PHYSICS

Electrical Simulation of Optics of Moving Media

THE early experiments of Fresnel-Fizeau on the velocity of light in a moving medium can be described in modern terminology as the development of an optical delay line with controlled dwell time. Similar changes in a light beam can be generated by present-day versions of an optical delay line (of which there are a number), where controlled dwell time is achieved by the use of an electro-optic medium[1,2].

It should be mentioned that the explanation of the Fresnel-Fizeau experiment is in terms of the Doppler effect of the virtual Huygens sources. The description of Fizeau's experiment rests on the following fact[3]: If a refracting medium of index n is moving away from a stationary observer with a velocity v and if ν is the frequency of the light relative to an observer moving with the medium, then the Lorentz transformation requires the frequency to assume the value

$$\nu' = \nu\beta\,[1 + n(v/c)] \tag{1}$$

relative to a stationary observer. Thus, to a first approximation, the velocity of propagation of light in the moving medium relative to the stationary observer is

$$u' = \lambda'\nu'/n = (c/n)\,[1 + n(v/c)\,(1 - 1/n^2)] \tag{2}$$

(the primes being used to denote quantities relative to the stationary observer). To the stationary observer, the velocity of light in the moving medium may be increased or decreased as compared to the value c/n determined by an observer moving with the refracting medium.

As would be expected, the value for ν' is that measured by an observer for a source moving relative to the observer with a velocity v, that is, the virtual Huygens sources act as sources moving with a velocity v.

In Fresnel's terminology, the effect considered so far may be called the convection Doppler effect. This is not directly observable. What is observable is only the overall result, the controlled dwell time of an optical delay line. More direct is the possibility of simulating the Doppler effect resulting from reflection at a moving mirror. This is based on the characteristics of a symmetrical side band generator. It is well known and can be shown from the representation of the electromagnetic field in terms of Hertz vectors that side bands occur when the electric susceptibility of the medium varies harmonically with time[4].

The equations defining these vectors are[5]:

$$\begin{aligned} \nabla^2\Pi_e - \ddot{\Pi}_e/c^2 &= -4\pi P \\ \nabla^2\Pi_m - \ddot{\Pi}_m/c^2 &= 0 \end{aligned} \tag{3}$$

if $M = 0$.

In terms of these vectors,

$$B = H = \mathrm{curl}\,(\dot{\Pi}_e/c + \mathrm{curl}\,\Pi_m)$$

$$D = E + 4\pi P = \mathrm{curl}\,(-\dot{\Pi}_m/c + \mathrm{curl}\,\Pi_e) \tag{4}$$

In a refracting medium, the polarization P varies directly as the electric field E, that is,

$$P = \eta E, \text{ where } \eta \text{ is the electric susceptibility} \tag{5}$$

The case of interest for the operation of the simulator has the following characteristics: The medium through which the light beam is propagated is isotropic and the susceptibility η is specified by

$$\eta = f(\nu)e^{2\pi i\nu_P t} + \ldots + \text{constant term} \tag{6}$$

where $\nu_P \neq \nu$ is a frequency which determines the harmonic variation of ν with time, the constant term is proportional to $n^2 - 1$, and $f(\nu)$ is independent of the spatial co-ordinates. It follows from equations (5) and (6) that the strength of the polarization generated by the light beam depends on its frequency.

In the case $f(\nu) \equiv 0$, the Hertz equations lead to the familiar result $\lambda\nu = c/n$. Independently of the form of $f(\nu)$, both side bands, $\nu \pm \nu_P$, are present. Depending on the dimensions of the medium, its optical characteristics, and the Poynting flux of the incident radiation, the energy in the incident light beam will eventually be concentrated in the side bands. In general these side bands will consist not only of the two bands $\nu \pm \nu_P$ adjacent to the frequency of the incident light but also of the extended spectrum of side bands $\nu \pm m\nu_P$ where $m > 1$ is an integer. When the radiation is coherent, it would simplify simulation if conditions could be formulated under which only one side band is generated. In a highly dispersive medium, the side bands may be markedly deflected from the direction of the light beam of frequency ν, depending on the uniformity of the susceptibility of the medium.

Consider the special case where in certain definite regions the function $f(\nu)$ decreases steeply with ν, such regions of abrupt descent being separated by less sharply reached maxima or, possibly, by plateaux. The light in the side bands is channelled into these frequency ranges of steep descent. Let ν_M be the frequency at the edge of a region in which $f(\nu)$ tends rapidly towards zero; the radiation in the side bands will tend to concentrate near $\nu = \nu_M$, and on the side of the maximum where the susceptibility decreases sharply with ν. Such an asymmetrical distribution of radiant energy with frequency relative to that of the incident light beam would correspond roughly to the pattern expected for a Doppler shift.

The structure required for achieving a time-dependent polarization with a dependence on ν consisting of steep descent and shallow rises would occur in a medium with a sharp absorption (resonance) line in the neighbourhood of ν, the frequency of the incident radiation, provided the strength of the absorption line could be made to vary harmonically with time. This condition could be achieved if the concentration in the lower level of the radiative (absorption) transfer were made to vary harmonically with time, for example by optical pumping with high intensity coherent radiation varying harmonically with time.

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Fresh Fall-out in Israel from the Second Chinese Nuclear Detonation

A NUCLEAR detonation was reported to have occurred on the Chinese mainland on May 14, 1965. The test was apparently conducted in the atmosphere and involved a uranium-235 fission device[1]. Fall-out attributable to this detonation was first detected in Israel on air filters on May 28, 1965. About 3 weeks later, iodine-131 was detected in milk samples and in animal thyroids. Monitoring of iodine-131 in these samples was continued for several months.

Surface air activity. About 200 m^3 of air were sampled daily, using a 'Victoreen' positive displacement pump. The activity collected on the filter paper was determined using a well-type sodium iodide (thallium-activated) scintillation crystal coupled to a multi-channel gamma-spectrometer.

Iodine-131 was first detected in air on May 28, 1965, and zirconium-95–niobium-95 appeared 3 days later. Barium-140–lanthanum-140 were detected on June 1, 1965. The fact that radio-iodine was detected in surface air