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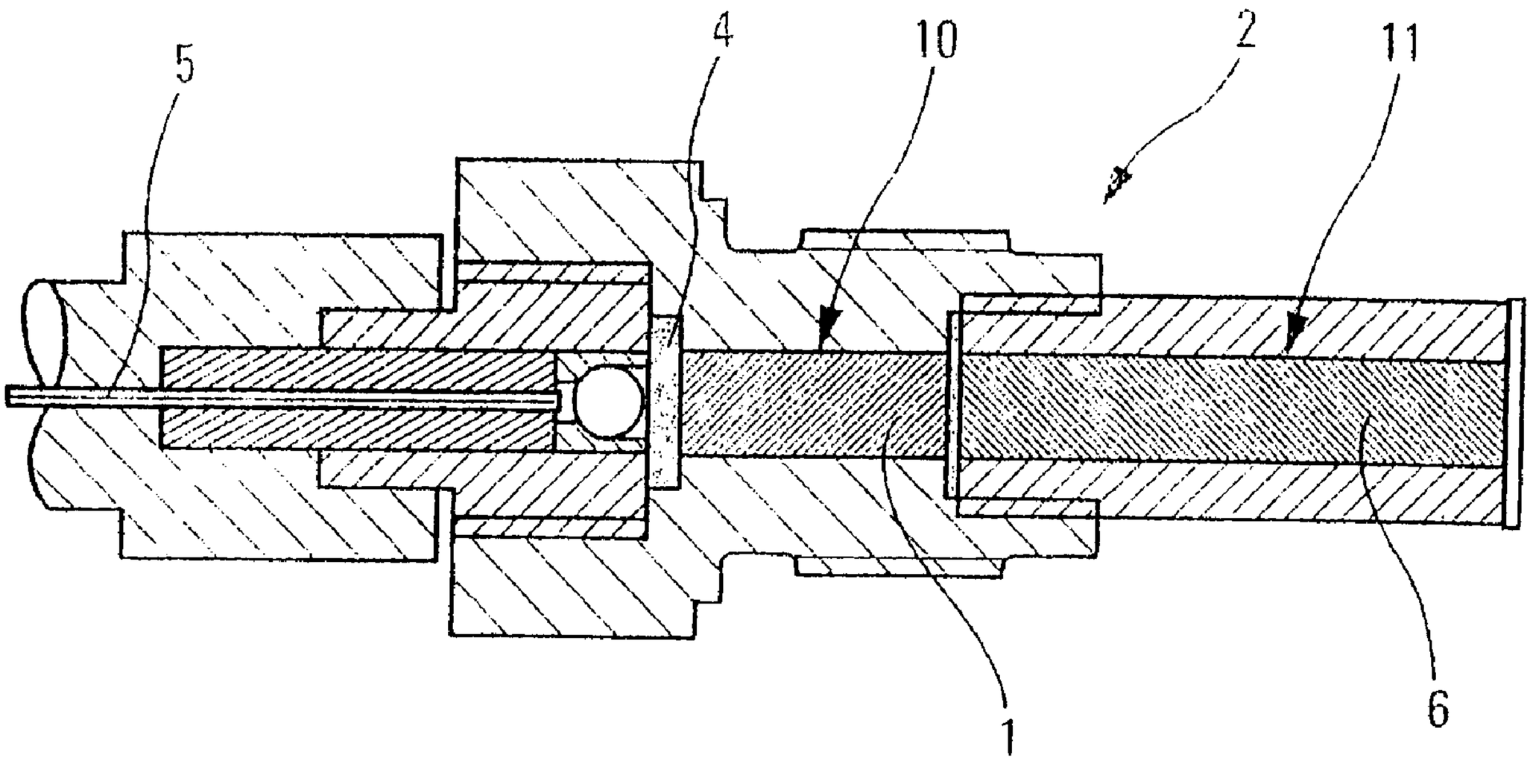
(54) Title: OPTICALLY DOPED ENERGETIC IGNITER CHARGE



(57) Abrégé/Abstract:
The invention relates to an energetic igniter charge consisting of a mixture of at least one secondary explosive and an optical doping material in powder form. In accordance with the invention, the optical doping material is a metal. The energetic igniter charge can be used in a detonator as well as in an igniter.

ABSTRACT

The invention relates to an energetic igniter charge consisting of a mixture of at least one secondary explosive and an optical doping material in powder form. In accordance with the invention, the optical doping material is a metal. The energetic igniter charge can be used in a detonator as well as in an igniter.

OPTICALLY DOPED ENERGETIC IGNITER CHARGE

Field of the Invention

The present invention relates to an energetic igniter charge for the use in an optical detonator (igniter with explosive) or an optical initiator (igniter with pyrotechnic mixture).

