

DETECTING MICROSCOPIC OBJECTS IN FLUIDS

FIELD

The present disclosure relates generally to monitoring quality of fluids, such as water. In particular, the
5 present disclosure relates to methods and apparatuses for monitoring microscopic particle or microbe content of fluids by means of optical sensing.

BACKGROUND

Water quality is an important parameter for various
10 applications where clean water is produced, supplied, or used. Water quality may be critical as well for the safety and health of people as end users of municipal water as for various industrial processes where water having specific quality requirements is used.

15 Conventionally, thorough water quality analysis has been carried out as a time-consuming laboratory process where a water sample is investigated by means of analysis instruments. However, in many
20 applications, much more rapid response time is required. Examples of such include e.g. monitoring the water quality in water treatment plants, in municipal water supply networks, or in the internal water delivery in some critical types of residential water
25 supply systems such as those on hospitals, elderly houses, or nurseries, as well as in certain industrial processes.

In-line holography or holographic microscopy has been
30 proposed as one potential technology for rapid water quality monitoring. In US 2004/0169903 A1, an in-line holography method for tracking particles and life forms in sea water is disclosed. In another example, compact in-line holographic microscope for detection
35 of pathogenic waterborne parasites is disclosed in

Mudanyali O, Oztoprak C, Tseng D, Erlinger A, Ozcan A. Detection of waterborne parasites using field-portable and cost-effective lensfree microscopy. *Lab on a chip*. 2010;10(18):2419-2423. Electronic publication at
5 www.rsc.org.

In prior art holographic microscopy methods, the reconstruction phase in which the holographic image is reconstructed, using complex mathematical algorithms,
10 into one or more two-dimensional images of the sample, requires burdensome and time-consuming calculations and powerful, expensive computing equipment. This may hinder implementation of small-size, low-cost sensor-level implementation of in-line holographic microscopy
15 systems.

Similarly to water quality monitoring, also various other applications exist where foreign microscope objects in a fluid need to be detected and/or
20 analyzed.

SUMMARY

This summary is provided to introduce a selection of concepts in a simplified form that are further
25 described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter

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In a first aspect, the present disclosure provides a method for detecting microscopic objects of foreign origin present in a fluid by utilizing first, second, and third image data originating from first, second,
35 and third digital image frames, respectively, captured sequentially in time by an image sensor receiving light propagated across a sample volume containing a

fluid possibly comprising moving microscopic objects of foreign origin while illuminating the sample volume by coherent light, whereby the possible microscopic objects scatter part of the light, the scattered and non-scattered light interfering so as to form interference fringes behind the microscopic objects, each image data comprising, for a moving microscopic object of foreign origin present in the sample volume at the time of capture of the associated digital image frame, a hologram pattern with spatially alternating intensity formed by the interference fringes, the method comprising: obtaining first differential image data comprising the difference of the first and the second image data, the first differential image data comprising, for each hologram pattern present in the first or second image data, a differential pattern; obtaining second differential image data comprising the difference of the second and the third image data, the second differential image data comprising, for each hologram pattern present in the second or third image data, a differential pattern; automatically generating product of difference (POD) image data comprising the product of the first and the second differential image data, the POD image data comprising, for each hologram pattern present in the second image data, a product pattern; and automatically detecting the presence of moving microscopic object(s) of foreign origin in the sample volume on the basis of product pattern(s) present in the POD image data.

In a second aspect, the present disclosure provides an apparatus for detecting microscopic objects of foreign origin present in a fluid, the apparatus comprising a computing arrangement configured to perform the operations of the method according to the first aspect.

In a third aspect, the present disclosure provides a computer program product comprising program code instructions which, when executed by a processor,
5 cause the processor to perform the method according to the first aspect.

In one embodiment, a method may be implemented which may be used for detecting microscopic objects of
10 foreign origin present in a fluid. The method may be used, for example, for monitoring water quality in water supply, distribution, or use systems and networks. The microscopic objects may be, for example, impurity particles and/or microbes. In other
15 embodiments,

comprising, for each hologram pattern present in the second image data, a product pattern.

5 Finally, the method comprises automatically detecting the presence of moving microscopic object(s) of foreign origin in the sample volume on the basis of product pattern(s) present in the POD image data.

10 In the method, some principles known from in-line holographic microscopy may be used.

In another embodiment, an apparatus may be implemented which may be used for detecting microscopic objects of foreign origin present in a fluid, the apparatus
15 comprising a computing arrangement configured to perform the operations of the method as defined above.

In yet another embodiment, a computer program product may be implemented, comprising program code
20 instructions which, when executed by a processor, cause the processor to perform the method as defined.

Many of the attendant features will be more readily appreciated as the same becomes better understood by
25 reference to the following detailed description considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

30 The present description will be better understood from the following detailed description read in light of the accompanying drawings, wherein:

FIGs. 1, 5, and 7 illustrate, as schematic flow diagrams, methods for detecting microscopic objects of
35 foreign origin present in a fluid;