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Friedrich-Schiller-Universität Jena

Propagation characteristic of ultrawide bandwidth Airy surface plasmons

Amit V Singh, Matthias Falkner, Michael Steinert, Matthias Zilk, Thomas Kaiser, Goran Isic, Thomas Pertsch

Grating

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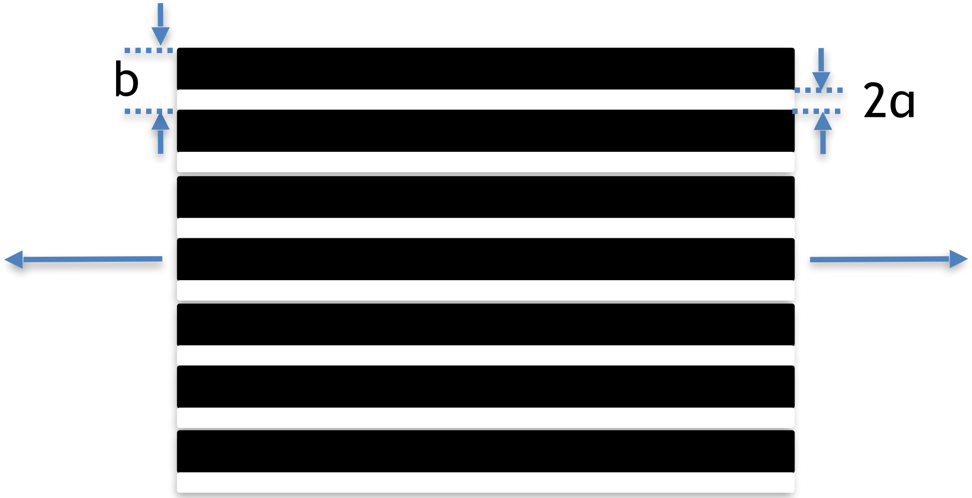
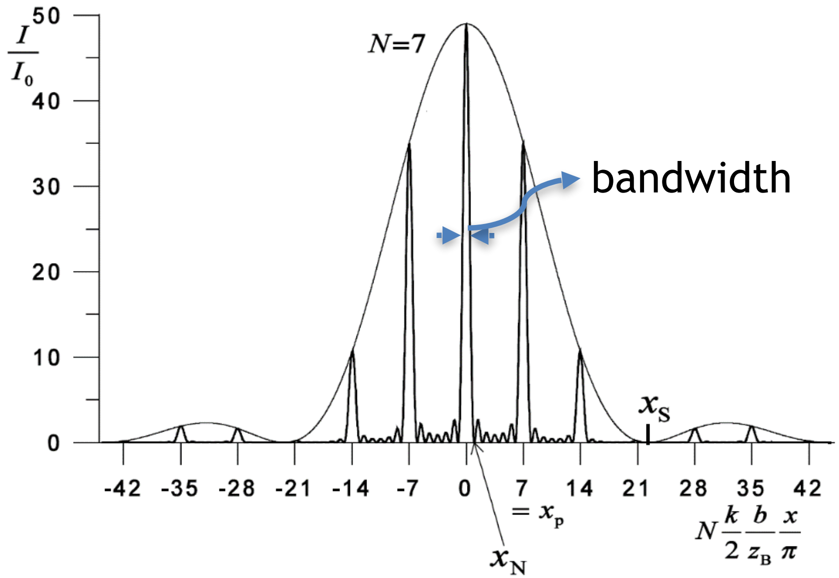


