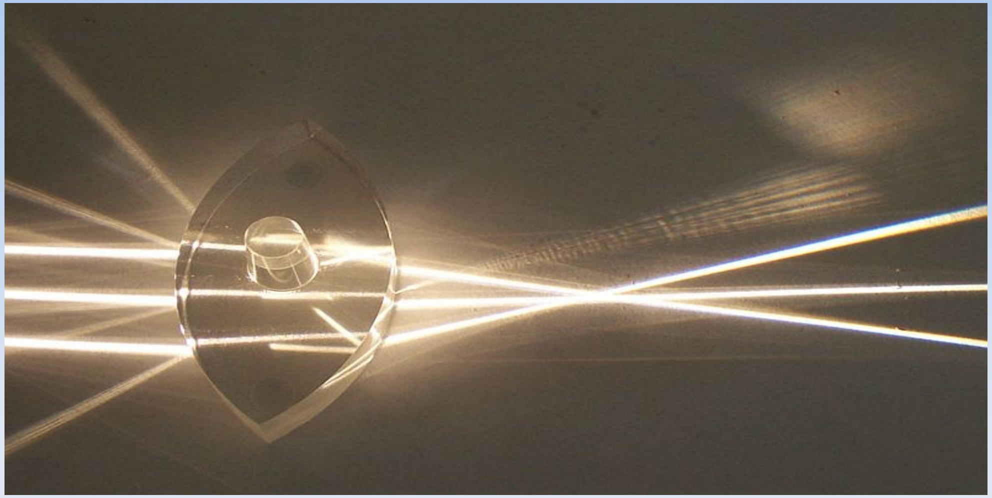
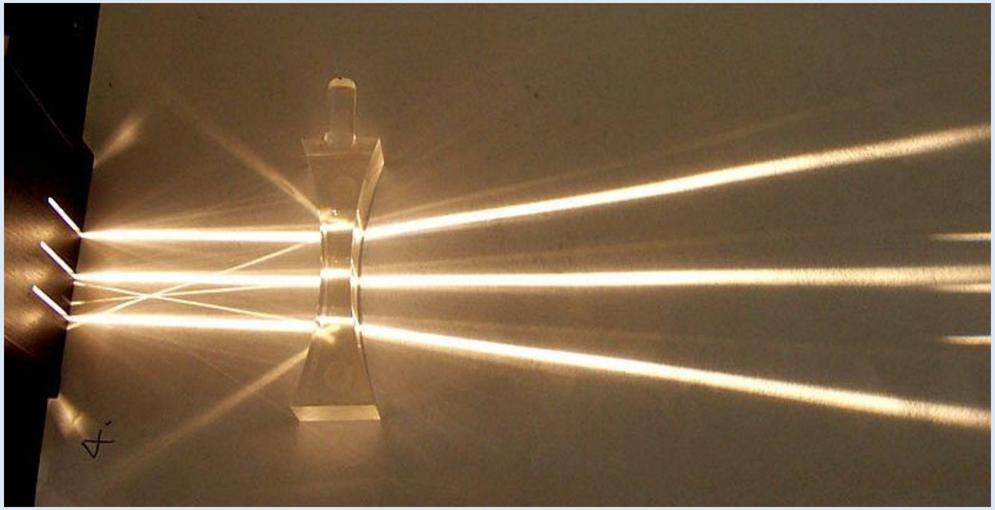
# Super-lenses

