

Dec. 2, 1969

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3,482,136

CHARGED PARTICLE BEAM SPREADER SYSTEM INCLUDING
THREE IN-LINE QUADRAPLE MAGNETIC LENSES

Filed April 13, 1966

3 Sheets-Sheet 1

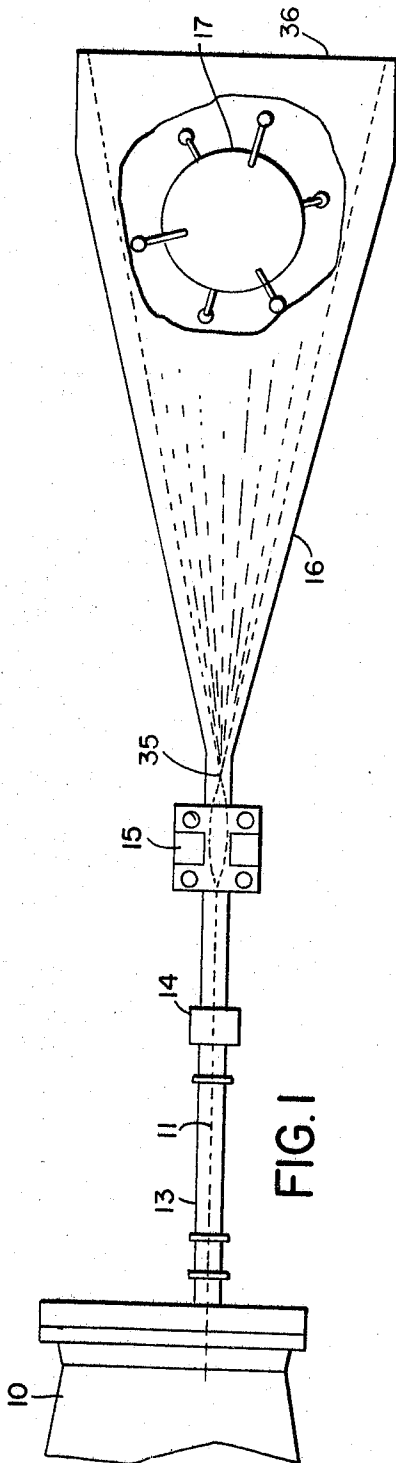