Background Art

Laser sources used in detonators must be robust, space saving and economical, especially for military or astronautical applications. They are therefore either Nd-YAG-solid lasers (for military applications) with a power density of about 3 $MW.cm^{-2}$, or laser diodes with, generally, 1 W power output (for astronautical applications) and a power density of about 20 $KW.cm^{-2}$, which is too low for direct initiation of the secondary explosive detonation which requires a power density of about 1 $GW.cm^{-2}$.

In conventional optical detonators, these power densities lead, however, to a temperature increase of the secondary explosive in the first detonator stage up to the self-sustaining decomposition temperature. At this temperature, a very violent breakdown reaction occurs through which the secondary explosive detonation in the second stage is initiated (depending on the detonator configuration and the characteristics of the secondary explosives used) either by a deflagration-detonation transition process or a percussion-detonation transition process. However, since the secondary explosives do not absorb the light in the near infrared range as emitted by the laser sources, the energetic igniter charge in the first detonator stage is a mixture of secondary explosive and soot powder, the latter being used as optical doping material which absorbs the radiation emitted by the laser source and transfers the required heat energy for the achievement of the critical temperature of the secondary explosive.

The effectiveness of soot however decreases strongly in applications which expose the detonator to extreme climatic conditions. For the validation of a detonator for such an application, experiments must be conducted which emulate a temperature variation stress according to the requirements of the application. In the field of astronautics, such a temperature variation stress includes, for example, a temperature increase to 100°C during five hours as well as a subsequent cooling down to room temperature. When a laser diode is used as the laser source, ignition of the secondary

explosive mixture with 1 percent by weight (wt.%) soot no longer occurs subsequent to such a temperature variation stress, even when a maximum diode power of 1 W is used, although a power of 0.1 W is normally sufficient for ignition of the detonator.

A first solution to the problem of providing the required high power laser source for ignition of a detonator under such difficult climatic conditions is described in French Patent FR 2 831 659. According to that disclosure a pyrotechnic redox mixture is placed in the first detonator stage between the secondary explosive and the optical focusing interface, which mixture absorbs light in the infrared range and initiates a redox reaction that releases the heat energy required for ignition of the secondary explosive. The pyrotechnic mixture used (ZPP) is however generally very sensitive to friction and electrostatic discharges.

Furthermore, for a reliable ignition of the pyrotechnical redox mixture in optical initiators using a laser diode (especially a 1-W laser diode) as laser source, pyrotechnic mixtures must be used, wherein the reducing agent has a very fine particle size (typically between 1 and 2 μm). However, due to this small particle size, the pyrotechnic redox mixture is extremely sensitive to friction and electrostatic discharges, which leads to dangerous manufacture and handling conditions.

Summary of the Invention

It is now an object of the present invention to ignite an optical igniter (detonator or initiator) with a laser source of low power and to provide a solution for the above mentioned problem inherent with igniters of the last generation.

In accordance with the invention, the igniter includes an energetic igniter charge with a mixture of a secondary explosive and a metal in powder form, whereby the metal serves as optical doping material.

The ignition of the main igniter charge of the igniter (secondary explosive in the case of a detonator or pyrotechnical mixture in the case of an initiator) is made possible with such a mixture even when a low power laser source such as, for example, a laser diode with a power of 1 W is used. This results in a simultaneous reduction of the risks during handling of the main igniter charge.

In one aspect of the invention is provided an optical igniter including a cavity, an energetic igniter charge in accordance with the invention located in the cavity, an optical focusing interface sealing the cavity and being in contact with the igniter charge and a

light conductor having a first end for receiving light from a laser radiation source and a second end connected to the optical focusing interface.

Brief Description of the Drawings

Further advantages and characteristics of the present invention are apparent from the description of the preferred embodiments presented in the following as non-exhaustive examples of the invention, and illustrated in the enclosed drawings, wherein

Figure 1 is a cross-section of a preferred optical detonator in accordance with the invention, with an energetic igniter charge in accordance with the invention located as main igniter charge of the detonator in the cavity of the first detonator stage;

Figure 2 shows a cross-section of another preferred embodiment of an optical detonator in accordance with the invention having an igniter charge in accordance with the invention and a main igniter charge of secondary explosive in the cavity of the first detonator stage; and

Figure 3 shows a cross-section of a further preferred embodiment of an optical initiator in accordance with the invention, having in its cavity an energetic igniter charge in accordance with the invention and a main igniter charge of a pyrotechnical mixture.

Detailed Description

The energetic igniter charge 1 in accordance with the invention consists of a mixture of at least one secondary explosive and a metal in powder form, which serves as optical doping material.

