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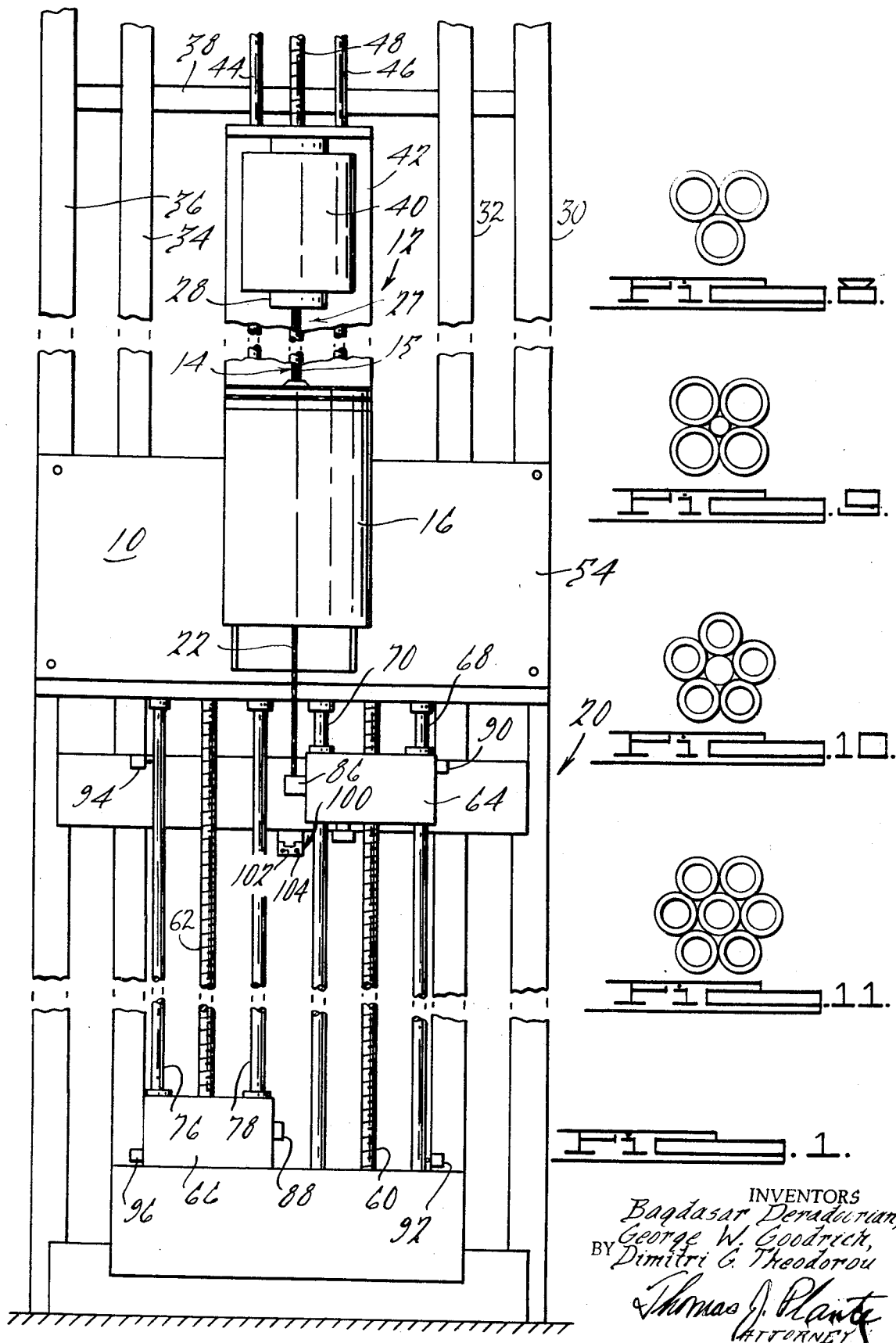
B. DERADOORIAN ET AL