FIG. 1

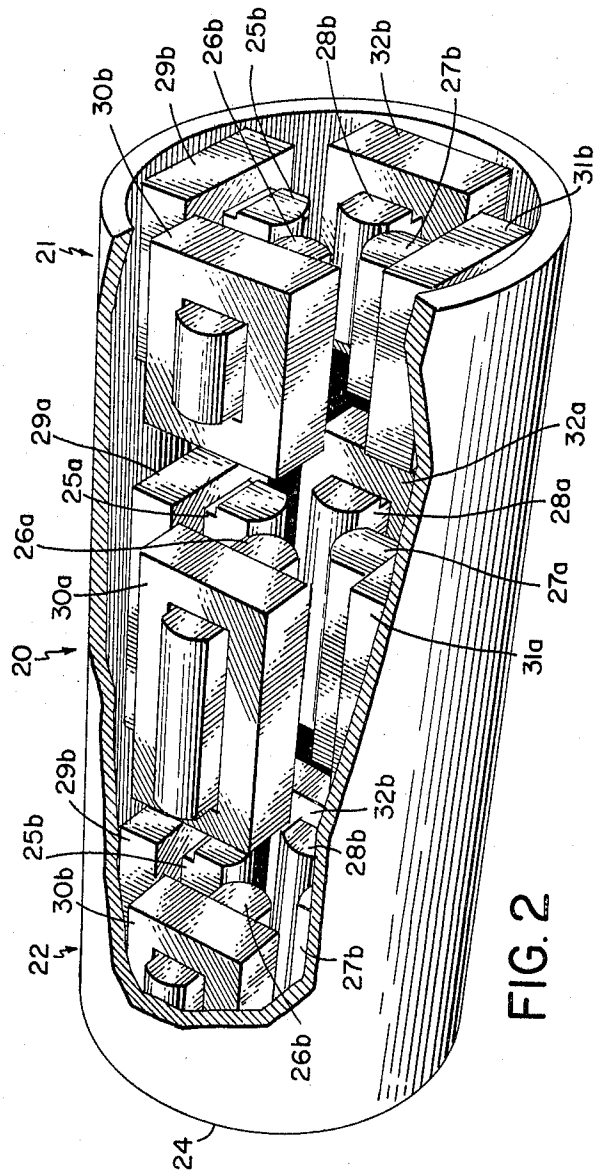


FIG. 2

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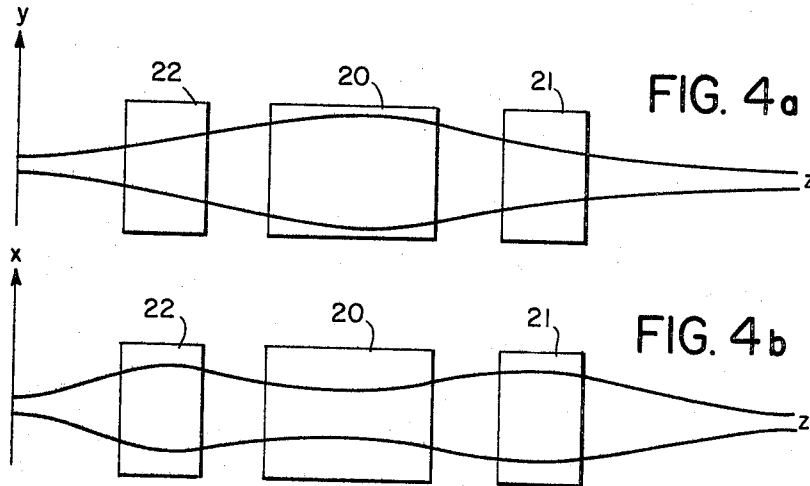


FIG. 3a

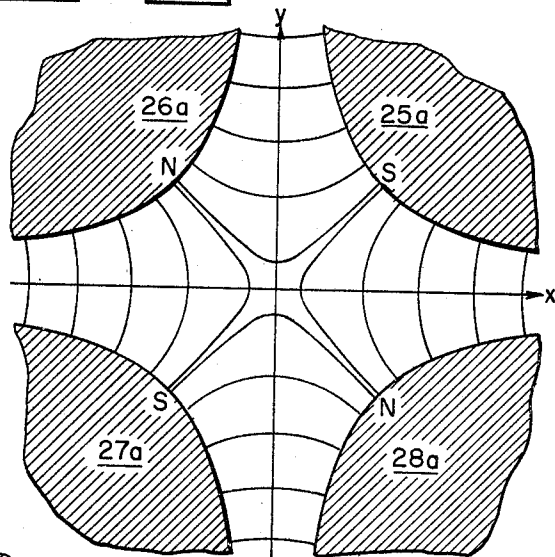
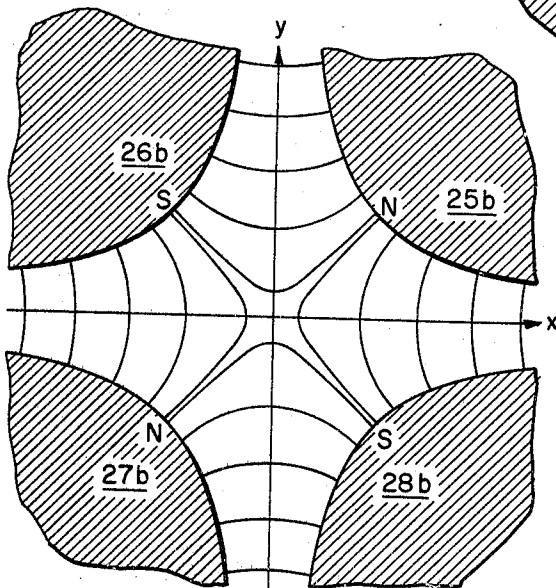


