

Aug. 9, 1966

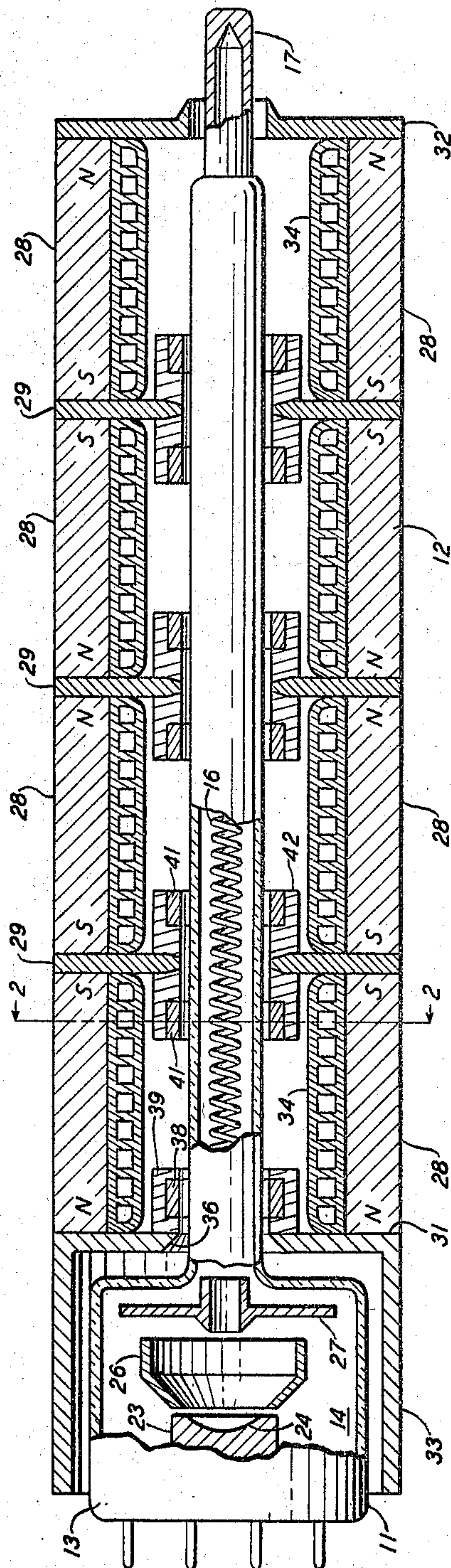
Filed July 3, 1962

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FIELD PERTURBING MEANS FOR PREVENTING BEAM SCALLOPING
IN REVERSED FIELD FOCUSING SYSTEM

