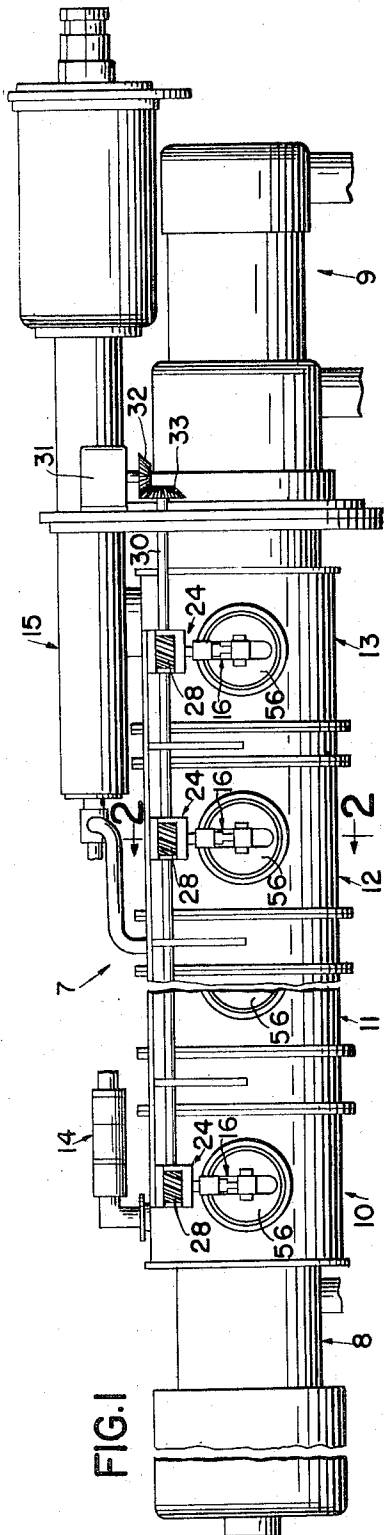
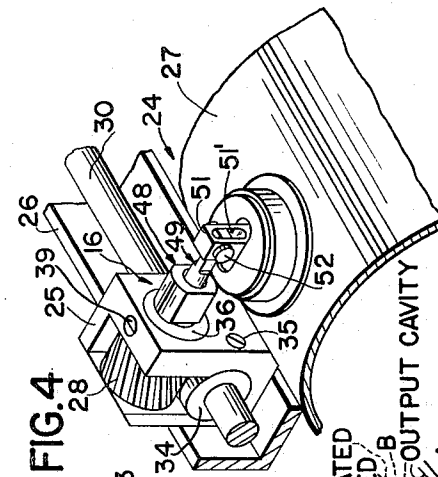
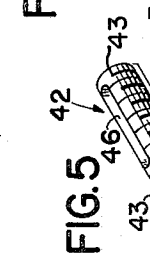
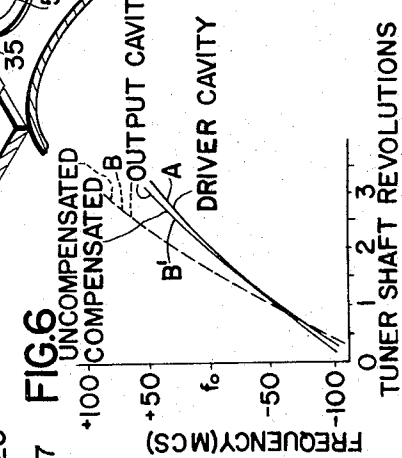
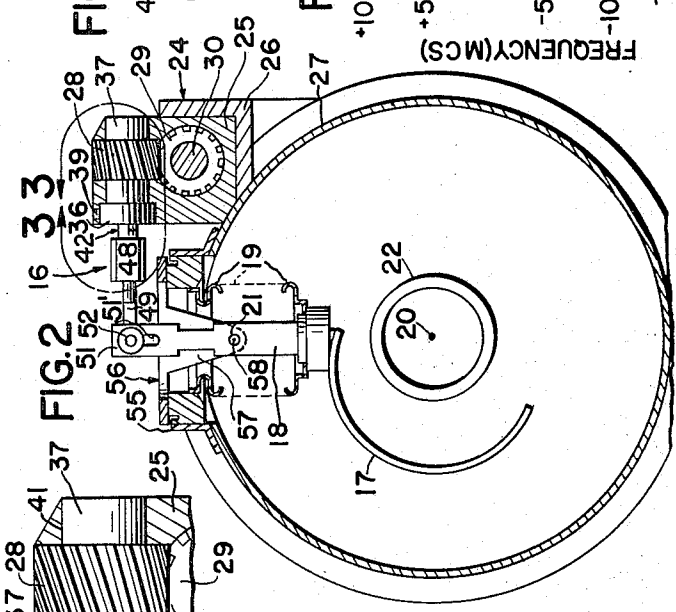
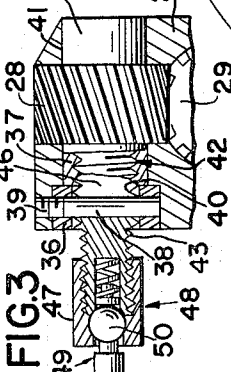


