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Bullet_Impact

Simulacion de impacto

Version 1

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Problema Especial IMEC

Simulacion de impacto entre proyectil ductil y objetivo fragil

Disponible en repositorio publico SPH

Se omiten tildes para evitar problemas de compatibilidad en ecoding

```
clear all; clc; close all;
```

Definir Geometria del Objetivo

Todas las unidades son dadas en el sistema internacional de unidades

Se define las posiciones de las particulas que conforman el objetivo

Geometria del objetivo

```
T_dy = 0.5e-4; %    Separacion entre particulas
T_dx = T_dy*2;   %
k = 2.0;   %    Constante para expandir radio de soporte
h = k*T_dx;  %    Radio de soporte

T_width = 0.0005;               % Ancho del objetivo
T_height = 0.005;              % Alto del objetivo
T_x = -T_width : T_dx : T_width;
T_y = -T_height : T_dy : T_height;
[X,Y] = meshgrid(T_x, T_y);     % Matriz con la malla de las posiciones x,y para l
Target = [X(:),Y(:)];           %   | x_1 , y_1 |   En esta matriz organiza
                                %   | .   , .   |   todas las posiciones de las
                                %   | x_n , y_n |   particulas.
                                %   [T_np x 2]

T_np = size(Target,1);          % Numero de particulas en el objetivo
```

Asignacion de defectos puntuales en Objetivo

Constantes para asginacion de fallas en basalto

```
m = 3;
k = 7;
T_V = T_dx*T_dy*1;    % Volumen infinitesimal

Nflaws = T_np*log(T_np);        % Numero de defectos puntuales a asignar
Nflaws = round(Nflaws);
assign_flaws = randi(T_np,Nflaws,1,'uint32'); % [Nflaws x 1]
                                %  Nflaws numeros aleatorios entre 1 y T_np
[Flaws{1:T_np,1}] = deal([]);   %  Flaws [cell array] {T_np x 1}
                                %  Cell array con ''T_np matrices vacias
                                %  Cell de pre-alocacion para fallas

for i = 1:Nflaws
    Flaws{assign_flaws(i),1}(size(Flaws{assign_flaws(i),1})+1) = ...
        (i/(k*T_V))^(1/m);
end
```

assign_flaws [Nflaws x 1] vector que contiene *Nflaws* posiciones de las fallas a generar. Las posiciones estan dadas como numeros enteros en relacion al numero de cada particula.

Flaws cell{T_np x 1} Contiene *T_np* matrices vacias que identifican las fallas para cada particula. **Flaws** se va llenando de forma aleatoria con las posiciones que indica *assing_flaws*. La primera vez que se pasa por una amtriz de Flaws, le asigna el numero (i/(k*V))^(1/m) formando una matriz 1x1. La segunda vez que se pasa por la misma matriz, aumenta la dimension de la matriz en una sola direccion para asignar otro numero. Asi, si semi-aleatoriamente, el numero *k* aparecio *n* veces de *assign_flaws*, la celda *Flaws* en su posicion *k* debe contener una matriz nx1 con numeros asignados. Los numeros asignados corresponden a las deformaciones de activacion para los defectos puntuales de cada particula

Constantes del Material Objetivo

Todas las unidades estan en el sistema internacional de unidades

```
T_rho = 7850;                %Densidad volumetrica del objetivo
T_m0 = T_dx*T_dy*T_rho;      %Masa de una particula

%Parametros de Huggoniot
T_ss = 4699;
T_C = 3630;
T_S = 1800;

%Parametros de XSPH
T_gamma = 1.81;
T_alpha = 0.5;
T_beta = 0.5;
T_eta = 0.01;
T_eps = 0.5;

%Parametros de Elasticidad
T_G = 8e10;          % Modulo de cortante
T_Y0 = 6e8;          % Esfuerzo de fluencia
T_E = T_ss^2*T_rho;   % Modulo de Young
```

Definir Geometria del Proyectil

Se definen las posiciones de las particulas que conforman el proyectil.

Se asume que el proyectil se mueve en la direccion horizontal.

Proyectil rectangular

```
%{
s_x = 4e-4;              % Separacion en x entre proyectil y objetivo
B_width = T_width/5;     % Ancho del proyectil
B_height = T_height/5;   % Alto del proyectil
B_x0 = min(Target(:,1))-B_width-s_x;
B_y0 = mean(Target(:,2)); % Posiciones de referencia para el objetivo
B_dx = T_dx;             % Separacion entre particulas del proyectil
B_dy = B_dx;

B_x = [-B_width : B_dx : B_width] + B_x0;
B_y = [-B_height : B_dy : B_height] + B_y0;
[X,Y] = meshgrid(B_x,B_y);  % Matrices con la malla para las posiciones
                            % de la particulas en el proyectil
Bullet = [X(:),Y(:)];       % Posicion de las particulas en el pryectil
B_np = size(Bullet,1);      % Numero de particulas en el proyectil
%}
```

Proyectil redondo

```
s_x = h/5;          % separacion en x entre proyectil y objetivo
B_dr = 1e-4;         % Variacion en el radio del proyectil
B_rmax = 0.002;  % Radio maximo del proyectil
B_r = B_dr:B_dr:B_rmax; % Valores del radio en el proyectil
n_theta = 18*2;          % Numero de puntos a considerar en el angulo
B_theta = linspace(0,2*pi,n_theta); % Valores del angulo
B_cx = min(Target(:,1)) - B_rmax - s_x; % Centro del proyectil
```

```
B_cy = mean(Target(:,2));
B_np = length(B_r)*length(B_theta); %Numero de particulas en el proyectil
Bullet = zeros(B_np,2); % Posiciones x,y de las particulas en el proyectil
for i = 1:length(B_r)
    for j = 1:length(B_theta)
        Bullet((i-1)*n_theta+j,:) = [B_r(i)*cos(B_theta(j))+B_cx,...
            B_r(i)*sin(B_theta(j))+B_cy];
    end
end
```

Constantes del Material Proyectil

Por el momento estas magnitudes corresponden a las mismas del objetivo

Consultar Propiedades para algun metal y reemplazaralas

```
B_rho = 7850;               %Densidad volumetrica del objetivo
B_m0 = pi*B_dr^2*B_rho;     %Masa de una particula
B_V = pi*B_dr^2*1;
%Parametros de Huggoniot
B_ss = 4699;
B_C = 3630;
B_S = 1800;

%Parametros de XSPH
B_gamma = 1.81;
B_alpha = 0.5;
B_beta = 0.5;
B_eta = 0.01;
B_eps = 0.5;

%Parametros de Elasticidad
B_G = 8e10;             % Modulo de cortante
B_Y0 = 6e8;             % Esfuerzo de fluencia
B_E = T_ss^2*T_rho;     % Modulo de Young
```

Alocacion de Matrices Requeridas para calculos

```
N_part = T_np + B_np; % Numero total de particulas

Particles = [Target;Bullet];    % Posiciones de particulas
V1 = zeros(N_part,1);   % Velocidad en la direccion 1
V2 = zeros(N_part,1);
dV1 = zeros(N_part,1);  % Derivada total de V1
dV2 = zeros(N_part,1);
    dv1dx1 = zeros(N_part,1);
    dv1dx2 = zeros(N_part,1);   % Derivada de V1 en direccion 2
    dv2dx1 = zeros(N_part,1);
    dv2dx2 = zeros(N_part,1);
P = zeros(N_part,1);    % Presion Hidrostatica
```

```
Tau11 = zeros(N_part,1);
Tau12 = zeros(N_part,1);    % Esfuerzos en cara 1 con direccion 2
Tau21 = zeros(N_part,1);
Tau22 = zeros(N_part,1);
    dTau11 = zeros(N_part,1);
    dTau12 = zeros(N_part,1); % Derivada de esfuerzos en cara 1 con dir 2
    dTau21 = zeros(N_part,1);
    dTau22 = zeros(N_part,1);

eps11 = zeros(N_part,1);
eps12 = zeros(N_part,1);    % Deformacion unitaria en cara 1 con dir 2
eps21 = zeros(N_part,1);
eps22 = zeros(N_part,1);

E_int = zeros(N_part,1);        % Energia Interna
    dE_int = zeros(N_part,1);   % Derivada de Energia Interna
```

Asignacion Selectiva de Propiedades

Hay que revisar esta matrices porque las propiedades deben inicializarse de acuerdo al *tipo de las particulas*, es decir que se deben asignar propiedades diferentes a las particulas del **objetivo** y a las particulas del **proyectil**

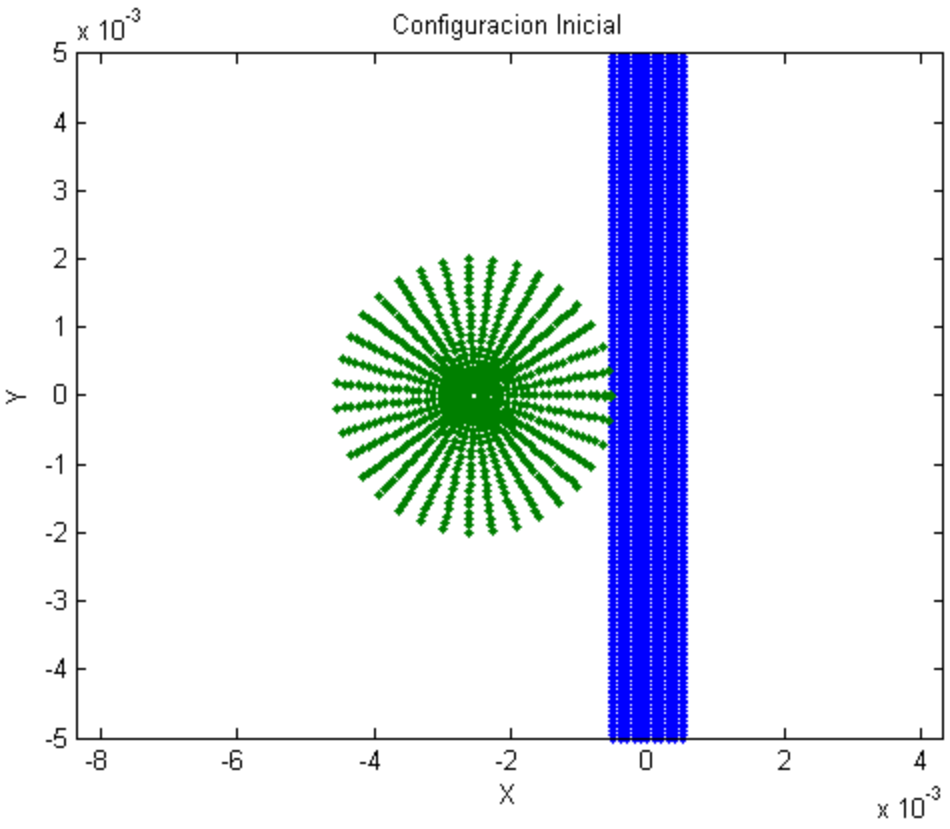
```
M = zeros(N_part,1);        % Masa de las particulas
M(1:T_np) = ones(T_np,1)*T_V*T_rho; % Particulas del objetivo
M(T_np+1:end) = ones(B_np,1)*B_V*B_rho; % Particulas del proyectil

cs = zeros(N_part,1);       % Velocidad del sonido
cs(1:T_np) = ones(T_np,1)*T_ss;
cs(T_np+1:end) = ones(B_np,1)*B_ss;

Rho = zeros(N_part,1);      % Densidad
Rho(1:T_np) = ones(T_np,1)*T_rho;
Rho(T_np+1:end) = ones(B_np,1)*B_rho;

    dRho = zeros(N_part,1); % Derivada de la densidad

D = zeros(N_part,1);        % Damage
```

Asignacion de condiciones iniciales

```
V_1 = 50;
%rr = randint(50,1,[1,T_np]);
V1(T_np+1:N_part) = V_1; % Velocidad inicial del Bullet
```

Representacion de condiciones iniciales

```
figure(1)
plot(Target(:,1),Target(:,2),Bullet(:,1),Bullet(:,2),...
    'Marker', '.', 'LineStyle','none')
title('Configuracion Inicial')
xlabel('X'); ylabel('Y'); axis('equal')
```



Inicio de Simulacion

```
display('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~');
display('   Inicio de la simulacion')
display('~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~')

t = 0;  %Tiempo Inicial
dt = max(h/cs); % Paso de tiempo
                % El paso de tiempo se define de esta forma para que la
                % simulacion sea capaz de detectar el fenomeno mas rapido
                % al que sea sensible el problema
                % La definicion correcta es
                % min(h/cs)
                % pero lo ejecuta con max para que dt sea diferente de 0 y
                % la simulacion no sea muy larga
tf = 0.5e-6*20; % Tiempo final
steps = round(tf/dt);  % Numero de pasos
```

```
        ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
           Inicio de la simulacion
        ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

Matrices para guardar informacion de la simulacion

```
n_m = round(20/100*steps);     % Numero de datos para muestreo
```

```
Coordenadas = zeros(N_part,n_m);
Velocidad1 = zeros(N_part,n_m);
Velocidad2 = zeros(N_part,n_m);
Presion = zeros(N_part,n_m);
Esfuerzos11 = zeros(N_part,n_m);
Esfuerzos12 = zeros(N_part,n_m);
Esfuerzos21 = zeros(N_part,n_m);
Esfuerzos22 = zeros(N_part,n_m);
Densidad = zeros(N_part,n_m);
```

Recorrido principal en el tiempo

```
fprintf('Numero de Pasos = %d\n',steps)
for ti = 1:steps

    %fprintf('%d..',ti);
```

Busqueda de Vecinos

Nearpart cell {N_part x 1}: En el compartimiento *i* de **Nearpart**, se encuentra un vector [1 x n] que contiene los indices de las n particulas vecinas a la particula de identidad *i*.

Dist cell {Npart x 1}: En el compartimiento *i* de **Dist**, se encuentra un vector [1 x n] que contiene la distancia *r_n* a la que se encuentra cada una de las *n* particulas vecinas de la particula *i*.

```
    [Nearpart,Dist] = rangesearch(Particles,Particles,h);

    %
    % Se genera el _cell_ para el kernel *kern*. Este cell tiene las mismas
    % dimensiones que el cell _Dist_, con la diferencia que todos los
    % valores son _0_
    kern = cellfun(@(x) x*0, Dist, 'un', 0);
        dkernx = kern;  %Inicializar en 0 las derivadas del kernel
        dkerny = kern;

    % Usando las funciones kern1, dkernx1 y dkerny1 se calcula el kernel
    % y las derivadas del kernel x-y evaluadas en las particulas vecinas
    % de cada una de las particulas del dominio.
```

Recorrido en las particulas del Target

```
    for i = 1:T_np
        kern{i} = kern1(Dist{i},h);
        dkernx{i} = dkernx1(Dist{i}, h, Particles, Nearpart{i}, i);
        dkerny{i} = dkerny1(Dist{i}, h, Particles, Nearpart{i}, i);

        %%%Calcular Presion hidrostatica con ecuacion de Mie-Gruniensen
        %
        %   Esta parte se puede hacer mas eficiente. De esta forma es
        %   ineficiente porque realiza validacion y asignacion para cada
        %   particula. Creo que si hago recorridos independientes para las
        %   particulas del objetivo y del proyectil, solo hago dos
        %   asignaciones y ninguna verificacion.
```

```
P(i) = EOSmie(E_int(i), T_rho, T_C, T_S, Rho(i), T_gamma);

%%%Derivadas espaciales de las Velocidades
[dv1dx1(i), dv1dx2(i), dv2dx1(i), dv2dx2(i)] = ...
    Velgradesp(Rho, M, V1, V2, dkernx{i}, dkerny{i},...
    Nearpart{i},i);

%%%Deformacion unitaria
[eps11(i), eps12(i), eps21(i), eps22(i)] = ...
    deform(dv1dx1(i), dv1dx2(i), dv2dx1(i), dv2dx2(i));

%%%Derivadas de Esfuerzos Cortantes
[dTau11(i), dTau12(i), dTau21(i), dTau22(i)] = ...
    devstresshooke(dv1dx2(i), dv2dx1(i),...
        Tau11(i), Tau12(i), Tau21(i), Tau22(i),...
        eps11(i), eps21(i), eps22(i), T_G);

%%%Calcular Esfuerzos
% No se puede hacer opearacion vectorizada porque el Tau
% se corrgie con criterio de Von Mises
Tau11(i) = Tau11(i) + dTau11(i)*dt;
Tau12(i) = Tau12(i) + dTau12(i)*dt;
Tau21(i) = Tau21(i) + dTau21(i)*dt;
Tau22(i) = Tau22(i) + dTau22(i)*dt;

%%%Criterio de falla de Von Mises
J = Tau11(i)^2 + 2*Tau12(i)*Tau21(i) + Tau22(i)^2;
f = sqrt(2*T_Y0/3);
if J > T_Y0*3/2
    scalar = f/sqrt(J);
    Tau11(i) = Tau11(i)*scalar;
    Tau12(i) = Tau12(i)*scalar;
    Tau21(i) = Tau21(i)*scalar;
    Tau22(i) = Tau22(i)*scalar;
end

