



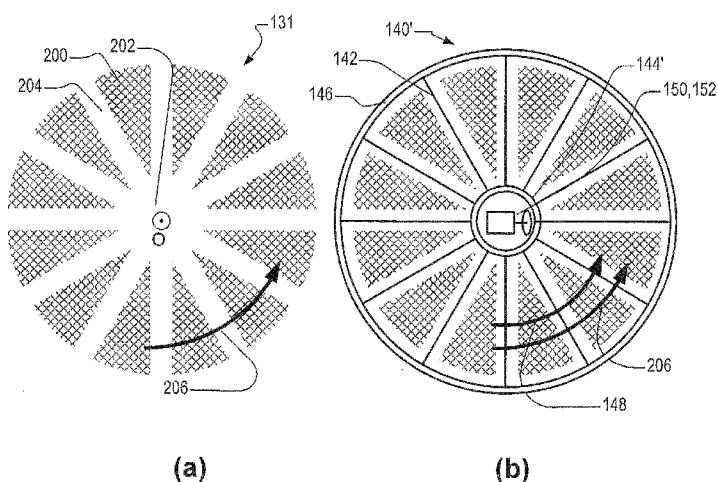
- (51) **International Patent Classification:**
G03F 7/20 (2006.01) *H05G 2/00* (2006.01)
- (21) **International Application Number:**
PCT/EP2013/074713
- (22) **International Filing Date:**
26 November 2013 (26.11.2013)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
61/745,217 21 December 2012 (21.12.2012) US
- (71) **Applicant:** ASML NETHERLANDS B.V. [NL/NL]; P.O. Box 324, NL-5500 AH Veldhoven (NL).
- (72) **Inventors:** BANINE, Vadim; Eendracht 21, NL-5751 SB Deurne (NL). BENSCHOP, Jozef; Sprookjesberg 2, NL-5508 EB Veldhoven (NL). MOORS, Johannes; Dierdonk-laan 56, NL-5709 MT Helmond (NL).
- (74) **Agent:** SIEM, Max Yoe Shé; P.O. Box 324, NL-5500 AH Veldhoven (NL).
- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) **Title:** BEAM DELIVERY FOR EUV LITHOGRAPHY**Fig. 8**

(57) **Abstract:** An EUV radiation source comprises a laser beam delivery system for delivering a beam to a target position. EUV radiation is emitted by a plasma at a position and is collected by a grazing incidence collector and focused to a desired position. A debris trap (140') is provided to prevent contamination from the plasma reaching the collector and other optical surfaces. The laser beam delivery system is designed to provide said laser radiation with a modified intensity distribution comprising substantially all the energy of the incoming radiation, but having regions (202, 204) of low intensity corresponding to the locations of parts (142, 144') of the debris trap. In an example with a rotating foil trap, a rotating, segmented intensity distribution is generated using faceted axicon elements. A central low intensity region allows bearing, drive and cooling apparatus to be mounted at the hub of the debris trap.

BEAM DELIVERY FOR EUV LITHOGRAPHY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of US provisional application 61/745,217, which was filed on 21 December 2012, and which is incorporated herein in its entirety by reference.

FIELD

[0002] The present invention relates to arrangements for delivering laser radiation to a target. The target may be a fuel source in a laser produced plasma (LPP) source of an EUV optical apparatus. The optical apparatus may be, for example, an EUV lithographic apparatus.

BACKGROUND

[0003] A lithographic apparatus is a machine that applies a desired pattern onto a substrate, usually onto a target portion of the substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that instance, a patterning device, which is alternatively referred to as a mask or a reticle, may be used to generate a circuit pattern to be formed on an individual layer of the IC. This pattern can be transferred onto a target portion (e.g. comprising part of, one, or several dies) on a substrate (e.g. a silicon wafer). Transfer of the pattern is typically via imaging onto a layer of radiation-sensitive material (resist) provided on the substrate. In general, a single substrate will contain a network of adjacent target portions that are successively patterned.

[0004] Lithography is widely recognized as one of the key steps in the manufacture of ICs and other devices and/or structures. However, as the dimensions of features made using lithography become smaller, lithography is becoming a more critical factor for enabling miniature IC or other devices and/or structures to be manufactured. A theoretical estimate of the limits of pattern printing can be given by the Rayleigh criterion for resolution as shown in equation (1):

$$CD = k_1 * \frac{\lambda}{NA} \quad (1)$$

where λ is the wavelength of the radiation used, NA is the numerical aperture of the projection system used to print the pattern, k_1 is a process dependent adjustment factor, also called the

Rayleigh constant, and CD is the feature size (or critical dimension) of the printed feature. It follows from equation (1) that reduction of the minimum printable size of features can be obtained in three ways: by shortening the exposure wavelength λ , by increasing the numerical aperture NA or by decreasing the value of k_1 .

[0005] In order to shorten the exposure wavelength and, thus, reduce the minimum printable size, it has been proposed to use an extreme ultraviolet (EUV) radiation source. EUV radiation is electromagnetic radiation having a wavelength within the range of 5-20 nm, for example within the range of 13-14 nm. It has further been proposed that EUV radiation with a wavelength of less than 10 nm could be used, for example within the range of 5-10 nm such as 6.7 nm or 6.8 nm. Such radiation is termed extreme ultraviolet radiation or soft x-ray radiation. Possible sources include, for example, laser-produced plasma sources, discharge plasma sources, or sources based on synchrotron radiation provided by an electron storage ring.

[0006] EUV radiation may be produced using a plasma. A radiation source apparatus for producing EUV radiation may include a laser for exciting a fuel to provide the plasma, and a source collector apparatus for containing the plasma. The plasma may be created, for example, by directing a laser beam at a fuel, such as particles of a suitable material (e.g. tin), or a stream of a suitable gas or vapor, such as Xe gas or Li vapor. The resulting plasma emits output radiation, e.g., EUV radiation, which is collected using a radiation collector. The radiation collector may be a mirrored normal incidence radiation collector, which receives the radiation and focuses the radiation into a beam. The radiation source apparatus may include an enclosing structure or chamber arranged to provide a vacuum environment to support the plasma. Such a radiation system is typically termed a laser produced plasma (LPP) source.

[0007] Two challenges in the design of LPP sources are to achieve efficient coupling of the laser radiation into the fuel, and to avoid contamination of optical elements from debris emitted in the process of plasma generation. Various debris mitigation arrangements such as rotating foil traps, gas traps and the like have been developed for protecting the optical components that capture and process the generated EUV radiation. Each has advantages and disadvantages. A separate problem is to protect the beam delivery optics of the laser that produces the plasma. For various reasons, the ability to use devices such as rotating foil traps have been restricted. Problems include loss of radiation that hits parts of the foil trap, heating of the foil trap under the

intense laser radiation, and the undesirability of reflection of the laser radiation back into the laser.

[0008] To enable new configurations of laser beam delivery systems apparatus in LPP sources and to increase the operating lifetime of sources by mitigating contamination of components, it is desirable to address some challenges that prevent the use of foil traps to protect the laser beam delivery system.

SUMMARY

[0009] According to an aspect of the invention, there is provided a beam delivery apparatus for delivering laser radiation to a target location, the apparatus comprising a debris trap located in the path of said laser radiation, the apparatus comprising optical components arranged to receive said laser radiation having an incoming intensity distribution and to output said laser radiation with a modified intensity distribution, said modified intensity distribution comprising substantially all the energy of the incoming radiation, but having regions of low intensity corresponding to the locations of parts of said debris trap.

[0010] The low intensity regions may correspond, for example, to a central hub portion and/or to radially extending vanes of the debris trap.

[0011] According to an aspect of the invention, there is provided a beam delivery apparatus for delivering laser radiation through a debris trap located in the path of the laser radiation to a target location, the apparatus comprising: a plurality of optical components arranged to receive said laser radiation having an incoming intensity distribution and to output said laser radiation with a modified intensity distribution, said modified intensity distribution comprising substantially all the energy of the incoming radiation, with regions of low intensity corresponding to the locations of parts of said debris trap.

[0012] According to an aspect of the invention, there is provided a method of delivering laser radiation to a target location, wherein a debris trap located in the path of said laser radiation, the method comprising receiving incoming laser radiation and modifying an intensity distribution of said laser radiation prior to said debris trap, the modified intensity distribution comprising substantially all the energy of the incoming radiation, but having regions of low intensity corresponding to the locations of parts of said debris trap.

[0013] According to an aspect of the invention, there is provided a method of delivering laser radiation to a target location, wherein a debris trap located in the path of said laser radiation, the method comprising receiving incoming laser radiation and modifying an intensity distribution of said laser radiation prior to said debris trap, the modified intensity distribution comprising substantially all the energy of the incoming radiation, with regions of low intensity corresponding to the locations of parts of said debris trap.

[0014] The debris trap may be of a type that moves during operation to sweep up particles moving up to a certain speed. The modified intensity distribution can be made to move synchronously with the debris trap so as to maintain correspondence between the low intensity regions and the parts of the debris trap. An example of a moving debris trap is a rotating foil trap (RFT), in which a number of radially extending vanes are made to rotate about an axis. The invention is not limited to any particular shape of trap, or to any particular type of movement.

