United States Patent [19]

Beasley et al.

[11] **3,902,089**

[45] **Aug. 26, 1975**

[54] **CHANNEL PLATE MATRIX OF TUBES HAVING TWISTED SEPTA**

[75] Inventors: **Robert Malcolm Beasley; Derek Washington,** both of Salfords, near Redhill, England

[73] Assignee: **U.S. Philips Corporation,** New York, N.Y.

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[21] Appl. No.: **267,111**

[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ..... **313/105;** 65/2 X; 57/140 G

[51] **Int. Cl.**..... **H01j 43/22;** N01j 29/41

[58] **Field of Search**..... 313/105, 104

[56] **References Cited**

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Primary Examiner—Robert Segal

Attorney, Agent, or Firm—Frank R. Trifari; Ronald L. Drumheller

[57] **ABSTRACT**

The channels in a channel plate are divided into sub-channels by longitudinal septa which are twisted along the length of the channels in order to prevent ion feedback. An angle of twist of 360° may be used in order to permit each sub-channel to represent a separate picture element.

1 Claim, 16 Drawing Figures

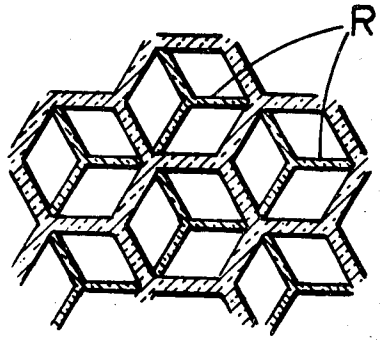


Fig. 1(a)

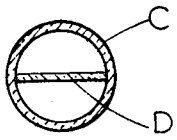




Fig. 1(b)

Fig. 2.

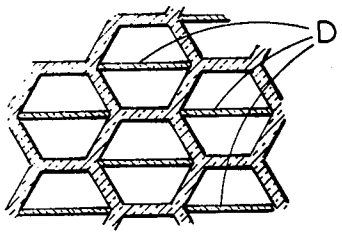
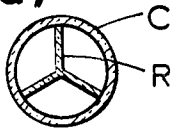


Fig. 3(a)



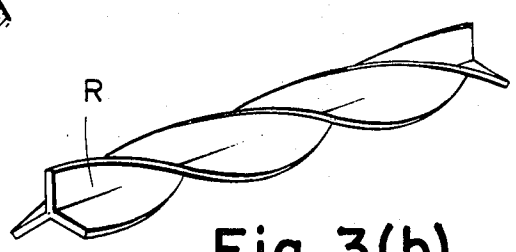


Fig. 3(b)

Fig. 4.

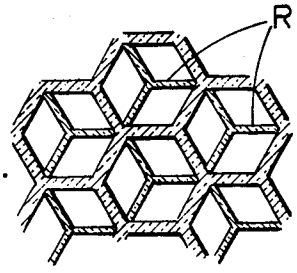


Fig. 5.

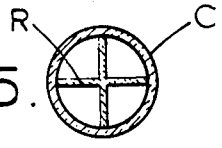
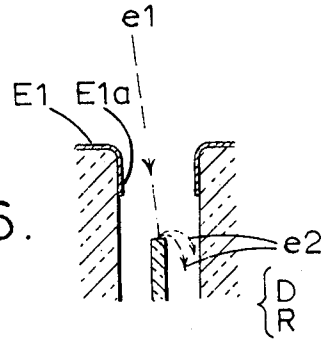


Fig. 6.



