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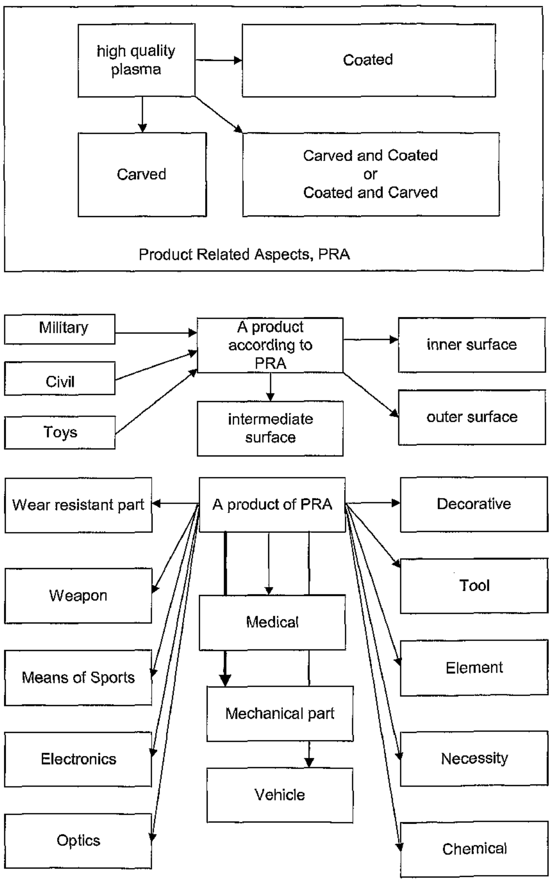

(57) Abstract: The invention relates to an ablation based cold work method, so that the method comprises ablating, along a predefined ablation path on an ablation target surface, to a predefined ablation depth by laser radiation having at least one characteristic wavelength and at least one pulse characteristic for each wavelength for the radiation to be used for ablation of said ablation target material, wherein the radiation from the source is directable via an optical path onto the working spot on said ablation target via a turbine scanner. The invention also relates to an ablation based cold work arrangement, so that the arrangement comprises a laser radiation source to provide the laser radiation be used in the ablation, and at least one turbine scanner arranged into the optical path arranged to lead laser radiation from said laser radiation source to the hit spot of the ablation target at the ablation path location. Such an arrangement can be used in manufacturing technology in automated systems, but also in weapon technology.

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A Cold-work Method

The invention relates to material science related laser technology via the ablation in general, but in more specified way as expressed in the preamble part of an independent method claim. The invention relates also to an ablation based arrangement as expressed in the preamble part of an independent claim on arrangement. The invention relates also to a weapon as expressed in the preamble part of an independent claim on weapon. The invention relates also to an explosive disarmament device as expressed in the preamble part of an independent claim thereon.

Fibre lasers and/or the comprising fibres therein for guiding the laser beam have not been able to deal with high powered compressed laser pulses in their delivery to the working area. In general, the fibres do not tolerate transfer of high power pulses. Reasons why to use fibres for the transference of the laser radiation, seem to relate to the problems that occur in situation in which free radiation paths were used but the path direction changes are made by deflection and/or mirroring. Such free paths can be even more difficult to be implemented with sufficient precision, but they can also be dangerous, especially if used in industrial scale, however, not to mention the problems that may be related to the distances and the radiation geometry degeneration as well as the intensity problems via the absorption/scattering from the air borne particles and/or other constituents, for instance.

Fully fibrous semiconductor lasers of diode-pumped type compete nowadays with lasers that are lamp-pumped and having the laser beam first conducted into the fibre and further on to the target. At the priority date of the current application according to the knowledge of the writer, such fibrous laser based systems are only way to make laser ablation related industrially remarkable production.

The commercially available fibres reduce the radiation power that could have been conducted through them and thus also limit the target materials to be ablated. Al can be ablated as such with reasonable pulse power, whereas higher pulse power is needed for such substances as Cu, W, etc. for getting them ablated.

Fibrous laser-related technology suffers also from other problems. For example, fibres can not be used to transfer high amounts of energy in short time scale without degrading effects of the fibre. Such effects as melting, fragmentation and/or other deformations in the fibre structure due to the energy of the light, for instance, lead consequentially to the degeneration of the grade of the laser light pulse while directed through a path via a fibre that is suffering degrading effects. Even pulse energy of 10 μJ can degrade a fibre that has even smallest structural or qualitative defects. Special points for defects in a fibrous optical path are the fibre connectors for instance, that are used to connect together several power sources such as diode-pumps, but the connectors are worn out during their stay in duty.

If an arbitrary pulse with constant energy is considered, the pulse energy that can pass a fibre can be kept reasonable if the power of a single pulse increases, while the pulse duration is shortened in a corresponding way. These problems with the high energy and/or powers can be met even within nanosecond lasers.

An important application for fibrous lasers is laser ablation. In laser ablation it is important to provide as large pulse power and pulse energy as possible, but optimized. If a situation were considered in which the pulse duration is 15 ps and the pulse energy 5 μJ and the total power of the laser equipment is 100 W, the pulse power level were somewhat between 300 000 and 400 000 W (300-400 kW). At the priority date of the current application the writer does not know any commercially available such fibre that would tolerate even 200 kW with pulse duration of 15 ps for a fibre penetrating non-deforming laser pulse so that the pulse were preserving the shape.

The problems of the fibrous lasers are not limited only to the fibres, but also to the connecting of separate diode pumps together via optical connectors for achieving the desired total power for the beam, to be directed to the working target via one fibre.

The applicable optical connectors should also tolerate the power levels and/or energy of a pulsed radiation as much as the optical fibre itself that is used to direct the high power pulse to the working target. In addition, the pulse shape should be preserved at the optimum in each transferring phase of the pulse to the hit spot on the working target. Even the prices of the optical connectors that tolerate the powers in the above mentioned example are very high, although the expensive manufacturing process can not guarantee for sure the operational safety even to a fair level. Additionally, those connectors are worn out little by little causing variation to the system drifting of from the initial conditions in question and thus possibly drifting the product quality in long term as well, but cause also expenses in the maintenance.

The laser beams, generated by their sources and/or directed for utilisation via fibres in the optical path according to the known techniques, at the priority date of the current application, suffer power and quality related problems that limit the applications of the devices to the ablation. Such problems can relate to scanning of the beam by scanners that have to be used at a limited repetition frequency, but without a facility to raise the frequency to such a level that industrial mass production were realizable for good and uniformly qualified products. Such scanners according to the state of the art can also suffer from the losses further caused by the optical windows that are to be used in the inserting of the beam via an optical path from outside of the chamber in which the working target is held for the ablation duration in under pressure conditions, for instance.

At the priority date of the current application, according to the knowledge of the applicant, the effective power of known devices in ablation remain in the order of 10 W. Thus, for instance, the repetition rate can limit to bare 4 MHz of a pulse frequency of a pulsed laser. If the pulse frequency were tried to be increased, the state of the art solutions for scanners suffer from uncontrolled directing of the beam to the walls of the laser equipment, but also directing of the beam into the plume of the already ablated material in plasma phase. Such problems have an adverse net effect on to the surface that were under manufacturing by the ablated material, by the beam directed by using such a scanner, but also adverse effects to the production rate, which effects are constituted by the uncontrollable radiation flux variations at the hit spot on the target. The quality of the plasma may be inappropriately applicable for the tolerances of a certain product to be manufactured, i.e. with the reasonable surface structure quality in question.

Consequently the working methods according to the state of the art may suffer degrading of the cutting power and/or the quality of the product being the object whose surface was targeted in the process. Also fragments are probable to be ejected from the hit spot on the target surface under the working methods according to the state of the art. Such fragments can deposit on to the surrounding surfaces in an unpredictable way and so degrading the resulting product. The state of the art techniques demands also time, especially if there are several surfaces and/or layers to be coated, but the quality of the layers may vary in a non-desired way. Especially, before the priority date of the priority application for this document, the writer did not know commercially available methods to manufacture sufficiently strong and substantial pieces for 3D-objects printing and/or copies.

At the spoken priority date, the writer knows that the scanning speeds of the state of the art scanners are of about 3 m/s, and the speed can vary during the scan, so being not a constant. This is a consequence of the known scanner structures of the type that stop for a while the scanner mirror turns backwards after a single scan to make another scan. It is also known that during the backward movement the scanner makes a second scan similarly as the first one. Also back and forth moving mirrors of plate type are known per se, but they suffer the same problem of unequal movement and thus the unequal scanning speed during the scan. Such an ablation techniques has been shown in patent publications US 6,372,103 and US 6,063,455. The scanning part of the scanner accelerates, decelerates, stops etc, consequently causes that the scanning speed is not constant, inducing also that the yield of the plasma, due to the ablation at the hit spot on the working target, varies. Especially at the ends of the scanning path on the target, the variation related adverse effects of the plasma production are highlighted so also degrading the product. As a general rule in a general level, the higher pulse energy and the number of pulses per time unit, the grater the expectance of an adverse effect to be encountered.

In a successful ablation event the material vaporizes to atomic domain particles. But in an interference event occurring, the target material can be ejecting fragments that can have size of several micro meters, and thus degrade the surfaces on the target in question, to be worked, cut and/or to be coated with the plume material.

The increased pulse frequency as such is not a solution, because the speeds of the scanners according to the state of the art are inappropriately low. The increase of the pulse frequency and thus the related high power levels of the pulses that are more frequently loading of the mirror of the scanner, so that the high power levels could melt/burn the existing known mirrors, if the beam were not expanded before the entry of the beam on to the scanner. Thus, the state of the art techniques need a separate lens assembly between the scanner and the target to focus the beam to the hit spot, contributing to absorption of the beam in wrong place.

According to the operational reasons in the state of art scanners, they are light weighted, which means also low mass and thus low capability to balance/equilibrate the absorbed energy from the laser pulses. Thus the melting/burning sensitivity may be increased for the state of the art scanners.

The scanning width of a state of the art scanners may be a problem. The line wise scanning method used with the mirror-film scanners can contribute to the nominal scanning width of 70 mm, for example, but in practice the scanning width can reduce to 30 mm at the target, with unequal ends of the scanning path, and/or different from the parts between the ends. Such small effective scanning widths can cause serious incompatibility problems in such cases that large, widely sized objects are to be worked and/or coated. The problems may even to make industrial scale production if not totally impossible, quite hard and/or unremunerative.

Figure 1 illustrates a problem related situation according to the state of the art. The laser beam appears to be out of the focus in the Figure 1. The plasma generated has a low quality. The plasma can comprise fragments 116 from the target. The target and/or the vapours can degenerate even to useless level of quality. Such a typical problematic situation of the state of the art techniques can be occurring with a too thick target 114. In order to keep the focus intact in optimum, the target 114 should be moved towards the direction 117, z-movement, from which the laser beam 111 is coming as much as the target is used in ablation by ablating the layers 111, 112 and 113. Unsolved remaining is the problem that relates to the changed or potentially changed structure and/or composition on the surface of the target, totally or locally, as the change being the stronger the more material from the target 114 has been vaporized, although the target 114 were returned to the focus. Special problems are met with the state of the art techniques, if the target is a composition or a compound of substances, as to be mentioned as an example of an easy to understand example on the problem.