[0015] Further features and advantages of the invention, as well as the structure and operation of various embodiments of the invention, are described in detail below with reference to the accompanying drawings. It is noted that the invention is not limited to the specific embodiments described herein. Such embodiments are presented herein for illustrative purposes only. Additional embodiments will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0016] Embodiments of the invention are described, by way of example only, with reference to the accompanying drawings, in which:

[0017] Figure 1 depicts schematically a lithographic apparatus having reflective projection optics;

[0018] Figure 2 is a more detailed view of the apparatus of Figure 1 including a first example of a laser produced plasma ("LPP") radiation source;

[0019] Figure 3 shows an alternative configuration for the LPP radiation source in the apparatus of Figures 1 and 2, including a side view of a rotating foil trap;

[0020] Figure 4 is an axial view of the rotating foil trap of Figure 3;

[0021] Figures 5 and 6 show schematically (a) modified intensity profiles of a laser beam and (b) their relation to the structure of the rotating foil trap in different embodiments of the present invention;

[0022] Figures 7 and 8 show schematically (a) modified intensity profiles in different embodiments of the present invention and (b) their relation to the structure of a modified rotating foil trap according to further embodiments of the present invention;

[0023] Figure 9 is a schematic diagram an axicon arrangement usable as part of a laser beam delivery system for producing the intensity profiles of Figures 5 to 8;

[0024] Figure 10 shows the form of (a) conical and (b) pyramidal axicon elements used in producing the intensity profiles according to embodiments of the invention; and

[0025] Figures 11 and 12 illustrate variations of the axicon arrangement based on reflective instead of refractive axicon elements.

[0026] The features and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings, in which like reference characters identify corresponding elements throughout. In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements.

DETAILED DESCRIPTION

[0027] Figure 1 schematically depicts a lithographic apparatus 100 including a source module SO according to an embodiment of the invention. The apparatus comprises: an illumination system (illuminator) IL configured to condition a radiation beam B (e.g. EUV radiation); a support structure (e.g. a mask table) MT constructed to support a patterning device (e.g. a mask or a reticle) MA and connected to a first positioner PM configured to accurately position the patterning device; a substrate table (e.g. a wafer table) WT constructed to hold a substrate (e.g. a resist-coated wafer) W and connected to a second positioner PW configured to accurately position the substrate; and a projection system (e.g. a reflective projection system) PS configured to project a pattern imparted to the radiation beam B by patterning device MA onto a target portion C (e.g. comprising one or more dies) of the substrate W.

[0028] The illumination system may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, for directing, shaping, or controlling radiation.

[0029] The support structure MT holds the patterning device MA in a manner that depends on the orientation of the patterning device, the design of the lithographic apparatus, and other conditions, such as for example whether or not the patterning device is held in a vacuum environment. The support structure can use mechanical, vacuum, electrostatic or other clamping techniques to hold the patterning device. The support structure may be a frame or a table, for example, which may be fixed or movable as required. The support structure may ensure that the patterning device is at a desired position, for example with respect to the projection system.

[0030] The term “patterning device” should be broadly interpreted as referring to any device that can be used to impart a radiation beam with a pattern in its cross-section such as to create a pattern in a target portion of the substrate. The pattern imparted to the radiation beam may correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit.

[0031] The patterning device may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable LCD panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions. The tilted mirrors impart a pattern in a radiation beam which is reflected by the mirror matrix.

[0032] The projection system, like the illumination system, may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of a vacuum. It may be desired to use a vacuum for EUV radiation since other gases may absorb too much radiation. A vacuum environment may therefore be provided to the whole beam path with the aid of a vacuum wall and vacuum pumps.

[0033] As here depicted, the apparatus is of a reflective type (e.g. employing a reflective mask).

[0034] The lithographic apparatus may be of a type having two (dual stage) or more substrate tables (and/or two or more mask tables). In such “multiple stage” machines the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposure.

[0035] Referring to Figure 1, the illuminator IL receives an extreme ultra violet radiation beam from the source module SO. Methods to produce EUV light include, but are not necessarily limited to, converting a material into a plasma state that has at least one element, e.g., xenon, lithium or tin, with one or more emission lines in the EUV range. In one such method, often termed laser produced plasma (“LPP”), the required plasma can be produced by irradiating a fuel, such as a droplet, stream or cluster of material having the required line-emitting element, with a laser beam. The source module SO may be part of an EUV radiation system including a laser, not shown in Figure 1, for providing the laser beam exciting the fuel. The resulting plasma emits output radiation, e.g., EUV radiation, which is collected using a radiation collector, disposed in the source module. The laser and the source module may be separate entities, for example when a CO₂ laser is used to provide the laser beam for fuel excitation.

[0036] In such cases, the laser is not considered to form part of the lithographic apparatus and the radiation beam is passed from the laser to the source module with the aid of a beam delivery system comprising, for example, suitable directing mirrors and/or a beam expander. In other cases, the source may be an integral part of the source module, for example when the source is a discharge produced plasma EUV generator, often termed as a DPP source.

[0037] The illuminator IL may comprise an adjuster for adjusting the angular intensity distribution of the radiation beam. Generally, at least the outer and/or inner radial extent (commonly referred to as σ -outer and σ -inner, respectively) of the intensity distribution in a pupil plane of the illuminator can be adjusted. In addition, the illuminator IL may comprise various other components, such as faceted field and pupil mirror devices. The illuminator may be used to condition the radiation beam, to have a desired uniformity and intensity distribution in its cross-section.

[0038] The radiation beam B is incident on the patterning device (e.g., mask) MA, which is held on the support structure (e.g., mask table) MT, and is patterned by the patterning device. After being reflected from the patterning device (e.g. mask) MA, the radiation beam B passes through the projection system PS, which focuses the beam onto a target portion C of the

substrate W. With the aid of the second positioner PW and position sensor PS2 (e.g. an interferometric device, linear encoder or capacitive sensor), the substrate table WT can be moved accurately, e.g. so as to position different target portions C in the path of the radiation beam B. Similarly, the first positioner PM and another position sensor PS1 can be used to accurately position the patterning device (e.g. mask) MA with respect to the path of the radiation beam B. Patterning device (e.g. mask) MA and substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2.

[0039] The depicted apparatus could be used in at least one of the following modes:

1. In step mode, the support structure (e.g. mask table) MT and the substrate table WT are kept essentially stationary, while an entire pattern imparted to the radiation beam is projected onto a target portion C at one time (i.e. a single static exposure). The substrate table WT is then shifted in the X and/or Y direction so that a different target portion C can be exposed.
2. In scan mode, the support structure (e.g. mask table) MT and the substrate table WT are scanned synchronously while a pattern imparted to the radiation beam is projected onto a target portion C (i.e. a single dynamic exposure). The velocity and direction of the substrate table WT relative to the support structure (e.g. mask table) MT may be determined by the (de-)magnification and image reversal characteristics of the projection system PS.
3. In another mode, the support structure (e.g. mask table) MT is kept essentially stationary holding a programmable patterning device, and the substrate table WT is moved or scanned while a pattern imparted to the radiation beam is projected onto a target portion C. In this mode, generally a pulsed radiation source is employed and the programmable patterning device is updated as required after each movement of the substrate table WT or in between successive radiation pulses during a scan. This mode of operation can be readily applied to maskless lithography that utilizes programmable patterning device, such as a programmable mirror array of a type as referred to above.

[0040] Combinations and/or variations on the above described modes of use or entirely different modes of use may also be employed.

[0041] Figure 2 shows an embodiment of the lithographic apparatus 100 in more detail, including a radiation system 42, the illumination system IL, and the projection system PS. The radiation system 42 as shown in Figure 2 is of the type that uses a laser-produced plasma as a radiation source. EUV radiation may be produced by a gas or vapor, for example Xe gas, Li

vapor or Sn vapor in which a very hot plasma is created to emit radiation in the EUV range of the electromagnetic spectrum. The very hot plasma is created by causing an at least partially ionized plasma by, for example, optical excitation using CO₂ laser light. Partial pressures of, for example, 10 Pa of Xe, Li, Sn vapor or any other suitable gas or vapor may be required for efficient generation of the radiation. In an embodiment, Sn is used to create the plasma in order to emit the radiation in the EUV range.

[0042] The radiation system 42 embodies the function of source SO in the apparatus of Figure 1. Radiation system 42 comprises a source chamber 47, which in this embodiment not only substantially encloses a source of EUV radiation, but also collector 50 which, in the example of Figure 2, is a normal-incidence collector, for instance a multi-layer mirror.

[0043] As part of an LPP radiation source, a laser system 61 is constructed and arranged to provide a laser beam 63 which is delivered by a beam delivering system 65 through an aperture 67 provided in the collector 50. Also, the radiation system includes a target material 69, such as Sn or Xe, which is supplied by target material supply 71. The beam delivering system 65, in this embodiment, is arranged to establish a beam path focused substantially upon a desired plasma formation position 73.