As illustrated in Figures 1 to 3, the energetic igniter charge 1 during use is located in a cavity of an optical igniter 2,3 and in contact with an optical focusing interface 4. The interface closes the cavity and supplies to the energetic igniter charge 1 infrared radiation emitted from a laser radiation source and guided from the radiation source through a light conductor 5 to the optical focusing interface 4. One end of the light conductor is connected to the laser radiation source and the other to the optical focusing interface 4.

Metals useful in the present invention have the ability to absorb infrared light emitted by the laser source and store the light energy as heat. The metals also have the

ability to transfer the stored heat by way of heat conduction to the explosive with which they are preferably homogeneously admixed. This heat transfer leads to initiation of the ignition of the secondary explosive.

For efficient heating of the secondary explosive by the metal, the metal preferably has a temperature conductivity of at least 10^{-5} $m^2 \cdot s^{-1}$, more preferably at least $5 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$ or most preferably $9 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$. Temperature conductivity is defined as the quotient of heat conductivity and the product of heat capacity and density of the respective metal. Preferred metals are aluminum ($9.8 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$), an aluminum alloy (Al2024 "Dural" with a conductivity of $4.5 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$), tungsten ($6.8 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$), copper ($11.7 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$), magnesium or a magnesium alloy ($11.7 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$) and even nickel, zirconium or titanium. Aluminum is preferred due to its high temperature conductivity and low cost.

A relatively small amount of metal is thereby sufficient. Since the metal is used for its physical properties, namely the ability to absorb infrared light and transfer heat and not for its chemical properties (as in aluminum containing explosives). The metal portion is therefore at most 10 wt.%, preferably at most 5 wt.% or even about 1 wt.% of the energetic igniter charge 1. The higher the metal portion, the shorter the ignition time of the energetic igniter charge 1. In applications in which very short ignition times are not critical, an igniter charge with more than 5 wt.% metal has an unnecessarily high sensitivity during standard safety testing to percussion, friction, or electrostatic discharges.

The secondary explosive used in the energetic igniter charge 1 can be, for example, octogen, hexogen or hexanitrostilbene. The energetic igniter charge 1 can also include several secondary explosives, such as, for example, octogen and hexanitrostilbene, whereby the latter has a relatively low friction sensitivity.

The specific contact surface between the secondary explosive and the metal is preferably made as large as possible so that the temperature increase of the secondary explosive occurs at high speed and a short and reproducible reaction time of the optical igniter 2,3 is achieved. The secondary explosive is therefore preferably in powder form and preferably has a particle size of less than 6 µm (more preferably less than 3µm). The metal is preferably also a fine powder with an average particle size of less than 6 µm, more preferably less than 2µm, most preferably 1 µm, which conforms to the wavelength of the emitted laser light.

To reduce the operating time of the igniter 2,3 (as well as the threshold power density of the laser source required for initiation of the decomposition of the energetic igniter charge 1), the energetic igniter charge 1 in accordance with the invention is preferably pressed into the detonator cavity at a high loading density, preferably above 80% of the maximum nominal density of the igniter charge 1.

For an easier admixture of the energetic igniter charge 1, this process is preferably carried out mechanically by wetting the admixture with a dispersion agent for the prevention of lump formation (for example isopropanol), which is subsequently removed by drying.

The energetic igniter charge 1 preferably also includes an inert polymer binder or wax (preferably at a portion of at most 5 wt.% of the mixture) in order to reduce its sensitivity to mechanical stress in the standard safety tests. Graphite can also be admixed in order to use the lubricant capabilities of this material and to guarantee higher safety during use of the energetic igniter charge 1.

Furthermore, an especially homogeneous mixture of secondary explosive and metal is preferred in order to ensure a most reliable ignition and reproducible reaction time of the optical igniter 2,3. This is especially important, since the radiation can only be absorbed by the metal in a very small effective cavity region: the laser spot at the output of the optical focusing interface 4 has a similar diameter as the light conductor 5 (the diameter can be reduced to 50 μm) and the absorption thickness lies in the same order of magnitude.

The use of an energetic igniter charge 1 in accordance with the invention in an optical detonator 2 is illustrated in Figures 1 and 2. A conventional optical detonator 2 includes two stages: the laser source heats an energetic main igniter charge (a mixture mainly with one or two secondary explosives) in the cavity 10 of the first stage to the ignition point so that subsequently a very violent decomposition reaction takes place, by which (depending on the configuration of the detonator 2 and the characteristics of the secondary explosives used in the first and second stages) the detonation of a secondary explosive 6 in the cavity 11 of the second stage is initiated either by a deflagration-detonation transition process or a percussion-detonation transition process.

Figure 1 illustrates a detonator 2, the energetic main igniter charge of which consists of the energetic igniter charge 1 in accordance with the invention.

