# United States Patent

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[54] **GAS-DYNAMIC DISCHARGE LIGHT SOURCE**


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[51] **Int. Cl.**..........................**H01j 61/30,** H01j 61/40

[58] **Field of Search**......313/185, 231, 113, 201, 220, 313/221, 224; 315/111


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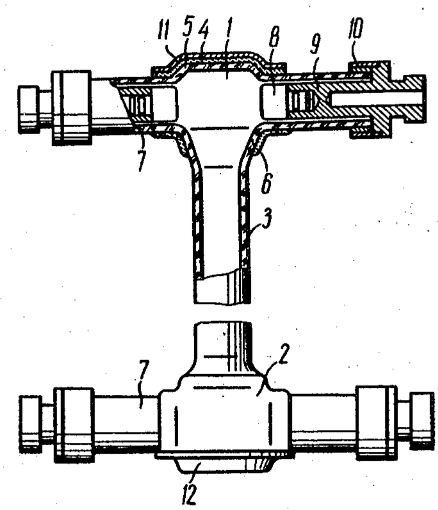
[57] **ABSTRACT**


The present invention relates to light-source in which light emission in the optical wavelength range is produced by moving shock waves and plasma streams. According to the invention, a gas-dynamic discharge light-source comprises at least two gas-filled discharge chambers interconnected by a tube in which shock waves and the gas-discharge plasma are propagated. On the outside, the discharge chambers have current-carrying buses each of which is series-connected with the discharge gap of the respective discharge chamber.

The light source according to the invention is intended to produce strong recurrent light flashes of short duration, for use mainly in the optical pumping of active media, predominantly liquid-type lasers based on organic dyestuffs.