3,265,925

4 Sheets-Sheet 1

FIG. 1



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4 Sheets-Sheet 2

FIG. 2

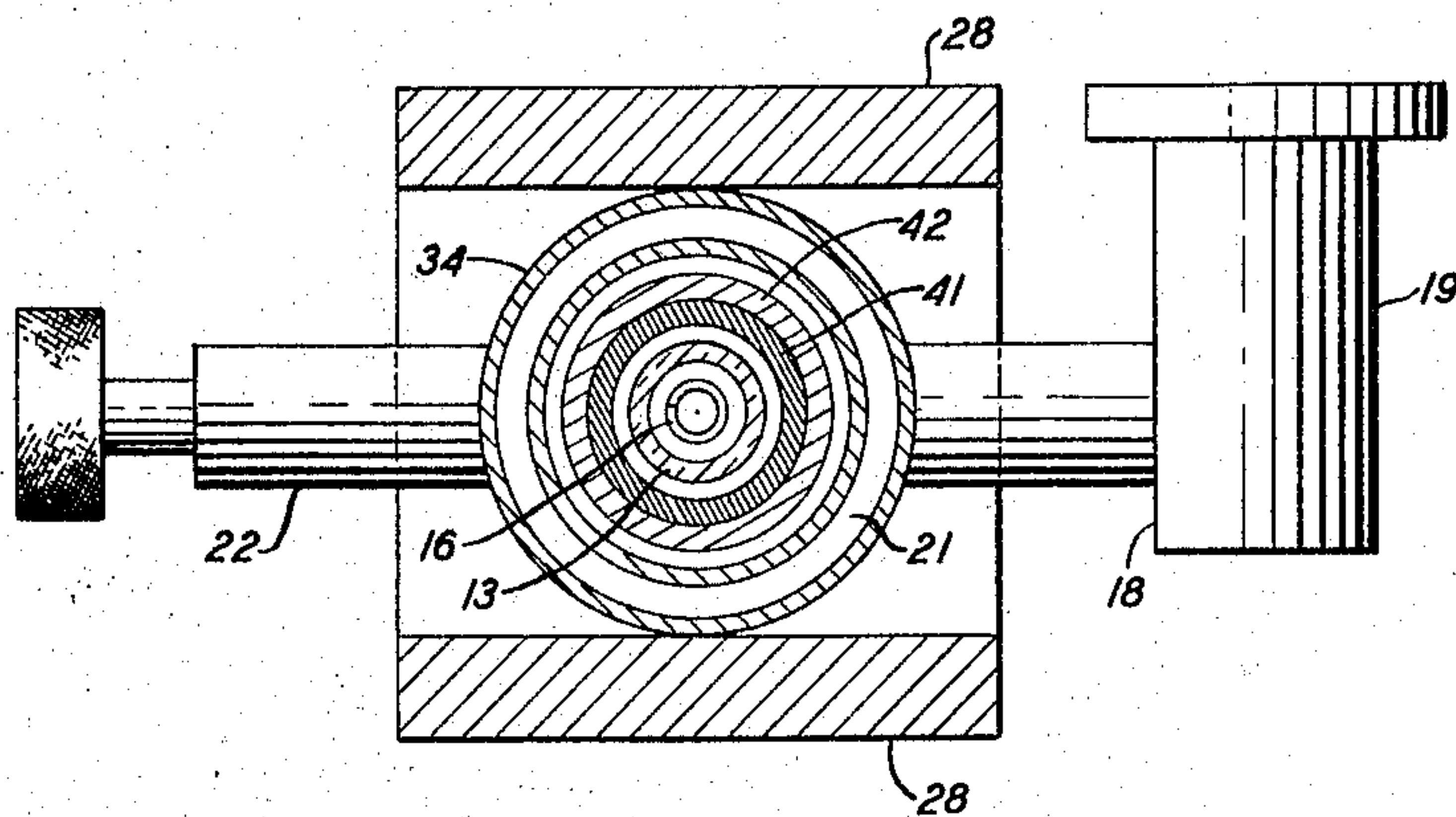
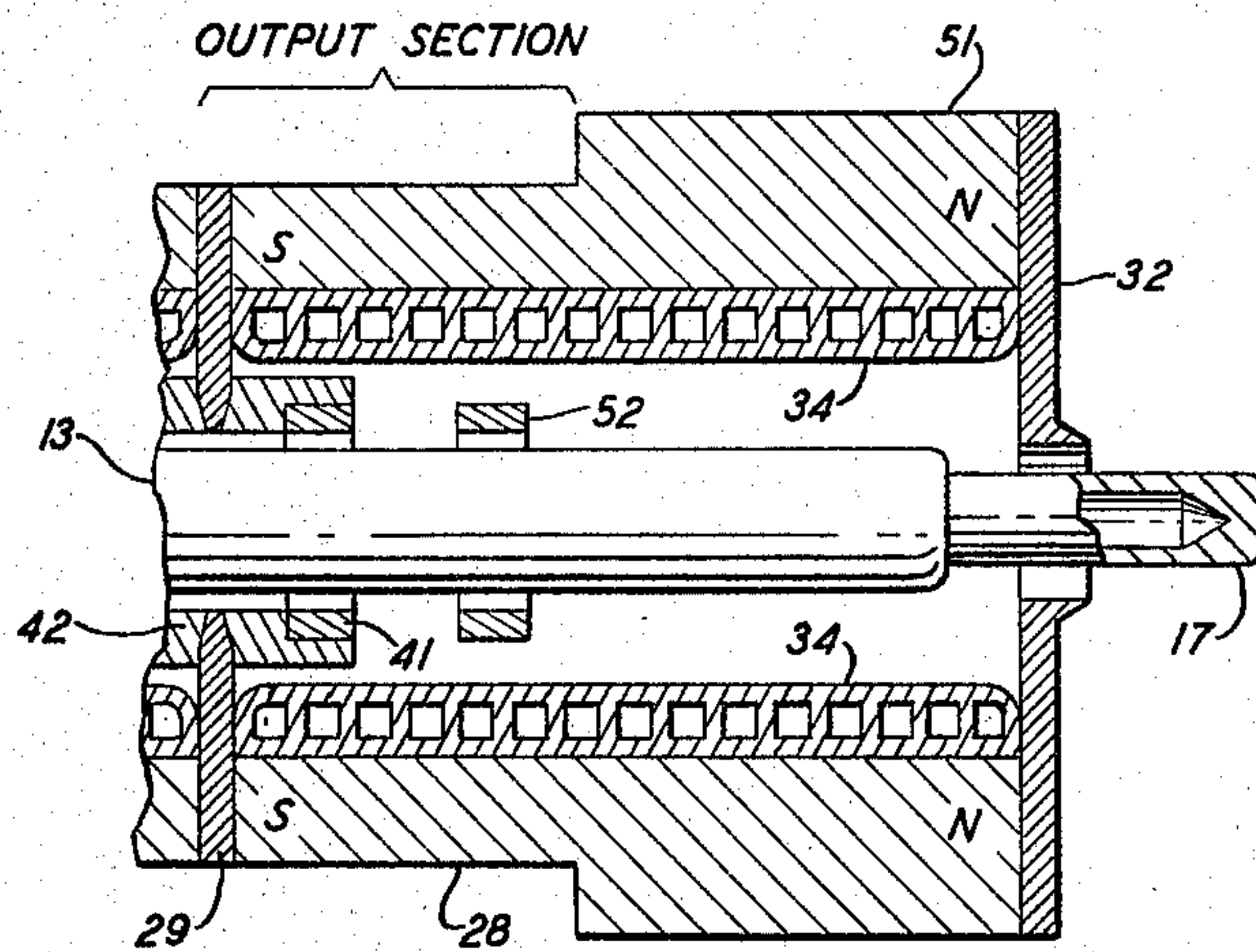


