sition $T_G \approx 1500$K and surface tension $\gamma \approx 0.3$J.m^{-1}. Note that low values of T_G/γ had already been reported in [3]. In this work, AFM measurements on a fragment of photonic band gap fibre led to estimates of the ratio T_G/γ in the range $[500-5000]$ with a central value $T_G/\gamma = 1500$. A possible origin of this lower than expected surface roughness of glass fibres may lie in the drawing process. Recent experimental and numerical results suggest indeed that capillary waves may be attenuated under flowing conditions [15, 16].

6. Conclusion

We have presented an optical, non-contact method able to characterize the roughness of ultra-smooth glass surfaces with sensitivities down to 10pm, and have validated its ability to deliver quantitative height measurements on model samples. On flat glass surfaces, the capillary wave-driven sub-nanometer roughness has been obtained in a new spatial frequency range $[5 \cdot 10^{-3} \mu\text{m}^{-1} - 10^{-1} \mu\text{m}^{-1}]$ with a quantitative statistical charactarization of the spatial correlations. These measurements compare well to glass physics models as well as to AFM measurements [8]. Beyond its excellent sensitivity, which goes beyond the performances of most current AFM regarding height measurements, a further advantage of this method resides in its ability to obtain measurements over distances of the order of hundreds of micrometers. Using an oil immersion technique, we show that these measurements can be performed at a distant glass/air interface, either on the back side of thin glass plates or, more interestingly, inside hollow glass tubes. This immersion-based method allows the study of unopened hollow fibres, thus avoiding the necessity to mechanically open the fibre and therefore preserving the pristine cleanness of the surface, which is essential considering the extremely low roughness levels measured here. The ability to access the inner surface of glass tubes, coupled with the ability to measure a previously unexplored range of spatial frequencies at the very high sensitivity presented here is expected to be of great interest for the study of roughness and loss mechanisms in photonic bandgap fibres, providing valuable input to their understanding and optimization.

Acknowledgements

This work was supported by the EU 7th Framework Programme under grant agreement 228033 (MODE-GAP). X.B. acknowledges the support of Programme DIM OxyMORE, Ile de France. The authors thank the technology center MIMENTO, Femto ST institute, for the realization of the silica steps.