**8 Claims, 5 Drawing Figures**



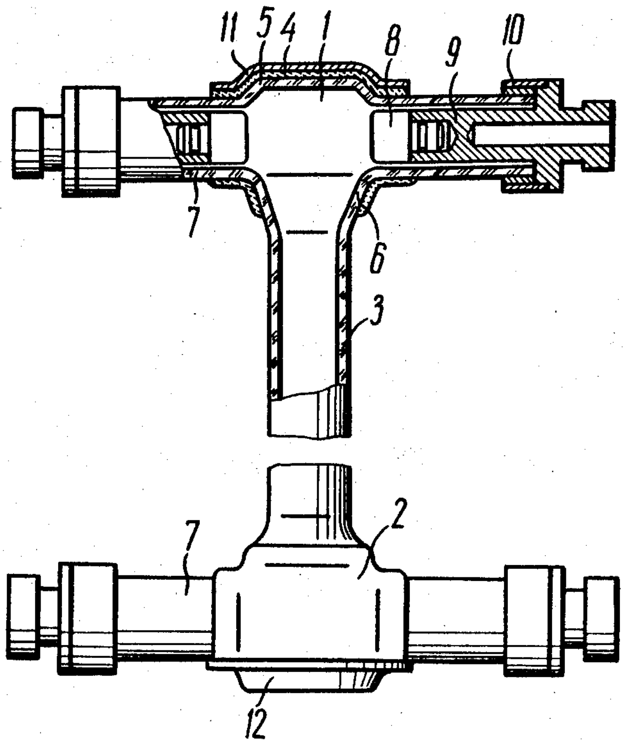



FIG. 1

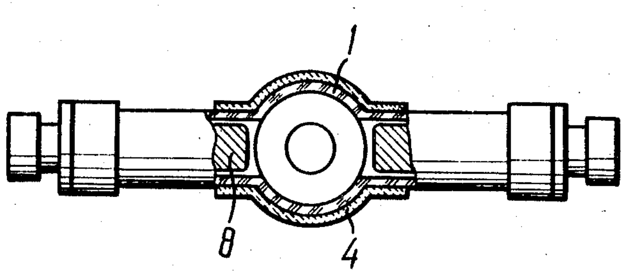



FIG. 2

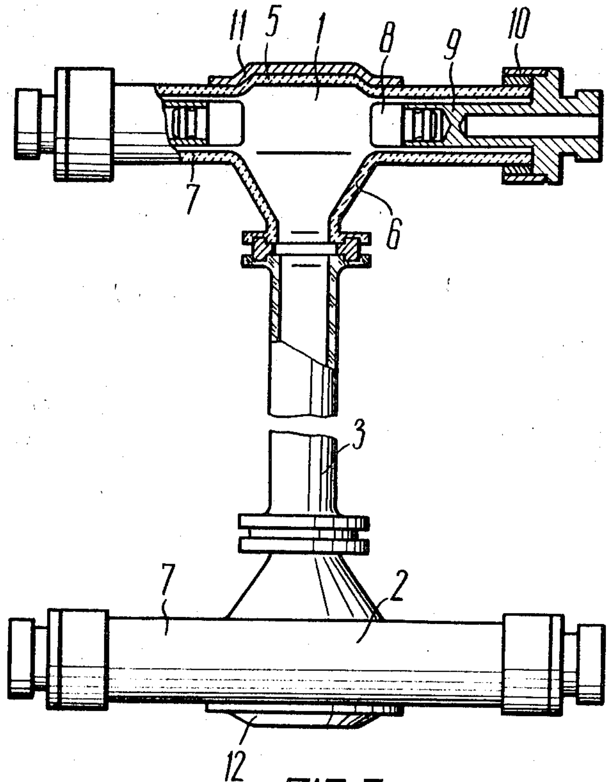



FIG.3

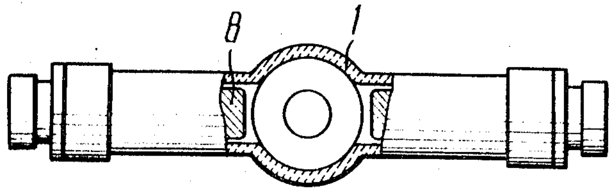



FIG.4

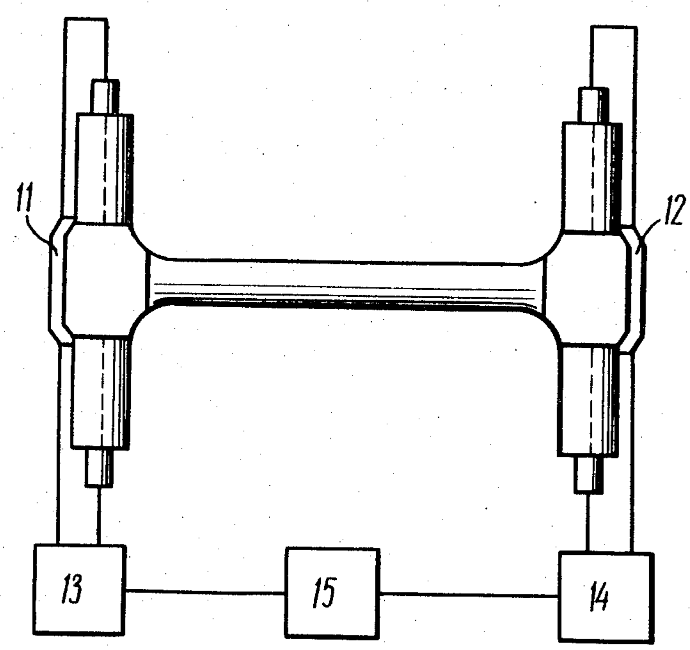



FIG. 5

## GAS-DYNAMIC DISCHARGE LIGHT SOURCE

The invention relates to gas-discharge light sources, and more specifically to gas-dynamic impulse discharge devices in which emission in the optical wavelength range is produced by moving shock waves and plasma streams.

There exists a gas-discharge device in which emission in the optical wavelength range is produced by shock waves, used in the study of the high-temperature plasma or as a light source.

