Modal Excitation of Optical Fibers
(4): Radial Overfill Launch (ROFL)
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1. Summary/Outline

See the 6/15/1998 [1], 6/25/98 [2], and 7/1/98 [3] notes which summarize the background for estimating the mode power distribution P_m from measurements of the nearfield $I(r)$ and for estimating the MPD for the offset launch.

This note summarizes results for the radial over-filled launch (ROFL) where we assume only the radial modes ($\mu = 0$) are excited. The *ideal* launch has $P_m = 1$ for all modes, while in practice [4] the power decreases exponentially with mode number.

One suggested way of looking at the intensity data is to plot $rI(r)$ rather than $I(r)$, because of the cylindrical symmetry.

The theoretical ROFL curves don't seem to agree very well, even in a qualitative way, with the experimental data, and for that reason the work should be viewed as preliminary results which are still being evaluated.

2. Theoretical Results

Figure 4.1 shows the intensity distributions $\psi_m^2(r)$ for some of the radial modes. All radial modes have a positive value at $r = 0$.

Figure 4.2 shows the intensity distribution I(r) for an ideal ROFL launch. Recall we assume

$$I(r) = \sum_m P_m \psi_m^2(r)$$

where the sum is over all the individual modes in the radial launch and for the ideal launch $P_m = 1$. This intensity distribution is extremely peaked near $r = 0$ and had a flat tail.

Figure 4.3 helps to better interpret the ROFL distribution by looking at the function $rI(r)$, which is what one would be integrating to get the total intensity (because of the cylindrical symmetry). $rI(r)$ shows oscillations due to the high order oscillations of the highest modes but seems to approximately follow a semicircle. Thus

$$rI_{ROFL}(r) \approx (1 - r^2)^{1/2}$$

though this may just be an approximation.

Figure 4.4 shows the effect of actual ROFL launches on the shape of $I(r)$ and $rI(r)$. The ideal ROFL launch corresponds to an *infinite* dB backoff, and the other curves correspond to smaller backoff or setback. In the limit of a 0 dB backoff, one would recover the fundamental mode again. The mode power distribution for an ROFL launch is modeled as assuming $P_m = 0$ if m is not a radial mode, and

$$P_m = \exp(-am)$$

for the radial modes, where a is a constant depending on the backoff of the Gaussian spot. If the maximum radial mode is $m = 17$ and the power drops by a factor of 2 from the fundamental mode $m = 1$ to $m = 17$, then $a = 0.04077$. Figure 4.4 shows the curves for a number of values of a.

Note that the oscillations go away and that $I(r)$ and $rI(r)$ become smooth and monotonic.

3. Experimental Results

Figure 4.5 and **Figure 4.6** are experimental data from Jim Tatum (Honeywell) for an ROFL launch. These figures show both $I(r)$ and $rI(r)$ for two scans across the 2D CCD data.

Note that the data has large oscillations which don't appear in the theoretical model, and that $I(r)$ and $rI(r)$ don't closely resemble the theoretical curves.

This may indicate an error in the calculation or that the experimental procedure in more complicated than what is being modeled.

4. References

[1] Abbott, J.S., "Modal Excitation of Optical Fibers. Estimating the Modal Power Distribution", *TIA 2.2tg Draft Notes* June 15, 1998.

[2] Abbott, J.S., "Modal Excitation of Optical Fibers. Initial Results: Calculation of Modal Power Distribution", *TIA 2.2tg Draft Notes* June 25, 1998.

[3] Abbott, J.S., "Modal Excitation of Optical Fibers. (3): Offset Launch with Gaussian Spot", *TIA 2.2tg Draft Notes* July 1, 1998.

