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AN028

Clipping Loss for Square and Circular Gaussian and Super-Gaussian Beams through a Cassegrain Telescope Aperture

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Introduction

Beam shaping can be used to achieve better efficiency in transmitting a typical laser beam profile through the annular aperture of a Cassegrain telescope. One alternative to shaping intensity profiles is to simply clip and core the beam with the annular Cassegrain aperture. In some instances this approach can achieve acceptable loss in a laser system. In this application note we determine the loss associated with transmitting circular and square super-Gaussians and Gaussians through an annular aperture.

Analysis Technique

In this study we generated an intensity profile on a 128 x 128 grid of points. The square super-Gaussian profile was generated using the Matlab code,

```
        I = exp(-2 * (g.xx ./ w).^order) .* exp(-2 * (g.yy ./ w).^order);
```

where g.xx and g.yy are 2D grids of x and y coordinates, w is the size factor, and order is the super-Gaussian order. The circular super-Gaussian profile was generated using the Matlab code,

```
        I = exp(-2* (g.r ./ w).^order);
```

where g.r is the 2D grid of radial coordinates. The Cassegrain aperture clipping was applied by multiplying by an annular aperture generated on the same grid as the intensity profile.

In this study we varied the outside aperture size and the central obscuration size for a given intensity profile. The aperture size was calculated as a multiple of the Gaussian size. The central obscuration size was calculated as a fraction of the outside aperture diameter.

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Gaussian Intensity Profile Results

Figure 1 shows an example annular-clipped Gaussian beam.

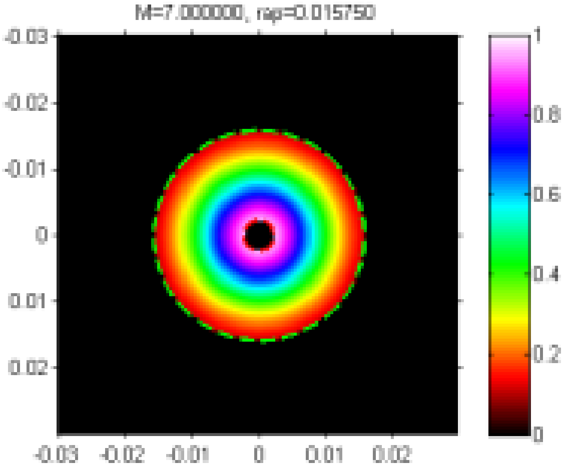

Figure 1 - Annular Clipped Gaussian Beam

The following table shows the transmission of a Gaussian beam through an annular aperture.

$r_{aperture}/r_{co}$

r_{ap}/W

	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.75	60.65	63.01	64.45	64.93	65.67	65.91	65.91
0.85	67.76	70.53	72.19	73.63	74.11	74.60	75.09
0.95	73.03	76.67	78.55	79.74	80.70	81.18	81.67
1.05	76.14	80.35	83.12	84.77	85.49	86.22	86.70
1.15	77.94	82.50	85.68	87.54	88.72	89.92	90.16
1.25	77.73	84.09	87.45	89.53	90.70	91.89	92.61
1.35	77.12	83.51	87.90	90.18	91.57	93.22	93.70
1.45	75.49	82.70	87.66	90.36	92.44	93.14	94.33

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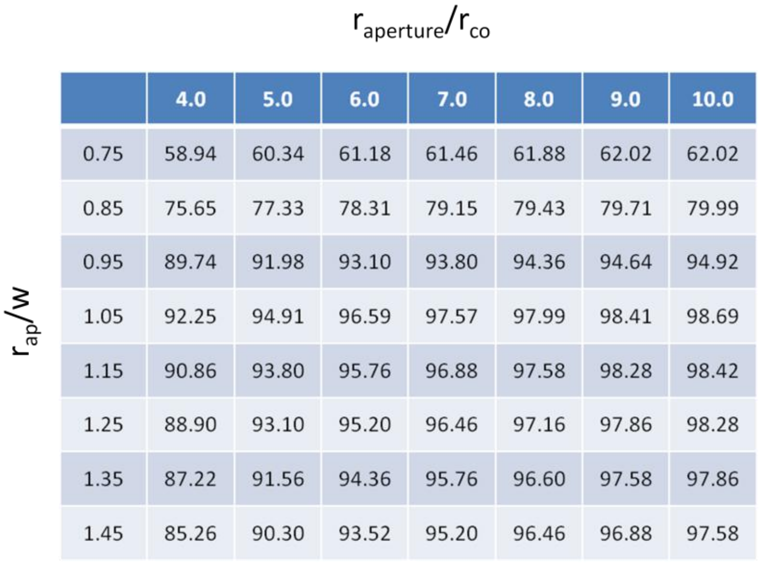
Circular 20th-Order Super-Gaussian

The following is the transmission efficiency of a 20th-order circular super-Gaussian through an annular aperture.



