

Nov. 5, 1968

D. J. LEWIS ET AL

3,408,937

LIGHT ENERGIZED EXPLOSIVE DEVICE

Filed Aug. 24, 1966

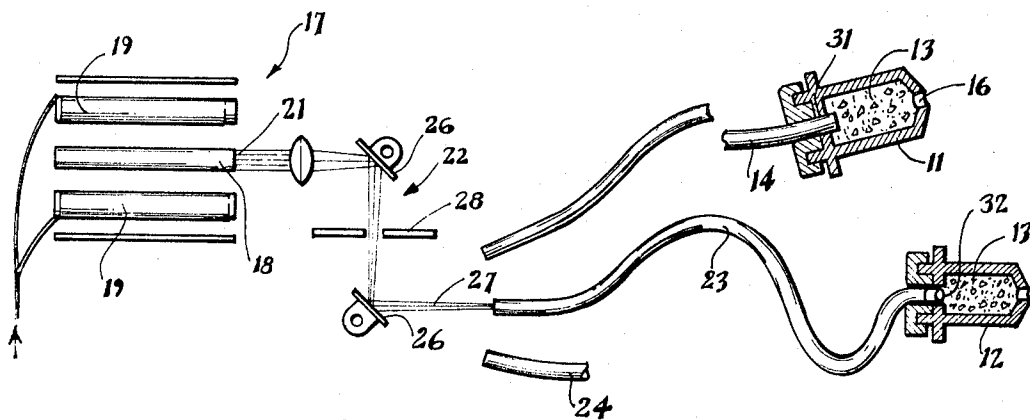


FIG. 1

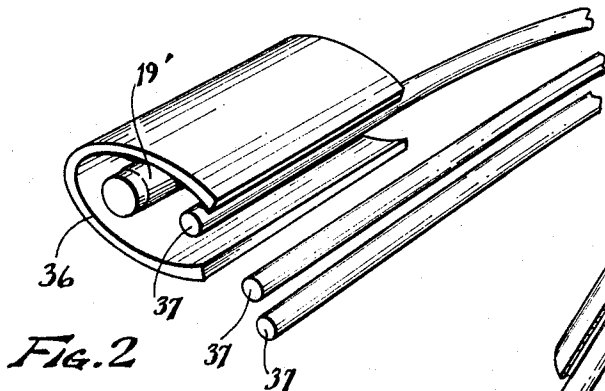


FIG. 2

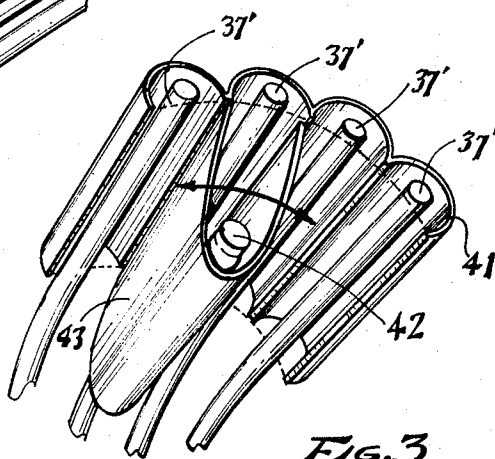


FIG. 3

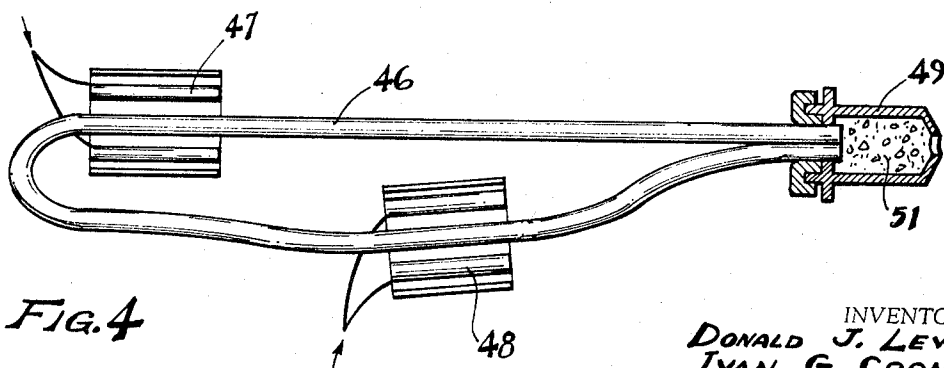


FIG. 4

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1

3,408,937

LIGHT ENERGIZED EXPLOSIVE DEVICE

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Filed Aug. 24, 1966, Ser. No. 574,796