By Bernard Landon

# What is a lens ?

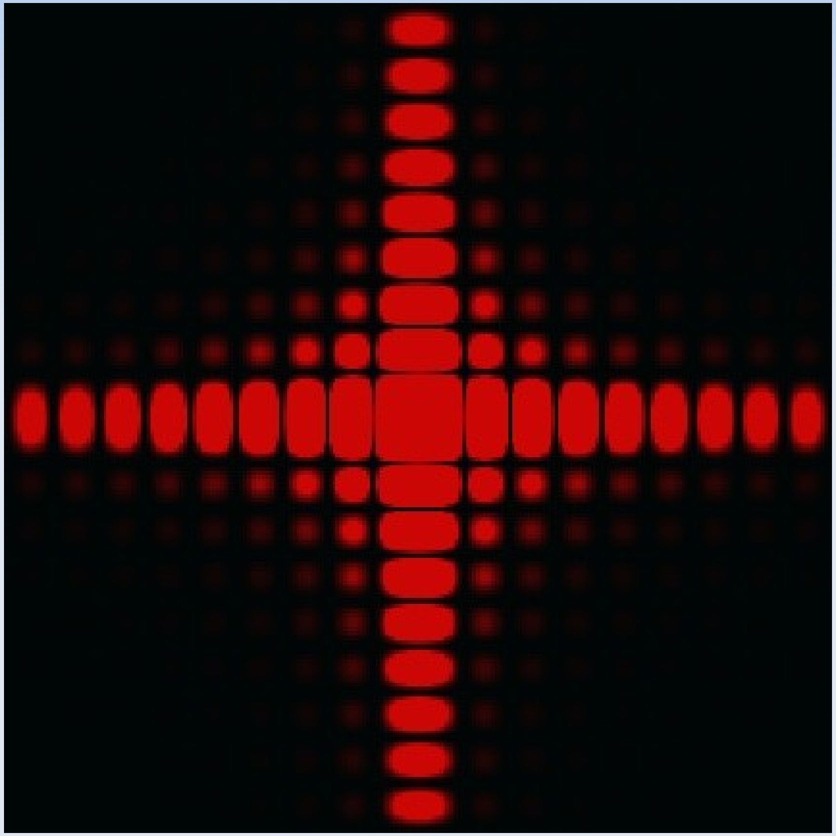
- Optical device
- Focus or diverges light
- Magnifying factor





# Limits

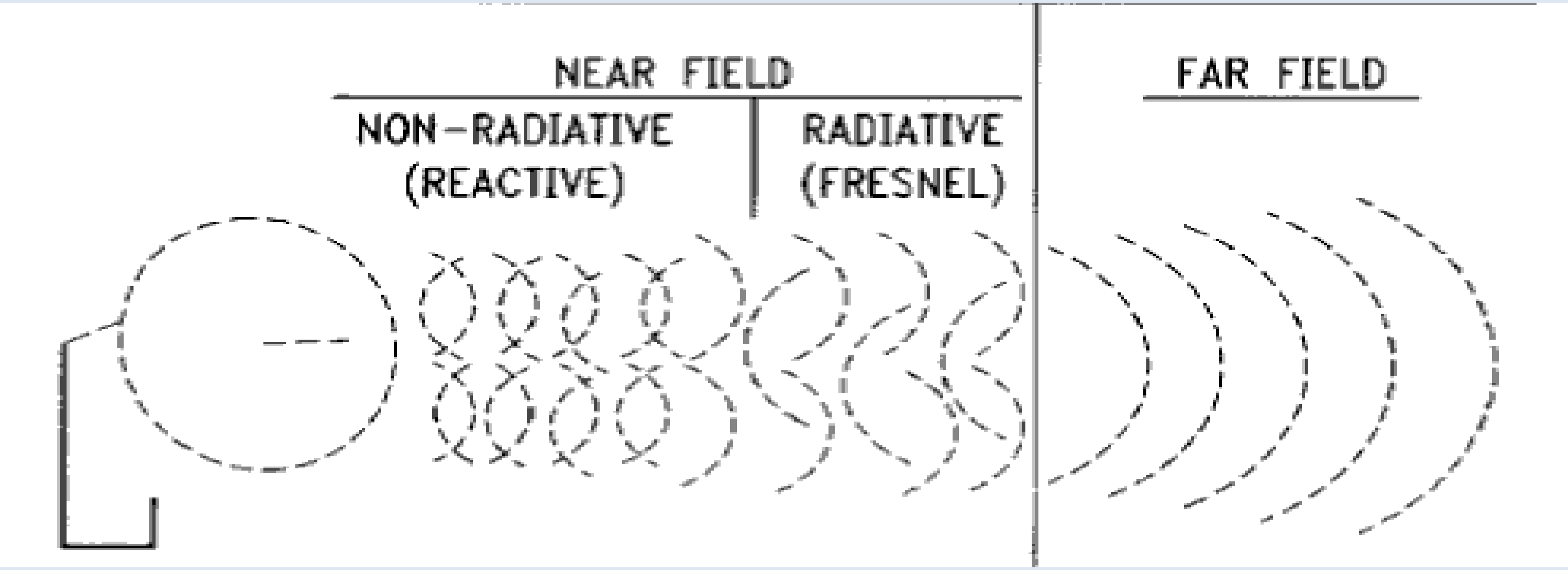
- Aberrations : chromatic, spherical, coma...
- Diffraction : when sizes get really small



