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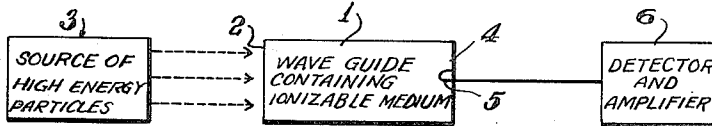
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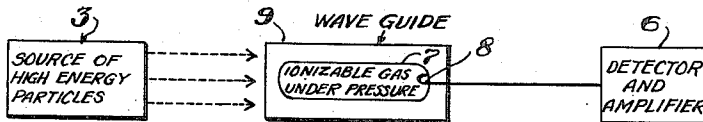
ELECTROMAGNETIC WAVE GENERATION

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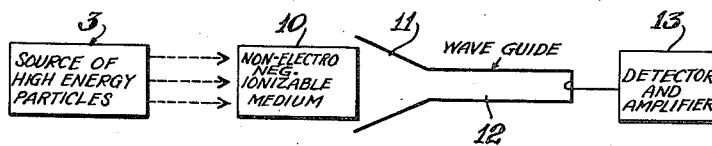
*Fig. 1.*



*Fig. 2.*



*Fig. 3.*



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## ELECTROMAGNETIC WAVE GENERATION

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9 Claims. (Cl. 250—36)

This invention relates to high-frequency generation, and more particularly to the generation of super-high-frequency electromagnetic waves.

In a gas tube or other ionizable medium, a certain ionization takes place due to penetration by alpha or other high-energy particles. Thus a noise effect is created due to ion and electron displacement or oscillation in the medium. This effect has been noted and in gas the ionized medium is generally referred to as a "gas plasma." The oscillations are of a very wide band, the ion displacement being at relatively low frequencies while the electron displacement may be at ultra-high frequencies. I have found that it is possible to generate super-high-frequency electromagnetic waves by subjecting to high-energy radiations or particles, certain materials which have the property of producing a high density of free electrons.

It is an object of my invention to provide a novel arrangement employing an ionizable medium for the production of ultra-high-frequency electromagnetic waves, whether the said medium be gaseous, solid or liquid.

Another object is to produce super-high-frequency electric waves by interaction between the dielectric wave-propagating medium whose dielectric and wave-propagating properties can be controlled, and a source of high-energy particles for ionizing said medium.

A further object is to provide a method for selectively producing super-high-frequency electric waves by means of high-energy particles and an ionizable medium traversed by the said particles, said ionizing medium being particularly chosen of a type which has a very low content of free electro-negative ions when subject to an ionizing force.

A feature of the invention relates to the combination of a source of high-energy particles, and a dielectric wave guide coupled to said source and having incorporated therein an ionizable medium which is capable of setting up super-high-frequency electromagnetic oscillations under control of said particles, the wave guide being dimensionally correlated with the frequency of said oscillations so as to transmit only such oscillations above a predetermined frequency.

A further feature relates to the combination of a wave guide containing a high density ionizable medium which is arranged to have very high electron densities set up therein by means of high energy particles traversing the medium.

A further feature relates to an improved super-high-frequency wave detector employing an ionizable gas or metallic vapor which is substantially non-electronegative.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood, by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawing, wherein:

Fig. 1 is a schematic illustration of one embodiment of the invention.

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Figs. 2 and 3 are schematic illustrations of respective modifications of the invention.

The present invention basically involves the traversal of a high density ionizable medium by high-energy particles such as alpha particles, protons, deuterons, mesons, fission fragments, etc., to produce high electron charge densities in the medium, and without the use of any external electric field or with such a field of low intensity to derive super-high-frequency electromagnetic waves. Examples of such media are rare gases under high pressure, metallic vapors, solid crystals, and certain liquids, all of which are capable of supporting free electrons therein when traversed by the said high energy particles. In accordance with one feature of the invention, the ionizable medium is a gas or vapor chosen from the group which is characterized as non-electronegative and of which the rare or inert gases such as neon, krypton, argon, and helium, and nitrogen, hydrogen, sodium vapor, and mercury vapor, are representative.

When such media are traversed by high energy particles, the resultant ionization creates free electrons which after being separated from their respective ions, are subjected to their respective ion fields. As a result of the electron displacement during ionization, the local space charge density undergoes corresponding variations. These local space charge variations give rise to corresponding variable electric fields and corresponding perturbations. With a heavy particle of sufficiently high energy, for example more than  $5 \times 10^6$  electron volts, in a medium of sufficiently high density such as a gas under atmospheric pressure or higher than atmospheric pressure, or a liquid, or a solid such as germanium or diamond, or other crystals, the density of ionization is very high along the track of the ionizing particle. Since free electrons are liberated during the ionizing process, it can be assumed that in the ionized medium the electrons will remain free until they disappear by recombination or by diffusion. By producing a high density of ionization, there is likewise produced a high electron density of the free electrons. The forces acting on these free electrons are: (a) the coulomb forces due to the positive ions, and to the rest of the atom or molecule from which the electron originates (initial and/or preferential recombination); (b) coulomb forces due to neighboring positive ions; (c) the force of an applied or external field where such is used; and (d) repulsive coulomb forces between electrons. Therefore, before recombination of the free electrons can take place, they will oscillate under the action of the field of the heavy positive ions. Since the medium is traversed by the high energy particles, it produces a region of space constituting a positive ion track. It has been found that this track acts, with respect to the free electrons, somewhat analogously to the positive grid of a positive grid oscillator such as an oscillator of the Barkhausen type. These oscillations which will be referred to herein as super-high-frequency oscillations, which occur at frequencies  $\gamma$  determined by the free electron densities  $n$  in the ionized medium, in accordance with the following formula:

