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Effect of Limited Pixel Resolution on Power-In-A-Bucket Measurements

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1 Introduction

It is often easiest to achieve power-in-a-bucket (PIB) measurements with a camera instead of setting up an aperture and a photodetector. In many optical setups, the pixel size is set to a multiple of λ/D, often making good beam quality difficult to observe. In this application note, we examine the potential for extracting a good estimate of PIB with limited pixel resolution of the diffraction-limited spot size.

2 Analytical Approach

To analyze this effect, we began by creating a well-resolved version of the diffraction-limited spot on a 1024x1024 mesh grid as follows:

```
I = exp(-1 * (( sqrt((xx-dx).^2 + (yy-dy).^2)/w).^2));
```

where dx and dy are offsets from the center, xx and yy are the grid of pixel coordinates, and w is the size of the Gaussian beam. The offset in x (dx) was scanned from 0 to 48 in mesh size increments. The pixelated version of this image was created by summing 16x16 mesh samples to create each pixel. The term w (Gaussian waist) was scanned from in size from half a pixel in size to 10 pixels. The PIB curve was extracted by summing the power in a virtual aperture for different sizes. The error in the extracted PIB curve was calculated by looking at the RMS difference between the high resolution PIB extracted from the mesh and the lower resolution PIB extracted from the pixelated version.

3 Results

The following figures show examples for 0.5 and 10 Gaussian beam waist scale factors. In every case, the total power was normalized.

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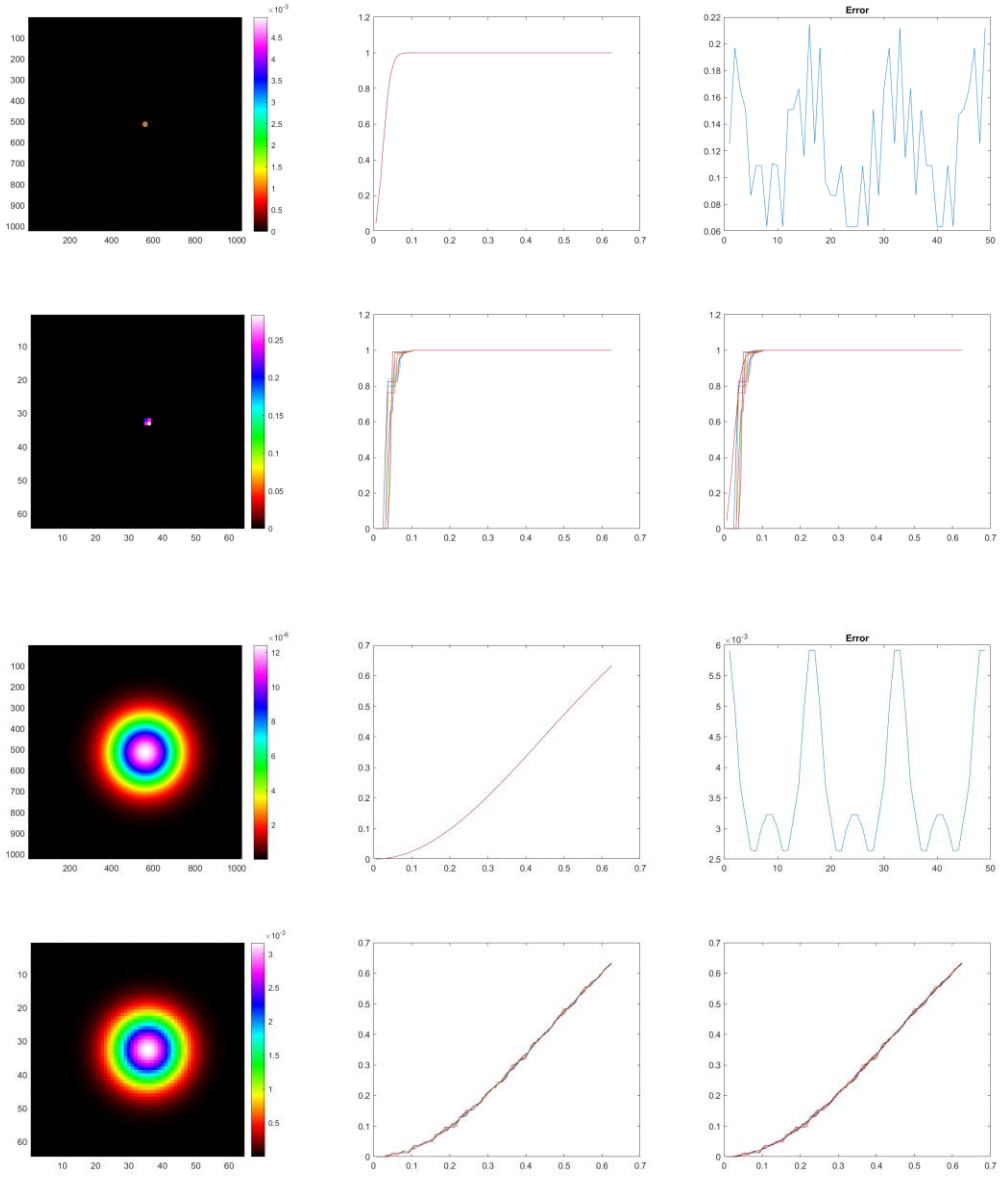

