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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 3 : B08B 7/00; B23K 26/00, 26/02 B63B 59/06

A1

(11) International Publication Number: WO 83/ 01400

(43) International Publication Date: 28 April 1983 (28.04.83)

(21) International Application Number: PCT/US82/01489

(22) International Filing Date: 21 October 1982 (21.10.82)

(31) Priority Application Number: 313,894

(32) Priority Date: 22 October 1981 (22.10.81)

(33) Priority Country: US

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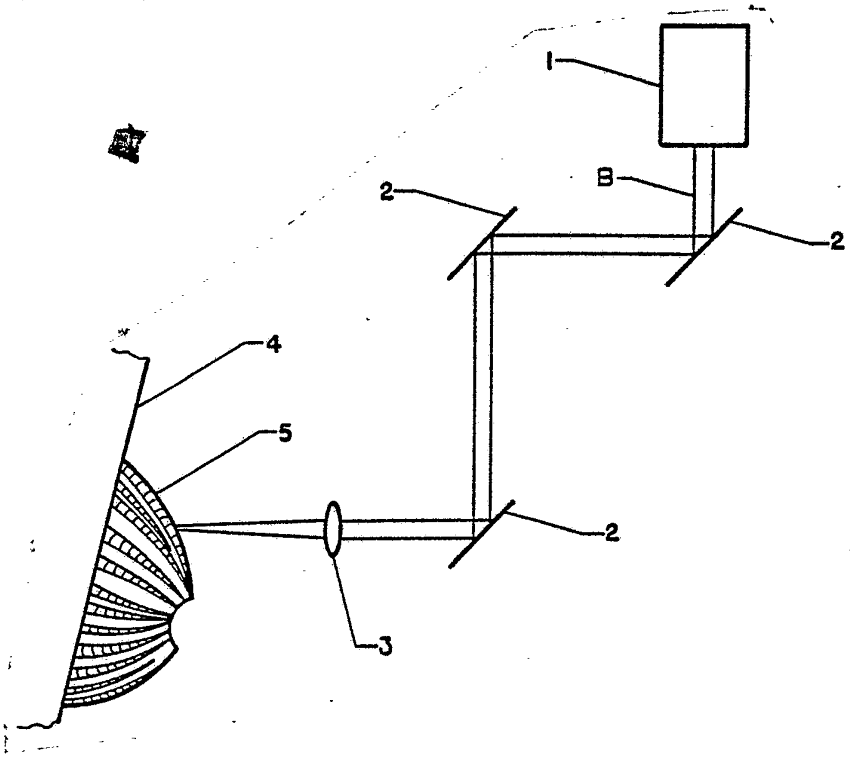
(81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

**Published**
*With international search report.*

(54) Title: LASER REMOVAL OF MATERIALS FROM SURFACES

(57) Abstract

Non-contacting removal of undesired materials from the surfaces of objects is accomplished by directing coherent electromagnetic radiation from a laser (1) onto the undesired material. The power density of the impingement radiation is effective to remove the undesired material without damage to the underlying object. Principles of the invention are applicable to numerous surface cleaning situations including the de-fouling of marine surfaces. For de-fouling a ship's hull (4), the laser radiation is conducted by mirrors (2) and focused (3) on the hull (4). Barnacles (5) are shocked and dislodged from the hull (4).



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# LASER REMOVAL OF MATERIALS FROM SURFACES

## TECHNICAL FIELD

This invention relates generally to the non-contacting removal of undesired surface materials from objects by use of coherent electromagnetic radiation derived from devices commonly known as lasers.

## BACKGROUND ART

There are many occurrences of accumulation of undesired materials on the surfaces of objects. A particular example involves marine fouling on a ship's hull. The accumulation of barnacles leads to loss of sailing efficiency in the form of increased fuel consumption and/or loss of speed. Losses anywhere from 5 percent to 30 percent are representative. Needless to say, this problem also reduces the speed and range of the ship. One current practice for removing barnacles requires dry-docking at periodic intervals with the barnacles being removed by scraping and sandblasting while the vessel is in dry-dock. Another current practice involves the use of underwater brushes at intermediate stages to partially remove fouling.

Naval vessels currently employ anti-fouling paints to retard the growth of such marine life. These paints do not eliminate the need for periodic dry-locking; they merely increase the length of service time between dry-dockings. Accordingly, at the present time dry-docking is required at periodic intervals during the life of a vessel in order to remove marine fouling. The need to dry-dock a vessel creates a number of problems. The vessel is of course out of service during the time it is in dry-dock and hence is unavailable for use. In the case of naval vessels this can mean loss of readiness in the event of emergency.

In a commercial dry-dock the magazines have to be emptied and later be restocked. There is also a shortage of dry-dock facilities. Because of this shortage the intervals between dry-dock operations are longer than would be otherwise desired. This means that the impairment of sailing efficiency referred to above is prolonged.

The procedure for removing the marine fouling also possesses disadvantages. It involves a high cost because of the labor intensive nature of the operation, and the workers involved in the procedure are exposed to particulates, chips, dust and the like which may require extra precautions. The chips of anti-fouling paint that are removed possess certain toxic characteristics that require care and proper disposal.