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HIGH FREQUENCY ELECTRON DISCHARGE DEVICE TUNING MEANS HAVING
MEANS TO CONVERT FROM ROTATIONAL TO RECIPROCATING MOTION
Filed Aug. 26, 1964



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HIGH FREQUENCY ELECTRON DISCHARGE DEVICE TUNING MEANS HAVING MEANS TO CONVERT FROM ROTATIONAL TO RECIPROCATING MOTION

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This invention relates in general to high frequency electron discharge devices and more particularly to klystrons and tuning means therefore.

In the field of high frequency electron discharge devices such as the multi-cavity, broadband klystron continuous research on methods of lowering per unit tube cost while simultaneously improving the resultant end product is being undertaken. The present invention provides multiple advantages with regard to cost improvement and product enhancement of multi-cavity broadband klystrons. Considering the problem of broadbanding a high frequency multi-cavity klystron one conventional design approach would lead one skilled in the art to utilize differential cavity dimensions in order to obtain a broadband overall frequency response. This approach, of course, results in increased per unit cost because of the differing sizes and is therefore not an optimum solution. Another approach involves utilizing equivalent cavity dimensions and obtaining a broadband frequency response by appropriate cavity tuner means. In each of the above approaches, it is desirable to utilize tuner means (inductive, capacitive, combination of inductive and capacitive) in order to cover as wide a range of frequencies as possible in a single tube as well as employing stagger tuning for broadbanding purposes. The present invention provides a simplified tuner actuator mechanism in conjunction with a capacitive gap tuner design incorporated in a multi-cavity klystron which permits utilization of a single drive shaft to vary tuning rate as well as total frequency range for each cavity on an independent basis. This, of course, permits utilization of the tuner actuating mechanism of the present invention in klystrons which are stagger tuned on a cavity dimensional basis only or on klystrons which are stagger tuned on a tuner basis only or on klystrons which are stagger tuned on a combination of the above. The flexibleness of the tuner actuating mechanism of the present invention is further utilizable in capacitive gap tuned klystron oscillators as well as amplifiers and in plural as well as single cavity klystrons.

The present invention provides novel means for translating rotational motion of a single drive shaft into a reciprocating motion of a plurality of tuner drive screws which motion in turn is translated into oscillatory pendulum motion on a plurality of capacitive gap tuner paddles on an independent basis with regard to tuning rate and total frequency range of coverage as well as relative location of center frequency f_0 for a plurality of coupled resonant cavities.

It is therefore an object of the present invention to provide an improved high frequency electron discharge device.

A feature of the present invention is the provision of a klystron having means for providing pendulum type motion to a capacitive tuner mounted in a resonant cavity integrated with said klystron.

Another feature of the present invention is the provision of a klystron having a plurality of resonant cavities wherein each of said cavities are provided with capacitive gap tuner means actuated by a single drive shaft which provides for translation of rotational motion of the drive shaft into a reciprocating motion on a plurality of tuner

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drive screws which motion in turn is translated into oscillatory pendulum motion of said plurality of capacitive gap tuner means on an independent basis with regard to tuning rate and total frequency range of coverage as well as relative location of center frequency f_0 for said plurality of resonant cavities.