The variations of the focus, in the state of the art techniques occurring in the middle of the ablation event, induce immediately a change in the plasma quality. The energy density of the pulse at the surface of the target material diminishes (normally), so the vaporization/plasma generation may be not any more ideal/perfect in the circumstances. As a consequence, the plasma energy may remain in low level, and unnecessary large number of fragments may be met, and the surface morphology may be changed, the adhesive properties and/or the thickness of the coating, if applied, can also be changed.

Such a problem has been tried to get mitigated by a focus control. When the state of the art related apparatus have small repetition frequency, for instance, such as below 200 kHz and the scanning speed below 3 m/s, the rate of change in intensity of the plasma is small thus leaving time for the apparatus to react to the plasma intensity change by adjusting the focus. So called real-time plasma intensity observing system can be used when a) the surface quality and/or the smoothness are not so critical measures of quality, b) the scanning speed is low, order of 3 m/s.

In such a case the state of the art solutions cannot produce high quality plasma at the priority date of the priority application of the current document, and thus many high quality coated surfaces are not manufacturable according to the state of the art technology.

The state of the art systems can have complicated control systems that are to be used as a must. In the methods in the known processes the target appears as a thick rod or plate. The lens for focusing may be implemented as a zoom lens as applied, or the target is moved towards the beam in the rate of the target material utilisation. Even the implementation attempt, may be very difficult if not entirely impossible, for a reliable apparatus to be used for the industrial scale production. The quality variation may be great, leading to unbearable burden to the quality control out of the scope of implementation with sufficient precision. Thick targets are also expensive to be manufactured etc.

As the publication US 6,372,103 B1 shows the state of the art technology is able to direct laser pulses to the target only by mainly S-polarized or optionally mainly P-polarized or as circularly polarized light, but not as randomly polarized.

In material science, a branch of which relating to laser technology, ablation has been known as such as a technique of removing material from a phase of the target material to plasma phase. It is known as such that such a phase transition can be made to occur by intensive laser radiation onto the target piece. Also some vapour from the target material can be released in the process in certain conditions.

Conventional laser ablation utilizes long pulsed lasers for the ablation, which is more or less a consequence of raising the temperature of the ablatable part of the target and to remove the material at that spot away. However, although the pulse power is very often limited by the optical path material that is used to direct the laser pulse onto the target and its hit spot where the pulse energy is used for heating the material at the hit spot to vaporize the material therein, long pulses can cause very often extensive heat transfer from the hit spot to the surrounding structures and thus can cause stress, melting and/or other unwanted effects to the locations of the structure-units. Stresses can dismiss by a mechanism in which the forces can enable fragmentation of the target at the hit spot, tore the material into lumps and/or pieces to be ejected around the hit spot environment, which effect is quite often a non-wanted co-effect of the long pulsed lasers.

Considering what is a long pulse and what is a short pulse can depend on the thermal heat transfer mechanism occurrence timescale in the material structure of the target. When the radiation pulse hits the hit spot of the target, the pulse energy of a long pulse finds time to be delivered into the surrounding target structure in the time scale of the heat transfer mechanism of the material structure, but a short pulse does not significantly in said time scale. Thus, short pulse duration lasers can be regarded as cold work lasers, as the heat is not transferred, the ablation occurs so rapidly that the mechanism does not have sufficient time to transfer the received pulse energy into the lattice or other surrounding structure of the hit spot. Thus, there will be less melting, supersaturated vapours, stress in the material and thus fragmentation and/or particle formation near the surface, which are significantly reduced if not completely ceased. Thus, the cold-work ablation leaves a finer and smoother target piece after the cold-work made as a hot-work process.

So, the material surfaces after the cold work has less fragments if not completely does not have them at all, which is important advantage of such embodiments of the invention that use in the cold-work short laser pulses for a fine and sharp results of the ablation target as the work piece.

Summary of the invention

The invention is aiming to show a surface handling arrangement, aiming to solve or at least mitigate problems of the state of the art. The invention is aiming to show also method, device/arrangement/apparatus and/or a system for cold working a surface of the target piece, more efficiently and/or with a better quality surface material than know at the moment of the priority date of the priority application. Still as an object of the invention, the invention is aiming to show an arrangement for handling surfaces as applied to be used in a 3D-printer by repeatable coating/carving of a body with better quality surface material than know at the moment of the priority date of the priority application.

The object of the invention is achieved by a surface handling arrangement that utilises according to an embodiment of the invention a turbine scanner in the radiation path between the radiation source and the target. The object of the invention relate to the objectives in the following:

A first objective of the invention is to provide at least a new method and/or related means to solve a problem how to provide available such high quality, fine, plasma practically from any target, so that the target material do not form into the plasma any particulate fragments either at all, i.e. the plasma is pure plasma, or the fragments, if exist, are rare and at least smaller in size than the ablation depth to which the plasma is generated by ablation from said target.

A second objective of the invention is to provide at least a new method and/or related means to solve a problem how, by releasing such fine plasma, to produce a fine cut-path in for such a cold-work method, that removes material from the target to said ablation depth, so that the target to be cold-worked accordingly keeps without any particulate fragments either at all, or the fragments if exist, are rare and at least smaller in size than the ablation depth to which the plasma is generated by ablation from said target.

A third objective of the invention is to provide at least a new method and/or related means to solve how to coat a substrate area to be coated with the fine plasma without particulate fragments either at all or without fragments larger in size than the ablation depth to which the plasma is generated by ablation from said target, i.e. to coat substrates with pure plasma originating to practically any material.

A fourth objective of the invention is to provide a good adhesion of the coating to the substrate by said fine plasma, so that wasting the kinetic energy to particulate fragments is suppressed by limiting the existence of the particulate fragments or their size smaller than said ablation depth. Simultaneously, the particulate fragments because of their lacking existence in significant manner, they do not form cool surfaces that could influence on the homogeneity of the plasma plume via nucleation and condensation related phenomena. In addition, in accordance with the fourth objective, the radiation energy in the ablation event is transformed to the kinetic energy of the plasma effectively by minimizing the heat affected zone by using preferably short pulses of the radiation pulses, i.e. in the picosecond range or shorter pulses in time duration, with a pitch between two successive pulses.

A fifth objective of the invention is to provide at least a new method and/or related means to solve a problem how to provide a broad scanning width simultaneously with fine plasma and high quality and broad coating width even for large bodies in industrial manner.

A sixth objective of the invention is to provide at least a new method and/or related means to solve a problem how to provide a high repetition rate to be used to provide industrial scale applications in accordance with at least one of the objectives of the invention mentioned above.

A seventh objective of the invention is to provide at least a new method and/or related means to solve a problem how to provide fine plasma for coating of surfaces to manufacture products according to at least one of the objectives from the first to sixth, but still save target material to be used in the coating phases producing same quality coatings/thin films where needed.

An further objective of the invention is to use such method and means according to said at least one of the first, second, third, fourth and/or fifth objectives to solve a problem how to cold-work and/or coat surfaces for such products of each type in accordance with the objects.

The objectives of the invention are achieved by a radiation-based surface treatment apparatus which includes in its radiation transmission line a turbine scanner according to an embodiment of the invention.

Then, using the surface treatment apparatus according to the invention, the removal of material from the surface treated and/or the yield for coating can be raised to a level required by high-quality coating, yet with sufficient speed and without unreasonably limiting the power of the radiation used.

With the surface handling arrangement according to the invention, the ablation rate along the ablation path on the target can be set to sufficient level for appropriate surface handling of the body to be machined, coated and/or to be used as target to be carved, drilled and/or otherwise cold-worked, but however, so that the rate is in sufficient range but the radiation to be used is not unnecessarily limited.

The cold work method according to the invention is characterized in that the method comprises ablating, along a predefined ablation path on an ablation target surface, to a predefined ablation depth by laser radiation having at least one characteristic wavelength and at least one pulse characteristic for each wavelength for the radiation to be used for ablation of said ablation target material, wherein the radiation from the source is directable via an optical path onto the working spot on said ablation target via a turbine scanner.

The cold work arrangement according to the invention is characterized in that the arrangement comprises a laser radiation source to provide the laser radiation be used in the ablation, and at least one turbine scanner arranged into the optical path arranged to lead laser radiation from said laser radiation source to the hit spot of the ablation target at the ablation path location.

Ablation based cold work system according to the invention is characterized in that the system comprises at least one ablation based cold-work arrangement and automating means arranged to handle the ablation target bodies for their input, movement and/or removal from the system.

A weapon according to the invention is characterized in that what is characteristic to the cold work arrangement according to the invention.

An explosive disarmament device according to the invention is characterized in that what is characteristic to the cold work arrangement according to the invention.

The radiation source can be a suitable laser source according to an embodiment as embodied later in the document.

Other embodiments of the invention are indicated in the dependent claims and in the following part of the description, by a reference to be made to give examples on the embodiments of the invention in a non-restrictive manner, so not only to restrict the scope to the indicated examples of the embodiments, but instead helping to understand advantages of the embodiments of the invention.

Various embodiments of the invention are combinable in suitable part. The term “comprise” has been used as an open expression. Term “one embodiment” as well as “another embodiment” has been used for simplicity reasons to refer to at least one embodiment, but can also comprise an ensemble of embodiments with the indicated feature, alone, or in combination of suitable other embodiments. When read and understood the invention, the skilled men in the art may know many ways to modify the shown embodiments of the invention, however, without leaving the scope of the invention, which is not limited only to the shown embodiments which are shown as examples of the embodiments of the invention.

Figure 1 illustrate some problems relating to state of the art techniques,

Figures 2A, 2B, 2C, 2D each illustrate cutting results according to an embodiment of the invention,

Figure 3 illustrates an example of an arrangement according to an embodiment of the invention,

Figure 4 illustrates a cold work method according to an embodiment of the invention,

Figure 5 illustrates a scan according to an embodiment of the invention,

Figure 6 illustrates an arrangement according to an embodiment of the invention, and

Figure 7 illustrates a turbine scanner according to an embodiment of the invention.

Figure 8 illustrates products according to embodiments of the invention.

Ensemble of embodiments of the invention

According to an embodiment of the invention a suitable pulse length for a target material is less than 30 ps to be counted as a short pulse. However, even shorter pulses can be used down to the 1 ps scale in one embodiment, but pulses within the fs-scale duration in another embodiment or even as-scale (attosecond-) in a further embodiment can be used down to 0,05 as (attosecond).

According to an embodiment of the invention, the pitch between two successive pulses is equal or shorter than the pulse duration, but kept constant. According to an embodiment of the invention the pitch duration is longer than the pulse duration but kept constant. Constant pitch and/or pulse length makes the radiation source simpler and easier to manufacture as a laser source. But according to an embodiment of the invention, a pumped laser source can be arranged to have at least some intermittency for the pitch and/or the pulse duration achievable in the energization by using a plurality of pumping mechanisms timed intermittently or differently timed to yield intermittence and to make the pumping either optically and/or electrically embodied in suitable part. Such an intermittent radiation can be used, for instance, if different material/structure of the ablation path is to be desired to the target. The intermittently pulsed laser can be a pumping laser to be used to pump a power laser according to an embodiment, or the intermittently pulsed laser can be itself a power laser, that is pumped by several mechanisms.

