CLAIMS

WE CLAIM:

1. A fluid injector system, comprising:

at least one injector for pressurizing and delivering at least one fluid from at least one fluid reservoir;

at least one fluid path section in fluid communication with the at least one injector and having a predetermined index of refraction;

a first proximal sensor and a first distal sensor arranged along the at least one fluid path section, each of the first proximal sensor and the first distal sensor comprising:

an emitter configured to emit light through the at least one fluid path section;

a detector configured to receive the light emitted through the at least one fluid path section and generate an electrical signal based on the received light; and

at least one processor programmed or configured to determine, based on a difference in the electrical signals generated by the first proximal sensor and the first distal sensor, at least one property of a content of the at least one fluid path section.

2. The fluid injector system of claim 1, wherein the at least one property of the content is selected from at least one of an identity of the fluid in the fluid path section, the presence of one or more air bubbles in the fluid path section, a volume of one or more air bubbles in the fluid path section, a velocity of one or more air bubbles in the fluid path section, a priming status of the fluid path section, and combinations of any thereof.

3. The fluid injector system of claim 1 or 2, wherein the at least one processor is programmed or configured to:

determine a velocity of an air bubble passing through the at least one fluid path section based on a time offset between detection of the air bubble by the first proximal sensor and detection of the air bubble by the first distal sensor.

4. The fluid injector system of any of claims 1 to 3, wherein the emitter of the first proximal sensor is arranged on a first side of the fluid path section,

wherein the emitter of the first distal sensor is arranged on a second side of the fluid path section, and

wherein the second side of the fluid path section is approximately 180° opposite the first side of the fluid path section.

5. The fluid injector system of any of claims 1 to 4, wherein the controller is configured to actuate the emitter of the first proximal sensor and the emitter of the first distal sensor in alternating pulses.

6. The fluid injector system of any of claims 1 to 5, wherein the fluid injector system comprises a first fluid reservoir and a second fluid reservoir for delivering a first fluid and a second fluid, respectively;

a first fluid path section in fluid communication with the first fluid reservoir and a second fluid path section in fluid communication with the second fluid reservoir; and

first and second proximal sensors and first and second distal sensors, wherein the first fluid path section is associated with the first proximal sensor and the first distal sensor and the second fluid path section is associated with the second proximal sensor and the second distal sensor.

7. The fluid injector system of claim 6, wherein the fluid injector system further comprises a manifold comprising the first fluid path section and the second fluid path section, wherein the manifold positions the first fluid path section and the second fluid path section to interface with the first and second proximal sensors and the first and second distal sensors, respectively.

8. The fluid injector system of claim 7, further comprising a manifold housing module for removably receiving the manifold, wherein the manifold housing module comprises the first and second proximal sensors and the first and second distal sensors.

9. The fluid injector system of claim 8, wherein the manifold comprises at least one rib for indexing the manifold within the manifold housing module.

10. The fluid injector system of claim 9, wherein the emitter and the detector of each of the first and second proximal sensors and the first and second distal sensors are located behind associated optical surfaces of the manifold housing module, and wherein the at least one rib

prevents the manifold from contacting the associated optical surfaces of the manifold housing module.

11. The fluid injector system of any of claims 8-10, wherein the manifold housing module comprises at least one filter for filtering light from entering the detector.

12. The fluid injector system of any of claims 8-11, wherein at least one of the manifold and the manifold housing module comprises a lens for concentrating or dispersing light emitted from the emitter.

13. The fluid injector system of any of claims 8-12, wherein the manifold housing module comprises a collimator for collimating light emitted from the emitter.

14. The fluid injector system of any of claims 1-13, wherein the at least one fluid reservoir comprises at least one syringe, and wherein the fluid injector system further comprises a syringe tip comprising the at least one fluid path section.

15. The fluid injector system of any of claims 1-14, further comprising a reference detector for receiving light from the emitter that has not passed through the at least one fluid path section.

16. The fluid injector system of any of claims 1-15, wherein the emitter of at least one of the first proximal sensor and the first distal sensor is arranged to emit light perpendicular to a fluid flow direction through the at least one fluid path section.