6 Claims. (Cl. 102—70.2)

ABSTRACT OF THE DISCLOSURE

This invention relates to apparatus for igniting an explosive device such as a pyrotechnic detonator or initiator. It is characterized by the use of laser energy conveyed to the explosive device by means of a light pipe, sometimes known as fibre optics.

Background of the invention

Detonators and initiators are coming into increasing use in connection with space craft, particularly when such vehicles must be remotely controlled. They are used in explosive nuts; to operate valves, switches and other devices, through pressure on an operating piston; to deploy parachutes and gas bags; to actuate knife edges and blades for performing various severing operations; to actuate shaped charges; and in general wherever intense, instantaneous and momentary pressure, heat or shock is required. These devices are characterized by the incorporation of a pyrotechnic material which is ignited and exploded by the application thereto of triggering energy, usually in the form of heat.

The most common manner of triggering such explosive devices is to incorporate a bridge wire which is heated quickly and rapidly by the application of electric current, to ignite the pyrotechnic and operate the explosive device.

Such actuation of the explosive device is accompanied by a number of troublesome problems, one of which is the ever-present danger of accidental operation through the reception of stray radio frequency energy, electrostatic energy, or incidental and momentary temperature extremes above the ignition temperature of the pyrotechnic. This constant danger, which, because of the critical installation of such explosive devices, could be disastrous to an entire project, necessitates extreme care and expense in the design and fabrication of such igniting or triggering systems.

Summary of the invention

In accordance with the present invention, explosive devices are ignited by high-level, monochromatic, radiant energy derived from some form of laser, and the energy is conveyed to the explosive device by a walled conduit or light pipe, preferably in the form of a solid flexible light conductor. Such conductors are known in the art under the general term fibre optics.

By use of the present invention, there is virtually absolute certainty that there can be no accidental igniting of the explosive device. Since the only entrance or input to the explosive device is that formed by the opening into which the light pipe is injected, there can be no danger of accidental ignition from stray radio frequency energy, electrostatic energy, or the like, such as plagues the use of bridge wires and electrical firing. Because of the extremely high-energy level instantaneously obtainable from a laser, the pyrotechnic may be chosen to be insensitive to all temperatures except those which are very high—well beyond the range of accidental ignition through subjection to possible ambient temperature extremes. The pyrotechnic, for example, may be chosen to operate only at a temperature of 10° kelvin with a power density of approximately

2

5 megowatts per square centimeter. This virtually precludes any operation except that which is deliberately intended by operation of the energizing laser.

By use of the present invention, the need for electrical shielding is completely eliminated. The rejection by the light pipe of all external light sources is inherent in the construction of such fibre optics. This is because these fibre optics are totally internally reflecting, and consequently, totally externally reflecting, thus rejecting any and all outside light sources. The fibre optics are such that they are available in materials having great flexibility, equivalent to that of electrical conductors. Furthermore, it is quite feasible to use a plurality of small stranded conductors twisted or wound together into a cable, which gives high transmission capacity and at the same time retains the inherent flexibility of the tiny optical fibres. Thus, the light conductor or leads leading from the laser to the explosive device may be snaked through serpentine passages and configurations in a physical system. Maximum flexibility is thus achieved in the physical placement of the laser and the explosive devices to be ignited thereby.

Illustrative examples of the present invention are illustrated in the accompanying drawing wherein:

FIGURE 1 is a partially-schematic view of a system in which a single laser is selectively employed to successively energize a number of different and independent explosive devices.

FIGURE 2 shows a modified form of the selective operation possible with the present invention.

FIGURE 3 shows a still further form of the present invention where several devices are ignited from a single energizing source.