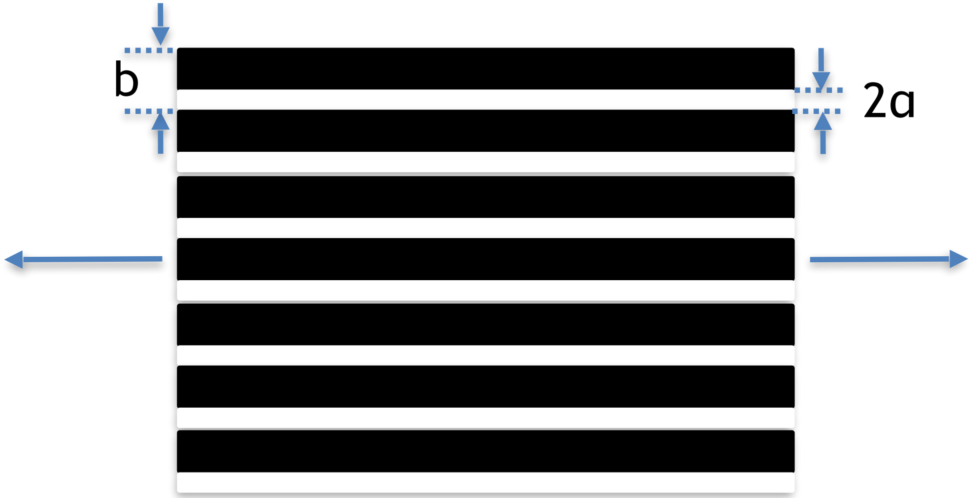


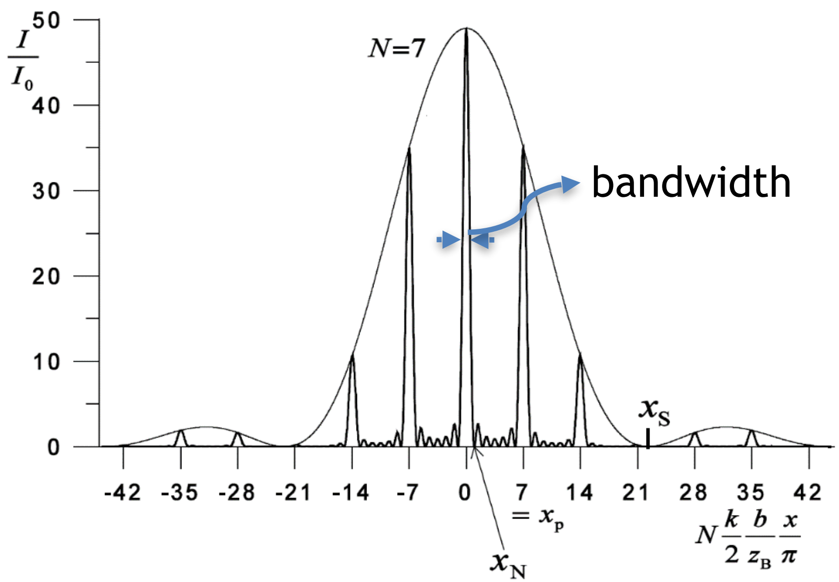
$$x_N = \frac{\lambda z_B}{Nb}$$

N ↑ x_N ↓

finite size grating → finite bandwidth

Grating





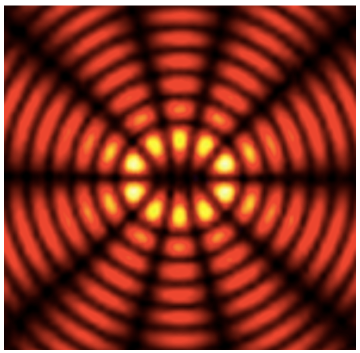
Bandwidth of Airy plasmon generation??

Airy surface plasmon polaritons (Airy SPPs) propagating surface plasmons (SPPs) consisting of the properties of Airy beams.

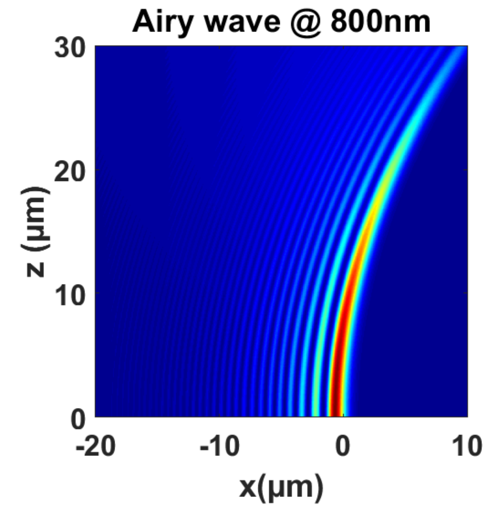
Non diffracting Beams

Non diffracting beam remains intensity invariant during propagation.

Mathieu



Bessel



Basic characteristics

- Non diffracting beams contains infinite power or energy.
- Can be generated through conical superposition of plane waves

Basic characteristics

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M. Mazilu, D. J. Stevenson, F. Gunn-Moore, and K. Dholakia, *Laser Photonics Rev.* 4, 529 (2010).
or J. Durnin, J. J. Miceli, and J. H. Eberly, PRL **58**, 1499 (1987). Check out to which these figures belong

Non diffracting Beams

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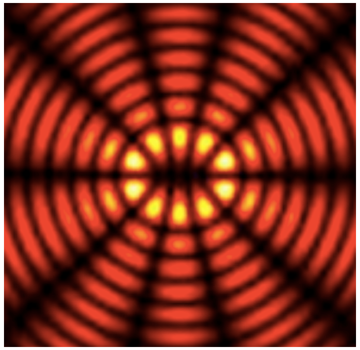
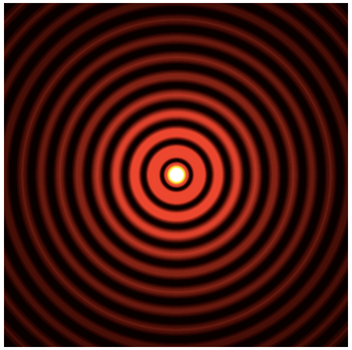
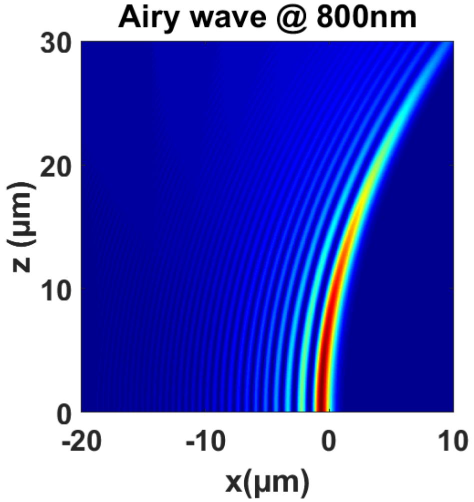


Bessel





Basic characteristics

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Basic characteristics

- Non diffracting beams contains infinite power or energy.
- Solution of 1D paraxial wave equation

