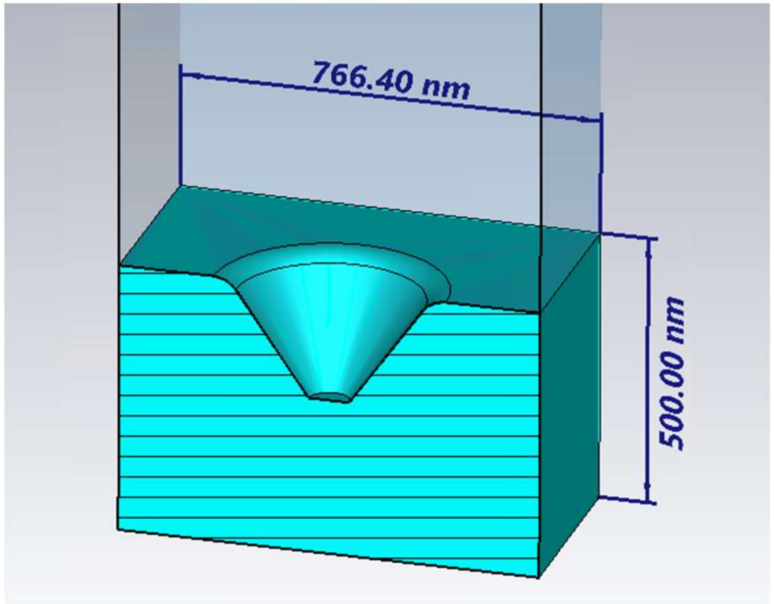

Important findings:

- Optimal cone ratio (Top radius / bottom radius) = 0.2 for different wavelengths
- Periodicity changes the resonant wavelength linearly

Parameter	Optimal value
Periodicity	767.6 nm
Radius	186 nm
Blending radius	50 nm
Depth	210 nm
Ratio	0.2