There are other instances where undesired materials occur on the surfaces of objects. Principles of the present invention, while disclosed in the preferred embodiment of removal of marine fouling, are also contemplated to be applicable to the removal of other undesired materials from the surfaces of other objects, such as scale from pipes, rust from steel, and paint removal. For example in the case of pipe, chemical and mineral scale may accumulate on the inside wall of the pipe; in the case of steel which is exposed to air, rust may occur on the surface of the steel due to chemical action.

U.S. patent 3,503,804 discloses the use of a laser in a cleaning operation but in conjunction with a liquid jet wherein the laser beam is used to enhance the cleaning action of the liquid jet. In other words it does not use a laser alone.

U.S. patent 4,131,484 relates to a laser machining operation and while it refers to an electronic cleaning concurrent with the laser machining, such electronic cleaning occurs by electrically energizing the device which is being laser machined.

DISCLOSURE OF THE INVENTION

The present invention comprises a new and unique method for efficiently and effectively removing undesired materials from the surfaces of objects in a non-contacting fashion through the use of coherent electromagnetic radiation as is provided by devices commonly known as lasers.

With application of the present invention in cleaning of a ship's hull, the problems referred to above are overcome. Cleaning operations can be accomplished in significantly less time and without the labor intensive aspects associated with prior procedures. There is reduced exposure of personnel to potentially hazardous materials which may exist in the materials being removed from the object. With these attributes of the invention, dry-docking operations are more efficiently accomplished thereby alleviating the current shortage of dry-dock facilities while at the same time reducing the out-of-service time of a vessel. While at the present time the invention, in one form, involves dry-docking of a vessel, it is contemplated that the invention may also be practiced without the necessity of dry-docking; in other words, the de-fouling operations may be conducted underwater.

Because the cleaning operation is accomplished without damage to the underlying object, the invention may be practiced where objects of much lighter weight and greater delicacy than the hull of the ship are involved. Accordingly, it is further contemplated that the invention may be practiced for cleaning aluminum aircraft skin, automotive surfaces and other more fragile material. A wide variety of types of undesired materials may also be removed. These undesired materials may accumulate through biological growth, sedimentation, depositions, chemical actions, or in other ways. They may also comprise coatings or materials which were originally applied intentionally to a surface, but which now must be stripped from the surface.

The foregoing features, advantages, and benefits of the invention, along with additional ones will be seen in the ensuing description and claims which should be considered in conjunction with the accompanying drawings. The drawings disclosed a preferred embodiment illustrating the best mode contemplated at the present time for carrying out the invention.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a schematic view illustrating the invention being practiced in the context of cleaning a ship's hull.

Fig. 2 is a perspective view illustrating a dry-dock at which the invention is being practiced.

Fig. 3 is a schematic diagram illustrating further detail of the apparatus shown in Fig. 2.

Fig. 4 is a block diagram illustrating a further embodiment for the practice of the invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Fig. 1 illustrates the practice of the invention in the context of removing marine fouling from the hull of a ship. This drawing figure shows a set of three mirrors designated by the reference numeral 2, a focusing lens 3 and a source of coherent electromagnetic radiation 1, commonly referred to as a laser. The laser generates a laser beam designated by the reference letter B. The beam is emitted from the laser and directed toward the first mirror 2. The beam is turned and reflected by the first mirror 2. For certain mechanical motions a second mirror 2 and finally the third mirror 2 may be needed. After reflection from the first or third mirror the beam passes through the lens 3 to be focused to a concentrated point on the surface 4 of the ship's hull which is being cleaned. The drawing further schematically illustrates (on an enlarged scale) a barnacle 5 which has adhered to the surface 4 of the vessel.

A barnacle attaches itself to a marine surface by depositing a bonding material in the form of barnacle cement between itself and the marine surface. This barnacle cement provides a tenacious bond which makes the barnacle very difficult to remove. The illustrated arrangement of laser mirrors and focusing lens allows a laser beam to be focused at a concentrated point and optically swept so as to concentrate the power of the laser at the surface of the ship's hull where barnacles are attached. By suitable selection of the laser operating parameters the energy input to the point of attachment of the barnacle to the ship's hull is of such a nature that the bond due to the barnacle cement is broken, thereby separating the barnacle from the hull.

The physical phenomenon which occurs at the point of attachment of the barnacle to the ship's hull by which the barnacle is separated involves what is considered to be a shock removal arising from the rapid heating of the hull surface because of the concentrated energy input from the laser at this particular point. This shock removal of barnacles has in fact been actually demonstrated in experimental procedures. It has been discovered that both barnacle shells and barnacle cement are relatively transparent to the characteristic wavelengths of certain lasers which are commercially available. Hence, even though a ship's hull is well-layered with barnacles, the laser energy passes through them to the hull surface. The physical characteristics of the hull material are such that substantial amounts of the laser beam energy are absorbed and appear as heat. The temperature rise is rapid and vapor is generated that in turn creates a shock which fractures the cement and forcefully separates the barnacle from the hull.

