CLAIMS

1. A parallel scanning confocal microscope comprising:

an optical circulator including a first port, a second port and a third port;

a light source optically coupled to the first port of the optical circulator;

an optical arrangement in optical communication with the second port of the optical circulator;

an focusing lens in optical communication with the optical arrangement; and

a photodetector optically coupled to the third port of the optical circulator, wherein

the light source is configured to emit light towards the optical arrangement through the first port and the second port along an illumination path,

the optical arrangement is configured to direct the light as multiple optical beams towards the focusing lens along the illumination path,

the focusing lens is configured to focus the multiple optical beams into multiple illumination points to confocally and simultaneously illuminate a sample under observation by the parallel scanning confocal microscope along the illumination path,

the focusing lens is further configured to collect the light reflected from the sample confocally along a reflection path, and

the optical arrangement is further configured to direct the reflected light towards the photodetector in a form of reflected photons through the second port and the third port along the reflection path.

2. The parallel scanning confocal microscope as claimed in claim 1, wherein the photodetector is a single-pixel photodetector or array detectors.

3. The parallel scanning confocal microscope as claimed in claim 1 or 2, wherein the light source comprises a non-coherent light source, preferably a light emitting diode; and

wherein the optical arrangement is a single spatial light modulator configured to modulate the light in forming the multiple optical beams along the illumination path.

4. The parallel scanning confocal microscope as claimed in claim 3, further comprising a data acquisition unit in electrical communication with the photodetector, wherein the data acquisition unit is configured to acquire and process information based on the reflected photons to generate a reconstructed image of the sample.

5. The parallel scanning confocal microscope as claimed in claim 4, wherein the single spatial light modulator is configured to generate a plurality of time-varying coded patterns based on the light reflected from the sample at pre-determined sampling intervals; and/or

wherein at each pre-determined sampling interval, the photodetector is configured to detect the reflected photons comprising correlated light intensities between each time-varying coded pattern of the plurality of time-varying coded patterns and a target image of the sample.

6. The parallel scanning confocal microscope as claimed in claim 5, wherein

each time-varying coded pattern of the plurality of time-varying coded patterns forms a row of an encoded matrix F,

the target image is represented by a target matrix having a plurality of elements, each element of the target matrix representing a light intensity at a location on the sample and the target matrix being expanded to a vector X,

for M number of pre-determined sampling intervals forming a complete sampling cycle, the reflected photons are represented by a measurement vector S,

where S = FX, to facilitate the generation of the reconstructed image of the sample; and/or

wherein the parallel scanning confocal microscope is configured to perform compressive sensing, and the reflected photons are represented by a modified measurement vector S', where S' = FBθ, to facilitate the generation of the reconstructed image of the sample, B being a known basis of X, and θ being a sparse vector.

7. The parallel scanning confocal microscope as claimed in claim 1or 2, further comprising:

one or more additional optical circulators, each including a first port, a second port and a third port; and

one or more additional photodetectors, each optically coupled to the third port of each of the one or more additional optical circulators, preferably the one or more additional photodetectors comprise one or more additional single-pixel photodetectors, or one or more additional array detectors,

wherein the light source comprises multiple output ports, each output port optically coupled to the first port of each of the one or more additional optical circulators, preferably the light source comprises a light emitting diode or a laser diode,

wherein the optical arrangement is further in optical communication with the second port of each of the one or more additional optical circulators,

wherein for each of the one or more additional optical circulators, the optically coupled output port is configured to emit light towards the optical arrangement through the first port and the second port along the illumination path, and

wherein for each of the one or more additional optical circulators, the optical arrangement is further configured to direct the reflected light towards the optically coupled additional photodetector through the second

port and the third port, along the reflection path, forming a part of the reflected photons.