$r_{aperture}/r_{co}$

r_{ap}/w

	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.75	58.94	60.34	61.18	61.46	61.88	62.02	62.02
0.85	75.65	77.33	78.31	79.15	79.43	79.71	79.99
0.95	89.74	91.98	93.10	93.80	94.36	94.64	94.92
1.05	92.25	94.91	96.59	97.57	97.99	98.41	98.69
1.15	90.86	93.80	95.76	96.88	97.58	98.28	98.42
1.25	88.90	93.10	95.20	96.46	97.16	97.86	98.28
1.35	87.22	91.56	94.36	95.76	96.60	97.58	97.86
1.45	85.26	90.30	93.52	95.20	96.46	96.88	97.58

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Square 20th-Order Super-Gaussian

The following is the transmission efficiency of a 20th-order square super-Gaussian through an annular aperture.

$r_{aperture}/r_{co}$

r_{ap}/w

	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.75	46.49	47.59	48.25	48.47	48.81	48.92	48.92
0.85	59.91	61.24	62.01	62.67	62.89	63.12	63.34
0.95	73.33	75.10	75.98	76.53	76.97	77.19	77.42
1.05	83.15	85.25	86.57	87.34	87.67	88.01	88.23
1.15	88.44	90.76	92.31	93.19	93.74	94.30	94.41
1.25	90.14	93.45	95.11	96.10	96.66	97.21	97.54
1.35	89.86	93.29	95.50	96.60	97.26	98.04	98.26
1.45	88.38	92.35	94.89	96.22	97.21	97.54	98.09

Transmission Summary

As expected, super-Gaussian beam s transmit through an annular Casesgrain telescope much better than a Gaussian beam.

PIB Efficiency

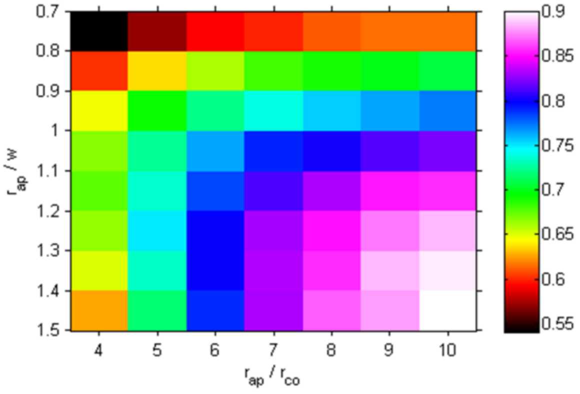
Next we need to analyze the far-field of the transmitted beam to establish power in the bucket efficiency where the bucket is equal to $\lambda/D_{aperture}$.

Gaussian Beam

rap/rco

rap/w

	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.75	54.04	57.09	59.19	59.92	61.04	61.47	61.47
0.85	60.13	63.68	66.05	68.23	69.01	69.82	70.67
0.95	64.61	69.36	72.14	73.99	75.56	76.35	77.20
1.05	66.82	72.37	76.41	79.07	80.22	81.49	82.33
1.15	67.58	73.61	78.32	81.30	83.28	85.38	85.81
1.25	66.48	74.89	79.88	83.17	85.20	87.31	88.58
1.35	65.15	73.41	79.86	83.45	85.78	88.68	89.53
1.45	62.51	71.71	78.94	83.28	86.75	88.00	90.09

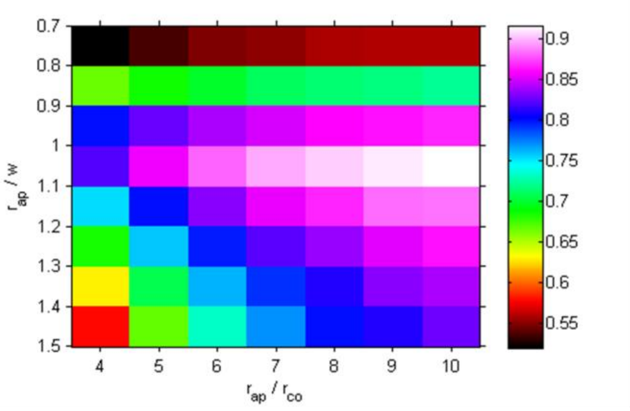


Circular 20th-Order Super-Gaussian

rap/rco

rap/w

	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.75	51.90	53.59	54.71	55.09	55.66	55.88	55.88
0.85	66.49	68.49	69.75	70.87	71.27	71.68	72.11
0.95	79.80	82.53	84.05	85.04	85.85	86.26	86.69
1.05	81.97	85.63	88.13	89.69	90.35	91.08	91.57
1.15	75.29	79.93	83.33	85.41	86.76	88.17	88.46
1.25	68.42	75.64	79.61	82.13	83.64	85.24	86.19
1.35	62.99	70.60	76.14	79.12	81.01	83.32	83.98
1.45	57.75	66.64	73.17	76.92	79.86	80.89	82.62