While the physical phenomena by which undesired material is removed from the surface of an object will depend upon the physical characteristics of both object and material, it will also be a function of the parameters of laser operation. It is believed that one predominant effect in the removal process involves the thermal effect of the focused laser beam at the interface between the undesired material and the object. The shock wave can be generated either by thermal expansion or by vapor blow-off involving the creation of pressurized vapor either of which produce a shock which is capable of mechanically fracturing the bond between the undesired material and the object. In the case of barnacle removal, the sudden thermal heating of the hull surface creates a mechanical shock force which forcefully dislodges the barnacle from the hull. Alternatively the laser energy input may give rise to thermal conditions whereby the undesired material is melted or vaporized by virtue of the temperature of the undesired material being elevated above its melting, boiling, or decomposition point. It is also conceivable that the surface of the object may be melted, vaporized, or decomposed to a limited depth thereby also causing removal of undesired material. Energy absorption for creating shock, vaporization, melting, decomposition, etc. is a function of the physical characteristics of the object and the undesired material. It is anticipated the shock removal procedure offers the most economical approach for cleaning surfaces from a commercial standpoint since less material would have to be brought to elevated temperatures thereby enabling lasers of lower average power output to be used.

Other assistive devices and procedures may be used in conjunction with the laser. For example, as assist gas could be directed onto the object to blow away melted material and/or to help oxidize, or even chemically reduce, heated material, similar to the manner used to enhance laser cutting processes.

One particular advantage of lasers involves the capability for focusing the coherent light of the laser beam to a very small spot. This means that power densities as great as $10^6 w/cm^2$ can be achieved with a laser having a continuous output of several hundred watts. Greater power densities in the range of $10^7$ to $10^{12} w/cm^2$ can be obtained by compressing the energy output of the laser into short pulses. Such peak power densities are difficult or even impossible to achieve with any other heat source. The invention can be practiced with either a continuous laser beam output or a pulsed laser beam output, depending on the requirements for particular foreign matter removal.

While peak power density is an important parameter for a procedure, high average power is desirable for completing large cleaning jobs in reasonable time. The reason why peak power density and pulse width are important parameters can be understood from considering what happens when a surface is suddenly, almost instantaneously heated. As heat is applied to the exterior surface of a material, that surface is simultaneously being cooled by the inward conduction of heat. Thus the rate of temperature rise at the surface depends on both the intensity of the heat source and the rate of heat conduction by the material. In the case of the removal of barnacles both the barnacle shell and the barnacle cement are transparent to laser beams at wavelengths of 10.6 micrometers and 1.06 micrometers. These constitute the characteristic wavelength of the laser beams which are emitted by $CO_2$ lasers and YAG lasers, respectively. Hence the laser beam energy is absorbed directly at the surface of the underlying material and the sudden rapid heat at the surface gives rise to the shock phenomenon which acts between the surface of the hull and the barnacle cement. Hence both the barnacle and its cement are separated from the ship's hull by the laser beam energy. The energy input is controlled in such a manner that it is sufficient to remove only the undesired material from the object, without damaging the object itself.

In addition to removal of marine fouling from the surface of the ship's hull the present invention may be used to remove previously applied coatings such as the anti-fouling paint referred to earlier. Where a layer of paint or similar material has been applied to the surface of an object the characteristics of the paint or material will be important in determining the best procedure for its removal. Certain materials may require a complete heating of the thinkness of the layer which will require longer times. Alternatively a layer may be susceptible to shock removal by heating the surface of the underlying material to a high temperature by means of laser beam pulses of a very short pulse duration at high intensity.

The invention may also be used to advantage for purposes of cleaning the interior of a ship's hull. Current procedures for cleaning the interior of the hull create airborne matter such as dust, particulates, and vapors in the confined interior space. Cleaning personnel are exposed to these substances. With the present invention, the interior cleaning can be accomplished in an efficient and an effective manner without the degree of personnel exposure to such materials which occurs with the current cleaning procedures such as sandblasting. The sandblasting procedure has the further disadvantage that the sand itself must be cleaned up and removed.

In order to accomplish the cleaning of the entire ship's hull, it is necessary that the laser beam be directed over the entire area to be cleaned. In order to efficiently conduct the cleaning procedure, it is desirable that the laser be associated with additional mechanical apparatus which can produce the desired directional control of the laser beam in an efficient manner. Fig. 2 illustrates an example of a dry-dock 7 which is occupied by a vessel 10. Apparatus for practicing the invention is designated by the reference numeral 6 and is shown in association with dry-dock 7.

The apparatus comprises a laser cart 8 which is mounted for horizontal travel lengthwise of the dry-dock on a rail 9. The rail is disposed to one side of vessel 10. The apparatus includes additional components by which the laser beam B is directed and focused onto the ship's exterior hull surface. As the cart travels along rail 9 the laser beam B traverses up and down the side of the ship. The focusing mechanism 12 is adjustable to maintain the desired power density of the laser beam on the hull surface. Fig. 3 illustrates further detail of the apparatus which directs the laser beam from the laser cart to the surface of the ship's hull. The reflecting mirrors 2 are disposed to turn the laser beam so that it is directed against the ship's hull and the focusing mechanism 12 is operated to adjust the function of lens 3 so that the desired power density of the laser beam is obtained.