M. Mazilu, D. J. Stevenson, F. Gunn-Moore, and K. Dholakia, *Laser Photonics Rev.* 4, 529 (2010).

G. A. Siviloglou and D. N. Christodoulides *Opt. Lett.* 32, 979 (2007).

Non diffracting Beams

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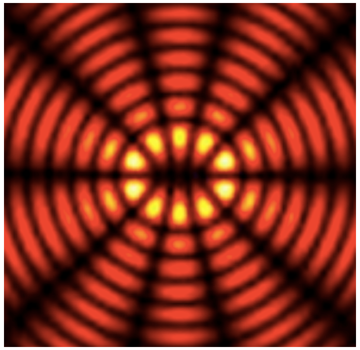
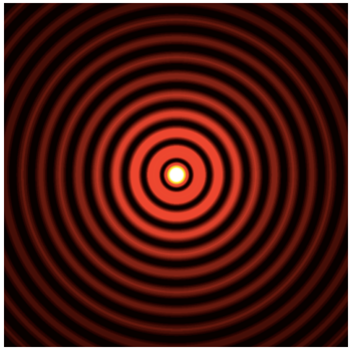
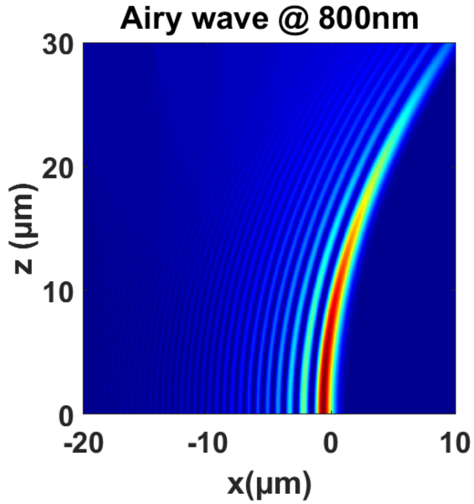
Mathieu



Bessel





Basic characteristics

- Non diffracting beams contains infinite power or energy.
- Can be generated through conical superposition of plane waves

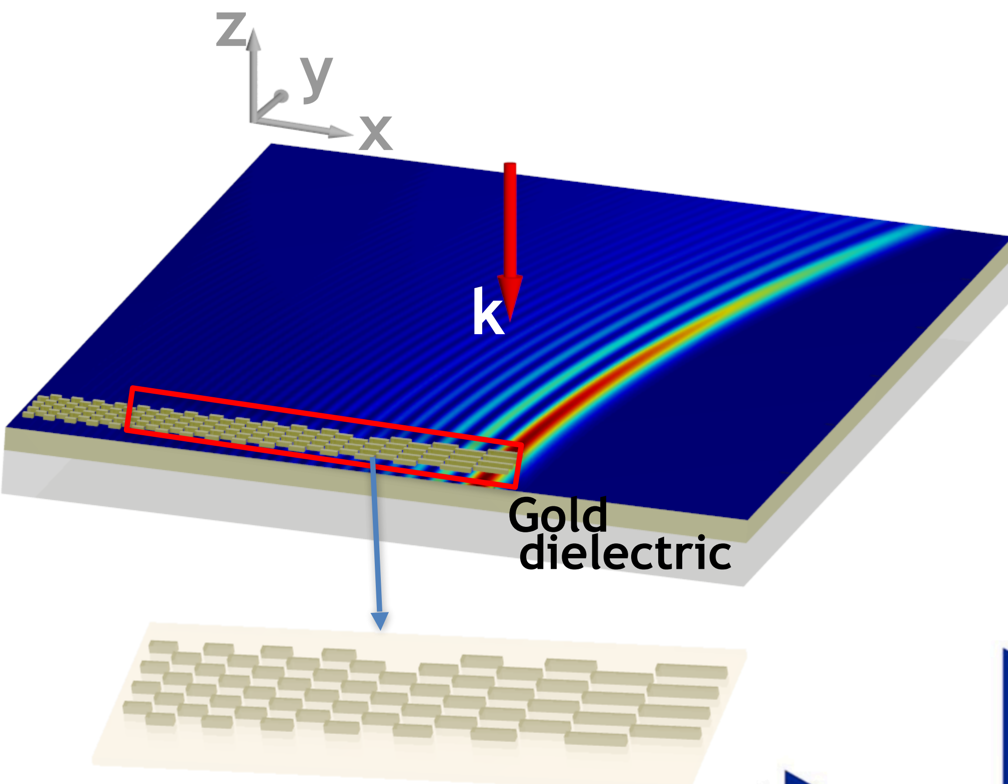
Properties

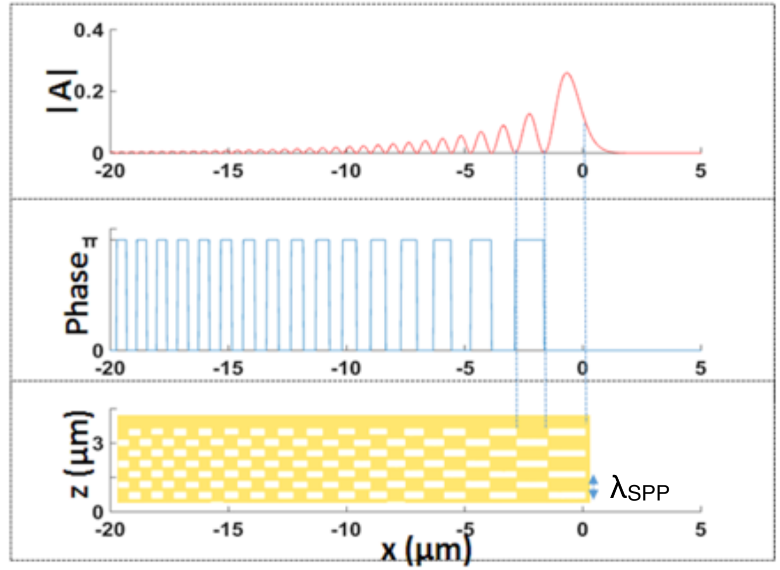
- Airy beams can exist in a planar system, so particularly suitable for plasmonics.
- Accelerating
- Self bending
- Self healing