According to a cold work method according to an embodiment of the invention, the pulse characteristics of the radiation to be used for the ablation can comprise such features as the pulse power, pulse energy, pulse shape, pulse duration, pitch between two successive pulses, intermittence, pulse/pitch repetition rate of the pulses on the target, repetition rate of the pulses on the scanner, cover ratio of the pulses on the target and/or a combination thereof. The cover ratio of the pulses can be defined by a ratio of the common area of two successive hit spots to the area of an arbitrary hit spot.

According to a cold work method according to an embodiment of the invention, characteristic wavelength means a wavelength that originates to the laser source that is used for the ablating. The laser source can have several polarization modes at the characteristic wavelength, from which a certain mode can be selected to be used in the ablation in one embodiment, but in another embodiment several modes and/or characteristic wavelengths can be used when associated to the suitable pulse characteristic or characteristics. According to an embodiment of the invention the radiation to be used is in the wavelength range from radio wavelengths down to ultraviolet wavelengths or even down to low energy x-ray wavelengths. According to an advantageous embodiment of the invention the wavelength of the radiation comprises monochromatic and coherent radiation component that has a wavelength of radio waves IR, UV, visible light. Also intermediate ranges can be applied in embodiments.

According to a cold work method according to an embodiment of the invention, ablation path can be predefined, so as to be used for defining the order in which the material from the ablation target is to be ablated. According to an embodiment of the invention the ablation path can comprises a spot or to be a spot-like, for applications in which a dot "." is to be formed on the ablation target. The dot can be gap, cavity or an ablation-drilled hole, even through the ablation target piece from its one side to another, said dot having a shape derivable from the ablating radiation geometry. According to an embodiment of the invention the path comprises a line, which is thus a queue of the hit spot on the target surface.

Provided that the hit spots are essentially or completely non-overlapping, the hit spots form a line along the surface on the ablation target surface, according to the radiation geometry of the pulsed laser beam to form the dots, is referred as a carving embodiment. According to an embodiment directed to the drilling, in such embodiment of the invention, the hit spots are essentially at the same location for making a hole and/or cavity along the normal of the surface. However, also holes that define a direction with such an angle that is between a surface and its normal can be drilled according to an embodiment of the invention. In such a case non-normal-direction drilling, the overlapping of the hit spots are arranged to define the direction of the cavity. According to an embodiment of the invention, the drilling may happen at least some part so that part of the radiation of the pulse goes through the plume. According to an embodiment of the invention the plume can be further ablated by another beam arranged to remove the plasma, or the ablated plasma can be removed at least partly by electromagnetic means arranged to provide an electromagnetic field to interact with the charged plasma particles in order to deflect the plume away from the incoming radiation pulses. According to an embodiment of the invention the ablation-originating plume is kept small so to be easily and quickly dismissed.

According to an embodiment of the invention, the pulse shape is chosen so that the laser pulse has a first pulse-part that has a first power level capable of ablating target material at the hit spot, and a second pulse-part that has a second power level, which is higher than said first power level so capable to compensate extinction of the plume. Such a pulse can be advantageous in certain embodiments in which the carving and/or drilling should be made through the plume directed radiation pulses.

According to an embodiment of the invention the ablation target can be in rest in respect to the laser source. According to an embodiment of the invention, the ablation path on the ablating target is defined by a respective movement of the laser source and the target body. According to an embodiment of the invention, the target is hold by a holder that is arranged to move the ablation target body so that its surface comprises at least partly the ablation path having the characteristic dimensions of the ablation path and the appropriate ablation depth in each defined location of the ablation path, as defined according to radiation geometry of the laser source.

According to an embodiment of the invention the ablation target can be arranged to rotate so having the ablation path along the surface of said target. If the rotational movement is suitably constant and occurs around a fixed axis, an embodiment of the invention can be used for cutting the ablating target, as in turning machines and/or reamers. Also other carving-like actions can be arranged to occur in a similar way as in a turning machines and/or reamers.

For example, according to an embodiment of the invention, the target piece can be placed on to a robot providing movements in an xy-plane, z-plane and/or at least one rotating movement so providing at least in theory access of the ablating beam to any visible surface location, for a carving action and/or cutting parts of the ablation target body.

According to an embodiment of the invention the carving can be made in a low pressure that is however higher pressure than the pressure in outer interstellar free space, but lower than an atmospheric pressure. According to an embodiment of the invention the carving can be made in over pressure condition, and/or in a specific gas atmosphere for yielding protection against the diffusing plume materials to the parts that may be critical for the material.

According to an embodiment of the invention the laser radiation geometry can be a beam, as approximated as a one-dimensional line from the source to scanning optics and further to the ablation target, so advantageous to be utilised in formation of ablation paths that have a breadth in order of ten or several tens of times or smaller breadth. According to another embodiment of the invention, the laser radiation geometry can be as a fan of beams, as approximated as a two-dimensional plane from the source to scanning optics and further to the ablation target on which the fan causes a surface oriented line by one pulse shot, so defining an area to be carved on to the ablation target by several adjacent pulses.

According to an embodiment of the invention several fans of beams can be arranged to hit the ablation target simultaneously so defining an area by one pulse shot, provided that the power is sufficiently large to cause ablation at said area to the appropriate ablation depth of one pulse shot. This can be also provided by a bunch of optical fibres and/or beam expanders with sufficient tolerance to tolerate high energy level of the laser.

According to an embodiment the examples that were shown to enlighten the embodiments of the invention that has been concentrated to the manufacturing or creating something that has to be cut or carved.

According to an embodiment, the ablation target is kept in rest and the ablating radiation is directed via an optical path to the ablation target that is held still.

According to an embodiment both the ablation target and the ablating radiation are to be moved in respect in each other, but also in respect to a virtual third party observer.

According to an embodiment of the invention, the system can be embodied so that in one embodiment the system comprises a measurement unit to be used to measure the measures of a body to be copied, and a cold-work means embodied according to an arrangement according to an embodiment of the invention so to cold work a target by carving and/or drilling to the measures of the body to be copied. According to an embodiment the copy is scaled to different measures as the original, but according to another embodiment to the same measures as the original. The system according to an embodiment of the invention can also embody a copy machine, to be used in copying a body in 3D. According to an embodiment of the invention such a copy machine is implemented as a turning machine or alike.

According to an embodiment of the invention the copy machine can be implemented by repeatable way constructing layers that originate to an ablated material. The ablated material is used so that the plume is directed to coat a surface layer by layer so forming the object to be copied with the measures of the original or with scaled measures.

However, the method has also embodiments that are directed to destruction of enemy and/or the military material of such. According to an embodiment of the invention, when the working method embodied applicable as to weapons, also long pulsed lasers can be used having the pulse duration over 80 ps, even up to micro second scale. The fragments may be not the problem of the weapon user, and thus also the thermal transfer does not have a role to play, does a destroyed enemy the material, vehicle and/or tank have smooth cut line or not.

According to an embodiment of the invention cold-work lasers can be used also in disarmament of explosives, so cutting by ablation the detonating path from the ignition primer to the essential explosive material away, or by ablating critical parts of a bomb so to disarming it. Optionally or in addition, the explosive material is cut to smaller pieces to be removed so that if the ignition occurs, only the primer and/or a small amount of the explosive goes off. That is possible because the material structure of the explosive is not sufficient enough capable to relay the thermal transmission from the hit spot to the surrounding material. Also, the detonation speed can be in order of 10 km/s, may be much lower in reality, which shown estimate speed is quite slow in comparison to the actions that happen in the material between its structural parts.

According to an embodiment of the invention the cold-work by ablation can be used in purification of materials, provided that the plume is to be handled as such, so as at least some of the constituents to be separated in suitable part from the other. According to an embodiment of the invention the material that is ablated from the ablating path is arranged to originate from such a target that has a material layer arranged to be used in coating by the ablation released plasma, by placing and/or moving the body to be coated into the plume of the plasma of high quality (an ensemble of examples on embodiments, see Fig.8).

According to an embodiment of the invention the ablating radiation is directed from the source to the working spot at the ablation target via an optical path, which can be embodied in one embodiment by a fibre based path in suitable part, but in another embodiment in suitable part in vacuum. According to an embodiment of the invention the path comprises a scanner arranged to scan the radiation to the working spot of the ablation target. According to a preferred embodiment of the invention, the scanner is a turbine scanner, which has a rotatable structure arranged so that it comprises a first mirror surface part that is arranged to direct said radiation towards the working spot while another, a second mirror surface part of a previous location of the radiation spot on a mirror surface of the scanner is arranged to cool.

According to an embodiment of the invention the turbine scanner comprises a polygon geometry so that there are at least three mirrors and/or angles from which said first and second mirror surfaces are selectable due to the rotation. According to an embodiment, the polygon geometry can be arranged by more than three mirrors and/or angles. According to an embodiment of the invention, the angles at the corners are rounded so better to define the direction of the radiation pulses when shifting from a first mirror to the next one. According to an embodiment of the invention the rounded corners are surface-worked to comprise structure aiming to minimum turbulence of the medium so to avoid influence of the eddies in the medium to the laser beam power level.

According to an embodiment of the invention a flat, disk like turbine scanner is used; preferably for radiation geometries that are arranged to provide a dot oriented hit spot. According to an embodiment of the invention, also geometry of the beam can be adjusted by a suitable beam expander where necessary to apply the scanned beam to a certain geometry to enlarge the hit spot to a hit area, provided that sufficient power for the ablation at the area is available. According to an embodiment of the invention a prismatic-like but longer than a disk turbine scanner, in direction of the rotation axis length, can be used for radiation geometries that are arranged to provide a line oriented hit spot. According to an embodiment of the invention, the number of sides of the polygon is not limited in theory, but for practical reasons of manufacture precision the number of polygon sides is lower than or equal to 300, preferably lower or equal to 64, but most preferably in an embodiment equal or lower than 16.

According to an embodiment of the invention the mirrors comprise a curved surface part so arranged to deflect the ablation path at the ablation target in a certain repeatable way. According to an embodiment of the invention the curvature can be, as arranged in the plane of the rotation, positive but according to another embodiment negative, as respectively defined by the distance of the nearest part of the mirror to the rotation axis as being in minimum with the positive curvature and as maximum with the negative curvature. According to an embodiment of the invention the curvature can be arranged in the plane of the rotation axis, i.e. in perpendicular to the rotation defined plane. According to an embodiment of the invention also multiple curvatures can be used in order to arrange a repeatable ablation path on the ablation target.

