Physical optics analysis for the partially constructed FYST model

The FYST telescope, currently pre-assembled in Xanten, will be partially constructed from the centra and one-half panels of its two mirrors, as depicted in Figure 1. To check the possibility of using the half antenna to test the FYST holographic system, I simulated the beam patterns of the incomplete antenna and studied the influence of the Carbon Fiber structure on the antenna's beam patterns.
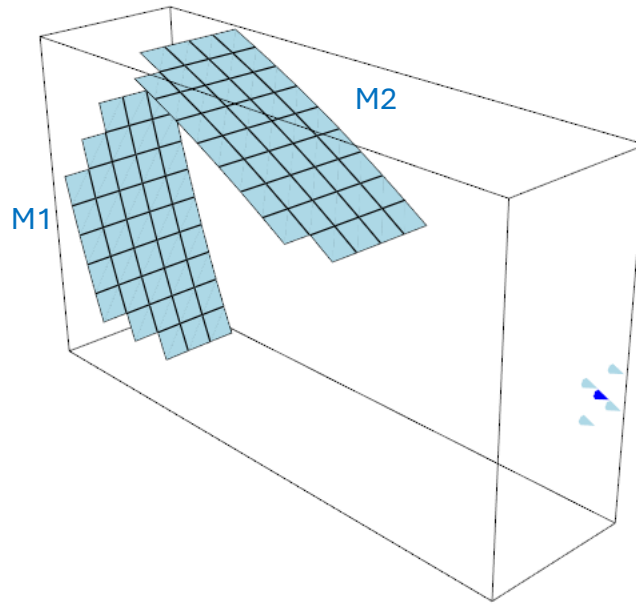

Figure 1. Partially constructed FYST model. The model consists of centre and Right-side panels on M1 and M2.

1. Beam pattern of the half antenna

The telescope is horizontal reflection symmetric. Compared to the full-mirror antenna, only half power of input signal can be delivered to the receiver. Then the gain loss is greater than or equal to 3dB. Figure 2 shows the simulated beams of the half-antenna and full-mirror model. In the model, the source is located 300m away from telescope rotation axis, and receiver is 715mm behind the nominal focus. The gain is reduced by around 5dB, and the beam changes into elliptical beam. The beam size is also extended along elevation axis.
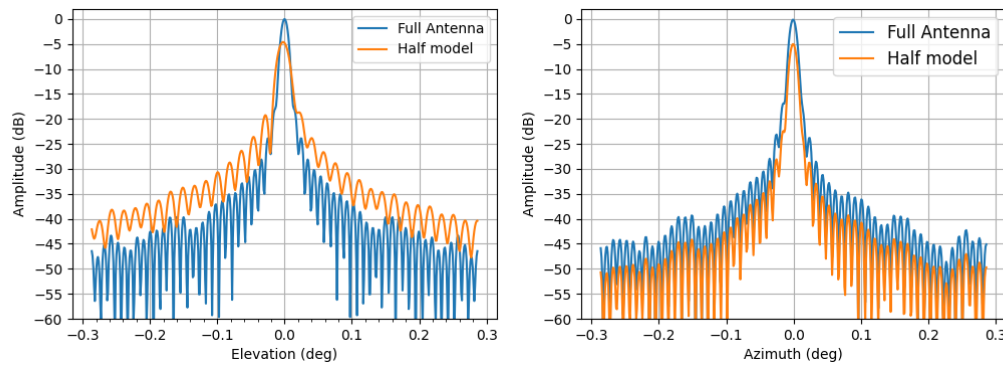