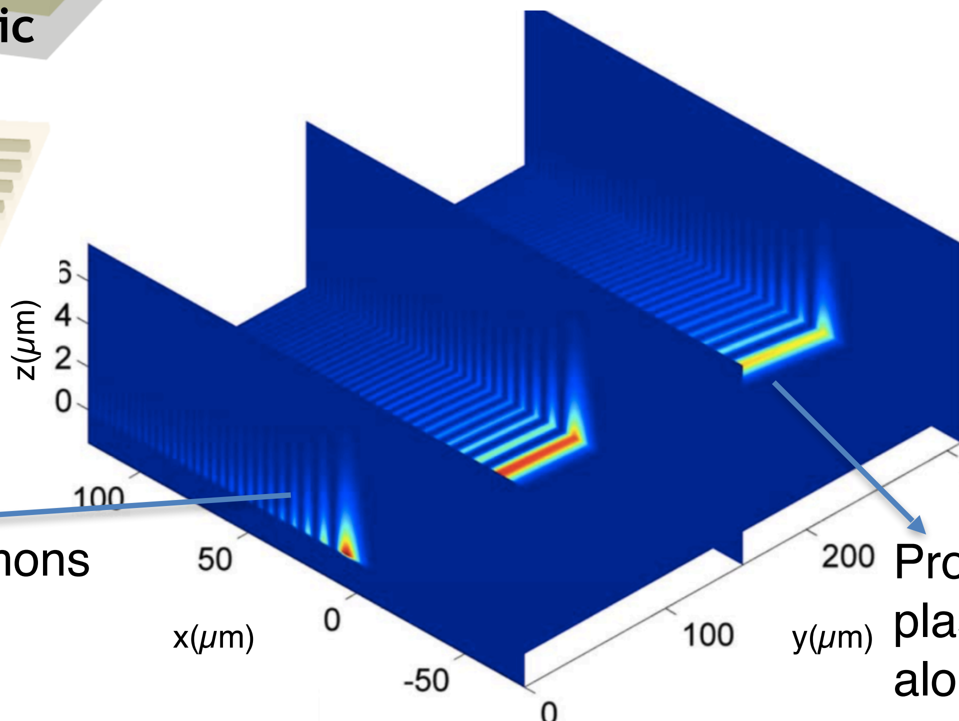
M. Mazilu, D. J. Stevenson, F. Gunn-Moore, and K. Dholakia, *Laser Photonics Rev*. 4, 529 (2010).

G. A. Siviloglou and D. N. Christodoulides *Opt. Lett*. 32, 979 (2007).

Airy Plasmon







Characteristic decay of plasmons normal to the interface

Propagation of plasmons along the interface

A. Minovich et al, *Phys. Rev. Lett.* , 107, 116802 (2011).
A. Salandrino and D.N. Christodoulides, *Opt.Lett*. 35, 2082 (2010)

Analytical solution: Non paraxial Airy plasmon

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The magnetic field amplitude of the non-paraxial Airy plasmon in Fourier-space is given by

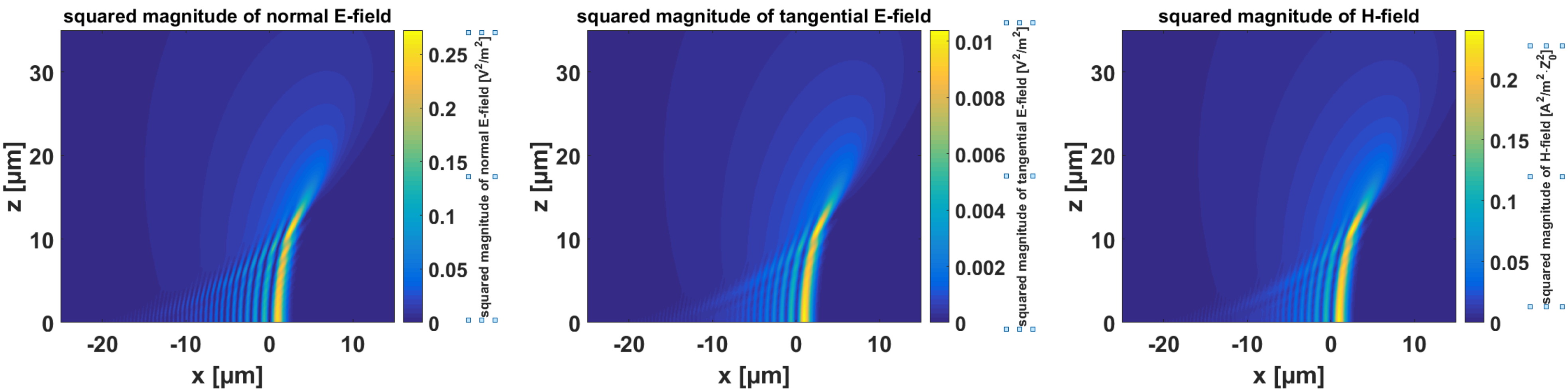
$$\tilde{A}_0(k_x; x_0, a) = \frac{1}{2\pi}\exp\Big(-ak_x^2x_0^2 + \frac{i}{3}[k_x^3x_0^3 - 3a^2k_xx_0 - ia^3]\Big) \qquad (1)$$

This yields the following magnetic field in real-space:

$$\mathbf{H}(x,y,z;x_0,a) = \hat{\mathbf{H}}(x,y;x_0,a)\begin{cases}\exp(\text{-}\alpha_I z) & \text{for } z>0\\ \exp(+\alpha_{II}z) & \text{for} z<0\end{cases} \qquad (2)$$

with

$$\hat{\mathbf{H}}(x,y;x_0,a) = \int_{-\infty}^{\infty}\tilde{A}_0(k_x;x_0,a)\Big(\frac{q(k_x)}{\beta}\boldsymbol{e}_x - \frac{k_x}{\beta}\boldsymbol{e}_z\Big)\exp\left(ik_xx + iq(k_x)z\right)dk_x \qquad (3)$$