According to an embodiment of the invention the rotation speed of the turbine scanner can be larger than 100 000 revolutions per second. According to another embodiment of the invention the rotation speed of the turbine scanner is lower than 1000 000 revolutions per second. According to an embodiment of the invention the revolution speed is constant during the operation of the scanning, but arranged to be adjustable between a maximum value and zero, to be set on to the suitable level to have sufficient amount of pulses to the working spots of the ablation path.

According to an embodiment of the invention, the turbine scanner to be used comprises parts made of nano-tube material because of the tolerance against the forces in a high-speed rotation. The scanning surfaces can be coated with carbonitride (C_3N_4) for improved mechanical and/or thermal durability to tolerate high-energy pulses of the laser source.

In the following, a working method according to an embodiment of the invention is described as an example in a non-restrictive manner as such.

According to an embodiment of the invention, ablation to be used in the cold work is made by a laser source radiating laser-radiation that has at least one characteristic wavelength. In an embodiment, single cavity can provide also harmonic waves with a different wavelength, but such may be not directly utilizable as such to the ablation according to an embodiment of the invention.

According to an embodiment of the invention the laser source is selected for the cold-work so that its radiation is pulsed so that the pulses have duration that is shorter than 50 ns (nanoseconds), but according to an embodiment advantageous for a probability to cause less fragmentation of the ablation target the pulse duration is shorter than 50 ps (picoseconds), but according a further advantageously for a probability to cause less fragmentation shorter than 10 ps. According to an embodiment of the invention the pulse length can be even shorter, as in one embodiment in the fs-range (femtosecond) arranged to be used for the ablation along the ablation path.

Example on Si cutting grooving (cutting) experiment

A new turbine scanner was used to demonstrate the effect of scanning speed on the groove and particle production in a carving like application to make grooves on the ablation target with an arrangement according to an embodiment of the invention. The ablation path was selected along the surface of the target material, and the laser beam was having a dot like geometry at the hit spot at the locations of the ablation path.

Samples were (100) Si wafers (mirror finish, commercial grade) 0.5 mm in thickness. The laser used in the demonstration was ultra short pulse fibre laser, 20 ps, 1064 nm, ϕ_{spot}=15-16 µm, 1 MHz by Corelase. Laser fluence (power/area) was manually adjusted to exceed ablation threshold of Si, then surface (groove) was ablated for the same time (30 s) at different scanning speeds of the focus spot (1.5, 15, 150 and 300 m/s) of the radiation. Each scanning speed was obtained by adjusting the rotation speed of a scanner head.

Cutting results were imaged using optical microscope and confocal microscope. Some images are indicating the results in the following comparison (Figs. 2A-2D). Already based on these images, it is obvious that significant improvement in the quality of groove, reduction of heat affected zone and particle production was achieved by increasing the scanning speed. Spot movement between adjacent pulses can be simply compared with the size of the spot (ϕ_{spot}=15-16 µm).

Calculated spot movement between the pulses at 1 MHz (the pitch, the time between pulses was set to 1 µs):

scanning speed of the spot (m/s)	spot movement (µm)
1.5	1.5 µm
15	15 µm
150	150 µm
300	300 µm

It can be noted that in this case already at scanning speed of 15 m/s, there is practically no overlap between adjacent pulses. In this example, as in the case, optimal scanning speed was already around 10-20 m/s. Similarly; optimal scanning can be obtained for different materials and repetition rates of a pulsed laser. At MHz repetition rates corresponding to high average power (now 5-20 W), optimal range was achieved only by using a turbine scanner as operated in this case with a scanning speed of 1-300 m/s, which is significantly higher than that of galvanic scanners (typically max around 2 m/s). In addition to better (particle free) material laser plume, scanning speed also increases the yield/pulse due to less absorption of the next pulse to the plume of the earlier pulse.

Figure 3 indicates a scanner head (exemplified with a protective Al shield) just before installation on the arrangement frame on the left. Example on the scanner controlling electronics is indicated on the right.

An ensemble of examples on further embodiments

Figure 4 illustrates a cold work method according to an embodiment of the invention. The method has phase 6001 of selecting and/or exposing the target to be exposed to the radiation to ablate material along the ablation path on the target. A radiation beam is directed to the selected target material in phase 6002 in order to expose a target material to the radiation at the hit spot. According to an embodiment of the invention there can be also another target material to be ablated. Although drawn in parallel to phase 6003 the second ablation phase 6004 is not necessary a parallel phase, but can be a serial phase according to one embodiment.

Certain optionality of the coatings, related not only to the different aspects of the invention, is illustrated by the dashed lines. According to an embodiment in which the cold work is used for coating material formation, if substrate is addressed to be coated with coating. According to one embodiment of the invention the target can comprise a constituent of the coating, but part of the coating can be formed by the atmosphere at the substrate, and/or the substrate surface constituent or several. According to another embodiment of the invention the target material is the same as the coating. The coating phase 6005 can be used as only coating phase according to one embodiment, but the second coating phase 6006 illustrates that in another embodiment there can be several phases of coating.

According to an embodiment of the invention the carving and coating phases can alter so at least partly remove parts of the just made coating to the ablation depth. This can be achieved by making the target to the substrate and/or vice versa to achieve the desired layers for the application.

According to an embodiment of the invention after each ablation and/or coating the method comprises a phase of checking if all the coating layers were already made. That is illustrated by the arrows directed as shown in figure backwards from higher reference numerated phases to the lower reference numerated phases.

The freedom to select of a coating 6011 for a phase 6003 and/or 6004, substrate 6010 and/or target material 6007 is illustrated by the periodic system of elements 6008, 6009. However, that is not limiting the said materials as such only to elements, although the target material is ablated. Also compounds of the elements can be used.

According to an embodiment of the invention, the body whose surface is to be carved, machined and/or coated by the cold-work according to an embodiment of the invention, said surface to be coated can be a surface of a body per se or an already coated, or a surface at least partly coated, optionally or in addition in suitable part, such a surface that is indicated in the priority document FI20060182, to be incorporated herein by reference.

Fig. 5 illustrates an operation of a scanner to be used in the radiation path according to an embodiment of the invention. The scanner is a conventional turbine scanner, or an improved turbine scanner 1502 according to an embodiment of the invention, i.e. with coated mirror surfaces with a high temperature tolerating reflective material, or totally manufactured from carbo-nitride and/or diamond in suitable part. The rotation direction is apparent in the figure. The radiation source 1600 (not shown in Fig 5, but demonstrated by the beam 1510) can be embodied as a laser source embodied according to diode-pump of PDAD-system or any other cold ablation capable laser, i.e. with sufficiently powered laser, preferably with 100 W or larger in total power and having pulse length of pico-second, femto-second, or atto-second, with an inter-pulse pitch, and a pulse repetition rate larger than 20 MHz, advantageously larger than 50 MHz. The wavelength can be in the visible light region, but is not limited to that only. Although just one drawn, there can be also two or more radiation sources, operable in the same path in parallel or in series, which are not limited to the embodiment of similar source nor to that with all-different sources.

In Fig. 5, the radiation beam is reflected as a reflected beam 1503 via the turbine scanner 1502 mirror surface to an optical lens 1501, to the target 1400. In an embodiment, the target can have a smooth surface structure, roughened arbitrarily or so to have a certain surface structure optimized for the ablation and the coating formation, but in an embodiment in which the target is addressed to mere carving phase, the structure of the target may be unoptimized for the carving as such. The ablation path provided by the hit spots at the target is illustrated by H and the related number to illustrate also the scan on the surface of the target along the ablation path at the numbered points of the path. So, the H1 defines a moment when the beam 1503P, which can be polarized to a certain polarization by its production and/or the optics 1501.

According to an embodiment of the invention, polarization of the beam can be used for the ablation optimum at the ablation path on the target surface, especially, if the polarization can be used for certain selectiveness of the ablation during a scan. The Fig. 5 demonstrate the scan points H1, H2, H3, H4 and H5 which forms a series of arbitrary points from the scan path, i.e. the beam path to produce on the target 1400 surface the ablation path. The scan path can be continuous, according to an embodiment, from the scanner mirror part edge to the next edge, but can be discrete according to another embodiment, as depending the exact repetition rate of the radiation source, and/or the rotation speed of the turbine scanner 1502, in a certain fixed geometry. Also the inter-point times T1, T2, T3, T4 and T5 are shown, and thus the rotation direction is demonstrated.

The 1503Tr illustrates the beam part, which can go through the substrate in certain embodiments, for instance if the embodiments are used for a cut into the shape application and/or with partly transparent targets. The component 1503Tr thus can be used for the estimating of even each individual pulse intensities and thus for the quality monitoring. However, in carving of metals for instance the 1503Tr can be neglibly small or a zero component at the drawn side. However, that component may be replaced an available reflection at the same side as the incoming radiation. In Fig.5 the beam 1510 formed in the radiation source meets an expander 1508, which expands the beam to tapered shape, then the collimator unit 1507 to form a curtain-like broad but thin radiation wedge to be deflected by the turbine scanner 1502, through the correction optics 1501 optionally or in addition to polarization operation so that the beam 1503P hit the ablation target 1400 at the H1.

Fig. 6 illustrates an arrangement 5700 according to an embodiment of the invention. The example shown comprises a radiation source 5701 and/or another radiation source 5707. The number of the sources as such is not limited only on one or two. In the arrangement, there is also indicated the target 5706, which can be target material according to an embodiment of the invention, or a target to be coldworked. Fig. 6 also illustrates radiation path 5703 as arranged to guide radiation from a radiation source 5701 to the target 5706, to used for ablating the target material. The path comprises a scanner 5704, but the number of scanners per path is not limited to the shown only. The figure illustrates adapter 5702, 5705 arranged to adapt the path 5703 to the source 5701and the target 5705, respectively. The adapter can comprise an expander, contractor and/or a correction optics parts, which are necessary for the focussing in such embodiments, in which the geometrical beam shape is necessary to change in the path from the source to the target.

Fig.6 also embodies such variations of the arrangement 5700 in which there is also an additional source 5707 to be used in parallel and/or in addition to the source 5701. The additional source can be exactly the same according to one embodiment but according to another a different one. According to one embodiment, the source is a heater arranged to heat the target. The adapter 5708 can be the same as 5702, but is not necessary such. It can be also an integrated adapter as an expander. The scanner 5709 can be same as the scanner 5704, but is not limited only thereto. The scanner is advantageously a turbine scanner according to an embodiment of the invention. According to the way of drawing, the adapter 5710 is arranged so that the radiation from source 5707 arrives to the target 5706, as the radiation from the source 5701. The arrangement do not necessary need the adapters at all, provided that the geometry of the beam directed via the scanner is sufficiently uniform and/or in correct focus, above, beneath or on the surface of the target material or its base. The radiation of the radiation source can be in one embodiment directed to several targets, although only 5706 shown as an example.