[4] Saijonmaa, J., and Halme, S. J., "Reduction of modal noise by using reduced spot excitation", *Applied Optics* **20** no. 24, December 1984, pp.4302-4306. (reference from D. Cunningham)

Figure 4.1

Examples of Individual Radial Modes

Each curve is an individual ψ_m^2

Note how all modes have a finite value at r = 0

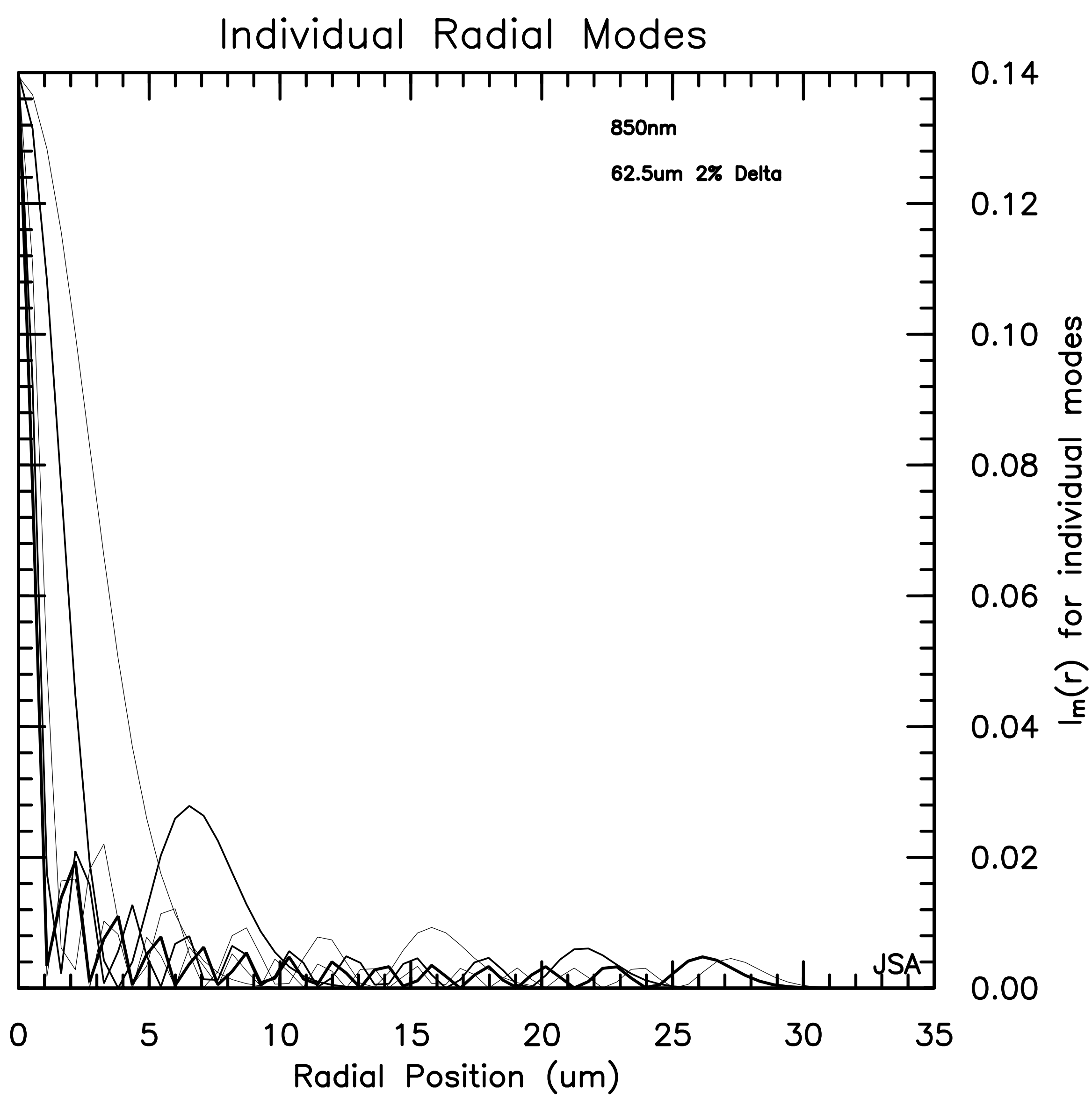

Figure 4.2

Ideal ROFL launch with P_m = 1 for all radial modes

Curves for first 1,2,5,and 10 radial modes also plotted