FIG. 5



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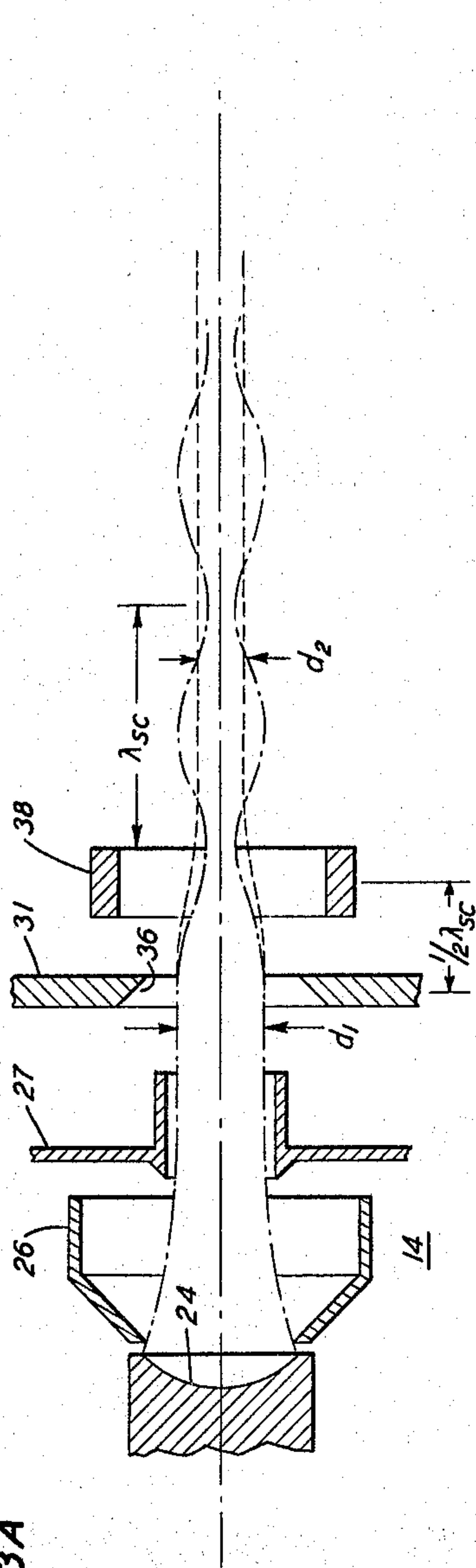