This device is made in the form of a T-shaped tube. Its discharge chamber is formed by the cross member of the said tube and two electrodes located at its opposite ends, between which the discharge takes place. The shock waves and the gas-discharge plasma thus produced are propagated into a cylindrical stub adjacent to the discharge chamber.

Among the disadvantages of this device are the low maximum permissible energies of the flash in the case of a short-duration discharge (not over 50 $\mu$ sec), the low rate of current rise in the discharge gap because of the high resistance of the discharge channel, and the low efficiency of conversion of the electrical energy introduced into the discharge chamber to light emission.

An object of the present invention is to provide a light source free from the above-mentioned disadvantages.

A specific object of the invention is to provide a compact and reliable gas-dynamic discharge light source based on the interaction between counter-directed shock waves and streams of the gas-discharge plasma, ensuring higher efficiency in the conversion of the applied electrical energy into light emission, shorter light flashes, a greater density of the emission from a luminous part of the device, and a greater share of radiation lying in the ultra-violet region of the spectrum.

This object is accomplished by the fact that a gas-dynamic discharge light source comprising a gas-filled discharge chamber with a discharge gap formed by electrodes and bounded by the walls of the discharge chamber connected to one end of a tube in which shock waves and the gas-discharge plasma are propagated, and a current-carrying bus arranged outside the chamber along the said gap and series-connected with it, has, according to the invention, at least one more discharge chamber in which a discharge is initiated simultaneously with a discharge in the first chamber, connected to the other end of the tube where shock waves are propagated, both discharge chambers having light-reflecting walls and the tube being made of an optically transparent material. It is preferable that the walls of the discharge chambers adjacent to the current carrying bus be flat and arranged at right angles to the longitudinal axis of the optically transparent tube. The discharge chambers may be made in the form of U-shaped tubes the middle parts of which are inter-connected by the optically transparent tube. It is desirable that the electrodes have flat working surfaces and be disposed so that their longitudinal axes are at right angles to the axis of the optically transparent tube.

It is also preferable that the discharge chambers have conical adapters for connection to the optically transparent tube, with a solid angle of 15° to 60°. It is preferable to make the discharge chambers from a heat-resistant material such as beryllium oxide, aluminum oxide, etc., with light-reflecting walls having axially arranged openings, sealed to a tube from fused quartz glass by one of the conventional methods. It is also possible to make the discharge chambers and tube from the same optically transparent material, such as fused quartz glass having a coat of partly sintered, diffuse-scattering silicon dioxide only on the discharge-chamber walls bounding the discharge gaps.

The gas-dynamic impulse discharge light source disclosed herein is free from the disadvantages inherent in the cited device owing to the use of interaction between shock waves and a travelling plasma. This makes it possible to improve the efficiency with which the electrical energy applied to the discharge is converted into light emission (by about 20 to 30 percent) as a result of the reduced scattering of the energy of the pushing gas-discharge plasma (the "pushing piston") owing to the radiation in the discharge gaps and utilization of the shock waves reflected from the flat walls of the chamber for heating the plasma. The duration of the light flash is reduced by shadowing the discharge gaps relative to the object being irradiated, which fact also eliminates the effect of the "luminous trail," that is, the residual radiation of the final phase of the discharge. It is possible to ensure a more uniform intensity of the radiation coming from the optically transparent tube as a result of the increased rate with which it is filled by the gas-discharge plasma owing to the additional photo-ionization of the gas ahead of the shock waves and streams of the luminous plasma travelling in the tube in opposition to one another. The adapter of gradually decreasing diameter between the discharge chamber and the tube serves to raise the velocity of shock waves in the said tube of smaller diameter according to the well-known relation

$$S=k/M^5,$$

where $S$ is the cross-sectional area of the tube in which shock waves are propagated, $M$ is Mach's number describing the velocity of shock-wave propagation, and $k$ is the constant of the light source, dependent on the shape and size of the source. A very important advantage of the gas-dynamic discharge light source disclosed herein is also the fact that the spectral efficiency (the spectral composition) of the resultant radiation can be varied over broad limits by varying the relative magnitude of the diameters of the emitting tube and discharge chamber, the voltage across the light source, and the pressure of the filling gas.