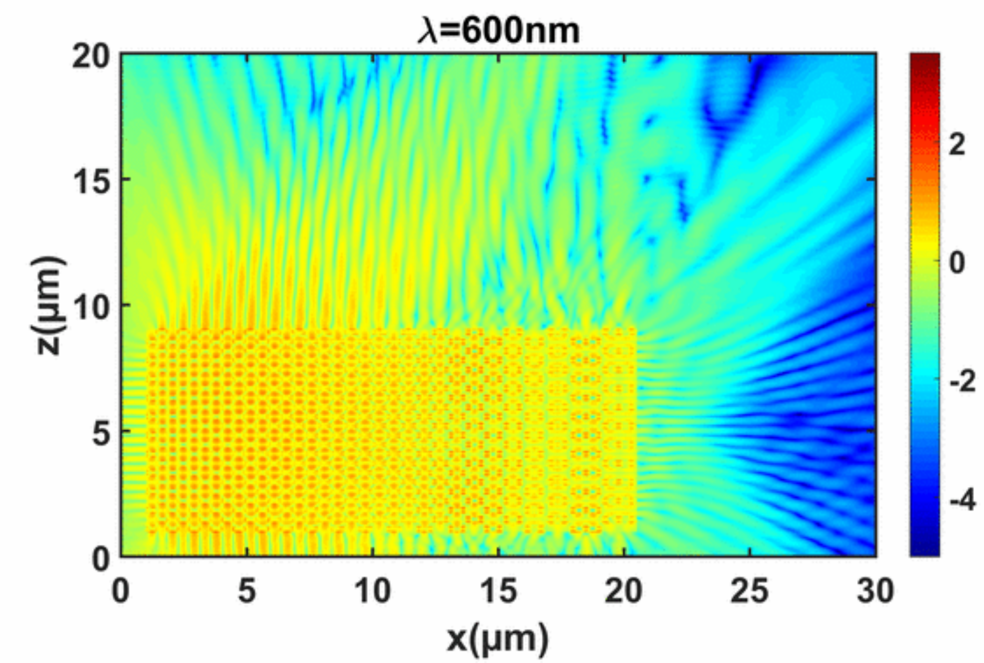
Simulation and experiment

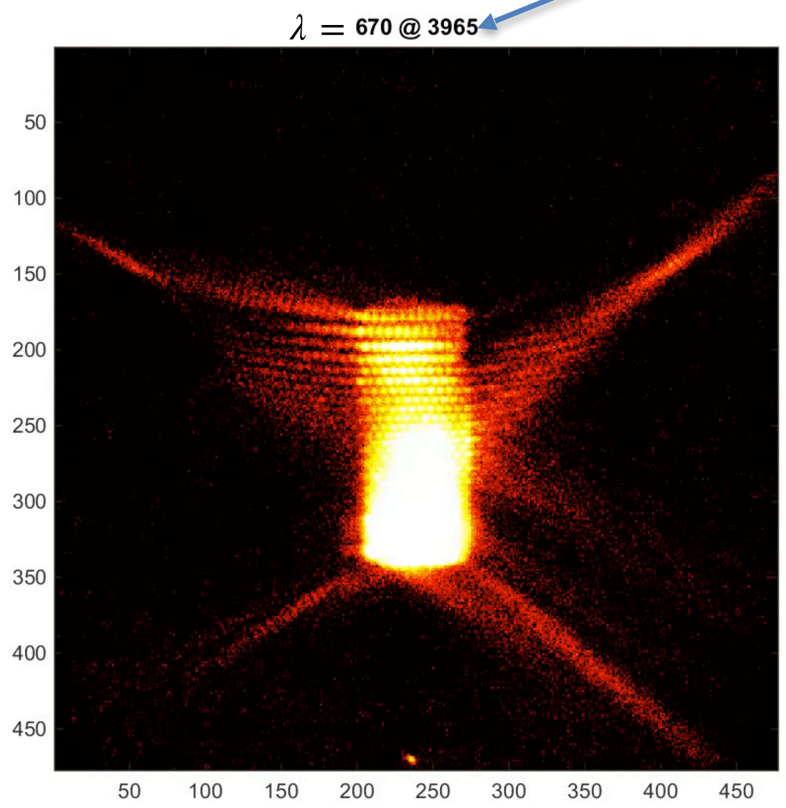
- Simulation: Lumerical FDTD solver
- Plane wave illumination (TFSF source)
- Angle of incidence: normal
- Spatial resolution 5 nm (uniform grid)

Advantage

- Computation region is divided into two distinct regions; total field and only scattered field
- suitable for non periodic structures in a multilayer system

- Experiment: Photoemission electron microscope (PEEM)
- Photoemitted yield are direct map of resultant field at the interface
- Photoemission is non-linear n-photon process
- Field of view is 80 µm (scale 660 pixels = 80µm)