These and other features of the present invention will become apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein:

FIG. 1 depicts a fragmented longitudinal elevational view of a broadband multi-cavity klystron amplifier incorporating the features of the present invention,

FIG. 2 is a sectional view partly in elevation taken along the lines 2-2 of FIG. 1,

FIG. 3 is a sectional view of that portion of FIG. 2 encompassed by lines 3-3,

FIG. 4 is a fragmentary perspective view partly sectioned depicting the tuner actuating mechanism utilized in the klystron depicted in FIG. 1,

FIG. 5 is a perspective view of the tuner drive screw portion of the present invention,

FIG. 6 is an illustrative graphical portrayal of the manipulation and effect of independent tuner rate control on a resonant frequency vs. drive shaft revolutions characteristic.

Referring now to FIG. 1, there is depicted a multi-cavity broadband klystron device 7 having a beam forming and projecting means (electron gun means) 8 disposed at the upstream end thereof and electron beam collector means 9 disposed at the downstream end thereof with a plurality of resonant cavities 10, 11, 12, 13 (electromagnetic interaction means) disposed intermediate said gun and collector means in vacuum sealed relationship therewith. The input cavity 10 is provided with suitable electromagnetic energy coupler means 14, preferably coaxial as shown, and the output cavity 13 is provided with electromagnetic energy coupler means 15 preferably as shown and described in co-pending U.S. patent application Serial No. 387,454, filed August 4, 1964, by Robert L. Woods and Ulrich Wolff which is assigned to the same assignee as the present invention. Quite obviously, the particular electromagnetic energy couplers, beam forming and projecting means, interaction means and overall functional characteristics as well as other portions of the klystron depicted in FIG. 1 may take any of the acceptable prior art constructions of which the literature is replete.

Each of the resonant cavities is provided with a capacitive gap tuner actuating mechanism 24 which includes the generic concept of a capacitive tuner plate 17 as best seen in FIG. 2 which is mounted on a pendulum tuner shaft 18 surrounded by vacuum bellows 19 and adapted and arranged for pendulum oscillation in a plane transverse to the longitudinal axis 20 of the klystron about pivot axis 21 as described and claimed in co-pending U.S. patent application Serial No. 387,740 filed August 6, 1964, by Oscar C. Lundstrum and assigned to the same assignee as the present invention. The tuner plate 17 is preferably shaped to conform to the exterior geometry of the drift tube 22 and is preferably disposed symmetrically about a plane which is normal to the tube (device) central axis 20 and equally spaced between the opposed re-entrant drift tubes in each cavity. Quite obviously, the particular relative dimensions and arrangement of the tuner plate and drift tubes can vary considerably from tube to tube depending on the chosen design. For example, asymmetric gaps and various tuner plate shapes designed for particular desired characteristics utilizing conventional empirical design techniques are within the purview of the present invention.

The tuner activating mechanism generally indicated by

24 includes a gear box 25 securely affixed to, by means of bracket 26, cavity wall 27. The gear box 25 includes two pairs of axially perpendicular vertically displaced bores extending through the defining walls of the box and a hollowed interior suitably dimensioned to receive helical translation gears 28, 29 best seen in FIGS. 2, 3 and 4. Each helical gear 29 is fixedly mounted, as by press fitting on an elongated drive shaft 30 which extends along the longitudinal extent of the tube and which is driven by means of motor 31 driving bevel gear 32 which in turn drives bevel gear 33 affixed to the drive shaft 30. A locking collar (not shown) in conjunction with locking bushing 34 retain each helical drive gear 29 in place within the gear box while permitting drive shaft rotation therein. A plurality of set screws such as 35 are preferably employed to lock the bushing 34 within the gear box 25. The helical tuner gear 28 is rotatably secured within the gear box 25 by means of a locking collar 36 in conjunction with tuner nut 37. Locking collar 36 is fixedly secured within gear box 25 to the tuner shaft by means of dowel pin 38 and a set screw 39. Tuner nut 37 is provided with internal threads 40 and a smooth external surface 41 and is press fitted within helical tuner gear 28 such that rotation of the tuner gear 28 will result in rotation of the tuner nut 37 without slippage over the tunable band of each cavity.

