APPENDIX B

QUALITY OF OPTICAL SURFACES

Manufacturing tolerances and imperfections in materials and polishing will lead to errors in the surface shapes and homogeneity of the optical components of the interferometer. This will lead to wavefront distortions, the effects of which will vary with the path length difference in the interferometer. At zero path difference only non-collimation errors will be seen, e.g. flatness errors of the reference mirror, inhomogeneity of the beamsplitter refractive index. At non-zero path differences, collimation errors will also be seen (even with perfectly flat reference mirror and homogeneous beamsplitter). These collimation errors include collimator spherical aberration and astigmatism, astigmatism in the collimator mirror and any defocus of the collimator.

The optics of the interferometer have been individually checked on a ZYGO Mk 4 interferometer - this is a phase-shifting Fizeau interferometer operating at $\lambda = 633$ nm, which has had its reference surface calibrated using absolute flatness techniques [1,2]. This reference surface shows a p-v variation of 0.02 $\lambda$.

**Astigmatism in mirrors**

A mirror, used at an oblique angle, will contribute a wavefront astigmatism of maximum amplitude $A\lambda$ if its surface has a minimum radius of curvature, $R_{min}$ given by

$$R_{min} = \frac{nD^2 \cos \theta}{4A\lambda} \left( \frac{1}{\cos^2 \theta} - 1 \right)$$  \hspace{1cm} (B.1)

where $n$ is the refractive index of the surrounding medium (air), $\theta$ is the angle of incidence and $D$ is the diameter of the beam.

**Collimator mirror**

The beam diameter is 80 mm, the angle of incidence 60°. Thus at a wavelength $\lambda = 633$ nm, $R_{min}$ is 3791/A metres. The collimator mirror was found to be flat to 0.06 $\lambda$. 
over its 150 mm diameter. By simple trigonometry, this is equivalent to a radius of curvature of approximately $6 \times 10^5$ metres, giving a value of the astigmatism of $A = 1/160$, i.e. $\lambda/160$ wavefront astigmatism.

**Reference mirror**

The angle of incidence at the reference mirrors is 0° (straight on). The reference mirror was found to be flat to 0.015 $\lambda$ and was smoothly varying.

**Path folding mirrors**

In the reference arm, the angle of incidence is 45° leading to $R_{min} = 1787/A$, and in the measurement arm the angle is 30°, leading to $R_{min} = 730/A$. These two mirrors are flat to 0.025 $\lambda$ leading to astigmatism of $\lambda/139$ in the measurement arm and $\lambda/57$ in the reference arm.

**Roof mirrors**

Roof mirror 1 was found to be flat to 0.025 $\lambda$ and roof mirror 2 was found to be flat to 0.03 $\lambda$, both with slight roll-off at the edges. The angle of incidence at both mirrors is 45°, leading to $R_{min} = 1787/A$. Roof mirror 1 thus contributes $\lambda/57$ of astigmatism and roof mirror 2 contributes $\lambda/48$ of astigmatism.

**Collimator lens**

The collimator lens was tested in a double-pass arrangement and found to have a double pass P-V wavefront distortion of 0.3 $\lambda$, giving a single pass distortion of less than 0.15 $\lambda$. This is mostly spherical aberration and its effect on measured length was shown in § 4.1.7.2 to be of magnitude $1 \times 10^{-9} L$.

**De-collimating lens**

The de-collimating lens was checked in the same manner as the collimating lens and found to have a P-V wavefront distortion of 0.1 $\lambda$, which was mostly spherical aberration. The effect on measured length is of magnitude $1 \times 10^{-9} L$.

**REFERENCES FOR APPENDIX B**