The RMS error as a function of the number of pixels per waist size is shown below. With 1 pixel per waist size, we see about a 5% RMS error in the curve. 1% is achieved around 4 pixels per waist.

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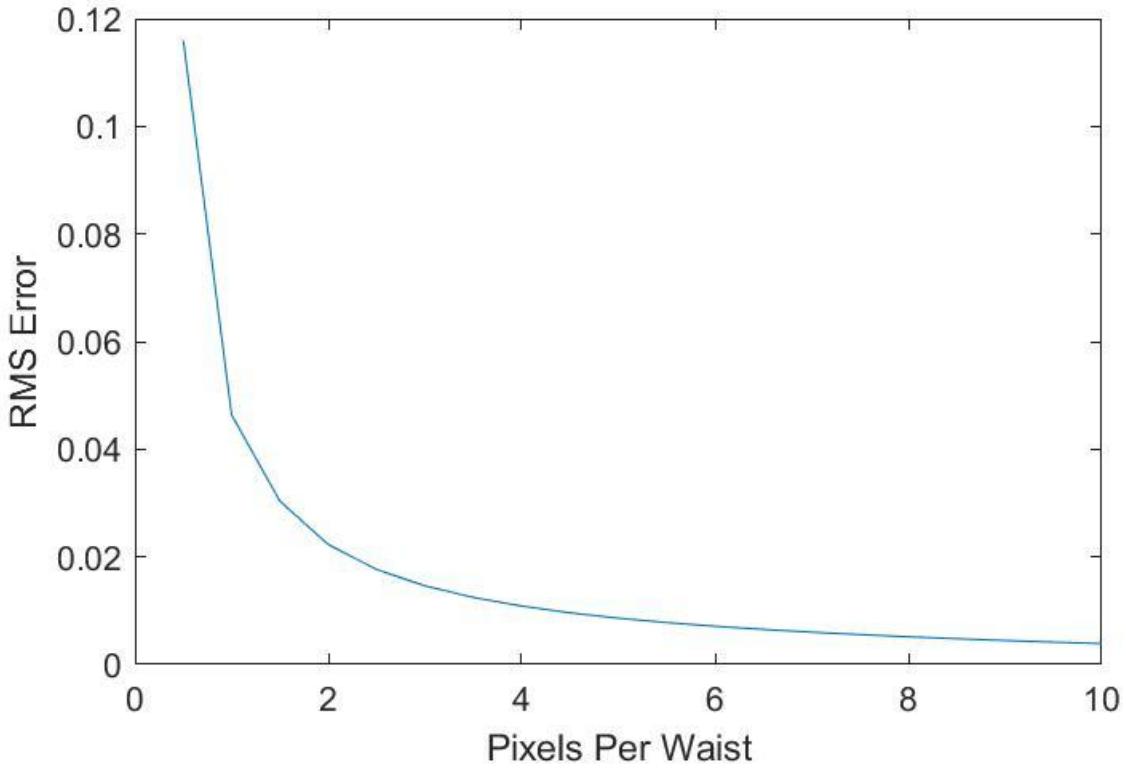

4 Conclusions

In this application note, we showed that there is additional error associated with pixelation of the far-field measurement, but even with the 1 pixel per Gaussian waist (radius), the result is only about 5% RMS error.

