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Interaction of electromagnetic waves with a moving perturbation in a stationary gas

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Abstract. We consider the problem of an electromagnetic wave, incident on a relativistically moving electromagnetic signal, which perturbs the energy levels of a stationary gas. The energy levels are Stark shifted by an impulse of voltage propagating along a parallel wire line. The reflection coefficient pertaining to this situation is obtained, as well as the frequency shift of the reflected wave. The results might be relevant in the search for new generators in the far infrared and for the understanding of the electromagnetic theory of moving media.

1. Introduction

In a recent experiment, Granatstein *et al* (1976) were able to produce intense pulses of 8 mm radiation by reflecting an incident 3 cm microwave pulse off the front of a relativistic electron beam, which played the role of a moving mirror. A relativistic mirror can also be obtained if, instead of an energetic electron beam, one uses a fast electromagnetic pulse which modifies the internal structure of a stationary gas, and some theoretical work has been achieved on this alternative approach. Previous work in the field includes that of Lampe *et al* (1978) concerning the interaction of electromagnetic waves with a moving ionisation or recombination front, and also that of one of us (Mendonça 1979), in which the moving front is that of an intense electromagnetic beam which nonlinearly changes the dielectric constant of a fully ionised plasma. A qualitatively new phenomenon appears in this case—the nonlinear collision of two electromagnetic pulses—which is the cause of the frequency upshifting of the reflected signal.

The present work is devoted to the analysis of the reflection from a different kind of front, which can occur in a stationary non-ionised gas which is suddenly submitted to an electrostatic field. Imagine a gas-filled dielectric tube placed between the two parallel plates of a transmission line, forming a long (say, a 1 m long) Stark cell, in which the Stark field is produced by an electric voltage suddenly applied to the line. The Stark field propagates along the line with a relativistic velocity which depends on the line characteristic impedance, progressively modifying the energy levels of the atoms or molecules contained in the gas. This can be the cause of a significant change in the gas susceptibility $\chi(\omega)$, for frequencies ω nearly equal to an allowed transition between two atomic, or molecular, levels. The resulting effect, which could be called a Stark mirror effect, is discussed in § 3. The expressions for the frequency shift and for the reflection coefficients are derived in § 2. The investigation concludes in § 4 with a discussion of a practically realisable experiment using infrared vibrational lines of NH_3.