

CLAIMS

1. A method for determining the relative position of an element of an optical system of an assembly for processing or measuring an object along a predetermined measurement line associated with the system, characterized in that it comprises the steps of:
- 5 - generating a measurement low coherence optical radiation beam, leading said measurement beam along said measurement line towards said element, and leading the measurement beam reflected or diffused by a back-reflective surface of said element on which said measurement beam impinges with an at least partial back-reflection, towards
- 10 optical interferometric sensor means, wherein the measurement beam travels a measurement optical path from a respective source to said optical interferometric sensor means including a first section between said source and said back-reflective surface of said element and a second section between said back-reflective surface of said element and the interferometric sensor means, having a respective predetermined nominal geometric length when said
- 15 element is in a predetermined nominal position corresponding to a predetermined operating condition of said system,
- generating a respective reference beam of said low coherence optical radiation, and leading said reference beam towards said optical interferometric sensor means, wherein the reference beam comprises a main reference beam which results from the travel of a main
- 20 reference optical path having an optical length equivalent to the optical length of the measurement optical path in a nominal operating condition in which the position of said element is the predetermined nominal position, and at least one additional multiplexed reference beam which results from the travel of an additional reference optical path having a geometric length different from the geometric length of said main reference optical path in
- 25 an operating condition in which the position of said element is a predetermined modified position;
- superimposing the measuring beam and the reference beam on at least a common region of incidence of said optical interferometric sensor means, along a predetermined illumination axis;
- 30 detecting along said illumination axis on said common region of incidence the position of a main pattern of interference fringes between the measurement beam and the main reference beam, wherein the extension of said pattern of interference fringes along the

- illumination axis corresponds to the coherence length of said low coherence optical radiation, and of an additional pattern of interference fringes between the measurement beam and the additional reference beam having (i) a peak or maximum of intensity of the envelope of the optical radiation different from the peak or maximum of intensity of the envelope of the optical radiation of the main pattern of interference fringes, or (ii) an intrinsic position of the intensity envelope of the optical radiation offset from the intrinsic position of the intensity envelope of the optical radiation of the main pattern of interference fringes, or (iii) a spatial frequency different from the spatial frequency of the main pattern of interference fringes, or
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- 10 - detecting on said common region of incidence the frequency of a pattern of fringes in the wavelength spectrum, obtained from the main interference between the measurement beam and the main reference beam by wavelength dispersion of said beams, the extension of which in the frequency domain is determined by the coherence length of said low coherence optical radiation, and by an additional pattern of interference fringes between the measurement beam and the additional reference beam (i) having a frequency different from the frequency of the main pattern of interference fringes, or (ii) determined by the superposition of the measurement and additional reference beams on an area of said common region different from the overlapping area of the measurement and main reference beams; and
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- 20 - determining a difference in optical length between the measurement optical path and the reference optical path or the additional reference optical path - indicative of a difference between (a) the current position of said element and (b) the predetermined nominal position or the predetermined modified position, respectively, of said element along the axis of the measurement beam - as a function respectively of the position of said pattern of interference fringes or of said additional pattern of interference fringes along said axis of illumination of said region of incidence, or of the frequency of said pattern of interference fringes or of said additional pattern of interference fringes in the frequency domain.
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2. A method for determining the separation distance between a working tool or a measuring instrument and an at least partially reflective surface of an object external thereto along a predetermined measurement line associated with at least a proximal portion of the
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tool, respectively of the instrument, with respect to the surface of the object, characterized in that it includes the steps of:

- generating an measurement low coherence optical radiation beam, leading said measurement beam towards said object surface through said proximal portion of the tool or
5 instrument, and leading the measurement beam reflected or diffused from the surface of the object through said proximal portion of the tool or instrument and towards optical interferometric sensor means, wherein the measurement beam travels a measurement optical path from a respective source to said optical interferometric sensor means including a first section between said source and said proximal portion of the tool or instrument and a second
10 section between said proximal portion of the tool or instrument and the interferometric sensor means, having a respective predetermined and invariant geometric length,
 - generating a respective reference beam of said low coherence optical radiation, and leading said reference beam towards said optical interferometric sensor means, wherein the reference beam comprises a main reference beam which results from the travel of a main
15 reference optical path having an optical length equivalent to the optical length of the measurement optical path in a nominal operating condition in which the distance between the proximal portion of the tool or instrument and the surface of the object corresponds to a predetermined nominal separation distance and at least one additional multiplexed reference beam which results from the travel of an additional reference optical path having a geometric
20 length different from the geometric length of said main reference optical path in an operating condition in which the distance between the proximal portion of the tool or instrument and the surface of the object corresponds to a predetermined modified separation distance;
 - superimposing the measurement beam and the reference beam on at least a common region of incidence of said optical interferometric sensor means, along a predetermined
25 illumination axis;
- detecting along said illumination axis on said common region of incidence the position of a main pattern of interference fringes between the measurement beam and the main reference beam, wherein the extension of said pattern of interference fringes along the illumination axis corresponds to the coherence length of said low coherence optical
30 radiation, and of an additional pattern of interference fringes between the measurement beam and the additional reference beam having (i) a peak or maximum of intensity of the envelope of the optical radiation different from the peak or maximum of intensity of the envelope of

- the optical radiation of the main pattern of interference fringes, or (ii) an intrinsic position of the intensity envelope of the optical radiation offset from the intrinsic position of the intensity envelope of the optical radiation of the main pattern interference fringes, or (iii) a spatial frequency different from the spatial frequency of the main pattern of interference fringes, or
- 5 fringes, or
- detecting on said common region of incidence the frequency of a pattern of fringes in the wavelength spectrum, obtained from the main interference between the measurement beam and the main reference beam, by wavelength dispersion of said beams, the extension of which in the frequency domain is determined by the coherence length of said low
 - 10 coherence optical radiation, and of an additional pattern of interference fringes between the measurement beam and the additional reference beam (i) having a frequency different from the frequency of the main pattern of interference fringes, or (ii) determined by the superposition of the measurement and additional reference beams on an area of said common region different from the overlapping area of the measurement and main reference beams;
 - 15 and
 - determine a difference in optical length between the measurement optical path and the reference optical path or the additional reference optical path - indicative of a difference between (a) the current separation distance between the proximal portion of the tool or instrument and the surface of the object and (b) the predetermined nominal separation
 - 20 distance, or respectively the predetermined modified separation distance - as a function respectively of the position of said pattern of interference fringes or of said additional pattern of interference fringes along said illumination axis of said region of incidence, or of the frequency of said pattern of interference fringes or of said additional pattern of interference fringes in the frequency domain.
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3. The method according to claim 1 or 2, wherein said main reference optical path and said additional reference optical path are superimposed at least for a portion and impinge co-linearly on a common region of incidence of said optical interferometric sensor means.
- 30 4. The method of claim 3, wherein said additional reference optical path includes at least a partial back-reflection at the surface of an optical element interposed along the optical path of the main reference beam.

5. The method of claim 3, wherein said additional reference optical path includes at least a back-reflection internal to an optical element interposed along the optical path of the main reference beam.
- 5 6. The method of claim 3, wherein said additional reference optical path includes a path section deflected with respect to the optical path of the main reference beam.
7. The method of claim 6, wherein said deflected path section is obtained by interposing
10 an optical element for the partial extraction of the reference beam from the optical path of the main reference beam and an optical element for the reintroduction of the extracted reference beam into the beam in the optical path of the main reference beam.
8. The method of claim 7, wherein said optical element for the beam partial extraction
15 is a beam splitting optical device.
9. The method according to claim 7, wherein said optical element for the beam partial extraction is a prism adapted to control the optical length of the section of the deflected path with continuity.
- 20 10. The method according to claim 1 or 2, wherein said main reference optical path and said additional reference optical path impinge on respective different areas of said common region of incidence of the optical interferometric sensor means.
- 25 11. The method according to any one of the preceding claims, wherein said optical interferometric sensor means comprise an arrangement of photodetectors along said illumination axis, and said arrangement of photodetectors is a linear arrangement of photodetectors.
- 30 12. The method according to any one of claims 1 to 10, wherein said optical interferometric sensor means comprise an arrangement of photodetectors along said

illumination axis, and said arrangement of photodetectors is a two-dimensional arrangement of photodetectors.