# Near and Far field

Emitting source :

- When r >> λ : far field
- When r << λ : near field



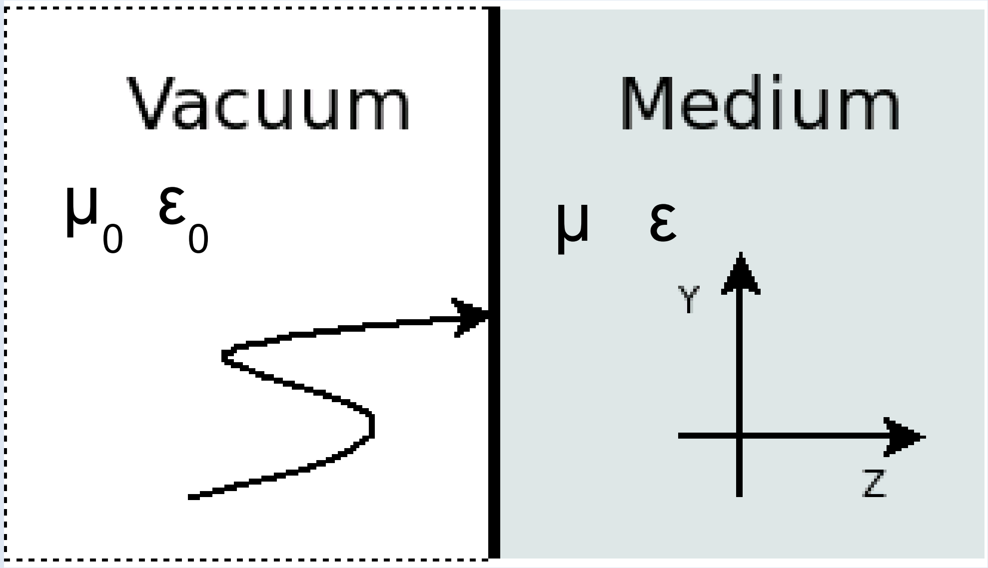
# Wave at an Interface

Incident Electric Field

Wave equation

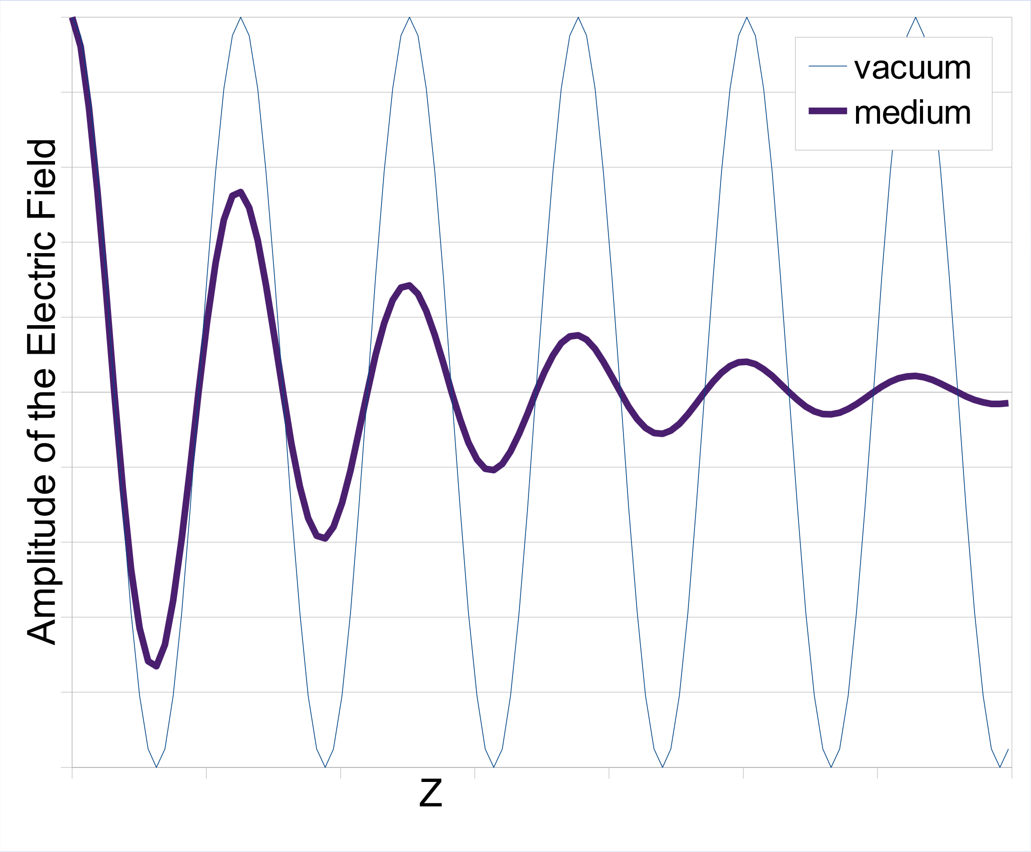
$$k_z = \sqrt{\frac{\mu \epsilon \omega^2}{c^2} - k_x^2 - k_y^2}$$