[0044] In operation, the target material 69, which may also be referred to as fuel, is supplied by the target material supply 71 in the form of droplets. When such a droplet of the target material 69 reaches the plasma formation position 73, the laser beam 63 impinges on the droplet and an EUV radiation-emitting plasma forms inside the source chamber 47. In the case of a pulsed laser, this involves timing the pulse of laser radiation to coincide with the passage of the droplet through the position 73. As mentioned, the fuel may be for example xenon (Xe), tin (Sn) or lithium (Li). These create a highly ionized plasma with electron temperatures of several 10's of eV. Higher energy EUV radiation may be generated with other fuel materials, for example Tb and Gd. The energetic radiation generated during de-excitation and recombination of these ions includes the wanted EUV which is emitted from the plasma at position 73. The plasma formation position 73 and the aperture 52 are located at first and second focal points of collector 50, respectively and the EUV radiation is focused by the normal-incidence collector mirror 50 onto the intermediate focus point IF.

[0045] The beam of radiation emanating from the source chamber 47 traverses the illumination system IL via so-called normal incidence reflectors 53, 54, as indicated in Figure 2 by the

radiation beam 56. The normal incidence reflectors direct the beam 56 onto a patterning device (e.g. reticle or mask) positioned on a support (e.g. reticle or mask table) MT. A patterned beam 57 is formed, which is imaged by projection system PS via reflective elements 58, 59 onto a substrate carried by wafer stage or substrate table WT. More elements than shown may generally be present in illumination system IL and projection system PS. For example there may be one, two, three, four or even more reflective elements present than the two elements 58 and 59 shown in Figure 2. Radiation collectors similar to radiation collector 50 are known from the prior art.

[0046] As the skilled reader will know, reference axes X, Y and Z may be defined for measuring and describing the geometry and behavior of the apparatus, its various components, and the radiation beams 55, 56, 57. At each part of the apparatus, a local reference frame of X, Y and Z axes may be defined. The Z axis broadly coincides with the direction of optical axis O at a given point in the system, and is generally normal to the plane of a patterning device (reticle) MA and normal to the plane of substrate W. In the source module (apparatus) 42, the X axis coincides broadly with the direction of fuel stream (69, described below), while the Y axis is orthogonal to that, pointing out of the page as indicated. On the other hand, in the vicinity of the support structure MT that holds the reticle MA, the X axis is generally transverse to a scanning direction aligned with the Y axis. For convenience, in this area of the schematic diagram Figure 2, the X axis points out of the page, again as marked. These designations are conventional in the art and will be adopted herein for convenience. In principle, any reference frame can be chosen to describe the apparatus and its behavior.

[0047] In addition to the wanted EUV radiation, the plasma produces other wavelengths of radiation, for example in the visible, UV and DUV range. There is also IR radiation present from the laser beam 63. The non-EUV wavelengths are not wanted in the illumination system IL and projection system PS and various measures may be deployed to block the non-EUV radiation. As schematically depicted in Figure 2, a transmissive SPF may be applied upstream of the virtual source point IF. Alternatively or in addition to such a filter, filtering functions can be integrated into other optics. For example a diffractive filter can be integrated in collector 50 and/or mirrors 53, 54 etc., by provision of a grating structure tuned to divert the longer, IR radiation away from the virtual source point IF. Filters for IR, DUV and other unwanted wavelengths may thus be provided at one or more locations along the paths of beams 55, 56, 57, within source module (radiation system 42), the illumination system IL and/or projection system PS.

[0048] To deliver the fuel, which for example is liquid tin, a droplet generator or target material supply 71 is arranged within the source chamber 47, to fire a stream of droplets towards the plasma formation position 73. In operation, laser beam 63 may be delivered in a synchronism with the operation of target material supply 71, to deliver impulses of radiation to turn each fuel droplet into a plasma. The frequency of delivery of droplets may be several kilohertz, or even several tens or hundreds of kilohertz. In practice, laser beam 63 may be delivered by a laser system 61 in at least two pulses: a pre pulse PP with limited energy is delivered to the droplet before it reaches the plasma location, in order to vaporize the fuel material into a small cloud, and then a main pulse MP of laser energy is delivered to the cloud at the desired location, to generate the plasma. In a typical example, the diameter of the plasma is about 2-3 mm. A trap 72 is provided on the opposite side of the enclosing structure 47, to capture fuel that is not, for whatever reason, turned into plasma.

[0049] Laser system 61 in may be for example of the MOPA (Master Oscillator Power Amplifier) type. Such a laser system 61 includes a “master” laser or “seed” laser, followed by a power amplifier system PA, for firing a main pulse of laser energy towards an expanded droplet cloud, and a pre pulse laser for firing a pre pulse of laser energy towards a droplet. A beam delivery system 24 is provided to deliver the laser energy 63 into the source chamber 47. In practice, the pre-pulse element of the laser energy may be delivered by a separate laser. Laser system 61, target material supply 71 and other components can be controlled by a controller (not shown separately). The controller performs many control functions, and has sensor inputs and control outputs for various elements of the system. Sensors may be located in and around the elements of radiation system 42, and optionally elsewhere in the lithographic apparatus. In some embodiments of the present invention, the main pulse and the pre pulse are derived from a same laser. In other embodiments of the present invention, the main pulse and the pre-pulse are derived from different lasers which are independent from each other but controlled to operate synchronously. A problem that can arise in the LPP source apparatus is that optical elements of the laser beam deliver system 65 will become contaminated with debris from the plasma. In particular a final optical element, be it a lens or a mirror, is directly exposed to particles of fuel ejected from the plasma. A refractive (transmissive) element will quickly become obscured by tin deposits, leading to reduced transmission of the laser radiation and undesired heating. A

reflective final element, such as a copper mirror, may be more tolerant of Sn deposits for time, but will need cleaning eventually to maintain efficiency of reflection and focusing.

[0050] In order to block as much contamination as possible, a contamination trap 80 of some sort may be provided between the plasma formation site 73 and optical elements of the beam delivery system 65. A so-called foil trap is known for use in such cases. The trap may be a static or a rotating foil trap, or a combination of both. The rotating foil trap (RFT), as is known in the art, comprises a number of thin vanes aligned with the radiation direction so as to present as little obstruction to the wanted radiation beam. The vanes extend in length parallel to the beam direction, and extend radially from the optical axis (O). When the foils rotate about the optical axis O, slower-moving contaminant particles are caught by the sweeping motion of the vanes. Unfortunately, the foil trap itself constitutes some obstruction to the beam, resulting in loss of radiation power delivered to the plasma formation position 73. The radiation absorbed by the trap leads to heating, consequently distortion of the trap and radiation from it. Consequently, the RFT may not be effective in maintaining overall performance of the apparatus. Other types of trap, for example those based on counter-flowing gas, are deployed instead (e.g. low pressure nitrogen). These other types of trap are not necessarily so effective at stopping the debris.

[0051] Figure 3 shows an alternative LPP source arrangement which may be used in place of that illustrated in Figure 2. A main difference is that the main pulse laser beam is directed onto the fuel droplet from the direction of the intermediate focus point IF, such that the collected EUV radiation is that which is emitted generally in the direction from which the main laser pulse was received.

[0052] Figure 3 shows the main laser beam delivery system 130 emitting a main pulse beam 131 delivered to a plasma formation position 132. At least one optical element of the beam delivery system, in this case a folding mirror 133 is located on the optical axis between plasma position 132 and the intermediate focus. (The term “folding” here refers to folding of the beam, not folding of the mirror.) The EUV radiation 134 emitted by a plasma at position 132, or at least the major portion that is not directed back along the optical axis O into the folding mirror 133 is collected by a grazing incidence collector 135. This type of collector is known already in the art, but is generally used in discharge produced plasma (DPP) sources, not LPP sources. Also shown is a debris trap 136, which will be described in more detail below. A pre-pulse laser 137 is provided to deliver a pre-pulse laser beam 138 to fuel droplets. In this example, the pre-pulse

energy is delivered to the side of the fuel droplet that faces away from the intermediate focus point IF. It should be understood that the elements shown in this schematic diagram are not to scale.

[0053] Because of the position of the folding mirror 133, it is more vulnerable to contamination than in the arrangement of Figure 2 and alternative debris traps such as gas traps are less suitable. Therefore in this example a debris trap 136 comprising at least one rotating foil trap (RFT) 140 is chosen. Optionally, a stationary foil trap (SFT, not shown) may be provided in front of or behind the RFT. Referring also to the view of Figure 4, RFT 140 comprises a series of foil vanes 142 radiating from a central hub 144 located on the optical axis O. All of the vanes terminate in a rim 146 and the structure comprising vanes, hub and rim is mounted to rotate about the optical axis. Associated with the RFT 140 are a drive arrangement 150 for causing rotation with a desired speed (arrow 148). Also associated with RFT 140 is a cooling arrangement 152 for removing heat deposited by the radiation beams 131, 134 and other radiation present within the source chamber. Bearings, not shown, are naturally provided, in this case around the rim 146.

[0054] As mentioned already, the presence of RFT 140 in the path of laser beam 131 brings certain challenges. One of these is loss of radiation power in the portion of the beam that strikes the vanes 142 and hub 144, which also leads to heating of the RFT and effort required in cooling system 152. Although these components are designed to appear as slim as possible when viewed in the direction of radiation, their cross-section is not negligible. Moreover, heating effects can cause distortion of the vanes, further increasing their effective cross-section in the beam and exacerbating the problem. Another problem is that a portion of the laser radiation may be reflected back along the beam path and into the laser. This reduces laser efficiency. The inventors have therefore sought to find ways of delivering the laser beam 131 to the plasma formation position 132 that allow for the presence of a foil trap, particularly a rotating foil trap, without loss of efficiency and/or with reduced back-reflection. The novel arrangements will be described in the context of the Figure 3 apparatus. They may be adapted also to the example of Figure 2 and debris trap 80.