Fig. 7 illustrates a prismatic low-faced turbine scanner 3321, but especially the rotor part of it 3321. The part 3321 can be a conventional turbine scanner part, but also a part according to an improved embodiment of the invention, provided with at least a coating of the mirrors with high durability for the high laser power pulses. In the example of the figure, the part 3321 has faces 3322, 3323, 3324, 3325, 3326, 3327 and 3328. The arrow 3320 illustrates the rotation of the part 3321 around the axis 3103. The faces are mirrors, each of which in-duty, arranged by its own turn, to deflect the incoming radiation beam via the radiation path and to cool when the mirror is off-duty. Tilt angles of the faces are shown for various embodiments. The Fig. 7 illustrate one revolution of the turbine scanner part in time scale from the first mirror, mirror 1, to the last mirror, mirror 8. An ablation path on the target can be thus demonstrated. The ablation path is indicated to hit the target, which can be any target to be cold-worked, at the right by reference 3329, but in the left indicated with the same reference number the scanning path to be used to provide the ablation path. The return of the beam is indicated by the line 3330. The mirrors are indicated by the apparent reference number. Although 40-μm-scan line has been demonstrated as an example, embodiments of the invention are not limited only to shown beam size and/or shape. The beam can be also as a line in an embodiment. The location of the scan line on the target material may be the same in one embodiment for at least two successive scans, but the scan line for two successive scans can be different in another embodiment, if for example, the material is likely to form fragments even in cold-work based on ablation. The number of faces is not limited to the 8, which is only an example in the figure. Faces can be of tens or even hundreds in number, however, influencing possibly to the scan line length. The mirrors can be also curved, although not shown in the Fig.7. The corners can be rounded according to an embodiment of the invention.

In one embodiment of the invention number of different scan lines at the target surface can be achieved by variation of the tilt from face to the next face of the turbine scanner, or in another embodiment by changing the face tilt of at least one mirror or several mirrors.

The turbine scanner has an advantage that the beam won't stop one location at the target and thus the yield is rapid and homogenous during a scan resulting a homogenous plume from the target.

The size of the turbine scanner is freely scalable for a skilled man in the art who has read the application text. The embodiments comprise variations of microscopic scaled to macroscopic scale so that in the macroscopic scale according to one embodiment the diameter is about 12 cm and height 5 cm. The distinction of low-faced turbine scanner from a high face turbine scanner can be made by the measures of the height of the mirror in an axial direction in relation to the width of the mirror in a perpendicular direction of the axial direction. If the height and width are essentially the same, or exactly the same such an intermediate embodiment is included to either low- or high- faced embodiment according to the ratio so that if the height is smaller than the width, it is low-faced but if the height is larger than the width it is high-faced.

It is advantageous to use turbine scanner in the radiation path for such systems in which use pico-second laser systems whose repetition rate is above 4 MHz, advantageously over 20 MHz and/or the pulse energy is above 1,5 μJ.

It is also advantageous to control the radiation power at the hit spot on the target, according to the possibilities. Thus, even each pulse can be evaluated and the knowledge on the departures of the pulse/radiation properties from pre-defined values can be used in a feed-back loop for controlling the radiation beam focus, the ablation of target material, substrate coating, and/or the plume formation.

An example on the radiation source

The radiation source to be used in the arrangement according to an embodiment of the invention can comprise at least one or several diode-pumped radiation sources and each radiation source can have an optical path of its own, but not necessarily the same as another. According to an embodiment the radiation is laser radiation originating to radiation source arrangement according to an embodiment.

A radiation source arrangement according to an embodiment of the invention comprises a first feature and/or a second feature, which is at least one of the following:

- (i) the wavelength characteristic to the radiation source,

- (ii) on-duty pulse length,

- (iii) length of off-duty period between two successive pulses,

- (iv) repetition rate of the on-duty occurrences,

- (v) radiation intensity,

- (vi) energy and/or power per pulse,

- (vii) polarization of the radiation, and

- a combination of at least two or more of the features (i)-(vii).

According to an embodiment of the invention said first feature is different than said second feature. According to an embodiment said feature is considered as an aspect of a radiation source.

A radiation source to be used in the arrangement according to an embodiment of the invention has at least one radiation source which is arranged to produce radiation having a wave length in range which wave length is at least one of the following:

- wavelength between a radio wavelength and an infrared wavelength,
- wavelength in infrared,
- wavelength of visible light,
- wavelength of ultraviolet,
- wave length of X-rays, and
- wavelength of gamma rays.

According to one embodiment of the invention the optical path is arranged to comprise at least one path for plurality of radiation sources comprising at least one radiation source arranged to direct at least one radiation beam to a plurality of targets comprising at least one target. If an embodiment is using intermittent pulsing for the cold working, the intermittency can be arranged in periodical way by using several sources each having own period, to be superposed at the hit point of the ablation path.

According to an embodiment, the laser source can be embodied, optionally or in addition, in suitable part according to the priority document FI20060182 incorporated herein by reference.

One further example embodies a laser arrangement according to an embodiment of the invention. The mentioned parameter values are examples, and are thus not restrictive only to the mentioned values. The turbine scanner as embodied is only an example, and thus not restrictive.

Diode-pumped fibrous laser system or other suitable laser system	**A** PICO-SECOND LASER	over 10 W advantageously, 20 …1000 W or even higher pulse energy 2…15μJ repetition rate 1 MHz, advantageously. 10…30 MHz or higher

+

Smooth operated, linear beam movement, high laser power, vacuum and/or atmosphere	**B** TURBINE SCANNER	Velocity 0…4000 m/s, or higher, typically 50…100 m/s or higher

+

Repetition 100%, High quality, High laser power	**C** Film and/or lamel target feed if used in embodiment	Material thickness a) below, b) the same or c) larger than inside the focus

+

Layer-structures, each layer formed from the same or different materials	**D** AUTOMATIC PULSE ENERGY/POWER CONTROL SYSTEM	control rang 0,5…15 μJ fast, max 1 μs pre-progammable, quality control even to micro-scale

+

Integration to the laser system possible	**E** INTEGRATED PLASM INTENSITY MEASUREMENT	Whole work width operation pulse precison quality control even to micro-scale

+

The shorter wave-length the better yield	**F** LASER RADIATIOIN WAVE LWNGTHS	1064 nm, 293…420 nm, 420…760 nm other wave lengths

+

Operation applicability according to the embodiement	**G** VACUUM, GAS-ATMOSPHERE, FREE SPACE	Choice according to the cleanliness, reactivity, coating rate, and/or the economics.

Pico-second laser system (A) + Turbine scanner (B) + target feed (C) as lamellas or film, in such applications where needed for coating for instance, yield high quality products and/or surfaces of large amounts. The products can be of single crystalline diamond and/or silicon to be used as a substrate for semiconductor industry for instance, produced in vacuum, or in a gas atmosphere.

The coating can be formed on a surface of any kind, for example, on metal, plastics and/or paper to mention few. In one embodiment the coating has a coating layer thickness of 5 µm. The semiconductor material can be a silicon as pure or as a compound, but in a flexible form, suitable into use of electronics, micro and/or nano-electronics. The points D, E, F and G help the manufacturing of high quality products in industrial scale, repeatable and promote the quality control.

Claims

1. Ablation based cold work method, **wherein** the method comprises ablating, by releasing high quality plasma, along a predefined ablation path on an ablation target surface, to a predefined ablation depth by laser radiation having at least one characteristic wavelength and at least one pulse characteristic for each wavelength for the radiation to be used for ablation of said ablation target material, wherein the radiation from the source is directable via an optical path onto the working spot on said ablation target via a turbine scanner.

2. The method of claim 1, wherein said ablation path comprises a spot, line and/or an area on the ablation target.

3. The method of claim 2, wherein the ablation path is parallel to the normal of the surface.

4. The method of claim 2, wherein the ablation path is perpendicular to the normal of the surface.

5. The method of claim 2, wherein the ablation path has a first spot and a second spot so that the ablation depth at said first spot is different than at said second spot.

6. The method of claim 2, wherein the ablation path and the ablation depth are so arranged to form a hollow formation such as a hole and/or cavity into the target piece.

7. The method of claim 2, wherein the ablation path has a first spot and a second spot so that the ablation depth at said first spot is same as at said second spot wherein the first and second spot are at a different location in respect to the surface.

8. Ablation based cold work arrangement, **wherein** the arrangement comprises a laser radiation source to provide the laser radiation be used in the ablation by releasing high quality plasma, and at least one turbine scanner arranged into the optical path arranged to lead laser radiation from said laser radiation source to the hit spot of the ablation target at the ablation path location.

9. Ablation based cold work arrangement, **wherein** the arrangement further comprises a holder for holding, moving and/or handling the ablation target arranged for releasing high quality plasma.

10. Ablation based cold work system, **wherein** the system comprises at least one ablation based cold-work arrangement so arranged for releasing high quality plasma and automating means arranged to handle the ablation target bodies for their input, movement and/or removal from the system.

11. The ablation based cold work system according to claim 10, **wherein** the system comprises at least one ablation based cold-work arrangement and automating means arranged to handle the ablation target bodies, for their input, exchange, movement and/or removal from the system.

12. The ablation based cold work system according to claim 11, **wherein** the system comprises automated means as arranged to feed ablation target material for maintaining an ablation plume, from the ablation target, for a coating of a substrate.

13. The ablation based cold work system according to claim 10, **wherein** the system comprises means to set and/or hold a substrate into contact with the plume of the ablation material as ablated from the ablation target.

14. A weapon, **comprising** the arrangement according to claim 8.

15. The weapon according to claim 14, **comprising** means to set aim at the target for setting said target as the ablation target.

16. The weapon according to claim 14, **comprising** a navigator and/or a communication means.

17. Use of the weapon shown in any claim 14-16 as a military weapon.

18. Use of the weapon shown in any claim 14-16 as a hunting weapon.

19. An explosive disarmament device, **comprising** the arrangement according to claim 8.

20. A radiation-based surface treatment apparatus **characterized** in that it comprises in its radiation transmission line a turbine scanner arranged to direct radiation from the source to the target for releasing high quality plasma.

