Comment on “Left-Handed Materials Do Not Make a Perfect Lens”

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In a recent Physical Review Letter [1] Garcia and Nieto Vesperinas (GNV) dispute the claim of perfect lensing made in [2]. GVN claim that the solutions proposed in [2] imply infinite energy density and are therefore inadmissible. They also claim that finite absorption leads to catastrophic collapse of the amplifying solutions vital to focussing. GVN calculate in equation (6) of their Letter the electric fields for amplifying solutions vital to focussing. GVN calculate the field in the vacuum, discontinuous at each surface of the slab. Secondly, two examples. Firstly the parallel electric field is polarised light, transverse wave vector $k_i$, incident on a slab of negatively refracting material. (The surfaces of the slab lie in the $xy$ plane and the electric field is assumed to lie along the $x$ axis.)

Note that equation (6) contains several errors. I give two examples. Firstly the parallel electric field is transverse wave vector $k_i$, incident on a slab of negatively refracting material. (The surfaces of the slab lie in the $xy$ plane and the electric field is assumed to lie along the $x$ axis.)

Clearly even infinitesimally small absorption prevents any divergence in this limit: 

$$\lim_{k_i \to \infty} E(z > 0) = \lim_{k_i \to \infty} \left[ A^{(t)}(z) e^{-Kz} 0 0 \right] e^{ik_iy - K(z - d)}$$

where $z_0$ is the location of the source, $K_i = \sqrt{k_i^2 - k_0^2}$, and the dielectric function $\varepsilon = -1 + i \varepsilon_i$. Which implies that fields in this region decay monotonically towards the interface. This solution is consistent with causality which requires that the reflected wave decays in the opposite direction to the incident wave. Causality which requires that the reflected wave decays in the interface. This solution is not consistent with GVN’s claim that the solutions proposed in [2] imply infinite energy density and are therefore inadmissible. They also claim that finite absorption leads to catastrophic collapse of the amplifying solutions vital to focussing. GVN calculate in equation (6) of their Letter the electric fields for amplifying solutions vital to focussing. GVN calculate the field in the vacuum, discontinuous at each surface of the slab. Secondly, two examples. Firstly the parallel electric field is polarised light, transverse wave vector $k_i$, incident on a slab of negatively refracting material. (The surfaces of the slab lie in the $xy$ plane and the electric field is assumed to lie along the $x$ axis.)

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Equation (6) of GVN shows a divergence in this limit but, in contrast, the correct result is finite:

$$\lim_{\varepsilon \to 0, \mu \to 0} E(z > d) = \lim_{\varepsilon \to 0, \mu \to 0} \left[ A^{(t)}(z) e^{-Kz} 0 0 \right] e^{ik_iy - K(z - d)}$$

$$\times \frac{-4e^{-Kz}K_d}{\left(i\mu_i + i\frac{k_0^2}{2K_i^2}(\varepsilon_i + \mu_i)\right)^2} = 0$$

What of the limit $\lim \varepsilon \to -1, \lim \mu \to -1$ taken at finite $k_i$? Equation (6) of GVN shows a divergence in this limit but, in contrast, the correct result is finite:

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$$\times \frac{-4e^{-Kz}K_d}{\left(i\mu_i + i\frac{k_0^2}{2K_i^2}(\varepsilon_i + \mu_i)\right)^2}\left(i\mu_i + i\frac{k_0^2}{2K_i^2}(\varepsilon_i + \mu_i)\right)^2 = 0$$

Clearly this gives the desired lensing solution with amplification of the incident wave field. This solution is valid provided that,

$$4e^{-Kz}K_d > \left(i\mu_i + i\frac{k_0^2}{2K_i^2}(\varepsilon_i + \mu_i)\right)^2$$

which sets a natural limit to the largest value of $k_i$ giving rise to an amplified solution, see [4], and hence a limit to the resolution. In principle by making absorption sufficiently small the resolution can be increased to be as large as desired without causing any divergences in the wave field. The disagreement with GVN arises from a combination of algebraic error, and neglect of causality.

REFERENCES