The apparatus 6 illustrated in Fig. 2 may be operated in such a matter that the laser beam travels horizontally lengthwise of the ship (i.e. with the cart) at a particular level of elevation. After the beam has made a pass along the length of the ship the elevation is adjusted to a different level (i.e. indexed) for the return pass. In this way the procedure may be repeated over the full extent of the hull surface which is to be cleaned. Alternatively, the beam may travel vertically and then at the end of each vertical pass the cart is indexed horizontally a suitable increment before the next pass, this procedure being repeated until one half (side) of the ship's hull has been cleaned. The apparatus may then be repositioned on the opposite side of the dry-dock to clean the opposite side of the hull or a second laser cart may be used to clean both hull halves simultaneously.

One of the factors in the operation of apparatus 6 is the nature of the particular material and object. Hence associated with the laser are adjustable controls which may be set to vary certain of the laser operating parameters such as the mode of operation of the laser (either continuous or pulsed), the energy output, and in the case of pulsed operation the pulse width and repetition rate. Additional controls are provided for setting the rate at which the laser beam travels over the hull, and these would involve the rate of travel of laser cart 8 on rail 9 as well as the vertical travel of the laser beam.

It may be necessary to maximize effectiveness of operation by keeping the laser beam normal to the hull surface at the point of impingement. To this end the arm structure of the apparatus which depends from cart 8 is of an articulated construction. Each of the mirrors 2 is mounted in an articulate joint endowing the arm segments of the mechanism with a pivotal positioning capability, as indicated by the respective double-headed curved arrows, so as to keep the beam normal to the hull surface at the point the beam impinges on the hull. Such articulated arms are well-known in the laser field.

Fig. 4 illustrates details of a laser cart 8 which may be used in the practice of the invention. The laser cart of Fig. 4 is basically like that of Fig. 3, but there are certain differences. The apparatus of Fig. 4 comprises a cart 8 which travels on a track alongside the dry-dock. Mounted on cart 8 is the laser 1. Associated with the laser are dichroic mirrors 13, 14, a beam expander 15, focusing optics 16 and beam deflectors 17. These individual components represent conventional devices which are presently used in the laser field. Also associated with the system as ancillary devices are a visible laser 18, 1 TV camera 19, and a TV monitor 20.

The dichroic mirrors are mirrors which are reflective at some wavelengths and transmissive at other wavelengths. The mirrors reflect the high power laser beam emitted by laser 1. The mirror 13 transmits the visible laser beam from the visible laser 18, after being reflected by mirror 2, and mirror 14 reflects the beam from the visible laser after it has passed through mirror 13.

The beam expander 15 is provided to expand the high power laser beam for the purpose of decreasing the power density in the optical components or to decrease the divergence so as to make the laser beam focusable to smaller spots. While the use of a beam expander is preferred, the necessity of using a beam expander depends upon the power and divergence characteristics of the particular high power laser. It is contemplated that for certain practices of the invention the use of a beam expander may be unnecessary.

The focusing optics 16 are for the purpose of changing the shape of the laser beam. Like the beam expander the usage of the focusing optics is preferred; however, whether focusing optics are actually required will depend upon the parameters involved in a specific application of the invention. Hence, it is contemplated that the invention may be practiced at times without the need to include focusing optics. By way of example, the focusing optics could comprise lenses which are spherical to converge or diverge the beam and/or cylindrical to change the beam shape.

The beam deflectors 17 are provided for the purpose of deflecting the laser beam over the surface of the object. By way of example, the beam deflectors could consist of either scan mirrors or rotating rings with mirror-faceted sides. If only a single deflector is used, scanning could be in the direction orthogonal to the motion of the cart (i.e., vertical to the horizontal cart travel). If two deflectors are used the beam can be deflected both horizontally and vertically. Hence, by incorporating the beam deflectors in the cart, it may be unnecessary to also use the articulated arm structure of Fig. 2.

While the disclosure in Fig. 1 shows the apparatus to be spaced laterally from the hull of the ship it is conceivable that an arrangement could be provided whereby the cart might roll in actual contact with the surface being cleaned.

The closed circuit TV system, while being preferred for use with the practice of the invention, is an optional feature. Hence the invention may be practiced without the necessity of such a closed TV system. The purpose is to provide to operating personnel a view of the cleaning operation while it is in progress. The view may be useful in that it may reveal situations where the operator may want to redo a portion of the surface or to make adjustments to the laser where the presence of undesired material is greater.

It is also contemplated that the invention may be used for cleaning the submerged hull without dry-docking of the vessel. Either all or a portion of the apparatus may be submerged and the laser beam directed onto the hull. If it is deemed preferable that the laser beam not pass through water, a suitable chamber may be designed to mount directly on the hull over an area to be cleaned and evacuated so as to be water-free. The laser beam passes through the water-free space directly onto the hull. The chamber may be moved on the hull from area to area to completely clean the submerged portion of the hull.