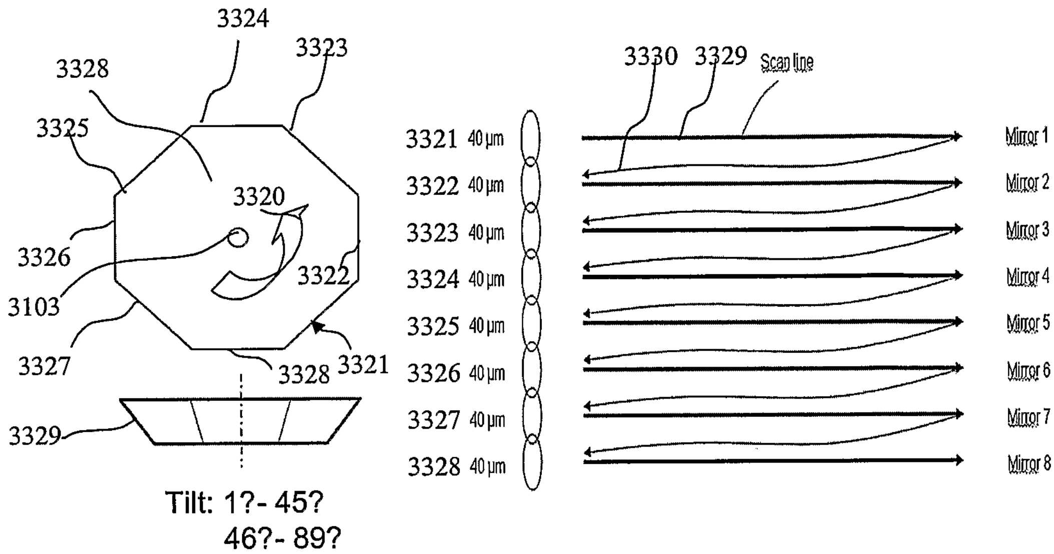

3324
3323
3328
3325
3320
3326
3322
3103
3327
3328
3321
3329
Tilt: 1?- 45?
46?- 89?
3330
3329
Scan line
3321 40 µm
3322 40 µm
3323 40 µm
3324 40 µm
3325 40 µm
3326 40 µm
3327 40 µm
3328 40 µm
Mirror 1
Mirror 2
Mirror 3
Mirror 4
Mirror 5
Mirror 6
Mirror 7
Mirror 8

Fig 7

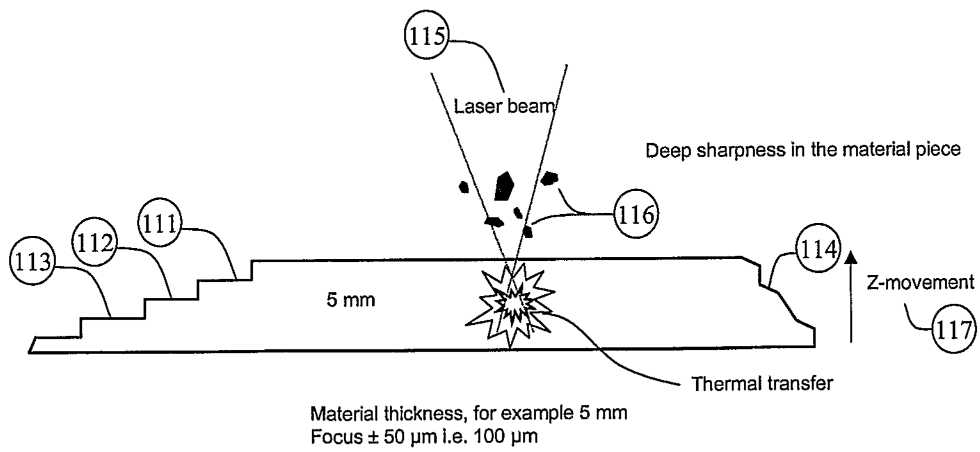
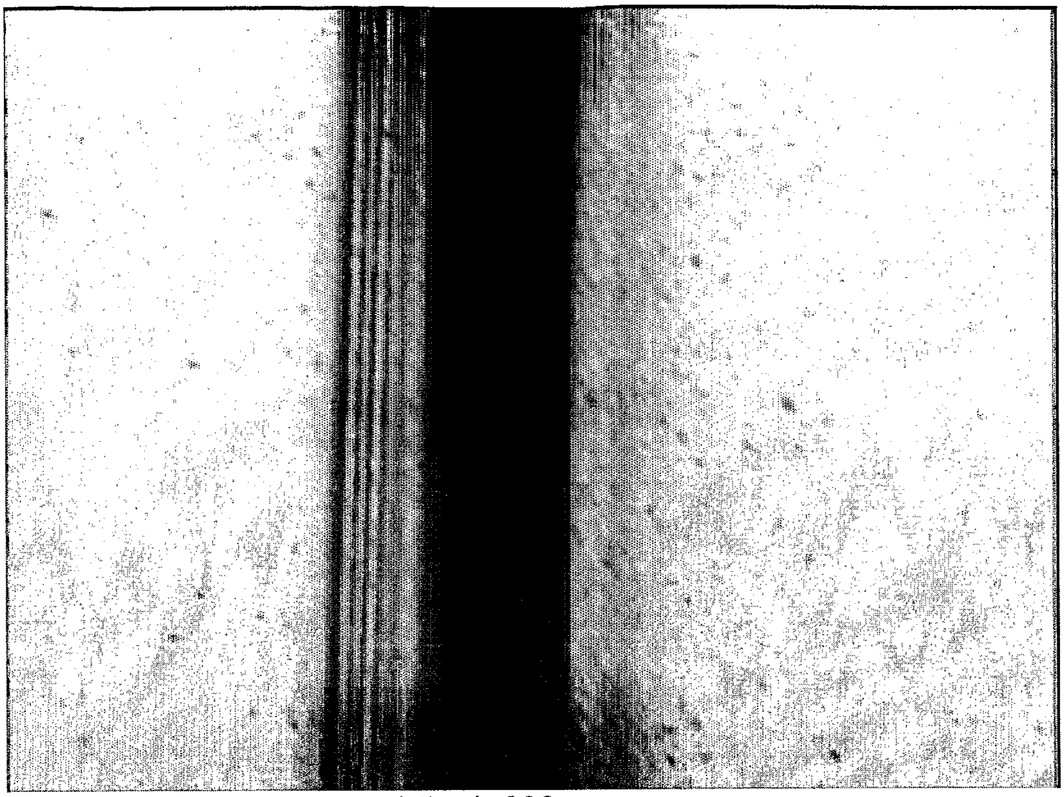
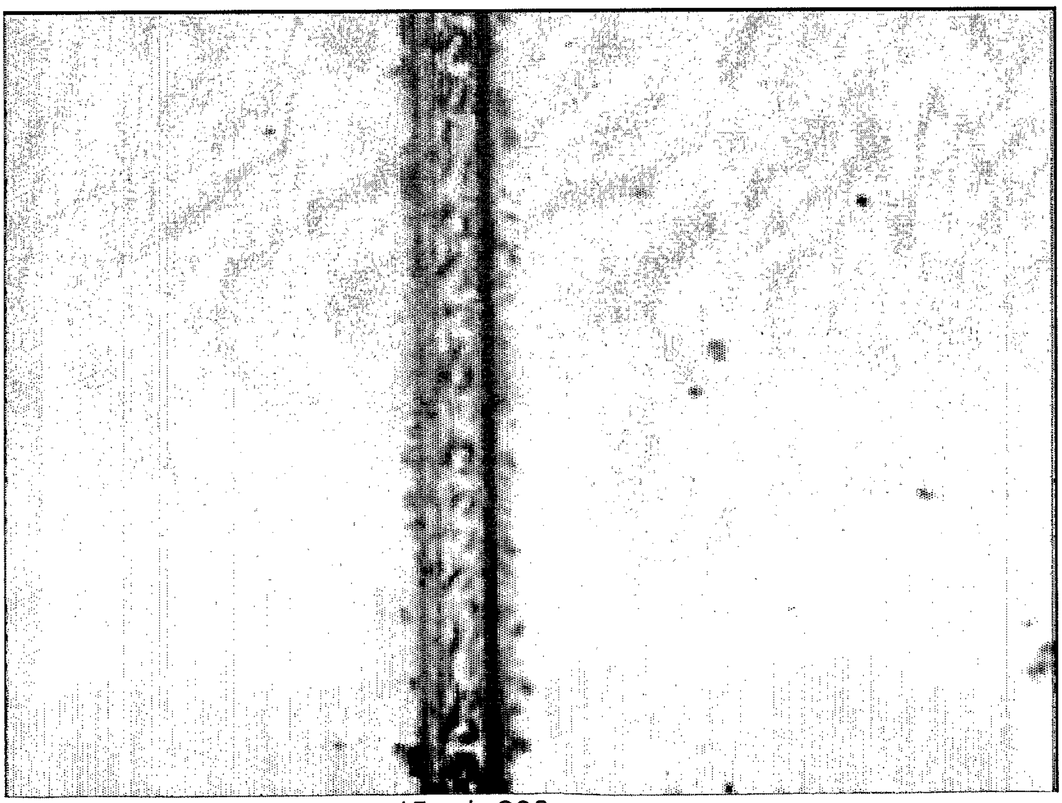

115
Laser beam
Deep sharpness in the material piece
116
111
112
113
114
5 mm
Z-movement
117
Thermal transfer
Material thickness, for example 5 mm
Focus ± 50 µm i.e. 100 µm