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5 Appendix A: Matlab Simulation Code

```
% script to study PIB efficacy vs. pixels per DL spot size
Setup;
ppt=1;

Nsamp = 16;
Dap = 1.0;
nxy = 1024;
thr = 0.01;
dxy = Dap*4/nxy;
dpix = Nsamp * dxy;

if (ppt)
    TitleSlidePowerPoint(sprintf('PIB Accuracy vs. Pixels Per Gaussian Waist'));
end;

ccc=0;
tic
wSFvec = 0.5:0.5:10;
for wSF = wSFvec;
    ccc=ccc+1;
    clear PIB;
    clear PIB0;
    w = dpix * wSF;
    Npix = nxy/Nsamp;

    x = ((-nxy/2):1:(nxy/2-1))*dxy;
    [xx,yy] = meshgrid(x,x);
    xp = ((-Npix/2):1:(Npix/2-1))*dpix;
    [xxp,yyp] = meshgrid(xp,xp);
    [xxi,yyi] = meshgrid(1:nxy,1:nxy);
    [xxpi,yypi] = meshgrid(1:Npix,1:Npix);
    dy = 0;

    clear PIB;
    cc = 0;
    for dx = dxy .* [0:1:(3*Nsamp)];
        cc=cc+1;

        I = exp(-1 * (( sqrt((xx-dx).^2 + (yy-dy).^2)/w).^2));
        I = I ./ sum(I(:));

        [xc,yc,x2,y2]=MomentsWithThreshold(I,thr);
        c=0;
        rbucketVec0 = (0.1:0.1:10).*Nsamp;
        for rbucket = rbucketVec0;
            c=c+1;
            bucket = sqrt( (xxi-xc).^2 + (yyi-yc).^2) < rbucket;
            PIB0(cc,c) = sum(sum(I.*bucket));
        end;


        for i=1:1:Npix;
            for j=1:1:Npix;
                Ip(i,j) = sum(sum(I((i-1)*Nsamp + [1:1:Nsamp],(j-1)*Nsamp + [1:1:Nsamp])));
            end;
        end;
        [xc,yc,x2,y2]=MomentsWithThreshold(Ip,thr);
        c=0;
        rbucketVec = 0.1:0.1:10;
        for rbucket = rbucketVec;
            c=c+1;
            bucket = sqrt( (xxpi-xc).^2 + (yypi-yc).^2) < rbucket;
            PIB(cc,c) = sum(sum(Ip.*bucket));
        end;

        piberr(cc) = RMS(PIB(cc,:)-PIB0(cc,:));
```


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```
        clf;
        subplot(2,3,1); show(I);
        subplot(2,3,2); plot(rbucketVec0.*dxy,PIB0);
        subplot(2,3,4); show(Ip);
        subplot(2,3,5); plot(rbucketVec.*dpix,PIB);
        subplot(2,3,6); plot(rbucketVec.*dpix,PIB); hold on;plot(rbucketVec0.*dxy,PIB0);
        %     subplot(2,3,3); plot(PIB-PIB0); title ('Error');
        subplot(2,3,3); plot(piberr); title ('Error');
        drawnow;
    end;
    PIB0Save{ccc} = PIB0;
    PIBSave{ccc} = PIB;
    errorSave(ccc) = RMS(PIB - PIB0);
    if (ppt) ToPPT2(sprintf('Pixels Per Waist = %.2f',w/dpix)); end;
end;

%% results summary
nf;
plot(wSFvec,errorSave);
xlabel('Pixels Per Waist');
ylabel('RMS Error');
if (ppt) ToPPT2('Error Summary'); end;

dtime = toc
if (ppt)
    TitleSlidePowerPoint(sprintf('Elapsed Time: %.2f',dtime));
end;
```


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