FIGURE 4 shows in schematic form a further modification in which the laser and the light pipe are incorporated into a single means or member.

Referring to the drawing, 11 and 12 are representative of explosive devices such as detonators or initiators. These devices are filled with a pyrotechnic material 13 which is ignited by the application thereto of laser energy injected into the device 11, for example, by a walled conduit in the form of a solid light-conducting pipe or conductor 14. As noted hereinbefore, the conduit 14 may be a plurality of smaller stranded conduits twisted together into a light-conducting cable.

Energy from the exploding pyrotechnic 13 is emitted and employed in any desired way, illustrated symbolically in FIGURE 1 by the energy opening 16. This energy may be used to operate a number of devices, as explained hereinbefore.

The energy is generated in a laser 17, shown schematically in FIGURE 1, and consisting for example of a ruby rod 18 into which light energy is pumped by any suitable source of conventional polychromatic light, illustrated symbolically at 19. Energy from the ruby rod 18 emerges from the face 21 and is directed, by an optical system shown generally at 22, to any one of a plurality of solid light tubes 14, 23, 24, and the like. By proper rotation of the mirrors 26, forming part of the optical system 22, the laser beam may be directed to the input of any one of the light tubes such as 23. Thus, a single laser 17 may be employed to successively ignite any number of explosive devices 11, 12.

If desired, a suitable shutter, illustrated symbolically at 28, may be employed to interdict the laser beam, so that it is not applied to any of the explosive devices.

No special connectors are required at either end of the light pipe 14. Inasmuch as only energy of laser intensity can affect the pyrotechnic 13, the junction at 31 between the solid light pipe 14 and the explosive device 11 need not be of particular concern to the designer. If desired, a

concentrating lens 32 may be employed at the output end of the light tube to concentrate the energy intensity as it is applied to the pyrotechnic 13. The lens 32 may also form a sealed window capable of withstanding the shock of the passage of the laser energy, and also of the resultant explosion of the pyrotechnic 13, thus forcing the energy from the explosion to exit through the proper path 16.

While the FIGURE 1 schematic implies that the laser 17 is of constant output, pulsed lasers may also be used and for many purposes are to be preferred. Pulses of laser energy are particularly suitable for the present invention, because only a momentary application of energy, but of very high intensity, is required to ignite or detonate the pyrotechnic 13.

The laser system 17 may be a gaseous laser, a ruby laser, a neodymium laser, a semi-conducting laser, a laser pumped by chemically-generated light, or any other suitable laser source that will provide the necessary high-energy optical output transmissible through the light pipes 14 to the explosive device 11.

The light pipe, as noted, is preferably a bundle of stranded or cabled light fibres made of such materials as styrene, wall silica glass, quartz fibres, or any other material which has suitable qualities to provide the characteristics necessary to confine and transmit the light pulse generated by the laser, with minimal loss.

Certain materials are known which are capable of serving not only as the laser generator into which light energy is pumped, but which are also flexible, and thus capable of serving as the light pipes or fibres themselves. In this case, the entire length of the light fibre is made to resonate and serve as a laser, with the light being ejected from one end directly into the explosive device. When such a multiple function laser and light pipe is employed, the selective operation of particular explosive devices may assume the form shown in FIGURE 2. Here the basic light source 19' is placed in a reflecting optical system 36 which focuses the light on a position occupied in the example shown by the laser/light pipe 37. Suitable physical mechanism (not shown) may be employed to selectively move and successively move any of the laser/light pipes 37 into the focus of the optical system 36, thus setting up the light pumping of the laser, with consequent energization of the explosive device to which the end of the light pipe 37 feeds.

A somewhat more elegant form of this variant is shown in FIGURE 3, where the several laser/light pipes 37' are permanently mounted in individual sections of a reflecting optical container for example shown in 41. Output from a single polychromatic light pump source 42 is selectively applied to a desired one of the laser/light tubes 37', by rotation of the pre-focused reflecting light container and reflector 43 rotating about the light source 42 as an axis. In this way, the only thing that has to be moved is the reflector 43. All other elements remain stationary. With the movement of the reflector 43 into registry with any one of the reflectors 41, the corresponding laser/light pipe 37' is pumped with energy, which emerges into its associate explosive device 11 with consequent ignition thereof.