Fig 1



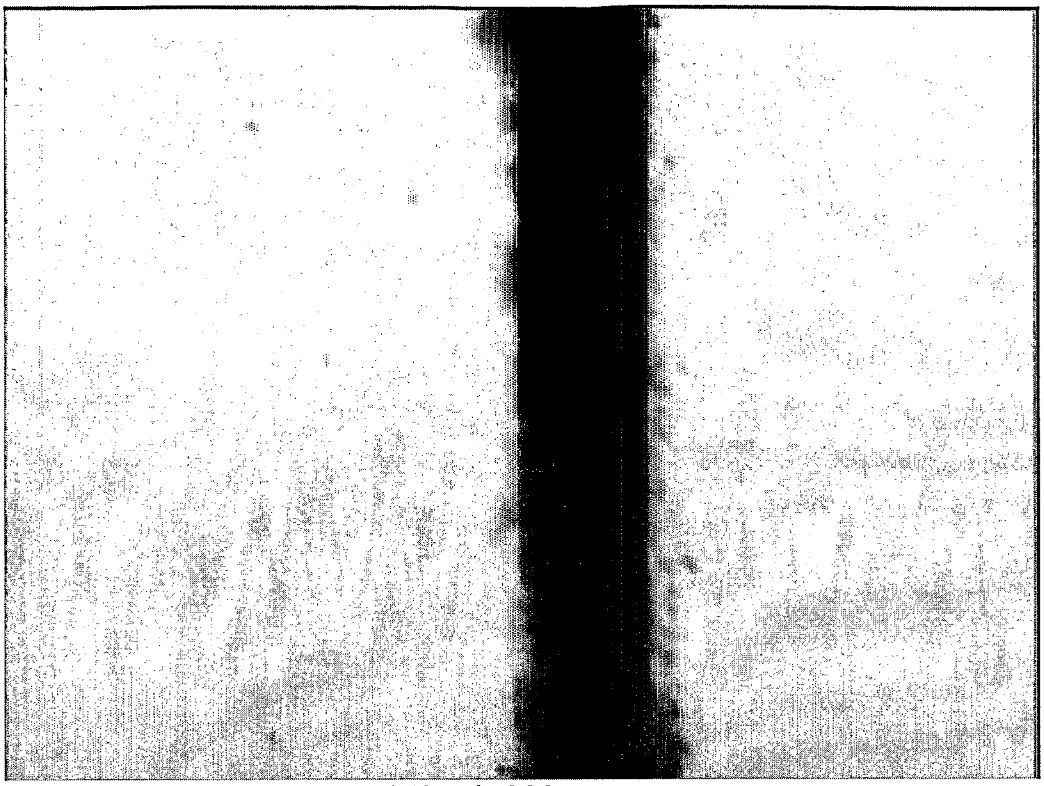
1.5 m/s 200x

Fig. 2A



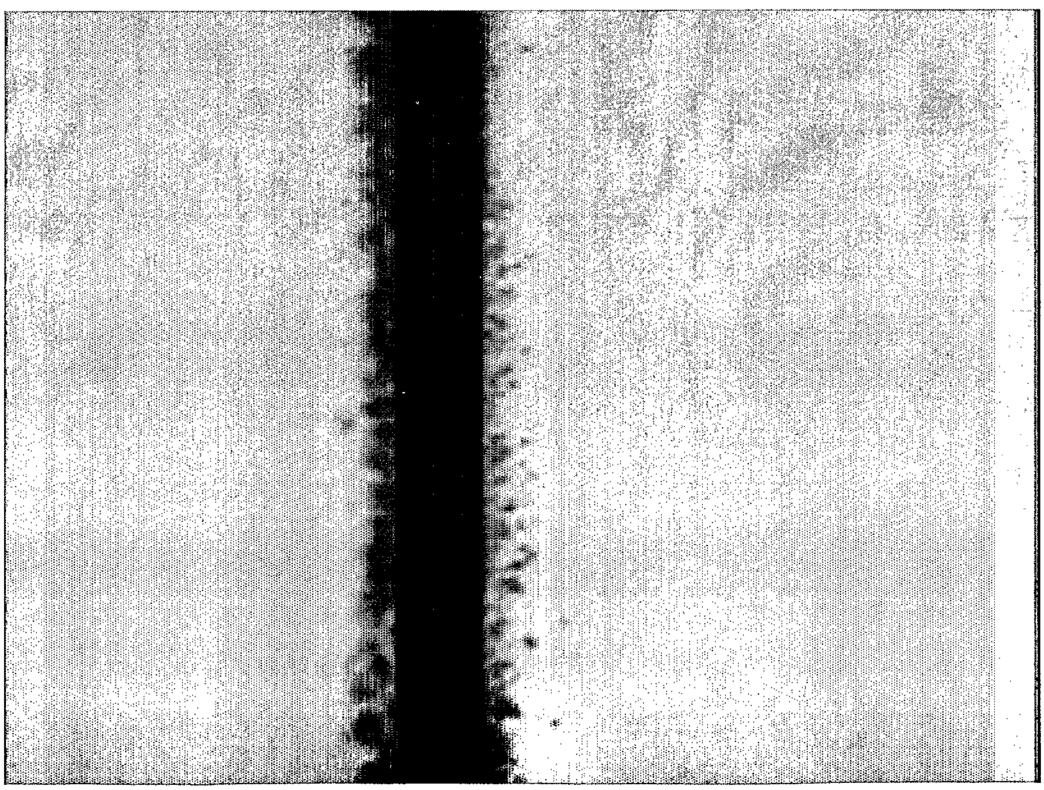
15 m/s 200x

Fig. 2B



150 m/s 200x

Fig. 2C



300 m/s 200x

Fig. 2D

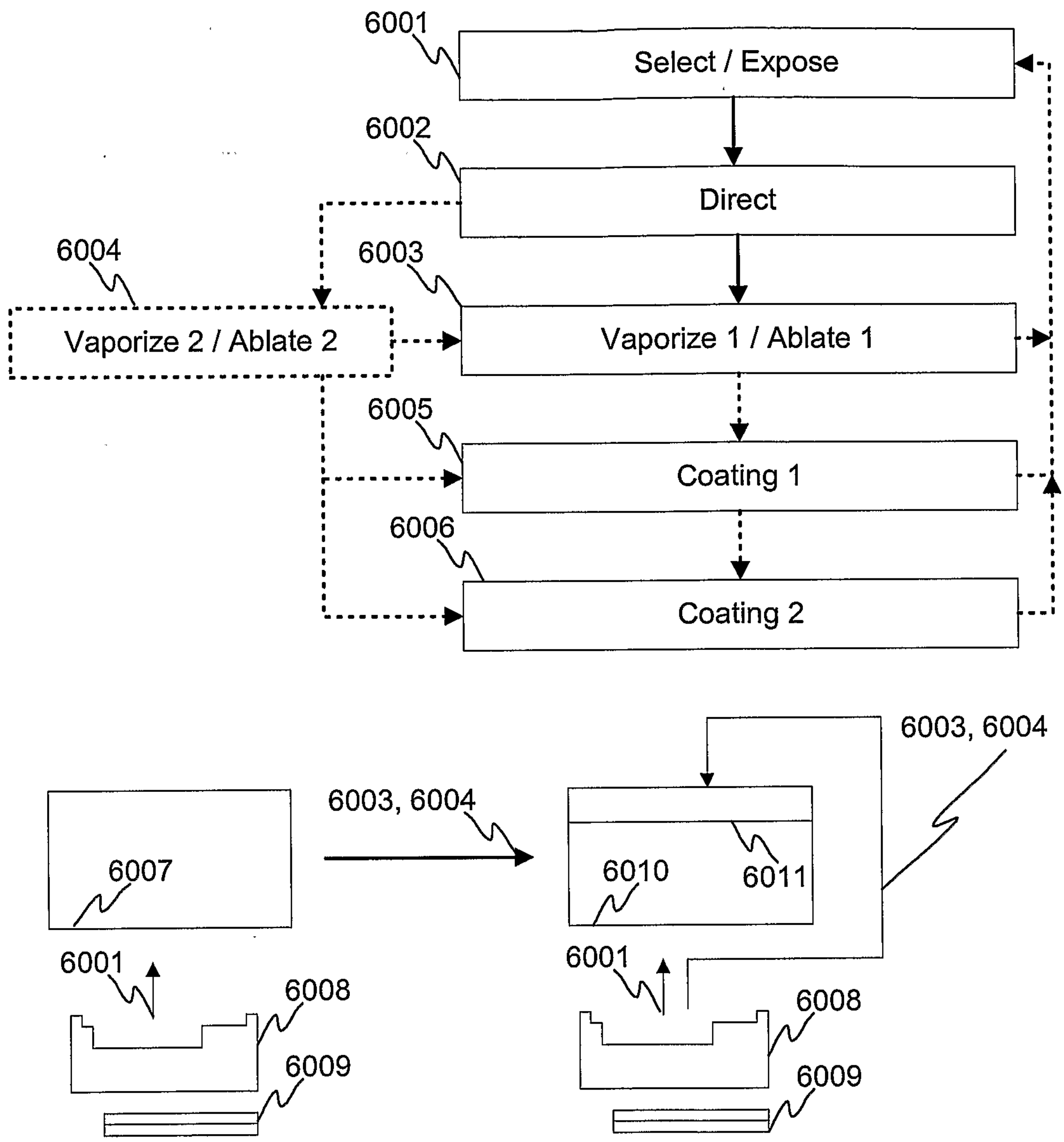

6001
Select / Expose
6002
Direct
6004
6003
Vaporize 2 / Ablate 2
Vaporize 1 / Ablate 1
6005
Coating 1
6006
Coating 2
6003, 6004
6003, 6004
6007
6010
6011
6001
6008
6009
6001
6008
6009