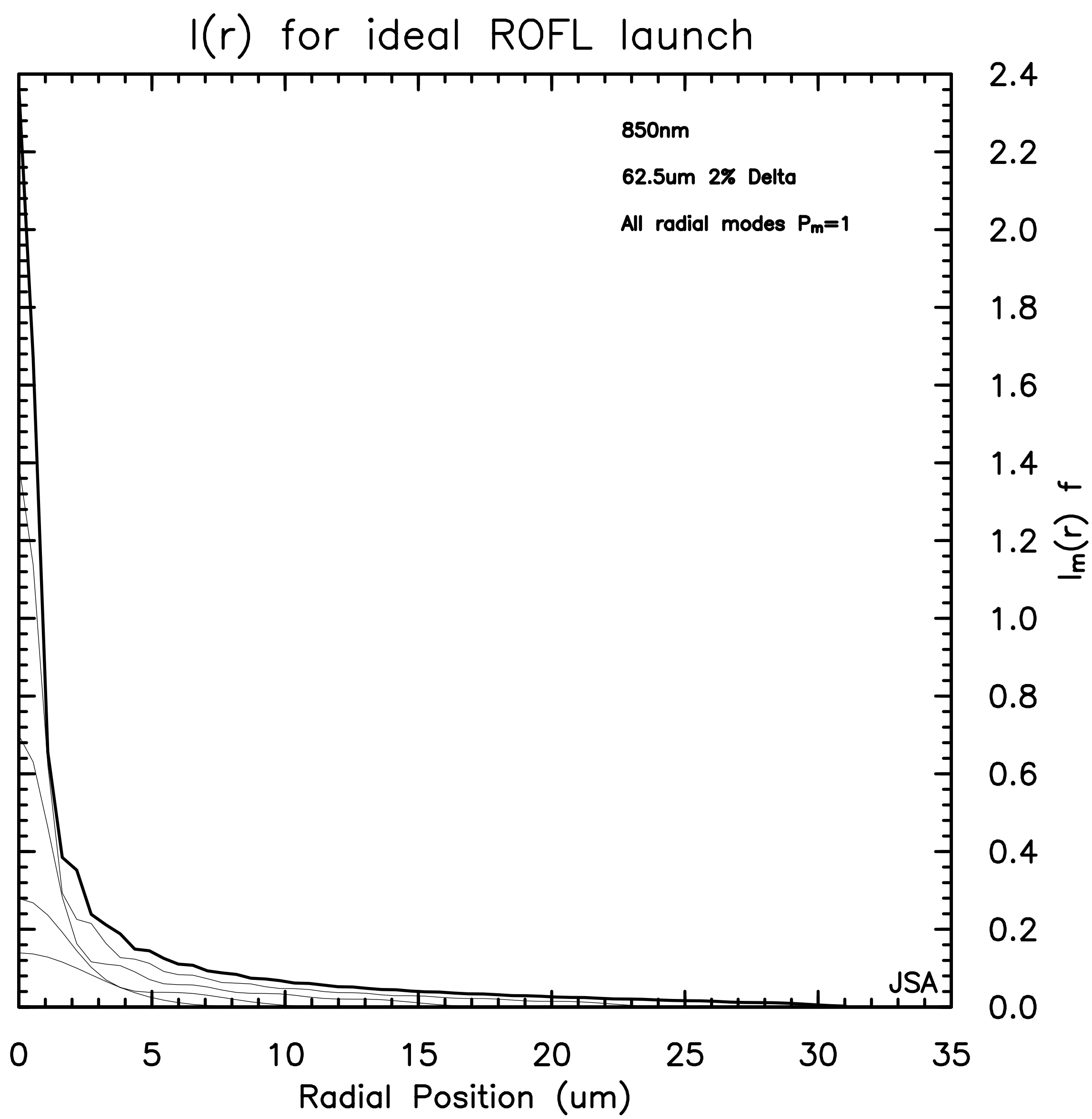

Figure 4.3

Analysis of I(r) for Ideal ROFL launch

r*I(r) looks like the semicircle $(1-r^2)^{.5}$

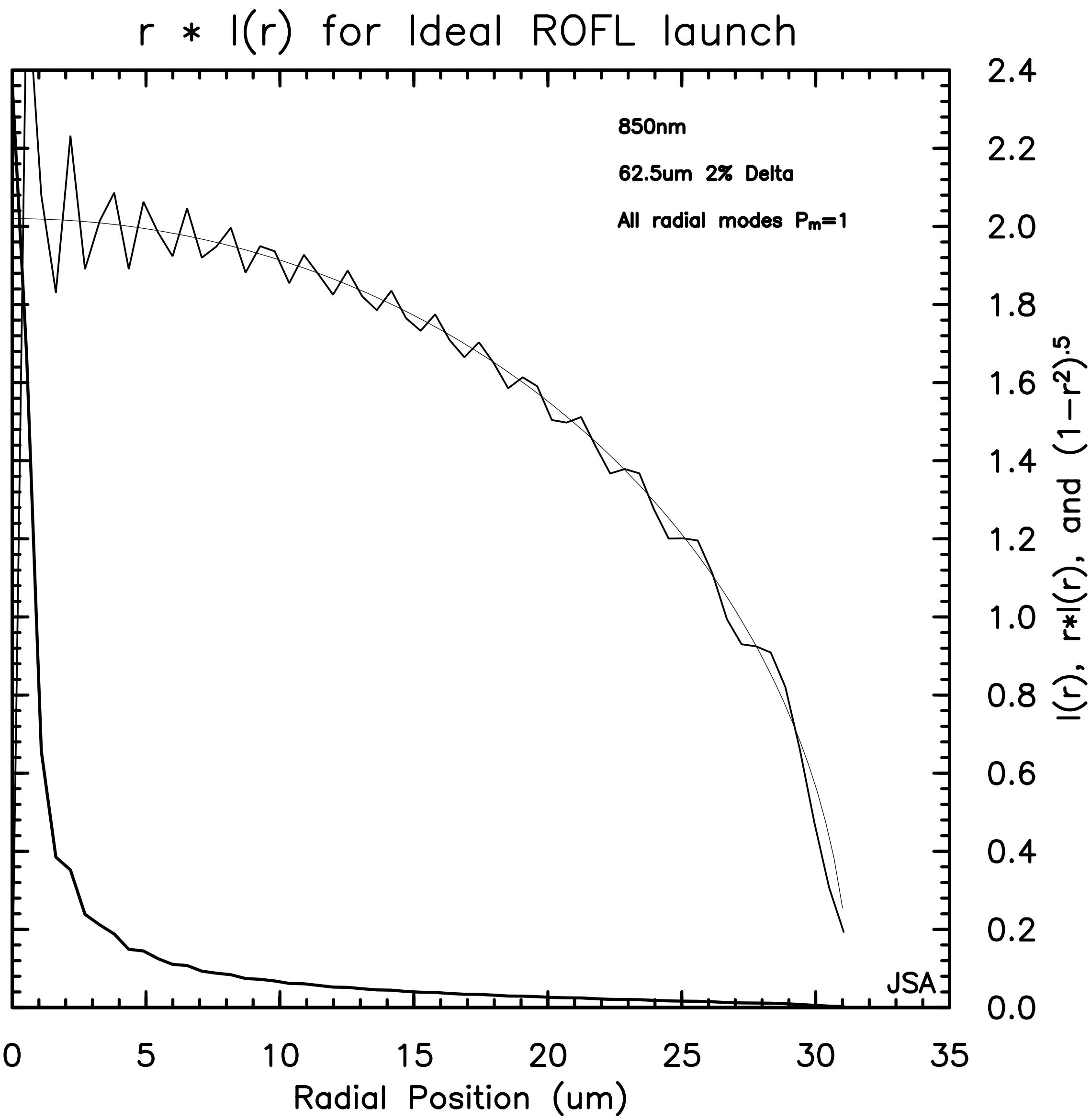

Figure 4.4