3,677,730

METHOD OF FABRICATING AN ARRAY OF CHANNEL MULTIPLIERS

Filed Dec. 18, 1968

2 Sheets-Sheet 1



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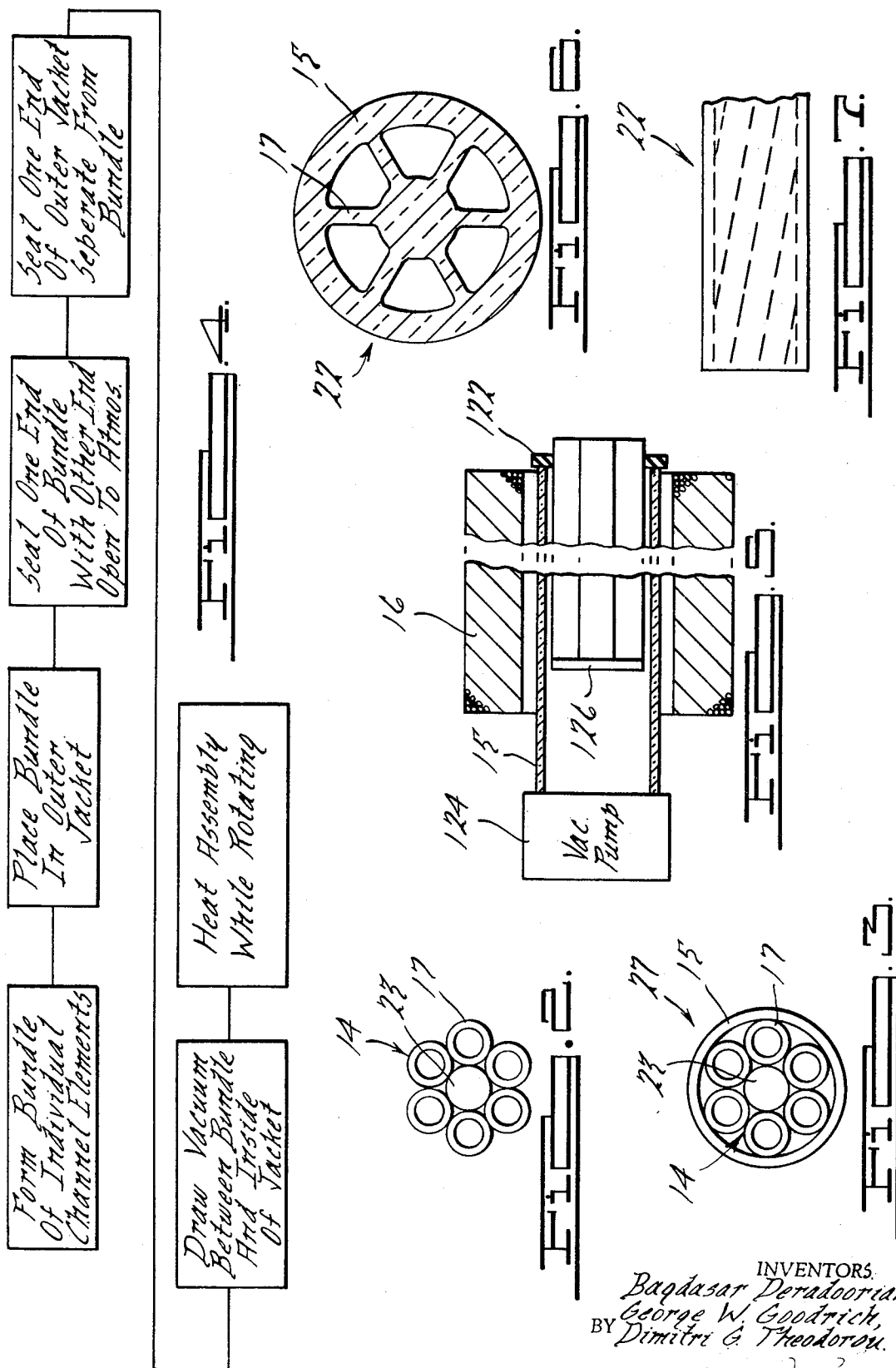
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METHOD OF FABRICATING AN ARRAY OF CHANNEL MULTIPLIERS