For example, with all other things being equal, a decrease in the ratio of the tube diameter to the discharge-chamber diameter will increase the velocity of shock waves and decrease the penetration of the gas-discharge plasma into the tube, thereby increasing the share of radiation lying in the ultra-violet region of the spectrum.

The device disclosed herein is intended to produce strong recurrent light flashes of short duration mainly used to optically pump active media, predominantly liquid-type lasers based on organic dyes. The device disclosed herein may be successfully used in physico-chemical investigations involving flash-photolysis of gases and solutions, in light-signalling equipment, etc.

The invention will be more fully understood from the following description of preferred embodiments when read in connection with the accompanying drawings, wherein:

FIG. 1 is a cut-away front view of a gas-dynamic discharge light source, according to the invention;

FIG. 2 is a cut-away top view of FIG. 1;

FIG. 3 is a cut-away front view of another embodiment of the invention;

FIG. 4 is a cut-away top view of FIG. 3;

FIG. 5 shows the connection of a gas-dynamic discharge light source.

Referring to FIGS. 1 and 2, there is a gas-dynamic discharge light source comprising two identically constructed opaque discharge chambers 1 and 2 having coaxial openings, sealed to an optically transparent tube 3 fabricated from fused quartz glass and intended to couple the emission. Said chambers 1 and 2 with light-reflecting walls are fabricated from a heat-resistant material such as beryllium oxide or aluminum oxide, or from fused quartz glass with a coat 4 of reflecting silicon dioxide sintered to zero porosity.

Each chamber has in its middle part a flat wall 5 and, on the opposite side, a conical adapter 6 for connection to the optically transparent tube 3. The chambers can be made as U-shaped tubes. The solid angle of the conical adapter between the discharge chamber and said cylindrical tube may be chosen anywhere between 15° and 60°. Built axially into the side walls of the discharge chambers 1 and 2 are two pairs of cylindrical amounts 7 which hold two pairs of identically constructed electrode assemblies with coincident longitudinal axes of symmetry, each of which comprises a thoriated-tungsten flat electrode 8 press-fitted into a hollow "Kovar" (Ni—Co—Fe alloy) holder 9 having a ring shoulder which gives support to a titanium cylinder IO forming an annular gap around the mount 7, filled with tin in the course of sealing.

The electrode assemblies of the light source disclosed herein are built into the mounts 7 so that the flat surface of each electrode having a diameter close to the inside diameter of the mount is arranged approximately to level with the tube 3 near the flat wall of the chamber, producing parallel discharge gaps. Mounted along said discharge gaps outside the discharge chamber and at right angles to the longitudinal axis of the tube 3 interconnecting the chambers 1 and 2 are two current-carrying buses 11 and 12 made in the form of metal caps put on the projecting flat walls of the chamber, through which the discharge-circuit current is passed. Each bus is connected to one of the electrode assemblies of each discharge chamber. The gas-dynamic discharge light source disclosed herein is filled with xenon under a pressure of 20 to 100 Torrs.

The gas-dynamic discharge light source shown in FIGS. 3 and 4 differs from the one described above in that its discharge chambers 1 and 2 are fabricated from an opaque, light-reflecting, heat-resistant ceramic material, such as beryllium oxide or polycrystalline aluminum oxide, and hermetically sealed to an optically transparent tube 3.

The gas-dynamic discharge light source disclosed herein operates as follows (FIG. 5). When the source is connected into a common-earth, low-inductance, balanced discharge circuit comprising two banks of storage capacitors 13 and 14 controlled by a two-channel series-firing unit 15, a gas discharge occurs simultaneously in both discharge chambers.