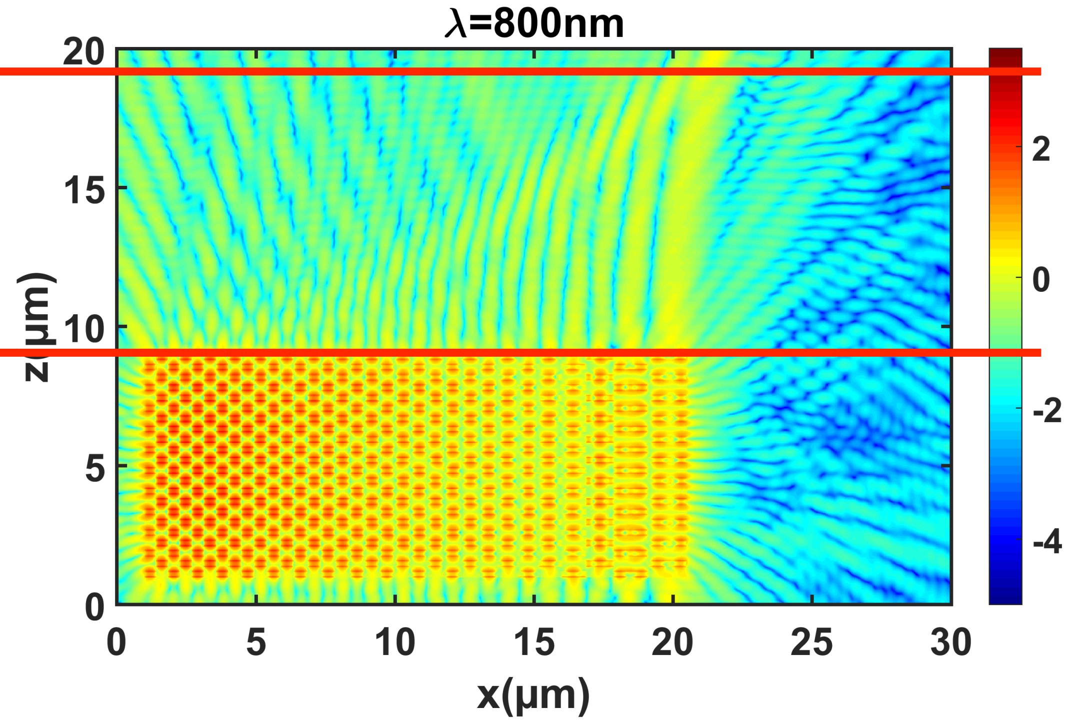


Results

field at farthest point

Propagator $e^{i\gamma y}$

field at grating edge



$$overlap = \left| Re\left[\frac{(\int \vec{\mathbf{E}}_a \times \vec{\mathbf{H}}_s . d\vec{S})(\int \vec{\mathbf{E}}_s \times \vec{\mathbf{H}}_a . d\vec{S})}{(\int \vec{\mathbf{E}}_a \times \vec{\mathbf{H}}_a . d\vec{S})} \right] \frac{1}{Re(\int \vec{\mathbf{E}}_s \times \vec{\mathbf{H}}_s . d\vec{S})} \right|$$

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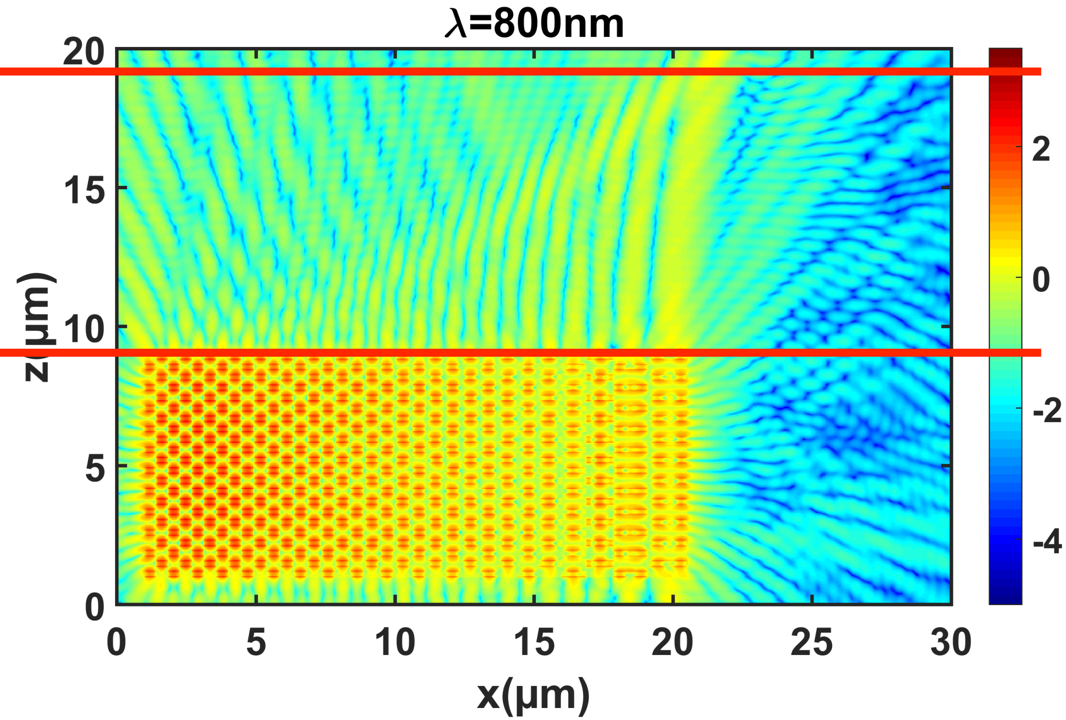

