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COLD CATHODE GAS LASER DISCHARGE TUBE

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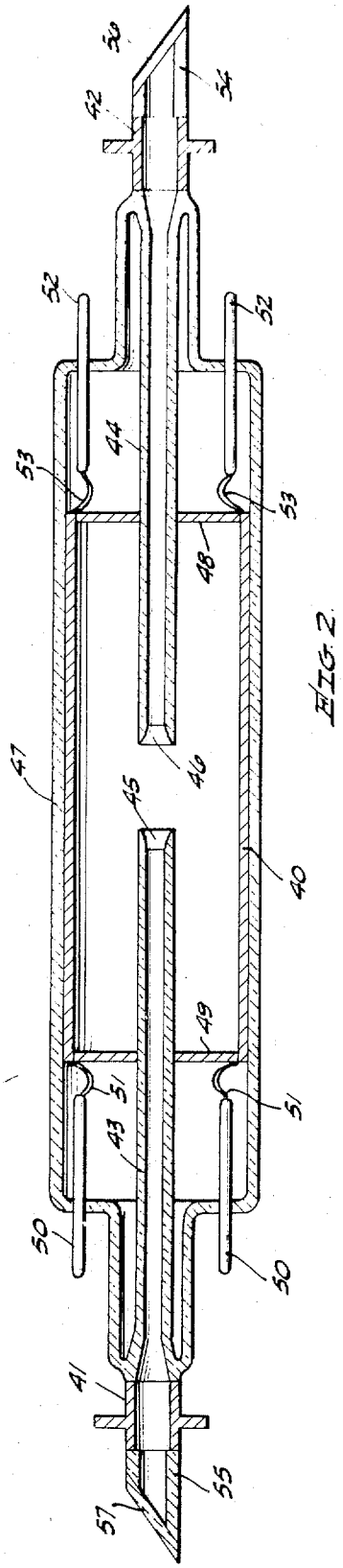

FIG. 2.

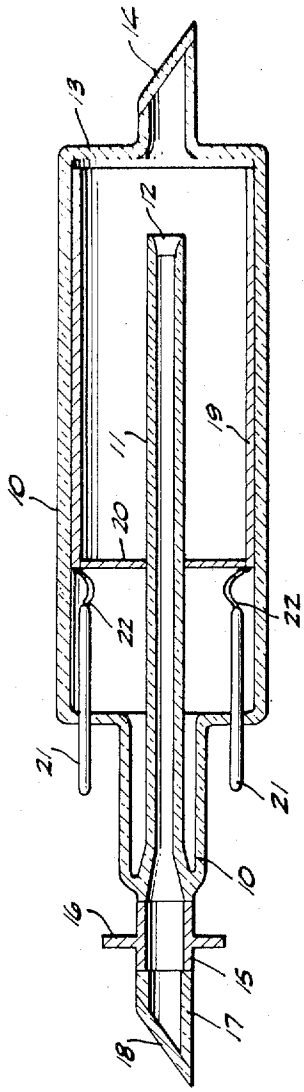

FIG. 1.

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COLD CATHODE GAS LASER DISCHARGE TUBE

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Int. Cl. H01j *17/04;* H01s *3/22*

U.S. Cl. 313—217 7 Claims

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

ABSTRACT OF THE DISCLOSURE

A cold cathode gas laser discharge tube of improved design is disclosed. A cylindrical cathode is disposed coaxially about a capillary discharge tube. A substantial longitudinal overlap of the capillary discharge tube and the cathode provides a shorter structure than available in the prior art, while still allowing a large area cathode emitting surface for long-life operation.

Field of the invention

This invention relates to gas laser structures and more particularly to cold cathode gas discharge apparatus for use in such structures.

Description of the prior art

One of the more commonly used methods for pumping the active medium of gas lasers to the necessary inverted energy level condition is by means of a cathode-anode electron discharge. In the past, both hot cathode and cold cathode structures have been used. For relatively low power laser apparatus the cold cathode arrangement is generally preferred.

Understandably, much development effort has been expended in the design of gas laser discharge tubes. Such effort has been largely directed to the development of improved cathode materials and structural design to achieve efficient long-life operation.

Accordingly, it is an object of the present invention to increase the reliability and lifetime of cold cathode laser discharge tubes.

In the past, the cold cathode laser discharge tubes have taken one of two basic structural forms. The first structural form utilizes an elongated discharge tube with the cold cathode, and frequently the anode as well, mounted in extension tubes or bulbs off of the main axis of the tube. This arrangement, while satisfactory for many applications, requires considerable space to accommodate the extension tubes in which the electrodes are mounted.