FIG. 3A

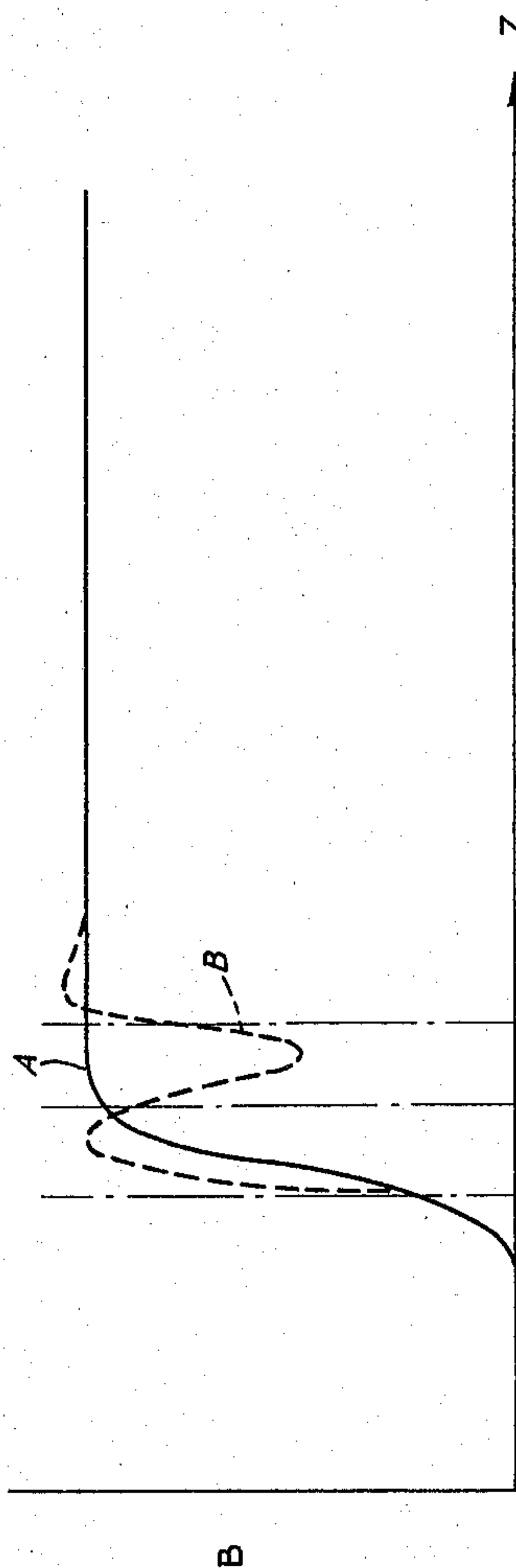


FIG. 3B

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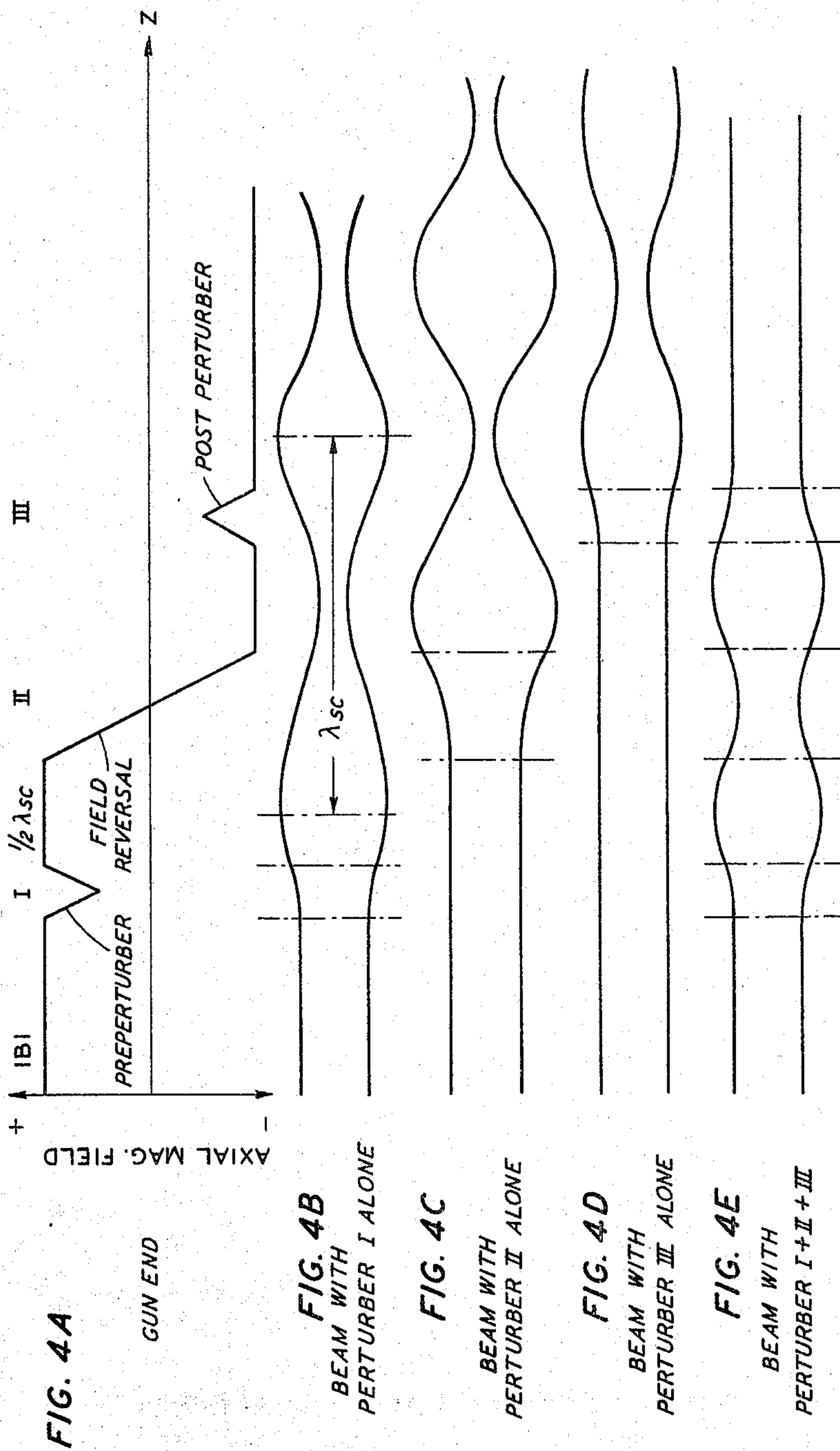
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4 Sheets-Sheet 4



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FIELD PERTURBING MEANS FOR PREVENTING BEAM SCALLOPING IN REVERSED FIELD FOCUSING SYSTEM

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This invention relates to magnetic focusing systems and more particularly to such systems for focusing a beam of charged particles over a relatively long path.

In a traveling wave tube, for example, an electron beam is focused over an extended path adjacent an interaction circuit, usually a helix, along which a wave is propagating with which the beam interacts. For most efficient operation, it is important to keep the electron beam cylindrical and, in general, confined within the helix. One well known system for creating and maintaining the electron beam cylindrical is Brillouin type focusing, which is especially useful with high density electron beams. In such an arrangement, the electron gun is shielded from the magnetic focusing field and the electrons, as they enter the magnetic field, are caused to spiral in a manner such that the inward force exerted by the magnetic field is exactly counter-balanced by the outward forces within the beam, namely space charge forces and the centrifugal forces exerted on the spiraling electrons.

In an electron beam device such as a traveling wave tube, as the frequency at which the device is to be operated is increased, the various elements of the tube and particularly the wave propagating circuit or helix diminish in size. This is especially true in the case of the diameter of the wave propagating circuit. As a consequence, it is quite common to utilize a converging type electron gun to produce a sufficiently small diameter electron beam which can pass through the interaction circuit without impingement thereon. However, there are certain limitations upon the amount of convergency of the electron beam that can be achieved, and consequently a limitation upon the density of the electron beam. Inasmuch as power output of the traveling wave tube is proportional to the density of the electron beam, at extremely high frequencies it has heretofore been quite difficult to achieve the desired beam density and, consequently, output power with conventional type electrostatic convergent electron guns, such as the well known Pierce gun, as described in U.S. Patent No. 2,268,197 of J. R. Pierce. In order to achieve the desired compression of the beam, i.e., beam density, or reduction in cross-sectional area of the beam as compared to the area of the cathode emission surface, it has heretofore been necessary to design complicated electron guns combining both electromagnetic and electrostatic focusing. Such arrangements are quite complex, difficult to manufacture, and quite difficult to maintain in proper operating condition.

In addition to the foregoing, where extremely high density beams are used, it is necessary to create much stronger magnetic focusing fields than is normally the case. This means that the focusing magnet itself is quite large and heavy. In the past, it has been the practice in many cases to resort to periodic focusing arrangements as described in the J. R. Pierce Patent No. 2,847,607, issued August 12, 1958, to achieve a reduction in magnetic weight and size. Periodic focusing arrangements, however, have certain drawbacks which include, among other things, difficulty of fabrication and the creation of stop and pass bands in which the electron beam is focused and defocused, respectively. By compromising on the periodicity of the magnetic field, that is, reducing the number of reversals of magnetic field, workers in the art have found it possi-

2

ble to achieve a certain amount of weight and size reduction while partially eliminating the problems of fabrication. In all cases where there are reversals of the magnetic field, however, the strength of the magnetic field at the transition or reversal region decreases from a maximum to zero and then to a maximum in the opposite direction. At this region of reversal, therefore, the magnetic field ceases to be of sufficient strength to maintain a beam cylindrical and scalloping of the beam results. Once the beam has commenced scalloping, it continues to do so despite the subsequent increase of the magnetic field to its appropriate value for maintaining the beam cylindrical. Such scalloping of the beam has several serious consequences. If the scalloping is of sufficient magnitude, the electron beam impinges upon the interaction circuit causing a loss of electrons, a reduction in efficiency, and a deleterious heating of the interaction circuit. Additionally, scalloping causes a decrease in the efficiency of the interaction between the electron beam and the traveling wave.