Figure 2. The beams of the half-antenna model compared to the original beams in elevation and azimuth axes.
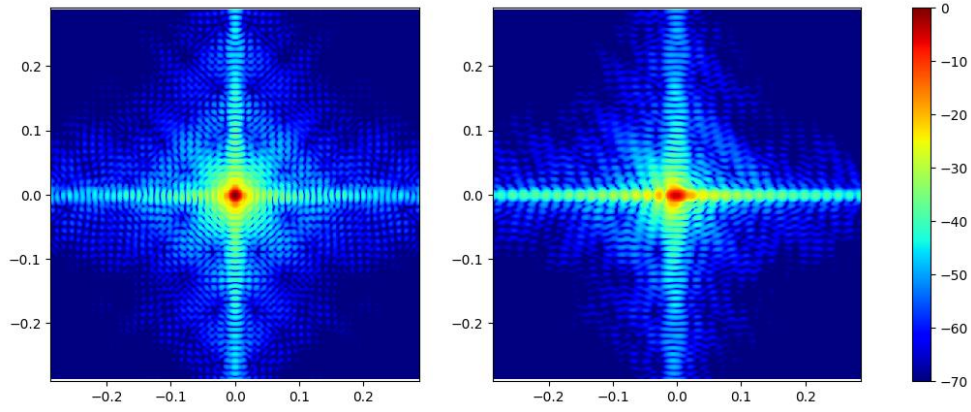
Figure 3. 2D beam pattern of the FYST beam pattern (left) and Half-antenna beam map (right).

The beam maps in Figure 3 shows a strong diffraction pattern in horizontal axis.

2. Effects of the exposed Carbon Fiber (CF) plate

Due to the absence of half panels, the carbon fibre would be exposed, see the model in figure 4. The flat plates do scatter the light and introduce error patterns in the antenna beam. Here we made an extreme assumption, treating the carbon fibre as **a flat metal plate** without loss in its surface.
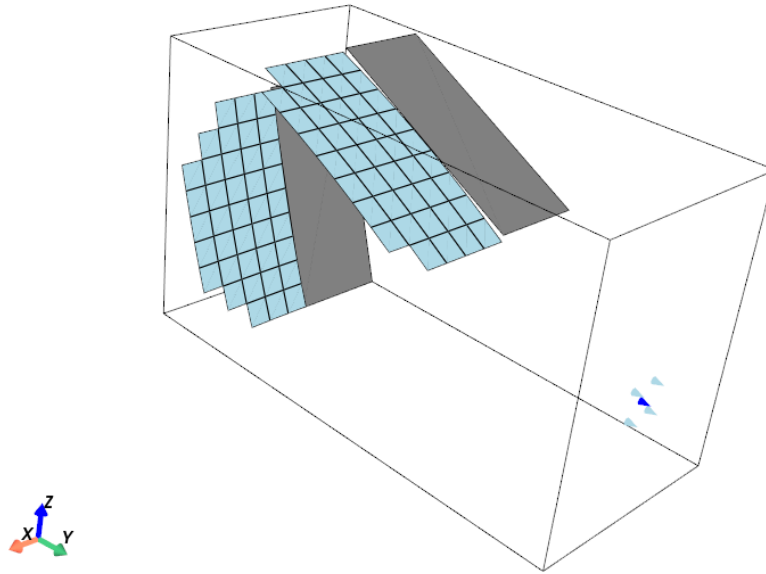

Figure 4. Carbon fiber plates (Gray) and the half panels.

