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Description

```
%title: SOMRAF Algorithm
%desc: an IFTA to determine phase distribution in CGH for beam shaping
%using amplitude freedom in certain region, uniform offset, and
 sofftness
%tunable kernel
%author: Muhammad Syahman Samhan
%email: mssamhan@students.itb.ac.id
%last update: November 27, 2019
%adapted from Gerchberg and Saxton (1971) and Pasienski & DeMarco
 (2008)
%inspired from
    %1. Musa Aydin (Sultan Mehmet Vakif University)
    %2. Dae Gwang Choi (KAIST, 2019)
    %3. Pasienski & DeMarco (2008)
```

General Variables

```
clc
clear all
close all
pixelx = 1024;
pixely = 1024;
padx = 2*pixelx;
pady = 2*pixely;
sizex = 0.864;              % from HoloEye website
sizey = 0.864;
x = linspace(-sizex, sizex, padx);
y = linspace(-sizey, sizey, pady);
[X,Y] = meshgrid(x,y);      %meshgrid for Input Beam
slmaperture = (X > -sizex/2 & X < sizex/2 & Y > -sizey/2 & Y <
 sizey/2);
x0=0; y0=0;             %center of CGH and Input Beam
tilt = 0;               %only if needed later
```

```
i_num = 30;             %number of iteration
error = [];             %error array is empty for first
```

Input Variables

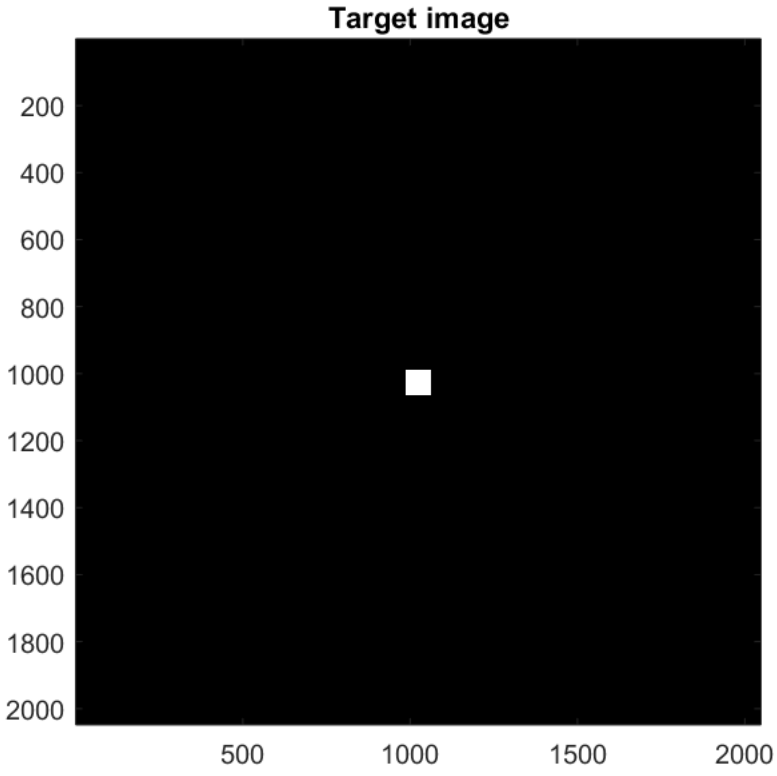
```
R = 200;
mu = 0;
B_con = 0;
B_lin = 0;
aspect_ratio = 1;
m = 0.98;
offset = 1;
kernel_waist = 100;
```

Generate Gaussian Input Beam

```
sigma = 0.74;                                   %beam waist in cm
A = 1;                                          %input amplitude
theta = ((X-x0).^2 + (Y-y0).^2)./(2*sigma^2);   %phase of Input beam
input = A*exp(-theta).*slmaperture;             %input amplitude for a
 given position
```