Analysis of I(r) for ROFL launches

$P_m = \exp(-a\ m)$, where a=0.04077, 0.14077, 0.24077, 0.44077

or P_1/P_{17} = 0.5, 0.09, 0.167, 0.000557

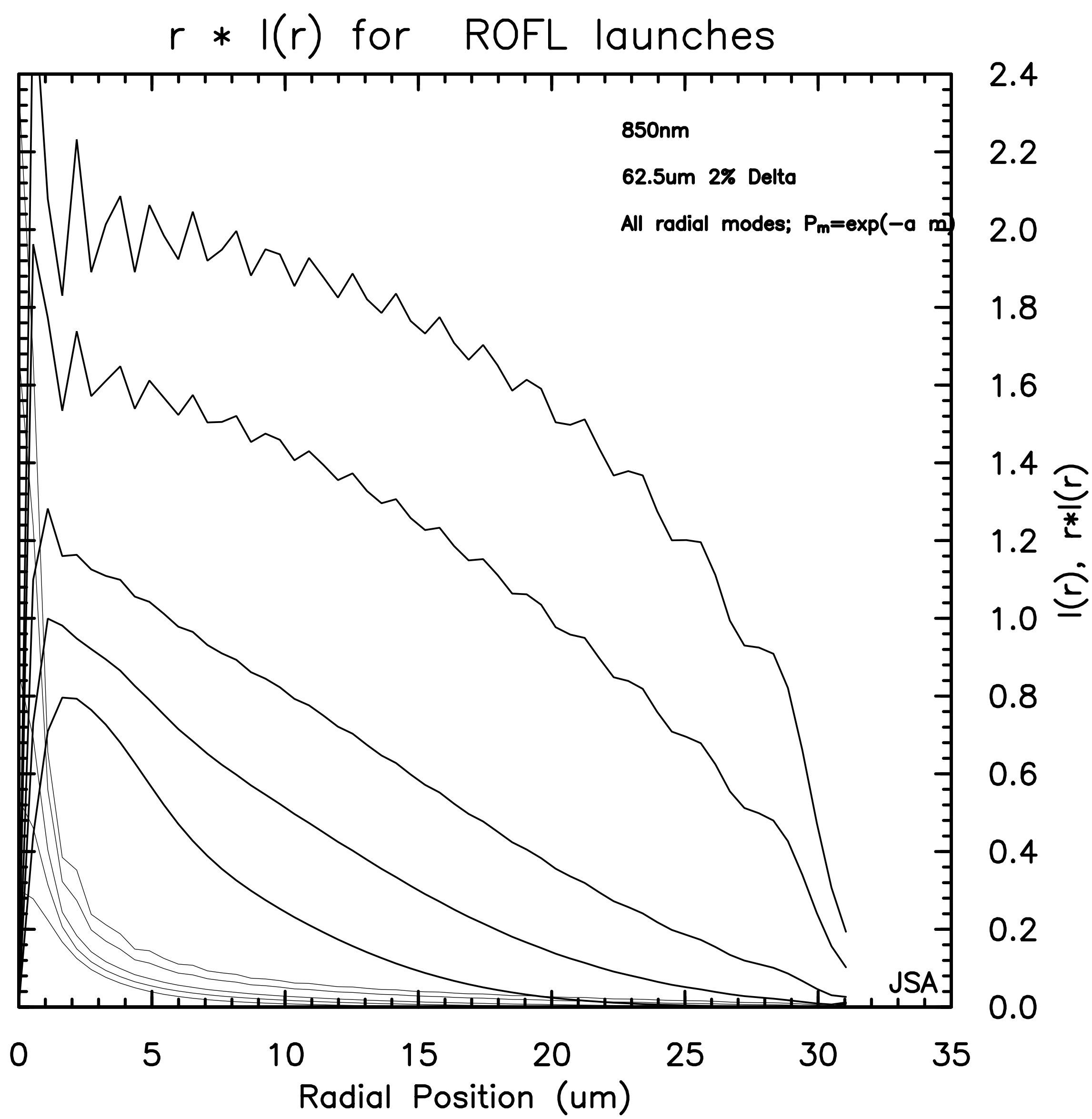

Figure 4.5

Experimental ROFL data: I(r), r*I(r)

