Claims

1. An apparatus for monitoring positions on an external object provided with at least one beacon (1(i), i = 1, 2, …, I; 130; 430), the apparatus comprising:
At least one image sensor (120; 321, 322; 420; 520);
At least one non-refractive optical element (101) arranged as objective for projecting light on said image sensor (120);
A processing unit (9);
Said processing unit (9) being arranged such as to allow communication with a memory (15) storing a computer program comprising instructions and data, which computer program can be run by the processing unit (9);
Said at least one non-refractive optical element (101) being configured to receive at least one light beam (5(i); 131) transmitted from said at least one beacon (1(i); 130; 430) and project said at least one light beam (5(i); 131) on said image sensor (120; 321, 322; 420; 520);
Said image sensor (120; 321, 322; 420; 520) being arranged to form image data based on said received at least one light beam (5(i); 131) and background light; and
Said processing unit (9) being arranged to process said image data such that it filters image data components relating to said background light and renders image data components relating to said at least one light beam;
wherein the at least one non-refractive optical element comprises a diffractive element diffracting the at least one light beam to form a diffracted light pattern on the image sensor.

2. The apparatus according to claim 1, wherein the non-refractive optical element (101) comprises at least one of a pinhole (102), two or more pinholes, one or more slits, one or more zone plates, one or more holographic optical elements, one or more masks, including binary masks, coding masks and wave front coding masks.

3. The apparatus according to claim 2, wherein the one or more zone plates (430; 436; 470; 474) are one of a Fresnel zone plate, a zone plate with a plurality of circular shaped concentric transparent rings (432; 438), and a zone plate with one or more concentric arcuate or circular transparent rings (444) of which at least one covers less than a complete circle.

4. The apparatus according to any one of the preceding claims, wherein the image sensor comprises a two-dimensional image sensor.

5. The apparatus according to any one of the preceding claims, wherein the apparatus is provided with a thermostat (103) coupled to the processing unit (9), the processing unit (9) being arranged to control the temperature of the at least one non-refractive optical element (101) by means of the thermostat (103).

6. The apparatus according to any one of the preceding claims, wherein the imaging sensor is at least one of a NMOS image sensor, digital photon counter DPC based image sensor, multi pixel photon counter MPPC based image sensor, CCD image sensor, CMOS image sensor and APD image sensor.

7. The apparatus according to any one of the preceding claims, wherein said processing unit is arranged to identify a specific, unique pattern in said image data and identifying the at least one beacon (1(i); 130; 430).

8. The apparatus according to any one of the preceding claims, wherein said processing unit is arranged to apply at least one of a high pass filtering on said image data such as to measure a noise floor, a low pass filtering to said image data such as to render image data components relating only to locked-on smart beacon signals, and a flat-field compensation algorithm.

9. The apparatus according to any one of the preceding claims, wherein said apparatus comprises additional optics (105) in front of said non-refractive optical element (101), such as at least one of a cover lens (620), a cone mirror for equatorial view, an off-axis cone mirror for wide-angle view, convex mirrors for near hemi-sphere view, off-axis convex mirrors for wide-angle view, a colour filter, and an interferometric filter.

10. The apparatus according to any of the preceding claims, wherein said processing unit (9) is arranged to

- identify said at least one beacon (1(i); 130; 430) within the image data based on the at least one light beam (5(i); 131),
- determine current location data of said at least one beacon (1(i); 130; 430) based on said image data,

- compare said current location data with former location data of said at least one beacon (1(i); 130; 430) as stored in said memory (15) and
- to determine whether said object has moved relative to a fixed reference frame based on said comparison.

11. The apparatus according to any one of the preceding claims, wherein the image sensor comprises a plurality of light sensitive elements arranged in a two-dimensional matrix forming a camera's image plane and wherein the non-refractive optical element comprises a pin hole.

12. The apparatus according to any one of the preceding claims, wherein the image sensor comprises a line sensor having plurality of light sensitive elements arranged in a one-dimensional matrix, and wherein the non-refractive optical element comprises a slit.

13. The apparatus according to claim 12, wherein the slit is oriented perpendicular to a line sensor longitudinal direction.

14. The apparatus according to any of the preceding claims, comprising one or more extra light sources (700) arranged optically behind the non-refractive optical element and arranged to illuminate the image sensor in order to create a bias in light sensing elements of said image sensor.

15. The apparatus according to any one of the preceding claims, provided with a housing comprising at least one wall (600) surrounding a void (610), wherein the image sensor (120) is mounted within the void, and wherein the housing is closed by a front wall or cover in which the non-refractive optical element is provided.

16. The apparatus according to claim 15, wherein the front wall or cover is sealed with a transparent cover (620).

17. An apparatus for monitoring positions on an external object provided with at least one beacon (1(i), i = 1, 2, …, I), the apparatus comprising:
An image sensor (120);
At least one non-refractive optical element (101) arranged as objective for projecting light on said image sensor (120);
A processing unit (9);

Said processing unit (9) being arranged such as to allow communication with a memory (15) storing a computer program comprising instructions and data, which computer program can be run by the processing unit (9);

Said non-refractive optical element (101) being arranged to receive at least one light beam (5(i)) transmitted from said at least one beacon (1(i)) and project said at least one light beam (5(i)) on said image sensor (120);

wherein the at least one non-refractive optical element comprises a diffractive element diffracting the at least one light beam to form a diffracted light pattern on the image sensor;

Said image sensor (120) being arranged to form image data based on said received at least one light beam (5(i)); and

Said processing unit (9) being arranged to

identify said at least one beacon (1(i)) within the image data based on the at least one light beam (5(i)),

determine current location data of said at least one beacon (1(i)) based on said image data,

compare said current location data with former location data of said at least one beacon (1(i)) as stored in said memory (15) and

to determine whether said object has moved relative to a fixed reference frame based on said comparison.