In order to validate the igniter charge 1 in accordance with the invention for astronautical applications, in which (in view of the importance of energy conservation in this field) the ignition threshold is determinative. Experiments were conducted using a 1 W diode as laser source, which was connected with the optical interface 4 by a light conductor 5 with 62.5 µm diameter. In these experiments, the igniter charge 1 is loaded into the cavity of the first stage at a density of about 1.7 $g.cm^{-3}$. The detonator 2 was exposed to a temperature variation test with a 5 hour long temperature stress at 100° C and subsequent cooling to room temperature. In a first detonator, the igniter charge 1 consisted of a mixture of octogen having a mean particle size of 2.5 µm with 1 wt.% aluminum having a mean particle size of 5 µm. In a second detonator, the igniter charge 1 consisted of a mixture of octogen having a mean particle size of 2.5 µm with 1 wt. % aluminum having a mean particle size of 160 nm. In both experiments, the ignition threshold was 110 mW. These experiments show the efficiency of fine aluminum powder as optical doping material even when used in small amounts. Thus, a large operable range can be ensured with such a low ignition threshold, since the diode can deliver a much higher power output of 1 W.

Further experiments were conducted using a compact Nd-YAG-solid laser source with a power density of 3 $MW.cm^{-2}$ (100 times higher than in the 1 W laser diode), in order to validate the igniter charge 1 in accordance with the invention for military applications in which the reaction time of the detonator and its reproducibility (for the serial ignition of several warheads) is determinative. The laser source used in these applications can be a solid laser which delivers a sufficiently high amount of energy so that the ignition threshold does not provide any challenge. In these experiments, the igniter charge 1 was loaded into the cavity of the first stage at a density of about 1.7 $g.cm^{-3}$, whereby the detonator was subjected to a temperature change test with a 5 hour long temperature stress at 100° C and subsequent cooling to room temperature. In a first detonator, the igniter charge 1 consisted of a mixture of octogen having a mean particle size of 2.5 µm with 1 wt.% aluminum having a mean particle size of 5 µm; in a second detonator the igniter charge consisted of octogen with a mean particle size of 2.5 µm and 1 wt.% aluminum having a mean particle size of 160 nm. The variability in the reaction time of the first dentonator was about 10 µs (compared to 30 µs with an energetic igniter charge of a mixture of secondary explosive and soot). The variability in the second detonator was below 2 µs, whereby the second detonator

had an operating time of 41 µs. Thus, in order to comply with the requirements of reproducibility of the operating time, the aluminum must have a particle size of about 1 µm or below.

Figure 2 illustrates a detonator 2 in accordance with the invention, wherein an energetic igniter charge 1 in accordance with the invention and in the form of a fine layer is located between the optical focusing interface 4 and an energetic main igniter charge 7 (a mixture including mainly 1 or more secondary explosives, such as, for example, octogen, hexogen, hexanitrostilbene…, without optical doping material), which main igniter charge is located in the same cavity 10 as the energetic igniter charge 1 in accordance with the invention, whereby the energetic main igniter charge 7 can be ignited with the energy released during the decomposition of the energetic igniter charge 1 in accordance with the invention.

Good results are achieved with this special embodiment because of the small thickness of the active cavity region. This can lead to cost savings when an energetic igniter charge 1 in accordance with the invention is used. A very laser ignition insensitive and safe explosive, such as for example hexanitrostilbene, can therefore also be used as a secondary explosive in the energetic main igniter charge 7, as well as other secondary explosives with very high decomposition temperatures.

Figure 3 illustrates the use of an energetic igniter charge 1 in accordance with the invention in an optical initiator 3. A conventional optical initiator includes a single stage. The laser source ignites an energetic main igniter charge (mainly consistent of a pyrotechnical redox mixture) by heating. During the combustion of the main igniter charge in the cavity 12 of the initiator 3 reaction, heat in the form of radiation, hot solids particles and some hot gas is released, whereby the burning of an external propulsive charge (propellant powder in the interior of the body of a pyrotechnical device, such as for example adjuster, cylinder, … or solid propulsive charge inside the housing of a rocket motor) is enabled.

An initiator 3 is shown in Figure 3 in which the energetic igniter charge 1 in accordance with the invention is in the form of a fine layer between the optical focusing interface 4 and an energetic main igniter charge 8 (mainly consisting of a pyrotechnical mixture), which is positioned in the same cavity 12 as the energetic igniter charge 1 in accordance with the invention. The energetic main igniter charge 8 can thereby be

ignited by the energy released during decomposition of the energetic igniter charge 1 in accordance with the invention.