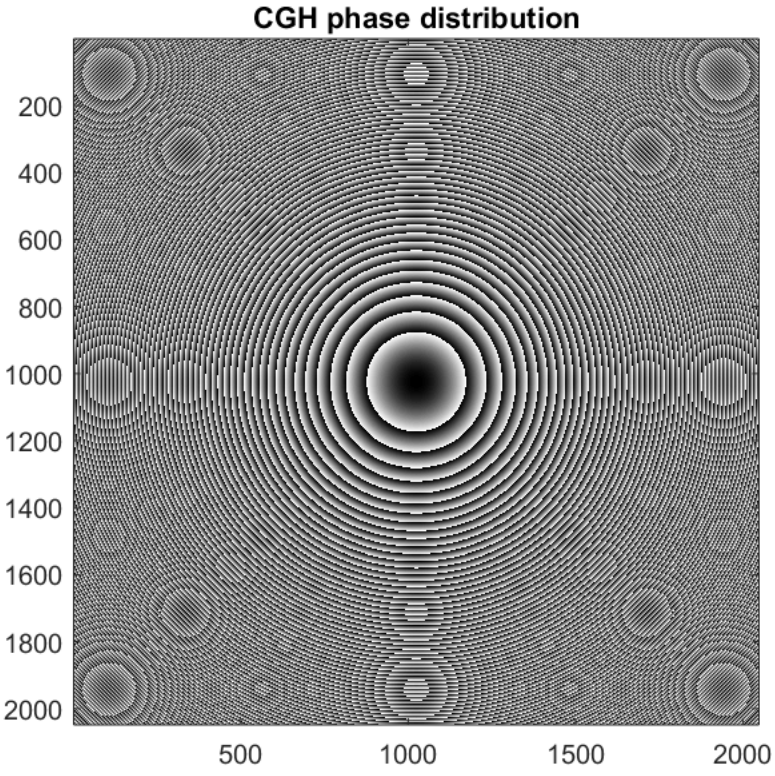
Target Image

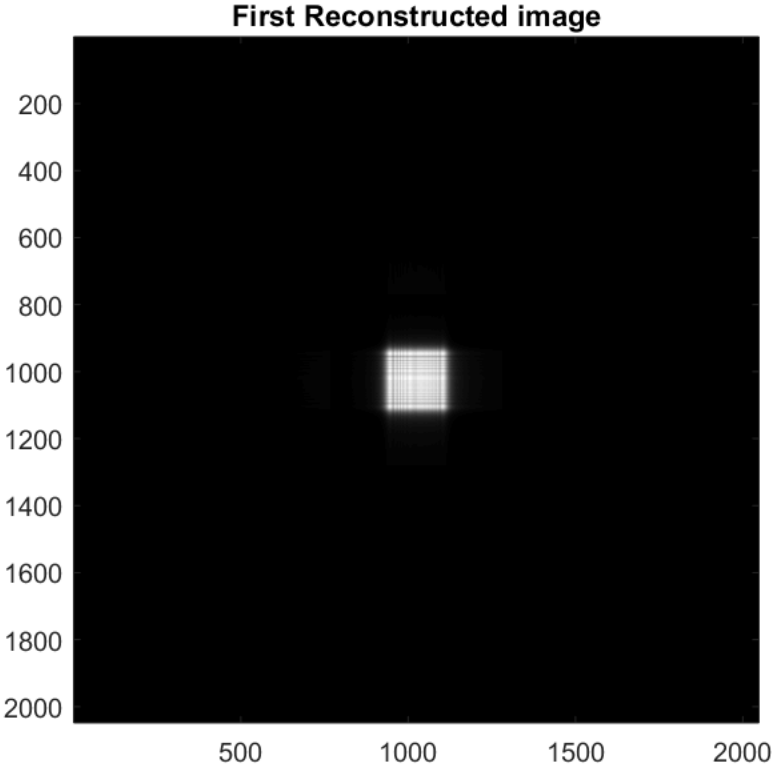
```
Target_Ori = rgb2gray(imread('square.bmp'));      %target image input
Target = double(Target_Ori);                    %changing the target
 into matrix of doubles with precision
Target = sqrt(Target.^2 + offset^2);

 figure %Original Target Image
    imagesc(Target), axis image, colormap('gray');
    title('Target image')

SR_Ori = rgb2gray(imread('SR.bmp'));               %signal region
 input
threshold = 0.5;
SR = (double(SR_Ori) >= threshold);            %change signal region
 into matrix of 1 and 0
NR = 1-SR;                                      %noise region = outside
 of signal region
MR = SR;
N_m = nnz(MR);
Target_m = MR.*Target;
```



Phase Initialization Step

```
alpha = aspect_ratio/(1+aspect_ratio);
A_quad = 4*R*(alpha*X.^2 + (1-alpha)*Y.^2);
A_lin = B_lin*(X*cos(mu) + Y*sin(mu));
A_con = B_con*sqrt(X.^2+Y.^2);
A = mod(A_quad + A_con + A_lin ,2*pi);
B = abs(input).*exp(1i*A);
C = fftshift(fft2(fftshift(B)));
figure %CGH Phase Distribution Result
     imagesc(abs(A)), axis image, colormap('gray');
     title('CGH phase distribution');
%
figure %First Reconstructed Image
     imagesc(abs(C)), axis image, colormap('gray');
     title('First Reconstructed image')
```


