(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 146 509**
A2

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 84850295.1

(22) Date of filing: 04.10.84

(51) Int. Cl.⁴: H 01 S 3/03, H 01 S 3/097, H 01 S 3/04

(30) Priority: 07.10.83 US 539993

(43) Date of publication of application: 26.06.85 Bulletin 85/26

(84) Designated Contracting States: AT BE CH FR IT LI NL SE

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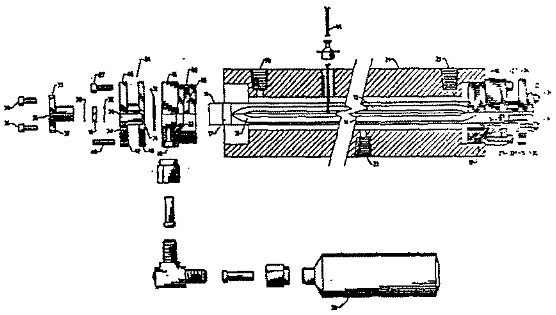
(54) **External electrode transverse high frequency gas discharge laser.**

(57) A circular bore transversely excited gas discharge laser (10) is disclosed which may be constructed and operated with no physical contact between the active discharge and the metal excitation electrode structure (14). The discharge is excited by RF in the frequency range 10 MHz to 1 GHz applied to a transverse metal electrode structure (14) designed to maintain a relatively uniform electric field in the discharge bore (12). The disclosed laser may be configured as a waveguide laser or a large bore laser operating in a nonwaveguide mode.

A means for inductively coupling RF energy from a suitable RF energy source to the electrode structure (14) and a means for attaching mirrors (15) to the discharge tube using no organic sealing material is disclosed. Without physical contact between the active discharge and the metal excitation electrode structure or organic sealants, long lifetime, superior laser performance, and capability for liquide cooling of the discharge tube is achieved.



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EXTERNAL ELECTRODE TRANSVERSE HIGH FREQUENCY GAS DISCHARGE LASER

Technical Field

The invention pertains to transverse RF excitation gas lasers with circular geometry having external electrode and to the attachment of mirrors to the laser discharge tube.

Background of the Invention

Since their earliest development, gas lasers have been constructed using hollow dielectric tubes. Excitation of the active laser gaseous medium has been traditionally accomplished by applying a relatively large DC voltage longitudinally along the length of the discharge tube via two or more metal electrodes places in contact with the gaseous medium at the ends of the discharge tube or at points intermediate to the ends. Early in the development of gas laser technology, the advantages of removing metal electrodes from contact with the active gaseous laser medium and using RF excitation was recognized. However, interest in removing the metal electrodes from contact with the active gaseous laser medium apparently did not reach the peak necessary to lead to the development of a laser utilizing the technique. In a similar manner, RF excited lasers were left to future development.

Recent development of waveguide lasers has stimulated renewed interest in RF laser excitation, and particularly inductive RF coupling to the laser as disclosed in U.S. Patent No. 3,772,611 issued November 13, 1973 to Peter W. Smith. The inductive coupling mechanism disclosed by Smith was ineffective in providing for high frequency excitation and results in a non-uniform discharge.

U.S. Patent No. 4,169,251 issued September 25, 1979 to Katherine D. Laakmann discloses a method for obtaining transverse RF discharge excitation of a waveguide laser. This method requires contact between the laser medium and the transverse metal electrode structure. Problems with reactions of the excited gas with the metal electrodes inside the laser discharge tube will inevitably lead to reduced laser lifetime in a sealed laser and ultimate degradation of laser performance. The invention disclosed in the Laakmann patent required a generally rectangular laser geometry rather than circular. This results in the probability of excitation of undesirable optical modes rather than the axially symmetric modes characteristic of a circular geometry. Furthermore, the Laakmann lasing device specifically is limited to transverse RF excited waveguide lasers.

With the metal electrodes in contact with the discharge medium, random discharge instabilities can occur in the discharge medium resulting in fluctuating laser output power as well as mode instability. Further, the rectangular "slab" construction of the waveguide geometry makes it virtually impossible to apply mirrors directly to the ends of the laser structure. The application of mirrors directly to the ends of the laser is highly desirable for modular construction and long laser lifetime.

Summary of the Invention

The present invention is intended to circumvent the undesirable feature of the prior art while retaining the inherent advantages of transverse RF discharge excitation such as reduction in required discharge voltage, reduced gas dissociation, increased operating efficiency, and discharge stability.

In particular, the present invention comprises construction of a transversely excited RF discharge laser of generally circular geometry from a single or monolithic and homogeneous piece of dielectric material. Electrodes are placed on the external surface of the discharge chamber and are therefore not in contact with the active discharge. The interposed layer of dielectric material serves not only to isolate the electrode material from the discharge, but to provide a discharge stabilizing, purely reactive (lossless), series impedance between the electrodes and the active discharge volume. Furthermore, the invention is not limited by application to waveguide lasers but can also be used with large bore laser structures which will be defined as lasers with bore areas greater than $10mm^2$.

Design of the discharge tube allows for circular symmetry to be maintained in the entire laser structure, including a circular cross-section laser discharge chamber. The electrode design maintains a nearly uniform electric field across the entire discharge volume, thereby providing more uniform laser pumping and promoting propagation of a single low order transverse laser mode.

An inductive RF coupling mechanism is disclosed that is efficient and readily tunable while still allowing for pi network coupling if desired.

The circular geometry provides for convenient attachment of mirrors directly to the ends of the discharge tube with brazed flanges and a malleable metal compression seal. Long laser structure can be fabricated by simply coupling a series of short sections together with all metal sealed flange assemblies or direct glassed or brazed connections. Thus, single unit integrity can be maintained to meter-length laser bores. The circular geometry further provides for application of integral concentric cooling and RF shielding enclosures, thus allowing use of dielectric fluid laser cooling and minimal EMI emissions from the complete operating laser assembly.

The laser of the present invention has the advantages over the prior art of:

(a) relatively long shelf life and operating life due to the sealed nature of the lasing tube and absence of metal electrodes in direct contact with the gas discharge;

(b) a high degree of mechanical ruggedness and stability as a result of the monolithic construction of the discharge tube and the mirror assemblies;

(c) excellent beam quality and stability as a result of the circular bore and the uniform field maintained by the capacitively coupled external electrodes;

(d) the capability of modulating the laser beam output power;

(e) relatively high efficiency because of the ability to use low power RF excitation to form a glow discharge or plasma; and

(f) relatively small, compact packaging.

Brief Description of the Drawings

Referring to the drawings, wherein like numerals represent like parts throughout the several views:

FIGURE 1A is a longitudinal sectional view of he waveguide laser embodiment of the present invention. FIGURE 1A illustrates the single solid homogeneous block of dielectric material used to construct the laser waveguide and electrode assembly.

FIGURE 1B is a longitudinal view of the waveguide laser embodiment as viewed from an orientation with is rotated 90° from the orientation shown in FIGURE 1A.

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