It is an object of the present invention to produce high compression electron beams utilizing a conventional electrostatic converging electron gun.

It is another object of the invention to maintain a high density electron beam cylindrical over the major portion of the interaction region in a focusing system in which there are multiple reversals of the direction of the magnetic field used to provide the focusing action.

It is a further object of the invention to increase the efficiency and power output of a traveling wave tube utilizing reversed field focusing, and an electrostatic electron gun.

These and other objects of the invention are achieved in an illustrative embodiment thereof wherein a conventional electron gun of, for example, the type disclosed in the aforementioned Pierce Patent 2,268,197, is utilized in a traveling wave tube for producing an electron beam.

In accordance with the principles of Brillouin focusing, the electron gun is shielded from the magnetic field over the region where the beam is converged to the desired diameter. A permanent magnet focusing system is utilized for focusing the electron beam, and the beam is introduced into the magnet field after it has been electrostatically converged to an appropriate diameter. In Brillouin type focusing, the necessary strength of the magnetic focusing field, as pointed out before, is determined by the beam density at the desired diameter, and, when properly chosen, maintains the beam cylindrical, the space charge and centrifugal forces being exactly balanced by the magnetic field forces. Any variation in one of these forces can upset the balance and produce scalloping of the beam. In the embodiment of the present invention, the electron gun is designed to converge the beam to the minimum possible diameter, which, in the case of most electrostatic electron guns is of the order of one-fifth of the diameter of the emissive surface of the cathode. The magnetic field producing means is designed to produce a magnetic field, not of the strength required for Brillouin focusing, but of a strength from four to six times greater than the Brillouin strength, thereby producing an imbalance of forces. As a consequence, the beam, upon entering the magnetic field, immediately commences to scallop about the diameter which is the appropriate Brillouin diameter for a magnetic field of that strength. Inasmuch as the magnetic field is of a greater strength than is normally required, the scalloping of the beam commences with a compression of the beam to a smaller diameter, which normally would be followed by an expansion of the beam to a larger diameter, with the average diameter being the Brillouin diameter for the actual magnetic field strength. The alternate contractions and expansions of the beam tend to occur at regular intervals so that one

cycle from minimum diameter to maximum diameter and back to minimum diameter may be defined as a scallop wavelength. This wavelength depends, of course, on a number of factors, including beam density, beam velocity, and magnetic field strength. The wavelength can, in all cases, be readily determined.

In accordance with the principles of the present invention, the scalloping of the beam is effectively halted as it reaches the Brillouin diameter for the actual magnetic field strength by means for restoring the balance of forces, which in the present illustrative embodiment, takes the form of a perturbation in the magnetic field produced by a ring of magnetic material surrounding the beam within the magnetic field. As will be explained more fully hereinafter, this ring produces a decrease or dip in the magnetic field strength over a short distance, less than one-half of a scallop wavelength, which tends to produce a scallop in the beam of opposite phase, with the net result that the beam ceases to scallop and becomes cylindrical, with a diameter substantially equal to the appropriate Brillouin diameter, which is many times less than the convergence diameter produced by the electron gun. The magnetic field beyond the dip is of sufficient strength to counteract the space charge and centrifugal forces on the beam so that Brillouin flow results with a greatly compressed beam. Advantageously, to realize the greatest possible beam compression, the field perturbing ring should be placed between one-quarter and one-half a scallop wavelength from the point when the scalloping commences, i.e., the point of beam entrance into the field, or between one and one-quarter and one and one-half wavelength from such point.

In the present illustrative embodiment, because the magnetic field is much greater than that required for normal Brillouin focusing with the initial beam compression, a focusing arrangement having a plurality of reversals of field direction is used to reduce the required magnet weight. In a specific case, for a single magnet, a weight of approximately thirty pounds is necessary to produce the required field, utilizing present day magnet materials. In the embodiment of the invention a field of three reversals is utilized, and the weight of the magnets required totals approximately one and one-half pounds. As pointed out in the foregoing, the field reversals in periodic focusing systems tend to produce scalloping of the beam. In accordance with the present invention, magnetic field perturbing rings of appropriate dimensions are placed on either side of the pole piece at each field reversal to produce a dip in the magnetic field on either side of the pole piece. These perturbing rings have the effect of introducing scallops on the beams, which, when properly phased relative to the scalloping produced by the field reversal, tend to cancel such latter scalloping, with the net result that the forces are balanced and the beam is cylindrical as it emerges from the field reversal region. Optimum positioning of these field perturbers depends upon a number of factors. It has been found in practice that best results are obtained when the perturbing rings are within one-half a scallop wavelength of the pole piece, the distance being measured between centers, but are more than one-quarter a scallop wavelength from the pole piece. As a consequence, utilizing the aforementioned principles of the invention, a highly compressed cylindrical beam is produced and maintained throughout its passage through the wave propagation circuit which, in the present embodiment, for illustrative purposes, is a helix.

Unlike conventional periodic focusing systems of the prior art, which are characterized by regularly occurring reversals, and, in turn, by stop and pass bands, in the present invention, the beam after each field reversal returns to a condition of laminar flow. This means that the length of each period can be chosen arbitrarily, and each period is independent of the others. This makes it possible to eliminate stop bands entirely from the operating range of the device, and also permits use of differ-

ent strength magnetic fields in different sections so that beam spreading due to R-F forces, for example, may be eliminated. As used hereinafter, the phrase "periodic focusing" when used in describing the present invention, is meant to include any and all of the foregoing variants.