CGH phase distribution
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000


First Reconstructed image
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000

Perform MRAF (Mixed-Region Amplitude Freedom) Algorithm

```
for i=1:i_num
    Target_So = imgaussfilt(Target, kernel_waist);
    kernel_waist = kernel_waist - kernel_waist*i/i_num;
    D = (m*abs(Target).*SR + (1-m)*abs(C).*NR).*exp(1i*angle(C)); %the
 main line of MRAF algorithm
    A = fftshift(ifft2(fftshift(D)));
    B = abs(input).*exp(1i*angle(A));
    C = fftshift(fft2(fftshift(B)));
    %Error Calculation: Root Mean Squre Error of Measure Region
        C_m = MR.*C;
        error_cur = sqrt((1/N_m)*sum(sum(((abs(C_m)./
max(max(abs(C_m)))) - abs(Target_m)./max(max(abs(Target_m)))).^2 ) ));
        error = [error; error_cur];
end
```

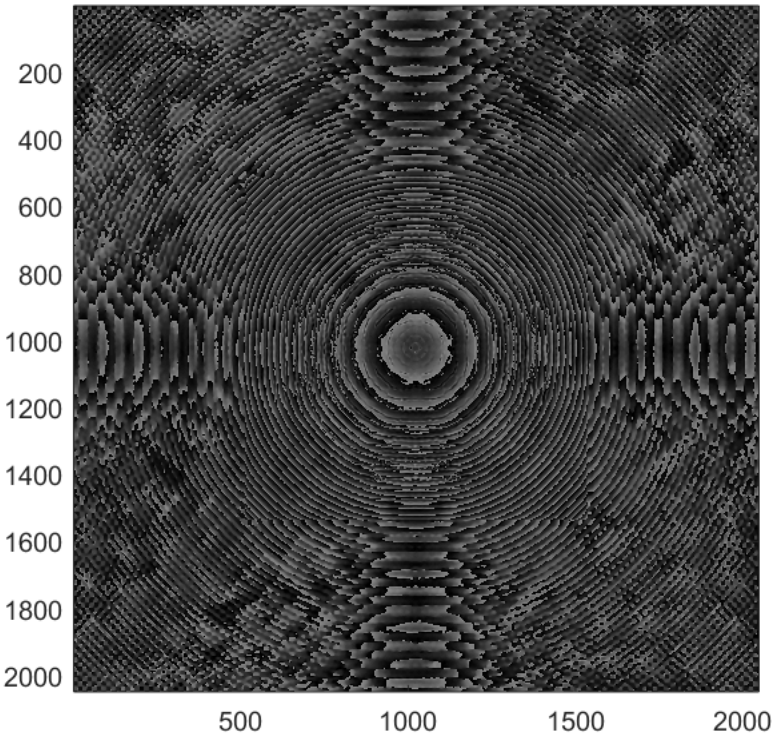
Calibration Section by Dae Gwang

```
Crop=angle(A)+pi;   % change range, from -pi to pi into 0 to 2pi
aaaa=136;           % maximum gray level for 2pi phase shift (depends
 on SLM)
Crop=floor(aaaa.*Crop./(2.0*pi)); % converting the phase shift into
 gray level

% This line changes the black into the white
for j=1:pady
    for k=1:padx
        if Crop(j,k) == 0;
            Crop(j,k)=aaaa;
        end
    end
end

% This line is the main calibration section, which we got after
 experiment
for qi=1:pady
    for qj=1:padx
        k= Crop(qi,qj);

 Crop(qi,qj)=round(0.863*k-0.00596*(k)^2+0.00008035*k^3-0.000000238*k^4+0.00000000
    end
end
```