8. The parallel scanning confocal microscope as claimed in claim 1 or 2, further comprising:

one or more additional optical circulators, each including a first port, a second port and a third port;

one or more additional light sources, each optically coupled to the first port of each of the one or more additional optical circulators, preferably the light source and the one or more additional light sources each comprises a light emitting diode or a laser diode; and

one or more additional photodetectors, each optically coupled to the third port of each of the one or more additional optical circulators, preferably the one or more additional photodetectors comprise one or more additional single-pixel photodetectors, or one or more additional array detectors,

wherein the optical arrangement is further in optical communication with the second port of each of the one or more additional optical circulators,

wherein for each of the one or more additional optical circulators, the optically coupled additional light source is configured to emit light towards the optical arrangement through the first port and the second port along the illumination path,

wherein for each of the one or more additional optical circulators, the optical arrangement is further configured to direct the reflected light towards the optically coupled additional photodetector through the second port and the third port, along the reflection path, forming a part of the reflected photons, and

wherein the light source and the one or more additional light sources are configured to emit the light simultaneously.

9. The parallel scanning confocal microscope as claimed in claim 7 or 8, wherein the optical arrangement comprises

a collimator configured to collimate the light from or to de-collimate the reflected lighted to the second port of each of the optical circulator and the one or more additional optical circulators; and

one or more scanning mirrors in optical communication with the collimator.

10. The parallel scanning confocal microscope as claimed in claim 9, further comprising a data acquisition unit in electrical communication with the photodetector and the one or more additional photodetectors, wherein the data acquisition unit is configured to acquire and process information based on the reflected photons to generate an image of the sample.

11. A parallel scanning confocal microscopy method comprising:

emitting light through a first port and a second port of an optical circulator along an illumination path,

directing the light as multiple optical beams along the illumination path,

focusing the multiple optical beams into multiple illumination points to confocally and simultaneously illuminate a sample under observation along the illumination path,

collecting the light reflected from the sample confocally along a reflection path, and

directing the reflected light in a form of reflected photons through the second port and a third port of the optical circulator along the reflection path.

12. The parallel scanning confocal microscopy method as claimed in claim 19, further comprising acquiring and processing information based on the reflected photons to generate an image of the sample, and/or

prior to the step of directing the reflected light, generating a plurality of time-varying coded patterns based on the light reflected from the sample at pre-determined sampling intervals,

wherein the step of directing the light comprises modulating the light and forming the multiple optical beams along the illumination path.

13. The parallel scanning confocal microscopy method as claimed in claim 12, further comprising detecting, at each pre-determined sampling interval, the reflected photons, wherein the reflected photons comprise correlated light intensities between each time-varying coded pattern of the plurality of time-varying coded patterns and a target image of the sample; and/or

wherein

each time-varying coded pattern of the plurality of time-varying coded patterns forms a row of an encoded matrix F,

the target image is represented by a target matrix having a plurality of elements, each element of the target matrix representing a light intensity at a location on the sample and the target matrix being expanded to a vector X,

for M number of pre-determined sampling intervals forming a complete sampling cycle, the reflected photons are represented by a measurement vector S, where S = FX, to facilitate the generation and reconstruction of the image of the sample.

14. The parallel scanning confocal microscopy method as claimed in claim 13, further comprising performing compressive sensing, wherein the reflected photons are represented by a modified measurement vector S', where S' = FBθ, to facilitate the generation and reconstruction of the image of the sample, B being a known basis of X, and θ being a sparse vector,

wherein θ is reconstructed through a minimization algorithm, preferably

the minimization algorithm comprises a convex optimization algorithm or a greedy algorithm, and/or

the minimization algorithm is defined by:

$$minimize\ ||\mathbf{X}||_1 \cdot subject \cdot to \cdot ||\mathbf{S} - \mathbf{FB\theta}||_2 \leq \delta$$

where δ is a noise boundary reflective of a real practical application.

15. The parallel scanning confocal microscopy method as claimed in claim 11 or 12, further comprising:

providing one or more additional optical circulators, each including a first port, a second port and a third port;

emitting light through the first port and the second port of each of the one or more additional optical circulators along the illumination path; and

directing the reflected light through the second port and the third port of each of the one or more additional optical circulators, along the reflection path, forming a part of the reflected photons,

wherein the step of emitting the light through the first port and the second port of each of the one or more additional optical circulators and the step of emitting the light through the first port and the second port of the optical circulator are carried out simultaneously,

preferably the step of directing the light as multiple optical beams along the illumination path comprises collimating the light from the second port of each of the optical circulator and the one or more additional optical circulators; and the step of directing the reflected light along the reflection path comprises de-collimating the reflected lighted to the second port of each of the optical circulator and the one or more additional optical circulators.