In the case of a vessel having, by way of example, seventy thousand square feet of hull to be cleaned, it is projected that cleaning operations can be completed within a 72 hour period using a single conventional industrial $CO_2$ laser. The total time required to de-foul a ship's hull obviously will be a function of many factors. The concurrent use of multiple lasers will reduce the de-fouling time but will require a greater capital investment. Larger, higher power lasers will be faster than smaller, lower power lasers. In any event, it can be perceived that the invention can substantially reduce the dry-dock time of a vessel for cleaning purposes. Cleaning by conventional procedures such as scraping and sandblasting would require the use of significant numbers of personnel and would take much longer.

Because of the larger number of potential applications of the invention, as well as the variable factors which may be encountered in each application, it will be appreciated that it is difficult to generalize as to the values of the operating parameters and procedures which will be best in a given application. Thus, in many instances, these are best arrived at empirically. Typically, the starting point will be a determination of impingement power density required to effectively remove the undesired material from the surface without damage to the underlying object. In this regard, for purposes of de-fouling a ship's hull, power densities in the range of 20 joules per square centimeter are a representative figure. Such power densities have been demonstrated to be effective in barnacle removal under certain conditions. It must be recognized, however, that this magnitude is merely representative, and that power densities differing by as much as an order of magnitude or even more may be appropriate in other instances. In all situations the variations in operating parameters, including power density along with other parameters such as pulse width, may be accomplished through conventional adjustment practices well-known in the laser field.

While the invention in its preferred embodiment has been disclosed in the context of cleaning the defouling marine surfaces such as a ship's hull, principles of the invention are applicable to other cleaning operations where undesired material is to be removed from the surface of an object. An example is where the invention is applied to cleaning the scale which has accumulated on the interior of a pipe, such as a hot water pipe. A suitable cleaning probe is directed into the pipe and includes suitable optical structure which allows a laser beam to be conducted through the pipe and then directed radially against the scale on the inside wall of the pipe. The laser is operated in the manner described above at suitably selected laser operating parameters so that the adhering interface between the scale and the wall of the pipe is broken. The scale may be flushed from the pipe as it is dislodged from the wall.

The invention may also be used in connection with removal of rust from the surface of an object. For example, certain untreated steels exposed to air will inherently, over time, develop a coating of rust on the exterior surface. By a suitable selection of laser operating parameters the present invention is applied to remove the rust from the surface of the steel. As a consequence the rust has been removed and the underlying surface of the steel has been cleaned to a polished appearance.

It is also possible, as noted above, to remove previously applied coating from the surface of an object. For example, an acrylic base paint may be a material which is susceptible to removal by the practice of the present invention. In general optimum overall removal rates can be attained by using maximum power density with an appropriate scan rate.

From the foregoing description, one can now perceive that the invention provides a new and unique procedure for cleaning the surfaces of objects. The invention has wide application and is particularly useful in the context of removing undesired material from the hull of a ship. While examples of application of the invention have been shown and while specific examples of apparatus for practicing the invention has also been shown, it will be appreciated that principles of the invention may be applied to other applications and the invention practiced with other embodiments of apparatus.

What is claimed is:

1. The method of removal of material from the surface of an object without damaging the object which comprises directing the beam from a source of coherent electromagnetic radiation toward the material and controlling the operating parameters such that the beam of radiation impinges upon the material and the object with a power density effective to remove the material without damaging the underlying object.

2. The method set forth in Claim 1 wherein the beam of radiation is moved over the area of the material in different directions so as to cover the entire area.

3. The method set forth in Claim 1 wherein the source of coherent electromagnetic radiation is operated in a pulsed mode to thereby generate the beam in corresponding pulses.

4. The method set forth in Claim 1 wherein the beam is focused upon the material and the object.

5. The method set forth in Claim 1 wherein the source of coherent electromagnetic radiation is operated at a characteristic wavelength which readily passes through the material.

6. The method set forth in Claim 1 wherein the beam from the source of coherent electromagnetic radiation is invisible and an auxiliary beam of visible coherent electromagnetic radiation is directed onto the undesired material and object collinearly with the invisible beam from the first source of coherent electromagnetic radiation and an image of the impingement of the visible laser beam on the undesired material is displayed by means of a closed circuit television system.

7. The method set forth in Claim 1 where said object is the hull of a navigable vessel containing marine fouling and said method comprises subjecting the areas of fouling to the beam of coherent electromagnetic

radiation and controlling the operating parameters so that the radiation impinges upon the area of fouling with a power density and irradiation time effective to remove the fouling without damaging the hull of the vessel.

8. A method set forth in Claim 7 wherein the fouling is caused by barnacles adhering to the hull of the vessel and wherein the source of coherent electromagnetic radiation is operated in such a manner that its impingement is effective at the interface between the barnacle cement and the vessel's hull to forcefully dislodge the barnacles from the hull.

9. The method set forth in Claim 7 wherein the de-fouling is conducted with the vessel in dry-dock.

10. The method set forth in Claim 9 wherein the source of coherent electromagnetic radiation is on a laser cart at one side of the vessel.