%%%Damage
% Damage solo aplica para las particulas del Target
% Modificacion importante respecto al codigo de Daniel:
%
% Cambio *if ei > length(Flaws{i}(j))* por
% *if ei > Flaws{i}(j)* Hago esta modificacion porque lo que se
% necesita es contar cuantos defectos puntuales se activan
%
%Energia de activacion
ei = J/((1-D(i))*T_E);

% Recorrido en los defectos puntuales
for j = 1:length(Flaws{i})
    count = 0;
    % Contar cuantos defectos se activan
    if ei > Flaws{i}(j)
        count = count + 1;
    end
```

```
        end

        % Damage depende del numero de fallas activas
        % Revisar refrencia de Damage, creo que este procedimiento no es
        % del todo correcto porque el Damage = 1 se alcanza solo cuando
        % todas los defectos estan activos. Entonces dberia ser algo de la
        % forma count/length(Flaws{i})
        %
        dD = Damageevol(Rho(i), M(i), cs(i)) * count;
        D(i) = dD^2*dt;

        % Escalar esfuerzos del material con el Damage
        Tau11(i) = Tau11(i)*(1-D(i));
        Tau12(i) = Tau12(i)*(1-D(i));
        Tau21(i) = Tau21(i)*(1-D(i));
        Tau22(i) = Tau22(i)*(1-D(i));


        %%%Ecuacion de la continuidad
        % Calcular la derivada de la densidad para una particula
        dRho(i) = derivadarho(M, V1, V2, ...
            dkernx{i}, dkerny{i}, Nearpart{i}, i);
    end

    %%%Avanzar la densidad en el tiempo
    Rho(1:T_np) = Rho(1:T_np) + dRho(1:T_np)*dt;

    for i = 1:T_np
       %%%Conservacion de Momentum
       [dV1(i),dV2(i)] = Momentumeq2d(Tau11, Tau12, Tau21, Tau22, P, Rho,...
           dkernx{i}, dkerny{i}, M, Nearpart{i}, i, cs, Dist{i}, Particles,...
           h, V1, V2);

       %%%%Conservacion de la Energia
       dE_int(i) = Deint(Tau11(i), Tau12(i), Tau21(i), Tau22(i), P, Rho,...
           dkernx{i}, dkerny{i}, M, Nearpart{i}, i, cs, Dist{i}, Particles,...
           h, V1, V2, eps11(i), eps12(i), eps21(i), eps22(i));
    end

    %%%Avanzar la velocidad
    V1(1:T_np) = V1(1:T_np) + dV1(1:T_np)*dt;
    V2(1:T_np) = V2(1:T_np) + dV2(1:T_np)*dt;
    E_int(1:T_np) = E_int(1:T_np) + dE_int(1:T_np)*dt;

    %%%Correcciones
    for i = 1:T_np
        %%%Velocidad del sonido
        cs(i) = Miespeedofsound(E_int(i), T_rho, T_C, T_S,Rho(i), T_gamma);

        %%%XSPH
        [V1(i),V2(i)] = XSPH(Nearpart{i}, M, Rho, V1, V2, kern{i}, i);
    end
    Particles(1:T_np,:) = Particles(1:T_np,:) + ...
        [V1(1:T_np), V2(1:T_np)]*dt;
```

```
% Hasta aca se tiene configurado completamente la simulacion para
% las particulas del target
```

Recorrido en las particulas del Bullet

```
for i = T_np+1:N_part
    kern{i} = kern1(Dist{i},h);
    dkernx{i} = dkernx1(Dist{i}, h, Particles, Nearpart{i}, i);
    dkerny{i} = dkerny1(Dist{i}, h, Particles, Nearpart{i}, i);

    %%%Calcular Presion hidrostatica con ecuacion de Mie-Gruniensen
    %
    %   Esta parte se puede hacer mas eficiente. De esta forma es
    %   ineficiente porque realiza validacion y asignacion para cada
    %   particula. Creo que si hago recorridos independientes para las
    %   particulas del objetivo y del proyectil, solo hago dos
    %   asignaciones y ninguna verificacion.
    P(i) = EOSmie(E_int(i), B_rho, B_C, B_S, Rho(i), B_gamma);

    %%%Derivadas espaciales de las Velocidades
    [dv1dx1(i), dv1dx2(i), dv2dx1(i), dv2dx2(i)] = ...
        Velgradesp(Rho, M, V1, V2, dkernx{i}, dkerny{i},...
        Nearpart{i},i);

    %%%Deformacion unitaria
    [eps11(i), eps12(i), eps21(i), eps22(i)] = ...
        deform(dv1dx1(i), dv1dx2(i), dv2dx1(i), dv2dx2(i));

    %%%Derivadas de Esfuerzos Cortantes
    [dTau11(i), dTau12(i), dTau21(i), dTau22(i)] = ...
        devstresshooke(dv1dx2(i), dv2dx1(i),...
            Tau11(i), Tau12(i), Tau21(i), Tau22(i),...
            eps11(i), eps21(i), eps22(i), B_G);

    %%%Calcular Esfuerzos
    % No se puede hacer opearacion vectorizada porque el Tau
    % se corrgie con criterio de Von Mises
    Tau11(i) = Tau11(i) + dTau11(i)*dt;
    Tau12(i) = Tau12(i) + dTau12(i)*dt;
    Tau21(i) = Tau21(i) + dTau21(i)*dt;
    Tau22(i) = Tau22(i) + dTau22(i)*dt;
```

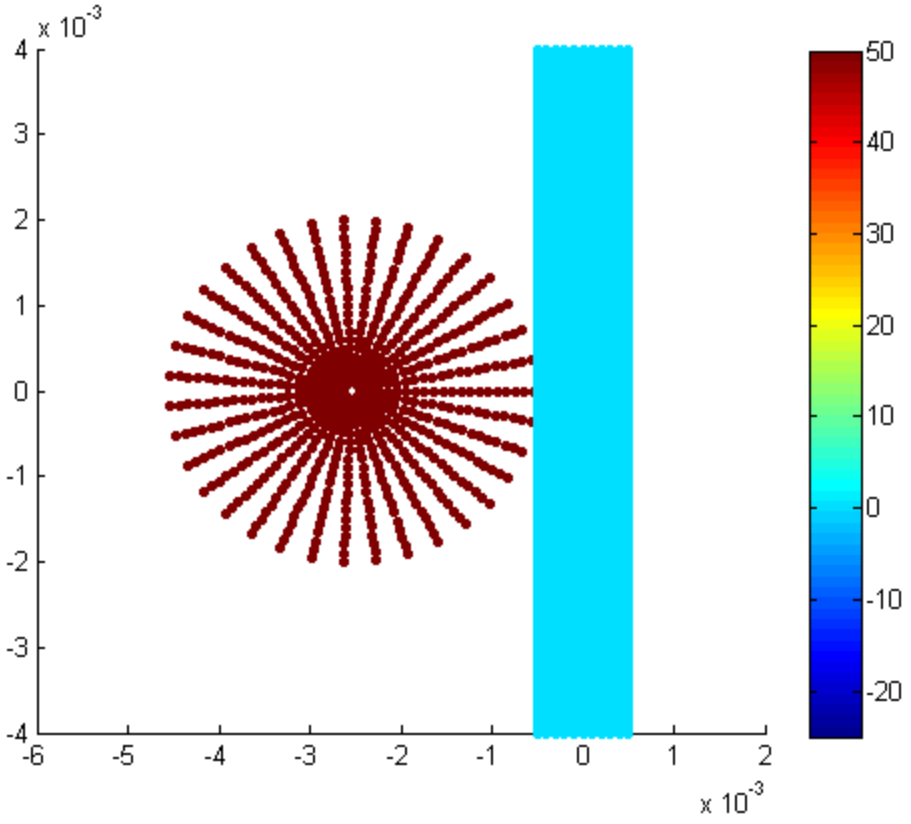
Criterio de falla de Von Mises

```
    J = Tau11(i)^2 + 2*Tau12(i)*Tau21(i) + Tau22(i)^2;
    f = sqrt(2*B_Y0/3);
    if J > B_Y0*3/2
        scalar = f/sqrt(J);
        Tau11(i) = Tau11(i)*scalar;
        Tau12(i) = Tau12(i)*scalar;
        Tau21(i) = Tau21(i)*scalar;
        Tau22(i) = Tau22(i)*scalar;
```

```
    end

    %%%Damage
    % Damage NO aplica para las particulas del bullet

    %%%Ecuacion de la continuidad
    % Calcular la derivada de la densidad para una particula
    dRho(i) = derivadarho(M, V1, V2, ...
        dkernx{i}, dkerny{i}, Nearpart{i}, i);
end

%%%Avanzar la densidad en el tiempo
Rho(T_np+1:N_part) = Rho(T_np+1:N_part) + dRho(T_np+1:N_part)*dt;

for i = T_np+1:N_part
   %%%Conservacion de Momentum
   [dV1(i),dV2(i)] = Momentumeq2d(Tau11, Tau12, Tau21, Tau22, P, Rho,...
       dkernx{i}, dkerny{i}, M, Nearpart{i}, i, cs, Dist{i}, Particles,...
       h, V1, V2);

   %%%Conservacion de la Energia
   dE_int(i) = Deint(Tau11(i), Tau12(i), Tau21(i), Tau22(i), P, Rho,...
       dkernx{i}, dkerny{i}, M, Nearpart{i}, i, cs, Dist{i}, Particles,...
       h, V1, V2, eps11(i), eps12(i), eps21(i), eps22(i));
end

%%%Avanzar la velocidad
V1(T_np+1:N_part) = V1(T_np+1:N_part) + dV1(T_np+1:N_part)*dt;
V2(T_np+1:N_part) = V2(T_np+1:N_part) + dV2(T_np+1:N_part)*dt;
E_int(T_np+1:N_part) = E_int(T_np+1:N_part) + dE_int(T_np+1:N_part)*dt;

%%%Correcciones
for i = T_np+1:N_part
    %%%Velocidad del sonido
    cs(i) = Miespeedofsound(E_int(i), B_rho, B_C, B_S,Rho(i), B_gamma);

    %%%XSPH
    [V1(i),V2(i)] = XSPH(Nearpart{i}, M, Rho, V1, V2, kern{i}, i);
end
Particles(T_np+1:N_part,:) = Particles(T_np+1:N_part,:) + ...
    [V1(T_np+1:N_part), V2(T_np+1:N_part)]*dt;
Particles = real(Particles);
```

Graficas

