DTU Fotonik
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Graphene Hyperlens for Terahertz Radiation

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Why hyperlens for THz?

- THz applications: biomedical imaging, spectroscopy, defense
- Large wavelength (10-300 μm) – low spatial resolution
- One of subwavelength imaging solutions is **hyperlens** [1] (HL) – lens made of material with hyperbolic dispersion

Why graphene for hyperlens?

- High conductivity and surface plasmon polaritons @ THz
- Ultrathin – truly subwavelength composite structures
- Tunable electromagnetic properties (doping or gate electrode)
- No graphene hyperlens for infrared – THz proposed so far

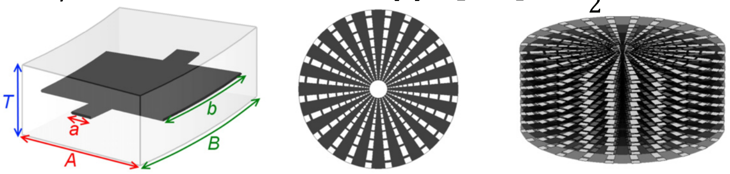
How to design hyperlens?

Hyperlens converts evanescent waves into propagating. It **requires**:

- Hyperbolic dispersion through strong cylindrical anysotropy

$$\frac{\beta^2}{\varepsilon_\theta} + \frac{k_t^2}{\varepsilon_r} = k_0^2 \qquad \varepsilon_r < 0, \varepsilon_\theta > 0$$

- Flat dispersion $\beta(k_t)$
- Small optical losses
- Fabry-Perot condition for thickness [2] $R_2 - R_1 = \frac{m\lambda_{eff}}{2}$



Graphene hyperlens design: properties depend on geometry

How to restore hyperbolic dispersion?

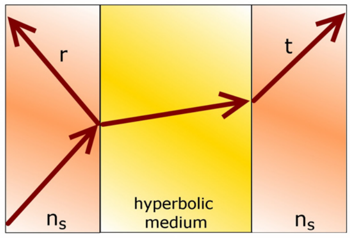
- Simulate reflection and transmission
- Various angles = various k_t
- Wavevector component [3]

$$\beta = \pm\frac{1}{d}\arccos\frac{1-r^2+t^2}{2t} + \frac{2\pi m}{d}$$

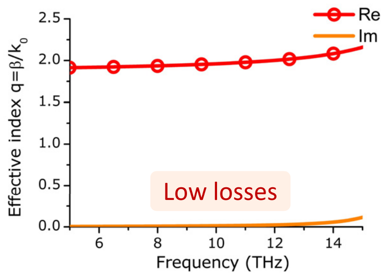
- For each frequency make linear regression + R^2 analysis of

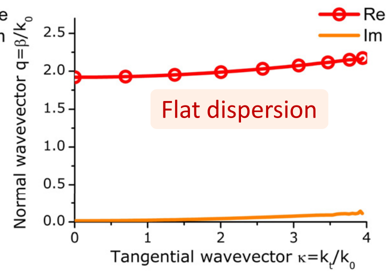
$$\beta^2 = \varepsilon_\theta k_0^2 - \frac{\varepsilon_\theta}{\varepsilon_r}k_t^2$$

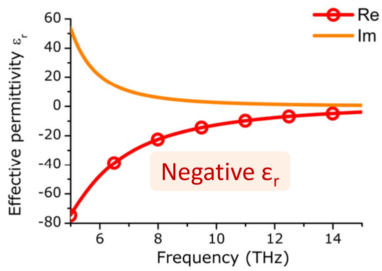
Both propagating and evanescent waves

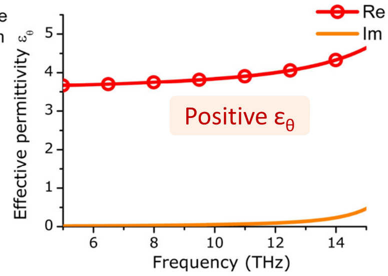


- Effective permittivity tensor + spatial dispersion check





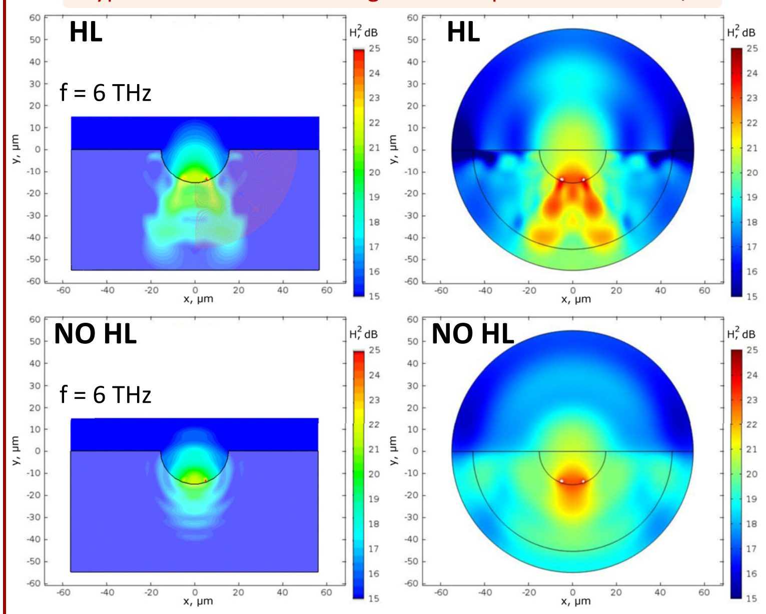




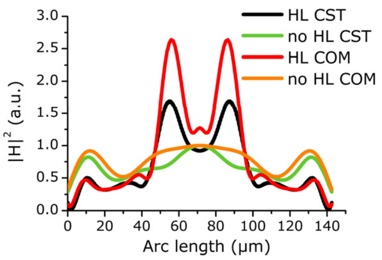
Results

CST 3D full structure vs **COMSOL 2D homogenized**

Hyperlens resolves and magnifies two point sources at λ/5

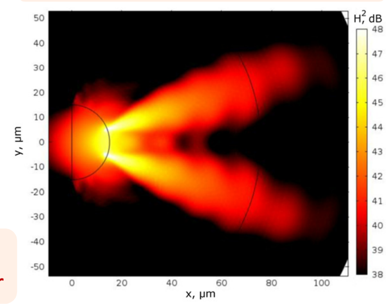


Perfect agreement between 3D and homogenized 2D simulations



Two point sources at λ/5 are well resolved with HL + intensity is larger

Thicker HL – larger magnification



Conclusions

- First numerical demonstration of graphene hyperlens for THz
- We proposed simple hyperbolic medium characterization method
- We showed that homogenized 2D simulations are as accurate as 3D full-size structure simulations: simple to design graphene hyperlens

References

[1] Z. Jacob, L. V. Alekseyev, and E. Narimanov, OE 14, 8247-56 (2006).

[2] M. Silveirinha, P. Belov, and C. Simovski, PRB 75, 035108 (2007).

[3] C. Menzel, C. Rockstuhl, T. Paul, et al., PRB 77, 195328 (2008).

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