A Tentative Mechanism for the Origin of Sidelobes in the Band 6 Beam Pattern

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Introduction

The present short note presents a proposed mechanism for the origin of the sidelobes found in the Band 6 beam pattern. It was at the origin of the proposal made on 17-Feb in an Email to J.Effland and D.Koller.

Unwanted sidelobes may arise, a.o. from:

1. The intrinsic properties of diffraction-limited optics;
2. Distortions of the wavefront due to fabrication defects;
3. Back-and-forth reflections within the optical train

Here we concentrate on the third of these possibilities. It is clear from the outset that, to send energy into a secondary beam propagating in nearly the same direction as the main beam, it takes ***two reflections***. It is, in that case, difficult to decide on a ***single cause*** for the problem.

Qualitative mechanism

The qualitative mechanism relies on the following known facts:

1. The horn is located in a plane conjugate with the aperture plane;
2. It is surrounded by flat metallic surfaces that are orthogonal to the main beam axis;
3. The horn has a small Δ, hence, there is (approximately) a beam waist at the horn aperture;
4. Some refocusing optics couple the horn to a beam waist located in the telescope focal plane;
5. Both the IR filter and the window are located (approximately) in the focal plane.
6. Both the IR filter and the window, in their nominal position, have their normal tilted by ≈2.4° wrt to the beam's chief ray.

Besides, it is a property of Gaussian optical systems that angular beam displacements in the focal plane translate to lateral displacements in the aperture plane, and conversely.

Referring to Fig.1, the main beam is reflected by the filter and/or window by $2 \times 2.4^{o} = 4.8^{o}$. At the level of the present qualitative discussion, we assume the filter/window is exactly at the beam waist. Then, except for the angular displacement, the beam travels retraces the propagation of the original beam, only backwards. After going through the refocusing elements, the angular offset translates to a pure lateral offset ➔ there results a beam waist, whose axis is normal to the mouth of the horn and the surrounding flat metal surfaces. Form the parameters of the B6 refocusing optics, an angle of 4.8° in the focal plane translates to a displacement of 3.6 mm at the horn aperture, i.e. approximately one aperture radius, putting the "hot spot" of the returning beam on the flat rim of the horn and/or on its flange. Because the backwards beam has (approximately) a waist near the horn aperture plane, it will be bounced back and retrace its propagation outward bound. (see red lines on Fig.1).

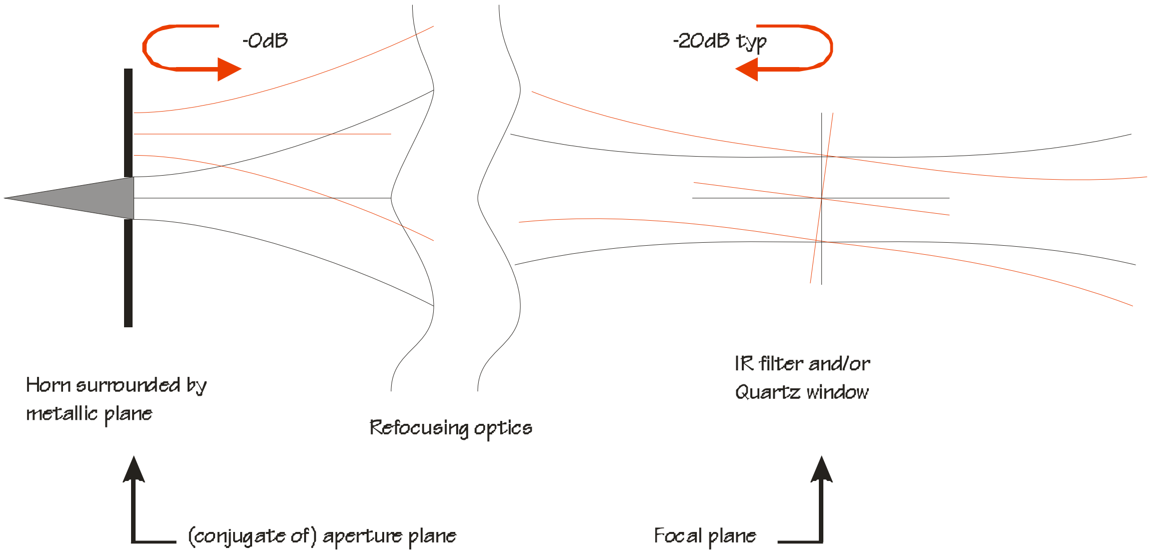

Figure 1. Explanatory sketch for sidelobe formation. See text.

Quantitative assessment of the model.

Offset between main and sidelobe.

According to the proposed model, the main and side lobe should coincide (approx) in position in the focal plane, with an angular offset of ~5°. Which translates, in the measurement plane ~500mm away, to a lateral offset of 42mm, close to what is observed

But the sidelobe stays at the same place when the window inclination is varied

The window and filter contribute comparable reflection coefficients (frequency dependent). Only one was ever moved at a time.

Level of sidelobe

It is up to –13dB relative to main lobe. But, its area is less. Say, energy-wise, it is –16dB. Window and filter may each contribute (in round numbers) up to –20dB. When they combine coherently, they can reflect up to –14dB. So, energy-wise, the mechanism is plausible.

Variability wrt frequency.

Because of the spatial separation between window and filter, and maybe also between the horn rim and the horn flange, frequency-dependent interferences are to be expected.

Minimum sidelobe level when quartz window is perpendicular to beam

Then the back-scattered beam from the window travels back and forth exactly superimposed on the main beam; the residual sidelobe is the contribution of the molded window alone.

Conclusions regarding corrective actions

If the model is accepted — at least as a working hypothesis —, the observed sidelobes are the consequence of the combination of a ~-20dB reflection on the window and/or filter and of a ~0dB reflection on the flat metal around the horn's radiating aperture. Which one has the largest potential for improvement is left for the reader to decide.

Furthermore, ***both*** window and filter might be tilted in the direction opposite to the beam (say, 5° from the dewar axis, i.e. ~7.5° from the beam axis, thus throwing unwanted reflections ~15° away from the main beam.