11. The method set forth in Claim 10 in which the beam of coherent electromagnetic radiation is focused before it impinges upon the hull.

12. The method set forth in Claim 10 in which the beam from the source of coherent electromagnetic radiation is directed onto the hull by a mirror system.

13. The method set forth in Claim 12 including a visible source of coherent electromagnetic radiation which is directed by at least a portion of said mirror system to impinge upon the vessel's hull collinearly with the beam of coherent electromagnetic radiation from said first source and further including a closed circuit television system which allows an observer to view the impingement of the beams on the hull.

14. The method set forth in Claim 7 wherein the de-fouling is conducted with the vessel in the water.

15. The method set forth in Claim 1 wherein the material is rust.

16. The method set forth in Claim 1 wherein the material is pipe scale.

17. The method set forth in Claim 1 wherein the material is paint.

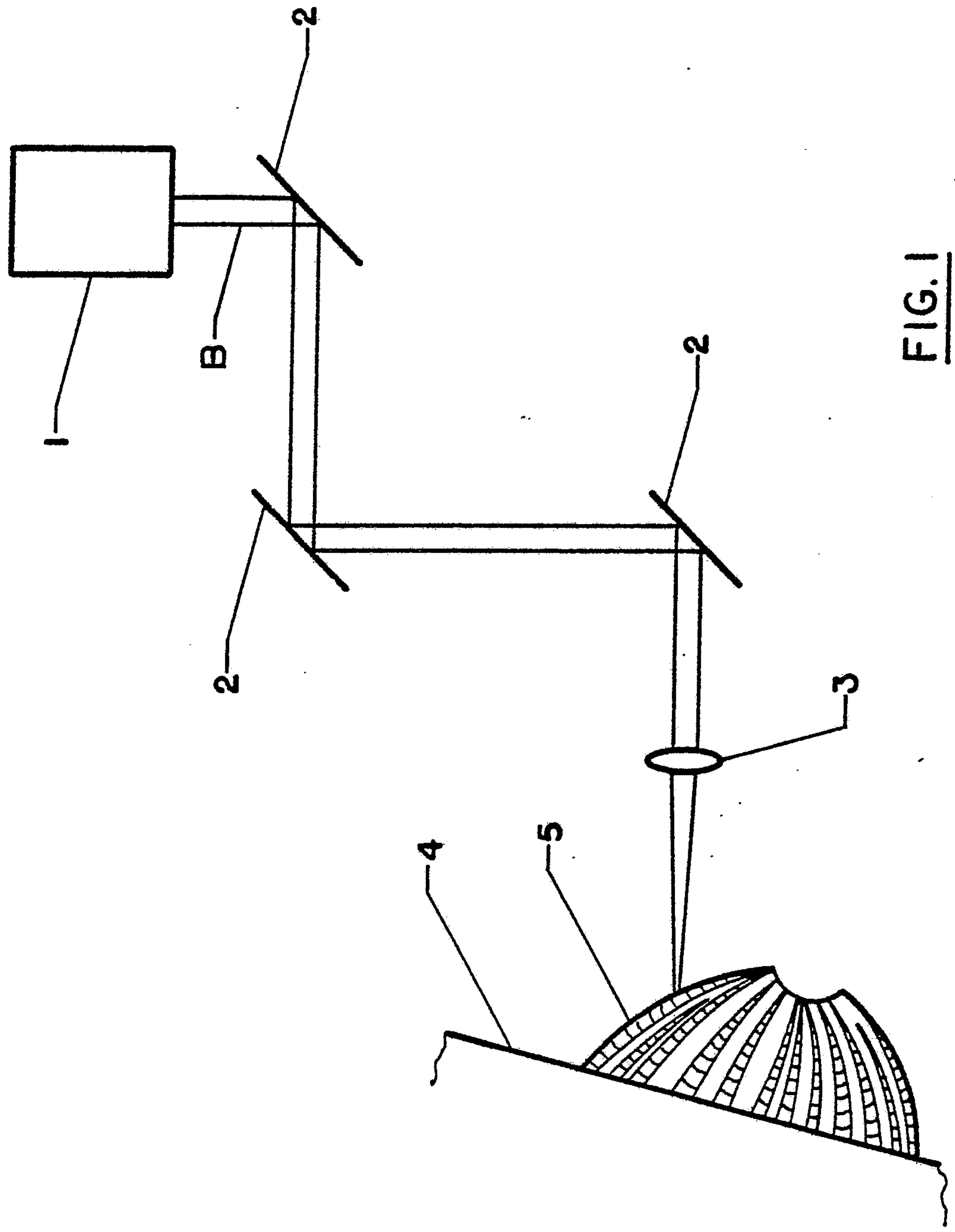


FIG. 1

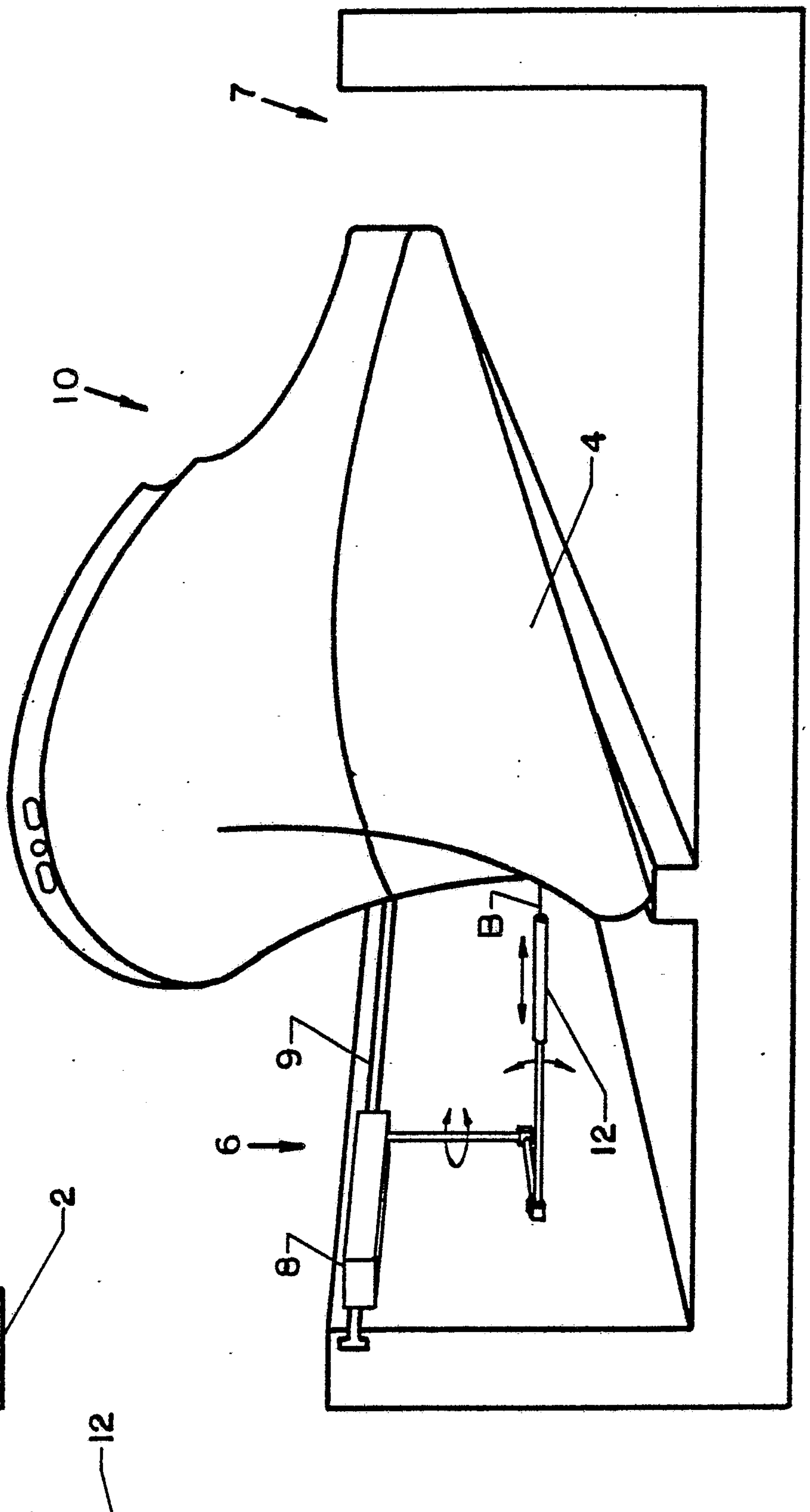


FIG.2

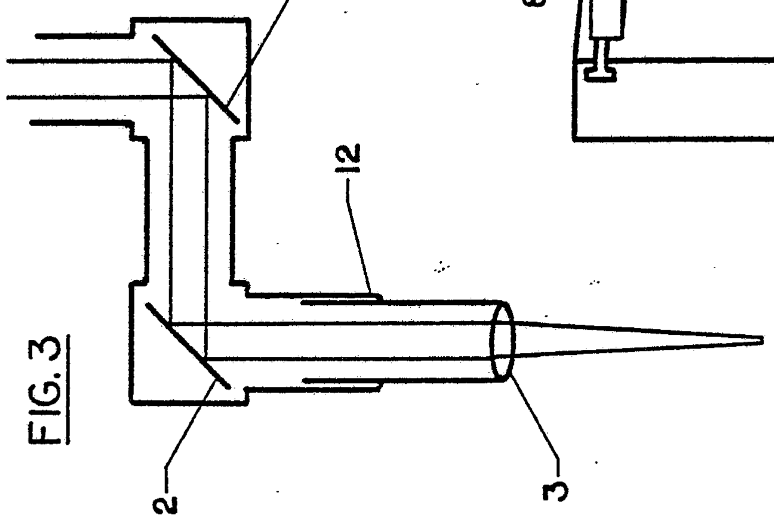


FIG.3

DETAILS OF LASER CLEANING SYSTEM

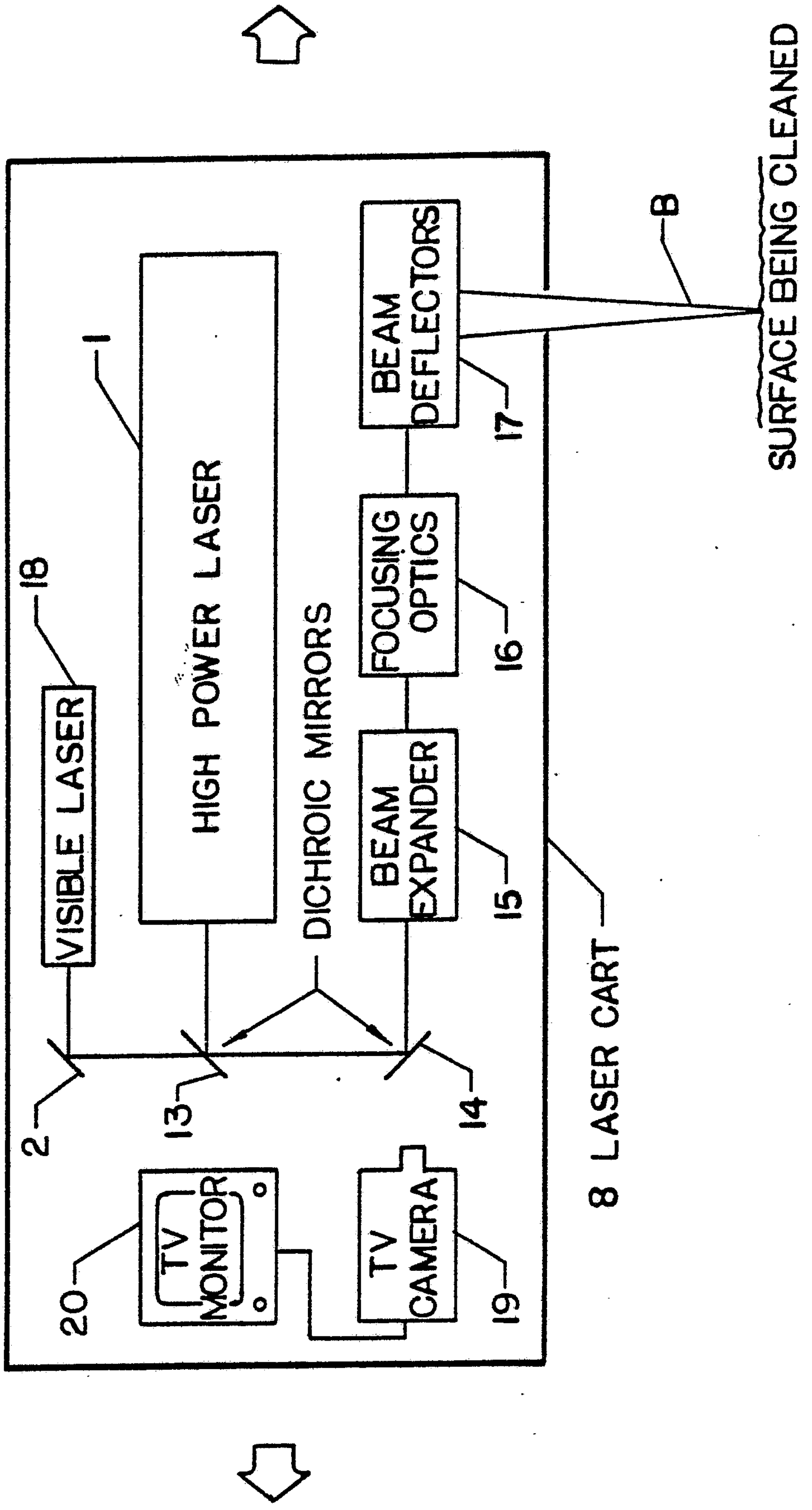


FIG. 4

# INTERNATIONAL SEARCH REPORT

International Application No PCT/US82/01489

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL. B08B 7/00; B23K 26/00, 26/02; B63B 59/06
U.S. CL. 134/1,18,22.11,38; 114/222

**II. FIELDS SEARCHED**

Minimum Documentation Searched [4]

| Classification System | Classification Symbols |
|---|---|
| US | 134/1,18,22.11,38 ; 114/222; 219/121L,121LM,121LF,121LN |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [14]

| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No. [18] |
|---|---|---|
| X | US,A, 3,503,804 PUBLISHED 31 MARCH 1970, SCHNEIDER. | 1-17 |
| X | US,A, 4,028,135 PUBLISHED 07 JUNE 1977, VIG ET AL. | 1-17 |
| Y | US,A, 3,922,991 PUBLISHED 02 DECEMBER 1975, WOODS. | 6-17 |
| A | US,A, 4,131,484 PUBLISHED 26 DECEMBER 1978, CARUSO ET AL. | 1-17 |

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search [2] | Date of Mailing of this International Search Report [2] |
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| **International Searching Authority [1]** | **Signature of Authorized Officer [20]** |
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