What happens if $k_y$ and $k_x$ become really big ?



# Amplitude decays

- $K_Z$ becomes complex
- Amplitude decays with z
- Loss of resolution



# Introducing a new material

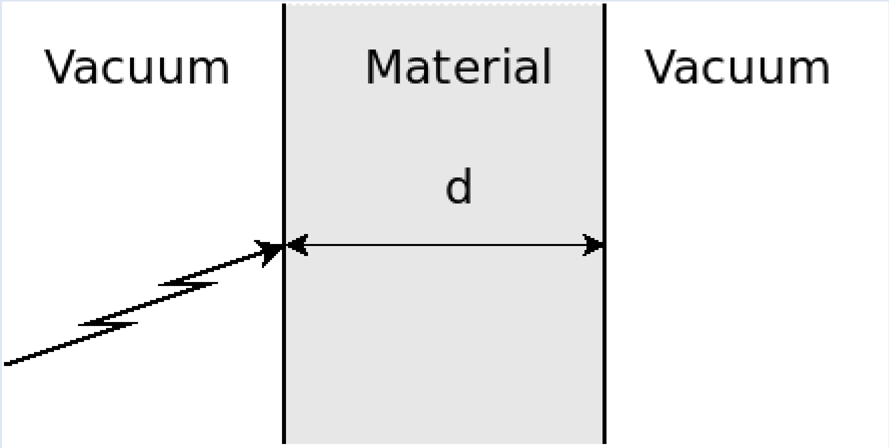
- Suppose a new material
- Permittivity is close to -1
- Permeability is close to -1
- The refraction index is -1