13. A method for determining the relative position of an element of an optical system of an assembly for processing or measuring an object along a predetermined measurement line associated with the system, characterized in that it comprises the steps of:
- generating a measurement low coherence optical radiation beam of, leading said measurement beam along said measurement line towards said element, and leading the measurement beam reflected or diffused by a back-reflective surface of said element on which said measurement beam impinges with at least a partial back-reflection, towards optical interferometric sensor means, wherein the measurement beam travels a measurement optical path from a respective source to said optical interferometric sensor means including a first section between said source and said back-reflective surface of said element, and a second section between said back-reflective surface of said element and the interferometric sensor means, having a respective predetermined nominal geometric length when said element is in a predetermined nominal position corresponding to a predetermined operating condition of said system, and comprises a main measurement beam which results from the travel of a main measurement optical path with transmission through each optical element interposed upstream of said element along the measurement line and an additional multiplexed measurement beam resulting from the travel of an additional measurement optical path having a geometric length different from the geometric length of said main measurement optical path;
 - generating a respective reference beam of said low coherence optical radiation, and leading said reference beam towards said optical interferometric sensor means, wherein the reference beam travels a reference optical path having an optical length equivalent to the optical length of the main measurement optical path in a nominal operating condition in which the position of said element is the predetermined nominal position;
 - superimposing the measurement beam and the reference beam on at least one common region of incidence of said optical interferometric sensor means, along a predetermined illumination axis;
- detecting along said illumination axis on said common region of incidence the position of a main pattern of interference fringes between the main measurement beam and

- the reference beam, wherein the extension of said pattern of interference fringes along the illumination axis corresponds to the coherence length of said low coherence optical radiation, and of an additional pattern of interference fringes between the additional measurement beam and the reference beam having (i) a peak or maximum of intensity of the envelope of the optical radiation different from the peak or maximum of intensity of the envelope of the optical radiation of the main pattern of interference fringes, or (ii) an intrinsic position of the intensity envelope of the optical radiation offset from the intrinsic position of the intensity envelope of the optical radiation of the main pattern of interference fringes, or (iii) a spatial frequency different from the spatial frequency of the main pattern of interference fringes, or
- 5 - detecting on said common region of incidence the frequency of a pattern of fringes in the wavelength spectrum, obtained from the main interference between the main measurement beam and the reference beam by wavelength dispersion of said beams, the extension of which in the frequency domain is determined by the coherence length of said low coherence optical radiation, and of an additional pattern of interference fringes between the additional measurement beam and the reference beam (i) having a frequency different from the frequency of the main pattern of interference fringes, or (ii) determined by the superposition of the additional measurement and reference beams on an area of said common region different from the overlapping zone of the main measurement and reference beams;
- 10 and
- 15 - determining a difference in optical length between the measurement optical path or the additional measurement optical path and the reference optical path - indicative of a difference between (a) the current position of said element and (b) the predetermined nominal position of said element along the axis of the measurement beam - as a function respectively of the position of said pattern of interference fringes or of said additional pattern of interference fringes along said illumination axis of said region of incidence, or of the frequency of said pattern of interference fringes or said additional pattern of interference fringes in the frequency domain.
- 20 25 30 14. A method for determining the separation distance between a working tool or a measuring instrument and an at least partially reflective surface of an object external thereto along a predetermined measurement line associated with at least a proximal portion of the

tool, respectively of the instrument, with respect to the surface of the object, characterized in that it includes the steps of:

- generating a measurement low coherence optical radiation beam , leading said measurement beam towards said object surface through said proximal portion of the tool or
5 instrument, and leading the measurement beam reflected or diffused from the surface of the object through said proximal portion of the tool or instrument and towards optical interferometric sensor means, wherein the measurement beam travels a measurement optical path from a respective source to said optical interferometric sensor means including a first section between said source and said proximal portion of the tool or instrument and a second
10 section between said proximal portion of the tool or instrument and the interferometric sensor means, having a respective predetermined and invariant geometric length, and comprises a main measurement beam that results from the travel of a main measurement optical path with transmission through each optical element interposed upstream of said tool or instrument along the measurement line and an additional multiplexed measurement beam
15 which results from the travel of an additional measurement optical path having a geometric length different from the geometric length of said main measurement optical path;
- generating a respective reference beam of said low coherence optical radiation, and leading said reference beam towards said optical interferometric sensor means, wherein the reference beam travels a reference optical path having an optical length equivalent to the
20 optical length of the main measurement optical path in a nominal operating condition in which the distance between the proximal portion of the tool or instrument and the surface of the object corresponds to a predetermined nominal separation distance;
- superimposing the measurement beam and the reference beam on at least one common region of incidence of said optical interferometric sensor means, along a
25 predetermined illumination axis;
- detecting along said illumination axis on said common region of incidence the position of a main pattern of interference fringes between the main measurement beam and the reference beam, wherein the extension of said pattern of interference fringes along the illumination axis corresponds to the coherence length of said low coherence optical
30 radiation, and of an additional pattern of interference fringes between the additional measurement beam and the reference beam having (i) a peak or maximum of intensity of the envelope of the optical radiation different from the peak or maximum of intensity of the

envelope of the optical radiation of the main pattern of interference fringes, or (ii) an intrinsic position of the intensity envelope of the optical radiation offset from the intrinsic position of the intensity envelope of the optical radiation of the main pattern of interference fringes, or (iii) a spatial frequency different from the spatial frequency of the main pattern of interference fringes, or

5 - detecting on said common region of incidence the frequency of a pattern of fringes in the wavelength spectrum, obtained from the main interference between the main measurement beam and the reference beam by wavelength dispersion of said beams, the extension of which in the frequency domain is determined by the coherence length of said
10 low coherence optical radiation, and of an additional pattern of interference fringes between the additional measurement beam and the reference beam (i) having a frequency different from the frequency of the main pattern of interference fringes, or (ii) determined by the superposition of the additional measurement and reference beams on an area of said common region different from the overlapping zone of the main measurement and reference beams;
15 and

 - determining a difference in optical length between the measurement optical path or the additional measurement optical path and the reference optical path - indicative of a difference between (a) the current separation distance between the proximal portion of the tool or instrument and the surface of the object and (b) the predetermined nominal separation
20 distance - as a function respectively of the position of said pattern of interference fringes or of said additional pattern of interference fringes along said illumination axis of said region of incidence, or the frequency of said pattern of interference fringes or said additional pattern of interference fringes in the frequency domain.

25 15. The method according to claim 13 or 14, wherein said main measurement optical path and said additional measurement optical path are superimposed at least for a portion and impinge co-linearly on a common region of incidence of said optical sensor interferometric means.

30 16. The method of claim 15, wherein said additional measurement optical path includes at least a partial back-reflection at the surface of an optical element interposed along the optical path of the main measurement beam.

17. The method of claim 15, wherein said additional measurement optical path includes at least a back-reflection within an optical element interposed along the optical path of the main measurement beam.

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18. The method of claim 15, wherein said additional measurement optical path includes a path section deflected from the optical path of the main measurement beam.

19. The method of claim 18, wherein said deflected path section is obtained by interposing an optical element for the partial extraction of the measurement beam from the optical path of the main measurement beam and an optical element for the reintroduction of the extracted measurement beam in the beam in the optical path of the main measurement beam.

20. The method of claim 19, wherein said optical element for the beam partial extraction is a beam splitting optical device.

21. The method according to claim 19, wherein said optical element for the beam partial extraction is a prism adapted to control the optical length of the section of the deviated path with continuity.

22. The method according to claim 13 or 14, wherein said main measurement optical path and said additional measurement optical path impinge on respective different areas of said common region of incidence of the optical interferometric sensor means.