$$\gamma = \sqrt{\frac{e^2 \cdot n}{\pi \cdot m}} \quad (1)$$

wherein "e" and "m" are the charge and equivalent mass respectively of an electron.

By super-high-frequency electromagnetic waves, I refer to waves having a frequency range of  $3 \times 10^9$  to  $3 \times 10^{11}$  cycles per second or a corresponding wave length between 10 centimeters and 0.1 centimeter. An illustrative example of the generation of such super-high-frequency electromagnetic waves is shown in the following.

A single alpha particle of  $5 \times 10^6$  electron volts, produces in argon at atmospheric pressure, approximately

1.6×10<sup>5</sup> pairs of ions, that is, as many electrons. The effective range of such an alpha particle in argon at atmospheric pressure is about 4 centimeters. The freed electrons are created with little kinetic energy and diffuse to a distance approximately 10<sup>-5</sup> centimeters from the point of their origin, that is, their originating atom. In the absence of any external fields, these electrons are pulled back by their respective positive ions and by neighboring positive ions which remain relatively at rest, while the electrons, because of their light mass, move away from them. The electron density in the column of ionization can be evaluated as follows. Since this column is a cylinder whose cross-section has a surface of π×(10<sup>-5</sup>)<sup>2</sup> square centimeters, its volume is 4π×10<sup>-19</sup> cubic centimeters. In this volume there are produced 1.6×10<sup>5</sup> electrons. The electron density in this volume is *n* equals approximately 1.27×10<sup>14</sup> electrons per cubic centimeter. This electron density determines the corresponding oscillation frequency which is approximately 10<sup>11</sup> cycles per second, and the wave length corresponding to this frequency is approximately 0.3 centimeter. It can be shown that the radiated energy density is

$$\frac{\epsilon E^2_{\text{max}}}{4\pi} \text{ ergs per cubic centimeter}$$

wherein  $\epsilon$  is the dielectric constant of the medium of propagation. In the above-noted column of ionization, the total maximum possible radiated energy is therefore 1.4  $\epsilon$ ×10<sup>-9</sup> ergs per alpha particle of 5×10<sup>6</sup> electron volts.

It can be shown that the duration *t* of this super-high-frequency radiation pulse is approximately 2.3×10<sup>-4</sup> seconds. In other words, the super-high-frequency occurs in pulses having a pulse width of approximately 2×10<sup>-4</sup> seconds. It is possible, therefore, with an appropriate source of high-energy particles, to produce a substantial amount of wave energy in the generated super-high-frequency pulses, using any one of the ionizable media above mentioned, namely a non electronegative gas or metallic vapor or combination of said vapors, crystals such as germanium, diamond, and liquids such as liquid argon, liquid nitrogen.

With respect to the direction of travel or trajectory of the high energy particles, it has been found that the electrons in the track of the particles move in a direction which is substantially perpendicular to the track, since no large number of atomic collisions occur while the recombination oscillations take place. Therefore the oscillating electrons can be considered as the equivalent of individual dipoles which emit radiation in a plane perpendicular to the direction of oscillations. The resultant radiation pattern is therefore that corresponding to a normal dipole.

During the traversal of the ionizing medium by the high energy particles, there are produced radiations of frequencies in the above-mentioned super-high-frequency range and also relatively lower frequencies resulting from ion displacements. In accordance with another feature of the present invention, the ionized medium may form the dielectric of a wave guide wherein the above-mentioned super-high-frequency oscillations are set up. However the said guide is chosen of such dimensions that its wave guide cut-off frequency is above the frequency representing that produced by the free ion movement as distinguished from the free electron oscillating movement. Because of this fact, there appear at the output end of the guide only those frequencies produced by the said free electrons, which oscillate with respect to the positive ion track.

Referring to Fig. 1 of the drawing, the numeral 1 represents a wave guide containing any one of the above-noted ionizable media. As an example, the guide 1 may be a rectangular hollow metal conductor which is closed off at one end by a wall or diaphragm 2 which is pervious

to the high-energy particles or radiations from a suitable source 3, as represented by the dotted arrows. The opposite end of the guide 1 may likewise be closed off by a partition 4 through which is inserted a suitable probe or pick-up loop 5 that can be connected to any suitable detector and amplifier 6. The guide 1 may contain a filling of a rare gas such as argon, neon, helium, or krypton, or mercury vapor, etc., at approximately atmospheric pressure or higher. In general the gas should be of a non-electronegative character for reasons pointed out hereinabove. In the case of an argon filling at atmospheric pressure and with the ionization being effected by an alpha particle of 5×10<sup>6</sup> electron volts, the guide 1 need not be materially longer than the length of the ionization track which under the above assumed conditions is approximately 4 centimeters. Therefore the guide 1 need not be more than 5 centimeters long. However its width and height are chosen so that its cut-off frequency as a wave guide prevents the transmission of frequencies below the super-high-frequencies corresponding to the free electron oscillations, for example frequencies of the order of 10<sup>11</sup> cycles per second.

