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A Note on Ultra-Short Waves and Radiation from Free Electrons.

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Recently, Prof. Yagi [1] has described some experiments with a Magnetron. He has succeeded in producing waves of the order of 10 cms. and has given a semi-theoretical formula, $\lambda = 2ct$, where, c = velocity of light and t = time taken by the electron to move from the filament to the anode.

He has, however, given no theoretical discussion regarding the origin of his short waves and we are, therefore, giving a preliminary explanation. The work seems to be of great importance for it brings out several points of novel interest.

In the ordinary oscillatory circuits radiations are generated because of the oscillations of electric charge in a metallic conducting path consisting of an inductance and capacity. However, if an electron could be made to describe

[1] Yagi. Proc. Inst. Radio Eng., Vol. 16, p. 715, 1928.

a closed path in space with frequency ν, it should become a source of radiation of this frequency. It seems that in Prof. Yagi's experiments we have an almost direct proof that such radiations are taking place, though Yagi himself does not offer any such explanation.

The Magnetron is a diode valve with a cylindrical anode and an axial filament placed in a magnetic field acting along the axis of the cylinder. The field can be adjusted in strength. When the field is sufficiently increased most of the electrons will just fail to reach the anode as they move tangentially past its surface. Knowing this critical field value and the anode voltage, e/m can be easily calculated.[2] At this critical field-value, in the anode cylinder there will be electorns moving in a closed path (almost circular of radius $b/2$), and therefore, radiating waves of wavelength,[3]

$$\lambda = 2.c.t.$$

$$= 2c.\pi b \sqrt{\frac{2eV}{m}}$$

where V = anode voltage and b = radius of the anode.

These waves are impressed on the oscillatory circuit of which the capacity is that between the anode cylinder and the filament. Oscillations are generated in this circuit and so the voltage of the anode undergoes slight fluctuations. But a slight increase in the anode-voltage above the critical value attracts most of the electrons that were previously moving only tangentially past it, whereas a slight decrease in the anode-voltage does not allow them to reach it. As in the

[2] D.S. Kothari, Ind. Jour. Phy. p. 485, July, 1928. (The paper contains the description of a laboratory method of determining e/m with a triode valve. Yagi's arrangements are identical, though they were meant for another purpose. His curves are of the same form and they give as good values of e/m).

[3] *Loc. cit.* Yagi.

critical condition the electrons are moving tangentially past the anode, a slight fluctuation in its voltage can attract them to it or repel them off from it. Thus the oscillatory current in the circuit, because of this reaction increases in strength.

There may seem one difficulty in this mode of explanation. From the filament electrons are issuing, and, they will be, while describing the closed path in the critical state, sources of approximately simple harmonic waves of constant amplitude but random phase. Lord Rayleigh's [4] analysis, however, of a large number of simple harmonic motions of constant amplitude and random phase clears this difficulty.

In order to verify the above theoretical considerations, we are attempting to repeat Yagi's experiments with a triode. As a preliminary, we have repeated the experiments of determining e/m and on short waves by B. Majumdar (*Ind. Jour. Phy.* 1928) Gill and Townsend (*Phil. Mag.* 1921) and others, and have found some interesting results.

It has been found that in the e/m expriments, the anode current which falls suddenly at the critical field-value, shows a slight increase for smaller values of the field. This increase in the anode current is interesting. It seems to be an effect of the space-charge, for, the increase obtained is much less with increasing anode-voltage, or smaller filament current or when the grid is given a positive bias. Theory also indicates that an increase in the anode current for small values of the magnetic field is to be expected when space-charge is predominant.

We may also note that in the paper of Mr. B. Majumdar it is stated that the capacity of the anode and the grid as measured experimentally by Toshniwal's method [5] was found to be about 40 cms., whereas, if it is calculated from the wavelength of the short waves generated ($\lambda = 2.\pi\sqrt{CL}$), it

[4] Lord Rayleigh's Sound. Vol. I.

[5] G. R. Toshniwal, Jour. Sci. Inst., July, p. 220, 1928.

comes out to be about 6 cms. only. This discrepancy is explained if the self-capacity of the wires forming the oscillatory circuit is taken into account. In calculating the frequency of the oscillations this self-capacity becomes a more predominating factor than the valve capacity.

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