Self-induced microwave sink via plasma generation

Benjamin Fromont[1,2], Romain Pascaud[2], Antoine Saucourt[2], Olivier Pascal[1], Jérôme Sokoloff[1], Laurent Liard[1], Théo Delage[3], Nicolas Lebbe[1], Julien De Rosny[4], Mathias Fink[4], Valentin Mazières[2]

[1] LAPLACE, 118 route de Narbonne 31062 Toulouse
benjamin.fromont0911@gmail.com
[2] ISAE-SUPAERO, 10 Av. Edouard Belin, 31400 Toulouse
[3] ENAC, 7 Av. Edouard Belin, 31400 Toulouse
[5] Langevin Institute, 1 Rue Jussieu, 75005 Paris

Abstract

Recently, various methods for sub-wavelength wave focusing have been proposed [1, 2]. In optics, this involves placing nanoparticles at the focal spot to act as sinks, enabling the excitation of Localized Surface Plasmons (LSPs). This leads to wave absorption via Coherent Perfect Absorption (CPA), achieving subwavelength focusing [1, 2]

We introduce a "self-induced" sink that does not require an initial sink at the focal point. Instead, the converging wave itself generates it. Inspired by recent works showing that time reversal can focus microwaves intensely enough to ionize gas and create plasma [3], we numerically demonstrate that plasma formed by microwave focusing can act as an electromagnetic sink. The CPA condition is met via LSP excitation, which occurs in the microwave regime due to the low plasma frequency [4]. The nonlinear nature of plasma breakdown enables this self-induced sink.

A BOR-FDTD (Body Of Revolution Finite Difference Time Domain) simulation was developed to describe this effect. A 40 ns pulse at 2.45 GHz (transverse magnetic TM) is focused at $r = 0$ with angular momentum $m = 1$, exciting LSPs. Fig. 1 shows the diffracted electric field evolution with (red) and without (blue) plasma generation. Fig. 2a presents a Bessel-like field distribution, characteristic of converging and diverging waves, with a focal length $d \approx \lambda/2$. In contrast, Fig. 2b reveals that under suitable conditions, LSP excitation alters the field distribution, creating a "swirling" effect due to the presence of only the converging wave. This results in an intensification of the electric field at the focal point and a focal length that contracts to $d \approx \lambda/10$. We will present the principle of a plasma-based microwave sink before presenting the results obtained for the self-induced sink.

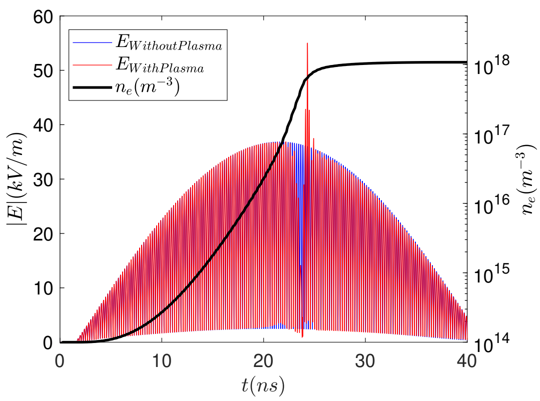
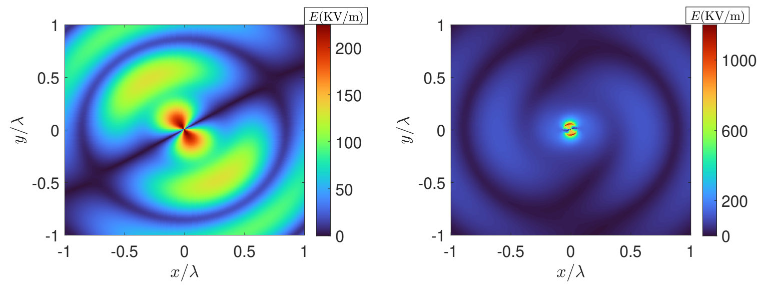


Figure 1: Evolution of the diffracted field without (blue) and with (red) plasma and electron density n_e (black) as a function of time at $r = \lambda/2$.



(a) Before the sink is formed at $t =$ 14 ns.

(b) When the sink is formed at $t =$ 21 ns.

Figure 2: Spatial distribution of the modulus of the electric field.

References

[1] H. Noh *et al.*, "Perfect coupling of light to surface plasmons by coherent absorption," *Physical review letters*, vol. 108, no. 18, p. 186805, 2012.

[2] ——, "Broadband subwavelength focusing of light using a passive sink," *Optics Express*, vol. 21, no. 15, pp. 17 435–17 446, 2013.

[3] V. Mazieres *et al.*, "Plasma generation using time reversal of microwaves," *Applied Physics Letters*, vol. 115, no. 15, 2019.

[4] A. Rider *et al.*, "Plasmas meet plasmonics: Everything old is new again," *The European Physical Journal D*, vol. 66, pp. 1–19, 2012.