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OPTIMIZATION OF IR-CATHODE VARIOUS GEOMETRIES

Square

Parameter	Optimal value
Periodicity	751.4 nm
Width	260 nm
Depth	240 nm

Round

Parameter	Optimal value
Periodicity	755.9 nm
Radius	150 nm
Depth	240 nm

Gaussian

Parameter	Optimal value
Periodicity	772.2 nm
FWHM	186 nm
Depth	170 nm

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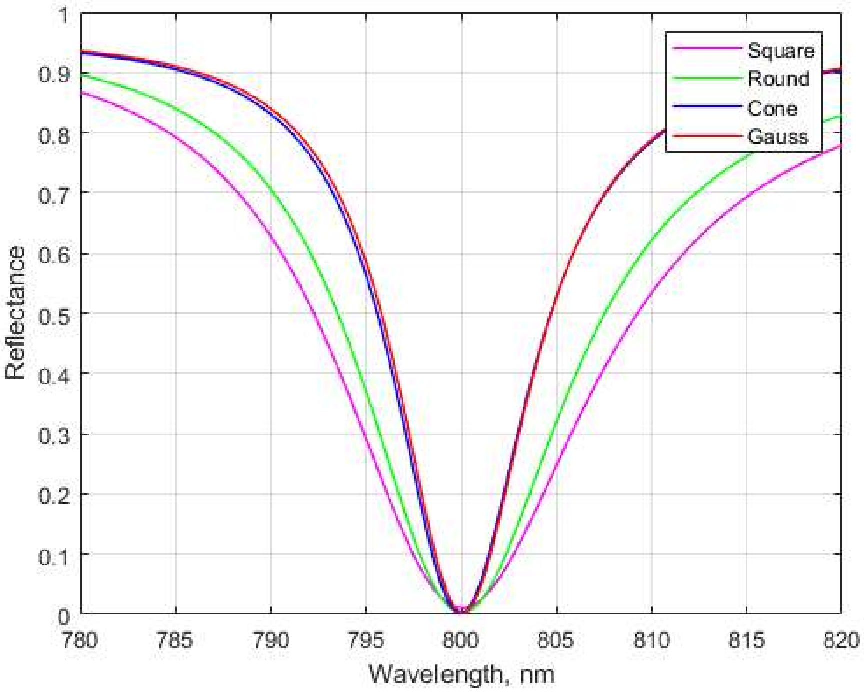
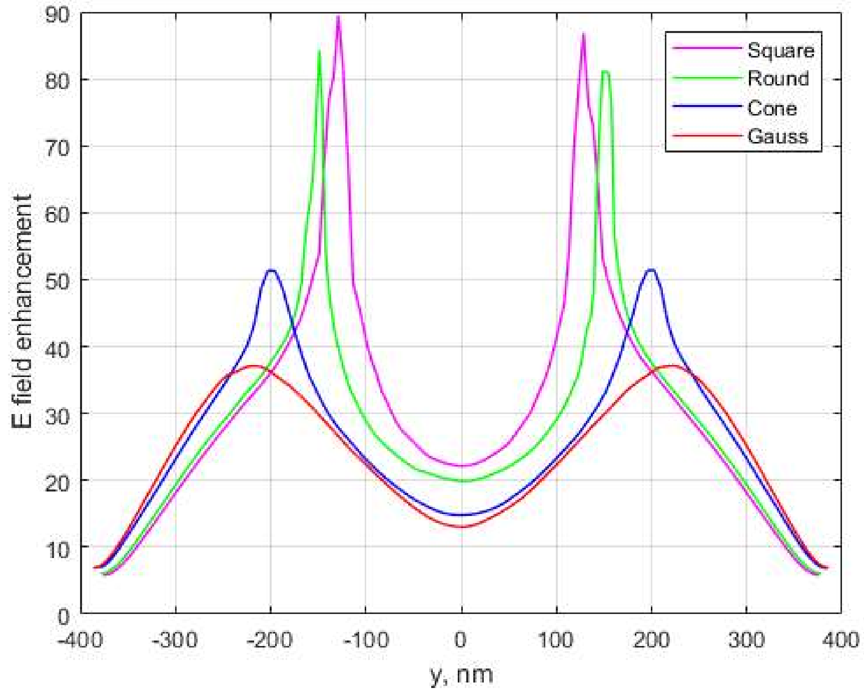
REFLECTANCE AND E-FIELD VARIOUS GEOMETRIES





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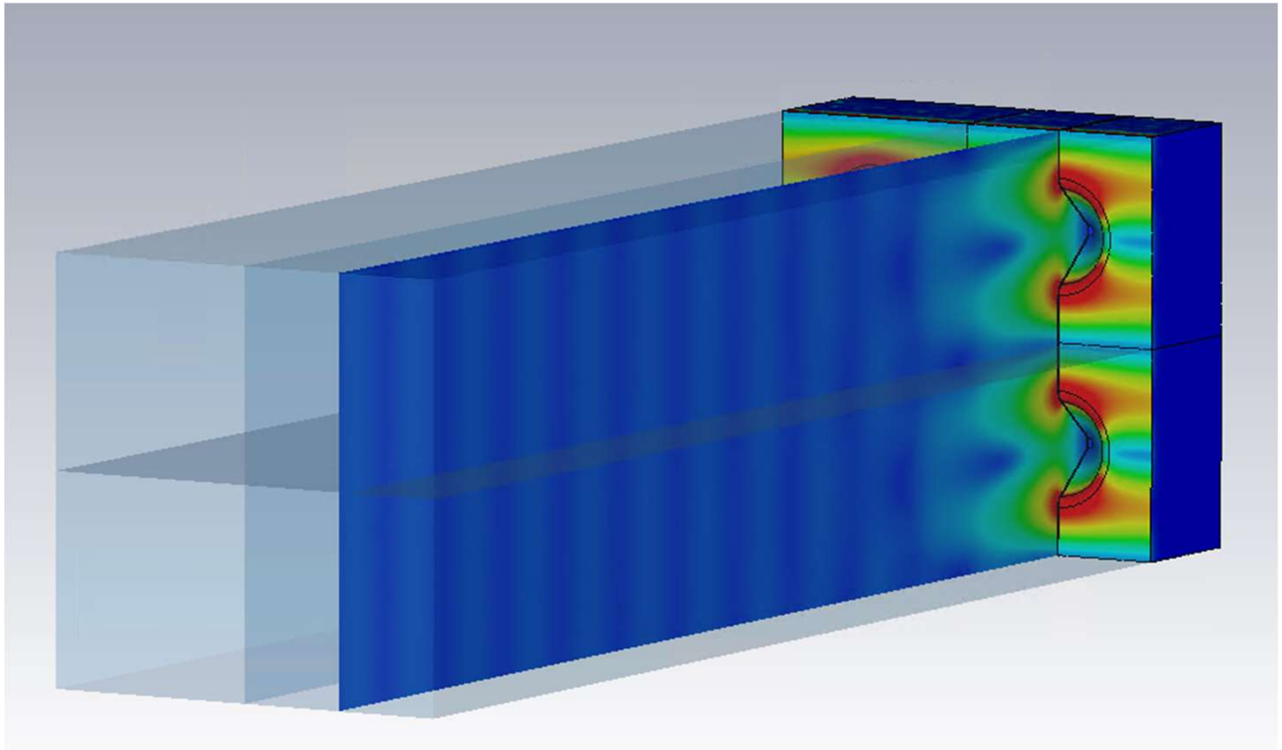

