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Comments on 'Electromagnetic Surface Waves in a Relativistic Magnetized Plasma Propagating in a Cylindrical Column' Applied Physics Research 16, 6 (2024)

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Abstract

The dispersion relations of electromagnetic surface waves in a magnetized relativistic beam propagating in a cylindrical column surrounded by vacuum have been recently derived by Lee, 2024, using relativistic fluid equations. We would like to draw attention to an important body of work to study the problem of electromagnetic surface waves propagating at the surface of a relativistic beam, both in a cylindrical column and in cartesian geometry, and both in the absence and in the presence of an external magnetic field of arbitrary intensity.

Keywords: surface waves, relativistic beams, dispersion relations

In a recent publication by Lee, 2024, the dispersion relations of electromagnetic surface waves in a magnetized relativistic plasma propagating in a cylindrical column and surrounded by vacuum has been derived by means of the relativistic fluid equations. Lee, 2024, mentions in the introduction the complexity of the equations and different approximations used in his derivation of the dispersion relations, like assuming a cyclotron frequency much smaller than the relativistic Doppler-shifted frequency of the wave. We would like to draw attention to an important body of work to study the problem of electromagnetic surface waves propagating at the surface of a relativistic beam, both in a cylindrical column and in cartesian geometry, and both in the absence and in the presence of an external magnetic field of arbitrary intensity. We start with the case without an external magnetic field. Lee, 2024, mention the work of Shoucri, 1999 in cartesian geometry. We have also the work of Shoucri and Gagné, as early as 1977 (the dispersion relation in Eq. (14) in this work is the same as Eq. (100) in Lee, 2024). The dispersion relation for a relativistic electron beam in a dielectric-lined waveguide is presented in cylindrical geometry in Shoucri, 1983, where the problem of the beam surface wave is also discussed. The interaction of the beam surface wave with the electromagnetic wave in the slow wave structure of the waveguide leads to the generation of microwaves. If the dielectric is replaced by vacuum, then Eq. (38) in Shoucri, 1983, is identical to Eq. (89) in Lee, 2024. Some of the results without magnetic field mentioned above have been extended to a situation when a weak magnetic field is present in the recent work of Lee, 2024. An important step in the derivation of these dispersion relations is the boundary condition at the beam surface, applied in all the above-mentioned literature, to calculate the discontinuity of the wave electric field component normal to the beam surface. This boundary condition has been carefully revisited in Shoucri, 2004. We verified that the boundary condition for the wave electric field component normal to the beam surface, which we derive directly from Maxwell's equations (see for instance Shoucri, 1977, 1999), agree with the results obtained from the definition of a polarisation charge and current at the beam surface, as defined by Bobroff (1959). We have these two different methods analyzed in Shoucri, 2004, leading to the same result, a very good confirmation for the method we have been using.

Lee 2024, has extended, as mentioned above, some of the results obtained without magnetic field to include the presence of a small cyclotron frequency. He mentions in his introduction the complexity of the equations, and different approximations used in his derivation of the dispersion relations, like assuming a cyclotron frequency much smaller than the relativistic Doppler-shifted frequency of the wave. The full solution for the problem of the relativistic beam-plasma system in cylindrical geometry with a cyclotron frequency of arbitrary value, has been derived and studied in several publications (Kitsenko and Shoucri, 1968, Shoucri and Kitsenko, 1968b, for a cylindrical geometry, and Shoucri and Kitsenko, 1968a. for a slab geometry). In the case of a slab planar geometry, we have studied the instability created in a planar structure by surface waves at the two edges of a nonrelativistic beam layer, surrounded by plasma on each side of the beam, the plasma in this sandwich structure acting as a slow wave structure propagating an electromagnetic wave. The application has been done for helicon waves propagating in solid-state plasma, this entire sandwich structure working as a solid-state Traveling Wave Tube. The idea of such device has been studied at Bell Laboratories by Baraff and Buchsbaum 1966. This would allow the amplification of helicon waves propagating in the plasma by the surface wave of the drifting carriers. The beam is non-relativistic since we are dealing with carriers in solid-state plasma. This instability is intrinsically connected with the presence of the surface wave of the carriers at the carriers-plasma boundaries. These results were extended to a cylindrical geometry by Shoucri, 1969. We mention also the experimental results at Princeton University by Bayless, Hooke and Sudan, 1969, were the interaction between the carriers and the electric field of helicon waves in a semiconductor (InSb) in a cylindrical geometry, has been observed, when the wave phase velocity approximately equals the carriers' velocity. In solids, the establishment of large drift of the carriers is not easy since it is then accompanied by large heat dissipation. However, with the nowadays development of superconductors, and the possibility of their applications to generate electromagnetic waves, we have here a very interesting problem to be revisited.

Competing interests

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal and publisher adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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