WHAT IS CLAIMED IS:

1. A metrology apparatus configured to measure properties of a plurality of targets on a substrate, each target being formed by overlying gratings that have been patterned in different layers on the substrate, the apparatus comprising:

a source configured to emit an illumination beam of radiation;

an objective lens configured to direct a measurement beam of radiation onto the targets on the substrate and to collect radiation diffracted by the targets; and

a sensor configured to detect an image of the targets;

wherein the source objective lens and sensor are arranged so that the illumination beam simultaneously illuminates the targets and the image of the targets that is detected by the sensor is formed by one first order diffracted beam; and the apparatus further comprises:

an image processor configured to identify separate images of respective ones of the targets in the image detected by the sensor; and

a controller configured to derive a measurement of a property by comparing a plurality of intensity values derived respectively from a plurality of separate images of respective targets derived for a single image detected by the sensor.

2. An apparatus according to claim 1, wherein the image processor comprises a pattern recognizer.

3. An apparatus according to claim 2, wherein the pattern recognizer is configured to recognize an array of four or more separate images.

4. An apparatus according to claim 1, 2 or 3, wherein the controller is further configured to determine an overlay error between layers of the substrate in which parts of the target are formed from the determined intensity values.

5. An apparatus according to claim 4, wherein the controller is configured to determine overlay on the basis of the following equation:

$$\left[I_{+1^{st}\ diffraction\ order} - I_{-1^{st}\ diffraction\ order}\right](overlay) \quad = \quad \sum_{n}^{N} K_n \cdot \sin\left(\frac{2\pi \cdot n}{pitch}\, overlay\right).$$

6. An apparatus according to any of claims 1 to 5 wherein the controller is further configured to determine the position of said target images within an image field of the sensor, and to apply a correction in the determined intensity or overlay value by reference to the determined position.

7. An apparatus according to any one of claims 1 to 6, wherein the targets include a first grating having a first bias and a second grating having a second bias, the second bias being different from the first bias.

8. An apparatus according to any one of claims 1 to 7, further comprising an aperture stop between the objective lens and the sensor, the aperture stop being configured to block the zeroth order of radiation diffracted by the targets.

9. An apparatus according to claim 8, wherein the aperture stop is configured to pass substantially only one first order of radiation diffracted by the targets.

10. A lithographic apparatus comprising:

an illumination optical system arranged to illuminate a pattern;

a projection optical system arranged to project an image of the pattern onto a substrate; and

a metrology device according to any one of claims 1 to 9.

11. An apparatus according to claim 10, including an exposure station, a measurement station and a substrate table moveable between the exposure station and the measurement station, wherein the metrology device is positioned at the measurement station.

12. A lithographic cell comprising a lithographic apparatus, at least one process device, a substrate handler and a metrology device according to any one of claims 1 to 9.

13. A method of measuring a properties of a plurality of targets on a substrate, each target being formed by overlying gratings that have been patterned in different layers on the substrate, the method comprising:

generating an illumination beam;

directing the illumination beam as a measurement beam onto the targets using an objective lens so that the measurement beam simultaneously illuminates the targets;

collecting radiation diffracted by the target using the objective lens;

detecting an image of the targets the image being formed by only one first order diffracted beam; and

identifying separate images of respective ones of the targets in the detected image; and

deriving a measurement of a property by comparing a plurality of intensity values derived respectively from a plurality of separate images of respective targets derived for a single image detected by the sensor.

14. A method according to claim 13, wherein the identifying is performed by a pattern recognizer.

15. A method according to claim 14, wherein the pattern recognizer is configured to recognize an array of four or more separate images.

16. A method according to claim 15, further comprising determining an overlay error between layers of the substrate in which parts of the target are formed from the determined intensity values.

17. A method according to claim 16, wherein the determining an overlay error is performed on the basis of the following equation:

$$\left[I_{+1^{st}\ diffraction\ order} - I_{-1^{st}\ diffraction\ order}\right](overlay) = \sum_{n}^{N} K_n \cdot \sin\left(\frac{2\pi \cdot n}{pitch} overlay\right).$$

18. A method according to any of claims 13 to 17 wherein a correction is applied in the determined intensity or overlay value in accordance with the position of each target image within the detected image.

19. A method according to any one of claims 13 to 18, wherein the targets include a first grating having a first bias and a second grating having a second bias, the second bias being different from the first bias.

20. A method according to any one of claims 13 to 19, further comprising blocking the zeroth order of radiation diffracted by the targets between the objective lens and a sensor used to detect the image.

21. A method according to any one of claims 13 to 18, further comprising allowing substantially only one first order of radiation diffracted by the targets to reach a sensor used to detect the image.

CLAIMS

1. An apparatus comprising:

an objective lens configured to direct a beam of radiation onto targets on a substrate and to collect radiation diffracted by the targets;

a sensor configured to detect an image of the targets; and

an image processor configured to identify separate images of respective ones of the targets in the image detected by the sensor,

wherein the source, the objective lens, and the sensor are arranged so that the beam substantially simultaneously illuminates the targets and so that the image of the targets that is detected by the sensor is formed by one first order diffracted beam.

2. The apparatus of claim 1, wherein the image processor comprises a pattern recognizer.

3. The apparatus of claim 2, wherein the pattern recognizer is configured to recognize an array of four or more separate images.