The second basic structural form, as exemplified in an article entitled "Cold Cathodes for Possible Use in 6328 A. Single Mode He-Ne Gas Lasers" by U. Hochuli and P. Haldemann, appearing in The Review of Scientific Instruments, vol. 36, No. 10, October 1965 at p. 1403, utilizes a cathode which is coaxially disposed along a longitudinal extension of a capillary discharge tube. Although this arrangement achieves a smaller cross-section, it does so at the expense of a greater length. In many applications, however, it is desirable or necessary to make the discharge tube as compact as possible while preserving its long-life operating characteristics.

It is therefore another object of the present invention to provide a cold cathode laser discharge tube of decreased longitudinal and cross-sectional dimensions.

Summary of the invention

In accordance with the principles of the present invention, these objects are accomplished with a cylindrical cathode configuration which, to a substantial degree, is coextensive with the coaxially disposed capillary discharge tube. Electrons emitted from the surface of the cathode traverse a folded path through the bore entrance of the capillary discharge tube to the anode where they are collected. Areas of very high localized fields which give rise to rapid cathode sputtering and shortened lifetime are avoided in the cathode design.

A second embodiment utilizing a single cathode in conjunction with two anodes and two axially aligned capillary discharge tubes provides a longer effective discharge path but with lower discharge voltages than required by the sinle anode embodiment.

Brief description of the drawings

The above-mentioned and other features and objects of the present invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a cross-sectional view of a first embodiment of the present invention; and

FIG. 2 is a cross-sectional view of a second embodiment of the present invention.

Description of the preferred embodiments

Referring more particularly to the drawings, FIG. 1 is a cross-sectional view of a preferred embodiment of the present invention. In FIG. 1 there is shown an outer envelope **10**. Coaxially disposed and structurally integrated with envelope **10** is an elongated capillary discharge tube **11** having an open end region **12** communicating with the interior region of envelope **10**. A first end member **13**, which is sealed to envelope **10**, is provided with an axially aligned light transmissive window **14**. Window **14** is disposed opposite the end region **12** of discharge tube **11** and is preferably oriented at the so-called Brewster angle as shown.

A hollow anode **15**, formed of conductive material, is coaxially disposed and bonded to the other end of capillary discharge tube **11**, where it joins the narrowed end of envelope **10**. Anode **15** can be fabricated of any suitable conductive material, such as Kovar, which can be readily fused or bonded to glass. Anode **15** can be provided with an annular flange **16** or other suitable means for facilitating mechanical and electrical connections. It is apparent that the anode shown in FIG. 1 is merely illustrative of one possible anode configuration. Other anode configurations can be readily adapted for use in the present invention if desired.

A second end member **17**, having a second light transmissive window **18**, is bonded, fused or otherwise joined to anode **15** opposite the second end of capillary discharge tube **11**. Envelope **10**, capillary discharge tube **11** and end members **13** and **17** are all fabricated of glass, quartz, or other suitable dielectric material, and together with anode **15**, form a hollow gas-tight structure, for containing the gaseous medium.

A cathode electrode **19** of cylindrical cross-section is disposed within envelope **10**, with its outer surface substantially coinciding with the inside surface of envelope **10**. Cathode **19** extends longitudinally from the end of envelope **10** near end member **13** toward the opposite end. There is thus a substantial longitudinal overlap of cathode **13** and capillary discharge tube **11**. An annular supporting ring **20** is mechanically joined to cathode **19**, thereby lending structural support and spacing for capillary discharge tube **11** and cathode **19**.

Many materials have been suggested for use as cold cathodes in laser discharge tubes. See, for example, the above-cited article "Cold Cathodes for Possible Use in 6328 A. Single Mode He-Ne Gas Lasers." In addition, it has been found that tantalum, having a thin oxide layer, is also well-suited for use in the fabrication of cold cathode **19**. Supporting ring **20** can be formed of the same material or other suitable conductive or dielectric materials without detracting appreciably from the operation of the present invention.

Conductive pins **21** extend through envelope **10** and are joined to cathode **19** by means of spring-like conductors **22**. In addition to providing electrical coupling, pins **21**, with conductors **22**, also lend structural support to cathode **19**. Although two conductive pins **21** are shown in the embodiment of FIG. 1, it is apparent that only one is necessary to provide electrical contact to cathode **19**. In practice, however, two, three, or even more may be desirable for mechanical support.

In operation, the gas through which the electrical discharge is to take place is confined within the structure of FIG. 1, usually at a very low pressure. To establish the electrical discharge a suitable power supply of conventional design, not shown, is connected between the cathode **19** and anode **15** by means of pins **21** and flange **16**, respectively. The power supply, as is well-known in the art, should be capable of providing a relatively high voltage at a relatively low current. The magnitudes of the voltage and current are largely determined by the particular design requirements of the discharge tube.