# Example (1/4)

- S polarized light

$$\vec{E}=\vec{E}_{0y}\exp(i k_z z+i k_x x-i w t)$$

- Slab thickness d
- Interface vacuum / slab then slab / vacuum



# Example (2/4)

- Maxwell equations
- Fourier series

$$1+r=t$$

$$\frac{k_z' t}{\mu}=k_z-k_z r$$

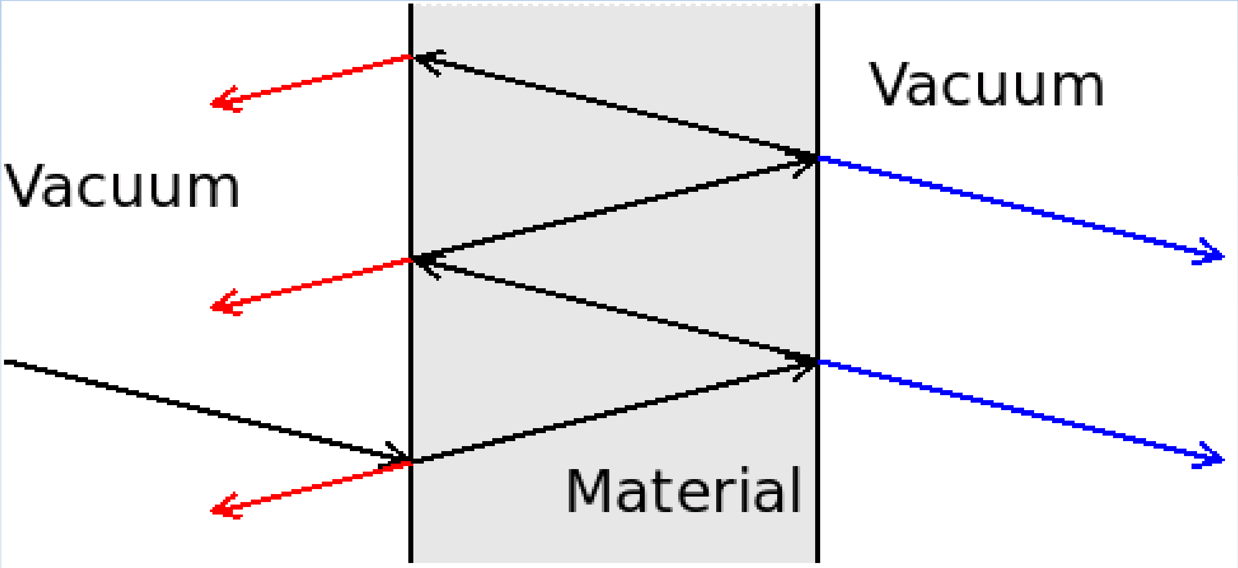
- Transmission coefficient

$$t=\frac{2\mu k_z}{\mu k_z+k_z'} \qquad t'=\frac{2k_z'}{\mu k_z+k_z'}$$

- Reflexion coefficient

$$r=\frac{\mu k_z-k_z'}{\mu k_z+k_z'} \qquad r'=\frac{k_z'-\mu k_z}{\mu k_z+k_z'}$$

# Example (3/4)




- Overall transmission coefficient $T = \exp(-ik_z d)$
- Overall reflexion coefficient $R = 0$

# Example (4/4)

- Overall effect : the decay is compensated !

$$\vec{E} = T_s \vec{E}_{0y} \exp(i k_z d + i k_x x - i w t) = \vec{E}_{0y} \exp(i k_x x - i w t)$$

- Conclusion

  All the waves are transmitted, even the small wavelengths

  Only the physicals limitations prevent a perfect image.

