

3.26 Propagation of nanosecond waves on plasma columns

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Pulse measurements on wave supporting structures have the general advantage to give information on group velocities directly. Experiments with a wave packet in the dipolar surface wave mode have been reported recently¹⁾. The wave packet in these experiments was obtained by passing sub-nanosecond pulses through a band pass filter set at 2.2 GHz. It was proved experimentally that the wave is actually of the dipolar type and its group velocity was determined as a function of ω/ω_p .

This report deals with the propagation of nanosecond wave packets in the axially symmetric TM mode on a positive column in mercury vapour. The experimental set-up is shown in Fig. 1. The tube diameters are 12.00 and 15.4₃ mm, the glass is pyrex ($\epsilon_g=4.8$) and the temperature of the mercury pool is controlled at 20°C. Waves are launched with a coaxial coupler, to prevent excitation of modes

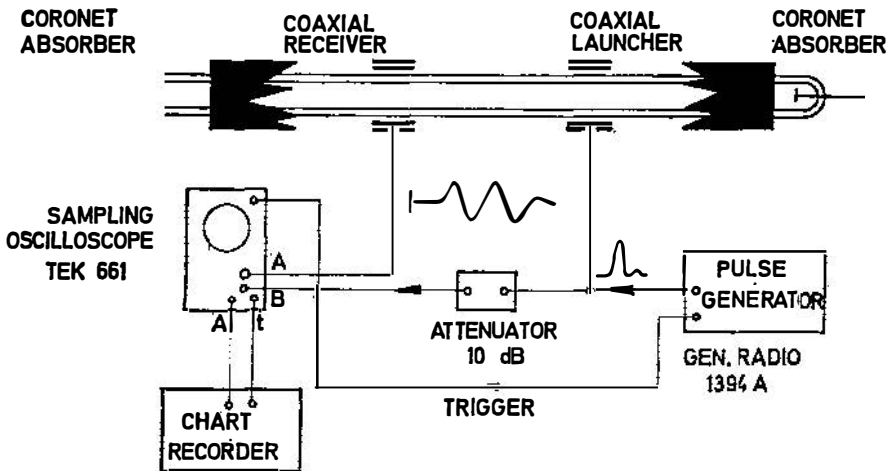


Fig. 1
The experiment.

with higher azimuthal variation. In reception, a similar coaxial coupler was connected to a sampling oscilloscope, the vertical and time outputs of which are linked to a chart recorder. In contrast to the experiments described in¹⁾, nothing was done to select a specific frequency range from the 4 V, 3 ns pulse. A typical record of waveforms is shown in Fig. 2. The general impression there is that the waveforms can be described well enough with a sine wave in a Gaussian envelope, which spreads gradually as the pulse progresses down the positive column. The frequency of the wave, measured at the maximum of the envelope, changes with discharge current, but the ratio of frequency and plasma frequency is nearly constant and varies between 0.14 and 0.19. We conclude that the launching and reception of

a surface wave with couplers of the type sketched in Fig. 1. are strongly frequency sensitive processes, with a prominent resonance at $\omega/\omega_p=0.16$ which selects a narrow frequency band from the broad spectrum of the 3 ns pulse.

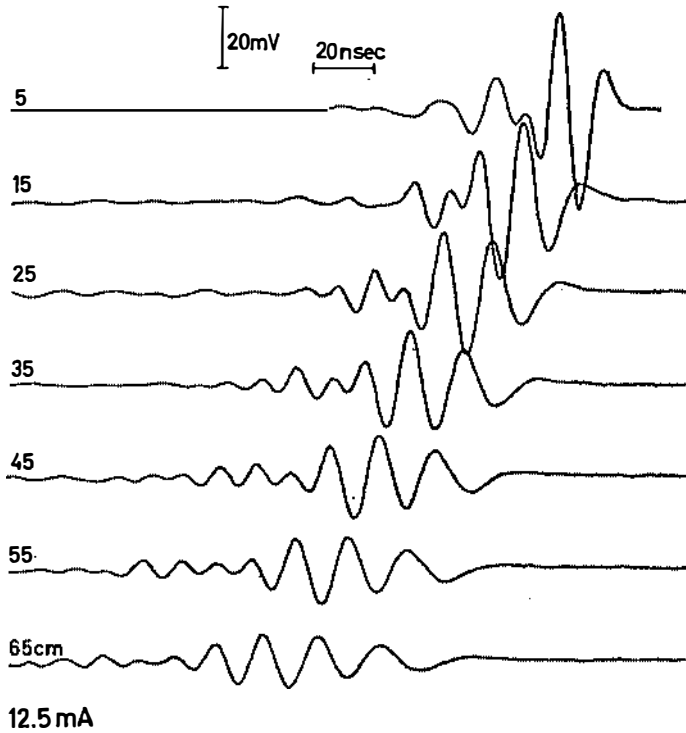


Fig. 2 Waveforms recorded at various distances from the launcher with a discharge current of 12.5 mA. Time runs from right to left. The parameter is the distance between launcher and receiver.