A tuner drive screw 42, best seen in FIGS. 3 and 5, having external threads 43 on both the enlarged main body portion 44 and the reduced neck portion 45 and an elongated generally rectangularly shaped slot 46 extending along a major portion of the enlarged main body portion 44 is threaded within tuner nut 37 and locked therein with respect to rotation relative to the gear box by means of dowel pin 38 extending through elongated slot 46. Tuner drive screw 42 is capable of linear one-dimensional non-rotational reciprocating motion by virtue of elongated slot 46 which prevents rotation of the screw while translating the rotational engagement of tuner nut threads 40 and tuner drive screw threads 43 into linear reciprocating motion of the tuner drive screw. The length of the slot 46 functions as a built-in limit stop means serving to define the extent of linear motion of the tuner drive screw 42.

The reduced neck portion 45 of the tuner drive screw serves in conjunction with annular clamping nut 47 as a ball joint 48 retaining a spring loaded spherically (ball) tipped drive rod 49. The ball tip end 50 of drive rod 49 is disposed in a matching socket portion of the clamping nut while the other end of drive rod 49 engages tuner pendulum shaft 18 in a slotted end portion 51 thereof, as best seen in FIGS. 2 and 4, by means of screw, washer and nut combination 52. The slotted end portion 51 of the tuner pendulum shaft 18 is provided with four 90° space rotated elongated slots 51' as best seen in FIGS. 2 and 4 which permit adjustment of the point of engagement between the drive rod 49 and tuner pendulum shaft 18 along the longitudinal extent of the pendulum shaft. The extent of this adjustment capability is obviously a function of the length of the aforementioned slots. The drive rod 49 and tuner screw 42 combine to function as reciprocating means 16.

The translation of the reciprocating motion of the drive rod into pendulum motion of the tuner shaft is due to the pivotal axis or point 21 about which the tuner shaft 18 oscillates in motion akin to a pendulum. The pendulum tuner shaft 18 is supported on and within a preferably annular housing collar 55 which with a support bridge 56 having a pair of spaced pivot arms 57 and a suitable support bearing shaft 58 serves to securely affix the shaft 18 with respect to the housing collar 55 while permitting pendulum motion about pivot axis 21. Many obviously equivalent pivotal mounting arrangements may be utilized in lieu thereof. See, for example, the arrangements set forth in the aforementioned co-pending application by Oscar C. Lundstrom. It is to be understood that the

terminology "reciprocating motion" covers both one dimensional and two dimensional motion of a drive rod such as 49 which couples and translates the rotational motion of the drive shaft 30 into the pendulum motion of the shaft 18. The two dimensional motion of a drive rod such as 49 may be varied according to the type of coupling mechanisms chosen for converting the rotational motion of the drive shaft 30 into the reciprocating motion of the drive rod 49 and according to what type of coupling mechanism is chosen for converting the reciprocating motion of the drive rod 49 into the pendulum motion of the pendulum tuner shaft 18.

The aforementioned tuner actuating mechanism 24 in operation is capable of providing efficient mechanical means for converting the rotation of bevel gear 32 by drive motor 31 into pendulum type motion of a plurality of capacitive tuners on an independent basis. The frequency range to be covered by each tuner can be easily preset by selection of an appropriate slot length 46 and the rate of tuning easily preset on an individual cavity basis by selection of appropriate thread pitches for tuner screw 42 and tuner nut 37.

The location of the tunable band for each cavity of a multi-cavity klystron can be independently preset by any of a number of ways or combinations thereof, as taught by the present invention. One method would be through selection of an appropriate tuner screw neck length 45 in order to preset the location of the tunable band limits. Another approach would be independent presetting of the location of the point of engagement between drive rod 49 and the slotted end portion 51 of pendulum shaft 18 along the length of slots 51'. Another technique would involve employing staggered physical locations in each tuner gear box 25 of the slots 46 in order to preset the location of the frequency band of coverage of each tuner on an independent basis. This technique would, of course, require careful design of the press fit between each tuner nut 37 and surrounding helical tuner gear 28 to allow slippage therebetween upon engagement of dowel pin 38 and each end point of the slot 46 such that the drive motor torque was adequate to handle rotation of at least $n-1$ slipping engagements, where n is number of tuner actuating mechanisms 16 and assuming the worst case, namely staggering of all slots 46 physically with respect to each other. Alternative techniques for control of tuning band locations are individual selection of drive rod 49 lengths which would be equivalent to selection of different neck portion lengths 45 of tuner screw 42. The aforementioned list of techniques for presetting the tunable band limits on an independent basis is not meant to be all inclusive but merely to indicate the flexibility of the present invention.