FIG. 3b



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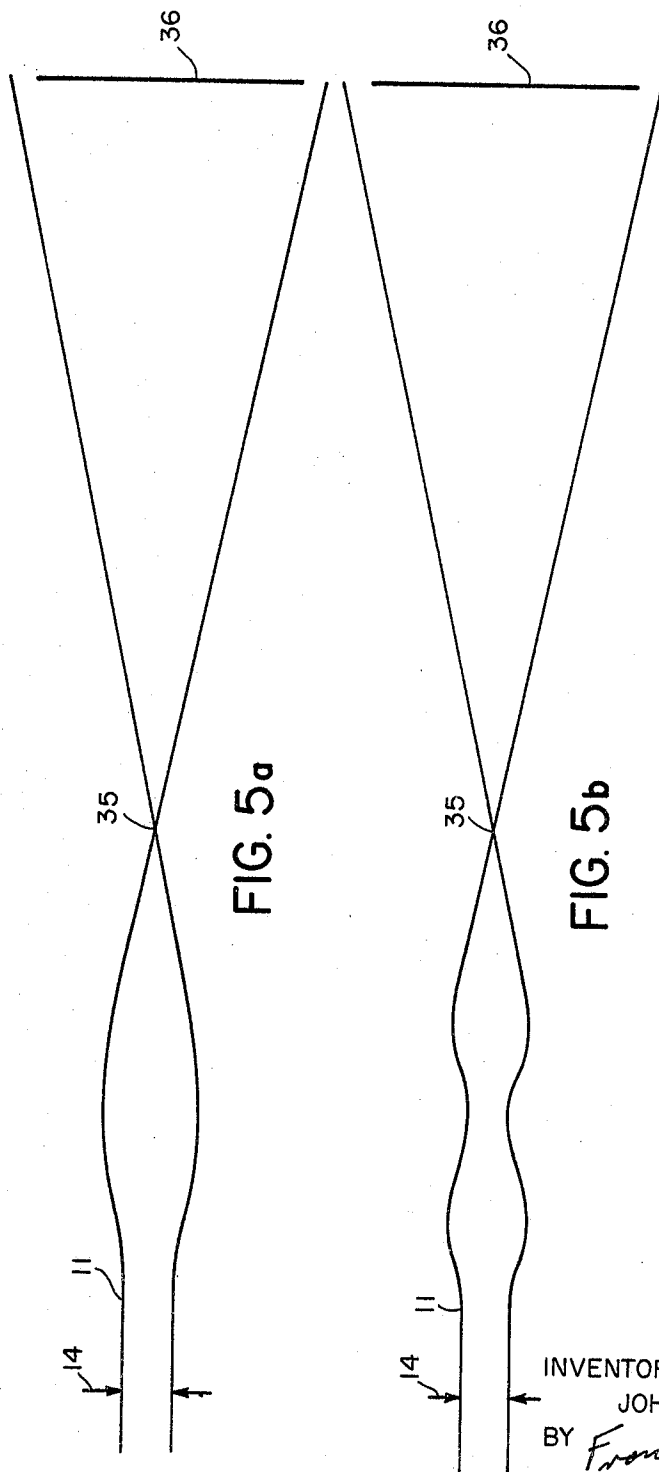
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3,482,136 CHARGED PARTICLE BEAM SPREADER SYSTEM INCLUDING THREE IN-LINE QUADRAPOLE MAGNETIC LENSES

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2 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for projecting and enlarging charged particle beams comprising a particle beam generator and accelerator feeding the beam through an aperture to a gradient lens system, composed of three in-line quadrupole lenses, which focuses it at a cross-over point such that the beam after passing the cross-over point expands uniformly to form a greatly enlarged distortion free image of the aperture.

This invention relates to charged particle beam manipulation and in particular to an apparatus for projecting and enlarging charged particle beams.

Charged particle beams of energies below 1 Bev. are being increasingly used in many diverse fields such as radiation chemistry and cosmic space simulation.

At present, the devices used for manipulation of these beams are capable only of either moving the beam from spot to spot, such as in the so-called flying spot scanners, or line by line such as shown in Patent No. 2,866,903, dated Dec. 30, 1958, entitled "Method of an Apparatus for Irradiating Matter with High Energy Electrons," issued to John Nygard.

Although the above described equipments are quite adequate for many situations, they fail in others. One typical application in which prior art devices are not adequate is in space radiation simulation in which it is necessary that a large body such as a space satellite be exposed to a high energy radiation field. Since such satellites usually depend on large numbers of potentially radiation sensitive, electronic circuits, it is necessary that such devices be tested by exposure to a radiation field such as may be encountered in interplanetary space.

In order to overcome the deficiencies encountered when using line or spot irradiation in such applications the present invention was conceived.

Broadly speaking the present invention is directed towards a charged particle beam manipulation device capable of simultaneously irradiating the entire exposed surface of a body and accomplishes this feat by passing a charged particle beam through a plurality of suitably disposed magnetic lenses capable of projecting and enlarging the beam through a significant solid angle.

The invention will be better understood in detail by reference to the following description when taken in conjunction with the accompanying illustrations of a specific embodiment thereof.

In the drawings:

FIGURE 1 is an overall view of the apparatus;

FIGURE 2 is a broken away view of the preferred lens system used in the apparatus of FIGURE 1;

FIGURE 3a shows the field configuration of the central lens of the system shown in FIGURE 2;

FIGURE 3b shows the field configuration of the end lenses of the system shown in FIGURE 2;

FIGURE 4a shows the particle trajectory in the Y plane of the lens system of FIGURE 2;

FIGURE 4b shows the particle trajectory in the X plane of the lens system of FIGURE 2;

FIGURE 5a shows the beam pattern of the apparatus of FIGURE 1 in the Y plane;

FIGURE 5b shows the beam pattern of the apparatus of FIGURE 1 in the X plane.

