Reflectionless Evanescent Wave Amplification by Two Dielectric Slabs

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Outline

- Negative Index of Refraction
- Physics of Evanescent Wave Amplification
- Dielectric Slabs
- Simple example
Veselago: Negative Refraction

\[ n = -1 \]

\[ n > 1 \]
$n = -1$

$\varepsilon < 0$

$T \to \exp(-ikzd), \quad R \to 0$  \quad (1)
Importance of Low Loss

Power in

Power reflected/absorbed

Power lost

Power extracted = Power in
- Power reflected/absorbed
- Power loss
One Dielectric Slab

\[ \tau = \frac{tt' \exp(ik'_z a)}{1 - r'^2 \exp(2ik'_z a)} \]
\[ \Gamma = r + \frac{tt' r' \exp(2ik'_z a)}{1 - r'^2 \exp(2ik'_z a)} \]

\[ \tau \to \infty \text{ and } \Gamma \to \infty \text{ if } r'^2 \exp(2ik'_z a) \to 1 \]
The Problem of Multiple Evanescent-Wave Reflections

Power reflected/absorbed

Power in

Object

\[ n > 1 \]

Detector

Power extracted

\[ \tau \to \infty \text{ and } \Gamma \to \infty \text{ if } r''^2 \exp(2ik'_za) \to 1 \]  (4)
Ideal Negative Index of Refraction Behaviour

\[ T = 1, \quad R = 0. \]
Two Dielectric Slabs

\[ R = \Gamma + \frac{\tau^2 \Gamma \exp(2ik_zd)}{1 - \Gamma^2 \exp(2ik_zd)} = 0, \quad T = \frac{\tau^2 \exp(ik_zd)}{1 - \Gamma^2 \exp(2ik_zd)} = -\exp(-ik_zd) \quad (6) \]

for some \( k_x \).
Correct Derivation

Let

\[ R = \Gamma + \frac{\tau^2 \Gamma \exp(2ikzd)}{1 - \Gamma^2 \exp(2ikzd)} = 0. \]  \hspace{1cm} (7)

Neglect the case where \( \Gamma = 0 \),

\[ \tau^2 = \Gamma^2 - \exp(-2ikzd). \]  \hspace{1cm} (8)

Given Eq. (8), the transmission coefficient \( T \) is always

\[ T = \frac{\tau^2 \exp(ikd)}{1 - \Gamma^2 \exp(2ikzd)} = -\exp(-ikzd). \]  \hspace{1cm} (9)
Does $R$ go to zero at all?

Let $\lambda = 230$ nm, $n = 2.7$ (diamond), $a = 20$ nm, $d = 20$ nm, TE polarization,
Simple Example Including a Source and a Detector

λ = 230 nm, n = 2.7, a = 20 nm, d = 20 nm, TE polarization,

Source

"Detector"

![Graph showing magnification and intensity distribution](image-url)
Conclusion

- Low loss
- many modes
- High refractive index material available (transparent down to $\lambda = 230$ nm, $n = 2.7$ for diamond)
- non-contact imaging, suitable for lithography and bio-imaging