[0055] Figures 5 to 8 illustrate the principle of the invention at work in different examples. The invention is not limited to these examples, and the features of the examples can be used in different combinations, according to the situation. In each Figure, part (a) illustrates

schematically an intensity profile in a cross-section of the main pulse laser beam 131 in the vicinity of RFT 140. Regions of high radiation intensity are indicated by hatching. The optical axis O is marked. In each Figure, part (b) indicates the position of the region or regions of high intensity as they impinge on the RFT 140. It will be described later how the illustrated intensity profiles can be achieved by modification of the beam delivery system 130 (or 65 in the example of Figure 2)

[0056] In Figure 5, the laser beam intensity profile (a) is rotationally symmetric about the optical axis O, but is not uniform in the radial direction. An annular region 200 of high radiation intensity is indicated by hatching. The region 202 immediately surrounding the optical axis has low intensity, indicated by no hatching. It will be understood that the intensity profile is not necessarily binary in character, and variations within these regions may be expected. The principle is unaffected, however, and benefits of the reduced radiation loss and reduced back-reflection can be achieved so long as the intensity in the un-hatched portions is significantly lower than in the hatched portions.

[0057] Figure 5(b) shows how the intensity profile (a) impinges on RFT 140. We see that the low-intensity central region 202 impinges on hub 144, rather than full intensity radiation. Therefore the hub portion is not subjected to significant heating, and also the radiation reflected back from the hub portion is reduced.

[0058] Figure 6(a) shows a further modified intensity profile in which high-intensity regions 200 are again hatched. Not only is there a central region 202 of low intensity, but also a number of radially extending regions 204. Putting it another way, the high intensity region 200 is angularly segmented. As can be seen in Figure 6(b), the spacing and orientation of these low intensity regions 204 is matched to the spacing and orientation of the vanes 142 in RFT 140. Moreover, the intensity profile is provided with a rotation 206 synchronized with the rotation 148 of RFT 140 itself, so that the regions 204 remain matched to the positions of the vanes as they rotate in operation. Consequently, even less of the high-intensity radiation impinges on any part of the RFT 140. The problems of heating, energy loss and back-reflection are reduced even further than in the example of Figure 5. Note that the radially-extending regions 204 of low intensity might be provided without providing a separate central region 202 of low intensity. The radially extending regions do not in principle need to extend the full radial extent of the profile in order to gain some benefit. For practical purposes, however, we envisage both types of regions

will be provided, with the radially extending regions extending from the optical axis to the outer periphery of the profile.

[0059] Figures 7 and 8 illustrate profiles similar to those of Figures 5 and 6, but where the structure of the RFT 140 is modified to take advantage of the low intensity region 202 at the center of the new intensity profile. In these embodiments, a modified RFT 140' has a hub 144' in the form of a ring so as to leave a space around the optical axis. Provided the low intensity region 202 at the center of the intensity profile is large enough and the intensity low enough, the amount of material in the hub 144' and within the central space can be substantial, without causing the loss of laser power, heating or back-reflection that would be incurred with a more conventional intensity profile.

[0060] The profile with low-intensity regions, particularly in the central region 202, enables greater freedom in the design of the RFT and its associated bearings, drive arrangement 150 and cooling system 152. Generally, in the mechanical design of the RFT 140', the modified hub 144' can perform a more structural role, improving stiffness of the vanes and reducing the burden on rim 146. In the case of Figure 8, the vanes 142 do not need to be so flat or thin to avoid blocking the radiation. The stronger hub 144' can play a role in the bearing and/or drive arrangements, where the hub 144 of the first RFT 140 cannot. The central space within hub 144' and space generally around the optical axis O in front of and behind the RFT 140' can be used to house components of the drive arrangement 150 and cooling system 152.

[0061] It will be appreciated that some modification of the beam delivery system 130 (or 63 in the example of Figure 2) is needed in order to achieve the profiles shown in Figures 5 to 8. As it is desired to use fully the radiation power in the laser beam 131, the modified beam delivery system 130 is designed to shape the profile to have low intensity regions 202 and/or 204 without simply sacrificing a corresponding portion of the energy in the beam. In the examples to be described, one or more axicon devices are used in the beam delivery system, as will now be illustrated and described with reference to Figures 9 and 10.

[0062] Figure 9 illustrates the basic concept of a beam profiler 220 for forming the intensity profiles with high and low intensity regions 200, 202, without loss of radiation. It should be understood that the beam profiled can either be provided in the path of laser beam 131 as a self-contained unit, or one or more elements of the beam profiler 220 can be integrated with existing elements in the beam delivery system 130, including the folding mirror 133. As is well known to

the skilled reader, a single optical element can be designed to perform more than one function, and the same principle applies in the design of the beam delivery system here. For example, a single element might perform a focusing function, a beam deflecting function, a filtering function and more. For simplicity of explanation, each function may be considered as if it were performed by a single-purpose element. Likewise, functions explained in terms of refractive elements may in general be implemented equivalently by reflective elements and/or diffractive elements. Of course, practical concerns may dictate a particular choice, without detracting from the general concept. These comments should be borne in mind in order to appreciate the range of possible structures envisaged within the following description.

[0063] The beam profiler 220 comprises in this example a dual axicon arrangement having a first axicon element 222 and a second axicon element 224. These are supported a certain distance apart along the optical axis O in the path of main pulse laser beam 131. The form of an axicon is generally an optical element similar to a prism wedge, but with a wedge profile that increases or decreases radially away from the optical axis, rather than in a single linear direction. Figure 10(a) illustrates the basic form of an axicon, which has a conical surface 226. Figure 10(b) shows a modified axicon element 224' having not a conical surface but a pyramidal surface, comprising individual wedge-like facets. Such an element can be made by assembling together pie-slice segments cut from a simple linear wedge, or it may be formed by grinding from a single piece of material. In the dual-axicon arrangement shown, the first axicon element 222 has a thickness increasing away from the optical axis, while second element 224 has a thickness decreasing away from the axis. Thus, second element 224 (or 224') has the form illustrated in Figure 10(a) (or Figure 10(b)), while in the first element 222 (not illustrated) the form of the conical (or pyramidal) surface is inverted (concave). As mentioned already, the elements may also incorporate focusing functions, filtering functions and the like. The first element may for example be integrated with a beam expander of the laser beam delivery system 130. The second element may be integrated with the folding mirror 133. Returning to the cross-sectional diagram of Figure 9, the effect of the axicon elements on the beam 131 can be seen. The incoming beam 131a from the laser has, for the sake of description, a uniform intensity profile. A certain amount of energy within it is represented by the block arrows. Upon passing through first axicon element 222, the radiation is diverted into beam 131b in which all rays are divergent from the optical axis with a certain angle. This opens up a low intensity region around the optical axis. The second

axicon element 224 cancels the divergence of the rays so that outgoing beam 131c has rays that are again parallel to the axis O. It will be appreciated that outgoing beam 131c has an intensity profile comprising a high intensity region 200 surrounding a low intensity region 202 centered on the optical axis O. The radial extent of the region 202 is a function of the wedge angles of the elements 222, 224 and the axial distance between them. If the spacing is made adjustable, the size of the central region 202 can be adjustable also. While it is illustrated that the axicon arrangement is in a part of the beam path where the rays are parallel, this is not essential. Rather one or both of the axicon elements may be located in a part of the beam that is being expanded, or is converging to focus at the plasma formation position 73/132.

[0064] The principles of using zoom axicons to generate an annular beam profile have been described in U.S. Patent No. 5,675,401. In U.S. Patent No. 5,675,401, a zoom axicon arrangement is applied in an optical lithographic apparatus to shape the illumination profile of the radiation beam used to illuminate the patterning device (MA in Figure 1). The apparatus in that case is a conventional DUV lithography apparatus, not one having an LPP source for EUV radiation. Nevertheless, some techniques applicable in the design of that illumination system may be applicable in the present laser beam delivery system 130 for generating a plasma as an EUV radiation source. For example, the patent illustrates the integration of axicon and focusing functions in a single element.

[0065] Depending whether the axicon elements 222 and 224 have the purely conical profiles (Figure 10(a)) or the pyramidal profiles (Figure 10(b)), the intensity profile may be circularly symmetric, as shown in Figures 5 and 7, or radially segmented as shown in Figures 6 and 8. Because the low intensity region 202 is created by diverging the rays, no energy is lost, as represented by the block arrows. In the case of the segmented profile being generated using pyramidal axicons, radially extending regions of low intensity open up gradually as the rays diverge in the beam 131b between the two elements. The outgoing beam 131c has the profile illustrated in Figure 6 and 8.

[0066] In the case of the segmented profile, and assuming that the debris trap in question is a rotating foil trap, a drive arrangement 250 is provided for the axicon arrangement 220. This rotates the pyramidal elements synchronously with the rotation of the foil trap, as described above with reference to Figures 6 and 8. Elements 222 and 224 are shown mounted in a common support for rotation by a single motor. They may of course be mounted independently in

different parts of the beam delivering arrangement 130, and each provided with its own synchronized drive arrangement. While an eight-faceted element 224' is illustrated in Figure 10(b), it will be understood that the element used to provide the profile in Figure 6(a) would have twelve facets. Further, in a real example, the number of facets may be much greater than eight or twelve. According to the number of vanes 142 in the RFT 140.