The pyrotechnical mixture 8 (mixture of a fine reducing agent powder and a mineral oxidation agent) can be, for example, the mixture ZPP (essentially a mixture of zirconium and potassium perchlorate) or BNP (essentially a mixture of borium and potassium nitrate).

Since the energetic igniter charge 1 in accordance with the invention has a very low sensitivity to friction and electrostatic discharges, pyrotechnical safety mixtures 8 can be used which have a reduced sensitivity to friction and electrostatic charges. Such a pyrotechnical main mixture 8 can be, for example, BNP or a ZPP-mixture optimized for safety purposes (zirconium with a larger particle size).

CLAIMS:

1. An optical igniter, comprising

a cavity,

an energetic igniter charge comprising at least one secondary explosive admixed with optical doping material in powder form, the optical doping material being a metal,

an optical focusing interface sealing the cavity and being in contact with the igniter charge; and

a light conductor having a first end for receiving light from a laser radiation source and a second end connected to the optical focusing interface.

2. The optical igniter according to claim 1, wherein the igniter is an optical detonator, and the optically doped energetic igniter charge serves as an energetic main igniter charge in a first stage of the detonator.

3. The optical igniter according to claim 1, wherein the igniter is an optical detonator, the optically doped energetic igniter charge is positioned between the optical focusing interface and an energetic main igniter charge consisting mainly of a secondary explosive and located in the cavity.

4. The optical igniter according to claim 1, wherein the igniter is an optical initiator, where the optically doped energetic charge is positioned between the optical focusing interface and an energetic main igniter charge consisting mainly of a pyrotechnical mixture in the cavity.

5. The optical igniter according to claim 1, wherein the optically doped energetic igniter charge is compressed to a density of about 80% of its maximum nominal density.

6. The optical igniter according to claim 1, wherein the metal in the energetic igniter charge has a temperature conductivity of at least 10^{-5} $m^2 \cdot s^{-1}$.

7. The optical igniter according to claim 1, wherein the metal in the energetic igniter charge has a temperature conductivity of at least $5 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$.

8. The optical igniter according to claim 1, wherein the metal in the energetic igniter charge has a temperature conductivity of at least $9 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$.

9. The optical igniter according to claim 1, wherein the metal in the energetic igniter charge includes aluminum, an aluminum alloy, tungsten, copper, magnesium, a magnesium alloy, or a combination of any one or more thereof.

10. The optical igniter according to claim 1, wherein the metal in the energetic igniter charge has a mean particle size below 6 μm.

11. The optical igniter according to claim 10, wherein the metal has a mean particle size below 2 μm.

12. The optical igniter according to claim 11, wherein the metal has a mean particle size of about 1 μm.

13. The optical igniter according to claim 1, wherein the portion of the metal in the igniter charge is at most 10 wt.%.

14. The optical igniter according to claim 13, wherein the portion of the metal in the igniter charge is at most 5 wt.%.

15. The optical igniter according to claim 14, wherein the portion of the metal in the igniter charge is at most 1 wt.%.

16. The optical igniter according to claim 1, wherein the secondary explosive is octogen, hexogen, or hexanitrostilbene, or mixtures thereof.

17. The optical igniter according to claim 16, including hexanitrostilbene and at least one further secondary explosive.

18. The optical igniter according to claim 1, wherein the secondary explosive is a powder with a particle size below 3 μm.