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2 Claims

ABSTRACT OF THE DISCLOSURE

A method of forming an array from a bundle of individual channel multipliers, the individual channels being fabricated of a lower temperature softening glass tube to permit the walls of the individual channels to be spiralled and also expanded to fill the interstices within a higher softening temperature outer tube. Also, the invention could be practiced utilizing glass tubes of the same temperature softening characteristic. The expanding and spiralling operation is performed simultaneously by drawing the bundle of individual channels through a furnace while rotating the feed or pull assemblies of the drawing apparatus to spiral the channel bundle and exhausting the area between the individual tubes and the equal or higher temperature softening glass tube to expand the individual channels.

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates generally to a channel multiplier array and a method of producing the array, and more particularly to a method of spiralling a bundle of individual channel multipliers for effectively suppressing ion and photon feedback from the output section of the channel multiplier array, while simultaneously expanding the individual channels within an outer glass jacket to fill the interstices thereby increasing the effective open area of the resultant channel multiplier array.

Early uses of electron multipliers involved the provision of a plurality of individual glass channels formed of straight-through tubes, the individual channels being stacked in a bundle to form an array. This array was utilized, for example, to multiply the number of electrons introduced at the input end of the channel multiplier array by means of secondary emission of electrons from an interior surface of the channels. Thus, an electron introduced into one end of the channel multiplier will successively strike the interior wall of the individual channels, dislodging secondary electrons to increase the number of output electrons relative to the number of input electrons.

However, it has been found that spurious outputs are produced by ion or photon feedback, this phenomena involving the feedback of ions or photons from the output end of the array to the area of the input end, the ion feedback producing a direct secondary multiplication effect and the photons causing the release of electrons from a photocathode surface.

Further, it has been found that the open area ratio or the ratio of the useful area to total area available in the array may be substantially increased by the expansion of the walls of the individual channel elements within the confines of an outer tube.

The ion or photon feedback signal may be effectively eliminated by a process of spiralling a plurality of individual channels of circular cross section while the channels are being drawn to size by a drawing process. In this way, the straight-through path from the output

to the input end of the channel multiplier array is effectively eliminated. Also, the open area ratio may be substantially increased by the expansion of the walls of the element within the confines of the outer tube during the drawing process. Specifically, an evacuation apparatus is included at the feed end or draw end of the reducing apparatus whereby the channels are simultaneously spiralled and expanded when the array is heated during the drawing process.

By use of the present invention, a spiral channel multiplier array may be fabricated and the interstitial spaces within the jacket may be eliminated to produce an array assembly which is relatively compact, has a relatively high open area ratio and an increased efficiency. For purposes of this disclosure, the word "soften" is intended to cover the temperature point of a given glass where the glass is capable of moving. "Softening point" is intended to mean the specific temperature at which a particular glass achieves a specific consistency. Normally, the temperature at which a glass "softens" is lower than the "softening point" temperature.

Accordingly, it is one object of the present invention to provide an improved channel multiplier array.

It is another object of the present invention to provide an improved channel multiplier array assembly wherein the individual channels are spiralled to eliminate feedback effect.

It is still another object of the present invention to provide an improved channel multiplier array assembly, the assembly being made up of a plurality of channel multiplier arrays which include an increased open area ratio and a reduced feedback efficiency.

It is still another object of the present invention to increase the ratio of open area to total area in a channel multiplier array or assembly by decreasing the wall thickness of the individual channels and eliminating any canes or mandrels from the center portion of the array.

It is still a further object of the present invention to provide an improved method of filling interstitial spaces in a channel multiplier array.