Figure of Calibrated CGH

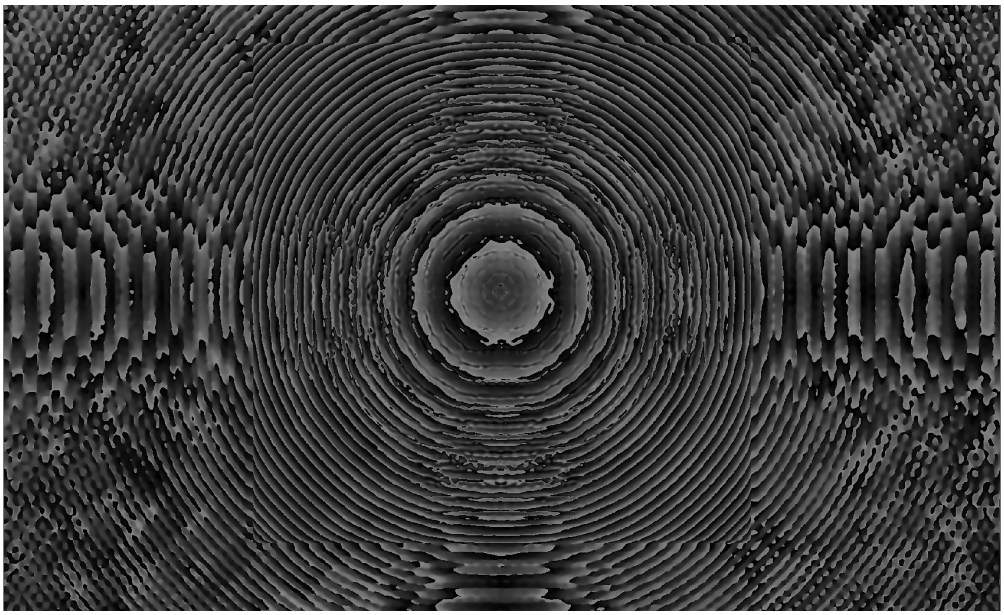
```
Crop=Crop';

figure
```

```
imagesc(Crop), axis image ,colormap('gray'), caxis([0,255]);
```



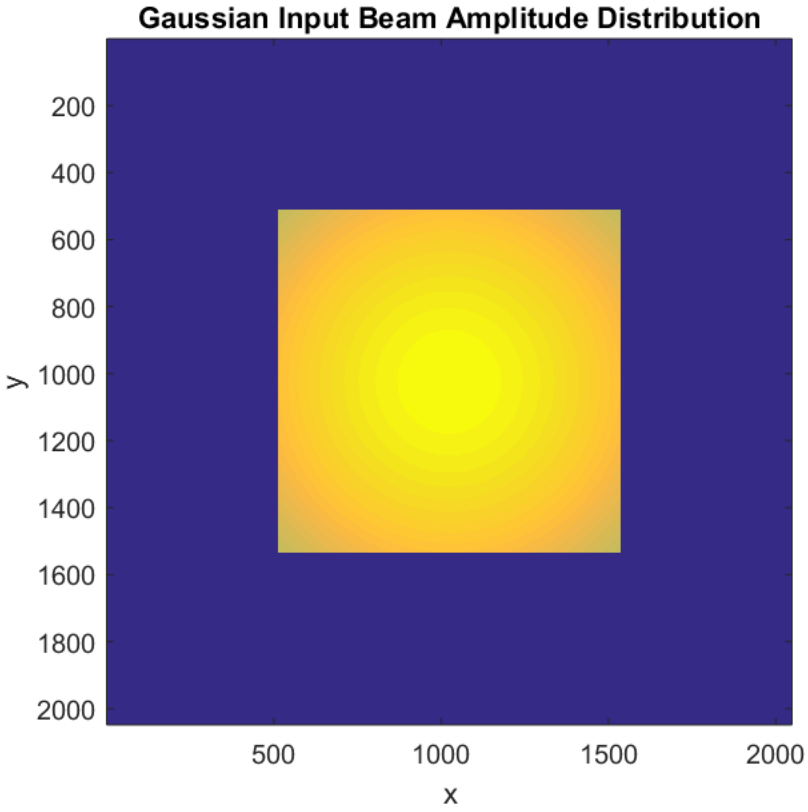
Setting the position, magnification, etc. of the CGH