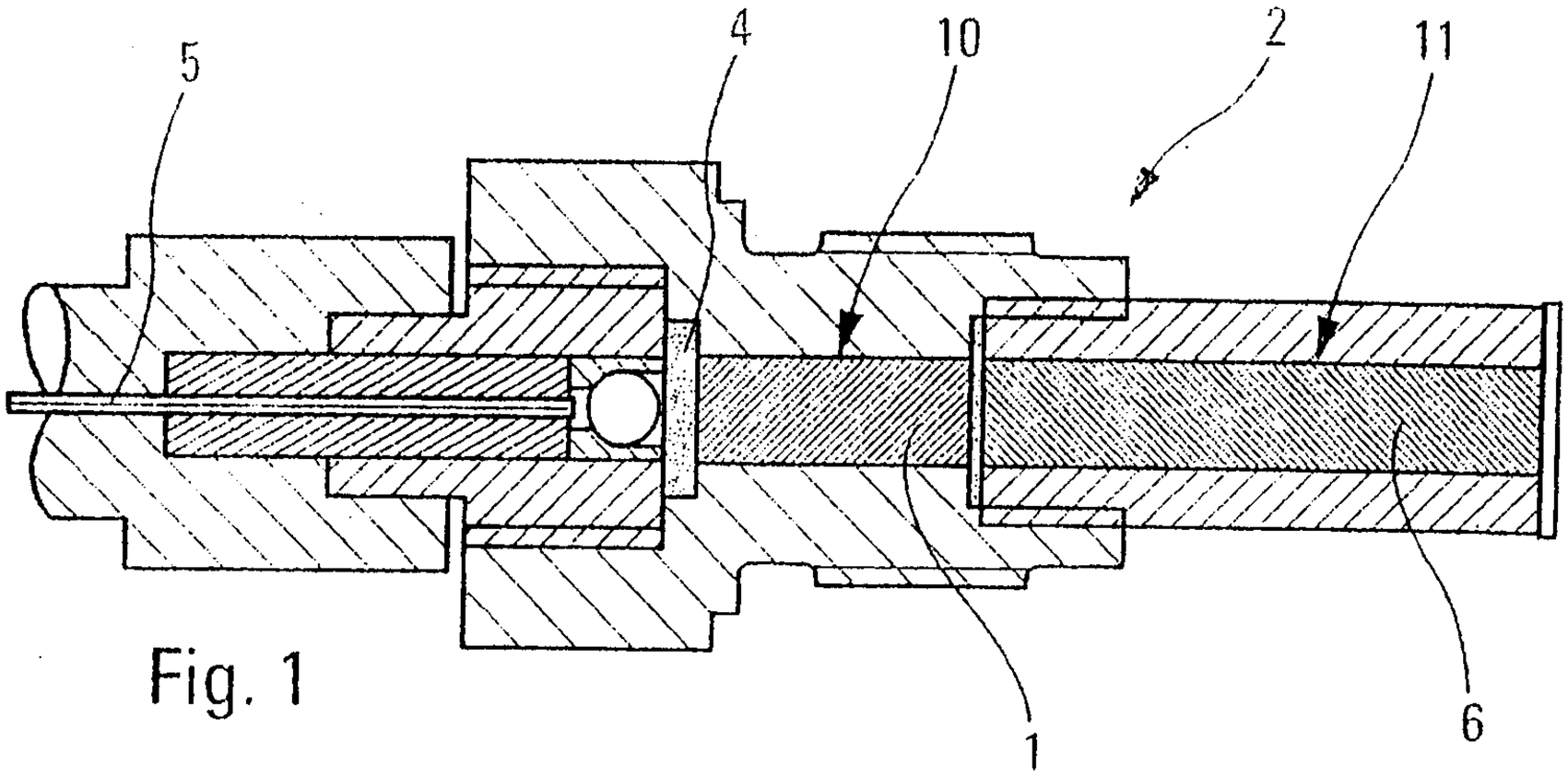


Fig. 1

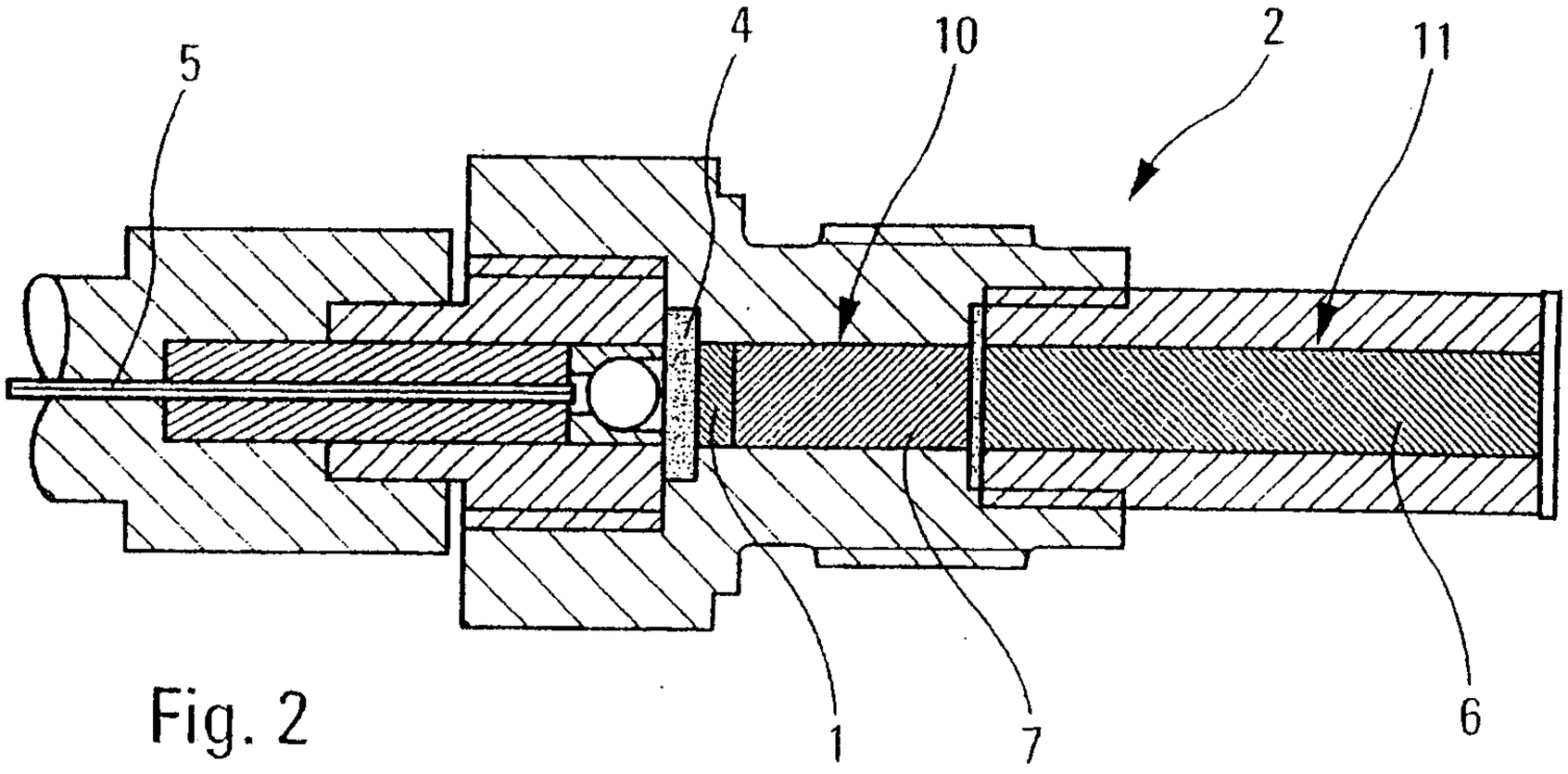


Fig. 2