It will be understood that the guide 1 can have on its interior instead of the above-mentioned gases, any relatively high density material which can be ionized by the high-energy particles. This material may take the form of a solid such as germanium, diamond; or a liquid such as liquid argon or liquid nitrogen. Furthermore, it is only necessary to fill the guide with the above-mentioned materials to an extent sufficient to have the entire effective track or range of the ionizing particles comprised within the filling.

It will be understood, of course, that the invention is not limited to any particular source for producing the high-energy particles. This source may take the form of radium, or it may take the form of a machine such as a cyclotron or other particle accelerators such as are well known in the atomic fission art.

If desired, the frequency of the oscillations that are to be produced and selectively passed through the wave guide, can be controlled as to their lower limits by a suitable choice of the ionizable filling or ionizable dielectric that is used within the guide.

While the drawing shows the container for the ionizable medium in the form of a rectangular cross-section wave guide, it will be understood that this wave guide may be circular or assume any other cross-sectional shape well known in the wave guide art, or it may take the form of a tunable cavity resonator. If desired, and as shown in Fig. 2, the ionizable medium can be contained in a suitably exhausted and sealed glass tube 7 having a probe 8 sealed through the envelope wall, and this glass tube can be located within a wave guide 9 having the desired lower cut-off frequency as above mentioned.

Fig. 3 shows a modification wherein the high-energy radiations or particles traverse the ionizable medium 10 which may be constituted of any of the materials above mentioned. This material can be mounted adjacent the input end 11 of a wave guide 12 having a cut-off frequency as above mentioned and having its output end connected or coupled to any suitable amplifier or load 13.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention.

What is claimed is:

1. An arrangement for generating super-high-frequency electro-magnetic waves, comprising, a source of high-energy particles, an ionizable medium in proximity to said source and adapted to be traversed by said particles, said medium being chosen from the group which is substantially non-electronegative to set up therein a positive ion track with a large quantity of free electrons oscillating with respect to said track, and means coupled to said me-

dium to pass for transmission therethrough only those oscillatory waves of frequencies above a predetermined minimum frequency.

2. An arrangement for generating super-high-frequency electric waves, comprising a source of high energy particles, a body of high-density ionizable medium disposed in proximity to said source whereby particles of said source are adapted to traverse said medium and set up therein oscillating free electrons and a waveguide associated with said body for transmission of waves therefrom of super-high frequencies, said waveguide having a predetermined cut-off frequency for transmission therethrough only those oscillatory waves of super-high frequencies above said cut-off frequency.

3. An arrangement according to claim 2, in which said medium is a substantially non-electronegative gas at least at atmospheric pressure.

4. An arrangement according to claim 3, in which the said pressure is chosen to produce an electron density in the ionization column of approximately  $1.27 \times 10^{14}$ .

5. An arrangement according to claim 2, in which said medium is in the form of a refractory crystalline element chosen from the class of germanium and diamond.

6. An arrangement for generating super-high frequency electric waves, comprising, an evacuated enclosing envelope having a filling of an ionizable gaseous conduction medium at least at atmospheric pressure, means in proximity to said envelope including a source of high-energy particles for ionizing said medium to produce therein a positive ionization track and a predetermined density of free electrons oscillating at super-high-frequency with respect to said track, and means coupled to said envelope for transmission therefrom only those waves of high frequencies above a predetermined minimum super-high frequency.

7. An arrangement for generating super-high-frequency electromagnetic waves comprising a source of high-energy alpha-particles, an ionizable medium disposed in proximity to said source to cause alpha-particles to traverse through said medium, said medium being chosen so that when traversed by alpha-particles having an energy of the order of  $5 \times 10^6$  electron volts there is set up with-

in said medium a frequency of the order of  $10^{11}$  cycles per second, and means for transmitting from said medium only those oscillatory waves of frequencies above a predetermined minimum super-high frequency.

8. An arrangement for generating super-high-frequency electric waves comprising a super-high-frequency-transmitting waveguide having therein a substantially non-electronegative gas at least at atmospheric pressure, a source of high energy particles disposed in proximity to said waveguide to cause particles from said source to traverse said gas and set up therein a positive ionization track, said waveguide further including means for passing therethrough only those oscillatory waves of frequencies above a predetermined minimum super-high-frequency.

9. An arrangement for generating super-high-frequency electric waves comprising a source of alpha particles, an evacuated waveguide disposed in proximity to said source having a filling of an ionizable and substantially non-electronegative gaseous conduction medium at least at atmospheric pressure, at least certain of said alpha particles traversing said medium to set up therein a positive ionization track, and said waveguide including means for transmitting therethrough only those oscillatory waves of frequencies above a predetermined minimum super-high-frequency.

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