Electrons emitted from the inner surface of cathode **19**, traverse a path through the open end **12** of capillary discharge tube **11** on their way to the inner surface of anode **15** where they are collected. The emitted electrons, in traversing this path interact with the gas within the discharge tube, thereby ionizing a portion of the atoms thereof and creating the desired discharge and energy level population inversion. When used in a laser oscillator structure, the cold cathode laser discharge tube of FIG. 1 can be disposed in an appropriate resonant optical cavity which is provided with output coupling means for extracting a portion of the output wave energy. In the alternative, windows **14** and **18** can be replaced by reflecting members such as mirrors for a unitary laser oscillator structure.

A second embodiment of the present invention, capable of providing greater output power but also utilizing the overlapping cold cathode configuration, is shown in the cross-sectional view of FIG. 2. The embodiment of FIG. 2 is a symmetrical extension of the embodiment of FIG. 1, incorporating a single cathode **40** and two anodes **41** and **42**. The capillary discharge tubes **43** and **44** are both provided with first end regions **45** and **46** which communicate with the interior region of the device. The second ends of capillary discharge tubes **43** and **44** are, as before, sealed to an outer envelope **47** which surrounds cathode **40**.

Cathode **40** is mechanically supported at either end by first and second supporting rings **48** and **49**. Conductive pins **50** extend through the wall of envelope **47** and are conductively connected to cathode **40** by means of spring-like conductors **51**. A second pair of pins **52** and spring-like contuctors **53** are similarly provided at the other end region of cathode **40**. As mentioned hereinabove, all of the pins **50** and **52** are not essential to the operation of the present invention since adequate electrical coupling is provided by one pin. However, in order to provide increased structural support for cathode **40**, pins and spring-like conductors can be utilized.

To complete the structure of FIG. 2, end members **54** and **55**, each provided with optically transmissive windows **56** and **57**, respectively, are fused or otherwise joined to the outer end regions of anodes **42** and **41**. Thus, the entire structure forms a gas-tight container for confining the gaseous medium therein.

The operation of the device is similar to that of FIG. 1, except that both anodes **41** and **42** are coupled to the source of electrical potential. Appropriate means, such as potentiometers, can be provided in the power supply circuit to equalize the current to each anode, if desired. It should be noted that since the embodiment of FIG. 2 essentially consists of two parallel connected electron discharge paths the current drain upon the power supply will be substantially twice that of the embodiment of FIG. 1. However, since the two capillary discharge tubes **43** and **44** are coaxially aligned, the discharge length is effectively doubled.

In all cases it is understood that the above-described embodiments are merely illustrative of but a small number of the many possible specific embodiments which can represent applications of the present invention. Numerous and varied other arrangements, including other envelope and anode configurations, can be readily devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A gas laser discharge apparatus comprising, in combination:

at least one elongated capillary discharge tube;

a cylindrical cathode electrode coaxially disposed with respect to said capillary discharge tube, the projection of said cathode and said capillary discharge tube being coextensive over a substantial portion of their respective lengths;

an anode electrode disposed at one end of said capillary discharge tube;

envelope means surrounding said cathode and capillary discharge tube;

coaxially aligned end members [having axially aligned optically transmissive windows], said end members and said envelope being adapted to provide a gas-tight structure for confining a gaseous medium therein; and

conductive means extending through said envelope, said conductive means being conductively connected to said cathode.

2. The gas laser discharge apparatus according to claim **1** wherein said anode is of cylindrical shape and is coaxially disposed at one end of said capillary discharge tube.

3. The gas laser discharge apparatus according to claim **1** wherein said cathode is fabricated of tantalum.

4. The gas laser discharge apparatus according to claim **3** wherein the inner surface of said cathode comprises a layer of tantalum oxide.

5. A gas laser discharge apparatus comprising, in combination:

first and second elongated capillary discharge tubes, said capillary discharge tubes being aligned along a common axis;

a cylindrical cathode electrode coaxially disposed with respect to said axis, said cathode electrode extending longitudinally a substantially distance along the respective lengths of said capillary discharge tubes,

first and second anode electrodes disposed at opposite ends of said first and second capillary discharge tubes, respectively;

envelope means surrounding said cathode and capillary discharge tubes;

coaxially aligned end members [including axially aligned optically transmissive windows], said end members and said envelope being adapted to provide a gas-tight structure for containing a gaseous medium therein; and

conductive means extending through said envelope, said conductive means being conductively connected to said cathode electrode.

6. The gas laser discharge apparatus according to claim **5** wherein said cathode is fabricated of tantalum.

7. The gas laser discharge apparatus according to claim 6 wherein the inner surface of said cathode comprises a layer of tantalum oxide.

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