```
%plot(Particles(:,1), Particles(:,2),'.b')
scatter(Particles(:,1),Particles(:,2),10,V1,'filled')
caxis([-V_1/2,V_1])
colorbar()
xlim([-6e-3,2e-3])
ylim([-4e-3,4e-3])
%axis('equal')
drawnow
```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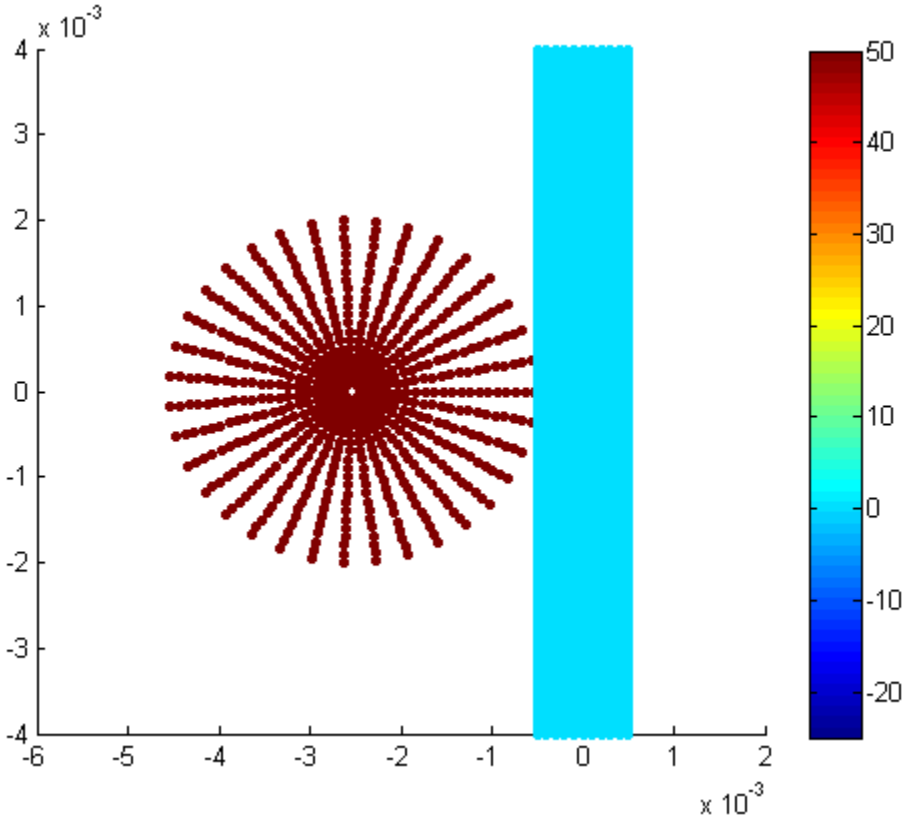
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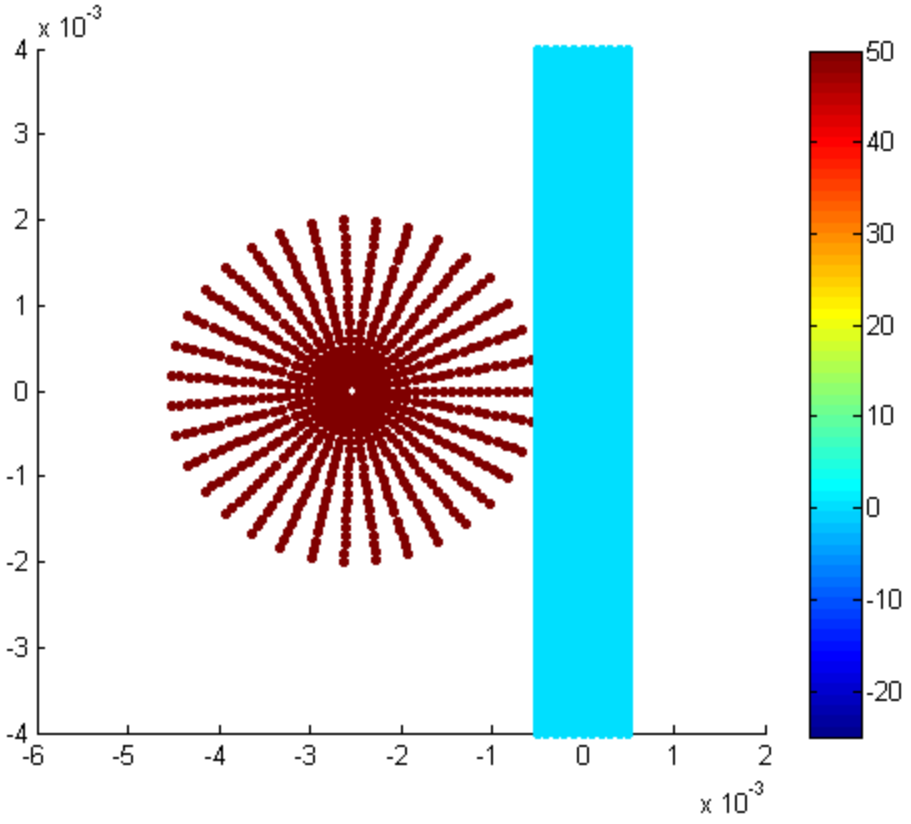
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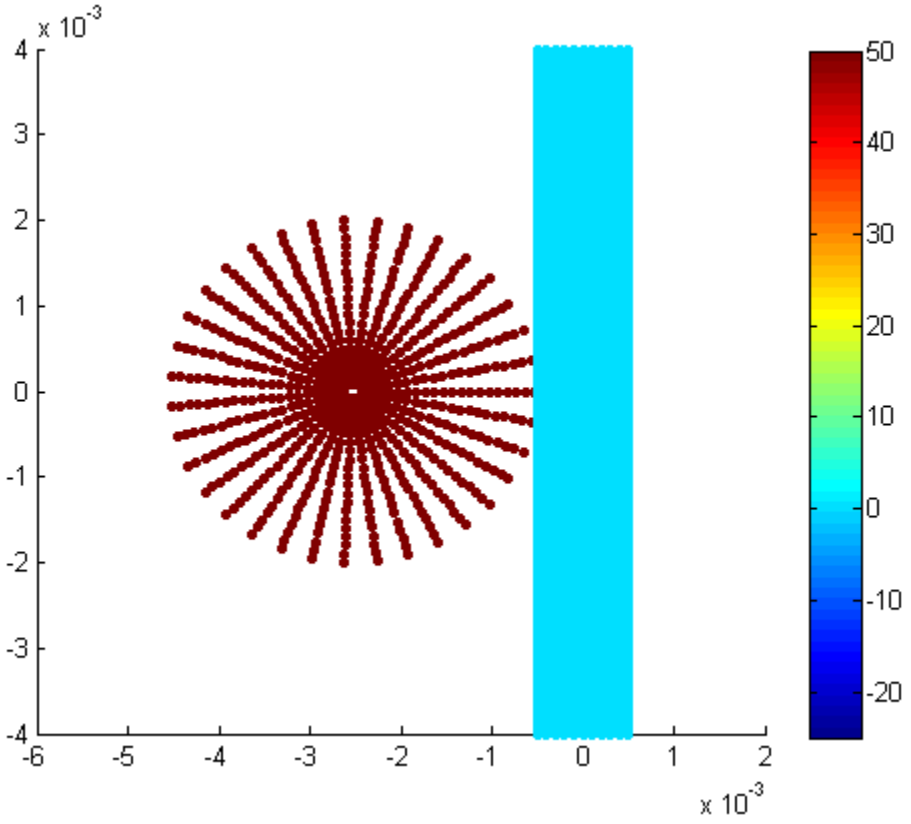
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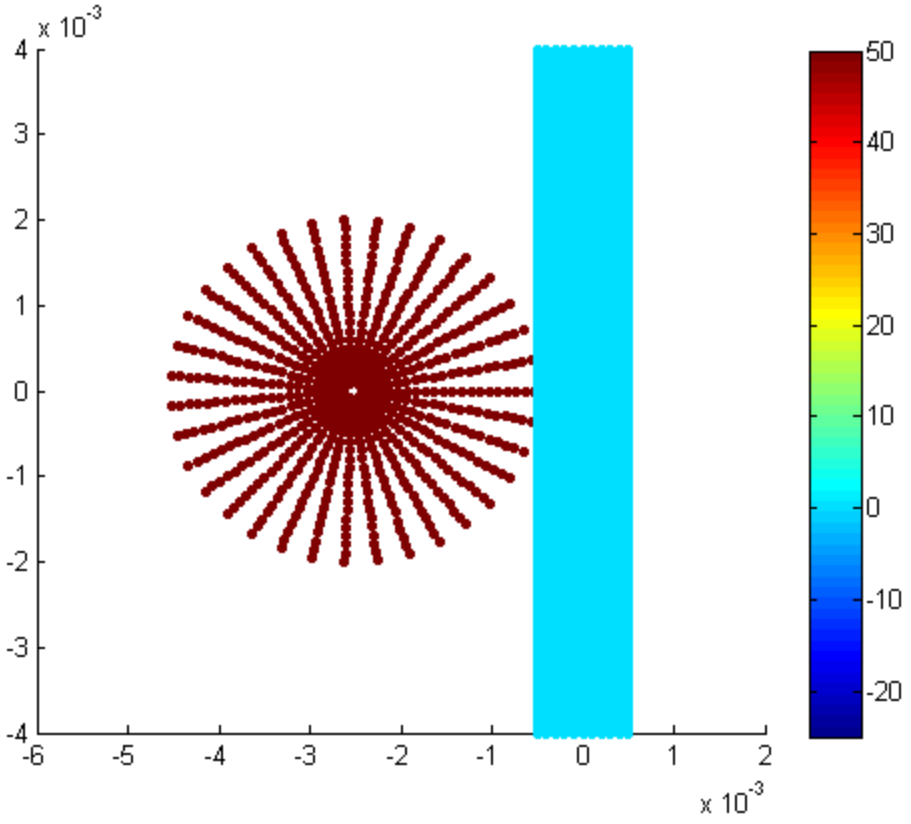
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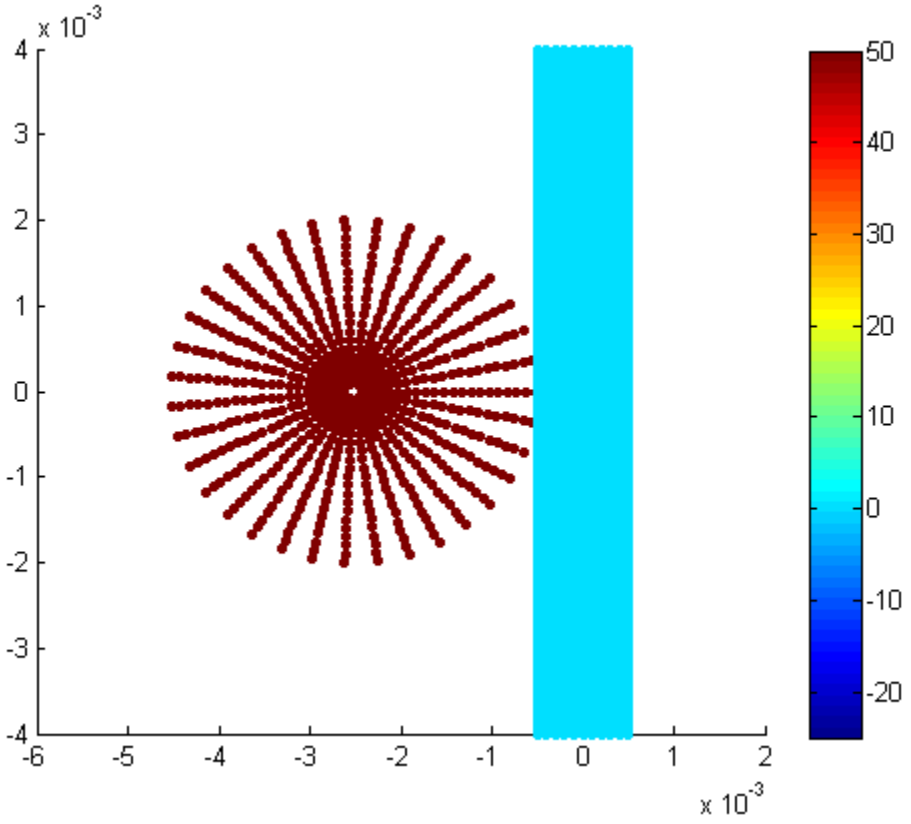
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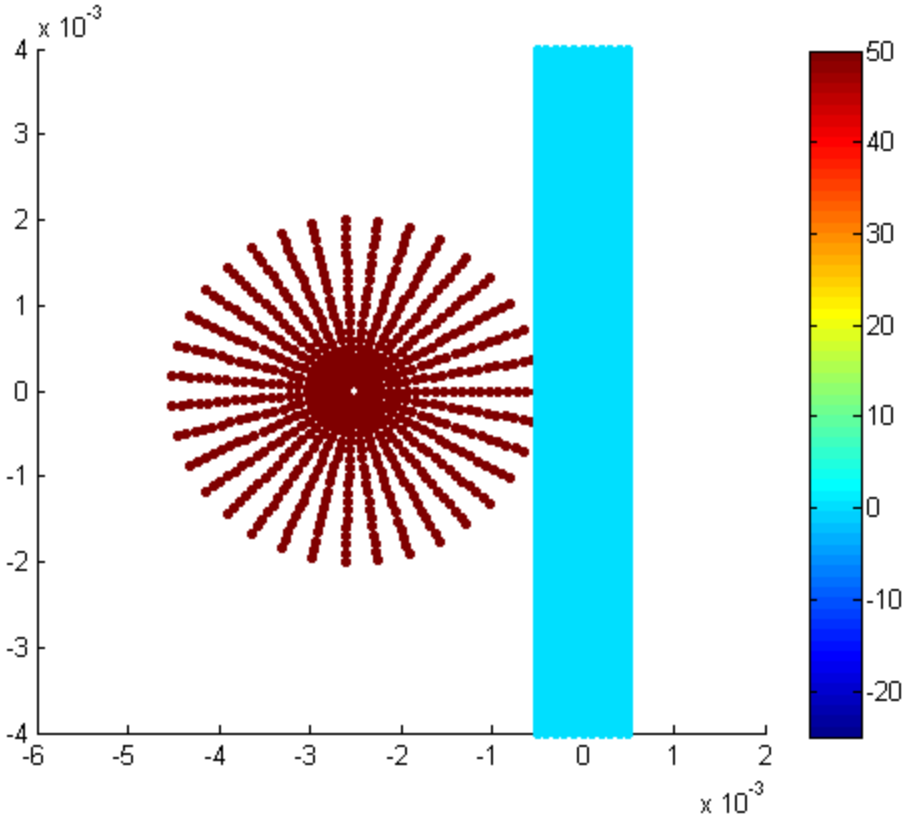
