LIGO Laboratory / LIGO Scientific Collaboration

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Tooling induced deformation of ears for Advanced LIGO monolithic suspension

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1.0 Introduction

The tooling used to allow precision placement of ears onto test masses[1,2] is essential to the success of the hydroxyl catalysis bonding process[3]. The major factor influencing the success of a bonded structure is the flatness of the components both must have surface peak to valley (PV) flatness of λ/10 or better. This equates to a maximum PV of ~63 nm using a 633 nm HeNe laser. The precision machining of the components should ensure that the specifications are met or bettered. However, during testing of the two sets of ears delivered to Glasgow, 'A'[4] and 'B'[5] prior to bonding to test disk inserts[6], it was discovered that the tooling itself could be inducing changes to the surface flatness. Section 2 looks at the changes in the 'A' style ears, while Section 3 looks at the 'B' ears. Section 4 looks at the effect of atmospheric turbulence on the flatness measurements.

To summarise, the PV flatness of the ears are both affected by tensioning the clamp. However, the measured change is diametrically opposite for the 'A' ears compared to the 'B' ears. PV flatness of the 'A' ears is improved from 0.135 to 0.092 λ by tightening the clamp. For the 'B' ears the flatness is degraded from 0.052 to 0.248 λ. The effect of atmospheric turbulence causes a variability of <5% on a surface flatness measurement. The measurements also show that the difference is in the opposite direction to that expected if turbulence was having an effect on the measurement.