# Nanomaterials

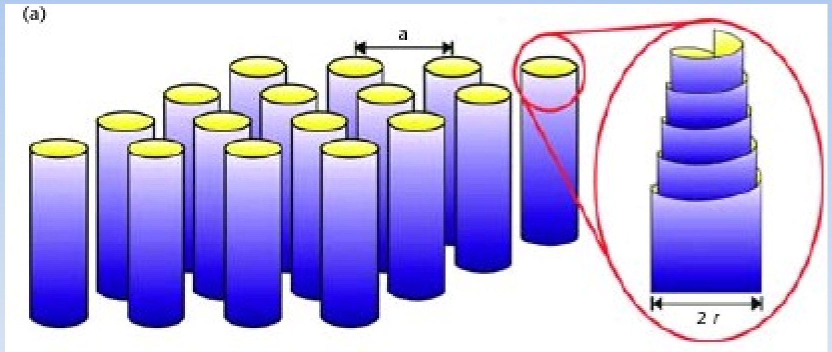
- Man-made materials
- Not found in nature
- Behave like plasmas

$$\epsilon \approx 1 - \frac{\omega_{ep}^2}{\omega^2}$$

$$\mu \approx 1 - \frac{\omega_{mp}^{\;2}}{\omega^2}$$

# Swiss Rolls

- Sheet of conductor
- Coated with an insulator
- Wound around a cylinder

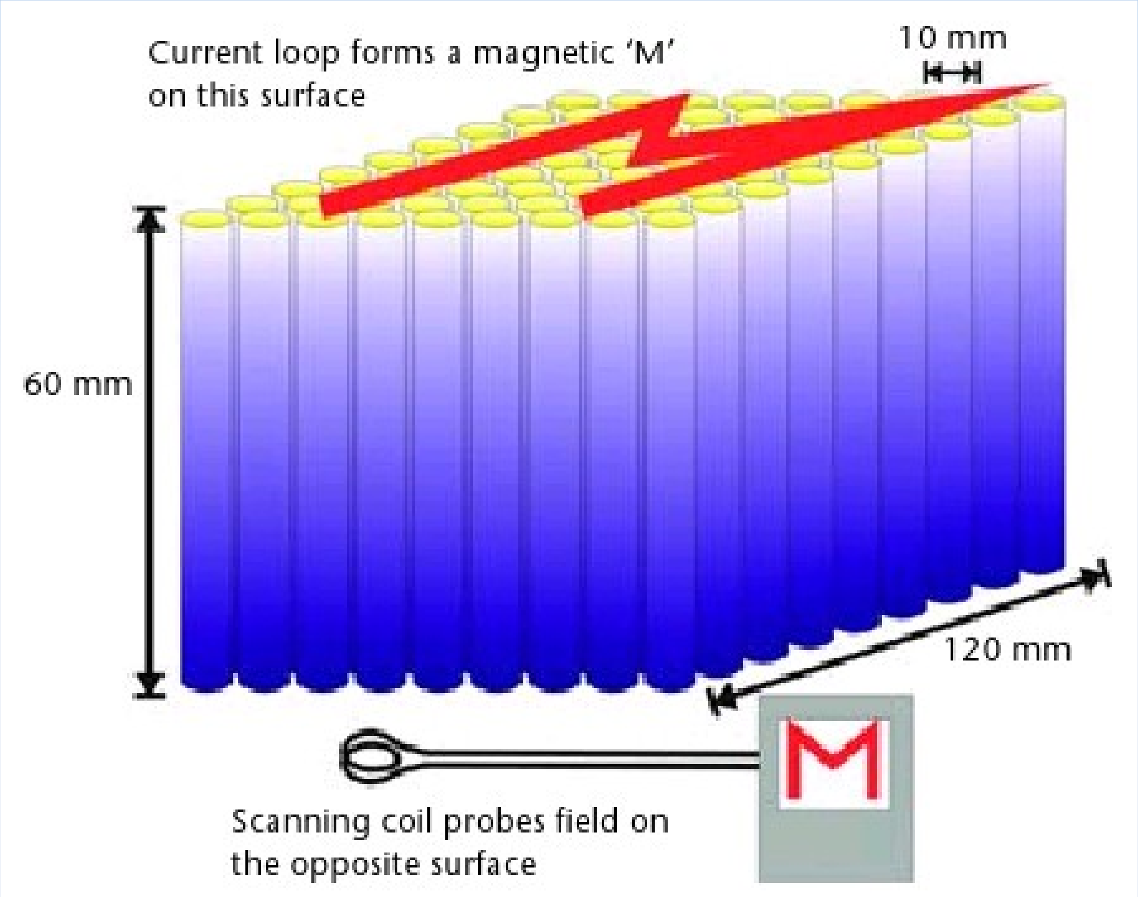



Pictures from J.B Pendry, "Manipulating the Near Field With Metamaterials", Optics & Photonics News, September 2004.