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23. A method for determining the position of a plurality of elements at least partially reflecting an optical radiation in a system including a plurality of optical components of a processing or measurement assembly, or including at least one optical element of a processing or measurement assembly and an object external thereto and subject to said processing or measurement, wherein said plurality of at least partially reflective elements is arranged along a predetermined common measurement line, characterized in that it comprises the steps of:

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- generating a measurement low-coherence optical radiation beam, leading said measurement beam along said measurement line towards a plurality of elements of the system, and leading the measurement beam reflected or diffused from a back-reflective surface of each element on which said measurement beam impinges with at least a partial back-reflection, towards optical interferometric sensor means, wherein the measurement beam travels a measurement optical path from a respective source to said optical interferometric sensors means including a first section between said source and said back-reflective surface of each element, and a second section between said back-reflective surface of each element and the interferometric sensor means, having a respective predetermined nominal geometric length when each element is in a respective predetermined nominal position corresponding to a predetermined operating condition of said system, and comprises a first measurement beam which results from the travel of a first measurement optical path with reflection from a first element along the measurement line and a second multiplexed measurement beam which results from the travel of a second measurement optical path with reflection from a second element along the measurement line, having a geometric length different from the geometric length of said first measurement optical path;
- generating a respective reference beam of said low coherence optical radiation, and leading said reference beam towards said optical interferometric sensor means, wherein the reference beam comprises a first reference beam which results from the travel of a first reference optical path having an optical length equivalent to the optical length of the first measurement optical path in a nominal operating condition in which the position of said first element is the respective predetermined nominal position, and a second multiplexed reference beam which results from the travel of a second reference optical path having a geometric length different from the geometric length of said first reference optical path in an operating condition in which the position of said second element is the respective predetermined nominal position;
- superimposing the first and second measurement beams respectively on the first and second reference beams on at least one common region of incidence of said optical interferometric sensor means, along a predetermined illumination axis;
- detecting along said illumination axis on said common region of incidence the position of a first pattern of interference fringes between the first measurement beam and the first reference beam, wherein the extension of said pattern of interference fringes along the

- illumination axis corresponds to the coherence length of said low coherence optical radiation, and of a second pattern of interference fringes between the second measurement beam and the second reference beam having (i) a peak or maximum of intensity of the envelope of the optical radiation different from the peak or maximum of intensity of the envelope of the optical radiation of the first pattern of interference fringes, or (ii) an intrinsic position of the intensity envelope of the optical radiation offset from the intrinsic position of the intensity envelope of the optical radiation of the first pattern of interference fringes, or (iii) a spatial frequency different from the spatial frequency of the first pattern of interference fringes, or
- 5 - detecting on said common region of incidence the frequency of a first pattern of fringes in the wavelength spectrum, obtained by the interference between the first measurement beam and the first reference beam by wavelength dispersion of said beams, whose extension in the frequency domain is determined by the coherence length of said low coherence optical radiation, and of a second pattern of interference fringes between the second measurement beam and the second reference beam (i) having a frequency different from the frequency of the first pattern of interference fringes, or (ii) determined by the superposition of the first measurement and reference beams on an area of said common region different from the overlapping area of the first measurement and reference beams; and
- 10 - determining:
- (i) a difference in optical length between the first measurement optical path and the first reference optical path - indicative of a difference between (a) the current position of said first element and (b) the predetermined nominal position of said first element along the axis of the measurement beam - as a function respectively of the position of said first pattern of interference fringes along said illumination axis of said region of incidence, or of the frequency of said first pattern of interference fringes in the frequency domain; and
- 15 (ii) a difference in optical length between the second measurement optical path and the second reference optical path - indicative of a difference between (a) the current position of said second element and (b) the predetermined nominal position of said second element along the axis of the measurement beam - as a function respectively of the position of said second pattern of interference fringes along said illumination axis of said region of
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incidence, or of the frequency of said second pattern of interference fringes in the frequency domain.

24. Machine for laser processing of a material, operating by means of a processing laser
5 beam conducted along an optical path for transporting the laser beam comprising an optical system, characterized in that it comprises a system for determining the relative position of an element of said optical system, arranged to carry out a method according to claim 1 or 13.

25. Machine for laser processing of a material, operating by means of a processing laser
10 beam conducted along an optical path for transporting the laser beam comprising a processing tool or a measuring instrument, characterized in that it comprises a system for determining the separation distance between said processing tool or said measuring instrument and the at least partially reflective surface of an object external thereto, arranged to carry out a method according to claim 2 or 14.

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