E-field distribution at 800 nm

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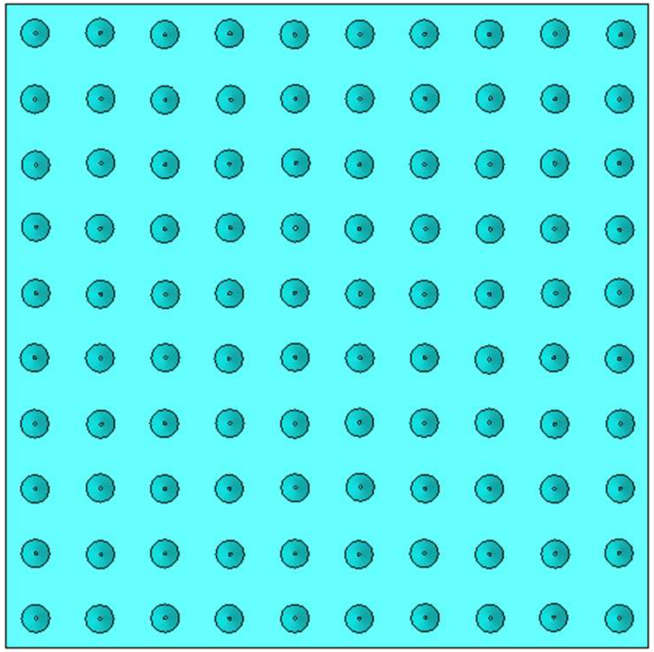
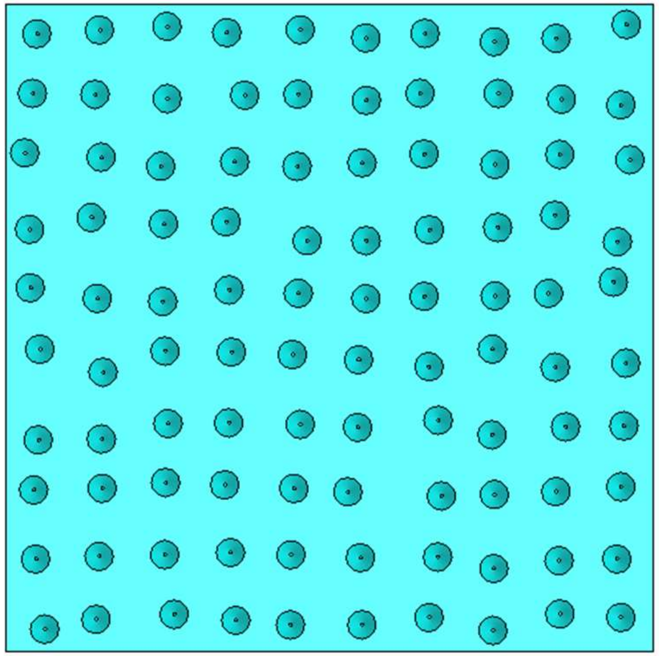
EFFECT OF GEOMETRICAL UNCERTAINTIES [TBD]