Techniques available for independent control of tuning rate besides the aforementioned control of thread pitches involve independent presetting of pivot point axis 21 relative to end points of the tuner pendulum shaft 18 and/or conversely variation of shaft lengths on an individual basis. This technique, of course, inherently involves tuning band location as well as tuning rate and this factor must be considered as well. In effect, the engagement point between drive rod 49 and shaft 18 is equivalent to the control of pivot axis location and tuner shaft length. Another technique for independent control of tuning rate would be pre-selection on an independent basis of helical gear (28, 29) pitches.

Of the aforementioned independent control techniques the preselection of tuner screw 42 pitch and tuner nut 37 pitch is preferred because of the relative ease of insertion of said elements by merely removing a dowel pin 38; unscrewing clamping nut 47 and removing the tuner screw 42 and tuner nut 37 and insertion of replacement elements.

FIG. 6 depicts an illustrative graphical example of the utilization of the independent control features of

the present invention with regard to converting the motion of a single drive shaft 30 into tuner shaft motion for a plurality of tuner shafts in a plurality of cavities having different tuning characteristics. For example, curves A and B are typical tuning curves for a driver cavity and an output cavity. It is seen that for a given amount of shaft 30 rotation assuming direct conversion and no compensation or independent control of the conversion between drive shaft revolutions and pendulum shaft movement will result in a far greater change in output cavity frequency than driver cavity frequency for a given amount of shaft rotation. Now, utilizing the independent control features of the present invention, such as for example, independent selection of thread pitches for each tuner screw 42 and tuner nut 37 such that the output cavity pendulum tuner shaft will move a smaller distance than the driver cavity pendulum tuner shaft for a given amount of shaft 30 rotation it is a simple matter to compensate the output cavity tuning characteristic such that it substantially corresponds to the driver cavity characteristic. See characteristic B' for an example of this.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A high frequency electron discharge device having beam forming and projecting means disposed at the upstream end portion thereof and beam collector means disposed at the downstream end portion thereof and electromagnetic interaction means disposed therebetween and coupled thereto in vacuum sealed relationship to form a vacuum envelope for said device, said interaction means including flexible vacuum sealing means coupled thereto, said electromagnetic interaction means having at least one frequency tuning mechanism coupled thereto, said tuning mechanism including means for varying the frequency of electromagnetic energy along the portion of said electromagnetic interaction means to which said tuning mechanism is coupled, means for physically moving said tuning means along an arcuate path relative to said electromagnetic interaction means in pendulum type motion about a pivot point means, said means for physically moving said tuning means including a pendulum tuner shaft adapted and arranged for oscillation about said pivot point means, means for moving said pendulum shaft about said pivot point means including motion translational means adapted and arranged for converting rotational motion into reciprocating motion of a reciprocating means coupled to said pendulum shaft to thereby drive said pendulum shaft in oscillatory motion about said pivot point means, said pendulum tuner shaft having said tuning means coupled thereto at the one end portion of said shaft, said pivot point means about which said shaft oscillates in pendulum motion being located along the length of the shaft intermediate the respective ends of the shaft, said means for moving said pendulum shaft about said pivot point means being coupled to said shaft at the other end portion of said shaft, said pivot point means being located exteriorly of the evacuated region formed by said vacuum envelope, said pivot point means serving to support said pendulum shaft independently of said flexible vacuum sealing means, said reciprocating means including a ball joint.

2. A high frequency electron discharge device having beam forming and projecting means disposed at the upstream end portion thereof and beam collector means disposed at the downstream end portion thereof and electromagnetic interaction means disposed therebetween and coupled thereto in vacuum sealed relation-

ship therewith, said electromagnetic interaction means having at least one frequency tuning mechanism coupled thereto, said tuning mechanism including means for varying the frequency of electromagnetic energy along the portion of said electromagnetic interaction means to which said tuning mechanism is coupled, means for physically moving said tuning means along an arcuate path relative to said electromagnetic interaction means in pendulum type motion about a pivot point, said means for physically moving said tuning means including a pendulum tuner shaft adapted and arranged for oscillation about said pivot point, means for moving said pendulum shaft about said pivot point including motion translational means adapted and arranged for converting rotational motion into reciprocating motion of a reciprocating means coupled to said pendulum shaft to thereby drive said pendulum shaft in oscillatory motion about said pivot point, said motion translational means including means for converting rotational motion about a first axis into rotational motion about a second axis displaced from said first axis, said rotational motion about said second axis inducing reciprocating motion of said reciprocating means.