Further objects, features and advantages of this invention will become apparent from a consideration of the following description, the appended claims and the accompanying drawings in which:

FIG. 1 is an elevation of an apparatus which may be utilized in practicing the method of the present invention for forming a channel multiplier array;

FIG. 2 is an end elevation illustrating a bundle of individual channel multipliers which may be utilized in conjunction with the features of the present invention;

FIG. 3 is an end elevation illustrating the bundle of channel multipliers after it has been placed inside the equal or high temperature softening glass tube;

FIG. 4 is a schematic diagram illustrating a preferred sequence of forming a channel multiplier array in accordance with a method utilizing the features of the present invention;

FIG. 5 is a sectional diagram schematically illustrating the apparatus for practicing the method of the present invention, the vacuum pump being incorporated into the feed or draw apparatus of the assembly illustrated in FIG. 1;

FIG. 6 is a sectional view illustrating the resultant channel multiplier array in cross section;

FIG. 7 is an elevational view illustrating the side of the channel multiplier array of FIG. 6;

FIG. 8 is a diagram illustrating an example of various other channel multiplier array configurations which may be fabricated with the method of the present invention;

FIG. 9 is still another example of another channel multiplier array configuration;

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FIG. 10 is still another form illustrating a further channel multiplier array configuration, and

FIG. 11 is another form of channel multiplier array configuration.

One form of a channel multiplier array may be utilized in connection with an image intensifying structure wherein a source of electrons, in the form of a photocathode, generates a pattern of electron flow which is directly related to the image focused on the photocathode. This electron flow is then directed through the channel multiplier array to increase the number of electrons generated as a result of the focused image. The array is positioned closely adjacent a phosphor screen such that the electrons emanating from the channel multiplier array will strike the phosphor screen and cause the screen to phosphoresce.

From the foregoing description, it is seen that the phosphorescence of the output screen could cause a feedback of the light energy through the straight-through channel multiplier tubes. Thus the light energy from the phosphor screen may be fed back through the array to the photocathode and cause further emission of electrons from the photocathode screen. Similarly, the impact of electrons or residual gasses on the phosphor screen may cause ionization effects, the ions also being attracted back through the channel multiplier array. These latter electrons may then strike the inside diameter of the channel multiplier to cause emission of secondary electrons.

In utilizing the process of the present invention, a plurality of channel multipliers are stacked in a bundle, the bundle being formed of any number of individual channel elements from one to several as for example, six. The individual channels are initially formed in a bundle consisting of, for example, six channels disposed about the circumference of a single inner channel. The individual channel elements at this point are of larger size than the size to be utilized in the final array. Accordingly, it is necessary to draw the individual channels to a smaller size, thus decreasing the wall thickness of the channel and filling the interstitial spaces between the individual channels. In drawing channel multipliers, it is important that the parameters of the drawing apparatus be very carefully controlled as to the uniformity of the pull and feed speeds, temperature control and uniformity of individual channels within an array. During this drawing process, either the feed or the pull apparatus is rotated at a slow speed to twist the entire bundle thereby spiralling the channels within the bundle and the outer tube. In the preferred embodiment, the feed apparatus is rotated to spiral the channels. Simultaneously, the interstices are evacuated to eliminate the voids between the individual channels and the outer tube.

Referring now to FIG. 1, there is illustrated one preferred apparatus 10 for utilizing the method of the present invention. Specifically, the apparatus 10 includes a feed drive assembly 12, which is adapted to feed a bundle 14 of individual channel multipliers 17, including an outer tube 15 through an oven assembly 16. The oven assembly is utilized to heat the individual channels 17 to soften the glass thereof and mold the channels into a solid bundle. It is to be noted that the heat supplied is sufficient to soften the glass of the individual channels but not sufficient to substantially soften the glass of the outer tube in the case of unequal temperature softening glass. Or, in the case of glass having equal temperature softening glass, both tubes are softened.

The channels 17 are then drawn by means of a pull assembly to reduce the diameter of the individual channel and form a reduced diameter array 22. Upon completion of the array, it is to be noted that there is a specific, predictable relation between the initial diameters of the bundle 14 and the final diameter. This relationship is determined by relative feed and pull speeds, the temperature within the oven 16 and the length of time that the materials are within the oven.