These and other principles and features of the present invention will be apparent from the following detailed description, taken in conjunction with the accompanying drawings in which:

FIG. 1 is a sectional view of a traveling wave tube and magnetic focusing system embodying the principles of the present invention;

FIG. 2 is a sectional view taken along the line A—A of FIG. 1;

FIGS. 3a and 3b are diagrammatic views of the electron beam behavior as it enters the focusing system of FIG. 1;

FIGS. 4a to 4e are diagrammatic views of the magnetic field configuration and electron beam behavior in the field; and

FIG. 5 is a sectional view of a modification of the output end of the traveling wave tube and magnetic focusing system of FIG. 1.

Turning now to FIG. 1, there is depicted a sectional view of a traveling wave tube 11 and focusing magnet assembly 12, which embodies the principles of the present invention. Traveling wave tube 11, which is supported within the focusing structure 12 by suitable means, not shown, comprises a glass envelope 13, electron gun 14, a wave propagation circuit 16, shown here as a helix, which is supported within the glass envelope 13 by suitable means, not shown, and an electron beam collector 17 which may be of copper or other suitable material. In addition, input and output circuits for introducing signals to be amplified onto helix 16 and extracting the amplified signal, are provided. In FIG. 2, there can be seen one such type of input circuit which comprises a waveguide 19, coupled to coaxial cavity 21 which is tuned by a tuning arrangement of the type shown in copending U.S. patent application Serial No. 155,661, filed November 29, 1961, now Patent No. 3,123,430, of J. P. Laico. While a particular type of input arrangement is shown, it is to be understood that various other types of inputs (and outputs) may be used.

Electron gun 14, which is of the electrostatically converging type, as shown in the aforementioned Pierce Patent No. 2,268,197, comprises a cathode 23 having a concave electron emissive surface 24, a beam forming electrode 26, and an accelerating anode 27. For simplicity, the various sources of voltage and electrical connections to the electrodes of the gun have not been shown. In addition, and for the same reason, the supporting means for the various electrodes have not been shown. Electron gun 14, in conjunction with the electrodes 26 and 27, is designed to produce a highly convergent electron beam, the cross sectional area of which, upon exiting from the accelerating anode 27, is of the order of $\frac{1}{25}$ of the area of emissive surface 24.

The magnetic structure 12 comprises a plurality of bar-shaped permanent magnets 28 separated by a plurality of identical pole pieces 29 of high permeability material. In accordance with the teaching of the aforementioned Pierce Patent No. 2,847,607, a spatially alternating magnetic field is achieved by reversing the magnetic sense of adjacent magnets, as indicated in the drawing. The magnetic structure is terminated by end pole pieces 31 and 32. Extending from pole piece 31 is a magnetic shield 33 which shields the electron gun 14 from the magnetic field in the region where the beam is converged to a minimum diameter. A plurality of field straighteners 34, which may be of the type shown in U.S. Patent No. 2,942,141 of C. C. Cutler are provided for insuring an axially straight magnetic field throughout the focusing region.

The electron beam from gun 14 enters the magnetic

field through an aperture 36 in pole piece 31. As pointed out in the foregoing, the magnetic field provided by magnets 28 is of a much greater strength than is necessary for Brillouin type focusing. As a consequence, the beam, upon passing through aperture 36 commences to scallop inwardly initially and unless such scalloping were corrected, the beam would continue to do so throughout its travel. In order to prevent scalloping of the beam and to achieve high compression thereof, a perturbing ring 38 of magnetic material is positioned adjacent pole piece 31. Ring 38 is supported within a nonmagnetic sleeve 39 and preferably is made adjustable—that is, axially movable within its support 39. Adjacent each pole piece 29 and positioned at either side thereof, are identical magnetic field perturbing rings 41 which are mounted in a supporting member 42 of copper or other suitable nonmagnetic material, which is in turn mounted to pole piece 29. As will be explained more fully hereinafter, these rings 41 prevent the scalloping of the beam which would normally result from the field reversal at pole pieces 29. As a consequence, the beam, which has been highly compressed into a high density cylindrical beam by the action of ring 38 is maintained substantially cylindrical throughout its travel to the collector.

For a complete understanding of the effects of the rings 38 and 41, reference should now be had to FIGS. 3 and 4. In FIG. 3A, there is shown a schematic view of the electron beam in the region where it is converged by gun 14 and enters the magnetic field by passing through aperture 36 in pole piece 31, and FIG. 3B is a representation of the magnetic field encountered by the beam, curve A being the field without ring 38, and curve B being the field with ring 38 in place.

Electron gun 14 electrostatically converges the beam to the minimum possible diameter d_1 with such an arrangement, at which diameter the beam has a cross sectional area approximately $\frac{1}{25}$ the area of emissive surface 24. At this diameter the beam can be maintained cylindrical by having a magnetic focusing field of the "Brillouin strength" specified for that diameter. However, it can readily be appreciated that the diameter d_1 places an upper limit on the frequency of operation of the tube inasmuch as the wave propagation circuit, for most efficient operation, must have an internal diameter slightly greater than d_1 . In addition, there is a limitation on power output of the tube inasmuch as the beam density is governed by the amount of convergence. In accordance with the principles of the present invention, however, the magnetic field has a strength from four to six times greater than the strength required for Brillouin flow at diameter d_1 . As a consequence, the beam, upon entering the magnetic field through aperture 36 in pole piece 31 commences to scallop about the Brillouin diameter of d_2 appropriate to this greater magnetic field. This behavior of the beam is depicted by the solid line in FIG. 3A. In order to prevent this scalloping and to achieve greater beam compression, magnetic ring 38 is placed approximately $\frac{1}{2}\lambda_{sc}$, where λ_{sc} is a scallop wavelength, from the approximate point of entrance of the beam into the magnetic field, as depicted in FIG. 3A. The ring 38, so placed, produces a magnetic field as depicted by dotted line B in FIG. 3B. The dip in the field produced by the ring 38 tends to cause additional scalloping of the beam. Proper placement of ring 38 imparts to this scalloping tendency a phase which counteracts the scalloping produced by the beam entrance conditions with the net effect that the beam becomes cylindrical at the Brillouin diameter d_2 as depicted by the dotted line in FIG. 3A. The actual location of ring 38 depends upon a number of factors, e.g., the ring width, which must produce a disturbance in the magnetic field that is less than $\frac{1}{2}\lambda_{sc}$ in length, the amount or depth of the dip produced, and, of course, the scallop wavelength λ_{sc} , which is governed by the strength of the magnetic field. For optimum results, ring 38 should be placed