2.0 Tooling induced changes 'A' ears

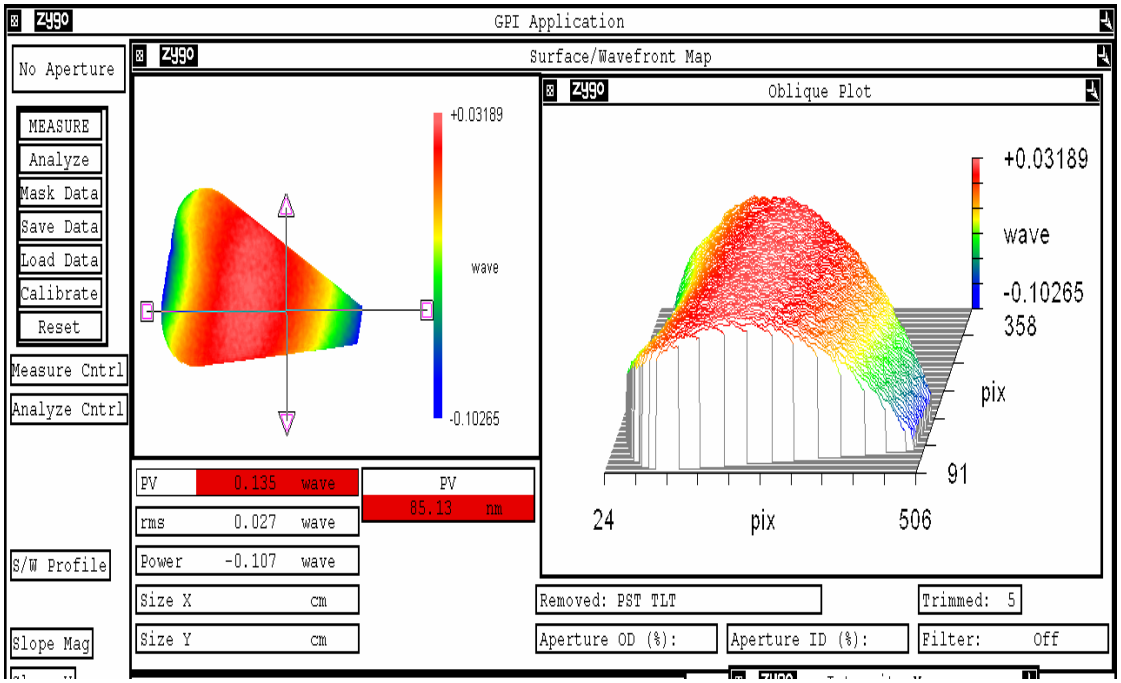

Figure 1 Ear A14 measured without holder, flatness 0.135 λ

[1]T070070-00-K Noise Prototype Ear Bonding Jig Review of Draft Design
[2]T070156-01-K Advanced Testing of Noise Prototype Ear Bonding Jig
[3]E050228-00-D (Specification) Silicate Bonding Procedure
[4]D060055-02-K NP-type Refined Ear (Type A)
[5]D060056-02-K NP-type Refined Ear (Type B)
[6]D060286-00-K NP-type Monolithic Testing Disc Insert