# Experiment of M. Wiltshire

- Magnetic M
- Swiss Rolls

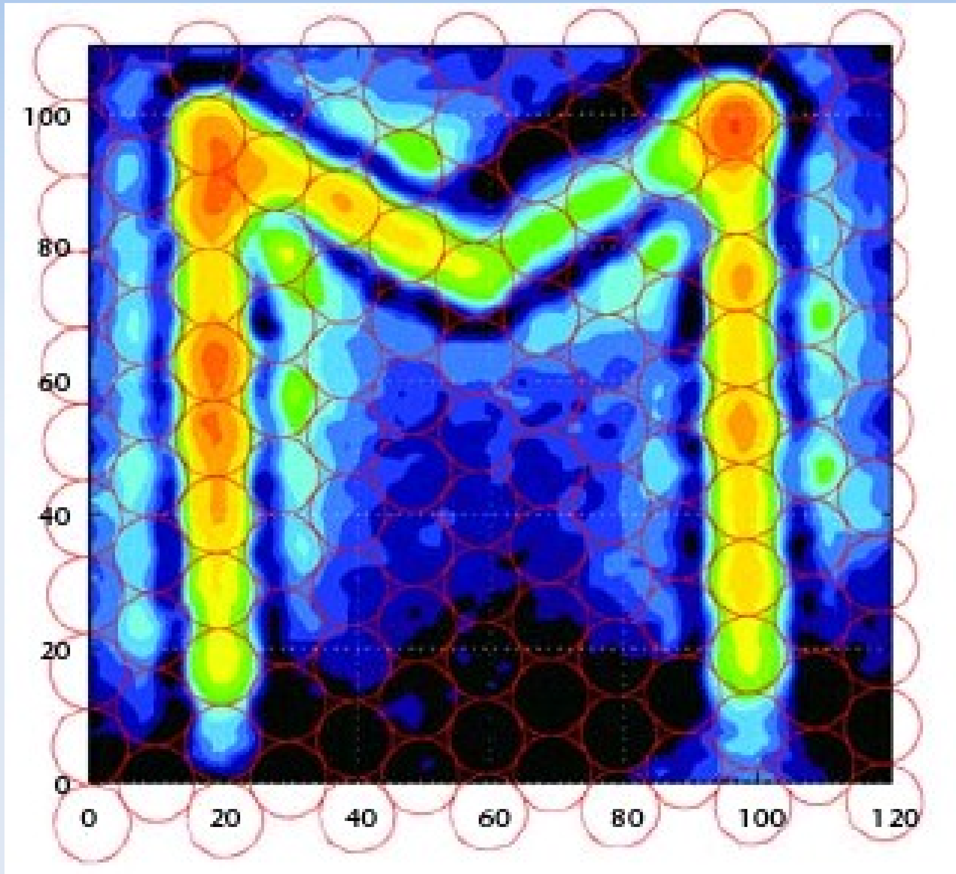
- λ = 15 m
- details = 10 mm




Pictures from J.B Pendry, "Manipulating the Near Field With Metamaterials", Optics & Photonics News, September 2004.

# Results

- D / λ < 1 / 1000
- Here is the result




Pictures from J.B Pendry, “Manipulating the Near Field With Metamaterials”, Optics & Photonics News, September 2004.

# Conclusion

- New field or research
- Enable us to make super-lenses
- Works for a given wavelength in the THz domain