3. The device as defined in claim 2 wherein said device further includes a drive shaft coupled to said motion translational means and a motor coupled to said drive shaft, said motor being mounted on said device whereby the torque of said motor is converted into oscillatory motion of said tuner shaft about said pivot point.

4. A high frequency electron discharge device having beam forming and projecting means disposed at the upstream end portion thereof and beam collector means disposed at the downstream end portion thereof and electromagnetic interaction means disposed therebetween and coupled thereto in vacuum sealed relationship therewith, said electromagnetic interaction means having at least one frequency tuning mechanism coupled thereto, said tuning mechanism including means for varying the frequency of electromagnetic energy along the portion of said electromagnetic interaction means to which said tuning mechanism is coupled; means for physically moving said tuning means along an arcuate path relative to said electromagnetic interaction means in pendulum type motion about a pivot point, said means for physically moving said tuning means including a pendulum tuner shaft adapted and arranged for oscillation about said pivot point, means for moving said pendulum shaft about said pivot point including motion translational means adapted and arranged for converting rotational motion into reciprocating motion of a reciprocating means coupled to said pendulum shaft to thereby drive said pendulum shaft in oscillatory motion about said pivot point, the coupling point between said reciprocating means and said tuner shaft being adjustable along the longitudinal axis of said tuner shaft.

5. A high frequency electron discharge device having beam forming and projecting means disposed at the upstream end portion thereof and beam collector means disposed at the downstream end portion thereof and electromagnetic interaction means disposed therebetween and coupled thereto in vacuum sealed relationship therewith, said electromagnetic interaction means having at least one frequency tuning mechanism coupled thereto, said tuning mechanism including means for varying the frequency of electromagnetic energy along the portion of said electromagnetic interaction means to which said tuning mechanism is coupled, means for physically moving said tuning means along an arcuate path relative to said electromagnetic interaction means in pendulum type motion about a pivot point, said means for physically moving said tuning means including a pendulum tuner shaft adapted and arranged for oscillation about said pivot point, means for moving

said pendulum shaft about said pivot point including motion translational means adapted and arranged for converting rotational motion into reciprocating motion of a reciprocating means coupled to said pendulum shaft to thereby drive said pendulum shaft in oscillatory motion about said pivot point, said motion translational means including a pair of gears coupled together for converting rotational motion about a first axis to rotational motion about a second axis displaced from said first axis, one of said pair of gears being coupled to a tuner nut, said tuner nut having a threaded internal surface and a tuner screw having an external threaded surface engaging said threaded nut surface, said tuner screw and said tuner nut being coupled together such that rotational motion of said tuner nut is translated into reciprocating nonrotational linear motion of said tuner screw.

6. The device as defined in claim 5 wherein said coupling means between said tuner screw and said tuner nut includes an elongated slot extending along a portion of the length of said screw and a dowel pin extending through said slot whereby said tuner screw is prevented from rotational motion while being capable of linear reciprocating motion.

7. A high frequency electron discharge device having beam forming and projecting means disposed at the upstream end portion thereof and beam collector means disposed at the downstream end portion thereof and electromagnetic interaction means disposed therebetween and coupled thereto in vacuum sealed relationship therewith, said electromagnetic interaction means having at least one frequency tuning mechanism coupled thereto, said tuning mechanism including means for varying the frequency of electromagnetic energy along the portion of said electromagnetic interaction means to which said tuning mechanism is coupled, means for physically moving said tuning means along an arcuate path relative to said electromagnetic interaction means in pendulum type motion about a pivot point, said means for physically moving said tuning means including a pendulum tuner shaft adapted and arranged for oscillation about said pivot point, means for moving said pendulum shaft about said pivot point including motion translational means adapted and arranged for converting rotational motion into reciprocating motion of a reciprocating means coupled to said pendulum shaft to thereby drive said pendulum shaft in oscillatory motion about said pivot point, said tuner mechanism including a tuner gear box mounted on said device, said gear box housing said motion translational means, said motion translational means including a pair of intermeshing helical gears mounted within said gear box, a cylindrical tuner nut having a smooth external surface and threaded internal surface coaxially disposed within one of said helical gears, said reciprocating means including a tuner screw having a threaded external surface coaxially threaded within said tuner nut, said tuner screw having one end portion adapted and arranged to function as a ball joint coupler means between said tuner screw and one end of a drive rod portion of said reciprocating means, said drive rod having its other remote end coupled in fixed, yet adjustable relation to said tuner shaft.