We still use our 'Two-step' Kirchhoff integration method to compute the beam pattern. Here, two intermediate focal planes must be used to compute the diffraction fields from curved panels and the flat CF plate, one is the intermediate focal plane of the modified hyperboloid mirror (M2) to collect the fields scattered by the panels, other is located at the image plane of the receiver relative to the flat carbon fibre plate and used to record the diffracted fields from the carbon fibre of M2, see the square plane behind M2 in Figure 5.
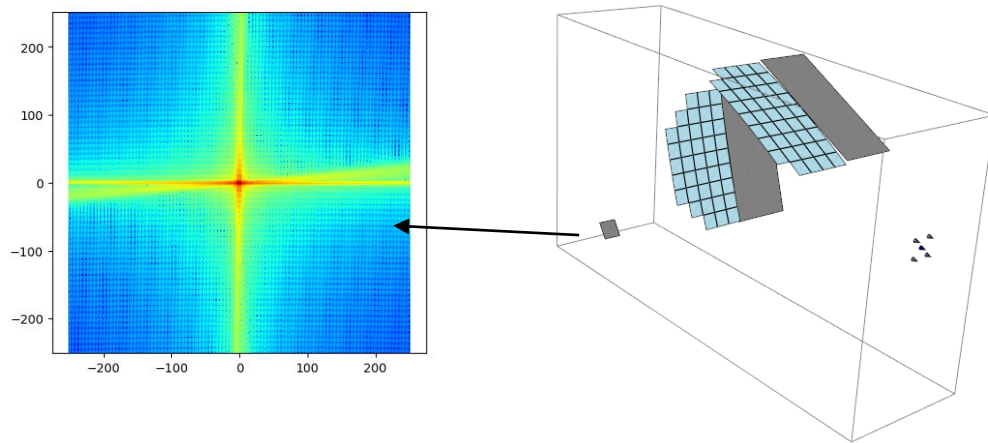
Figure 5. Right: The image plane of the Rx plane relative to the flat CF plate on M2; Left: Imaginary fields on the plane.

The fields on M1 are the sum of the scattered fields from the two intermediate planes and shown below. We can see the strong diffraction that is caused by the discontinuity on surface of M2.
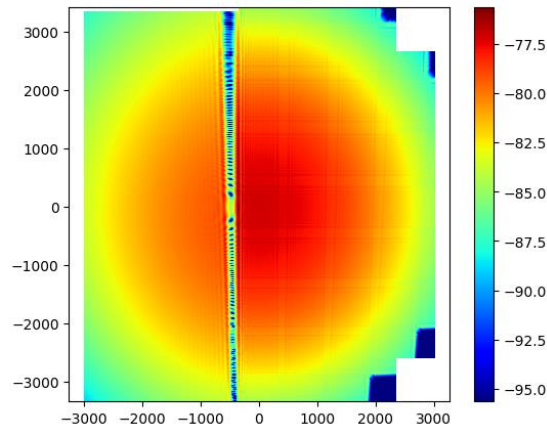

Figure 6. Fields on M1 surface and Carbon Fibre plane. It shows strong diffraction patterns in the discontinuity edge.

Then the beam map including the reflection fields of CF plate can be calculated from the fields on M1.
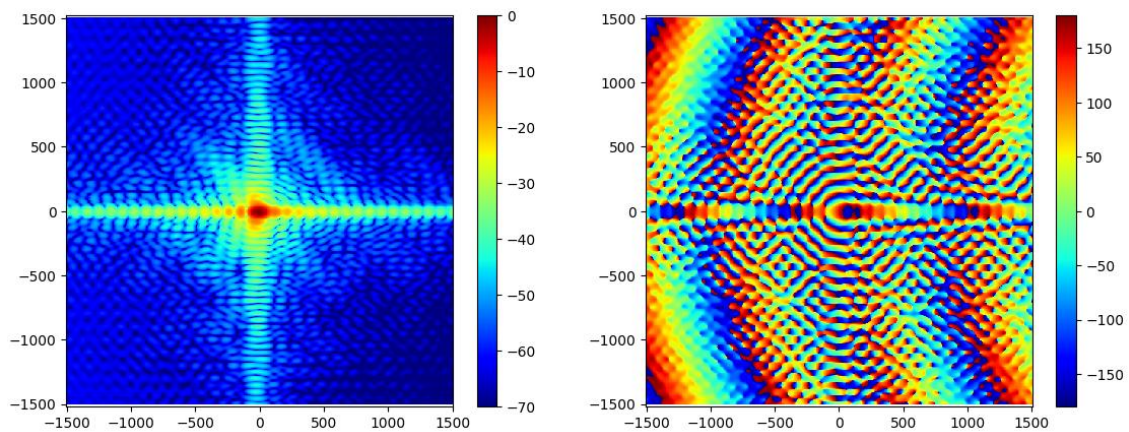

Figure 7. The beam map of the partially constructed antenna and CF plate. Left is its amplitude pattern, right is phase pattern.

