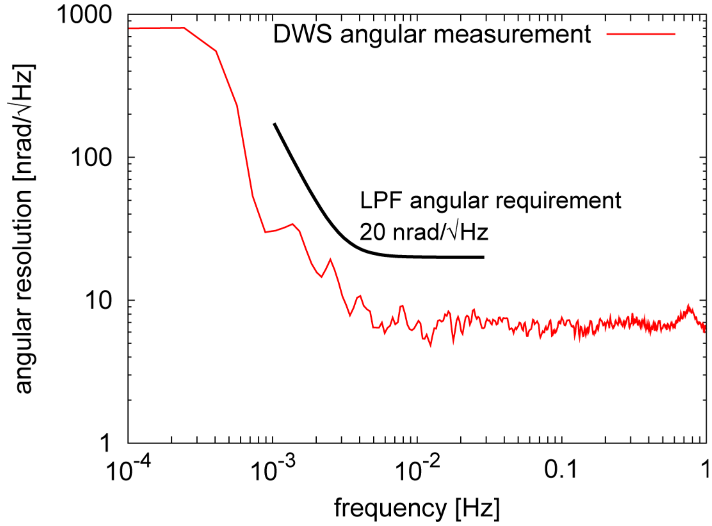

Fig. 7. Angular resolution obtained by applying a DWS algorithm to the phases extracted from individual cells of a quadrant photodetector.

8. Conclusions

We have presented an interferometry technique for high sensitivity length and angular optical measurements. This technique is based on the deep phase modulation (over several radians) of one interferometer arm and can be considered as an extension of the well-known "$J_1 \ldots J_4$" method [14–16]. The harmonic amplitudes are used to numerically solve an overdimensioned system of equations to extract the interferometer phase and other useful interferometer variables. This technique has been applied to experiments conducted on a very stable interferometer (the engineering model of the LISA Pathfinder optical bench), achieving an optical pathlength readout sensitivity of the order of $20\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ ($0.1\,\mathrm{mrad}/\sqrt{\mathrm{Hz}}$ in phase, which translates to $10\,\mathrm{pm}/\sqrt{\mathrm{Hz}}$ for free-floating test mass displacement), and alignment measurements with an angular resolution better than $10\,\mathrm{nrad}/\sqrt{\mathrm{Hz}}$ in the millihertz frequency band. This performance is comparable to the best heterodyne interferometers, and, e.g., only a factor of 2 above the LISA Pathfinder pathlength measurement requirements. Two main noise sources were identified, namely laser frequency fluctuations and the frequency response of the analog portion of the data acquisition system, which both were completely mitigated by appropriate data processing methods, hence improving the performance of this technique by over a factor 35. Unlike other interferometry techniques, no additional control loops, for instance, to actively stabilize the optical pathlength difference or laser power fluctuations, have been implemented or are required to reach the current sensitivity. Nonetheless, this could easily be done, in order to further improve the performance of this method.

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