18. The apparatus according to any of the preceding claims, wherein said processing unit (9) is arranged to identify said at least one beacon (1(i)) based on image processing of said image data.

19. The apparatus according to claim 18, wherein said processing unit (9) is arranged to perform image processing of said image data based on Fourier transformation.

20. The apparatus according to claim 18, wherein said processing unit (9) is arranged to perform image processing of said image data based on correlation or autocorrelation.

21. The apparatus according to any of the preceding claims, wherein the fixed reference frame is defined relative to the earth.

22. The apparatus according to any of the preceding claims, wherein the processing unit (9) is arranged to determine light intensity and/or wavelength of said at least one light

beam (5(i)) based on said image data, and to derive additional data as transmitted by said at least one beacon (1(i)) which modulated said light intensity and/or wavelength.

23. The apparatus according to claim 22, wherein said non-refractive optical element (101) is arranged to receive a consecutive series of light beams (5(i)) transmitted from said at least one beacon (1(i)) and transfer said consecutive light beams (5(i)) to said image sensor (120); said image sensor (120) is arranged to form consecutive pieces of image data based on said received consecutive light beams (5(i)); and said processing unit is arranged to determine consecutive light intensities and/or wavelength of said consecutive light beams (5(i)) based on said consecutive pieces of image data, and to demodulate said consecutive light intensities and/or wavelength to derive said additional data.

24. The apparatus according to claim 23, wherein said consecutive light intensities and/or wavelength are modulated by one of amplitude modulation, frequency modulation, and phase modulation.

25. The apparatus according to any of the preceding claims, wherein the apparatus comprises a light generating system (21) connected to the processing unit (9), the processing unit (9) being arranged to control said light generating system (21) to generate and transmit at least one outgoing light beam (6(i)) with a modulated light intensity and/or wavelength such as to contain outgoing additional data.

26. An apparatus for communicating with at least one external beacon (1(i), i = 1, 2, …, I), the apparatus comprising:

A processing unit (9);

At least one non-refractive optical element (101) connected to the processing unit (9);

An image sensor (120) connected to the processing unit (9) and to the non-refractive optical element (101);

Said processing unit being arranged such as to allow communication with a memory (15) storing a computer program comprising instructions and data, which computer program can be run by the processing unit (9);

Said non-refractive optical element (101) being arranged as an objective to receive at least one light beam (5(i)) transmitted from said at least one external beacon (1(i)) and project said at least one light beam (5(i)) on said image sensor (120), wherein the at

least one non-refractive optical element comprises a diffractive element diffracting the at least one light beam to form a diffracted light pattern on the image sensor;

Said image sensor (120) being arranged to form image data based on said received at least one light beam (5(i)); and

Said processing unit being arranged to determine light intensity and/or wavelength of said at least one light beam (5(i)) based on said image data, and to derive additional data as transmitted by said at least one beacon (1(i)) which modulated said light intensity and/or wavelength.

27. The apparatus according to claim 26, wherein said non-refractive optical element is arranged to receive a consecutive series of light beams (5(i)) transmitted from said at least one external beacon (1(i)) and transfer said consecutive light beams (5(i)) to said image sensor (120); said image sensor (120) is arranged to form consecutive pieces of image data based on said received consecutive light beams (5(i)); and said processing unit is arranged to determine consecutive light intensities and/or wavelengths of said consecutive light beams (5(i)) based on said consecutive pieces of image data, and to demodulate said consecutive light intensities and/or wavelengths to derive said additional data.

28. The apparatus according to claim 27, wherein said consecutive light intensities and/or wavelengths are modulated by one of amplitude modulation, frequency modulation, and phase modulation.

29. System comprising an apparatus according to any one of the preceding claims and one or more beacons, said beacon comprising:

A processing unit (25);

A light generating system (29) connected to the processing unit (25);

A memory (27) storing a computer program comprising instructions and data, which computer program can be run by the processing unit (25);

Said processing unit (25) being arranged to control said light generating system (29) to transmit an outgoing light beam with a modulated light intensity and/or wavelength, wherein the outgoing light beam may be modulated such as to contain outgoing additional data.

30. Method for monitoring positions on an external object provided with at least one beacon (1(i), i = 1, 2, …, I; 130; 430), the method comprising:

- transmitting light from said at least one beacon;
- projecting the light transmitted from said at least one beacon on at least one image sensor (120; 321, 322; 420; 520) using at least one non-refractive optical element (101) arranged as objective for projecting light on said image sensor (120), the at least one non-refractive optical element comprising a diffractive element, wherein projecting light onto the at least one image sensor comprises forming a diffracted light pattern on the image sensor using the diffractive element; and
- processing image data formed by said image sensor such as to filter image data components relating to background light and render image data components relating to said at least one light beam.

31. The method according to claim 30, further comprising:
determining angular positions of the at least one beacon by reconstructing the optical pathway between the non-refractive optical element and the image sensor in dependence of the angular positions of the at least one beacon in respect of the non-refractive optical element by using an algorithm using laws of diffractive optics in an iterative algorithm.

32. The method according to claim 30 or 31, wherein random noise or noise having a pre-determined pattern is added to each pixel of said image data before digitization.

33. The method according to any one of claims 30 to 32, further comprising calibrating non-linearity of each pixel of said image data and compensating for the non-linearity such as to make each pixel linear in said image processing.