17. The fluid injector system of any of claims 1-15, wherein the emitter of at least one of the first proximal sensor and the first distal sensor is arranged to emit light at an angle of between approximately 30° and approximately 60° relative to a fluid flow direction through the at least one fluid path section.

18. The fluid injector system any of claims 1-17, wherein the at least one processor is programmed or configured to halt actuation of the at least one injector in response to determining that the at least one fluid path section contains one or more air bubbles having a total air volume above a predetermined volume.

19. The fluid injector system of any of claims 1-18, wherein the at least one processor is programmed or configured to determine, based on the electrical signal, that the at least one fluid path section is present between the emitter and the detector of each of the first proximal sensor and the first distal sensor.

20. The fluid injector system of any of claims 1-19, wherein the emitter of at least one of the first proximal sensor and the first distal sensor is configured to emit light within at least one of the ultraviolet spectrum, the infrared spectrum, and the visible spectrum.

21. The fluid injector system of any of claims 1-20, wherein an index of refraction of a sidewall of the at least one fluid path section is closer to an index of refraction of a contrast media than to an index of refraction of air.

22. A fluid manifold for a fluid path component, the fluid manifold comprising:

at least one inlet port configured for fluid communication to at least one fluid reservoir;

at least one outlet port configured for fluid communication to at least one administration line;

at least one fill port configured for fluid communication to at least one bulk fluid source; and

at least one fluid path section in fluid communication with the at least one inlet port, the at least one outlet port, and the at least one fill port, the at least one fluid path section having a sidewall having a predetermined index of refraction such that light passes through the fluid path section at a known refraction.

23. The fluid manifold of claim 22, wherein the index of refraction of the sidewall of the at least one fluid path section is closer to an index of refraction of water than to an index of refraction of air.

24. The fluid manifold of claim 22 or 23, wherein the at least one fluid path section is rigid.

25. The fluid manifold of any of claims 22-24, wherein the at least one fluid path section comprises at least one rib extending radially outward and configured to engage a manifold housing module to index the fluid path section in the manifold housing module.

26. The fluid manifold of any of claims 22-25, wherein the at least one fluid path section has a surface finish configured to concentrate or disperse light passing through the fluid path section.

27. The fluid manifold of claim 25 and 26, wherein one of the manifold housing module and the at least one fluid path section comprises at least one lens to concentrate or disperse light passing through the fluid path section.

28. The fluid manifold of any of claims 22-27, wherein the at least one fluid path section is transparent to at least one of ultraviolet light, visible light, and infrared light.

29. The fluid manifold of any of claims 22-28, wherein each of the at least one outlet ports comprises a check valve.

30. The fluid manifold of any of claims 22-29, further comprising:

a first manifold section defining a first fluid path for a first medical fluid;

a second manifold section defining a second fluid path for a second medical fluid; and

at least one connecting beam connecting the first manifold section to the second manifold section,

wherein the first fluid path is isolated from the second fluid path, and

wherein the at least one connecting beam orients the first manifold section and the second manifold section in a position to fit within the manifold housing module and correctly interface the first fluid path with a first proximal sensor and a first distal sensor and interface the second fluid path within a second proximal sensor and a second distal sensor.

31. A method for determining one or more fluid properties of a fluid flowing in at least one fluid path section of a fluid injector system, the method comprising:

emitting light from an emitter of a first proximal sensor through a proximal portion of the at least one fluid path section;

detecting with a detector of the first proximal sensor the light that has passed through the proximal portion of the at least one fluid path section;

emitting light from an emitter of a first distal sensor through a distal portion of the at least one fluid path section;

detecting with a detector of the first distal sensor the light that has passed through the distal portion of the at least one fluid path section; and

determining at least one property of the fluid as it flows through at least one fluid path section based on a difference in light measurement valves determined by the first proximal sensor and the first distal sensor,

wherein the at least one fluid path section has a predetermined index of refraction such that the light passes through the fluid path section at a known refraction.

32. The method of claim 31, wherein determining the at least one property of the fluid comprises determining whether the at least one fluid path section contains a medical fluid, air, or one or more air bubbles.