[0067] Where multiple foil traps are used in cascade, for example to have two counter-rotating traps or rotating and stationary traps, multiple stationary and/or rotating axicon arrangements may be provided in cascade to ensure that the intensity of radiation is lowest wherever a foil vane or other part of the structure or ancillary apparatus is located in the beam path. Elements of the different arrangements may be integrated where possible. The first and second elements of the different arrangements may be interleaved or nested, rather than having to follow in sequence. Additional low-intensity regions may be provided besides central and/or radially extending regions. For example by providing an annular low intensity region one might allow additional bracing between vanes to be provided at a radius somewhere between the hub and the rim. Naturally, the additional complexity required to segment the beam in so many ways, and the small loss of energy incurred in each optical element, means it may not be justified to design a fully comprehensive network of low-intensity regions. It may be tolerated that one or more components is within the higher intensity region 200 for some or all of the time.

[0068] Figures 11 and 12 illustrate alternative axicon arrangements based on reflective elements rather than the refractive elements 222 and 224 shown in Figure 9. As mentioned earlier, optical elements used in the beam delivering system 130 may be refractive, diffractive or reflective, and the same applies to the axicon elements 222, 224. Conical and pyramidal mirrors can be substituted for the prisms shown in Figure 9. For example, Figure 11 illustrates a beam delivering system having a first reflective axicon element 322 and a second reflective axicon element 324. Drive arrangements can be provided to rotate the mirrors, in the case where they are pyramidal and the foil trap is rotating. The second axicon element 324 has an aperture through which the incoming beam 131a passes before hitting the first element 322. Figure 12 illustrates an arrangement based on the same principles but with a beam folding function integrated within it. Yet other arrangements are possible which combine reflective and refractive elements. Diffractive elements have already been mentioned as a further alternative that may be used. Either exclusively or in combination with refractive and/or reflective optics.

[0069] In conclusion, the techniques and arrangements described above enable the provision of beam delivering systems in LPP radiation sources, in which debris traps such as foil traps can be used without the problems that would otherwise be expected in loss of energy, heating, and/or back-reflection. This in turn enables new configurations of the EUV radiation apparatus, for example of the form shown in Figure 3, with the prospect of greater production of useable EUV radiation for lithography and other purposes.

[0070] Although specific reference may be made in this text to the provision and operation of an EUV radiation source in a lithographic apparatus, it should be understood that the EUV radiation apparatus described herein may have other applications in EUV optical apparatus. Further, the beam delivery system with debris trap can be applied in other applications of laser energy beams, where debris might be expected.

[0071] Further in the case of a lithographic apparatus, this may have other applications besides the manufacture of ICs, such as the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, liquid-crystal displays (LCDs), thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms “wafer” or “die” herein may be considered as synonymous with the more general terms “substrate” or “target portion”, respectively. The substrate referred to herein may be processed, before or after exposure, in for example a track (a tool that typically applies a layer of resist to a substrate and develops the exposed resist), a metrology tool and/or an inspection tool. Where applicable, the EUV radiation apparatus may be applied to such and other substrate processing tools. Further, the substrate may be processed more than once, for example in order to create a multi-layer IC, so that the term substrate used herein may also refer to a substrate that already contains multiple processed layers.

[0072] The term “lens”, where the context allows, may refer to any one or combination of various types of optical components, including refractive, reflective, magnetic, electromagnetic and electrostatic optical components.

[0073] While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The descriptions above are intended to be illustrative, not limiting. Thus it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below.

WHAT IS CLAIMED IS:

1. A beam delivery apparatus for delivering laser radiation through a debris trap located in the path of the laser radiation to a target location, the apparatus comprising:
a plurality of optical components arranged to receive said laser radiation having an incoming intensity distribution and to output said laser radiation with a modified intensity distribution, said modified intensity distribution comprising substantially all the energy of the incoming radiation, with regions of low intensity corresponding to the locations of parts of said debris trap.
2. An apparatus as claimed in claim 1, wherein said modified intensity distribution includes a low intensity region in a central region including an optical axis of the beam delivery apparatus.
3. An apparatus as claimed in claim 1 or 2, wherein said modified intensity distribution includes a plurality of low intensity regions, each low intensity region extending radially around an optical axis of the beam delivery apparatus.
4. An apparatus as claimed in claim 3, wherein said optical components are of a number and spacing so as to coincide with radially extending parts of said debris trap.
5. An apparatus as claimed in claim 3, wherein one or more of said optical components are arranged to rotate during operation synchronously with rotation of parts of said debris trap so that said radially extending regions of low intensity remain oriented with said radially extending parts of said debris trap.
6. An apparatus as claimed in any preceding claim, wherein said optical components include one or more axicon elements having generally conical or part-conical surfaces.
7. An apparatus as claimed in any preceding claim, wherein said optical components include one or more axicon elements have pyramidal or faceted surfaces so as to cause said modified intensity profile to include a plurality of low intensity regions, each low intensity region extending radially around an optical axis of the beam delivery apparatus.

8. An apparatus as claimed in claim 1 or 2, wherein one or more of said optical components are arranged to move during operation synchronously with movement of said parts of said debris trap so that said radially extending regions of low intensity remain coincident with said radially extending parts of said debris trap.

9. A beam delivery apparatus as claimed in any preceding claim, further comprising said debris trap and wherein said beam delivery apparatus is arranged such that said low intensity regions within the intensity distribution are substantially coincident with structural elements of said debris trap.

10. An apparatus as claimed in claim 9, wherein said debris trap is a rotating foil trap and said beam delivery apparatus is arranged to rotate said intensity distribution synchronously with rotation of said rotating foil trap.

11. A plasma generating apparatus comprising a beam delivery apparatus as claimed in any preceding claim, a fuel delivery system for delivering a stream of fuel to a target location, and a debris trap, wherein the beam delivery apparatus is configured to deliver laser radiation to said target location via said debris trap and with said regions of low intensity being coincident with the corresponding parts of said debris trap, so as to generate a plasma of said fuel material at said target location.

12. An EUV radiation apparatus comprising a plasma generating apparatus as claimed in claim 11 and an optical system for collecting EUV radiation emitted by said plasma and delivering said radiation to an intermediate focus point.

13. An EUV radiation apparatus as claimed in claim 12, wherein both said intermediate focus point and said beam delivery apparatus are both located with the debris trap between them and the target location.

14. An EUV optical apparatus comprising an EUV radiation apparatus as claimed in claim 12 and an EUV optical system for receiving said EUV radiation via said intermediate focus point and using said EUV radiation to perform one or more operations.

15. A lithographic apparatus, comprising an EUV optical apparatus as claimed in claim 14, said EUV optical system comprising

- an illumination system configured to condition the beam of radiation;
- a support constructed to support a patterning device, the patterning device being capable of imparting the beam of radiation with a pattern in its cross-section to form a patterned beam of radiation;
- a substrate table constructed to hold a substrate; and
- a projection system configured to project the patterned beam of radiation onto a target portion of the substrate.

16. A method of delivering laser radiation to a target location, wherein a debris trap located in the path of said laser radiation, the method comprising receiving incoming laser radiation and modifying an intensity distribution of said laser radiation prior to said debris trap, the modified intensity distribution comprising substantially all the energy of the incoming radiation, with regions of low intensity corresponding to the locations of parts of said debris trap.