1% deviation

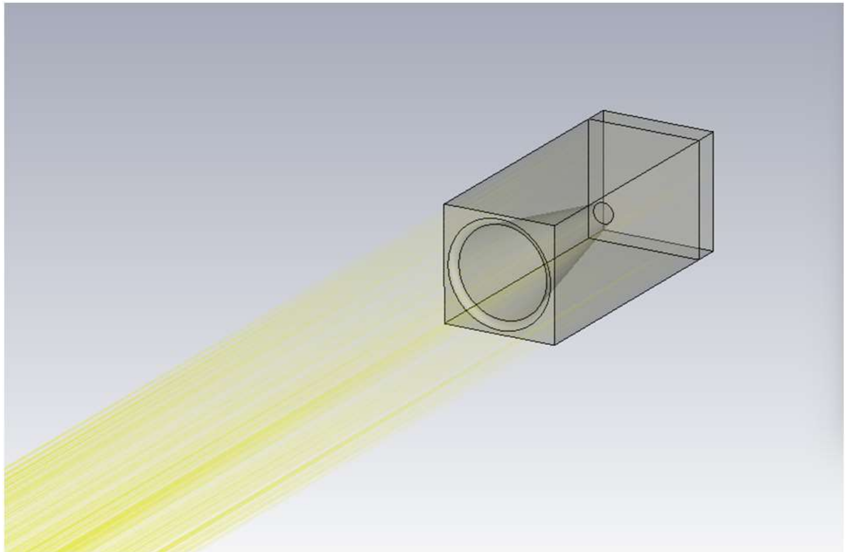


10% deviation

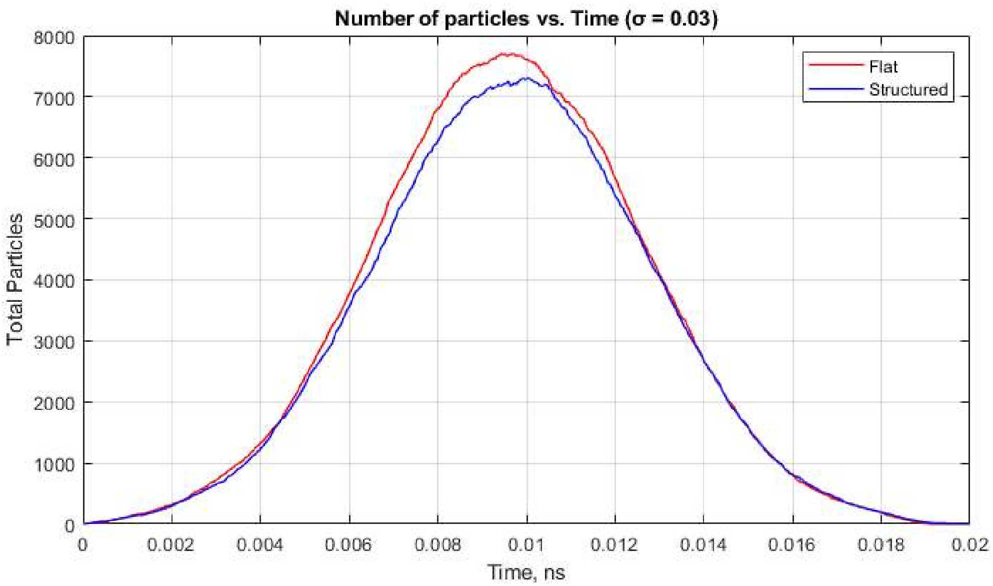
BEAM DYNAMICS A SINGLE NANO-CONE

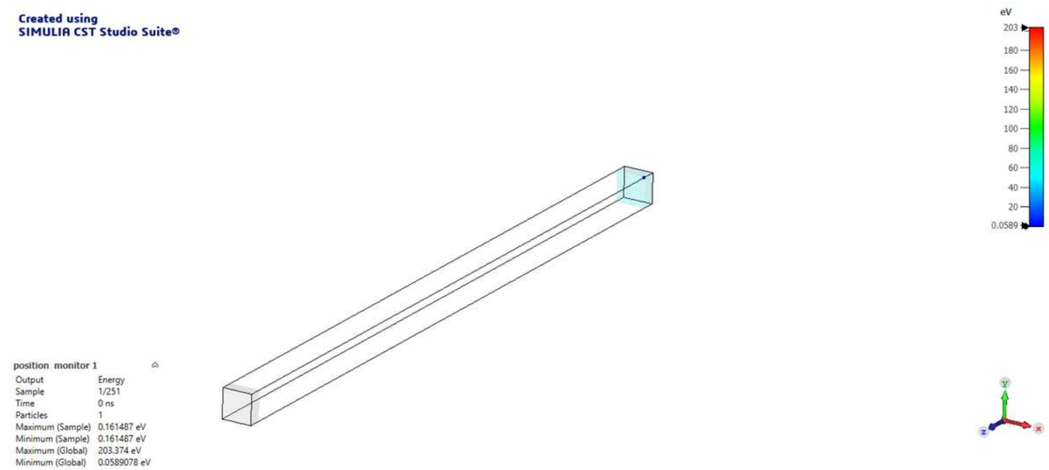
Optically induced emission model:

- Sample structure
- Use light source with given wavelength and power