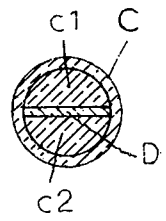


Fig. 7(a)

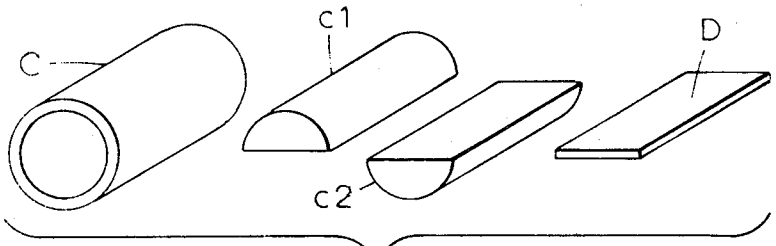


Fig. 7(b)

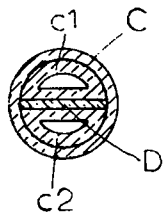


Fig. 8(a)

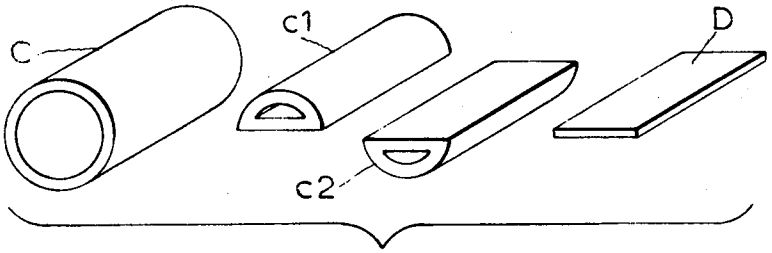


Fig. 8(b)

Fig. 9.

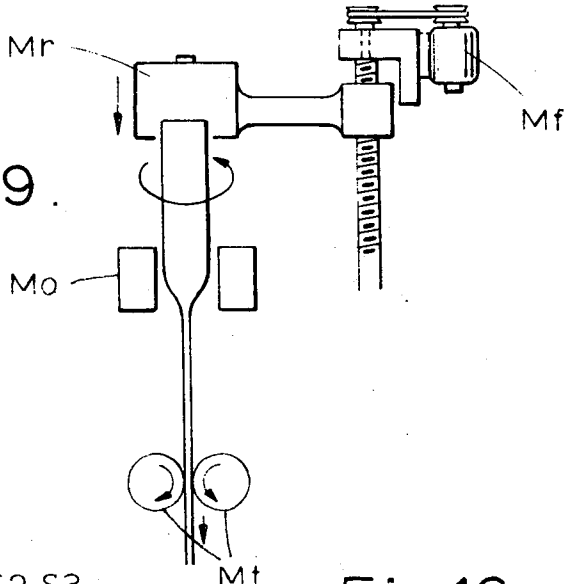


Fig. 10.

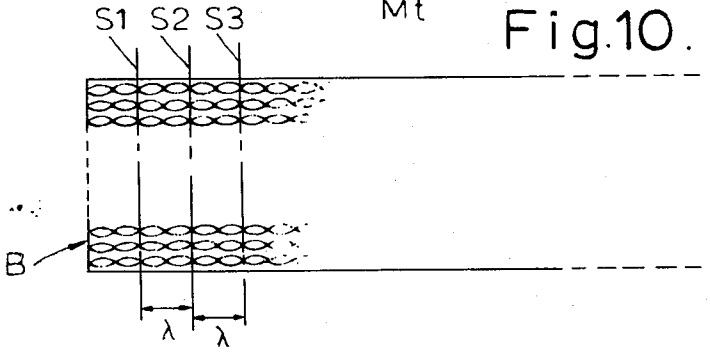


Fig. 11.