4. The apparatus of claim 1, further comprising a controller configured to determine an intensity value from each of the separate images.

5. The apparatus of claim 4, wherein the controller is further configured to determine an overlay error between layers of the substrate in which parts of the target are formed from the determined intensity values.

6. The apparatus of claim 5, wherein the controller is configured to determine overlay on based on:

$$\left[I_{+1^{st}\ diffraction\ order} - I_{-1^{st}\ diffraction\ order}\right](overlay) = \sum_{n}^{N} K_n \cdot \sin\left(\frac{2\pi \cdot n}{pitch}\, overlay\right).$$

7. The apparatus according to claim 4, wherein the controller is further configured to determine the position of said target images within an image field of the sensor, and to apply a correction in the determined intensity or overlay value by reference to the determined position.

8. The apparatus of claim 1, wherein the source and the objective lens are arranged to illuminate the targets in an off-axis illumination mode.

9. The apparatus of claim 8, wherein the off-axis illumination mode consists essentially of a single pole.

10. The apparatus of claim 8, wherein the off-axis illumination mode consists essentially of a first pole and a second pole.

11. The apparatus of claim 10, wherein the first pole is located on a first axis of the pupil plane and the second pole is located on a second axis of the pupil plane, the first and second axes being orthogonal.

12. The apparatus of claim 10, wherein the targets comprise at least one grating having lines perpendicular to the first axis and at least one grating having lines perpendicular to the second axis.

13. The apparatus of claim 1, wherein the targets include a first grating having a first bias and a second grating having a second bias, the second bias being different from the first bias.

14. The apparatus of claim 1, further comprising an aperture stop between the objective lens and the sensor, the aperture stop being configured to block the zeroth order of radiation diffracted by the targets.

15. The apparatus of claim 14, wherein the aperture stop is configured to pass substantially only one first order of radiation diffracted by the targets.

16. A lithographic apparatus comprising:

an illumination optical system arranged to illuminate a pattern;

a projection optical system arranged to project an image of the pattern onto a substrate; and

a metrology device comprising,

an objective lens configured to direct a beam of radiation onto targets on the substrate and to collect radiation diffracted by the targets;

a sensor configured to detect an image of the targets; and

an image processor configured to identify separate images of respective ones of the targets in the image detected by the sensor,

wherein the source, the objective lens, and the sensor are arranged so that the beam substantially simultaneously illuminates the targets and so that the image of the targets that is detected by the sensor is formed by one first order diffracted beam.

17. The apparatus of claim 16, further comprising:

an exposure station;

a measurement station; and

a substrate table moveable between the exposure station and the measurement station,

wherein the metrology device is positioned at the measurement station.

18. A lithographic cell comprising:

a lithographic apparatus;

at least one process device;

a substrate handler; and

a metrology device comprising,

an objective lens configured to direct a beam of radiation onto targets on a substrate and to collect radiation diffracted by the targets;

a sensor configured to detect an image of the targets; and

an image processor configured to identify separate images of respective ones of the targets in the image detected by the sensor,

wherein the source, the objective lens, and the sensor are arranged so that the beam substantially simultaneously illuminates the targets and

so that the image of the targets that is detected by the sensor is formed by one first order diffracted beam.

19. A method comprising:

directing an illumination beam as a measurement beam onto targets using an objective lens so that the measurement beam substantially simultaneously illuminates the targets;

collecting radiation diffracted by the targets using the objective lens;

detecting an image of the targets, the image being formed by only one first order diffracted beam; and

identifying separate images of respective ones of the targets in the detected image.

20. The method of claim 19, wherein the identifying is performed by a pattern recognizer.

21. The method of claim 20, wherein the pattern recognizer is configured to recognize an array of four or more separate images.

22. The method of claim 19, further comprising determining an intensity value from each of the separate images.

23. The method of claim 22, further comprising determining an overlay error between layers of the substrate in which parts of the target are formed from the determined intensity values.

24. The method of claim 23, wherein the determining an overlay error is based on:

$$\left[I_{+1^{st}\ diffraction\ order} - I_{-1^{st}\ diffraction\ order}\right](overlay) \;=\; \sum_{n}^{N} K_n \cdot \sin\left(\frac{2\pi \cdot n}{pitch}\, overlay\right).$$

25. The method according to claim 22, wherein a correction is applied in the determined intensity or overlay value in accordance with the position of each target image within the detected image.

26. The method of claim 19, wherein the illumination beam is directed onto the targets in an off-axis illumination mode.

27. The method of claim 26, wherein the off-axis illumination mode consists essentially of a single pole.

28. The method of claim 26, wherein the off-axis illumination mode consists essentially of a first pole and a second pole.

29. The method of claim 28, wherein the first pole is located on a first axis of the pupil plane and the second pole is located on a second axis of the pupil plane, the first and second axes being orthogonal.

30. The method of claim 29, wherein the targets comprise at least one grating having lines perpendicular to the first axis and at least one grating having lines perpendicular to the second axis.

31. The method of claim 19, wherein the targets include a first grating having a first bias and a second grating having a second bias, the second bias being different from the first bias.

32. The method of claim 19, further comprising blocking the zeroth order of radiation diffracted by the targets between the objective lens and a sensor used to detect the image.

33. The method of claim 19, further comprising allowing substantially only one first order of radiation diffracted by the targets to reach a sensor used to detect the image.