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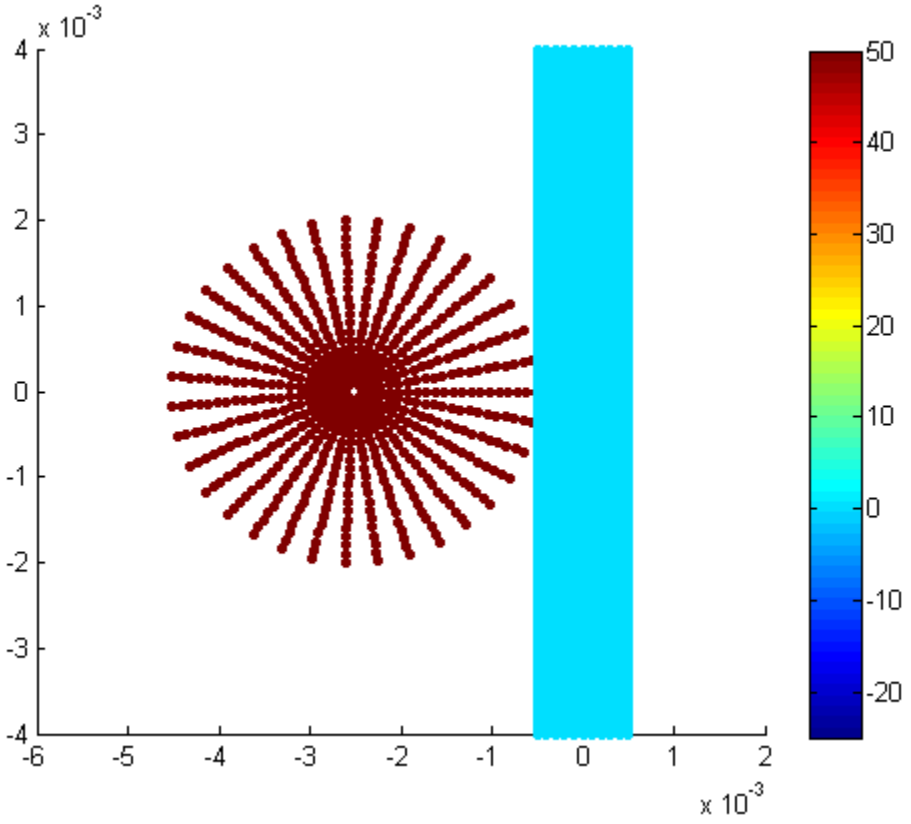
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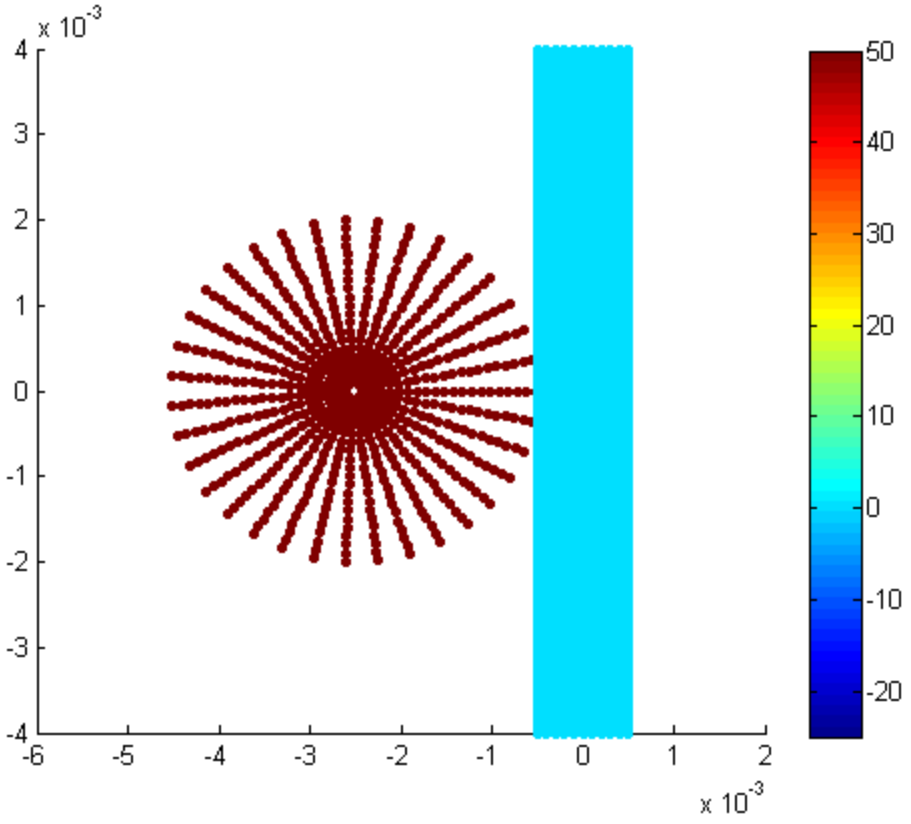
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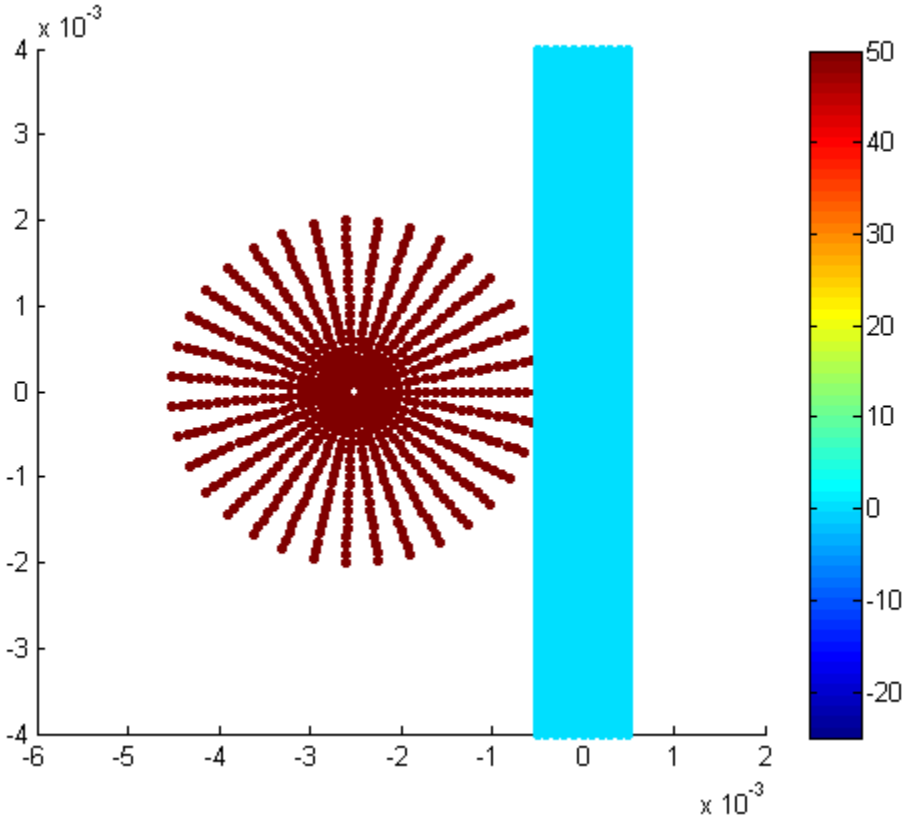
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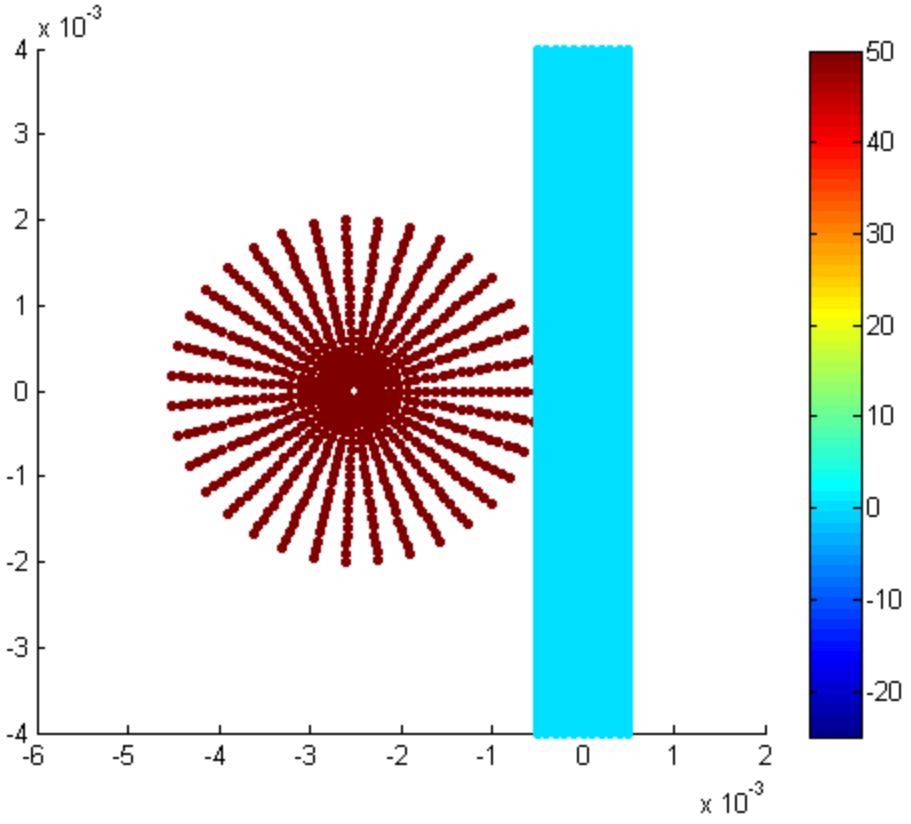
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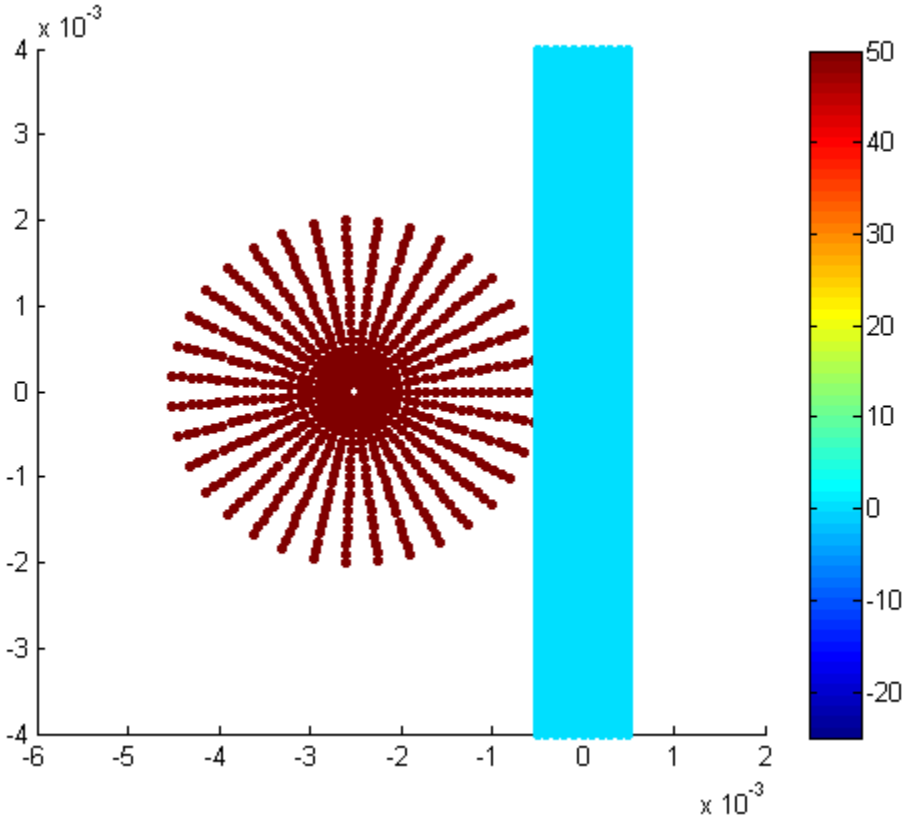
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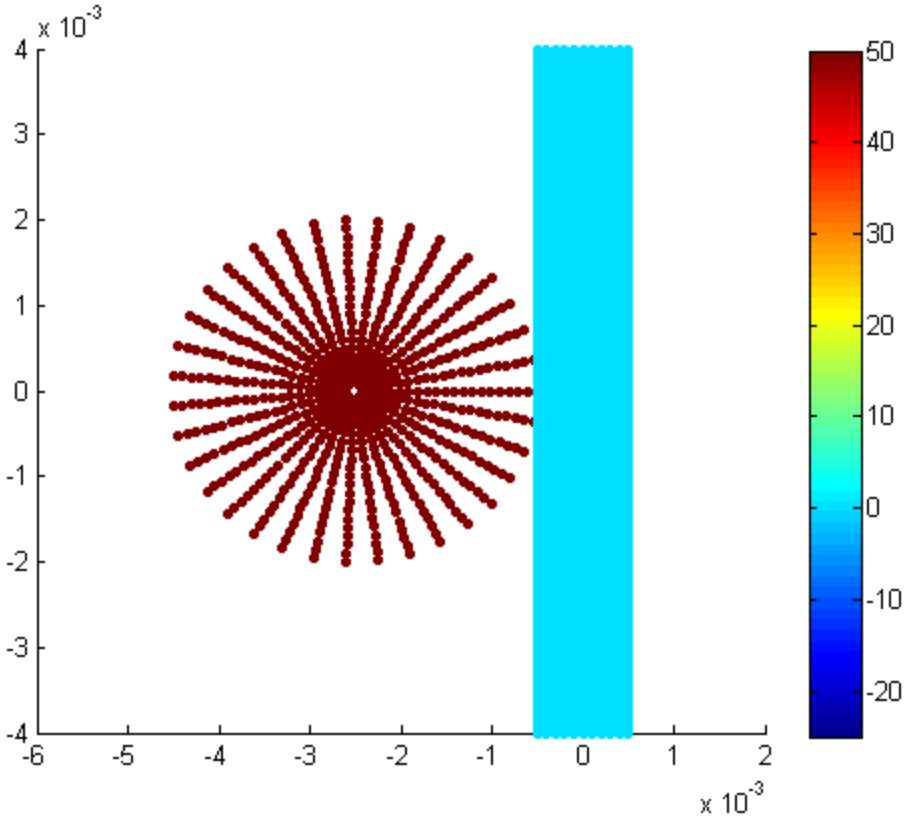
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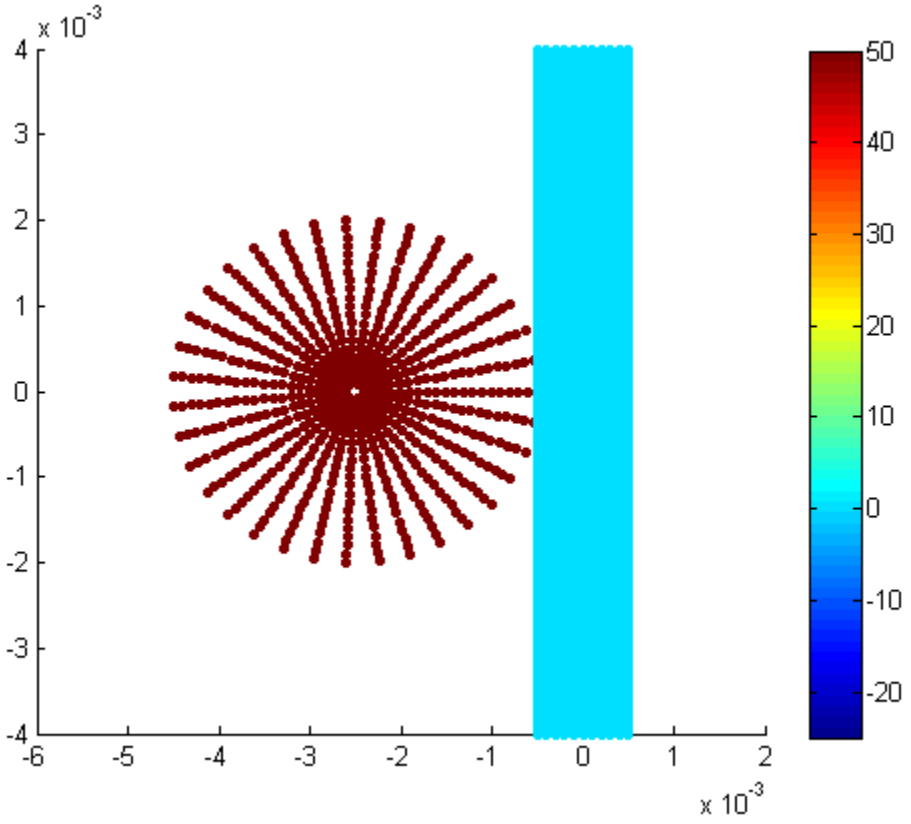
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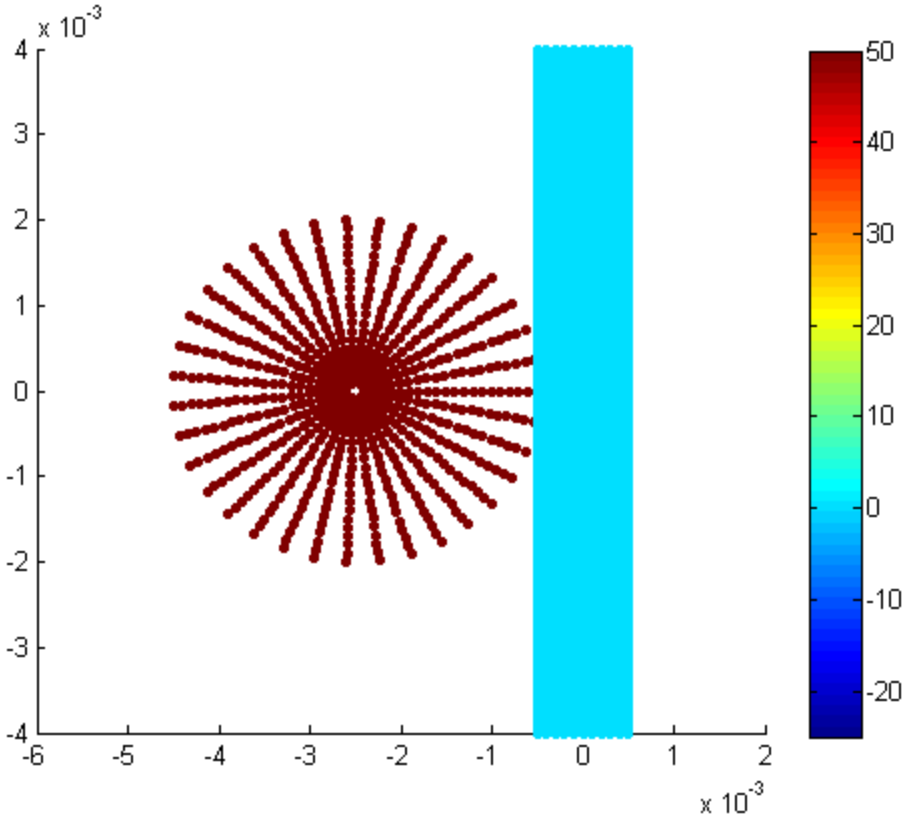