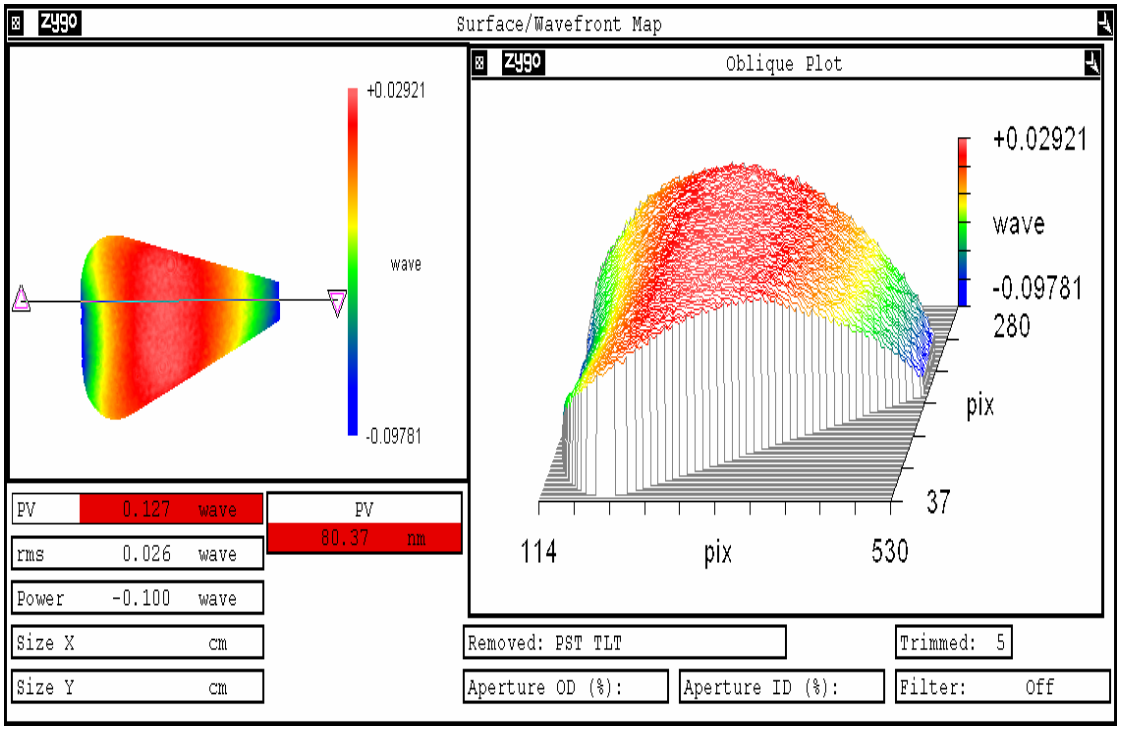

Figure 2 Ear A14 measured in holder unclamped, flatness 0.127 λ

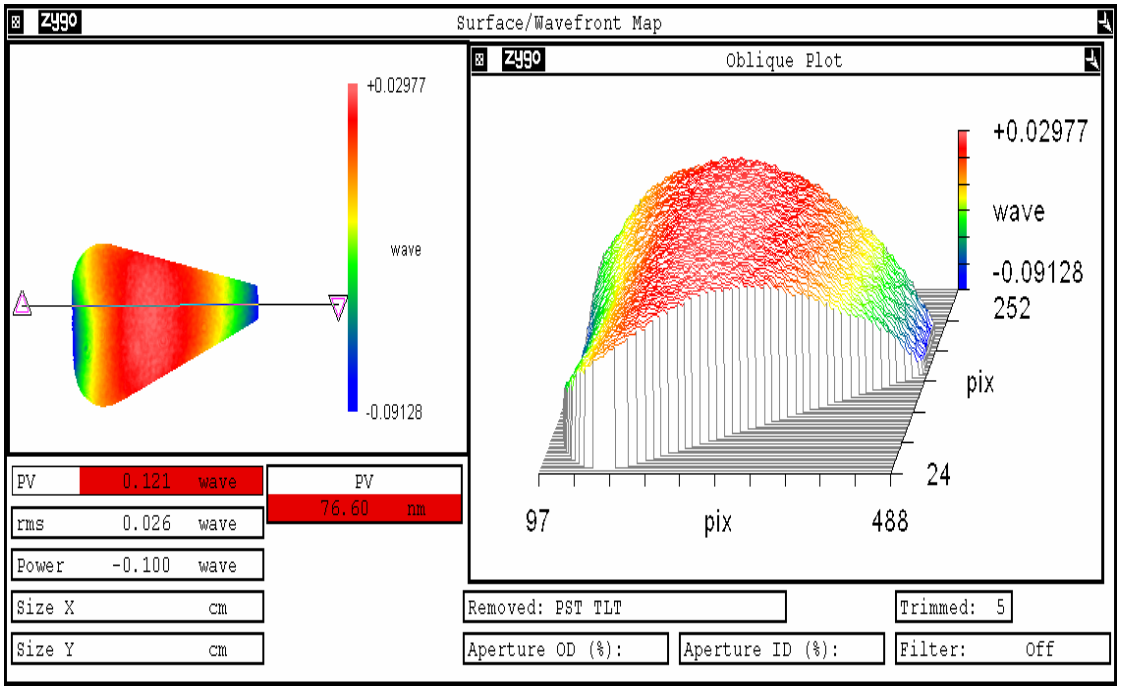

Figure 3 Ear A14 measured with minimal pressure on clamp, flatness 0.121 λ

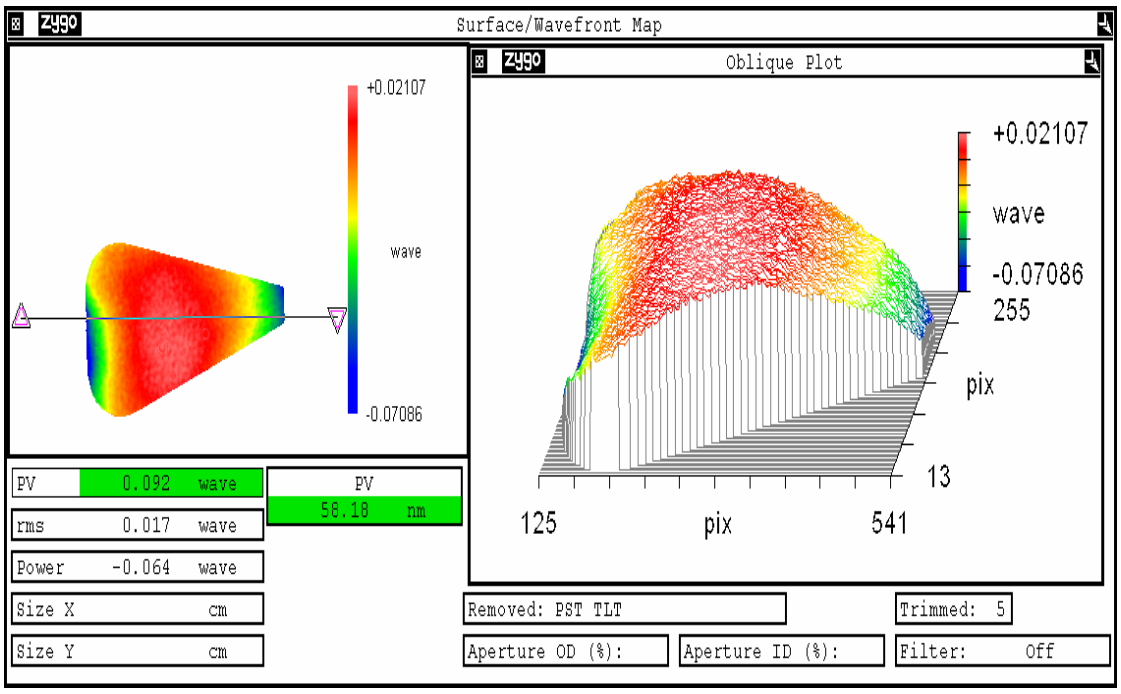

Figure 4 Ear A14 measured with clamp fully tightened, flatness 0.092 λ

All measurements were taken consecutively, on the same day in a temperature controlled clean lab. It can be seen that the flatness of the sample has been improved by reduction of the central domed region. This could be attributed to the affect of the pressure applied by the clamp twisting the ear against the locating pins. In this case the effect is beneficial, reducing the PV from 0.135 λ to 0.092 λ

