Light propagation in slow group velocity media

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Since the first observation of coherent population trapping (CPT) and electromagnetically induced transparency (EIT) by Alzetta *et al.* in the late 1970s [1], light propagation in coherently driven atomic gases has been an extremely active field thanks to the unique effects which can be observed, e.g. light propagation with velocities as slow as a few meters per second as well as its coherent storage [2, 3].

In the first part of the talk, we shall give a brief overview on the optical properties of this peculiar class of optical media; a special emphasis will be devoted to the discussion of basic points such as the physical origin of the EIT effect and its consequences on the dielectric constant of the medium; different regimes in which the group velocity is slow and positive or slow and negative [4] will be identified.

Some recent work of the Paris-Firenze-Pisa collaboration will then be presented; in the last months, our attention has been concentrated on issues related to the light propagation in moving media: thanks to the extremely slow value of v_g in EIT media, the magnitude of Fresnel drag effects [5] is strongly enhanced with respect to standard, weakly dispersive, materials and qualitatively new effects have been predicted. For example, if a light beam is normally incident on a transversally moving slab of slow v_g material, the light beam results transversally displaced [6]. If v_g is slow and positive, this *transverse Fresnel drag* is in the *downstream* direction with respect to the slab motion; if v_g is instead slow and negative, the drag is instead in the *upstream* direction. An experimental observation of such an upstream drag would finally resolve a longstanding debate [7] about the possibility of observing such a counterintuitive effect.

Apart from their intrinsic interest from the conceptual point of view, effects of this kind can also be useful as a diagnostic tool in cold atoms experiments, since they allow to image the current density profile of the sample; in this way, not only extremely slow drift velocities can be detected, but even topological excitations which are located deep in the interior of the sample. Simulations have been performed for the specific case of a curved vortex in a rotating Bose condensate: in this geometry, differently from standard methods, dispersive imaging in a EIT regime is able to clarly detect not only the presence of the vortex, but also to determine the shape of the vortex core.

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[1] G. Alzetta, A. Gozzini, L. Moi, and G. Orriols, Nuovo Cimento **36**B, 5 (1976); G. Alzetta, L. Moi, and G. Orriols, Nuovo Cimento **52**B, 209 (1979)

[2] E. Arimondo in *Progress in Optics XXXV*, ed. by E. Wolf (Elsevier Science, 1996), pag.257

[3] A. B. Matsko *et al.*, Adv. At. Mol. and Opt. Phys., **46**, 191 (2001)

[4] M. Artoni, G. C. La Rocca, F. S. Cataliotti, and F. Bassani, Phys. Rev. A **63**, 023805 (2001)

[5] M. Artoni, I. Carusotto, G. C. La Rocca, and F. Bassani, Phys. Rev. Lett. **86**, 2549 (2001)

[6] R. V. Jones, Proc. Roy. Soc. London A **328**, 337 (1972); R. V. Jones, Proc. R. Soc. London A **345**, 351 (1975); M. A. Player, Proc. Roy. Soc. London A **345**, 343 (1972); G. L. Rogers, Proc. Roy. Soc. London A **345**, 345 (1972);

[7] I. Lerche, Astroph. Journ. **187**, 589 (1974); H. C. Ko and C. W. Chuang, Astroph. Journ. **222**, 1012 (1978); H. C. Ko, Astroph. Journ. **231**, 589 (1979)