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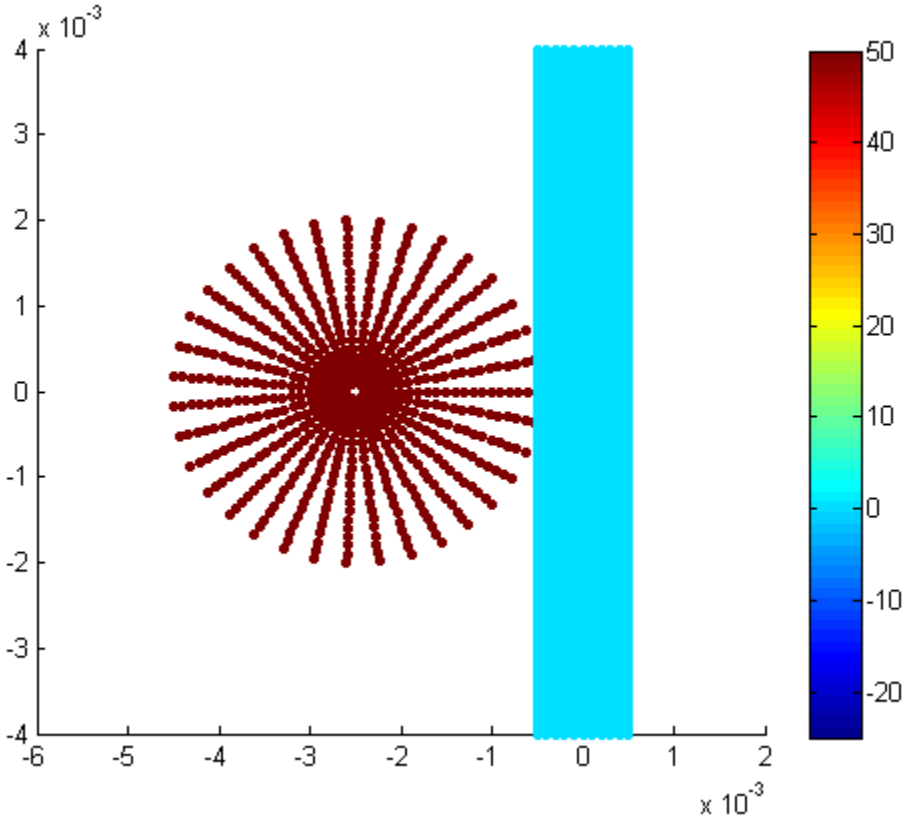
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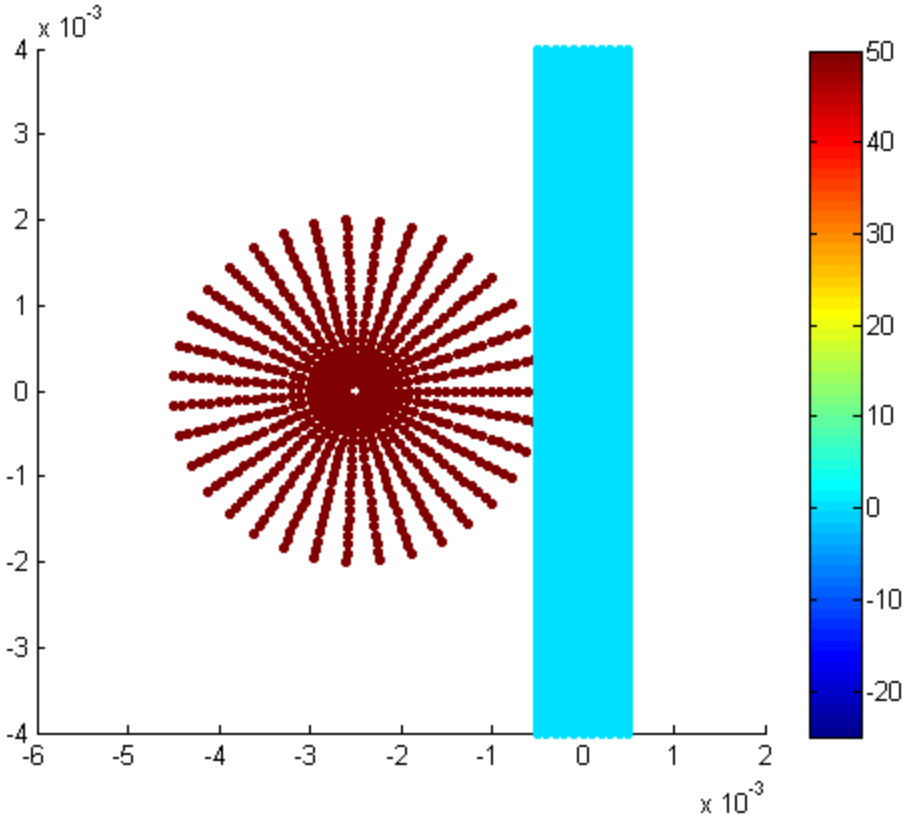
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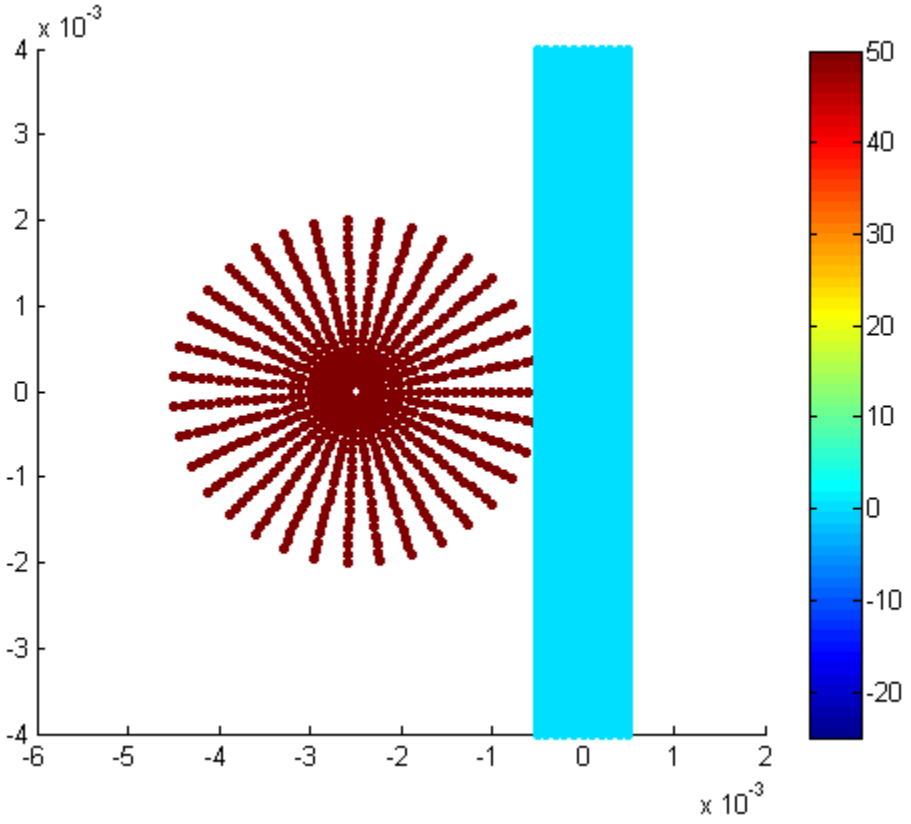
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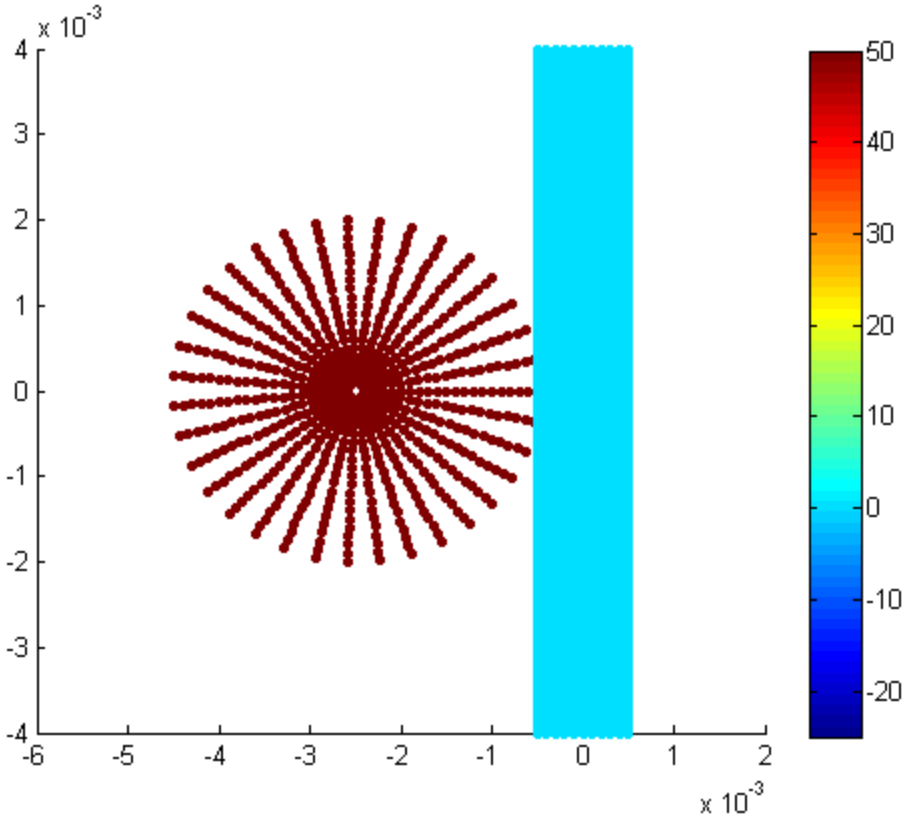
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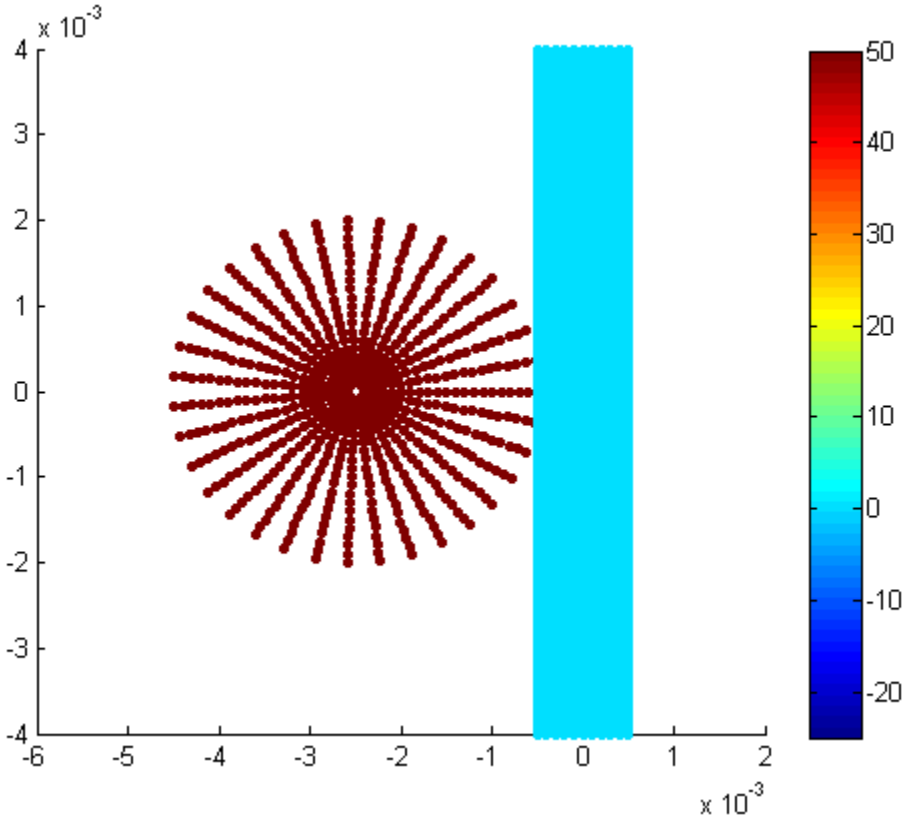
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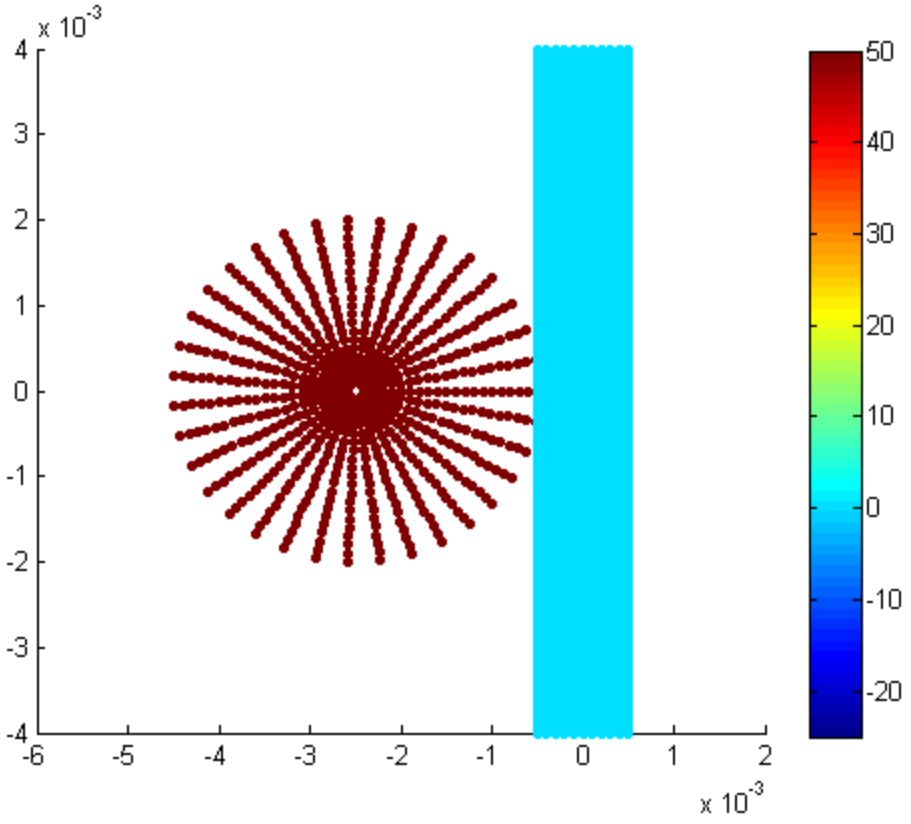
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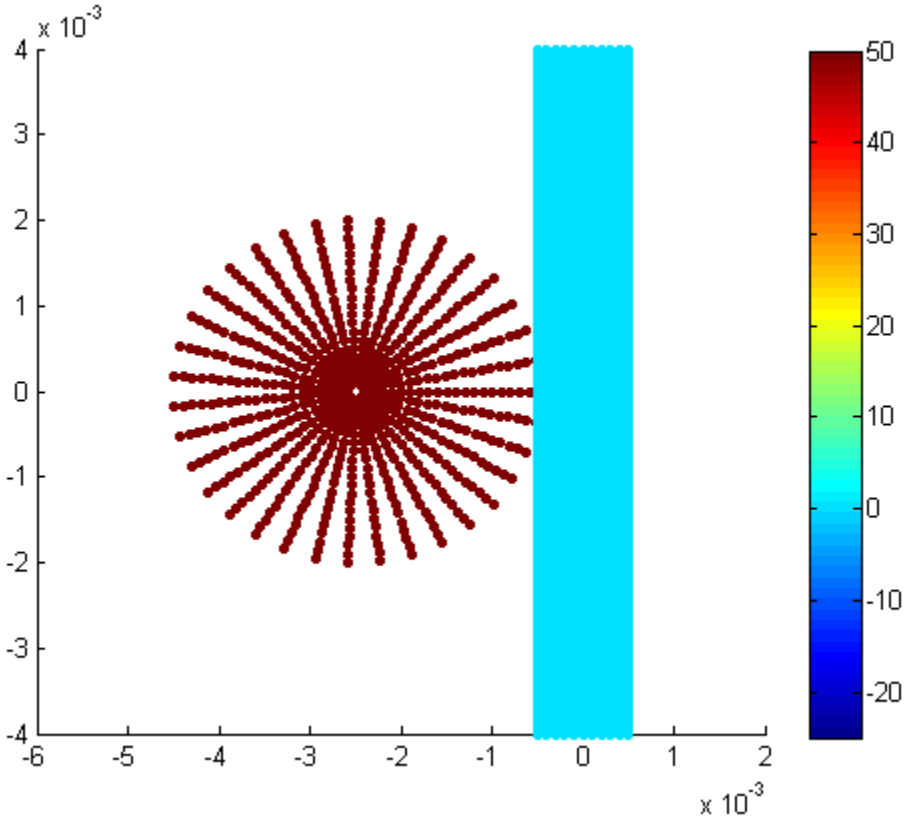
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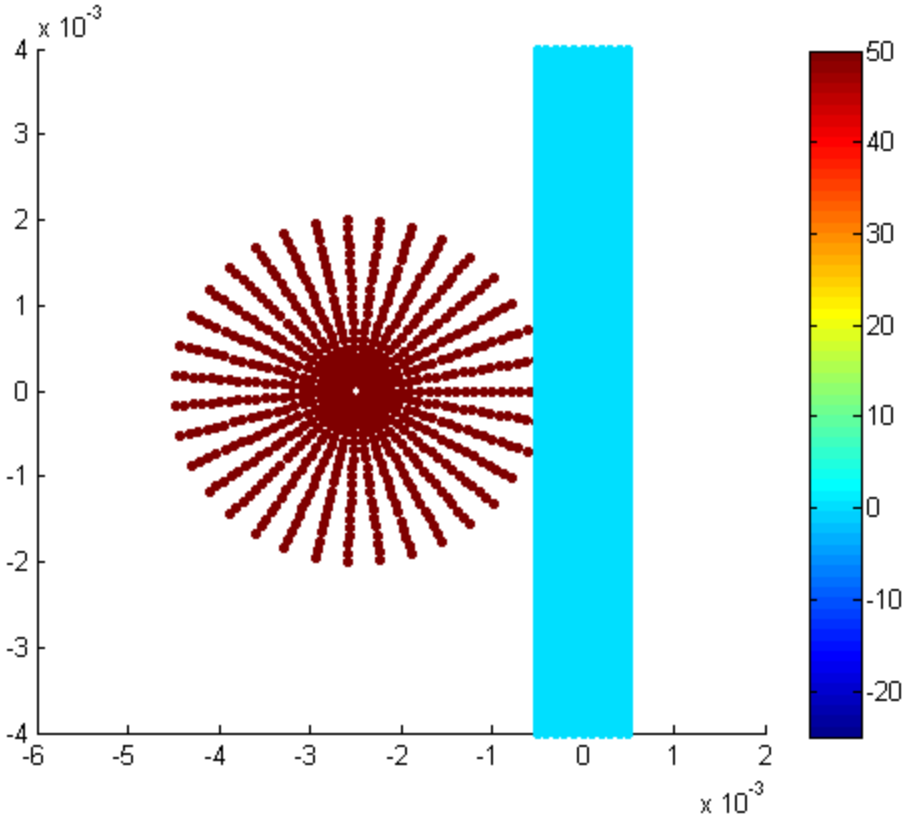
