



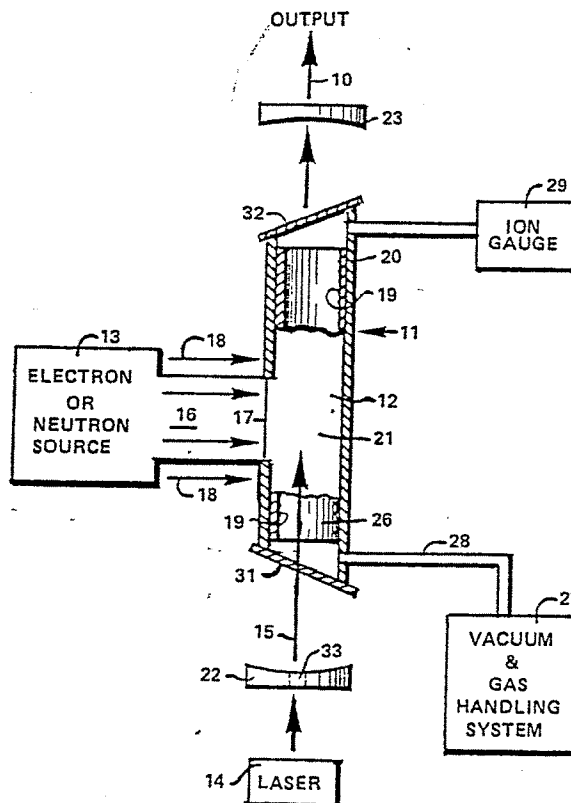
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification³ : H01S 3/093</p>	<p>A1</p>	<p>(11) International Publication Number: WO 83/ 01349 (43) International Publication Date: 14 April 1983 (14.04.83)</p>
<p>(21) International Application Number: PCT/US82/01391 (22) International Filing Date: 27 September 1982 (27.09.82) (31) Priority Application Number: 308,714 (32) Priority Date: 5 October 1981 (05.10.81) (33) Priority Country: US (71) Applicant: MIAMI UNIVERSITY [US/US]; 202 Roudebush Hall, Oxford, OH 45056 (US). (72) Inventors: WELLS, William, E., Jr. ; 405 East Vine Street, Oxford, OH 45056 (US). MARCUM, S., Douglas ; 604 South Main Street, Oxford, OH 45056 (US). DOWNES, Lawrence, Wayne ; 556 Brookfield Drive, Apartment 201, Fairfield, OH 45014 (US). TILTON, Richard, A. ; 9027 Bogata Circle, San Diego, CA 92126 (US). (74) Agents: BISSELL, Barry, S. et al.; Patent Administrator, Battelle Development Corporation, 505 King Avenue, Columbus, OH 43201 (US).</p>		<p>(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), SE (European patent). Published <i>With international search report.</i></p>

(54) Title: COLLISION LASER

(57) Abstract

Electromagnetic radiation (10) in a gas mixture (12) including helium in the X(1) state and nitrogen in the Y(1) state. The helium is pumped to excite a high population density of its atoms from the X(1) state to the X(2) state; and photons (15) of suitable frequency are injected into the mixture (12) to excite, via a three-body radiative collision of an atom of X(2) with a molecule of Y(1) and a photon (15), a high population density of molecules of the nitrogen from the Y(1) state to the Y(3) state, followed by a substantially simultaneous return of a substantial portion of the excited helium atoms to the X(1) state and a substantial depopulation of the Y(3) state of the nitrogen, causing the molecules thereof to drop to the lower energy Y(2) state, thereby stimulating the emission from the nitrogen of two photons (10) at the same wavelength for each absorbed photon (15), and thus providing a total quantity of photon emission (10) with sufficient gain for amplification of electromagnetic radiation (10), and finally resulting in the depopulation of the molecules in the Y(2) state by autoionization.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	LI	Liechtenstein
AU	Australia	LK	Sri Lanka
BE	Belgium	LU	Luxembourg
BR	Brazil	MC	Monaco
CF	Central African Republic	MG	Madagascar
CG	Congo	MR	Mauritania
CH	Switzerland	MW	Malawi
CM	Cameroon	NL	Netherlands
DE	Germany, Federal Republic of	NO	Norway
DK	Denmark	RO	Romania
FI	Finland	SE	Sweden
FR	France	SN	Senegal
GA	Gabon	SU	Soviet Union
GB	United Kingdom	TD	Chad
RU	Russia		

COLLISION LASER

FIELD

This invention relates to methods and apparatus for providing stimulated emission of electromagnetic radiation. Typical embodiments of the invention comprise laser
5 amplifiers and laser oscillators.

The invention is especially advantageous as a new type of laser amplification system, based upon a process of stimulated emission radiative collisions. The system produces a high population density of long lived excited
10 atoms that, in a three-body collision with a suitable atom or molecule in its ground state and with a photon of appropriate energy, results in photon emission with sufficient gain for laser amplification.