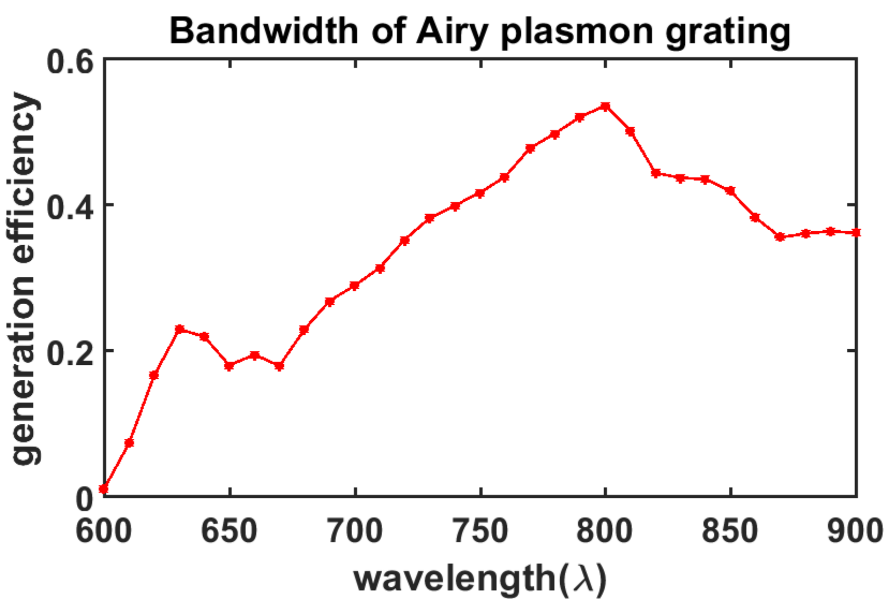

maximum generation efficiency 52 %

Spatiotemporal evolution of Airy plasmon pulse

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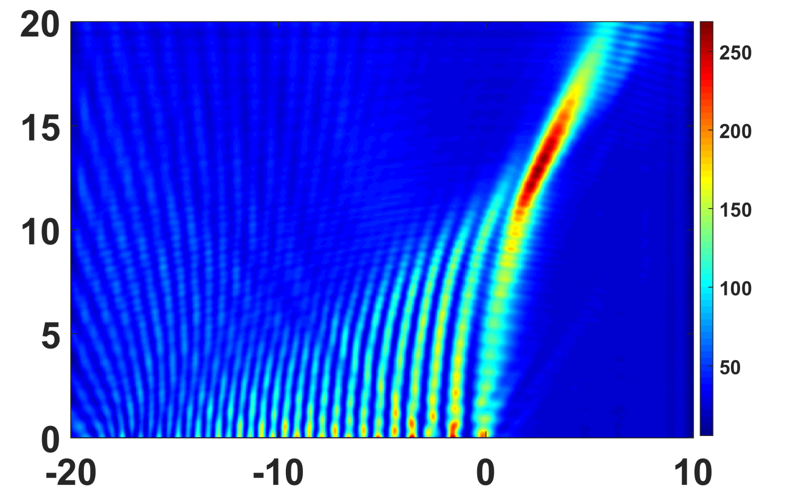
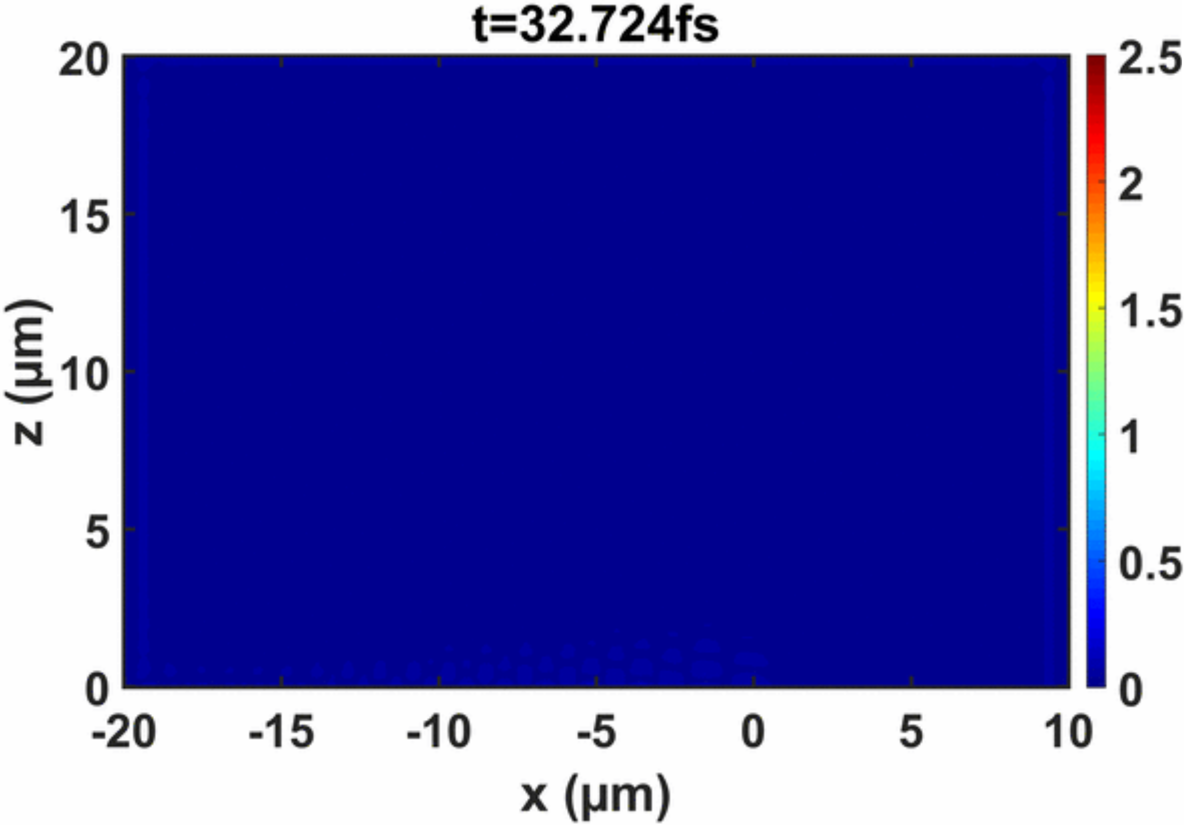
- Source: 20fs Gaussian pulse
- Normal incidence
- Central wavelength 745nm,
- Bandwidth 40nm
- Pulse offset 50fs.
- temporal resolution 0.033fs

