Claims

What is Claimed is:

1. A tunable lens comprising:

a lens element having a periphery;

a lens shaping element attached to the periphery of the lens element;

actuators distributed around the periphery, wherein each actuator is configured to adjust a position of the lens shaping element in a first direction within a displacement range; and

a structure that is attached to the lens shaping element and that extends in the first direction away from the lens shaping element, wherein the structure is in tension when the lens shaping element is within at least some of the displacement range.

2. The tunable lens defined in claim 1, wherein the structure is in tension when the lens shaping element is within the entire displacement range.

3. The tunable lens defined in claim 1, further comprising:

an additional lens element, wherein the structure is attached between the lens shaping element and the additional lens element.

4. The tunable lens defined in claim 3, further comprising a fluid that fills a chamber, wherein the lens element, the additional lens element, and the structure define walls for the chamber.

5. The tunable lens defined in claim 3, further comprising:

a chassis, wherein the actuators and the additional lens element are attached to the chassis.

6. The tunable lens defined in claim 5, further comprising:

a first magnetic structure that is connected to the lens shaping element; and

a second magnetic structure that is connected to the chassis, wherein the first and second magnetic structures are attracted to one another along the first direction.

7. The tunable lens defined in claim 1, further comprising:
bistable springs that are attached to the lens shaping element.

8. The tunable lens defined in claim 1, further comprising:
a cam roller mechanism that is attached to the lens shaping element.

9. The tunable lens defined in claim 1, further comprising:
a torsion spring that is attached to the lens shaping element.

10. The tunable lens defined in claim 9, wherein the torsion spring extends around the entire periphery.

11. The tunable lens defined in claim 1, wherein each actuator comprises a torsion spring that is configured to bias the lens shaping element in the first direction.

12. A tunable lens comprising:
a first lens element having a periphery;
a lens shaping element attached to the periphery of the first lens element;
a second lens element;
fluid interposed between the first and second lens elements;
actuators distributed around the periphery, wherein each actuator is configured to adjust a position of the lens shaping element in a first direction towards the second lens element;
a first magnetic structure that is attached to the lens shaping element, wherein the first magnetic structure moves in parallel with the lens shaping element; and
a second magnetic structure that is attracted to the first magnetic structure, wherein the second magnetic structure is adjacent to the second lens element.

13. The tunable lens defined in claim 12, wherein the first and second magnetic structures comprise first and second permanent magnets.

14. The tunable lens defined in claim 12, wherein one of the first and second magnetic structures comprises a permanent magnet and wherein a remaining of the first and second magnetic structures comprises a piece of material having a relative magnetic permeability of at least 15.

15. The tunable lens defined in claim 12, wherein the first magnetic structure is embedded within the lens shaping element.

16. The tunable lens defined in claim 12, further comprising:

a bellows structure that is attached between the first and second lens elements; and

a chassis that is attached to the second lens element.

17. The tunable lens defined in claim 16, wherein the second magnetic structure is embedded within the chassis.

18. The tunable lens defined in claim 16, wherein the second magnetic structure is attached directly to the bellows structure, the second lens element, or the chassis.

19. A tunable lens comprising:

a lens element having a periphery;

a lens shaping element attached to the periphery of the lens element;

actuators distributed around the periphery, wherein each actuator is configured to adjust a position of the lens shaping element in a first direction within a displacement range;

a bellows structure that is attached to the lens shaping element, wherein the bellows structure is in tension when the lens shaping element is within at least some of the displacement range; and

a fluid-filled chamber with walls that include at least the bellows structure and the lens element.

20. The tunable lens defined in claim 19, wherein the bellows structure comprises a structure selected from the group consisting of: a C-shaped structure and a W-shaped structure.

21. The tunable lens defined in claim 19, wherein the lens shaping element is pre-deformed to reduce peak forces needed by the actuators.