The invention typically uses the photon induced
15 collision between a metastable excited atom or molecular species and a ground-state molecule, to which metastable energy is transferred with high efficiency, simultaneously stimulating the emission of two photons at the same wavelength for each absorbed photon. The gain of the system
20 depends upon an inversion of the products of the population densities of atomic or molecular states. The term "density" as used herein always means number density (unless the context shows otherwise) regardless of whether the density is of state population, or of collisions.

25 The invention comprises a novel way to provide inversions, in that energy can be stored in one atom species in the upper laser levels, whereas the lower levels of the other atom or molecule of the collision pair can be depopulated as by a rapid decay mechanism. When this
30 principle is applied to a system in which a high density of upper level states is populated, while at the same time the lower level is rapidly depopulated, the gain and efficiency are significant, and conditions can be realized to provide a high power, high energy laser amplifier.

35 Hereinafter described in more detail is a new type

2

of laser based on radiative collisions, with a specific gas selection, namely He-N₂, as a typical embodiment. Gain in such a system can be described by the equation

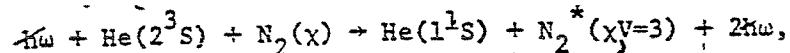
$$\text{Gain} = \frac{d\rho}{\rho dz} = \kappa_{\text{wk}} \{ [\varepsilon_{X(2)} \varepsilon_{Y(1)} [X(2)][Y(1)] - \varepsilon_{Y(2)} \varepsilon_{X(1)} [Y(2)][X(1)] \},$$

5 which is dealt with in detail later. For a given situation, when the numerical value of this equation is positive, amplification of a light signal can take place through stimulated emission.

To date, lasers have required a population inversion
10 within a single species. The analysis hereinafter shows that laser gain can be obtained by the inversion of the product of two densities, rather than just the individual densities. This is also shown in the equation above.

Such inversions are usually not possible for systems
15 of atomic or molecular species in thermal equilibrium. This invention provides specific means by which it is possible to produce the inversion of product population density.

The typical embodiment comprising a mixture of He and
20 N₂ is described by the equation

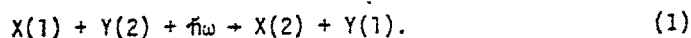


where He(2³S) represents the excited helium atoms produced in the gas mixture by the pumping source; N₂(X), the nitrogen molecules in their initial ground state; He(1¹S),
25 the ground-state helium atom products of the 3-body collision; and N₂^{*}(X, v=3), the product nitrogen molecules remaining after stimulated emission has occurred. As seen in the equation above, to achieve gain in the system the product densities in the right-hand term of the
30 equation must be low. In the present invention, this has been unexpectedly achieved by taking advantage of the fact that the N₂^{*}(X, v=3) molecule, which is still in an excited state with a high population density, is an auto-ionizing state with a very short lifetime. It

self-destructs rapidly, thereby depleting its population and making the product density of the right-hand term negligible.

BACKGROUND

5 In 1972, Gudzenko and Yakovlenko¹ described a process involving, effectively a three-body collision between atomic or molecular species X and Y, and a photon $h\nu$. Figure 1a shows the energy level for atoms X and Y that corresponds to



The absorption of the photon, having an energy $h\nu$, allows a resonant two-body
10 collision.

The production rate of state X(2) can be written

$$\frac{d[X(2)]}{dt} = k\rho [X(1)] [Y(2)], \quad (2)$$

where $[\]$ indicates concentration, ρ is the photon flux field and k is a three-body rate coefficient for the radiative collision. If we look at $k\rho$ in terms of a
15 normal binary collision, then

$$k\rho = \langle\sigma v\rangle, \quad (3)$$

where σ is the event cross section and v is the velocity, thus (2) becomes

$$\frac{d[X(2)]}{dt} = \langle\sigma v\rangle [X(1)] [Y(2)]. \quad (4)$$

Alternately, if we look at k in terms of photon absorption, then

$$20 \quad k [Y(2)] = B_{12}, \quad (5)$$

where B_{12} is an Einstein-like absorption coefficient. Now (2) can be written as

$$\frac{d[X(2)]}{dt} = B_{12} \rho [X(1)]. \quad (6)$$

When cast in the form of a collision, as in (3) and (4), the cross section σ , becomes a function of ρ , the photon flux field. When written in the form
25 of a radiative absorption, as in (5) and (6), the Einstein stimulated absorption coefficient, B_{12} , becomes a function of the density, $[Y(2)]$. The photon, $h\nu$ does not have the energy of the difference between X(2) and X(1), but approximately the energy difference between X(2) and Y(2). A third method of describing these collisions would be the absorption of a photon by a quasi-molecule or collision
30 complex Y(2)X(1). This model is conceptually useful.

Harris² has used the collisional model to describe his observations of

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.