The bundle 14 is initially prepared by collecting a plurality of individual channels 17 of substantially equal

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length into a bundle 14 of approximately two to six channels, as specifically illustrated in FIG. 2. The channels 17 are placed around a center channel 23 or cane element or empty space and the outer glass tube 15 receives the center bundle 14 to form the assembly 27 illustrated in FIG. 3. The assembly 27 is then secured to the head 28 of the feed apparatus 12 and directed through the oven section 16. The assembly 27 emerges from the lower portion thereof and is attached to the draw assembly 20. As stated above, the assembly 27 may consist of any number of individual channels, as for example, those illustrated in FIGS. 8 to 11, and the individual channels may be of any preselected size. Also, it is to be understood that a single channel with an off-center aperture may also be spiralled.

The feed apparatus 12 is mounted on a plurality of frame members 30, 32, 34, 36 by means of a cross bar member 38. The feed apparatus includes a main bundle mounting member 40 which is fixedly mounted to a plate member 42, the plate member 42 being vertically slidably supported on a pair of support rods 44, 46. The vertical movement of the plate member 42 and housing 40 is controlled by a rotatable screw jack assembly including a screw element 48 threaded into an aperture (not shown) formed on the back of the plate 42. Thus, as the threaded element 48 is rotated, the plate 42 and thus the holder 40 will be vertically moved to feed or retract the assembly 27 relative to the oven 16. The oven 16 is fixedly mounted on plate member 54 which is secured to the outboard support rods 30, 36 by any suitable means.

The head 28 is rotatably mounted in the mounting member 40 so as to be rotatable in the manner and for the purpose described, and an electric or fluid motor (not shown) or other means provided to rotate the head 28 to create the spiralling action.

The draw apparatus 20 is similar in a sense that the vertical movement of the draw apparatus is controlled by a pair of screw jacks 60, 62 which control draw heads 64, 66. The draw heads 64, 66 are adapted to pull the array 22 through the furnace or heater 16 in a hand-over hand method of operation. It is to be noted that the vertical movement of the heads 64, 66 is greater than that of the head 28 due to the increased length of the drawn array.

Specifically, the pull apparatus includes the first pull head 64, which is vertically slidably mounted on a pair of rods 68, 70. The vertical movement of the draw head 64 is controlled by the rotation of the screw jack element 60 in threaded engagement with a vertically disposed threaded aperture (not shown) in back of the pull head 64. The second draw head 66 is similarly slidably mounted on rods 76, 78 and the vertical movement of the head 66 is controlled by the rotation of the screw rod 62.

The heads 64, 66 include pairs of jaw members 86, 88 respectively, which are adapted to automatically engage the array 22 adjacent an end thereof. In the particular position illustrated, the jaws 86 are in engagement with the end of the array 22, and are commencing the downward movement to draw the array 22 through the oven 16. At such time as the head 64 reaches the point adjacent the bottommost position of its travel, the head 66 will travel upwardly to permit the jaws 88 to engage the array 22 and commence its downward movement. It is to be understood that this sequence is purely illustrative and may be varied to accomplish the same results.

The extreme positions of the heads 64 are sensed by means of a pair of limit switches 90, 92, the switch 90 sensing the uppermost position of head 64 and the switch 92 sensing the downmost position of head 64. Through this sensing the jaws 86 are operated and the upward motion of the opposite head, in this case 66, is controlled. A pair of limit switches 94 and 96 are provided to sense the limit travel of head 66. A severing apparatus 100 is provided with a pair of jaws 102, 104 for severing the completed array from the jaw 86 or 88, as appropriate.

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The severing apparatus 100 includes a position (not shown) which horizontally, slidably, match the jaws 102, 104 to permit the jaws to ride into engagement with the completed array 22. This severing operation, in the preferred embodiment, is accomplished when the head 64 is at its bottommost position and the head 66 is at its uppermost position.