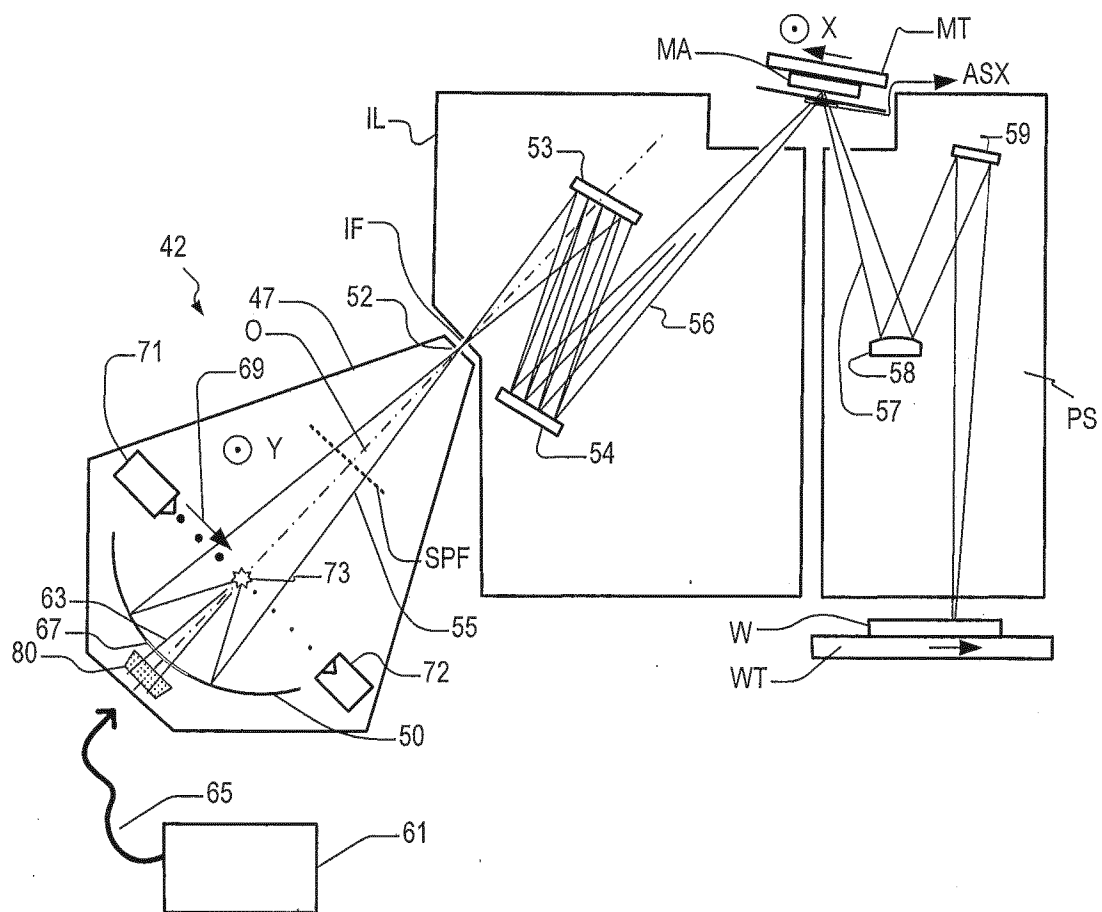
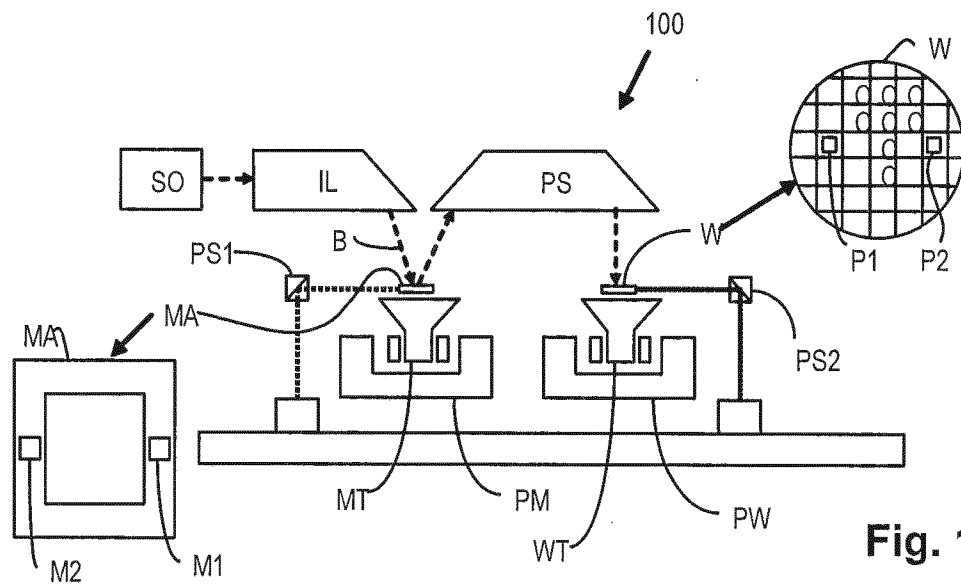
17. A method as claimed in claim 16, wherein said modified intensity distribution includes a low intensity region in a central region corresponding to has a central hub portion of said debris trap.

18. A method as claimed in claim 16 or 17, wherein said debris trap has a plurality of parts extending radially from a central axis and rotating about the axis, and wherein said modified intensity distribution includes a corresponding plurality of radially extending regions of low intensity that rotate so as to remain oriented with said radially extending parts of said debris trap.

19. A method as claimed in any of claims 16 to 19, wherein said modified intensity profile is created using one or more axicon elements having pyramidal or faceted surfaces and arranged to rotate about the axis.

20. A method as claimed in claim 15, wherein said at least part of said debris trap is moving during delivery of the laser beam, and regions of low intensity corresponding to the moving parts are made to move synchronously with the debris trap movement so as to remain coincident with those parts.