- Get sample emission points
- Produce new points with temporal profile out of sample points



BEAM DYNAMICS
FLAT VS STRUCTURED





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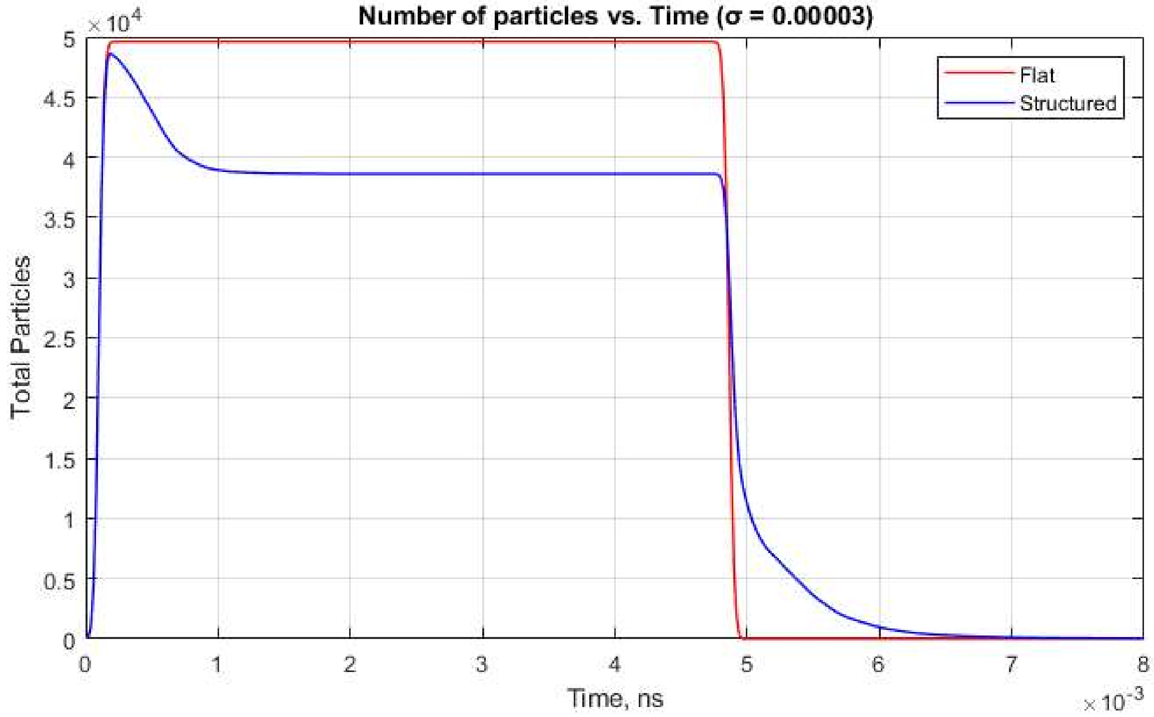
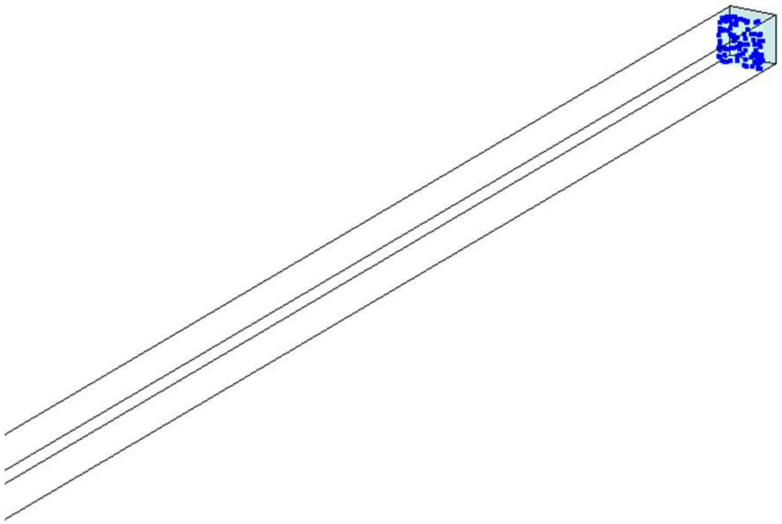
BEAM DYNAMICS FLAT VS STRUCTURED (SHORT BUNCH)