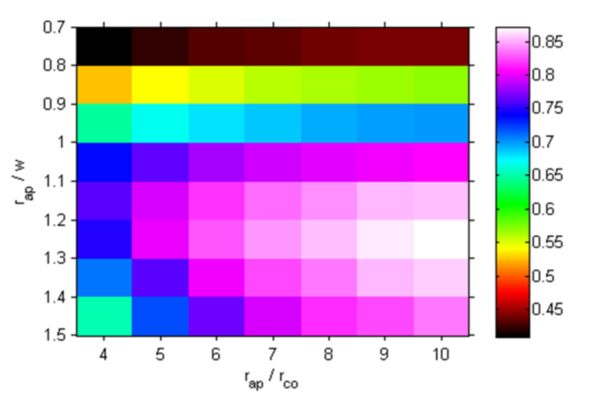


Square 20th-Order Super-Gaussian

rap/rco

rap/w

	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.75	40.93	42.26	43.15	43.45	43.89	44.07	44.07
0.85	52.59	54.17	55.16	56.04	56.36	56.68	57.02
0.95	64.68	66.80	67.97	68.73	69.36	69.67	70.01
1.05	73.72	76.39	78.20	79.32	79.80	80.32	80.66
1.15	76.30	79.55	81.92	83.34	84.27	85.25	85.44
1.25	74.88	80.01	82.69	84.40	85.43	86.55	87.19
1.35	70.82	76.34	80.26	82.34	83.67	85.31	85.78
1.45	65.32	71.93	76.71	79.49	81.64	82.38	83.64



Appendix: Matlab Code for Transmission Efficiency

```
%
setup;
ppt=1;

w = 15e-3;
Dap = 4*w;
nxy = 128;
dxy = Dap/nxy;
g=makegrid(nxy,dxy);
CIRCULARSUPERGAUSSIAN=1;
SQUARESUPERGAUSSIAN=2;
type = SQUARESUPERGAUSSIAN;
order=2;

for c = 1:3;
    if (c==1)
        type = CIRCULARSUPERGAUSSIAN;
        order = 2;
    elseif (c==2)
        type = CIRCULARSUPERGAUSSIAN;
        order = 20;
    else
        type = SQUARESUPERGAUSSIAN;
        order = 20;
    end;

    if (type==CIRCULARSUPERGAUSSIAN)
        I = exp(-2* (g.r ./ w).^order);
    else
        I = exp(-2 * (g.xx ./ w).^order) .* exp(-2 * (g.yy ./ w).^order);
    end;

    nf; show(I);
    caxis([0 1]);

    P0 = sum(I(:));
    pDapv = [0.75:0.1:1.5];
    rapv = w .* pDapv;
    c=0;
    Magv = 4:1:10;
    for rap = rapv;
        c=c+1;
        d=0;
        rcov = rap .* 1./Magv;
        for rco = rcov;
            d=d+1;
            ap=aperture(nxy,dxy,rap,0,0,rco,false);
            It = I .* ap;
            clf;
            show(g.x,g.y,It);
            caxis([0 1]);
            hold on;
            plotcircle(rap*2,0,0,'g--','LineWidth',2);
            plotcircle(rco*2,0,0,'r--','LineWidth',2);
            title(sprintf('M=%f, rap=%f',Magv(d),rap));
            drawnow;
            if (ppt)
                %ToPPT(gcf,'Annular Clipped Gaussians',[length(rcov) length(rapv)
length(rapv)*(c-1)+(d-1)+1],(d==1 && c==1));
                ToPPT(gcf,'Annular Clipped Gaussians',[length(rcov) length(rapv) length(rapv)*(d-
1)+(c-1)+1],(d==1 && c==1));
            end;
            T(c,d) = sum(It(:))./P0;
            disp(sprintf('c,d: %i,%i',c,d));
        end;
    end;

    nf; imagesc(Magv,pDapv,T);
```

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```
    %nf; imagesc(pDapv,Magv,T'); %this aligns with ppt better
    xlabel('Magnification');
    ylabel('rap / w');
    colorbar;
    if (ppt)
        ToPPT('Transmission Summary');
    end;

    for ii=1:length(Magv)
        sMagv{ii} = sprintf('%.1f',Magv(ii));
    end;
    for ii=1:length(pDapv)
        sDapv{ii} = sprintf('%.2f',pDapv(ii));
    end;

    if (ppt)
        SendTableToPowerPoint(T*100,12,'%.2f',...
            'Efficiency','rap/w','Magnification',sMagv,sDapv);
    end;

end;
```

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