By comparing the results with and without considering the CF plate, we can get the effects of the flat CF plates, which is less than -60dB relative to the beam peak.
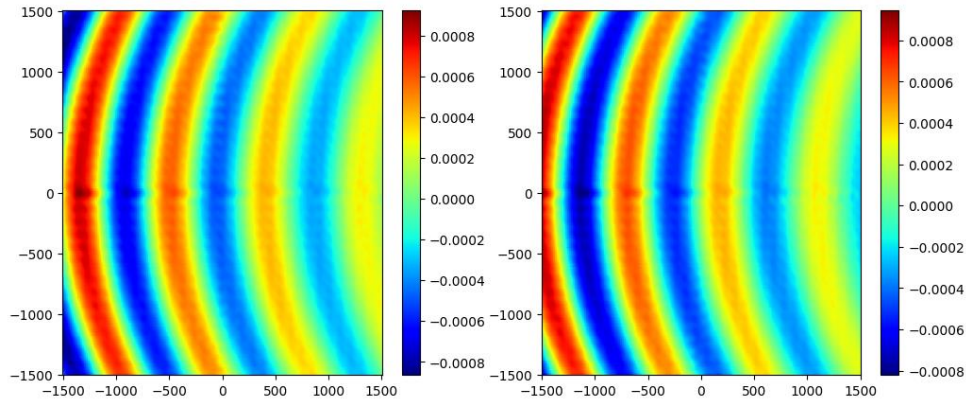

Figure 8. The fields produced by the Carbon Fiber plate on the beam maps. The plots show the real (left) and imaginary part (right) of the fields. The field is normalized by the total power of the focused beam. The effect is less than -60dB relative to the peak-value of the beam.
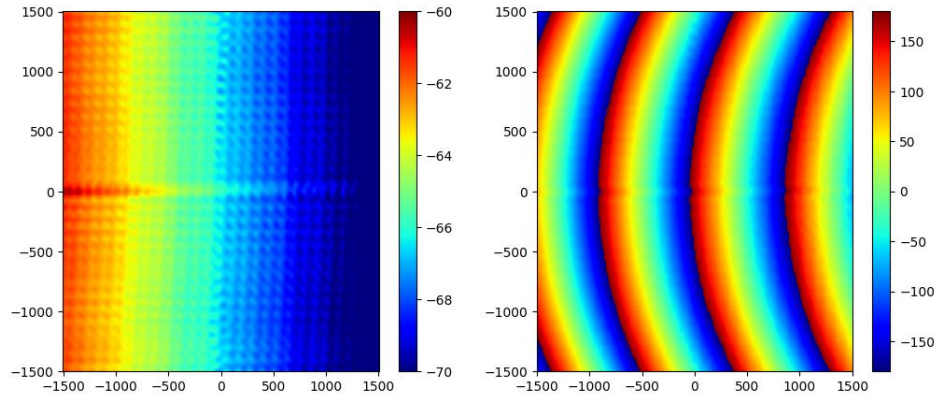

Figure 9. Scattered field from Carbon Fiber in amplitude and phase.

3. Effect on Holographic measurements.

The gain loss (~5dB) due to the missing half panels will not significantly affect the holographic measurement, because the measured noise is mainly limited by the lower SNR of reference Rx.

The full-antenna holographic simulation indicates that -60dB random noise with respect to the peak of the focused beam can degrade the measurement accuracy by 1.5um. Considering the resistance of the Carbon Fiber surface, we do think the effect on the Xanten holographic test can be neglected.