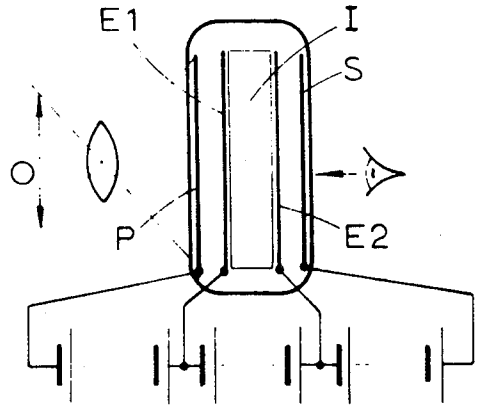
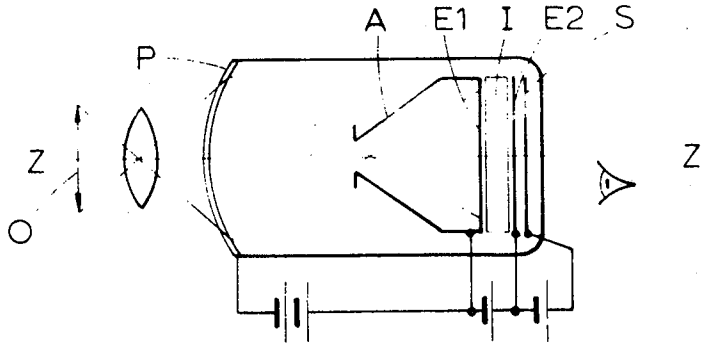


Fig. 12



CHANNEL PLATE MATRIX OF TUBES HAVING TWISTED SEPTA

This invention relates to electron multipliers and more particularly to electron multipliers of the channel plate type. The invention is applicable to channel plates for use in electronic imaging and display tube applications.

The type of device now known as a "channel plate" can be defined as a secondary-emissive electron-multiplier device comprising a matrix in the form of a plate having a large number of elongate channels passing through its thickness, said plate having a first conductive layer on its input face and a separate second conductive layer on its output face to act respectively as input and output electrodes.

The invention relates more particularly to channel plates of the continuous dynode type. This is a convenient term for channel plates having what is at present the conventional form of construction. Such channel plates can be regarded as continuous dynode devices in that the material of the matrix is continuous (though not necessarily uniform) in the direction of thickness, i.e. in the direction of the channels.

Continuous dynode channel plates are described, for example, in British Pat. No. **1,064,073** and in U.S. Pat. Nos. **3,260,876, 3,387,137, 3,327,151** and **3,497,759,** while methods of manufacture are described in British Pat. Nos. **1,064,072** and **1,064,075.**

In the operation of continuous dynode plates a potential difference is applied between the two electrode layers of the matrix so as to set up an electric field to accelerate the electrons, which field establishes a potential gradient created by current flowing through resistive surfaces formed inside the channels or (if such channel surfaces are absent) through the bulk material of the matrix. Secondary-emissive multiplication takes place in the channels and the output electrons may be acted upon by a further accelerating field which may be set up between the output electrode and a suitable target, for example a luminescent display screen.

Channel plates can be used in imaging tubes of various kinds, for example scanning tubes such as cathode-ray tubes and camera tubes and non-scanning image intensifier tubes (this Specification will, for convenience, refer to an image intensifier tube in those terms rather than as an "image converter" tube even in applications where the primary purpose is a change in the wavelength of the radiation of the image).

It is an object of the present invention to overcome or mitigate the problem of ion feed-back which arises in the practical use of channel plates. In an individual channel, ions are fed back from parts of the wall and interior space of the channel (these will be referred to as "channel ions") and in single channel multipliers this problem has been solved by considerable curvature of the channel tube (e.g. a curvature of **360°** so that the tube is in the form of one complete helical turn).

In the case of a channel plate used in an image intensifier having a phosphor display screen located near the output end of the channels, ion feedback may also derive from such screen. Furthermore, it now appears that many ions are generated also in the gap between such screen and the channel plate (such ions will be referred to as "gap ions").

When ion feedback occurs, the ions are accelerated by the field in the channels and can cause spurious secondary emission further back in the channels and/or at the photo-cathode, quite apart from damage to the photo-cathode.

Reduction of ion feedback from channel plate to photo-cathode can lead to improved life. In addition, reduction of ion feed-back permits operation in the pulse saturation mode. This can result in a more favourable pulse height distribution (P.H.D.) and reduced noise.