3.0 Tooling induced changes 'B' ears

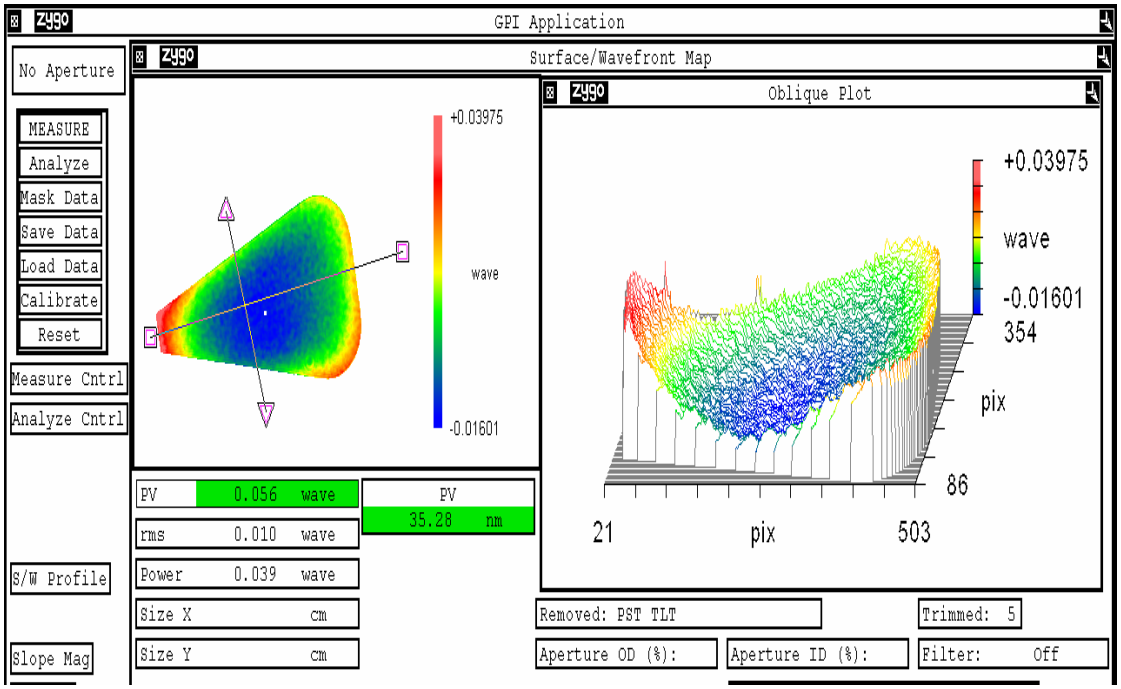

Figure 5 Ear B06 measured without holder, flatness 0.056 λ

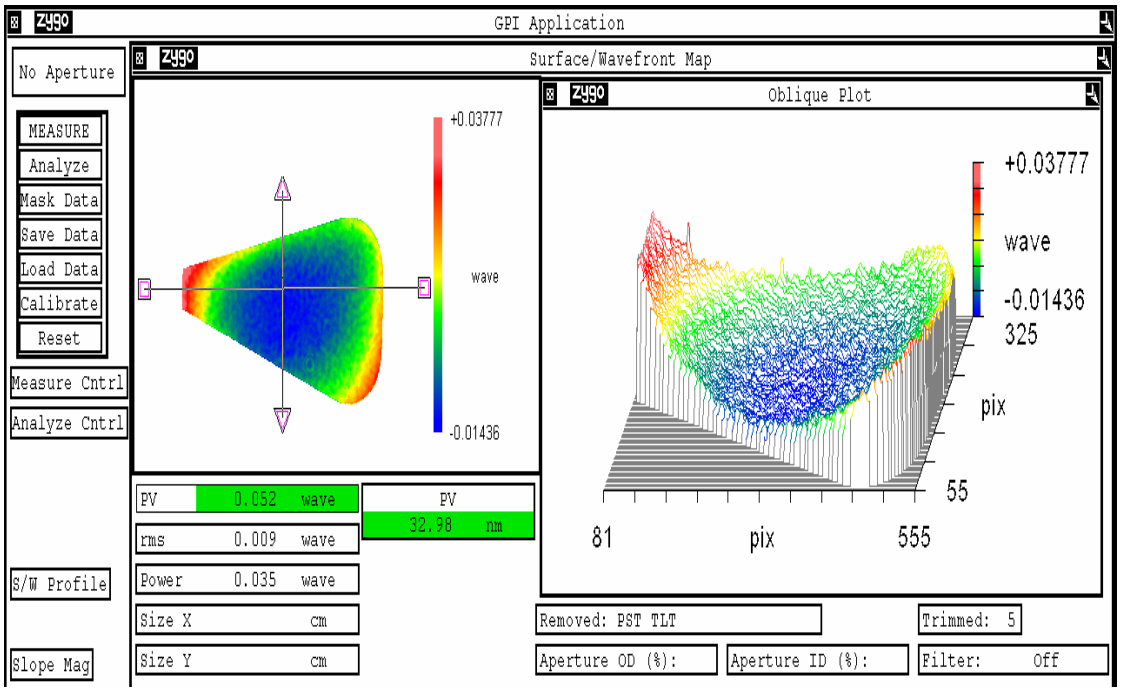

Figure 6 Ear B06 measured in holder unclamped, flatness 0.052 λ

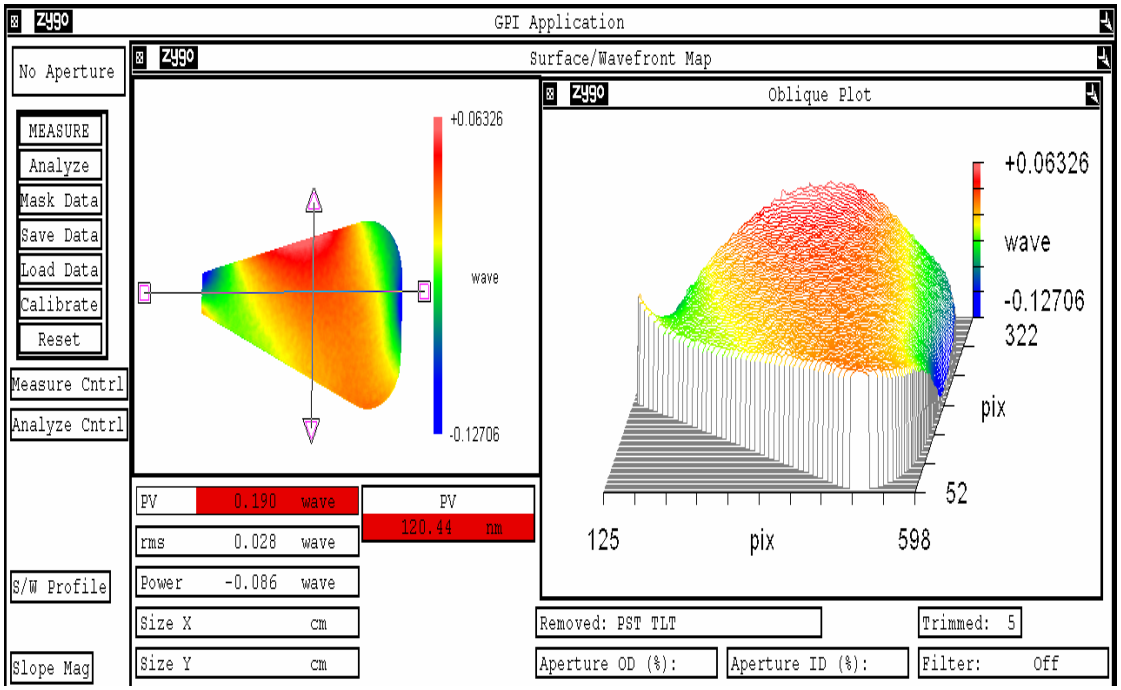

Figure 7 Ear B06 measured with minimal pressure on clamp, flatness 0.198 λ

