

## Dragging and amplifying light with space-time metamaterials

**P.A. Huidobro<sup>1,3</sup>, M.G. Silveirinha<sup>1</sup>, E. Galiffi<sup>2</sup> and J.B. Pendry<sup>2</sup>**

<sup>1</sup>Instituto de Telecomunicações, Instituto Superior Tecnico-University of Lisbon, Avenida Rovisco Pais 1, Lisboa, 1049-001 Portugal

<sup>2</sup>The Blackett Laboratory, Department of Physics, Imperial College London, London, SW7 2AZ

<sup>3</sup>p.arroyo-huidobro@lx.it.pt

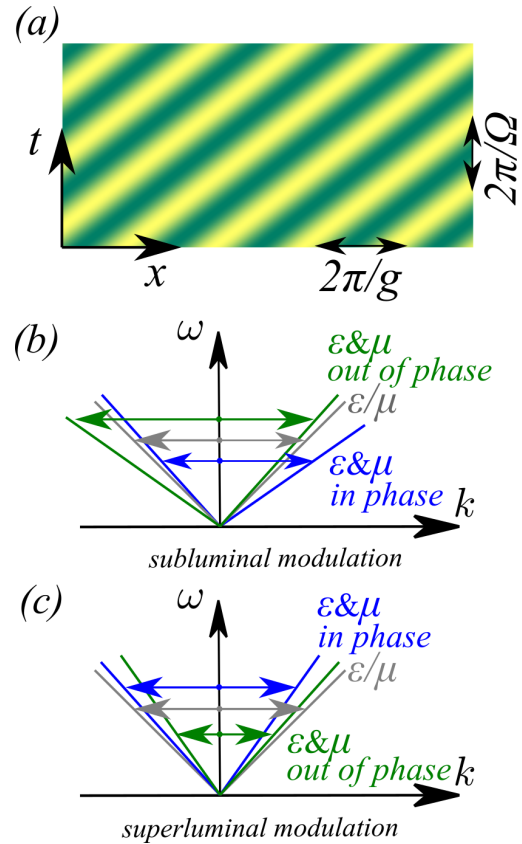
### Abstract

In this talk I will consider space-time metamaterials of travelling-wave type and introduce the theory of homogenisation of these modulated media [1]. This framework provides analytical expressions for the effective permittivity, permeability and magnetoelectric coupling of these media in the long wavelength limit. From the derived parameters we will see how it is possible to achieve nonreciprocal effects away from the asymmetric band gaps, and even down to the quasistatic limit if both the permittivity and permeability are modulated, and how the synthetic motion present in these systems allow us to make a link to the Fresnel drag effect of light in moving media [2].

Our theory also unveils a regime when the modulation speed approaches that of waves in the background medium where homogenisation breaks down and a new mechanism for gain emerges [3], enabling a form of nonreciprocal broadband amplification that could be realised in graphene [4], or that could be chirally selective by implementing an Archimedes screw for light [5].

### References

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- [3] Pendry, J. B., Galiffi, E., & Huidobro, P. A. (2021). Gain mechanism in time-dependent media. *Optica*, 8(5), 636-637.
- [4] Galiffi, E., Huidobro, P. A., & Pendry, J. B. (2019). Broadband nonreciprocal amplification in luminal metamaterials. *Physical review letters*, 123(20), 206101.
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(a) Sketch of space-time modulation of the permittivity and/or permeability of travelling wave kind. (b,c) The long wavelength dispersion relation of the electromagnetic modes is nonreciprocal if both the permittivity and permeability are modulated, and the sign and magnitude of the bianisotropic coupling can be tuned with the modulation parameters, e.g. by modulating the permittivity and permeability in or out-of phase, and by modulating at speeds larger or smaller than the speed of light in the medium. Reproduced from [1].