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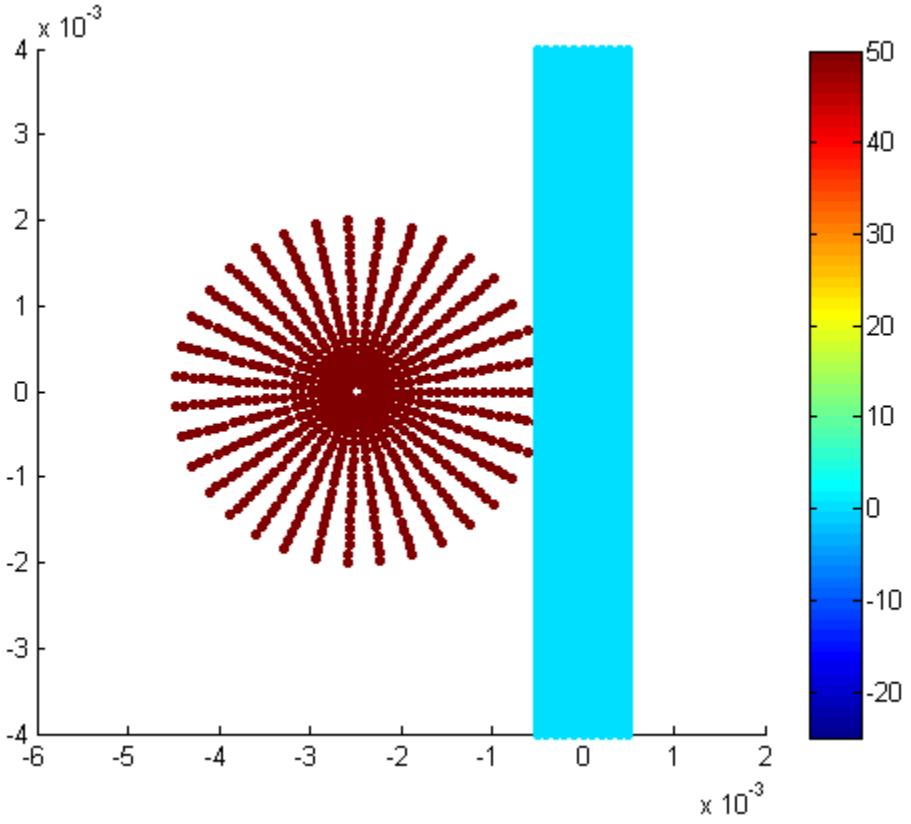
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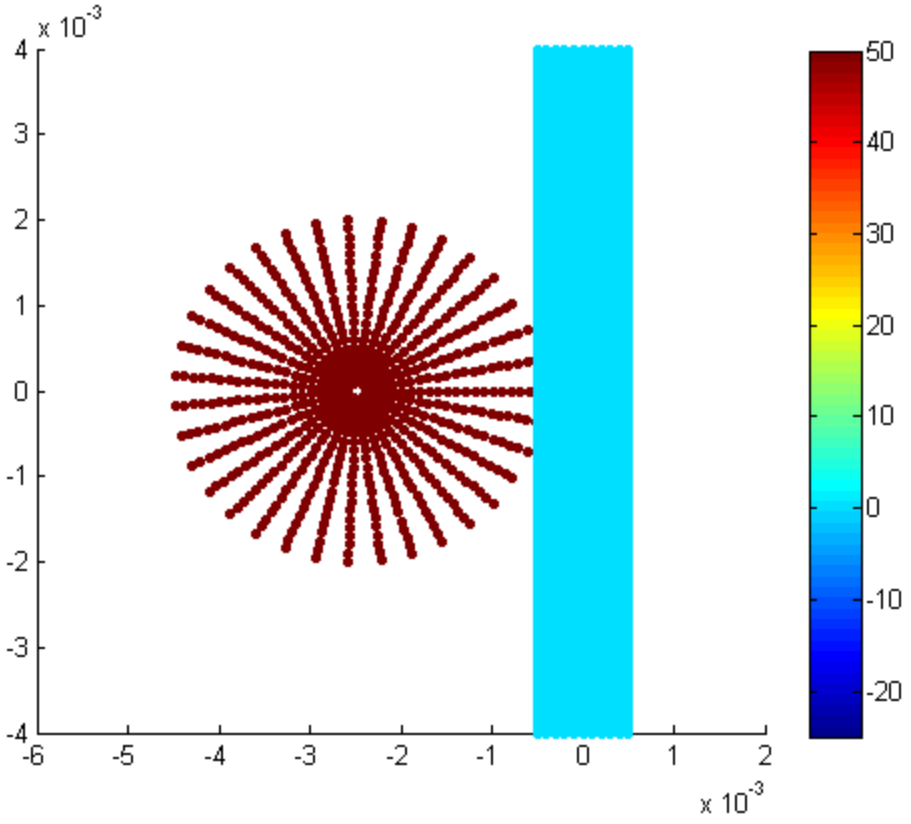
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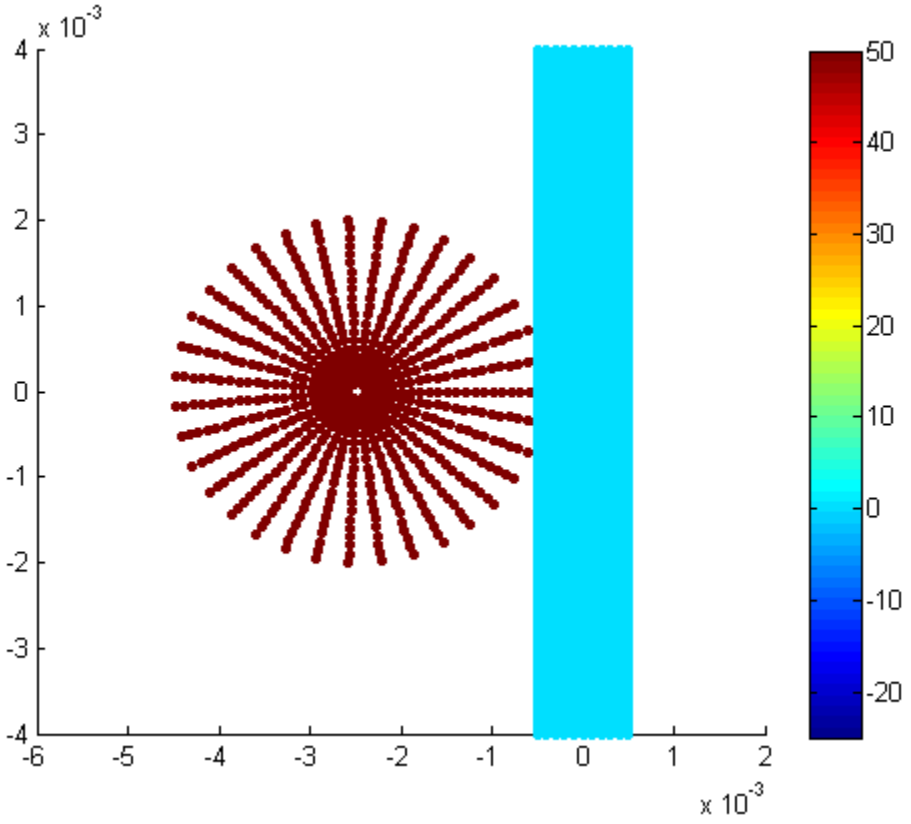
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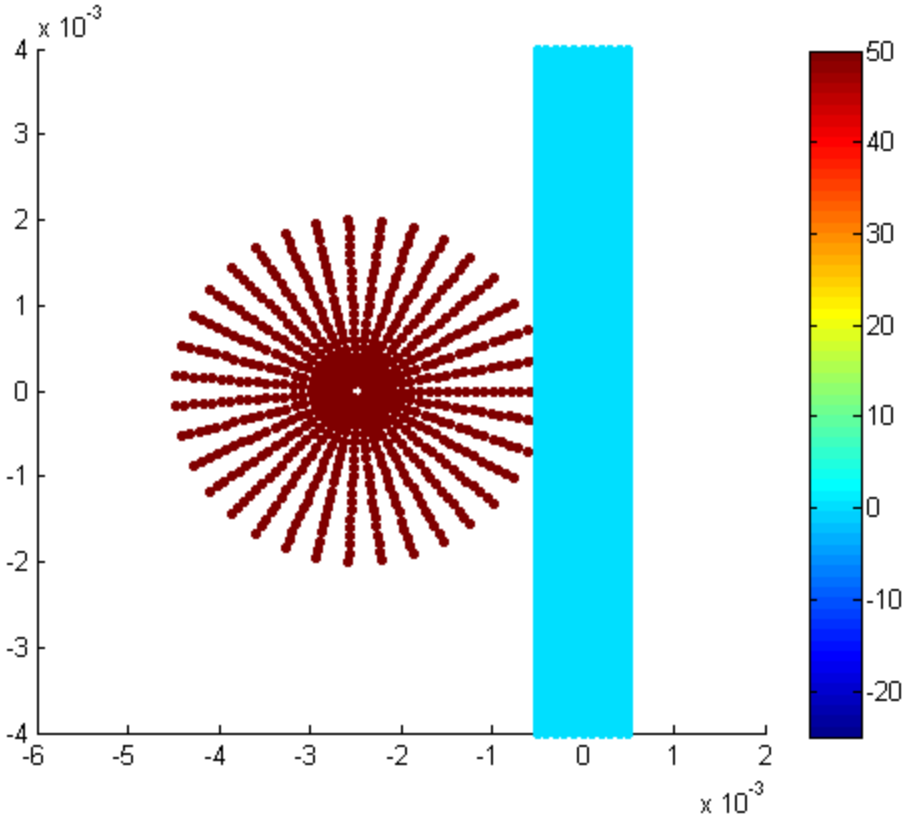
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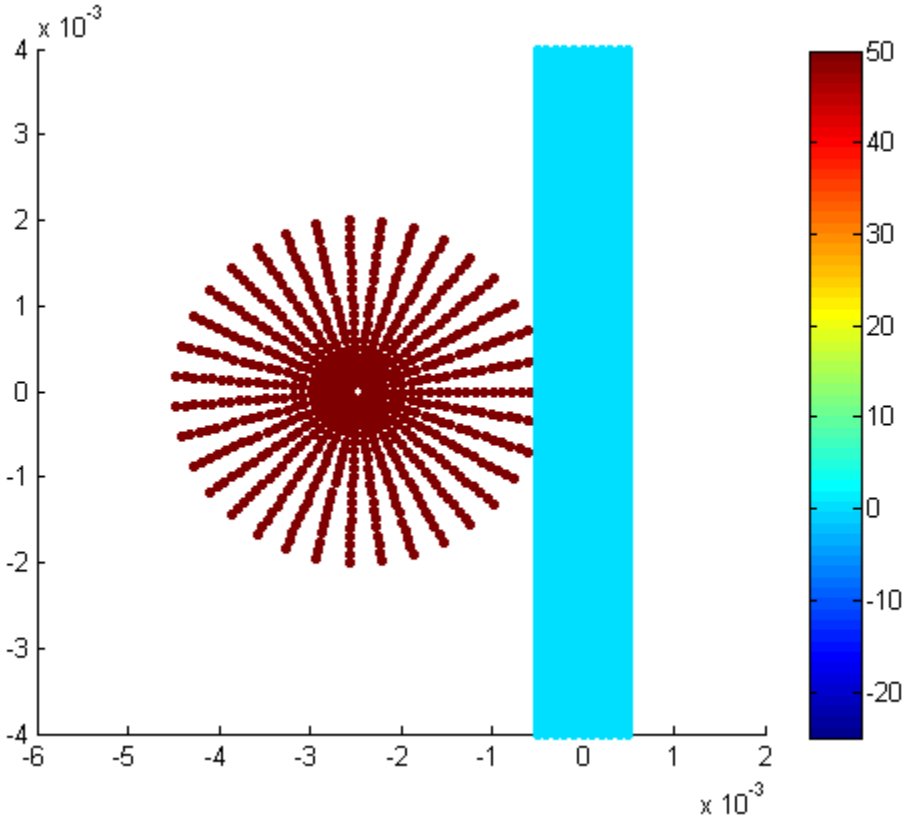
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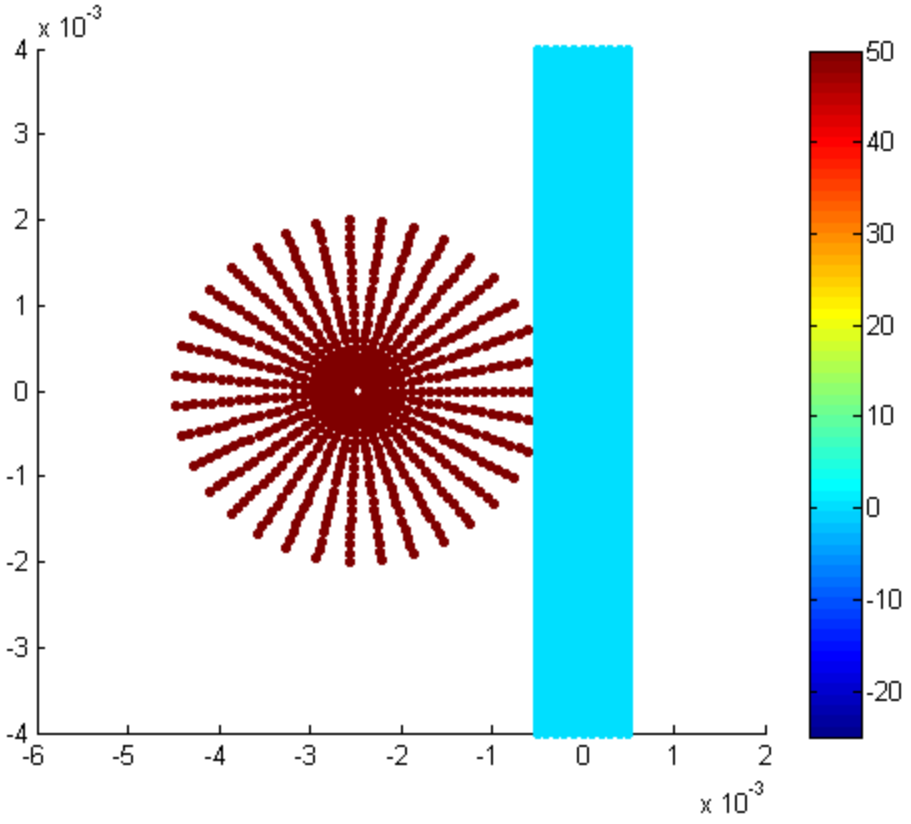
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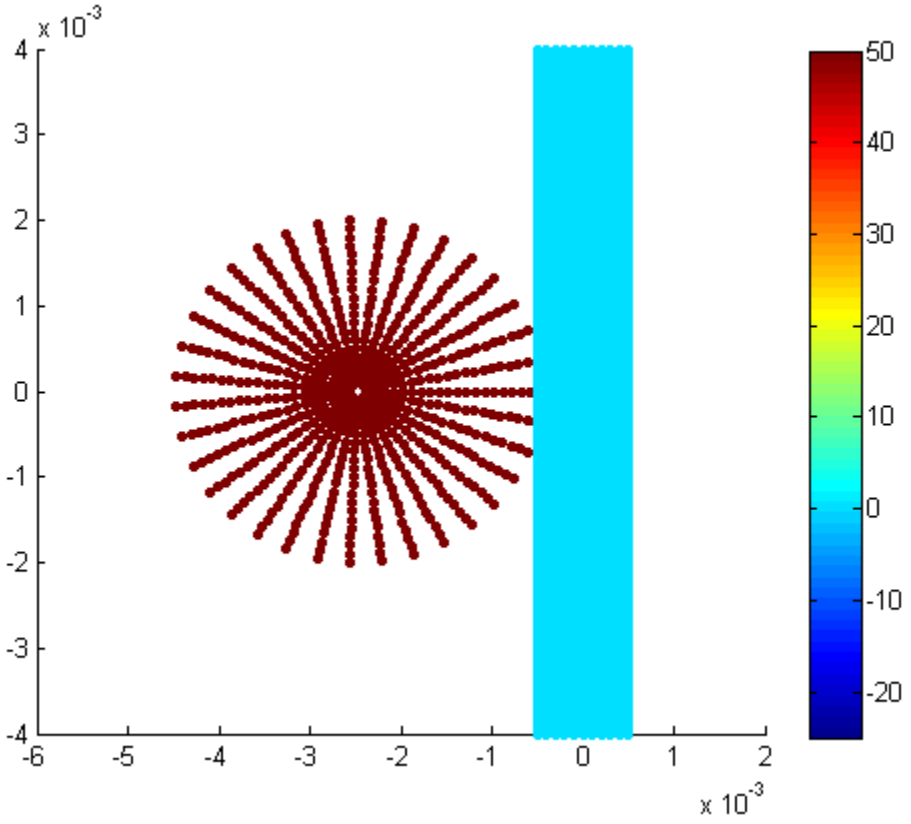
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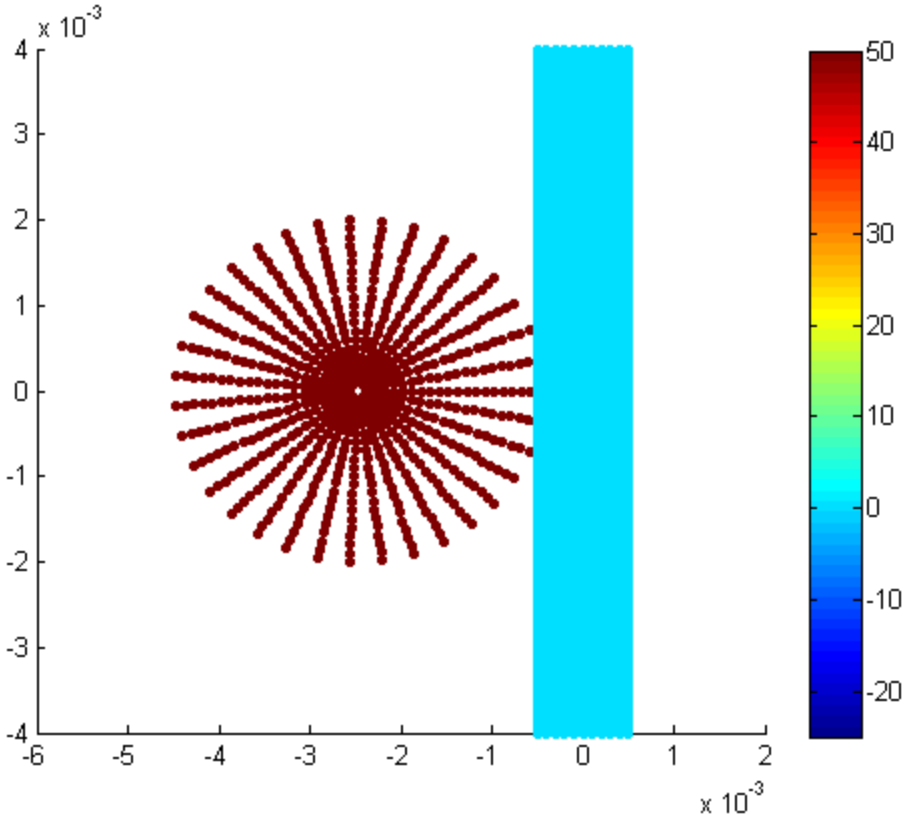
