

Claims

1. An apparatus for monitoring positions on an external object having at least one beacon (1(i), $i = 1, 2, \dots, I$; 130; 430) attached to it, the apparatus comprising:
At least one image sensor (120; 321, 322; 420; 520);
5 At least one non-refractive optical element (101) 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
10 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 transfer said at least one light beam (5(i); 131) to said image sensor (120; 321, 322; 420; 520);
15 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.
- 20 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 are one
25 of a Fresnel zone plate, and a zone plate with one or more concentric arcuate transparent rings of which at least one covers less than a complete circle.
4. The apparatus according to claim 1, 2 or 3, 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
30 element (101) by means of the thermostat (103).
5. The apparatus according to any of the claims 1-4, 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.

6. The apparatus according to any of the claims 1-5, 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).
7. The apparatus according to any of the claims 1-6, 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.
8. The apparatus according to any of the claims 1-7, 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.
9. The apparatus according to any of the claims 1-8, 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 one or more beacons (1(i); 130; 430) as stored in said memory (15) and
 - to determine whether said object has moved relative to said fixed reference frame based on said comparison.
10. The apparatus according to any of claims 1 to 9, 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.

11. The apparatus according to any of claims 1 to 9, 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.
- 5 12. The apparatus according to claims 11, wherein the slit is oriented perpendicular to a line sensor longitudinal direction.
13. 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 small bias
10 in light sensing elements of said image sensor.
14. An apparatus for monitoring positions on an external object having at least one beacon (1(i), i = 1, 2, ..., I) attached to it, the apparatus comprising:
An image sensor (11);
A lens system (13) for projecting light on said image sensor (11);
15 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 lens system (13) being arranged to receive at least one light beam (5(i))
20 transmitted from said at least one beacon (1(i)) and transfer said at least one light beam (5(i)) to said image sensor (11);
Said image sensor (11) 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
25 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 one or
30 more beacons (1(i)) as stored in said memory (15) and
to determine whether said object has moved relative to said fixed reference frame based on said comparison.

15. 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.
16. The apparatus according to claim 15, wherein said processing unit (9) is arranged
5 to perform image processing of said image data based on Fourier transformation.
17. The apparatus according to claim 15, wherein said processing unit (9) is arranged to perform image processing of said image data based on correlation or autocorrelation.
18. The apparatus according to any of the preceding claims, wherein the fixed
10 reference frame is defined relative to the earth.
19. 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
15 and/or wavelength.
20. The apparatus according to claim 19, wherein said lens system (13) 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 light detector (11); said light detector (11) is arranged to form consecutive pieces of
20 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.
- 25 21. The apparatus according to claim 20, wherein said consecutive light intensities and/or wavelength are modulated by one of amplitude modulation, frequency modulation, and phase modulation.
22. 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
30 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.

23. An apparatus for communicating with at least one external beacon (1(i), $i = 1, 2, \dots, I$), the apparatus comprising:
- 5 A processing unit (9);
A lens system (13) connected to the processing unit (9);
A light detector (11) connected to the processing unit (9) and to the lens system (13);
Said processor being arranged such as to allow communication with a memory (15)
10 storing a computer program comprising instructions and data, which computer program can be run by the processing unit (9);
Said lens system (13) being arranged to receive at least one light beam (5(i)) transmitted from said at least one external beacon (1(i)) and transfer said at least one light beam (5(i)) to said light detector (11);
15 Said light detector (11) 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
20 said light intensity and/or wavelength.
24. The apparatus according to claim 23, wherein said lens system (13) 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 light detector (11); said light detector (11) is arranged to form consecutive pieces of
25 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.
- 30 25. The apparatus according to claim 24, wherein said consecutive light intensities and/or wavelengths are modulated by one of amplitude modulation, frequency modulation, and phase modulation.

26. A beacon 1(i)) 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,
5 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 such as to contain outgoing additional data.
27. The beacon according to claim 26, wherein said processing unit (25) is arranged to
10 control said light generating system (29) to transmit a consecutive series of outgoing light beams (5(i)) each having its own outgoing light intensity and/or wavelength, which outgoing light intensity and/or wavelength is modulated over time, e.g. by one of amplitude modulation, frequency modulation, and phase modulation.
- 15 28. The beacon according to claim 26 or 27, wherein said beacon comprises
A light detector (33) connected to the processing unit (25);
Said light detector (33) being arranged to receive at least one light beam transmitted from at least one external light source (21);
Said light detector (33) being arranged to form command data based on said
20 received at least one light beam; and
Said processing unit (25) being arranged to determine light intensity of said at least one light beam based on said command data, and to derive additional data as transmitted by said at least one external light source (21) which modulated said light intensity and/or wavelength.
- 25 29. System comprising an apparatus according to any of the claims 1-25 and one or more beacons as defined in any of the claims 26-28.
30. Method of monitoring positions on an object having at least one beacon (1(i), i = 1, 2, ..., I) attached to it, the method comprising:
receiving at least one light beam (5(i)) transmitted from said at least one
30 beacon (1(i));
forming image data based on said received at least one light beam (5(i));

- identifying said at least one beacon (1(i)) within the image data based on at least one light beam (5(i)) received from at least one beacon (1(i)),
determining current location data of said at least one beacon (1(i)) based on said image data,
5 comparing said current location data with former location data of said one or more beacons (1(i)) and
determining whether said object has moved relative to a fixed reference frame based on said comparison.
31. Method of communicating with at least one beacon (1(i), $i = 1, 2, \dots, I$), the method
10 comprising:
receive at least one light beam (5(i)) transmitted from said at least one beacon (1(i));
forming image data based on said received at least one light beam (5(i)); and
determining light intensity and/or wavelength of said at least one light beam
15 (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.