Referring now to the drawing and more particularly to FIGURE 1, there is shown a charged particle apparatus 10 which is capable of forming a highly energetic charged particle beam 11, accelerating the beam, directing it along the center of an evacuated drift tube 13, through a defining aperture 14 and a gradient lens system 15 into an evacuated radiation chamber 16 in which there is positioned a device 17 which is to be irradiated. To provide uniform irradiation of the entire device surface, the device 17 is preferably rotatably supported in the chamber 16 by any suitable means (not shown).

In accordance with the invention when the beam passes through aperture 14, it is defined so that it is tight and uniform as it enters the lens system 15. As the beam passes through the lens system, it is successively manipulated in both the Y and Z planes such that the beam becomes concentrated at a cross-over point 35 posterior to the lens system. Upon passing this cross-over point the beam expands in all directions into an enlarged image of aperture 14.

The lens system 15, preferably used in the present invention, is a triplet quadrupole magnetic system and is shown in detail in FIGURE 2. This lens system comprises three quadrupole lenses 20, 21 and 22 all of which are maintained in line and enclosed in a single housing 24. Each lens consists of four pole pieces and surrounding electromagnetic coils. When power is supplied to the coils, the pole pieces become magnetized and a magnetic field is established between the faces of the respective pole pieces.

Because quadrupole magnets by their nature converge a charged particle beam passing therethrough in one direction while diverging it at right angles to the converging direction, it is necessary that each lens 20, 21 and 22 be arranged in such a manner that the beam passing therethrough will converge, in both the X and Y planes, at the cross-over point 35. This can be fully appreciated from a review of FIGURES 3a, 3b, 4a and 4b which show the magnetic fields which must be set up in each lens and the beam trajectories required in both the converging and diverging planes of each lens. This is accomplished by rotation of polarity of each end lens with respect to the central lens and by making the length of the central lens 20 twice that of the end lenses 21 and 22. This rotation of polarity of the end lenses 21 and 22 with respect to the control lens 20 is achieved by exciting the coils 29a and 31a of central lens 20 such that pole pieces 25a and 27a are south poles, while energizing coils 30a and 32a such that pole pieces 26a and 28a are north poles and simultaneously energizing both sets of coils 29b and 31b and 30b and 32b, of end lenses 21 and 22, such that pole pieces 26b and 28b are south poles and 25b and 27b are north poles.

The above described arrangement of the triplet quadrupole lens system will condense the beam at the cross-over point 35 and impart to the particles comprising the beam a direction such that a greatly enlarged reproduction of image 14 is produced at the end of chamber 16.

Since the beam expands uniformly in both the X and Y directions after it passes the cross-over point 35, an object placed in chamber 16, if smaller than the expanded beam, will have its surface uniformly irradiated. The chamber 16 can be lengthened to any desired size limited only by mechanical and vacuum considerations.

FIGURES 5a and 5b show the actual change in relative size of the beam 11 from the time it passes the aperture 14 until it strikes, 17 feet away, the end 36 of the chamber 16.

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It should, of course, now be obvious to those skilled in the art that the triplet lens described above may be replaced with an equivalent such as two, in line, quadrupole doublets.

Since other variations and modifications of the present invention may now become apparent to those skilled in the art, it is desired that the described invention be limited only by the following claims.

What is claimed is:

1. A beam enlargement apparatus for expanding a charged particle beam through a solid angle comprising means for generating a charged particle beam, means for accelerating said generated beam, an aperture inserted in the beam path for defining the accelerated beam, a gradient lens system means surrounding said defined accelerated beam for uniformly manipulating said beam in mutually perpendicular directions to concentrate said beam at a cross-over point posterior to said lens system and to form thereat a distortion free image of said aperture and expanding said beam through a solid angle to form an enlarged uniform image of said aperture, said gradient lens system consisting of three in-line quadrupole magnetic lenses, the first and third of said in-line lenses having their polarity crossed with respect to the second of said in-line lenses, said second lens being equal to the combined length of said first and said third lenses, housing means

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coupled to said accelerator means for containing the aperture and the lens system and means for evacuating said housing means.

2. The apparatus of claim 1 wherein said housing means has walls generally parallel to the accelerated beam and to each other which extend from said acceleration means to a position approximately coinciding with said cross-over point and which diverge at said position to substantially parallel said beam as said beam expands after passing said cross-over point to form a chamber which can be substantially filled by said expanded beam.

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250—49.5; 313—84, 160; 335—210