Note how this data has more waves than theoretical ROFL

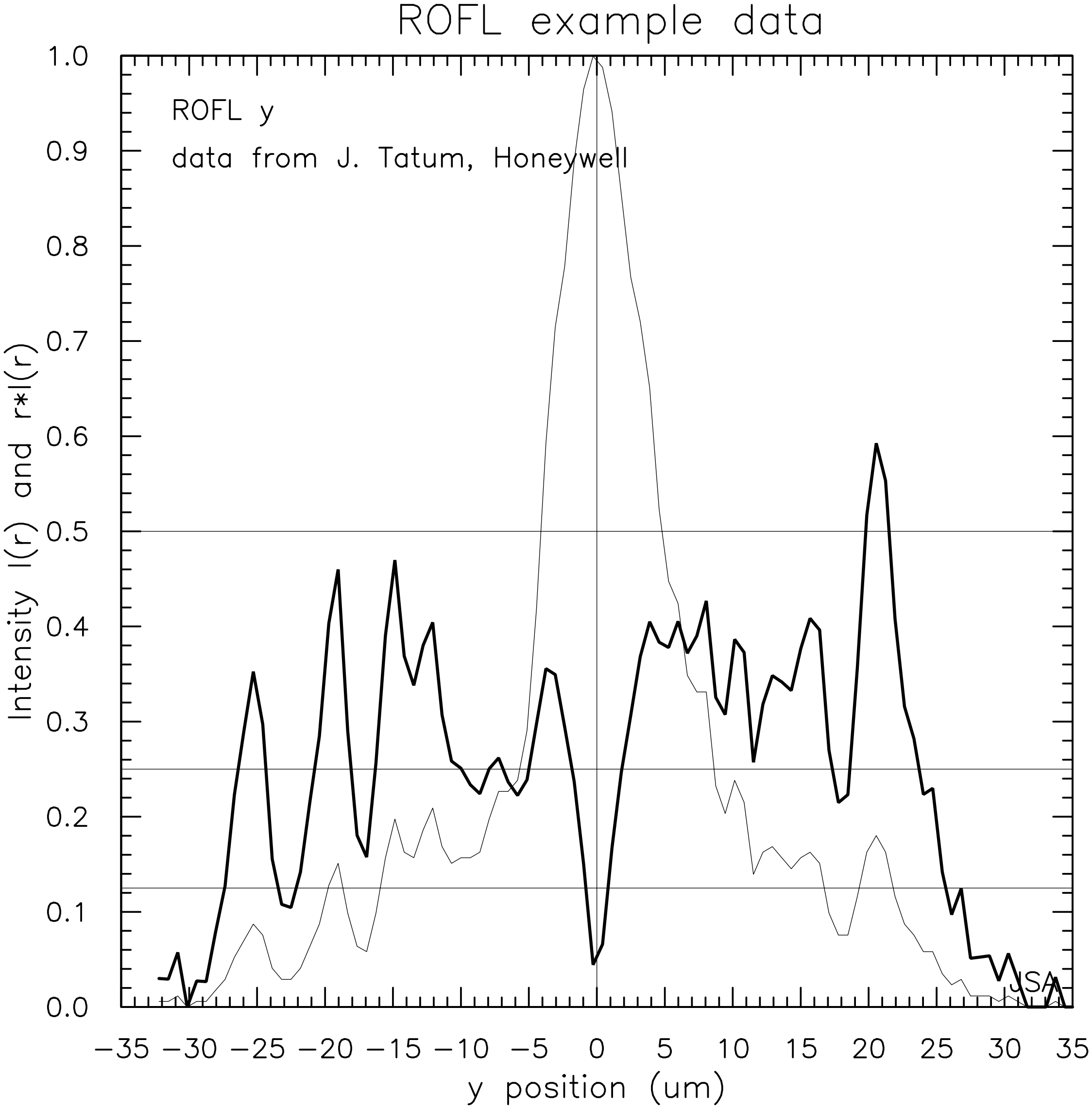

Figure 4.6

Experimental ROFL data: I(r), r*I(r)

Note how this data has more waves than theoretical ROFL