between $\frac{1}{4}\lambda_{sc}$ and $\frac{1}{2}\lambda_{sc}$ from the entrance point, depending upon the above factors, and for that reason, as pointed out in the discussion of FIG. 1, ring 38 is made adjustable within its support 39. For a given tube, once the proper distance has been determined, ring 38 may be fixed in position by any suitable means. In general, it is desirable to place ring 38 within $\frac{1}{4}\lambda_{sc}$ to $\frac{1}{2}\lambda_{sc}$ from the entrance point, as has been pointed out. However, in certain instances, such a placement may, because of the small sizes involved, for example, be difficult to achieve, in which case, ring 38 may be placed within the range of $\frac{1}{4}\lambda_{sc}$ to $\frac{1}{2}\lambda_{sc}$ to facilitate fabrication, although the shorter distance is the more desirable.

With ring 38 properly placed, it is possible to achieve beam compression of over 200 with an electrostatic convergent gun, as compared to a compression of 25 without the ring 38. This more than eight-fold increase in compression is highly desirable, especially in higher frequency tubes, inasmuch as smaller helix dimensions are possible and far greater power outputs are obtainable. Such high compressions have heretofore been obtainable only through the use of highly complicated electron guns and focusing systems, whereas the arrangement of the invention is quite simple.

In FIGS. 4A through 4E, there is depicted a series of curves showing the effects on the beam of perturbers 41 and the field reversal at each of the pole pieces 29. FIG. 4A represents the magnetic field configuration at a reversal region, with the perturbers 41 in place. FIG. 4B demonstrates the effect on the beam of the perturber 41 which precedes the field reversal, that is, the "pre-perturber," FIG. 4C shows the effect on the beam of the field reversal, FIG. 4D shows the effect on the beam of the perturber 41 following the field reversal, that is, the "post-perturber," and FIG. 4E shows the total effect on the beam produced by the magnetic field configuration of FIG. 4A. For a clear understanding, each of the figures has been clearly labeled and identified in the drawing. It can readily be seen from FIGS. 4B through 4D that each of the perturbers 41 and the field reversal produce scalloping of the beam. In FIG. 4E, it can be seen that when the perturbers are placed $\frac{1}{2}\lambda_{sc}$ on either side of the reversal, the distance measured between centers, the phases of the various scallops are such that the beam, although it undergoes some deformation within the region defined by rings 41 and the field reversal, is cylindrical when it emerges from the region. While the field perturbations are shown as being $\frac{1}{2}\lambda_{sc}$ on either side of the field reversal, some variation of this distance might, in certain cases, be necessary to achieve optimum results. In all cases, however, the rings 41 and, hence, the perturbations should not be less than $\frac{1}{4}\lambda_{sc}$ or greater than $\frac{1}{2}\lambda_{sc}$ from the midpoint of the field reversal in FIG. 1, two rings 41 are shown adjacent each field reversal. It is possible to maintain the beam cylindrical with a single perturbing ring, but such an arrangement permits too great a beam excursion within the reversal region, resulting in impingement of the beam upon the helix. Utilizing two rings, the beam excursion is quite limited, with the net result that beam transmission efficiencies of better than 99.9% have been achieved in practice. Such transmission efficiency is unusual in a periodic focusing system.

Inasmuch as rings 41 produce scalloping in the beam, greater coupling to the slow wave circuit, i.e., helix, at the output may be produced by the placement of a perturbing ring approximately $\frac{1}{4}\lambda_{sc}$ before the output section. With such a placement, the beam will be at its maximum scallop diameter at the output section, hence closer to the helix with a resulting increase in coupling, and a greater output efficiency.

In the foregoing, it has been shown how the principles of the invention prevent scalloping of the beam while achieving high compression. Utilizing these same principles it is possible to achieve even greater efficiency of operation by insuring collection of all of the electrons

in the beam. Ordinarily, in order to collect all of the electrons, it is necessary to use a high collector voltage, which means consumption of additional power. In FIG. 5, there is shown an arrangement utilizing the principles of the invention that permits the use of lower collector voltages to collect all of the electrons.

FIG. 5 is a sectional view of the output end of the assembly of FIG. 1 with the magnetic system modified to increase collector efficiency. For simplicity, the same reference numerals have been used. In FIG. 5 it can be seen that there is an abrupt increase in magnetic field directly beyond the output section, the increase being produced by an enlarged focusing magnet 51. This increase in field produces a compression of the beam, thereby increasing the space charge forces within the beam and decreasing the velocity spread among the electrons. A magnetic field perturbing ring 52, mounted by any suitable means, not shown, is positioned approximately $\frac{1}{2}\lambda_{sc}$ ahead of the point of increase of the magnetic field. Ring 52 functions in the manner as rings 41 to prevent scalloping of the beam as it enters the increased field region. Ring 52 could also be placed $\frac{1}{2}\lambda_{sc}$ beyond the point of field increase, or two rings, placed before and after the point of increase might also be used. As a consequence of the action of ring 52, the radial components of velocity of the electrons are substantially eliminated, which components would tend to hamper beam collection. The slight variations in longitudinal velocity of the beam do not matter inasmuch as the increased space charge forces insure that all of the electrons are "swept" to the collector, and thus the collector may be operated at a reduced voltage.