With channel plates used in multi-channel electron multipliers and image intensifiers attempts have been made to overcome or reduce ion feedback in the following ways:

A. U.S. Pat. No. **3,603,832** describes the provision of electron-permeable conductive membranes provided to obturate the entrances to the channels and thus prevent the passage of ions to the photo-cathode. This technique is relatively difficult and expensive especially for plates of large area.

B. U.S. Pat. No. **3,374,380** describes what is sometimes referred to as a "chevron" construction in which two separate channel plates are arranged in series with each other with the channel axes of one plate disposed at an angle to the channel axes of the other plate. This arrangement has the disadvantage that individual channels of one plate are not aligned with individual channels of the other plate so that definition is lost, and this loss may be increased by the gap which appears to be present between the two plates in the practical arrangements available.

However, since the publication of these prior patent specifications further studies of the ion feedback effect have been carried out by Applicants.

First, it is now clear that reduction of spurious secondary electron cascades resulting from ion feedback to the channel wall near the input can allow a plate to be operated at higher gain (for use in photomultipliers for example).

For a channel having a **50:1** length-to-diameter (L/D) ratio Applicants have discovered that about **75–90%** of ions formed inside the channels and which escape from the input may be formed in the last (i.e. output) **30%** of the length of the channel (the terms "input and output" are used herein exclusively with reference to electrons). For a single channel of a channel plate Applicants have, on this basis, made an estimate of the two-dimensional channel curvature required to mask this **30%** end region from the input, i.e. to ensure that such region cannot be "seen" from the input aperture. Such curvature turns out to be much less than the curvatures used in single-channel multipliers, One reason being the lower gains normally used in channel plates.

On the basis of this discovery, Applicants have described in British Application No. **12780/71** a matrix for a channel in which the axes of the channels are curved in one plane (the term "axis" is thus used to denote the finite centre-line of a channel and not a straight line in the normal geometrical sense). Such curvature is applied to the axes of the channels of a channel plate as an alternative to the conductive membrane and "chevron" arrangements referred to above.

The main object was, as before, to prevent ion feedback or, to use an alternative expression, to render the channels "ion blind" and a secondary object (for some applications) is to render them also "optically blind" to prevent optical feed-back from the display screen (for the latter purpose the matrix must be made opaque).

The present invention provides a further alternative solution to the ion-feedback problem in channel plates by adopting a modification of the "Spiraltron" principle. The Spiraltron is described in Trans. I.E.E.E., NS-15, No. 3, June 1968 where the electron multiplier is composed of a parallel stack of individual elements, that are termed Spiraltron multipliers, fused together. Each Spiraltron multiplier in turn comprises six single-tube multipliers twisted or wrapped about a solid central structural core.

In a later version (Review of Scientific Instruments, Vol. 41, No. 5, May 1970) the six helically twisted tubes are replaced by six twisted radial partitions which subdivide the space between the solid core and a cylindrical outer tube.

In both cases the solid core has a cross-sectional area which is comparable with that of each of the six channels and this renders the "Spiraltron" arrangements unsuitable for use in channel plates of imaging quality because of the loss of useful area (the solid cores occupy almost one-seventh of the total area). Another objectionable fact would be that each six-tube Spiraltron would effectively represent only one picture element if it were used in an imaging array instead of being used in the simpler photo-multiplier or detector applications described in the above references.

According to a first aspect the present invention provides a matrix for a channel plate of the continuous dynode type wherein each channel includes a longitudinal single or multiple septum which is twisted along the length of the channel without the provision of any solid structural core so that, apart from the thickness of the septum, effectively the whole cross-sectional area of each channel is subdivided into two or more separate sub-channels by said septum.

With such an arrangement angles of twist t much smaller than 360° can be sufficient to achieve ion blindness and also (if the matrix is opaque) optical blindness. However, for imaging purposes, each group of sub-channels can only represent one picture element unless, according to a second aspect of the invention, each septum is twisted through an angle t of 360°, or approximately 360° or a multiple of 360°, over the length of its channel so that the output aperture of each sub-channel is aligned with its input thereby permitting each sub-channel to represent a separate picture element. In this case the degree of accuracy required for the angle of twist t depends solely on the use of the sub-channels to provide high resolution by representing separate picture elements.