In both discharge gaps the discharge currents flow in the same direction which is opposite to the directions of the currents in the said metal buses.

Travelling with a high velocity due to the thermal expansion of the gas and electromagnetic interaction between the discharge current and the currents in the metal buses, the streams of the gas-discharge plasma simultaneously splash out of both chambers 1 and 2 into the interconnecting tube 3, giving rise to strong counter-directed shock waves.

This is accompanied by a marked photo-ionization of the gas in the said tube ahead of the travelling shock waves and gas-discharge plasma, which fact promotes a faster mixing of the plasma and the gas heated by the shock waves in the tube. On colliding, the shock waves give rise to a strong luminosity in the middle part of the tube. The zone of mutual penetration of the shock waves is characterized by a glow of an increased intensity, having a continuous spectrum in the visible region.

After they are reflected from each other, the shock waves now travel in the counter-directed expanding columns of the gas-discharge plasma heated by the energy of the discharge-gap currents and the shock waves reflected from the ends of the chambers. This phase of the discharge is characterized by the fact that the bore of the tube is filled with plasma and that the emission has a uniform density.

The light source disclosed herein has been tested under conditions of infrequent recurrent flashes with a duration of 25 to 40 $\mu$ sec and with a maximum discharge energy of over 4,000 joules.

What is claimed is:

1. In a gas-discharge light source device producing light emission which is substantially in the optical wave length range, by means of shock waves and plasma streams, of the type comprising a gas-filled discharge chamber with two oppositely located electrodes and light-reflecting walls, wherein shock-waves and gas-discharge plasma are generated and propogated into an adjacent cylindrical space to produce a light source, the improvement being that the device comprises: an additional gas-filled discharge chamber provided with light-reflecting walls and electrodes, and connected for simultaneous discharge with the other discharge chamber; an optically transparent tube interconnecting said discharge chambers and providing said cylindrical space; a discharge gap in each of said discharge chambers, formed by said electrodes; and a current-carrying bus located outside each of the discharge chambers and connected thereto.

2. The device, as claimed in claim 1 in which a wall portion of each discharge chamber, adjacent to the current-carrying bus, is made flat and arranged at right angles to a longitudinal axis of the optically transparent tube.

3. The device as claimed in claim 1, in which the discharge chambers are made in the form of U-shaped tubes the middle parts of which are interconnected by said optically transparent tube.

4. The device as claimed in claim 1, in which the electrodes have flat working surfaces and are so arranged that a longitudinal axis of each electrode pair is at right angles to the longitudinal axis of said optically transparent tube.

5. The device as claimed in claim 1, in which the discharge chambers have each a conical adapter for connection to the optically transparent tube, with a solid angle of 15°–60°.

6. The device as claimed in claim 1, in which the discharge chambers are made of a heat-resistant material, chosen from beryllium oxide, aluminum oxide, and the like, with internal light-reflecting walls, and have openings for communication with said optically transparent tube.

7. The device as claimed in claim 1 in which the gas-filled discharge chambers include xenon gas under a pressure of 20 to 100 Torrs.

8. In a gas-discharge light source device producing light emission substantially in the optical wave length range, by means of shock waves and plasma streams, of the type comprising a gas-filled discharge chamber with two oppositely located electrodes and light-reflecting walls, wherein, shock waves and gas-discharge plasma are generated and propagated into an adjacent cylindrical space, the improvement being that the device comprises: an additional gas-filled discharge chamber provided with light-reflecting walls and electrodes, and connected for simultaneous discharge with the other discharge chamber; a tube interconnecting said discharge chambers and providing said cylindrical space; a discharge gap in each said discharge chamber, formed by said electrodes; a current-carrying bus located outside each of the discharge chambers and connected thereto, the device further characterized in that the tube and the discharge chambers are formed of transparent fused quartz and the discharge chambers include a coat of partly sintered, diffuse-scattering silicon dioxide on its outside wall surface in the region bounding the discharge gaps.

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