8. A high frequency electron discharge device having beam forming and projecting means disposed at the upstream end portion thereof and beam collector means disposed at the downstream end portion thereof and electromagnetic interaction means disposed therebetween and coupled thereto in vacuum sealed relationship to form a vacuum envelope for said device, said interaction means including flexible vacuum sealing means coupled thereto, said electromagnetic interaction means having at least one frequency tuning mechanism coupled thereto, said tuning mechanism including means for varying the frequency of electromagnetic energy along the por-

tion of said electromagnetic interaction means to which said tuning mechanism is coupled, means for physically moving said tuning means along an arcuate path relative to said electromagnetic interaction means in pendulum type motion about a pivot point means, said means for physically moving said tuning means including a pendulum tuner shaft adapted and arranged for oscillation about said pivot point means, means for moving said pendulum shaft about said pivot point means including motion translational means adapted and arranged for converting rotational motion into reciprocating motion of a reciprocating means coupled to said pendulum shaft to thereby drive said pendulum shaft in oscillatory motion about said pivot point, said pendulum tuner shaft having said tuning means coupled thereto at the one end portion of said shaft, said pivot point means about which said shaft oscillates in pendulum motion being located along the length of the shaft intermediate the respective ends of the shaft, said means for moving said pendulum shaft about said pivot point means being coupled to said shaft at the other end portion of said shaft, said pivot point means being located exteriorly of the evacuated region formed by said vacuum envelope, said pivot point means serving to support said pendulum shaft independently of said flexible vacuum sealing means, said motion translational means including a tuner drive gear coupled to a tuner screw such that rotation of said tuner drive gear induces linear nonrotational reciprocating motion of said tuner screw.

9. A high frequency electron discharge device having beam forming and projecting means disposed at the upstream end portion thereof and beam collector means disposed at the downstream end portion thereof and electromagnetic interaction means disposed therebetween and coupled thereto in vacuum sealed relationship to form a vacuum envelope for said device, said interaction means including flexible vacuum sealing means coupled thereto, said electromagnetic interaction means having at least one frequency tuning mechanism coupled thereto, said tuning mechanism including means for varying the frequency of electromagnetic energy along the portion of said electromagnetic interaction means to which said tuning mechanism is coupled, means for physically moving said tuning means along an arcuate path relative to said electromagnetic interaction means in pendulum type motion about a pivot point means, said means for physically moving said tuning means including a pendulum tuner shaft adapted and arranged for oscillation about said pivot point means, means for moving said pendulum shaft about said pivot point means including motion translational means adapted and arranged for converting rotational motion into reciprocating motion of a reciprocating means coupled to said pendulum shaft to thereby drive said pendulum shaft in oscillatory motion about said pivot point, said pendulum tuner shaft having said tuning means coupled thereto at the one end portion of said shaft, said pivot point means about which said shaft oscillates in pendulum motion being located along the length of the shaft intermediate the respective ends of the shaft, said means for moving said pendulum shaft about said pivot point means being coupled to said shaft at the other end portion of said shaft, said pivot point means being located exteriorly of the evacuated region formed by said vacuum envelope, said pivot point means serving to support said pendulum shaft independently of said flexible vacuum sealing means, said device being a multi-cavity velocity modulation tube and said electromagnetic interaction means includes a plurality of coupled resonant cavities each having at least one of said frequency tuning mechanisms coupled thereto, a drive shaft extending along the longitudinal extent of said device, each of said tuning mechanisms being independently coupled to said drive shaft at spaced positions along the axial extent of said drive shaft such that rotation of said drive shaft induces independent oscillatory motion of each of said tuner

shafts about the pivot point means in each of said tuner mechanisms in an independent manner.

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