CLAIMS

What is claimed is:

1. A holographic security element comprising:

a substrate; and

an array of nano-reflectors configured to form a pattern on the substrate and to generate a holographic image corresponding to the pattern at a predetermined distance from the substrate when irradiated with a predetermined light source, wherein the array of nano-reflectors is configured to generate the holographic image at the predetermined distance and the holographic image has a size that is larger than a size of the pattern, wherein

the array of nano-reflectors is a two-dimensional array, each nano-reflector of the array of nano-reflectors having a largest lateral dimension in a range of 10 nanometers to 1,000 nanometers, and

spatial locations of the array of nano-reflectors on the substrate are configured to form the pattern such that interference of light reflected from the array of nano-reflectors when irradiated with the predetermined light source generates the holographic image having substantially said size at the predetermined distance.

2. The holographic security element according to claim 1, wherein the size of the pattern has a largest lateral dimension that is smaller than 1,000 micrometers and the size of the holographic image has a smallest lateral dimension that is larger than 1 centimeter.

3. The holographic security element according to claim 2, wherein the size of the holographic image is at least 50 times larger than the size of the pattern.

4. The holographic security element according to claim 1, wherein the array of nano-reflectors is configured to directly generate the holographic image at the predetermined distance.

5. The holographic security element according to claim 1, wherein the predetermined light source is a laser light source.

6. The holographic security element according to claim 1, wherein each of the array of nano-reflectors is a nano-mirror.

7. A method of forming a holographic security element, the method comprising:

providing a substrate; and

configuring an array of nano-reflectors to form a pattern on the substrate and to generate a holographic image corresponding to the pattern at a predetermined distance from the holographic security element when irradiated with a predetermined light source, wherein the array of nano-reflectors is configured to generate the holographic image at the predetermined distance and the holographic image has a size that is larger than a size of the pattern, wherein

the array of nano-reflectors is a two-dimensional array, each nano-reflector of the array of nano-reflectors having a largest lateral dimension in a range of 10 nanometers to 1,000 nanometers, and

said configuring the array of nano-reflectors comprises configuring spatial locations of the nano-reflectors in the array of nano-reflectors on the substrate to form the pattern such that interference of light reflected from the array of nano-reflectors when irradiated with the predetermined light source generates the holographic image having substantially said size at the predetermined distance.

8. The method according to claim 7, wherein the size of the pattern has a largest lateral dimension that is smaller than 1,000 micrometers and the size of the holographic image has a smallest lateral dimension that is larger than 1 centimeter.

9. The method according to claim 8, wherein the size of the holographic image is at least 50 times larger than the size of the pattern.

10. The method according to claim 7, wherein the array of nano-reflectors is configured to directly generate the holographic image at the predetermined distance.

11. The method according to claim 7, wherein the spatial locations of the nano-reflectors are configured based on a genetic algorithm, and

wherein based on the genetic algorithm, said configuring the spatial locations of the nano-reflectors comprises:

mutating a current chromosome array comprising nano-reflector location information to produce a mutated chromosome array;

computing an interference of light reflected at the predetermined distance based on the nano-reflector location information of the mutated chromosome array; and

determining whether to accept the mutated chromosome array based on whether the computed interference associated with the mutated chromosome array is closer to a target interference of reflected light at the predetermined distance for generating the holographic image than a computed interference of reflected light at the predetermined distance associated with the current chromosome array.

12. The method according to claim 11, wherein the current chromosome array comprises a plurality of elements, each element respectively corresponding to a nano-reflector location on the substrate and indicates a presence or an absence of a nano-reflector at the nano-reflector location, and said configuring the spatial locations of the nano-reflectors comprises performing iteratively, for each element of multiple elements or each subset of multiple subsets of elements of the plurality of elements, said mutating a current chromosome array, said computing an interference and said determining whether to accept the mutated chromosome array.

13. The method according to claim 12, wherein said configuring the spatial locations of the nano-reflectors further comprises generating an initial chromosome array comprising the plurality of elements, each element being randomly set to indicate

either a presence or an absence of a nano-reflector at the corresponding nano-reflector location.

14. The method according to claim 7, wherein the predetermined light source is a laser light source.

15. The method according to claim 7, wherein each of the array of nano-reflectors is a nano-mirror.

16. An article having one or more holographic security elements incorporated therein, each of the one or more holographic security element comprises:

a substrate; and

an array of nano-reflectors configured to form a pattern on the substrate and to generate a holographic image corresponding to the pattern at a predetermined distance from the holographic security element when irradiated with a predetermined light source, wherein the array of nano-reflectors is configured to generate the holographic image at the predetermined distance and the holographic image has a size that is larger than a size of the pattern, wherein

the array of nano-reflectors is a two-dimensional array, each nano-reflector of the array of nano-reflectors having a largest lateral dimension in a range of 10 nanometers to 1,000 nanometers, and

spatial locations of the array of nano-reflectors on the substrate are configured to form the pattern such that interference of light reflected from the array of nano-reflectors when irradiated with the predetermined light source generates the holographic image having substantially said size at the predetermined distance.