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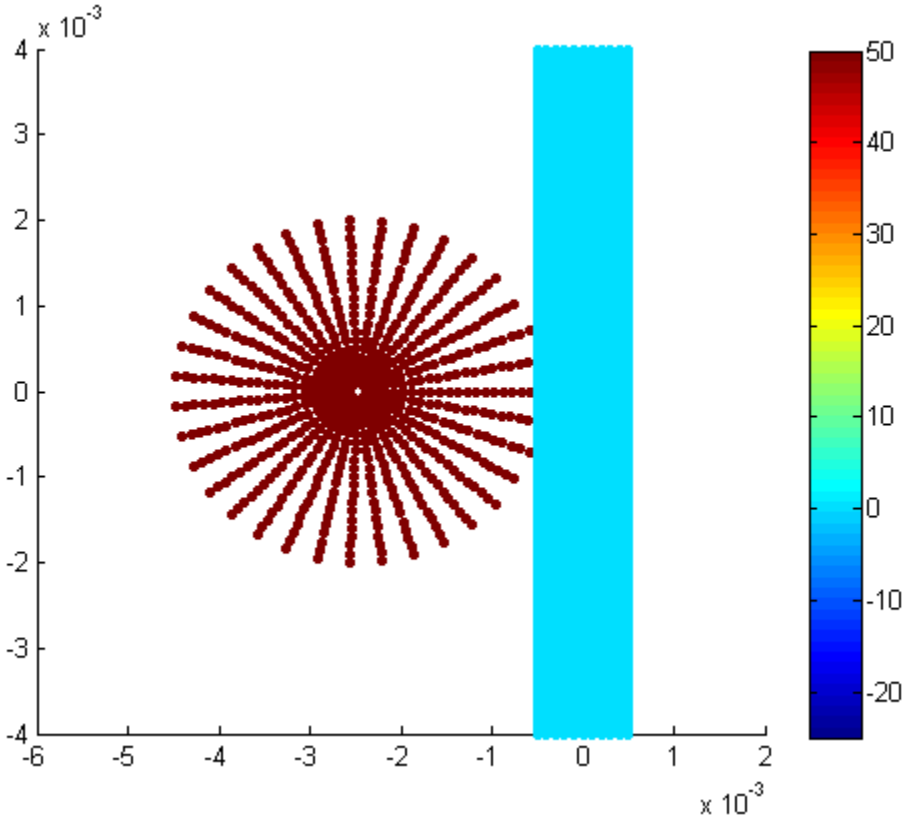
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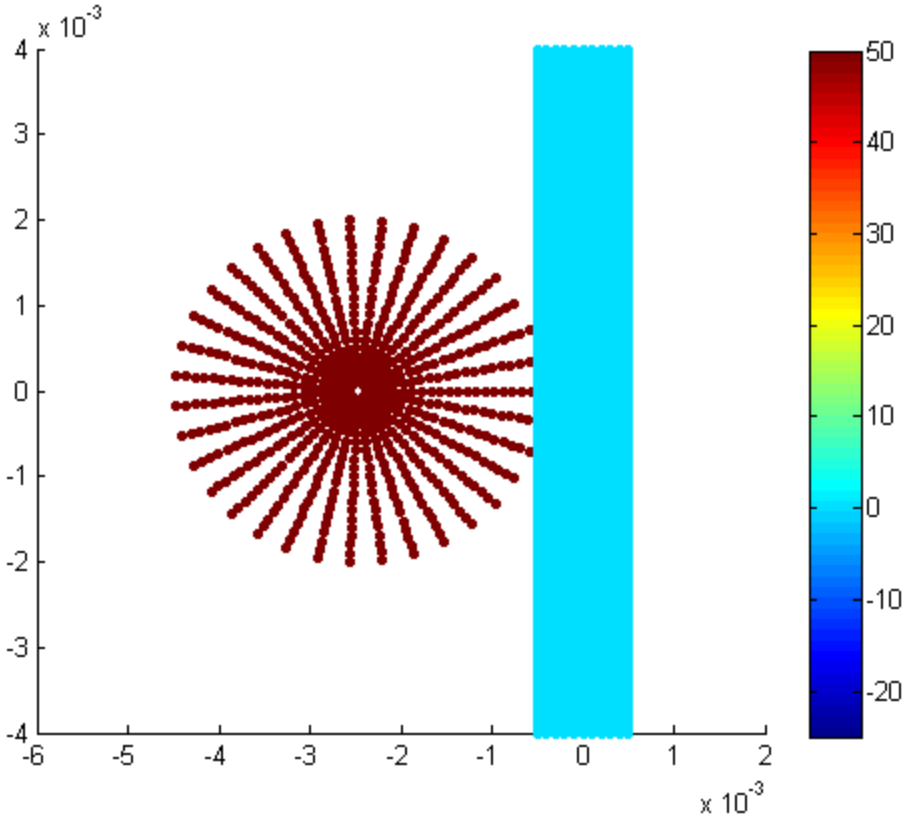
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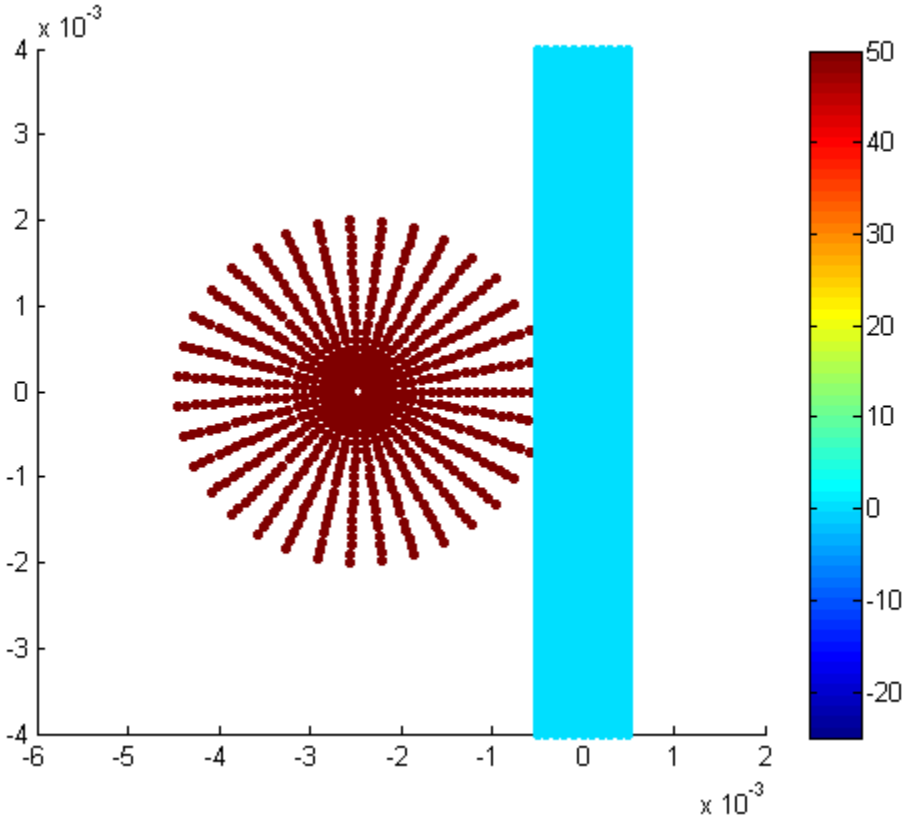
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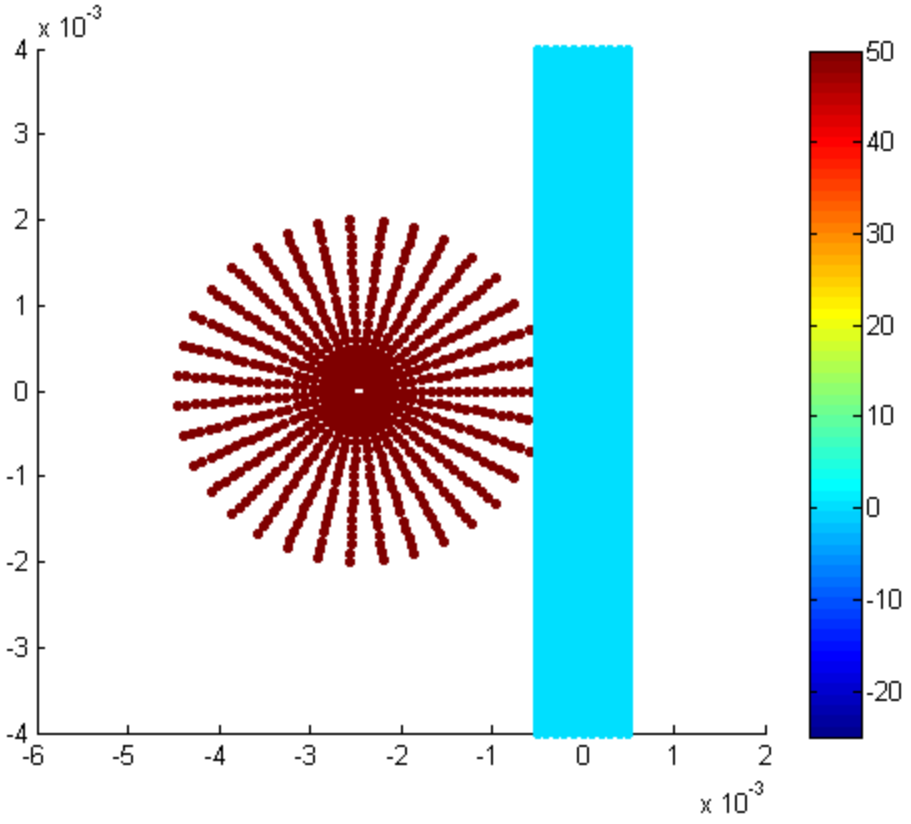
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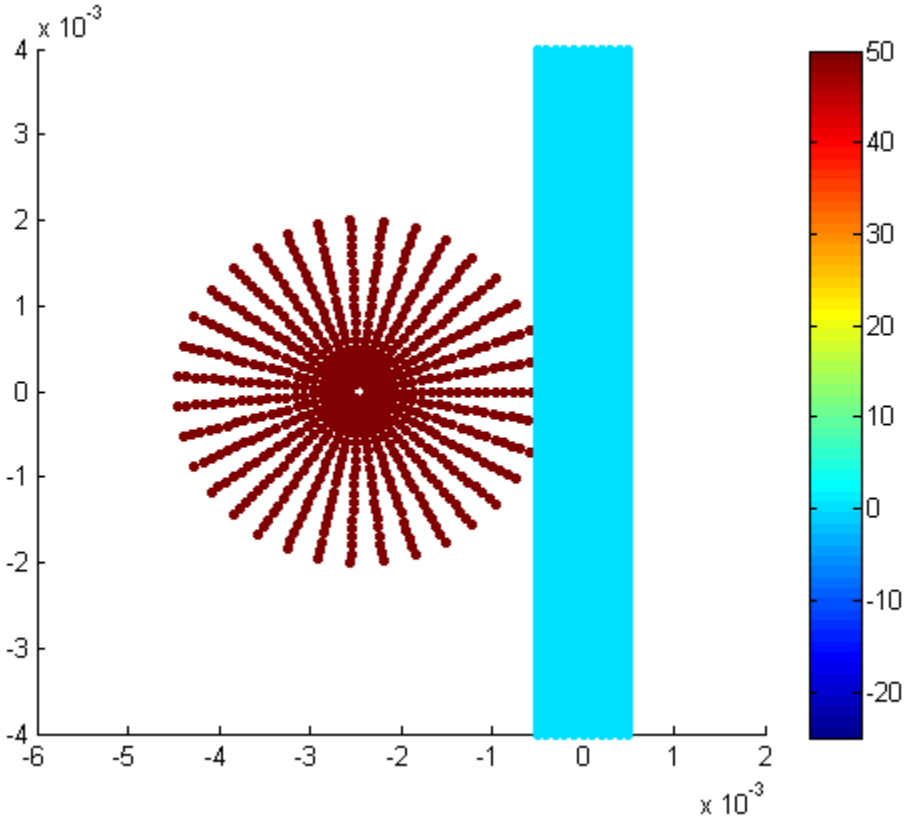
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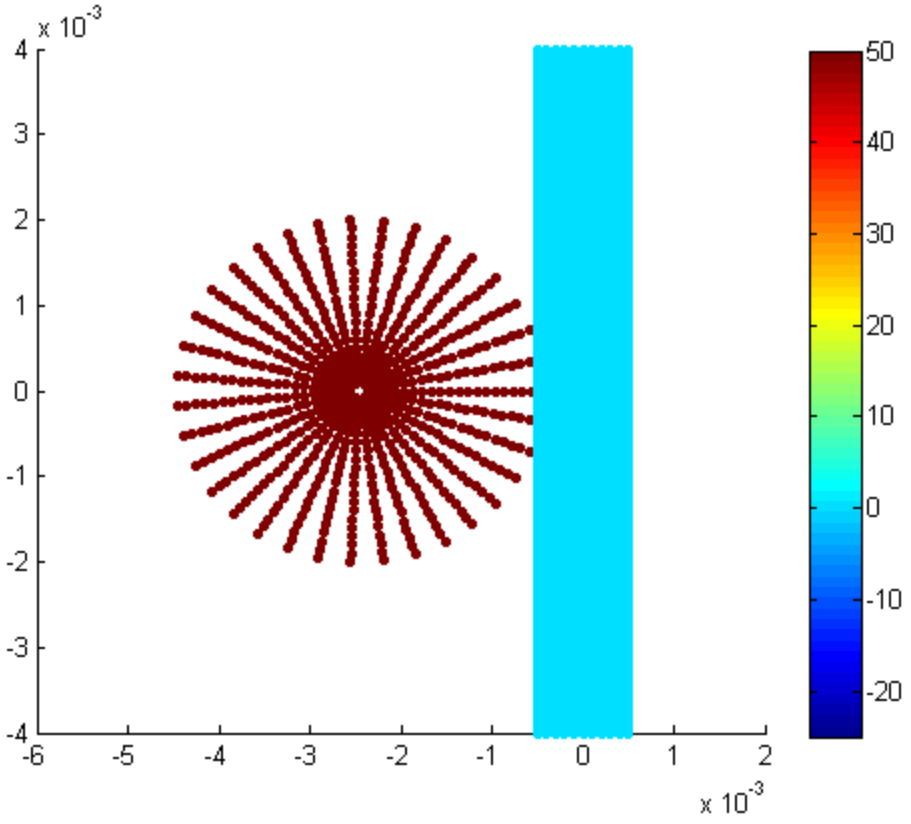
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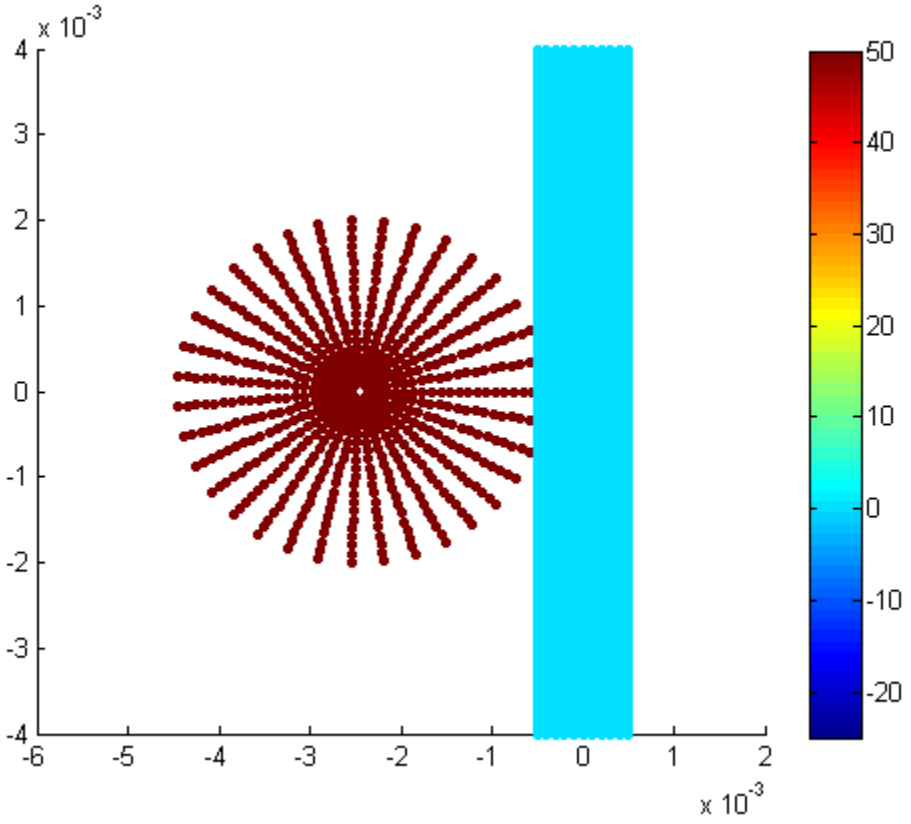
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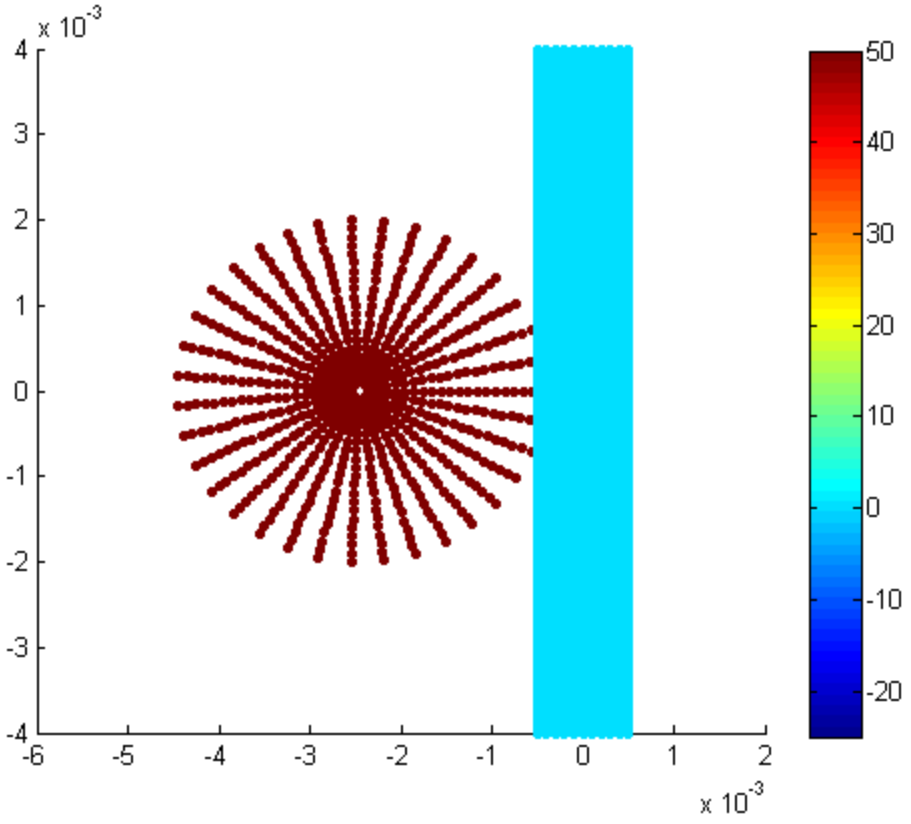