As was pointed out in the foregoing, laminar, or non-scalloping, flow of the beam depends upon the proper balance of space charge forces, centrifugal forces, and magnetic forces. Anything acting to change any one of these forces independently of the other produces scalloping, and a proper change in any of these forces can be used to counteract the scalloping by restoring the balance. The principles of the invention have been demonstrated in the foregoing by operation on the magnetic forces to control the beam and maintain it in laminar flow. In certain applications, however, such as cyclotron wave type amplifiers, it might be more desirable to operate upon the electric forces controlling the beam. In such case, the beam can be controlled by passing it through electronic lenses which, when properly placed and with proper voltage applied, produce expansions or contractions of the beam in the proper phase to restore the balance of forces. In order that reduced voltages on the lenses may be used, a number of lenses stacked in a series spaced apart by $\frac{1}{2}\lambda_{sc}$ with different voltages applied to successive lenses and the same voltages applied to every other lens. Preferably the voltages are greater and less than the drift tube or helix voltage by the same increment. With such an arrangement, beam scalloping is made dependent upon beam voltage, and laminar flow can be maintained. Beam compression can also be controlled by properly placed lenses in a manner analogous to that discussed in connection with FIG. 1.

While the principles of the invention have been demonstrated as used in a traveling wave tube, such principles are applicable to the other types of beam tubes where high density cylindrical beams are desired without resort to highly complicated focusing structures. In addition, while the magnetic field perturbing has been demonstrated using rings, other configurations are possible. The present invention, as explained in the foregoing, produces such electron beams utilizing a simple, straight-forward focusing arrangement. It will be readily apparent that such an arrangement can be adapted by workers in the art to many uses without departure from the spirit and scope of the invention.

What is claimed is:

1. An electron discharge device comprising an electron gun for producing a converging electron beam, magnetic focusing means for producing a magnetic field for focus-

ing said beam, and a collector electrode for said beam, means for shielding said gun and said beam from the magnetic field of said focusing means during convergence of the beam, means for introducing said beam into said magnetic field, said magnetic field having a strength sufficient to produce an imbalance of the forces governing the flow of said beam whereby an initial scalloping of said beam is caused to commence, magnetic field perturbing means adjacent said introducing means for symmetrically distorting said magnetic field and for producing an imbalance of the forces governing the flow of said beam, said last-mentioned means being placed between $\frac{1}{4}$ and $\frac{1}{2}$ of a scallop wavelength from said introducing means to produce a cancellation of the scalloping effect of said magnetic field.

2. An electron discharge device as claimed in claim 1 wherein said last-mentioned means comprises means for decreasing the strength of the said magnetic field in the region of minimum beam diameter.

3. An electron discharge device comprising an electron gun for producing a converging electron beam, magnetic focusing means for producing a magnetic field having a multiplicity of field reversals for focusing said beam, and a collector electrode for said beam, means for shielding said gun and said beam from the magnetic field of said focusing means during convergence of the beam, means for introducing said beam into said magnetic field, said magnetic field having a strength sufficient to produce an imbalance of the forces governing the flow of said beam whereby said beam is caused to scallop, magnetic field perturbing means adjacent said introducing means for creating an imbalance of the forces governing the beam flow, said last-mentioned means being positioned relative to said introducing means to produce a cancellation of the scalloping effect of said magnetic field, and magnetic field perturbing means adjacent the region of magnetic field reversals for producing a cancellation of the beam scalloping produced by said field reversals.

4. An electron discharge device as claimed in claim 3 wherein said last-mentioned means comprises magnetic field reducing means.

5. An electron discharge device as claimed in claim 3, wherein said last-mentioned means comprises magnetic field reducing means spaced from the region of field reversal by a distance of $\frac{1}{4}$ to $\frac{1}{2}$ a scallop wavelength.

6. An electron discharge device comprising an electron gun for producing an electron beam, magnetic focusing means for producing a magnetic field for focusing said beam, said focusing means being characterized by having at least one longitudinally extending region wherein said field is of sufficient strength to produce an imbalance of the forces governing the flow of said beam whereby said beam is caused to commence to scallop, magnetic field perturbing means adjacent the beginning of said region for symmetrically distorting said magnetic field and for producing an imbalance of forces governing the flow of said beam, said last-mentioned means being placed between $\frac{1}{4}$ and $\frac{1}{2}$ of a scallop wavelength from said introducing means to produce a cancellation of the scalloping effect of said magnetic field.

7. An electron discharge device as claimed in claim 6 wherein said last-mentioned means comprises a magnetic field reducing means.

8. A magnetic focusing system for an electron discharge device having an extended electron beam characterized by a scalloping wavelength, said focusing system comprising first and second magnetic pole pieces adjacent the ends of the electron beam path and a plurality of intermediate pole pieces between said first and second pole pieces, a plurality of magnet means for establishing magnetic focusing fields between successive pole pieces, successive magnetic focusing fields being reversed in sense and magnetic field perturbing means adjacent said first pole piece and each of said intermediate pole pieces for reducing the strength of the magnetic field in the region

of field reversal, each of said field perturbing means being positioned in a range between $\frac{1}{4}$ to $\frac{1}{2}$ a scallop wavelength from its associated pole piece.

9. A magnetic focusing system as claimed in claim 8 further comprising means for producing an increase in magnetic field strength between said second pole piece and the intermediate pole piece immediately preceding said second pole piece and magnetic field perturbing means positioned within $\frac{1}{2}$ a scallop wavelength of the point of the field increase.

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