Time-space diagrams like the one in Fig. 2 have been taken at discharge currents of 12.5, 25, 50, 90 and 120 mA. The values of frequency, wavelength, phase and group velocity obtained from these diagrams are listed in the table below:

<i>I</i> mA	<i>f_p</i> MHz	<i>f</i> MHz	<i>f/f_p</i>	<i>v_p</i> cm/s	<i>v_g</i> cm/s	<i>v_g/v_p</i>	<i>λ_g</i> cm	<i>β a</i>	$\frac{\omega/\omega_p}{\beta a}$	$\frac{\delta(\omega/\omega_p)}{\delta(\beta a)}$
12.5	350	60	.169	1.0	0.64	0.64	17.6	0.214	0.76	0.49
25	490	80	.163	1.5	1.0	0.63	18.3	0.206	0.82	0.52
50	700	110	.163	2.3	1.5	0.63	22.7	0.167	0.88	0.56
90	930	140	.151	3.2	2.3	0.72	23.3	0.162	0.92	0.67
120	1080	160	.151	3.8	2.6	0.68	25.7	0.146	0.94	0.64

The ratio of group and phase velocity is nearly constant and has an average value of 0.648 for all discharge currents. The theoretical ratio v_g/v_p is 0.659, derived from the dispersion relation for $\beta a=0.2$, a ratio of glass tube radii of 1.3 and pyrex glass ($\epsilon_g=4.8$). All other data in the table are also consistent with the dispersion

properties of the $n=0$ mode. The frequency data in the table are derived from waveforms recorded 35 cm from the launcher. There is a constant tendency of frequency to drop as the distance between receiver and launcher is increased.

Several auxilliary experiments were carried out. The linearity of the phenomenon was checked by reducing the pulse generator level to 2 and 1 V and comparing the resulting waveforms with the record obtained with 4 V. That the wave actually has no azimuthal variation was proved with a wire probe which produced the same signal irrespective of angular position. An attempt was made to launch the $n=1$ mode with split cylinder couplers in transmission and reception, but the polarization effect was not observed and the time of flight was exactly the same as with the axially symmetric antennae. This is at variance with the result in¹⁾, where the sensitivity was not limited to 2 mV by the sampling oscilloscope, due to the use of TWT amplifiers. Transmission was attempted with the discharge tube switched off, and the near field was measurable 10 cm from the launcher and not further.

Several assumptions regarding the resonant phenomenon at $f/f_p=0.16$ were tested. The first idea was to compute the amplitude of the surface wave from the residue of the surface wave pole in the complex wavenumber plane, working with a model magnetic current ring launcher, and see whether this exhibits any peaks in wavenumber or frequency. In fact a maximum was found, but not at the right value of wavenumber and too broad to account for the observed resonance. A second possibility, that the whole length of the guide is in resonance due to mismatch at the coronet absorbers, was eliminated by replacing the terminations with metallic reflectors, which proved not to affect the waveform. Waves were launched by applying the voltage pulse between the anode and a metallic sleeve around the glass tube, and two axially displaced copper rings. Compared with the coaxial couplers, these launching methods differ in efficiency, but the frequency remains basically the same. It was finally observed that the waveform changes when the length of the coaxial couplers is varied, which led to the assumption that the resonance is related with axial standing waves in the couplers themselves. This hypothesis is also supported by the observation that the waveforms depend on the relative axial displacement of inner and outer coupler electrodes and the fact that very short couplers lack the selective property when the distance from launcher to receiver is small. An important role seems also to be played by the combined effect of launching efficiency and attenuation, which tends to eliminate very low and very high frequencies from the spectrum. This effect is position dependent.

A c k n o w l e d g m e n t

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R e f e r e n c e

- 1) O. Demokan, H. C. S. Hsuan and K. E. Lonngren, A Time-of-Flight Study of Waves Guided by a Plasma — Abstract submitted for the Winnipeg Meeting of the American Physical Society, 22—24 June (1970).