1/6



2/6

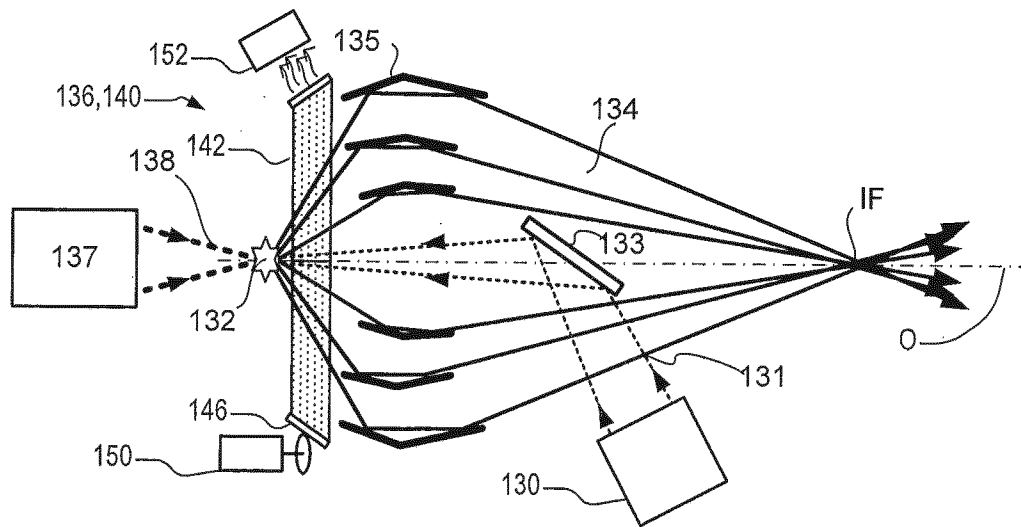


Fig. 3

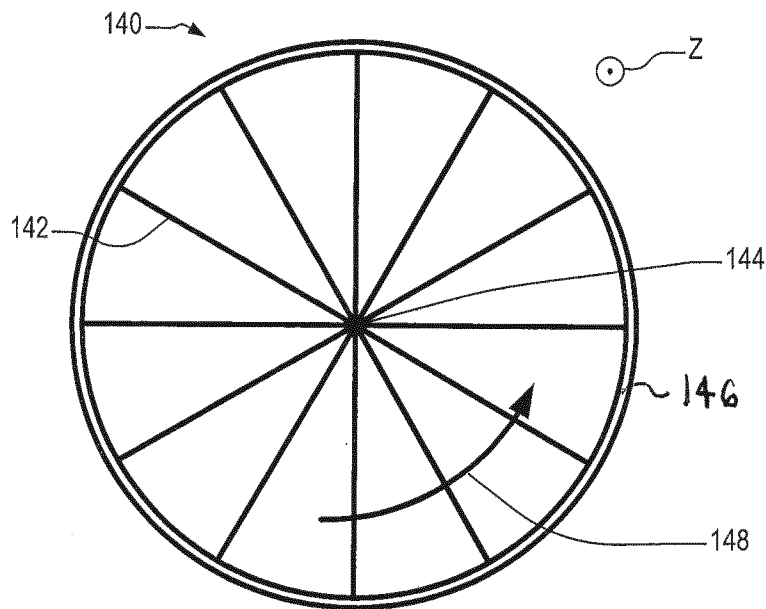


Fig. 4

3/6

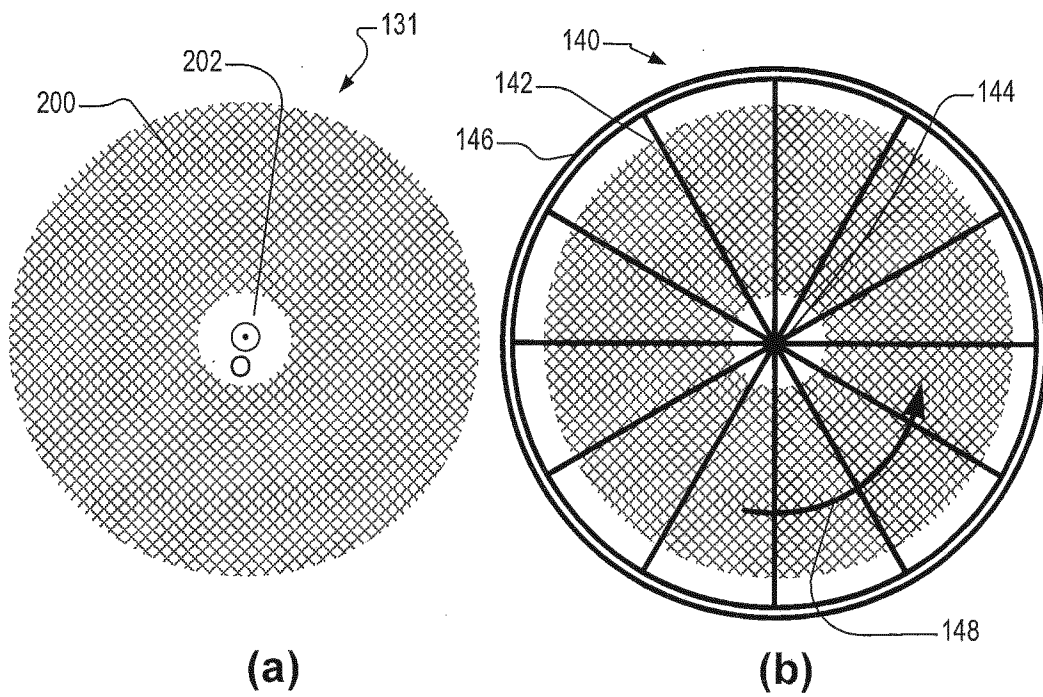


Fig. 5

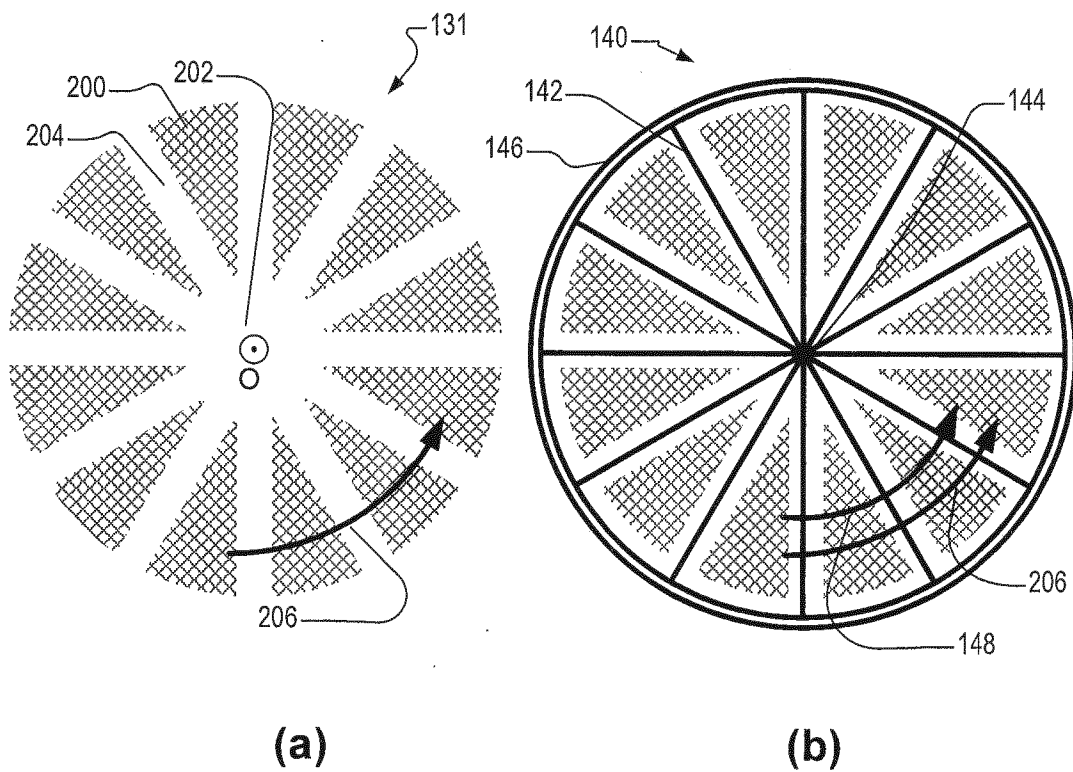


Fig. 6

4/6

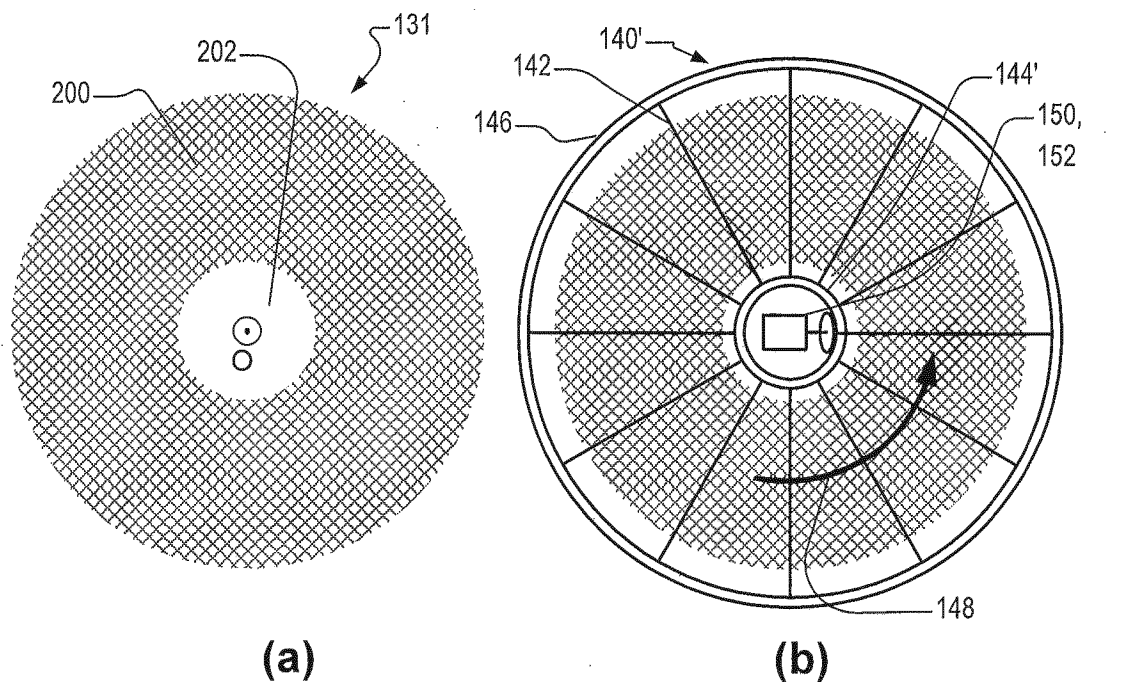


Fig. 7

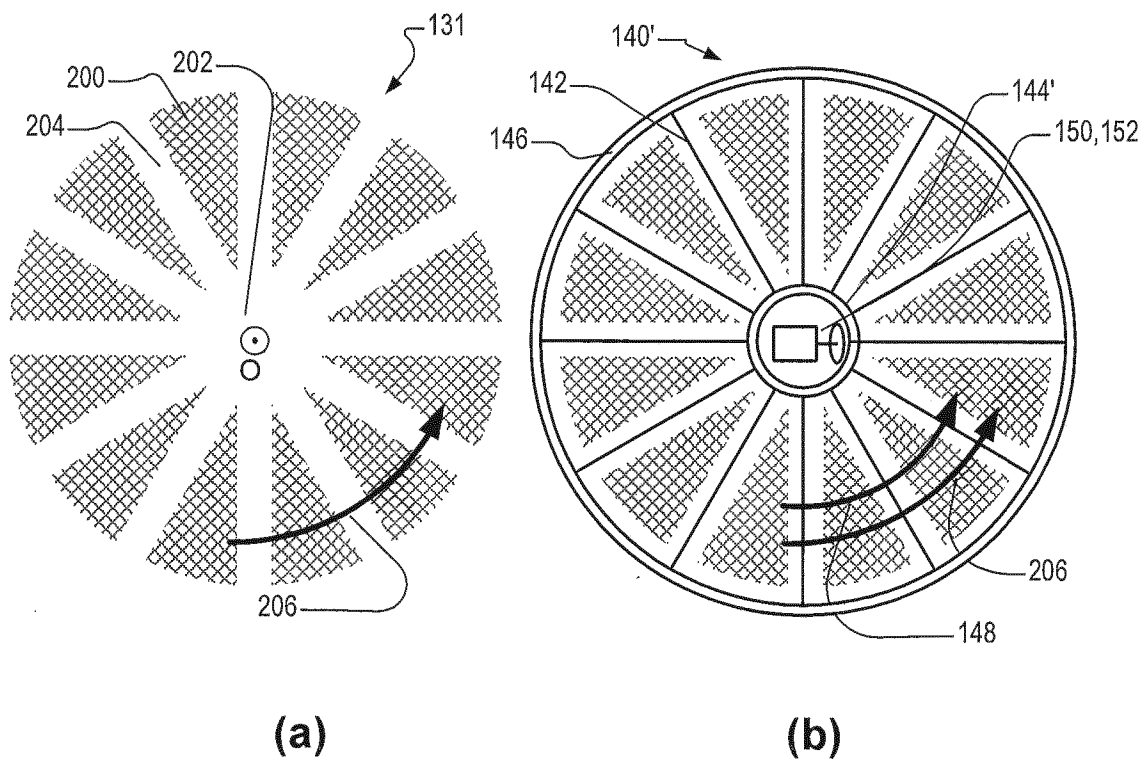


Fig. 8

5/6

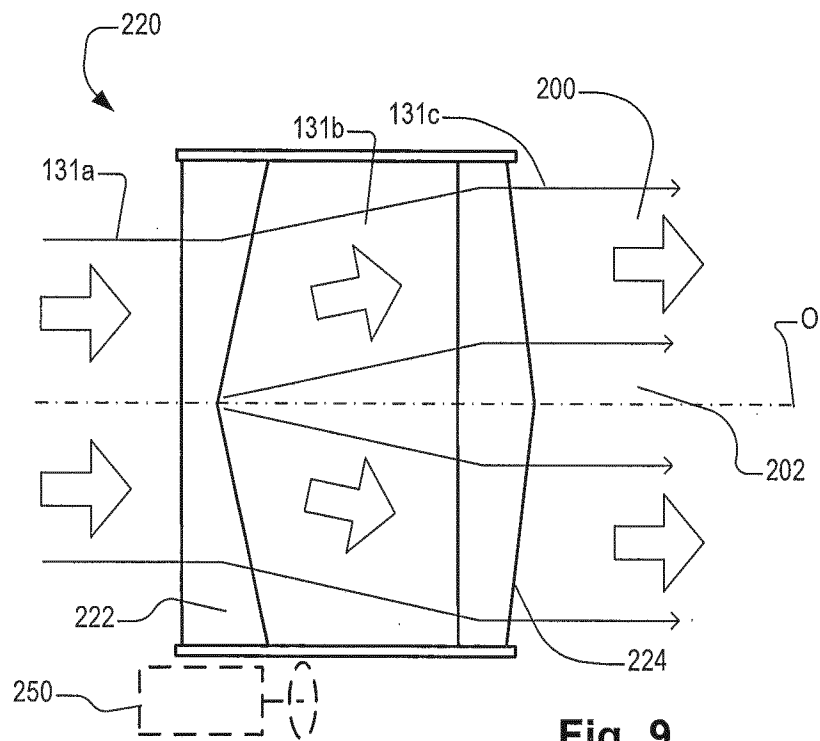


Fig. 9

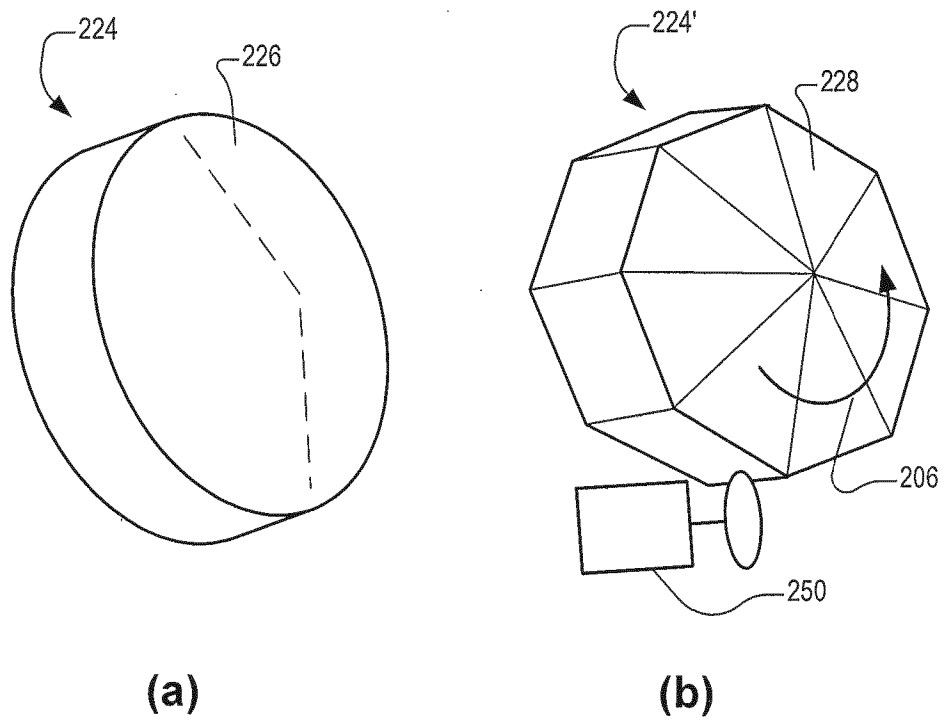


Fig. 10

6/6

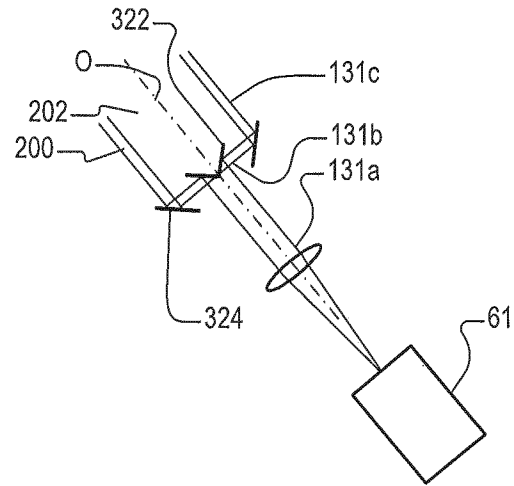


Fig. 11

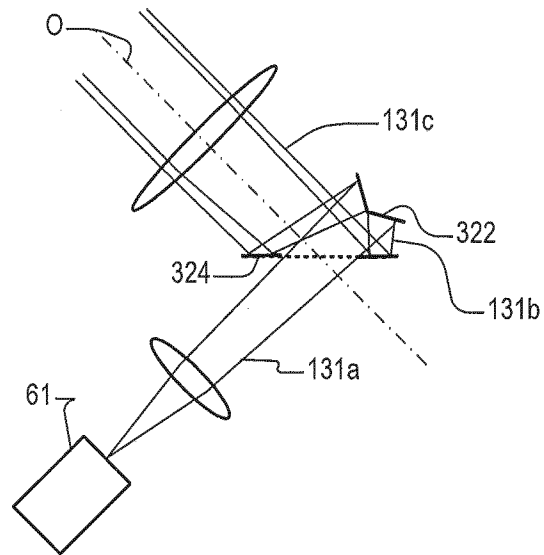


Fig. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/074713

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03F7/20 H05G2/00
ADD.

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 G02B G03F H01L H05G

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 practicable, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 486 316 A2 (NIPPON KOGAKU KK [JP]) 20 May 1992 (1992-05-20) abstract; figures 1, 10 page 12, line 17 - line 31 -----	1-5,7,8
X	EP 2 182 412 A1 (ASML NETHERLANDS BV [NL]) 5 May 2010 (2010-05-05) abstract; figure 3 paragraphs [0001], [0069] - [0074] -----	1-4,6,7
X	EP 1 734 408 A1 (PHILIPS INTELLECTUAL PROPERTY [DE]; KONINKL PHILIPS ELECTRONICS NV [NL] 20 December 2006 (2006-12-20) paragraph [0020]; figure 2 ----- -/-	1-3,5, 8-10



Further documents are listed in the continuation of Box C.



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 application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

21 February 2014

Date of mailing of the international search report

07/03/2014

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Heryet, Chris

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/074713