Time averaged Intensity of Airy plasmon pulse

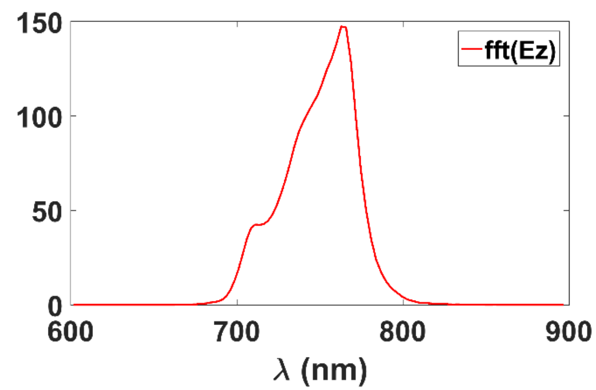
$$Intensity = \int \left[|E_x(x,y,t)|^2 + |E_y(x,y,t)|^2 + |E_z(x,y,t)|^2 \right] dt$$



temporal evolution of Airy bullet



Spectrum of generated Airy plasmon pulse



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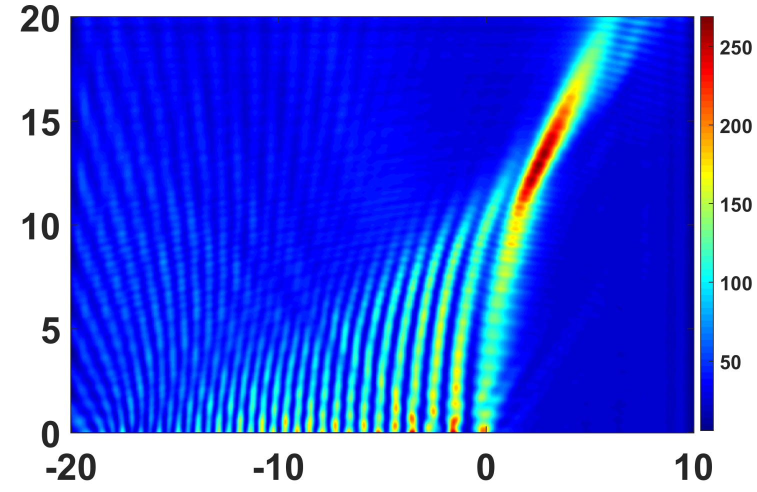

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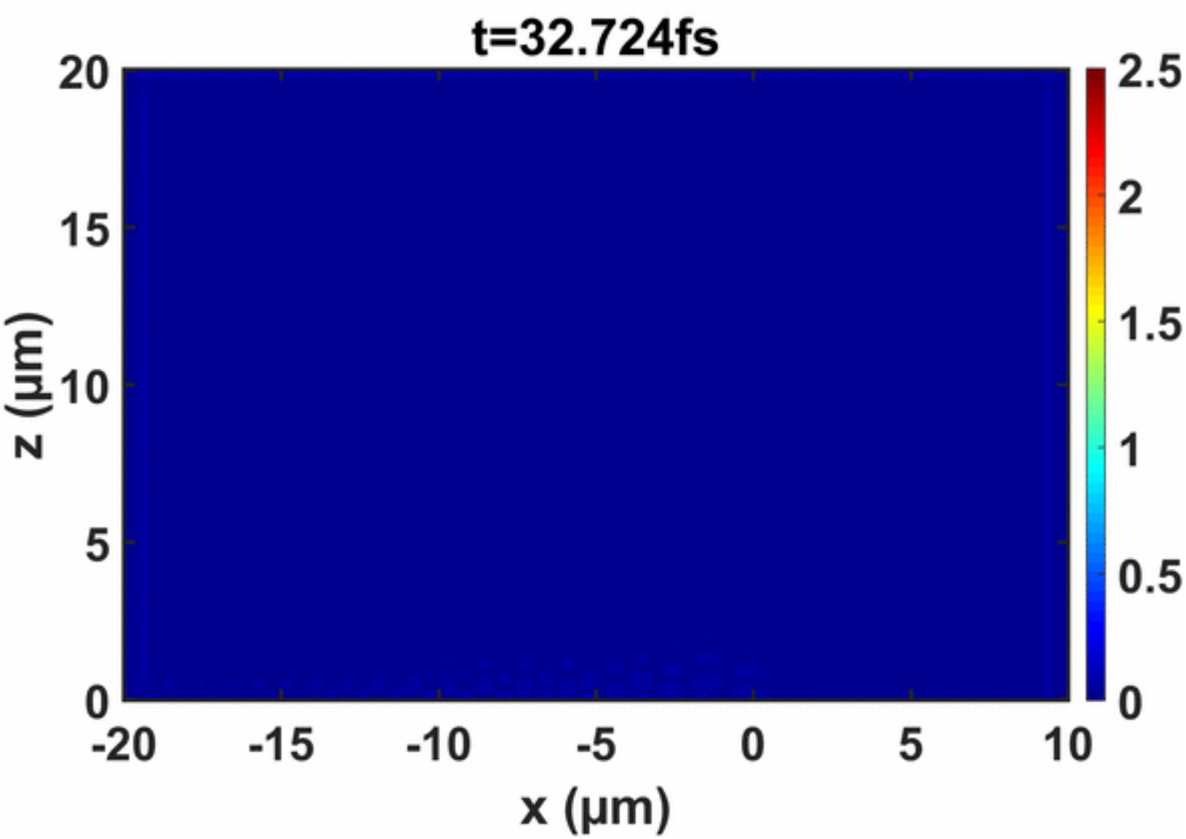

- Does not need diffraction and dispersion equalization
- possible under any dispersion conditions


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