Each channel may include a plain single septum which extends diametrically, or substantially diametrically, across the channel from side to side so as to divide it into two sub-channels. In this case the structure is a very simple one which can be made with little more difficulty than a conventional matrix.

Alternatively, each channel may include a radial multiple septum which radiates from the central axis of the channel and subdivides the channel into n sub-channels, the number n being preferably within the range 3 to 6 inclusive.

The input end of each septum may be set back with respect to the input aperture in order to increase the number of secondary electrons generated and utilized in the input region of the channel.

A method of manufacturing matrices according to the present invention may include the steps of forming an initial tubular structure with a septum supported in position therein, drawing said structure down to a single fibre, twisting said fibre during the drawing process, forming a boule from such twisted fibres and slicing said boule along parallel cutting planes. Preferably the fibre is twisted with constant pitch and the cutting planes are spaced apart substantially by 360° of twist or a multiple of 360°. A uniformly regular input and output pattern can be obtained if in addition the boule is formed in a regular manner in the sense that all septa have the same orientation in any one of a series of parallel transverse planes. In any event, for imaging purposes it is desirable to select the cutting planes so that the thickness of each resulting slice corresponds substantially to one pitch or a multiple of the pitch.

The drawing and twisting of the initial tubular structure can be carried out without using temporary internal etchable supporting cores since the septum can provide some internal support against unwanted deformation during subsequent processing, but the use of etchable cores in the sub-channels may still be desirable for particular reasons as will be explained.

Angles of twist smaller than 360° can be sufficient to mask the output aperture of a sub-channel from its input aperture so that gap ions are intercepted and can also be sufficient to mask the 30% end region of the sub-channel from its input aperture so as to intercept most channel ions. However, such considerations are not relevant when, as hereinnafter, angles t of 360° or multiples of 360° have been adopted in order to obtain maximum resolution.

Embodiments of the invention will now be described by way of example with reference to the diagrammatic drawings in which:

FIG. 1 (a) shows in cross-section a channel tube divided by septa into two sub-channels;

FIG. 1 (b) shows the twisted septa of FIG. 1 (a);

FIG. 2 shows in cross-section a fused stacked array of tubes of the type shown in FIG. 1 (a) with all the septa parallel;

FIG. 3 (a) shows in cross-section a channel tube divided by septa into three sub-channels;

FIG. 3 (b) shows the twisted septa of FIG. 3 (a);

FIG. 4 shows in cross-section a fused stacked array of tubes of the type shown in FIG. 3 (a) with the septa having the same orientation;

FIG. 5 shows in cross-section a channel tube divided into four sub-channels;

FIG. 6 shows a side cross-sectional view of a septum set back from the input end of the channel tube;

FIG. 7 (a) shows the structure of FIG. 1 (a) in one stage of manufacture;

FIG. 7 (b) shows the various component parts of the structure of FIG. 7 (a);

FIG. 8 (a) shows a modification of the structure of FIG. 7 (a);

FIG. 8 (b) shows the various component parts of the modified structure of FIG. 8 (a);

FIG. 9 schematically shows a machine for drawing fibers according to the present invention;

FIG. 10 schematically shows a boule or stacked array of channel tubes;

FIG. 11 illustrates the use of a channel plate according to the present invention in an image tube of the proximity type; and

FIG. 12 illustrates the use of a channel plate according to the present invention in an image tube of the "electron-optical diode" or "inverter" type.

Referring now to the drawings, FIG. 1 (*a*) shows in cross-section a glass channel tube C which includes a plain single septum D of glass which extends diametrically across the channel from side to side so as to divide it into two sub-channels. Such tubes can be assembled and fused to form a regular matrix structure and the structure is a very simple one which can be made with little more difficulty than a conventional matrix.