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/069898 A1 (GIGAPHOTON INC [JP]; WAKABAYASHI OSAMU [JP]) 31 May 2012 (2012-05-31)	1,2,6
Y	abstract; figures 1-4 paragraphs [0040], [0042] -----	11,12, 14,15
X	EP 2 113 813 A1 (ASML NETHERLANDS BV [NL]) 4 November 2009 (2009-11-04)	16
Y	paragraphs [0041] - [0045] figures 2, 3 -----	11,12, 14,15
Y	US 2012/050704 A1 (LEVESQUE RICHARD A [US] ET AL) 1 March 2012 (2012-03-01) paragraphs [0001], [0031], [0033] figures 4, 5A -----	13,17-20
Y	ANONYMOUS: "Methods for Final Focus Lens Protection and Control in an EUV Source", RESEARCH DISCLOSURE, vol. 579, no. 24, 14 June 2012 (2012-06-14), XP007141424, Killernan, Kilmaine, County Mayo, Ireland ISSN: 0374-4353 paragraphs [0001] - [0006] -----	13,17-20
A,P	ANONYMOUS: "Research Disclosure", RESEARCH DISCLOSURE, vol. 594, no. 67, 23 September 2013 (2013-09-23), XP055102388, Killernan, Kilmaine, County Mayo, Ireland ISSN: 0374-4353 the whole document -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/074713

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0486316	A2	20-05-1992	DE 69132120 D1 25-05-2000
			DE 69132120 T2 21-09-2000
			EP 0486316 A2 20-05-1992
			EP 0967524 A2 29-12-1999
EP 2182412	A1	05-05-2010	EP 2182412 A1 05-05-2010
			JP 5087060 B2 28-11-2012
			JP 2010114442 A 20-05-2010
			JP 2013008683 A 10-01-2013
			US 2010110405 A1 06-05-2010
EP 1734408	A1	20-12-2006	NONE
WO 2012069898	A1	31-05-2012	JP 2012114294 A 14-06-2012
			US 2013153794 A1 20-06-2013
			WO 2012069898 A1 31-05-2012
EP 2113813	A1	04-11-2009	EP 2113813 A1 04-11-2009
			JP 4907690 B2 04-04-2012
			JP 2009267408 A 12-11-2009
			US 2009272916 A1 05-11-2009
US 2012050704	A1	01-03-2012	DE 102011111244 A1 15-03-2012
			JP 2012049526 A 08-03-2012
			US 2012050704 A1 01-03-2012