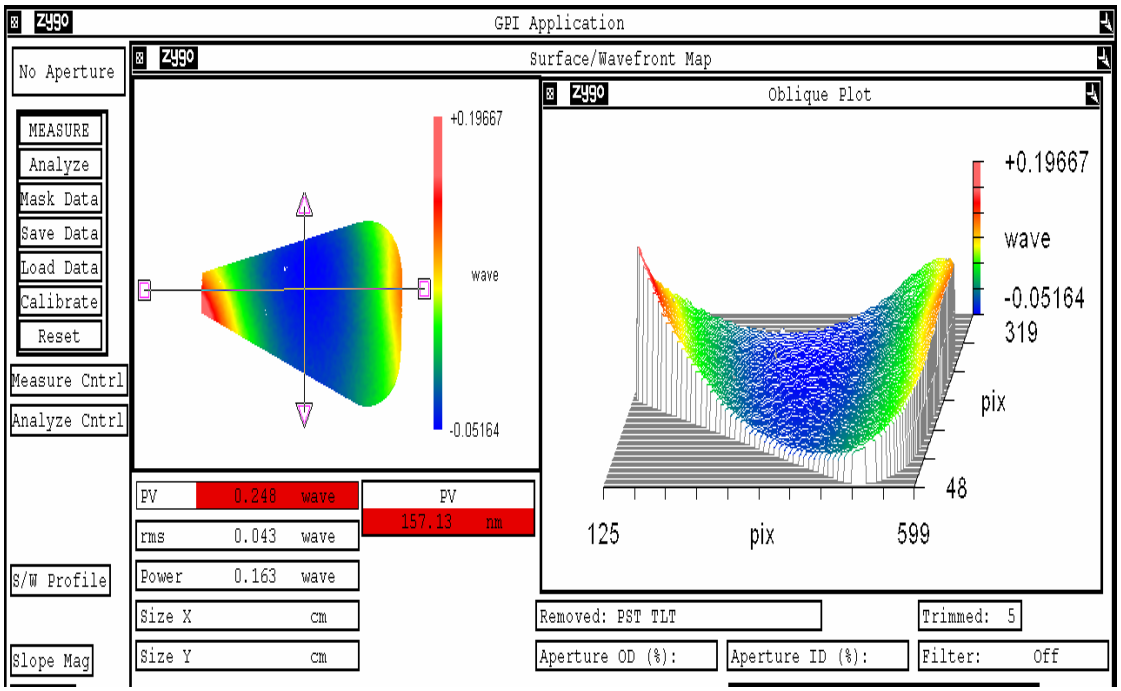

Figure 8 Ear B06 measured with clamp fully tightened, flatness 0.248 λ

All measurements were taken consecutively on the same day in a temperature controlled clean lab. The PV flatness changes from 0.052 to 0.248 λ as the pressure is increased by tightening the clamp. Changes in the shape of the central section can be observed as the clamp is tightened.

