The spread of the GAs solutions (the points in 4(a) and (b)) at each propagation distance isn't obviously correlated with the propagation distance or image contrast (Fig. 4(e)). This is consistent with this variability being the result of the stochastic nature of the simulations. Therefore, we expect that this variance can be reduced by averaging the SAF over more windows, at the expense of increased computation time.

Overall, the best solutions are quite close to the true distributions of the microspheres' diameters. Comparing the extremes of these solutions (at z = 0 m and z = 1 m) in Fig. 4(c) highlights that even in the worst case (z = 0 m), the solution is still quite accurate: the GM and GSD are in error by 1.5% and 2.9%, respectively. In Fig. 4(d) it can be seen that accuracy is worst at very short propagation distances, where phase contrast is weak, and at the largest propagation distances, where the size of the Gaussian kernel is greatest (not shown). The inverse relationship between the solution error and the speckle contrast is illustrated by comparing Figs. 4(d) and 4(e). Since speckle contrast is proportional to the signal to noise ratio, this relationship is not surprising. We note that our experimental images were of static samples, with a high intensity synchrotron source and significant exposure times. We expect that the benefit afforded by phase contrast would be of greater significance when imaging conditions are less ideal.

We encountered an unexpected result in the behaviour of the Gaussian low pass filter kernel over the range of propagation distances. We found that this parameter increased almost linearly over the range of propagation distances, at a rate greater than expected by penumbral blurring for the known source size of 150 µm (horizontal) by 10 µm (vertical). As mentioned, this accounts for the decrease in contrast at the largest propagation distances. Our hypothesis is that this may be the result of scattering/refraction within the volume of the sample, which we assume is negligible when we make the projection approximation. Alternatively, or additionally, it may be the result of scattering by optical elements and/or air along the beam path which hasn't been accounted for in our model. These hypotheses warrant further investigation.

5. Conclusions

In this paper we have outlined a new technique for the quantification of useful parameters related to random granular and porous systems without restriction on the mode of packing. The basis of the technique lies in retrieving structural information encoded in speckled phase contrast X-ray images of such systems. The experimental and synthetic results presented demonstrate the accuracy and robustness of this technique and that propagation based phase contrast significantly improves the accuracy. We have also shown that there is a limit to the gains that can be obtained by increasing the propagation distance due to an increase in blurring. The advantages of our technique are high temporal resolution and low radiation dose, which suggest potential applications for imaging dynamic and biological systems. Specifically, we envisage the technique being applied to the measurement of dynamic lung morphology, for physiological studies or disease detection.

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