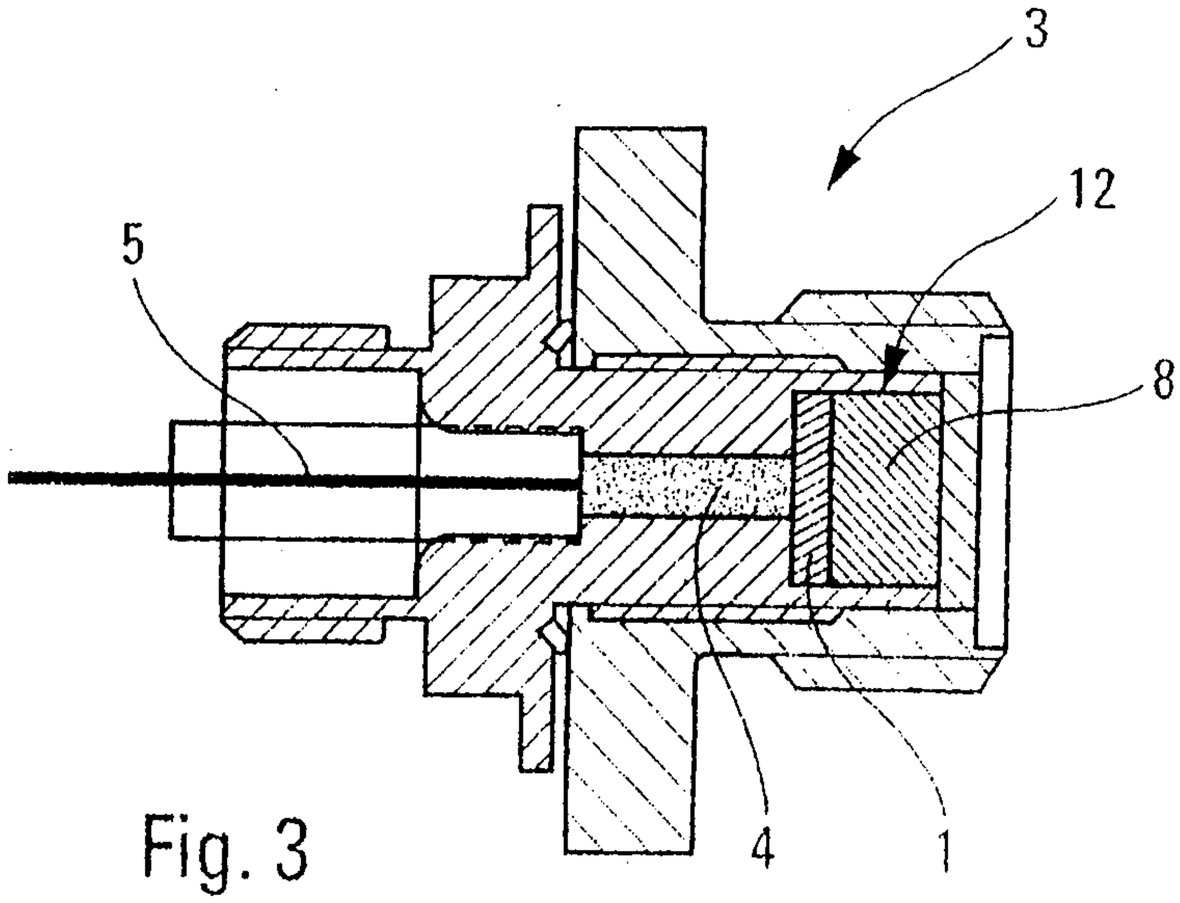


Fig. 3

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