33. The method of claim 31 or 32, further comprising: determining a velocity of an air bubble passing through the fluid path section based on a time offset between detection of the air bubble by the first proximal sensor and detection of the bubble by the first distal sensor.

34. The method of any of claims 31-33, further comprising: determining a volume of an air bubble passing through the fluid path section based on a time offset between detection of a bubble front and a bubble end of the air bubble by the first proximal sensor and detection of the bubble front and the bubble end of the air bubble by the first distal sensor and a pressure of the fluid within the fluid path section.

35. The method of any of claims 31-34, wherein the first proximal sensor is arranged on a first side of the fluid path section,

wherein the second distal sensor is arranged on a second side of the fluid path section, and

wherein the second side of the fluid path section is approximately 180° opposite the first side of the fluid path section.

36. The method of any of claims 31-35, further comprising emitting light from the first proximal sensor and emitting light from the first distal sensor in alternating pulses.

37. The method of any of claims 31-36, wherein the fluid injector system comprises a first fluid reservoir and a second fluid reservoir for delivering a first fluid and a second fluid, respectively;

a first fluid path section in fluid communication with the first fluid reservoir and a second fluid path section in fluid communication with the second fluid reservoir; and

first and second proximal sensors and first and second distal sensors, wherein the first fluid path section is associated with the first proximal sensor and the first distal sensor and the second fluid path section is associated with the second proximal sensor and the second distal sensor.

38. The method of claim 37, further comprising inserting a manifold comprising the first fluid path section and the second fluid path section into a manifold housing module,

wherein the manifold housing module comprises the first and second proximal sensors and the first and second distal sensors, and

wherein the manifold positions the first fluid path section and the second fluid path section to interface with the first and second proximal sensors and the first and second distal sensors, respectively.

39. The method of claim 38, wherein the manifold comprises at least one rib for indexing the manifold within the manifold housing module.

40. The method of claim 39, wherein the emitter and the detector of each of the first proximal sensor and the first distal sensor are located behind associated optical surfaces of the manifold housing module, and wherein the at least one rib prevents the manifold from contacting the associated optical surfaces of the manifold housing module.

41. The method of any of claims 38-40, wherein the manifold housing module comprises at least one filter for filtering light emitted from the first proximal sensor and the first distal sensor.

42. The method of any of claims 38-41, wherein at least one of the manifold and the manifold housing module includes a lens for concentrating or dispersing light emitted from the first proximal sensor and the first distal sensor.

43. The method of any of claims 38-42, wherein the manifold housing module comprises a collimator for collimating light emitted from the first proximal sensor and the first distal sensor.

44. The method of any of claims 31-43, further comprising:

detecting, with a reference detector of the first proximal sensor or the first distal sensor, a reference light that has not passed through the at least one fluid path section; and

comparing the reference light to the light that has passed through the at least one fluid path section to determine fluid content of the at least one fluid path section.

45. The method of any of claims 31-44, wherein the emitter of at least one of the first proximal sensor and the first distal sensor is arranged to emit light perpendicular to a fluid flow direction through the at least one fluid path section.

46. The method of any of claims 31-44, wherein the emitter of at least one of the first proximal sensor and the first distal sensor is arranged to emit light at an angle of between approximately 30° and approximately 60° relative to a fluid flow direction through the at least one fluid path section.

47. The method of any of claims 31-46, further comprising: halting an injection procedure of the fluid injector system in response to determining that the at least one fluid path section contains one or more air bubbles having a total air volume above a predetermined volume.

48. The method of any of claims 31-47, further comprising: determining, based on the detected light, that the at least one fluid path section is present between the emitter and the detector of each of the first proximal sensor and the first distal sensor.

49. The method of any of claims 31-48, wherein the emitter of at least one of the first proximal sensor and the first distal sensor is configured to emit light in at least one of the ultraviolet spectrum, the infrared spectrum, and the visible spectrum.

50. The method of any of claims 31-49, wherein an index of refraction of a sidewall of the at least one fluid path section is closer to an index of refraction of water than to an index of refraction of air.

51. The method of claim 50, further comprising: determining a cumulative total volume of air passing through the at least one fluid path section during an injection procedure by adding the volume of the air bubble to a previous cumulative total volume of air.