- Longer distance
- Shorter bunch
- Qualitative
- Fixed QE (1%)
- **Preliminary calculation**
- No space charge
- E is constant (≈50 MV/m)

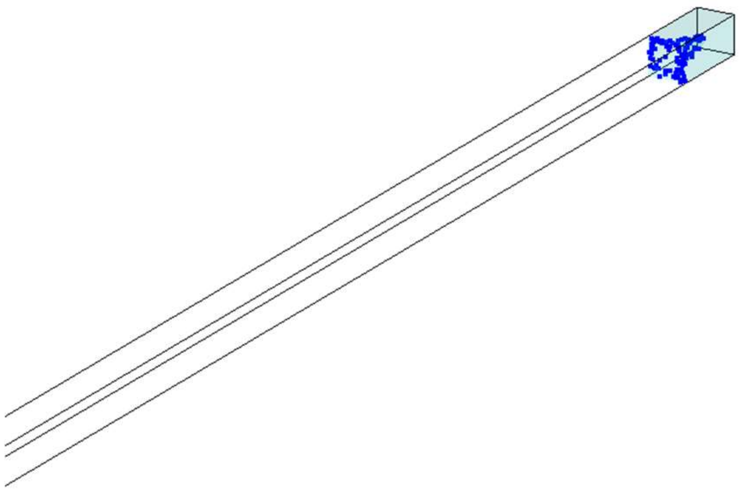


BEAM DYNAMICS FLAT VS STRUCTURED (SHORT BUNCH)

Flat cathode



Structured cathode



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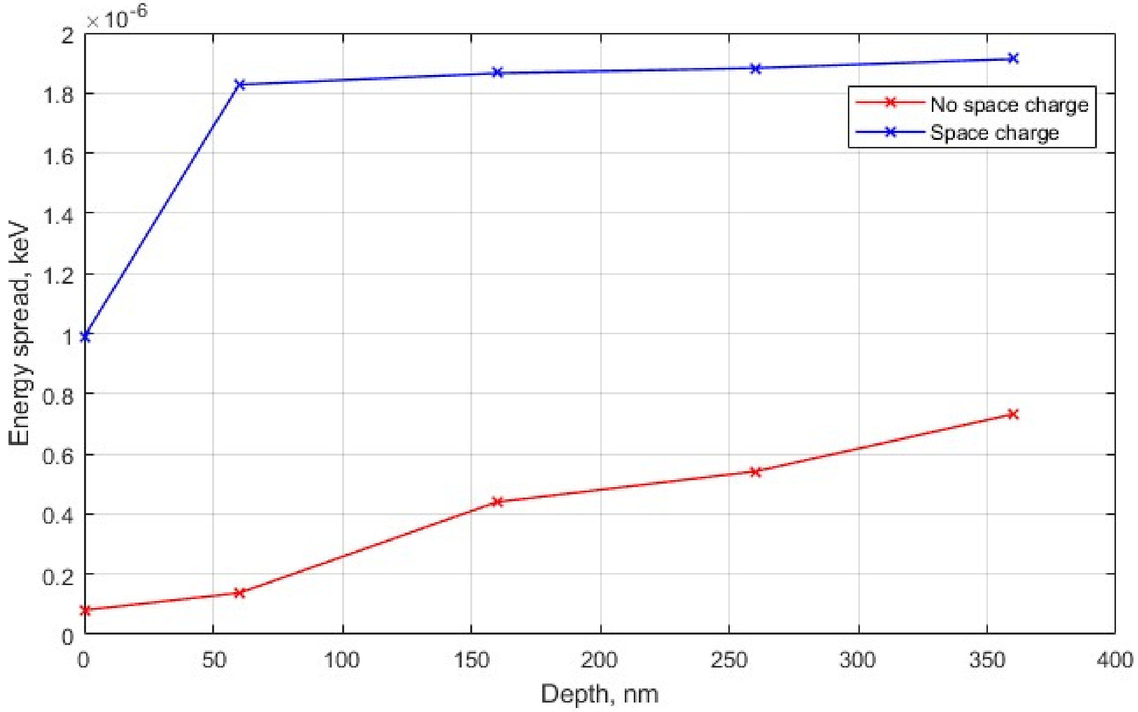
ENERGY SPREAD FOR A SINGLE NANO-CONE