4.0 Effects of air turbulence

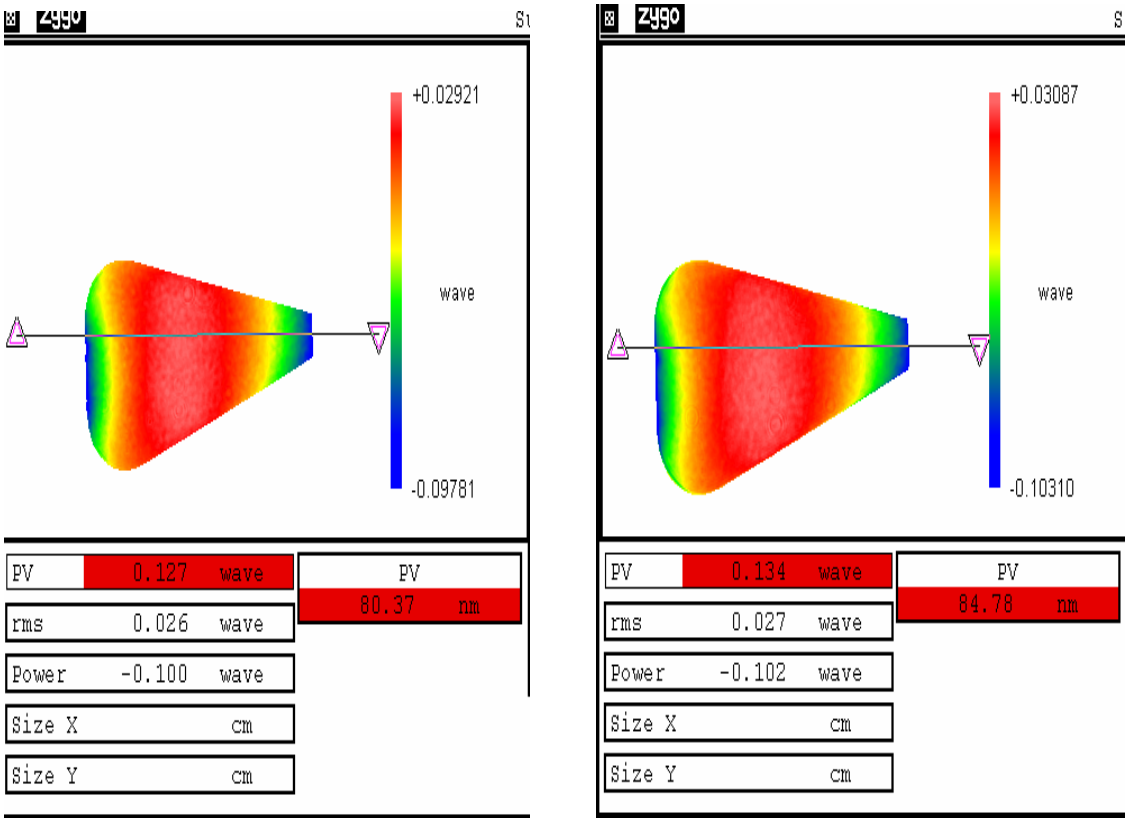

Figure 9 Left: laminar flow ON, Right: laminar flow OFF. No significant change to surface flatness observed

This representative test clearly shows no correlation between air turbulence and surface flatness, the change of 0.007 λ is less than ~5% of the measured flatness. The variation is also the opposite to what would be expected if the air turbulence was having an effect.