Referring now to FIG. 4, there is illustrated a sequence of operations which may be utilized in connection with the present invention. Specifically, the individual channels are formed into a bundle and the bundle is placed in an outer jacket. The one end of the tubes of the bundle is sealed by a suitable means to close off the end of the tubes from the space within the outer jacket. The other end of the bundle of individual channels is left open to the atmosphere. Finally, the open end of the individual channels is positioned spaced from the outer jacket and the spacing between the individual channels and the outer jacket is sealed from the atmosphere and all of the spaces between the individual channels are sealed.

A vacuum pump is then attached to the open end of the outer jacket to permit evacuation of the interstitial spaces between the individual channels and the outer jacket. This assembly is then placed within the heating unit 16 to soften the lower temperature softening glass or both tubes in the case of equal temperature tubes. It is to be noted that the vacuum pump 124 may be positioned either within the feed apparatus 12 (preferably), or within the draw apparatus 20 if certain modifications are made to the severing sequence caused by jaws 102, 104 to maintain the sealed relationship described above.

As is specifically illustrated in FIG. 5, the outer jacket 15 is sealed by any suitable method, for example, by placing the ring 122 of temperature resistant material at one end thereof and surrounding the bundle 14 of individual channels 17. The ring 122 is fastened to the outer jacket and the bundle, care being taken to preclude the sealing of the right end of the bundle of individual channels. The opposite end of the tube 15 is interconnected with the vacuum pump 124 which is capable of evacuating the space between bundle 14 and the tube 15. Further, the end of bundle 14 which is positioned between the seal 122 and the vacuum pump 124 is also sealed to preclude the evacuation of the volume within the inside diameter of the individual elements of the bundle 14. The other end of the bundle 14, the right end in the assembly illustrated is left open to the atmosphere. It is to be noted that the process described in conjunction with the description of FIG. 1 provides the necessary seals at the opposite end of the assembly 27 with the vacuum pump 124. The expansion of the glass seals the tube 17 to the outer tube 15 while leaving the tubes 17 open to the atmosphere.

During the drawing process, the vacuum pump is actuated to evacuate the volume described above and the heater assembly 16 is energized to soften the bundle 14. When the temperature approaches the softening point of the bundle 14, the pressure differential across the wall of the individual channel elements will cause the elements

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to expand and fill the interstitial spaces between the elements of the bundle 14 and between the bundle 14 and the outer glass tube 15. The resultant channel multiplier array 22 illustrated in FIGS. 6 and 7.

As is seen from FIG. 6, the walls of the individual element have expanded outwardly to combine only slightly softened outer jacket 15 and form an integral mass therewith. Similarly, the interior walls have expended to meet the interior walls of other elements. In this way a channel multiplier array is formed which has a high ratio of useful area to total area at a cross section thereof, thus increasing the efficiency of the channel multiplier array, and the problem of ion and/or photon feed-back has been substantially eliminated.

FIGS. 8 to 11 illustrate several different configurations of individual channel elements which may be utilized in practicing the features of the present invention.

While it will be apparent that the embodiments of the invention herein disclosed are well calculated to fulfill the objects of the invention, it will be appreciated that the invention is susceptible to modification, variation and change without departing from the proper scope or fair meaning of the subjoined claims.

What is claimed is:

1. A method of fabricating an array of channel multipliers comprising the steps of assembling a plurality of individual tubular channels into a bundle of a material having a first temperature softening characteristic inside a tube of a similar material but having a higher temperature softening characteristic; sealing the individual channels at one end; sealing the tube about the bundle while allowing the unsealed end of said bundle to remain open to the atmosphere; drawing a vacuum inside said tube and heating the tube and channel assemblage sufficiently to soften said bundle while twisting it about its own axis, whereby said individual channels expand to fill the spaces between themselves and between the outer individual channels and the tube and to fuse together while being spiralled to produce an array of greater effective cross-section and minimum feedback.

2. The method of claim 1 further including the step of drawing said bundle and tube during said heating and spiralling steps by advancing one end of the assembly relative the other to thereby reduce the thickness of the completed array during said process.

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