FIG. 1 (*b*) shows the twisted form of the septum D which in these examples is twisted through 360° to achieve high resolution, as aforesaid, by ensuring that each sub-channel will represent a separate picture element in its correct location. Such an angle of twist is at the same time more than sufficient to achieve ion — and (if the matrix is opaque) optical — "blindness". If it is desired, in addition, to have all the septa D orientated in the same direction, this can be achieved by more methodical stacking of the tubes during assembly, and the input and output pattern will then be completely regular as shown in FIG. 2.

FIGS. 3 (*a*) and 5 show single-channel units which include a radial multiple septum R which radiates from the central axis of the channel and sub-divides the channel into 3 or more sub-channels.

In particular, FIG. 3 (*a*) shows a tube with a triple septum R which defines three sub-channels, and FIG. 3 (*b*) shows the twisted form of the septum. If such units are assembled to form a regular matrix array and are fused under compression to an approximately hexagonal form, uniform definition can be obtained. In addition, a completely regular pattern of apertures can be obtained at the faces of the plate as shown in FIG. 4 if the tubes are assembled so that all the septa have the same orientation.

The further example given in FIG. 5 shows a tube C with a quadruple septum R defining four sub-channels.

As shown in FIG. 6, the input end of each septum may be set back to a depth *d* with respect to the input aperture in order to increase the number of secondary electrons generated and utilized in the input region of the channel. Primary electrons *e*1 and secondaries *e*2 are shown schematically and E1 represents the input electrode of the completed channel plate with a re-entrant conductive extension E1*a* in the mouth of each channel. With this arrangement it is easier to prevent metallization of the input edge of the septum and it is more likely that the secondaries therefrom will travel down the sub-channels and thus be utilized which action represents effectively an increase in the "open area" of the channel plate, i.e. the area capable of detecting incident electrons. The arrangement may be achieved by etching back the end of the septum and is applicable to the septa D of FIG. 2 and septa R of FIGS. 4 and 5.

A method of manufacture will now be described and it will be assumed that, apart from the provision of twisted septa required by the present invention, the basic process involves the drawing, stacking and fusing together of single tubular glass fibres with or without temporary supporting cores e.g. as described in the aforesaid British Pat. No. 1,064,072. When such cores are used (to control the deformation of the tubes during drawing and fusing) the cores will be etched out or otherwise removed after the formation of each plate. In particular, such cores may be of a glass which can be etched more readily than the tube and septum glass, and said cores may have a passage or bore to faciltate such etching in known manner.

Preferably the septa are of the same glass and have secondary-emissive and conductivity surfaces of the same kind as those of the channel walls of the tubes C. If so, etching back the septa according to FIG. 6 can be facilitated by making the septa thinner than the tube walls.

A method of manufacturing matrices according to the present invention may include the step of forming an initial tubular structure with a septum supported in position therein. The structure for the arrangement of FIG. 1 (*a*) can comprise merely the tube C and a flat (untwisted) septum element D. Preferably, however, the structure also comprises two "half-round" solid cores *c*1 – *c*2 as shown in FIGS. 7 (*a*) and 7 (*b*), such cores being etched or dissolved away at a later stage in accordance with the solid core principle described and claimed in the aforesaid British Pat. No. 1,064,072. The two solid cores may have passages to facilitate etching as shown in FIGS. 8(*a*) and 8(*b*).

Other arrangements such as those of FIG. 3 (*a*) and FIG. 5 can employ corresponding initial untwisted tubular structures in which three or four solid cores may be used. In such cases the cores are less important than in the plain septum case since a multiple septum is self-locating and can act to a greater extent as internal support during subsequent processing, but cores may still be desirable in many cases when cylindrical tubes C are forced together into a hexagonal pattern as in FIGS. 2 and 4 (this may occur when the septa are made thinner than the tube walls as aforesaid).