FIG 4

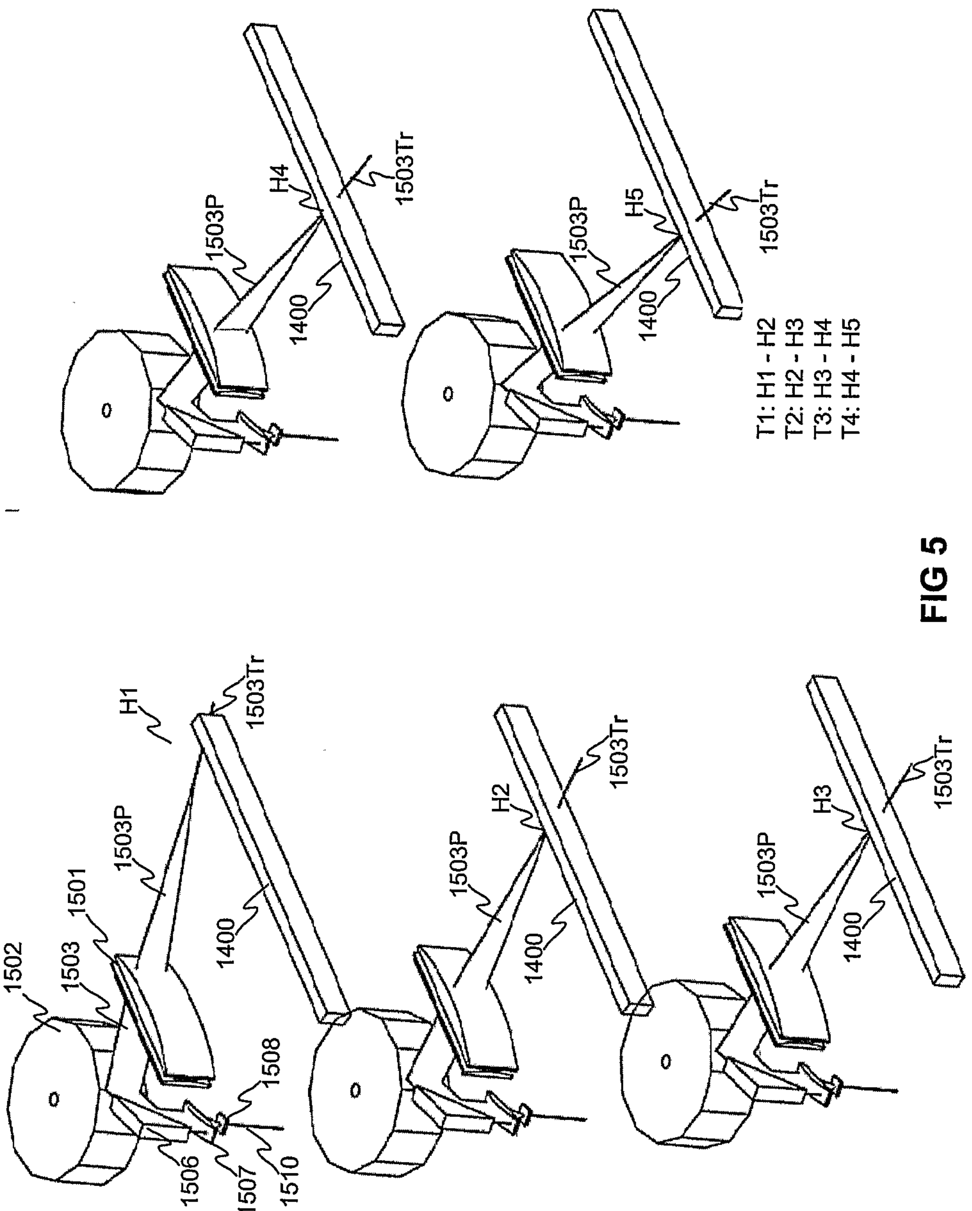

1502
1503
1501
1503P
1400
H1
1503Tr
1508
1506
1507
1510
H2
H3
H4
H5
T1: H1 - H2
T2: H2 - H3
T3: H3 - H4
T4: H4 - H5

FIG 5

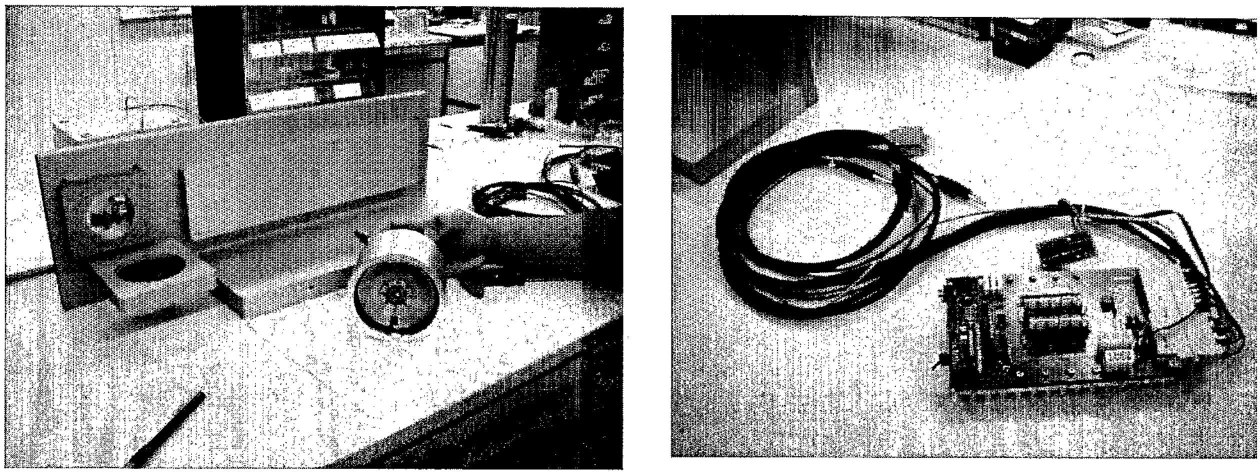


Fig. 3

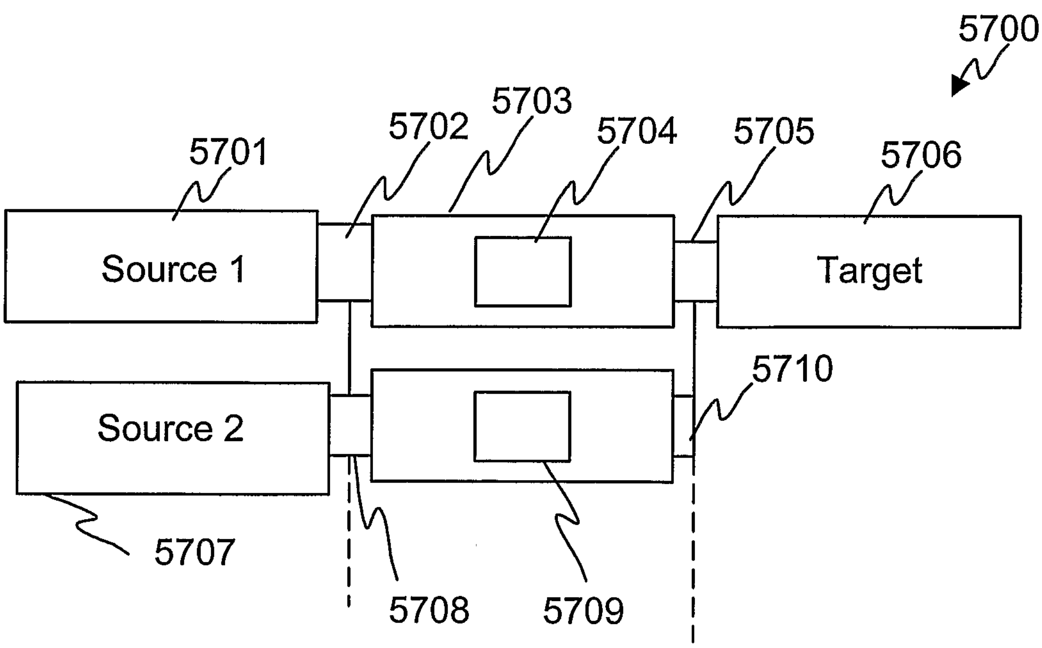
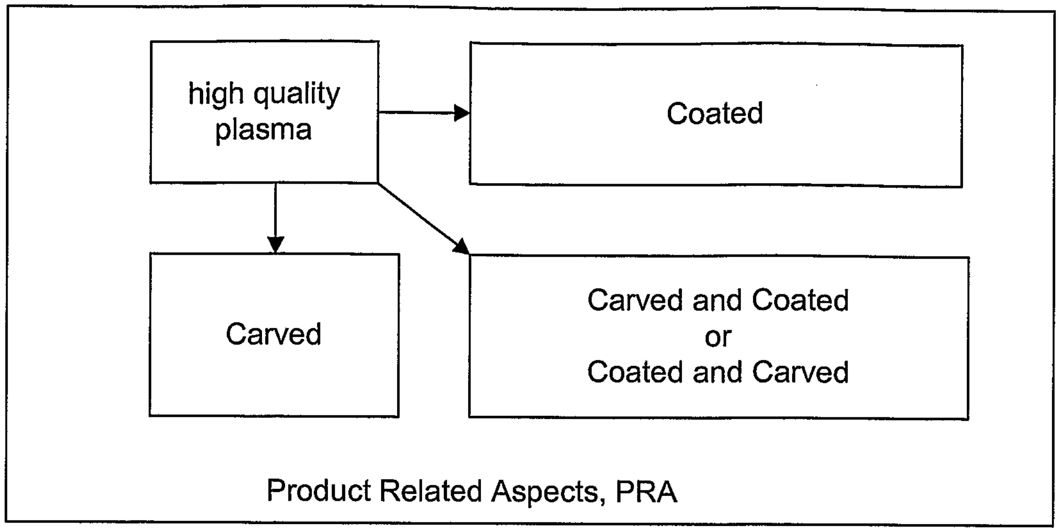

5700
5701
5702
5703
5704
5705
5706
Source 1
Target
Source 2
5710
5707
5708
5709

FIG 6


high quality plasma
Coated
Carved
Carved and Coated
or
Coated and Carved
Product Related Aspects, PRA

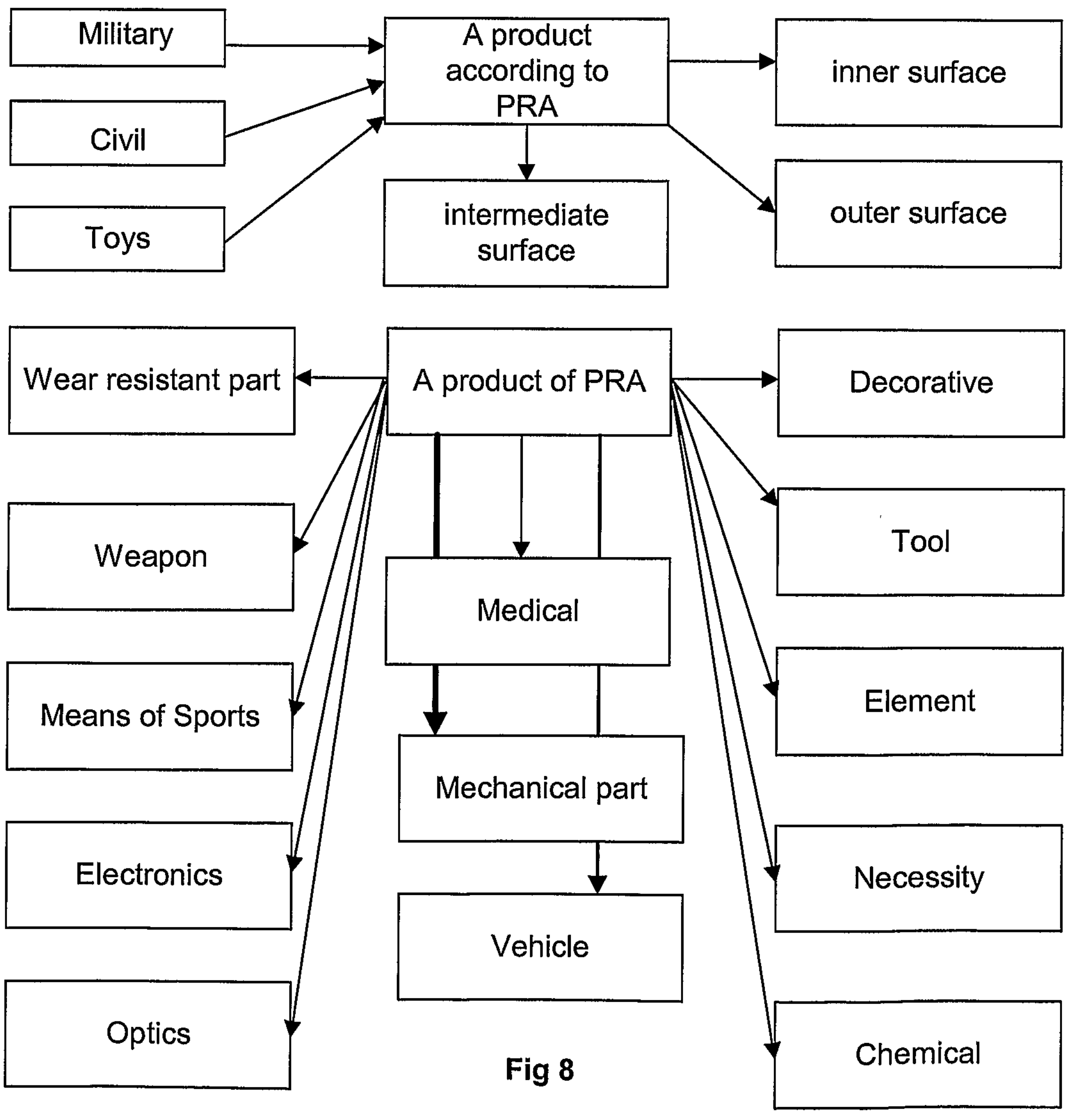

Military
Civil
Toys
A product according to PRA
inner surface
outer surface
intermediate surface
Wear resistant part
A product of PRA
Decorative
Weapon
Tool
Medical
Means of Sports
Element
Mechanical part
Electronics
Necessity
Vehicle
Optics
Chemical

Fig 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2007/000047

A. CLASSIFICATION OF SUBJECT MATTER
INV. B23K26/36 B23K26/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 1 430 987 A (CATERPILLAR INC [US]) 23 June 2004 (2004-06-23) paragraph [0011] - paragraph [0018]; claims 1,9; figures 1,2	1,9,10
Y	paragraph [0011] - paragraph [0018]; claims 1,9; figures 1,2	1,8,20
Y	K. TWIETMEYER: "Polygon Mirror Assemblies" pages 1-26, XP007902588 Retrieved from the Internet: URL:http://www.optics.arizona.edu/opti696/2005/Polygonal%20Mirror%20Assemblies.pdf> the whole document	1,8,20

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 July 2007	18/07/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Concannon, Brian

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2007/000047

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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