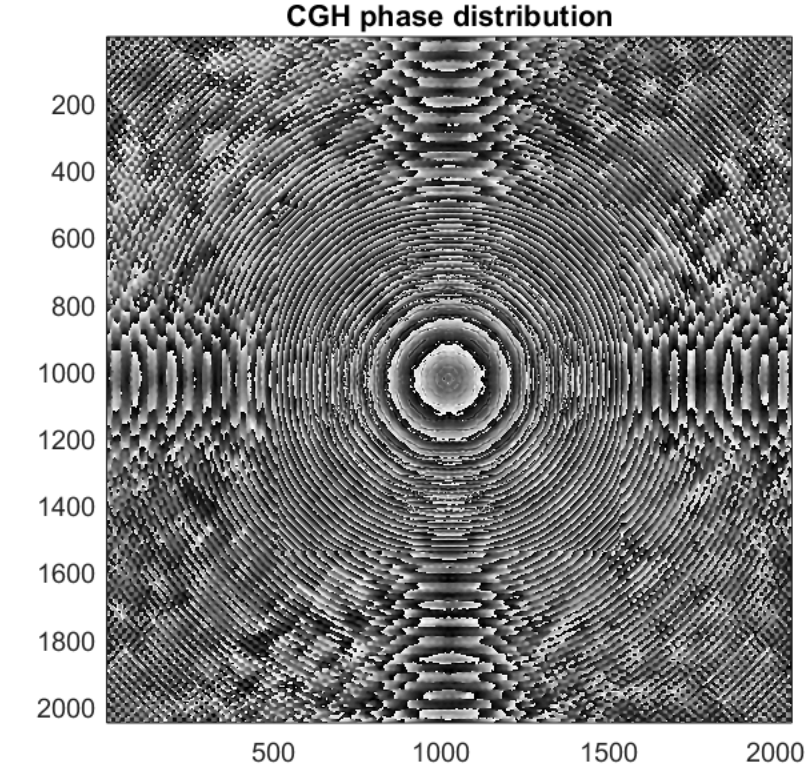
```
magni=1.65;

set(gcf, 'Units', 'Normalized', 'OuterPosition', [1 0.00 1 1]);
set(gca, 'Units', 'normalized','Position',[0. -0.3 1 magni]);
set(gcf, 'Toolbar', 'none', 'Menu', 'none','menubar','none','NumberTitle','off');
set(gca,'Yticklabel',[],'Xticklabel',[],'ytick',[],'xtick',[])
```