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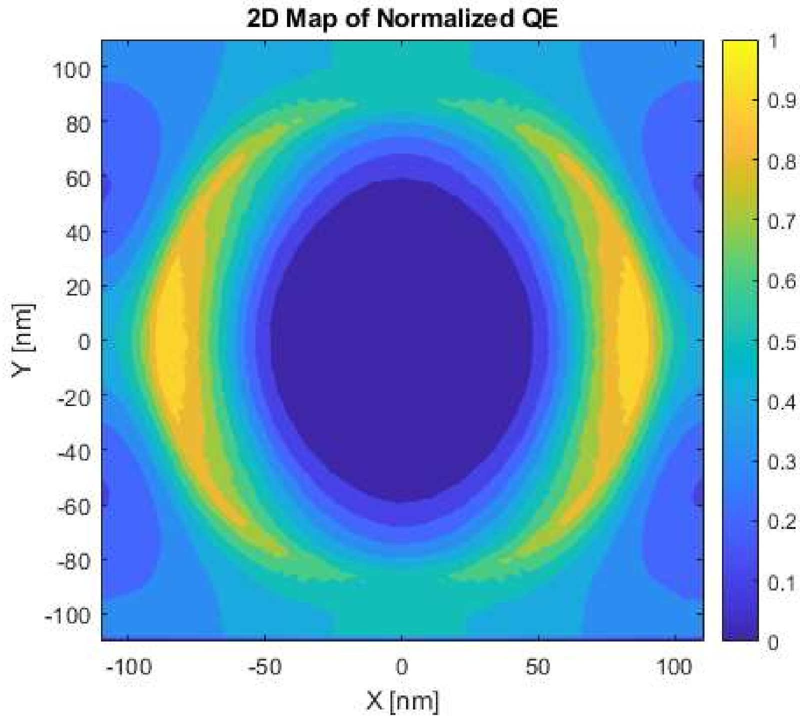
QUANTUM EFFICIENCY DISTRIBUTION

QE distribution 2D map:

- Calculated the power loss distribution in volume
- Integrated the losses over Z
- Calculated QE with simplified Moments model for metals:

$$QE(267nm) = \frac{(1-R)}{(1+p)}\frac{\mu(\hbar\omega-\phi)^2}{4\hbar\omega(\mu+\hbar\omega)(2\mu-\hbar\omega)}$$



RESULTS

- Own fitting of dispersion
- Optimized IR-operated cathodes for different nanohole geometries
- Implemented optically induced emission model
- Calculated preliminary beam dynamics for a single nano-cone
- Estimated the effect of nano-cone depth on the beam dynamics

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NEXT STEPS

- Finish calculation of the effect of geometrical uncertainties for 10x10 array of cones
- Implement QE distribution to beam dynamics calculation
- Implement Fowler-DuBridge quantum efficiency model
- Scale initial emission results to macroscopic spot size
- Calculate full beam dynamics for the electron gun
- Optimization including beam dynamics