The initial tubular structure thus formed is then subjected to the step of drawing down to a single fibre and twisting of said fibre during the drawing process. This step can be carried out by a drawing machine as shown schematically in FIG. 9, the machine being, if desired, conventional except for the provision of a motor Mr to rotate the initial stock while it is being drawn in the oven Mo and taken up as fibre by take-up rollers Mt (Mf represents the feed mechanism for the stock).

The process includes the subsequent steps of forming a boule B (FIG. 10) from twisted fibres all having the same pitch and slicing said boule along parallel cutting planes. A regular pattern such as those of FIGS. 2 and 4 can be obtained at each face of the matrix if in addition the boule is formed in a regular manner in the sense that all fibres have the same orientation in any one of a series of parallel transverse planes S1, S2, S3 etc. spaced apart by equal distances λ. Such planes are then used as the cutting planes so that the thickness of each resulting slice corresponds substantially to one pitch (λ) as shown or a multiple of the pitch.

Of course, in addition to the above processes, the slice or matrix may have to have its internal channel surfaces rendered secondary-emissive and slightly conductive and it has to be made into a channel plate by the addition of a first conductive layer on its input face and a separate second conductive layer on its output face to act respectively as input and output electrodes.

FIGS. 11 and 12 illustrate the use of channel plates in accordance with the invention in imaging tubes. In the examples given, a channel plate I having electrodes E1–E2 is shown inside the envelope of an image intensifier tube containing also a photo-cathode P and a lu-

minescent screen S. FIG. **11** shows a tube of the "proximity" type while FIG. **12** shows a tube of the "electron-optical diode" or "inverter" type having a conical anode A.

When a display screen S is used, the plate I can be made opaque so as to prevent optical feedback from S as well as ion feedback.

The invention may also be used for other imaging tubes, for example cathode-ray display tubes and camera tubes.

As will be appreciated, all the constructions and methods described with reference to the drawings can be carried out without the restriction to an angle of twist *t* of **360°** (or a multiple of **360°**) in which case ion-blindness can still be achieved but the individual sub-channels will no longer represent separate picture elements in their correct positions.

Alternative twisted structures are described in co-pending U.S. patent application Ser. No. **515,322.**

As was stated in the preamble, the required current flows through resistive surfaces formed inside the channels ("surface conduction" type of channel plate) or through the bulk material of the matrix ("bulk conduction" type). Suitable glasses exist for both types. The usual way of obtaining resistive surfaces inside the channels of an insulating matrix is to use a lead-glass and, as one of the last steps in the manufacturing process, to reduce some of the lead oxide to lead at the channel surfaces. As for performance, it can be said generally that the geometries given in this Specification are appropriate for surface-conduction plates; if bulk conduction is used with the same geometries, the performance will be at least equal.

The tube of FIG. **12** may replace one of the type described in U.S. Pat. No. **3,487,258** in which the channels are straight and have angles of tilt with respect to the electron paths such that it is possible to substantially avoid a "black spot" on the screen due to electrons passing straight through the channels without multiplication. Thus a channel plate having curved channels according to the present invention can be arranged to suppress the "black spot" effect while also counteracting ion feedback.

What we claim is:

1. An improved matrix for a channel plate electron multiplier having improved image resolution, comprising: a side by side stacked array of substantially identical tubes, each tube having an interior surface and a substantially geometrically centered longitudinal axis thereof, each tube having an identical number of substantially equally spaced septa extending from said axis to said interior surface, said septa spiralling about each other in the longitudinal direction to define within each of said tubes the same number of substantially identical longitudinal channels spiralling about each other, said number of channels being within the range of three to six inclusive, the inside surfaces of said defined channels being at least slightly conductive and secondary emissive, said septa being set back from the end of said tubes intended to be the input end and spiralling through an angle of substantially **360°** or an integer multiple thereof, whereby the ends of said defined channels are in the same relative position with respect to adjacent tubes on both sides of said stacked array thereby improving the image resolution of said array.

* * * * *