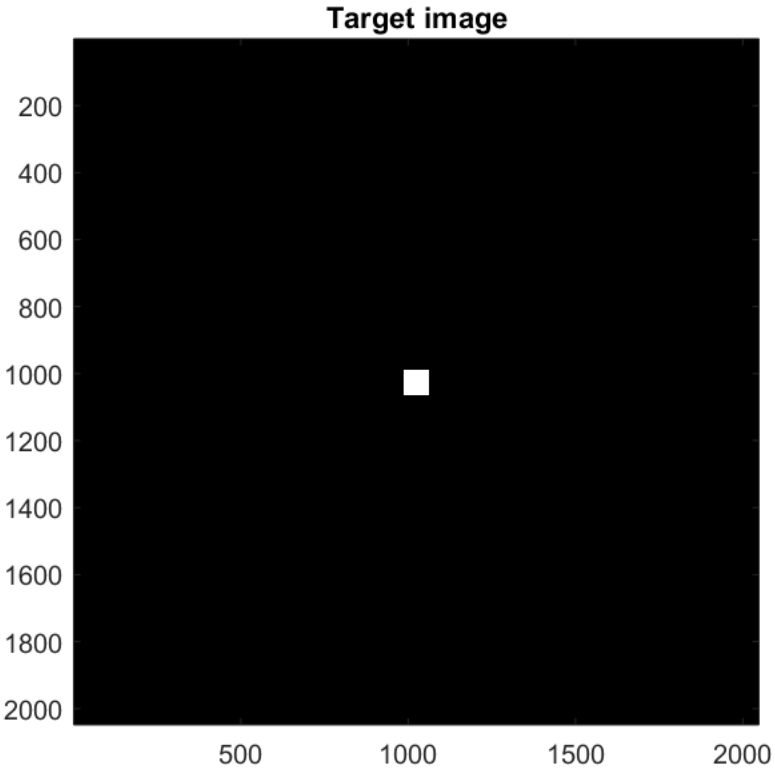


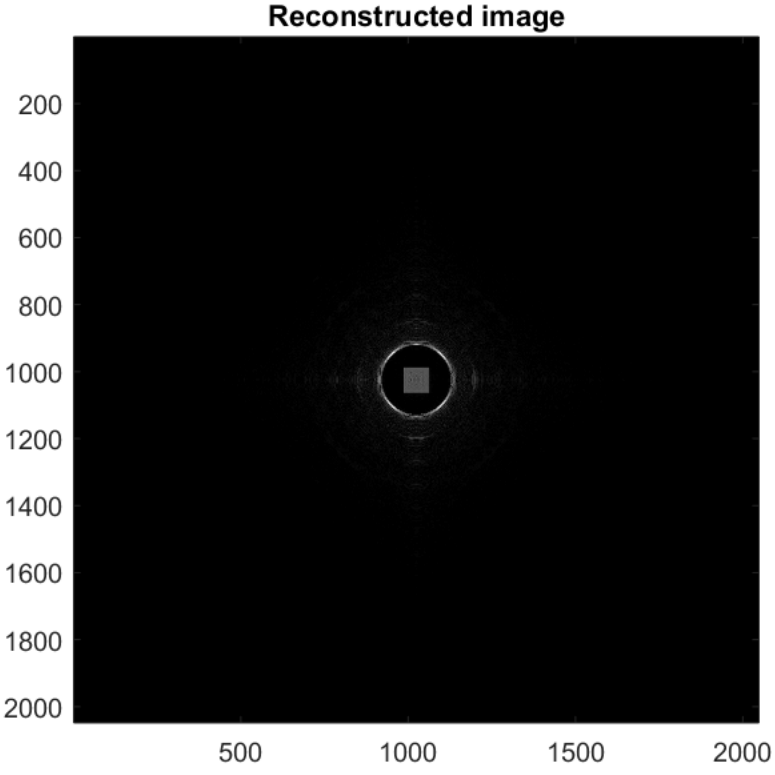
Show Result

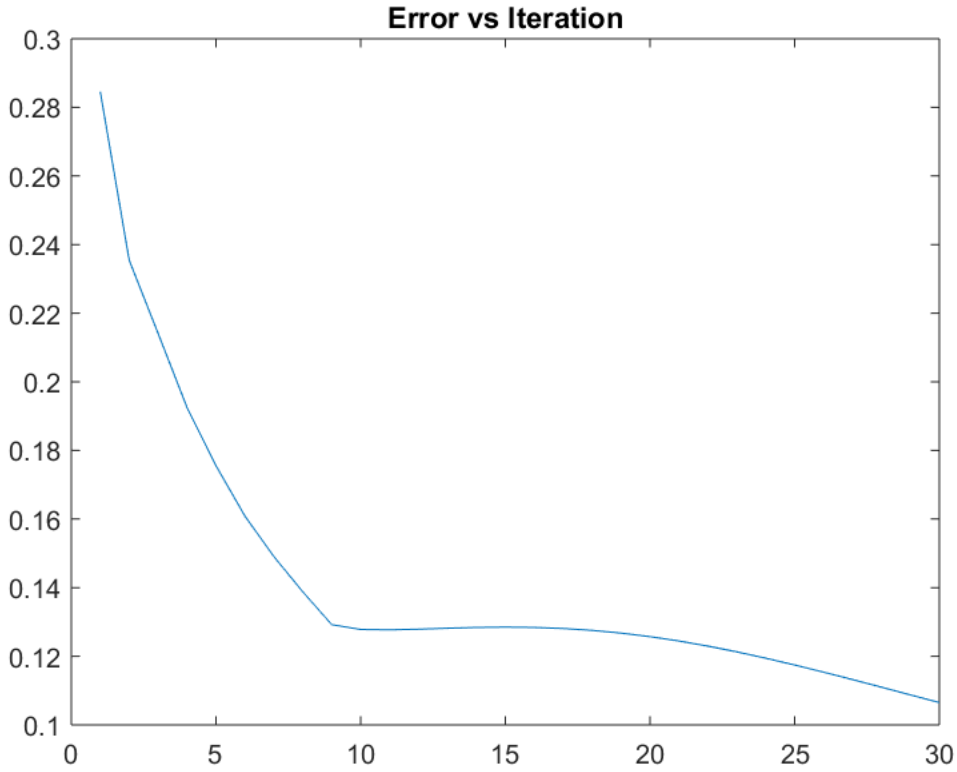
```
figure %Input Beam Distribution
    imagesc(input), axis image;
    title('Gaussian Input Beam Amplitude Distribution')
    xlabel('x')
    ylabel('y')

figure %CGH Phase Distribution Result
    imagesc(Crop), axis image, colormap('gray');
    title('CGH phase distribution');

figure %Original Target Image
    imagesc(Target), axis image, colormap('gray');
    title('Target image')

figure %Reconstructed Image
    imagesc(abs(C)), axis image, colormap('gray');
    title('Reconstructed image');

figure %Error vs iteration
    i = 1:1:i;
    plot(i,(error'));
    title('Error vs Iteration');
```


Gaussian Input Beam Amplitude Distribution
200
400
600
800
1000
1200
1400
1600
1800
2000
y
500
1000
1500
2000
x


CGH phase distribution
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000


Target image
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000


Reconstructed image
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000



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