A further example of the present invention is illustrated in FIGURE 4, wherein 46 represents a combined laser and light pipe into which light energy is pumped from a source 47, and which may be boosted if desired by another light source 48 placed elsewhere around the light tube 46. If desired, both ends of the tube 46 may terminate at an explosive device 49. Since presently known laser techniques require that the energy generated in the laser 46 be allowed to resonate, one end of the tube 46 will be mirrored, with the other end being optically open to emit its energy against the pyrotechnic material 51 in the explosive device 49.

Use of this invention makes possible much shorter explosive devices than were heretofore feasible. At this point, it might be well to discuss the distinction between

explosive devices, i.e. detonators and initiators, and deflagration devices. In the former, the crystal structure actually fractures under shock and the oxidizing phenomenon travels at a much higher speed than in the case of mere deflagration, where the burning material, e.g., a propellant fuel, merely breaks apart or tears asunder. It has been found heretofore that explosive devices, when set off by conventional means, such as bridge wires, require a certain minimum length in order to build up a shock wave of actual detonation. Use of the present invention allows the explosive device to be much shorter than the minimum heretofore required and still detonate in the required manner.

Use of the present invention also causes certain metal oxidants, when suitably confined within a small enough cross-sectional area, to actually detonate rather than merely deflagrate.

Examples of detonating materials are dynamite, RDX, TNT, PETN, mercury fulminate. Examples of typical deflagration material, where there is no substantial shattering of the crystalline structure, are black powder, metal oxide, metallized polyurethanes, various powdered fuels, high-temp and carbon oxidant mixes. As noted, certain metal oxidants, such as SOS 108, have been found to actually detonate, rather than merely deflagrate when incorporated into the system of the present invention.

It is thus seen that the present invention makes possible a triggering system for explosive devices, of utmost security, and without requiring critical and sensitive fabrication and construction techniques heretofore needed. This is made possible by the use of the aforescribed fibre optics, which maintains virtually impregnable integrity throughout the system, while still permitting maximum flexibility and ease of installation. Because of the laser output being of such extremely high energy concentration, the explosive material used may be compounds which function only when raised to very high temperatures, in the order for example 2,000° centigrade. Heretofore, when using hot or exploding electrical bridge wires, the pyrotechnic materials had to be sensitive to temperatures several orders of magnitude lower. This, of course, rendered the systems much more sensitive to accidental ignition and explosion with consequent danger of disastrous and tragic results.

Whereas the present invention has been shown and described herein in what is conceived to be the best mode contemplated, it is recognized that departures may be made therefrom within the scope of the invention which is, therefore, not to be limited to the details disclosed herein, but is to be afforded the full scope of the invention as hereinafter claimed.

What is claimed is:

1. Apparatus for igniting an explosive device comprising:

a plurality of explosive devices responsive to high-level, coherent, radiant energy;

a corresponding plurality of flexible light conductors, each having one end located in position to ignite a respective explosive device, the other ends of said light conductors being juxtaposed in position to selectively conduct coherent radiant energy;

laser means disposed at said other ends of said light conductors for the conduction of coherent, monochromatic, radiant energy through said plurality of conductors; and

means for energizing said laser means and selectively directing energy to different ones of said light conductors.

2. Apparatus in accordance with claim 1 in which said last-named means comprises a reflector.

3. Apparatus in accordance with claim 1 in which said laser means comprises a plurality of individual laser units incorporated into respective ones of said light conductors as an integral part at one end thereof.

4. Apparatus in accordance with claim 1 in which said

5

laser means comprises a plurality of individual laser units incorporated into respective ones of said light conductors as an integral part at one end thereof; which includes a polychromatic light pump source; and in which said last-named means includes a reflector for selectively directing energy from said light pump source to different ones of said laser units.

5. Apparatus in accordance with claim 4 in which said laser units are movable with respect to said reflector.

6. Apparatus in accordance with claim 4 in which said reflector is movable with respect to said laser units.

6

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