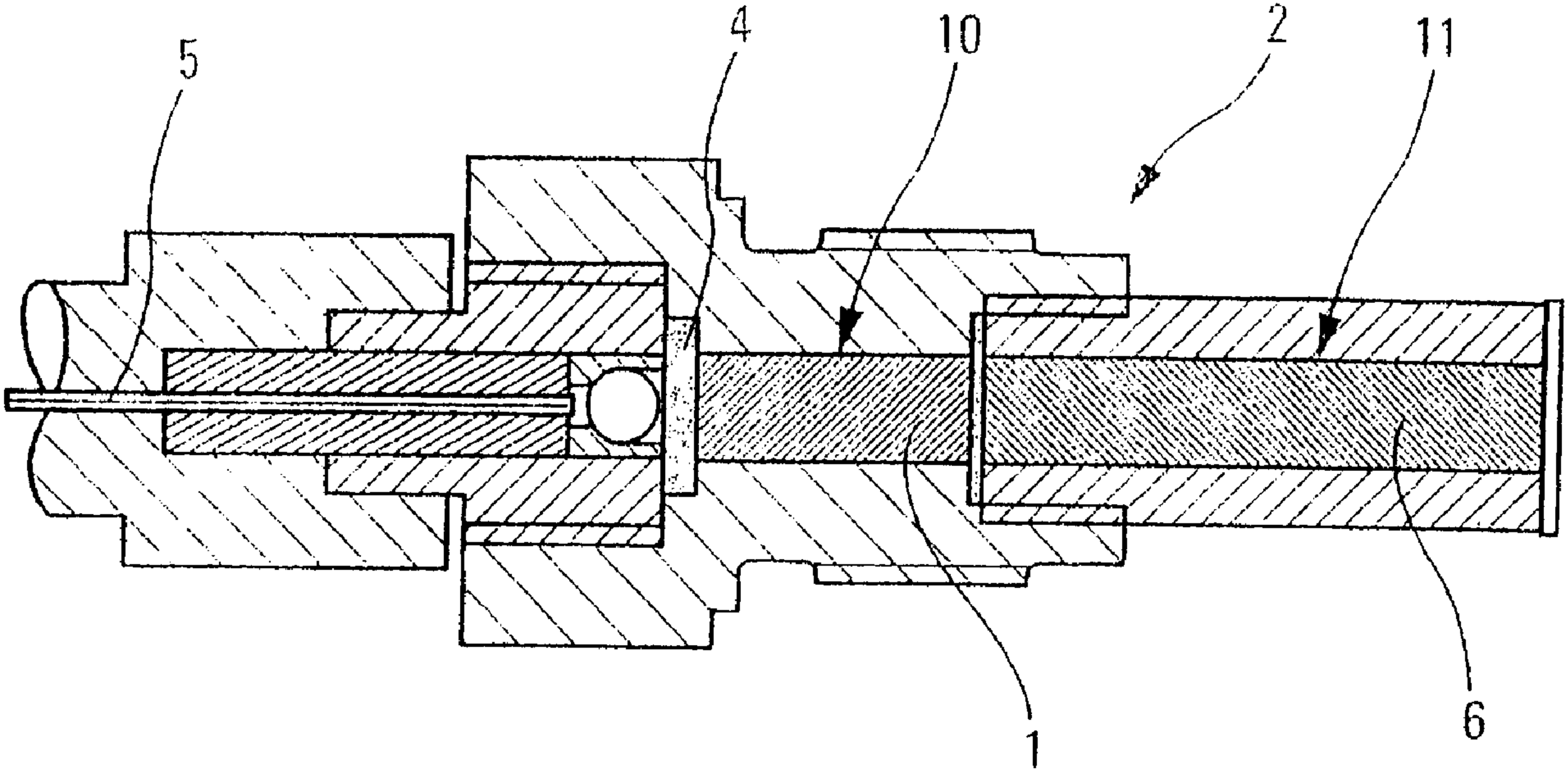
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