[0006] Some manufacturers of automated inspection equipment for pharmaceutical products have proposed, and implemented, techniques that attempt to address these problems. For example, U.S. Patent No. 8,036,444 (Nielsen), entitled "Method and System for Irradiating and Inspecting Liquid-Carrying Containers," describes an imaging system in which two line scan cameras generate flattened images of a spinning container. One camera is aligned with the central axis of the container, while the other camera is offset from the central axis. The technique leverages the basic principle that, when the container is rotated, particles on the outside of a container will move a longer distance horizontally (i.e., in a direction orthogonal to the container central axis) than particles inside the container. Images from the two line scan cameras are compared after multiple images have been acquired at different rotations, and the distances between particles are computed. This distance can in some cases be used to distinguish particles on the inside and outside of the container.

[0007] As another example, European Patent No. 3,062,292 (Kwoka), entitled "Inspection Method and Inspection Device for Monitoring Production Processes," describes an imaging system that uses a single area scan camera. When a particle is detected at a position along the central axis of the container, the position is digitally shifted to a point where it would be if it were on the outside of the container and the container were precisely rotated about its central axis a preset angle (~45^0). The container is then rotated and a new image is taken. If the particle is in fact on the outside of the container, it should overlap with the digitally shifted image. If the particle is instead inside the container, it will be offset from the digitally shifted particle by some amount.

[0008] While the techniques of U.S. Patent No. 8,036,444 (Nielsen) and European Patent No. 3,062,292 (Kwoka) may improve upon the conventional image subtraction method described above in some respects, both approaches have significant drawbacks of their own. One difficulty is that, with both approaches, any slight vibration of the container between images can cause significant errors. Moreover, if a particle on the inside of the container "slips" while the container is rotated, it may not be in the expected position to be properly detected. Furthermore, limitations on the spatial resolution of imagers may make the techniques insufficient to distinguish small blemishes inside the glass, which can be a large source of false rejects.

[0009] Further, while promising 3D imaging techniques are being developed and offer the ability to determine particle size and morphology from images, they are very computationally expensive, and may not work at typical manufacturing line rates (e.g., 300 to 600 containers per minute). Accordingly, there remains a need for improved methods to detect particles inside liquid-filled drug product containers, particularly (but not only) for containers holding highly viscous samples/products.

SUMMARY

[0009a] According to a first aspect of the present invention, there is provided a method for imaging a container holding a sample, the method comprising: illuminating the container with a laser sheet that impinges upon the container in a first direction corresponding to a first axis, wherein a plane of the laser sheet is defined by the first axis and a second axis orthogonal to the first axis; capturing, by an imager having an imaging axis that is substantially orthogonal to at least the first axis, an image of the container; and analyzing, by one or more processors, the image of the container to detect particles within, and/or on an exterior surface of, the container.

[0009b] According to a second aspect of the present invention, there is provided an imaging system comprising: positioning means for positioning a container; illumination means for generating a laser sheet that impinges upon the container in a first direction corresponding to a first axis, wherein a plane of the laser sheet is defined by the first axis and a second axis orthogonal

to the first axis; and imaging means for capturing one or more images of the container, the means for capturing one or more images of the container having an imaging axis that is substantially orthogonal to at least the first axis.

[0010] Embodiments described herein relate to systems and methods that improve upon conventional automated visual inspection techniques. In particular, an imaging system illuminates a container with a relatively thin sheet of laser light, with the laser sheet impinging upon the container from a direction substantially orthogonal to the imaging axis of the camera. The laser sheet may pass through the central axis of the container, for example. With this lighting configuration, particles can only be seen in the resulting image (or can only be seen with a certain intensity level, etc.) if those particles are within the thickness of the laser sheet. Thus, by using the laser sheet and the orthogonal orientation of the camera, it can easily be determined whether a particle seen in an image is inside or outside of the container: any imaged particles that are outside the container will be outside the container walls in the image, and any imaged particles that are inside the container will be between the container walls in the image.

[0011] In some embodiments, the container is rotated a number of times about its central axis, and imaged at each rotation while the laser sheet is still applied, in order to inspect the entire volume of the drug product (or other sample) within the container. While numerous rotations may be required, the image processing and computational load can be very light, and the probability of false rejects can be very low. Moreover, the technique has the unexpected benefit that some of the laser light scatters within the sample, or refracts at the container/sample (e.g., glass/liquid) interface, and travels around the inside