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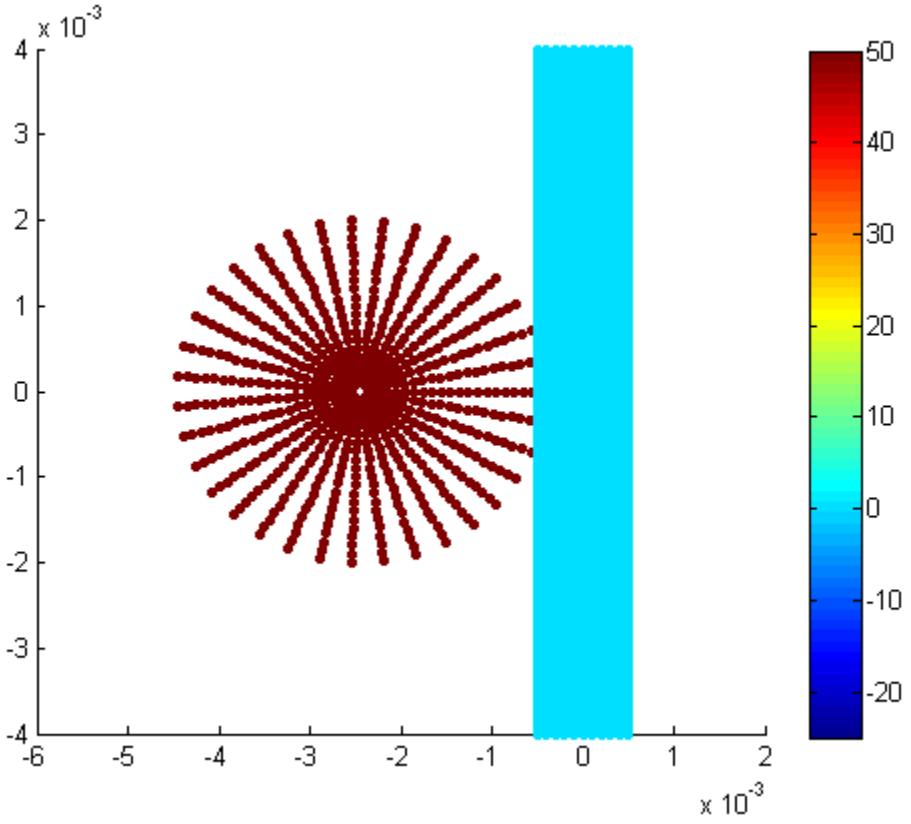
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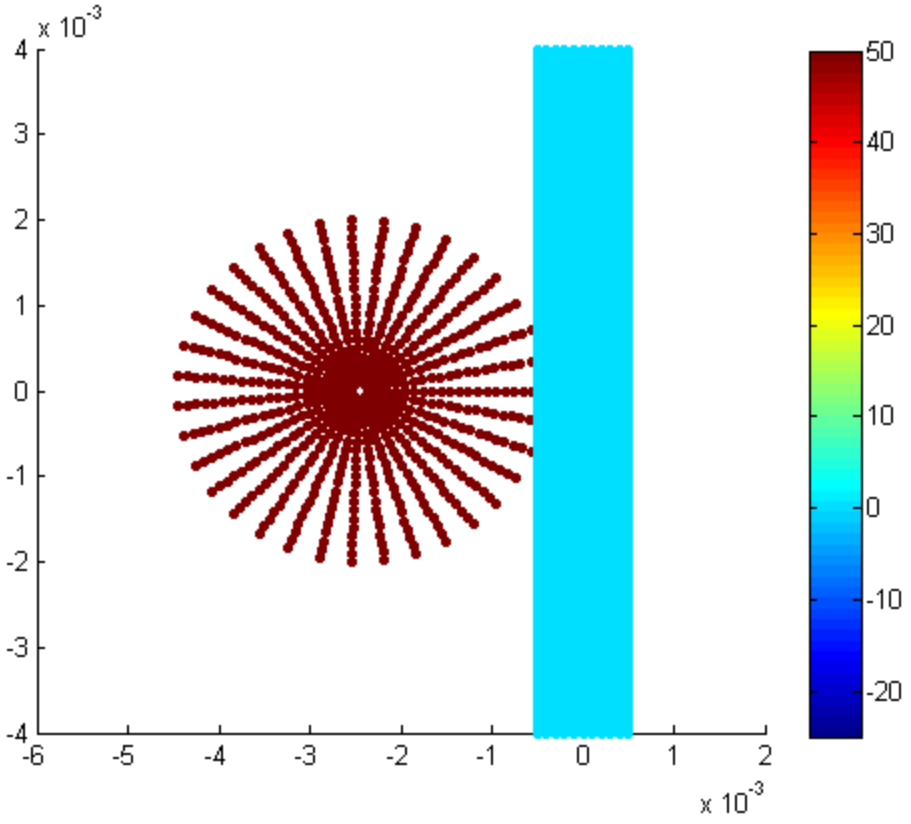
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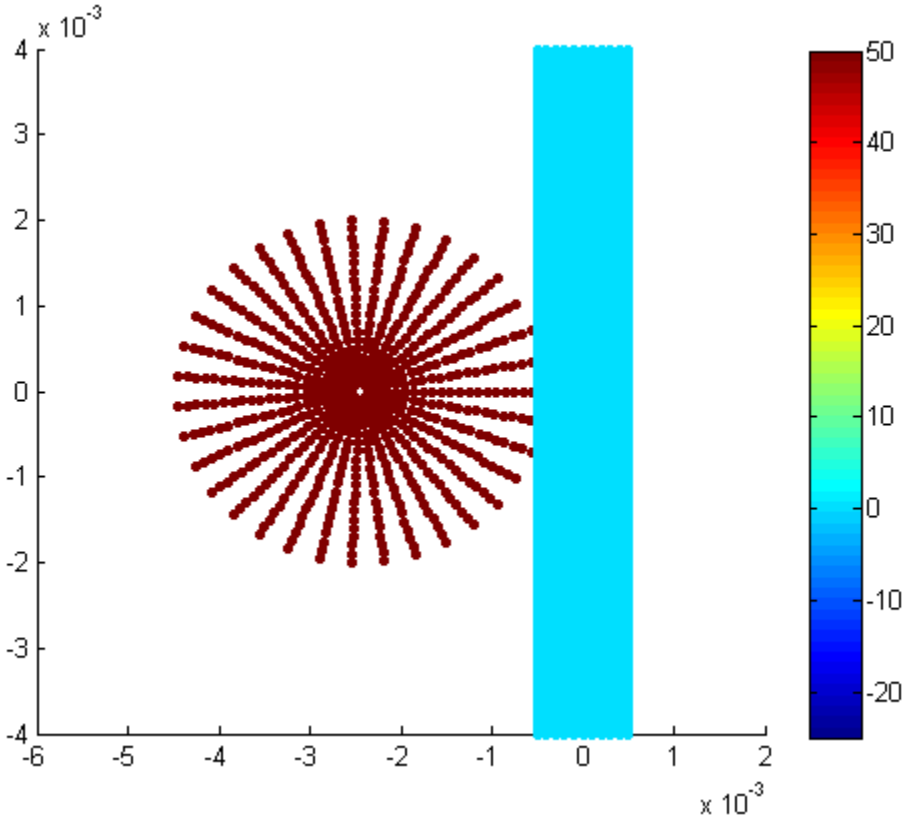
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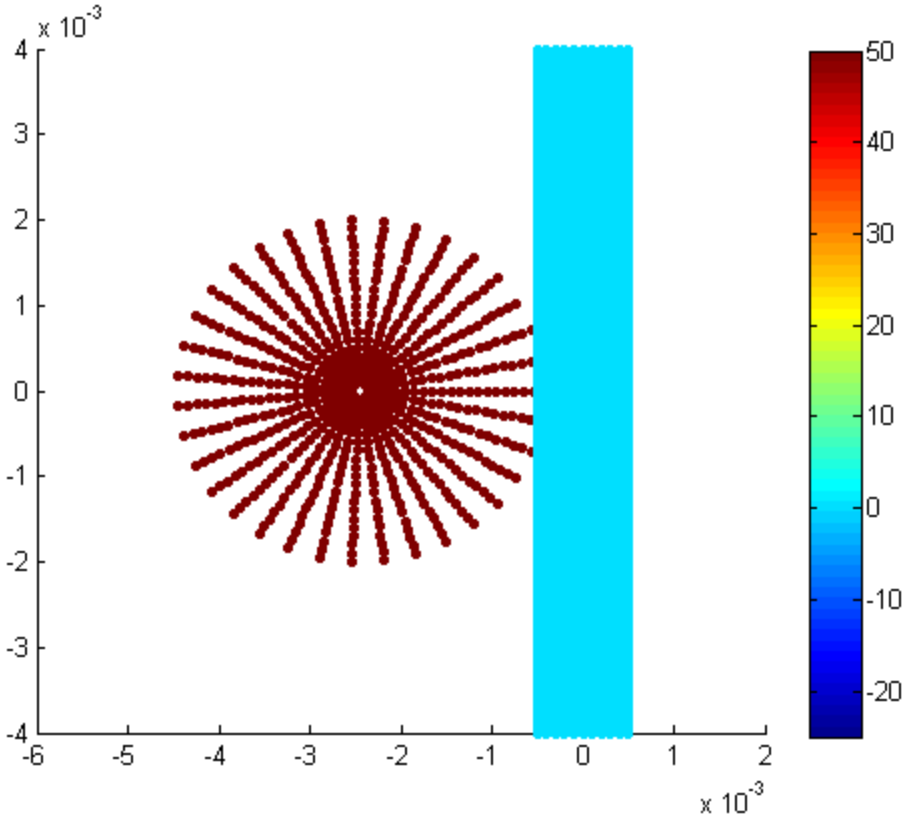
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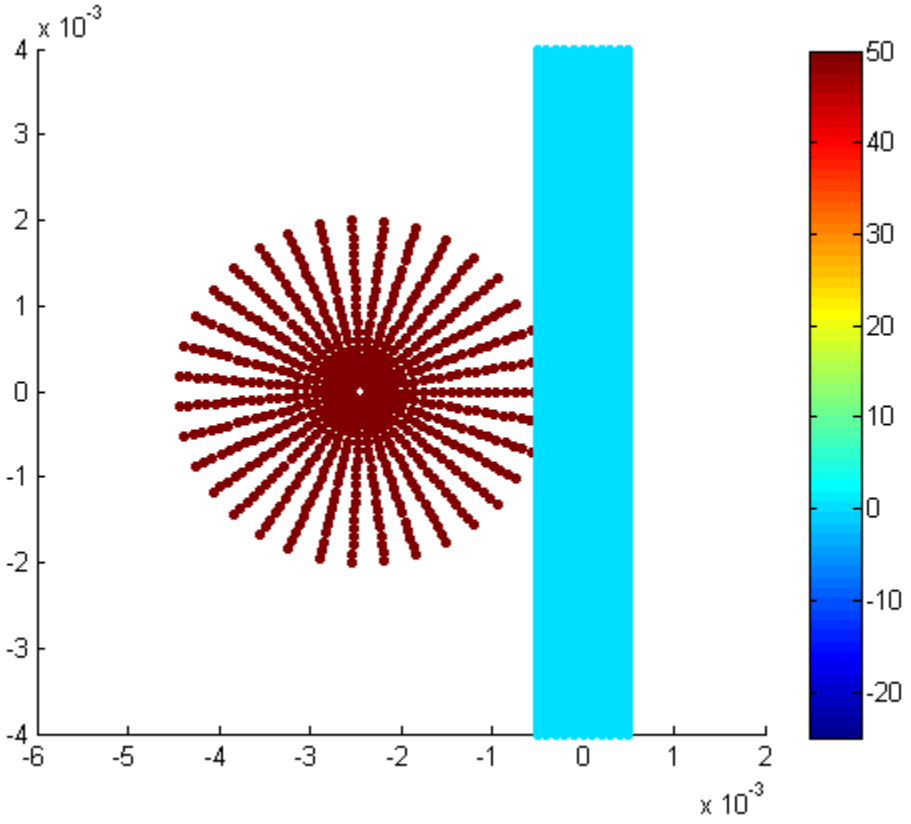
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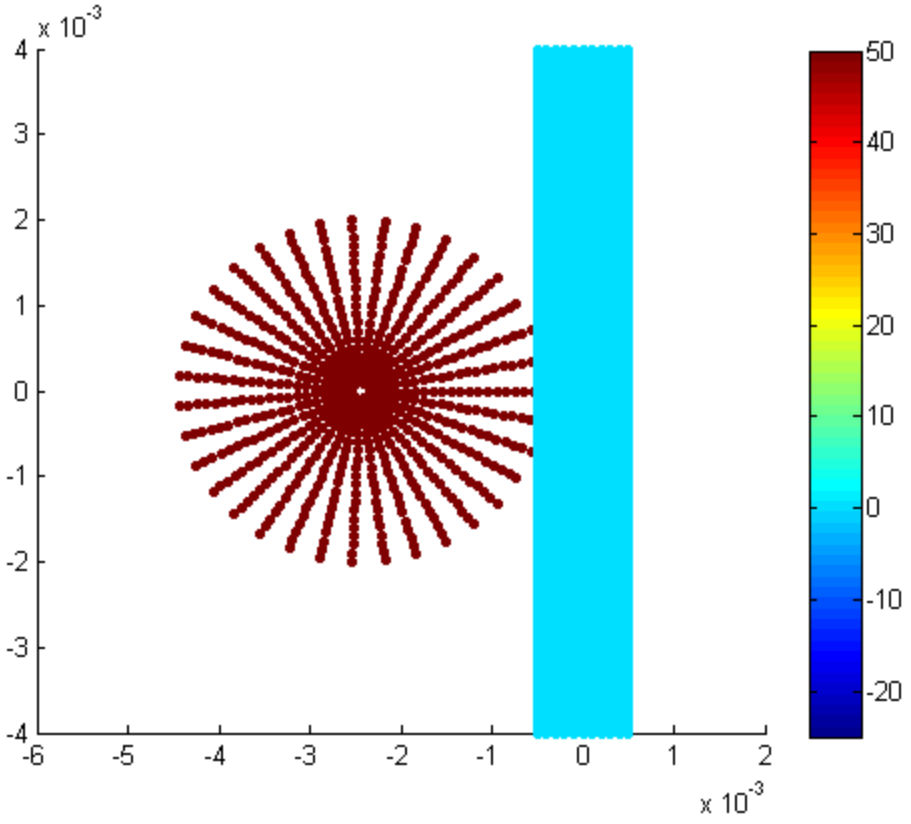
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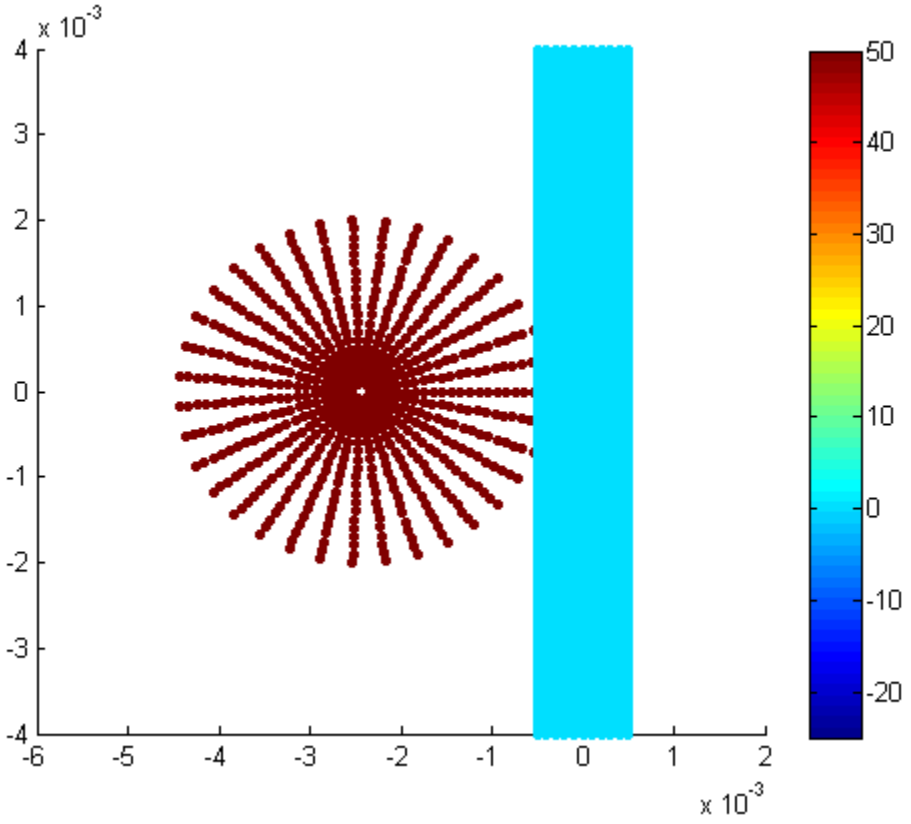
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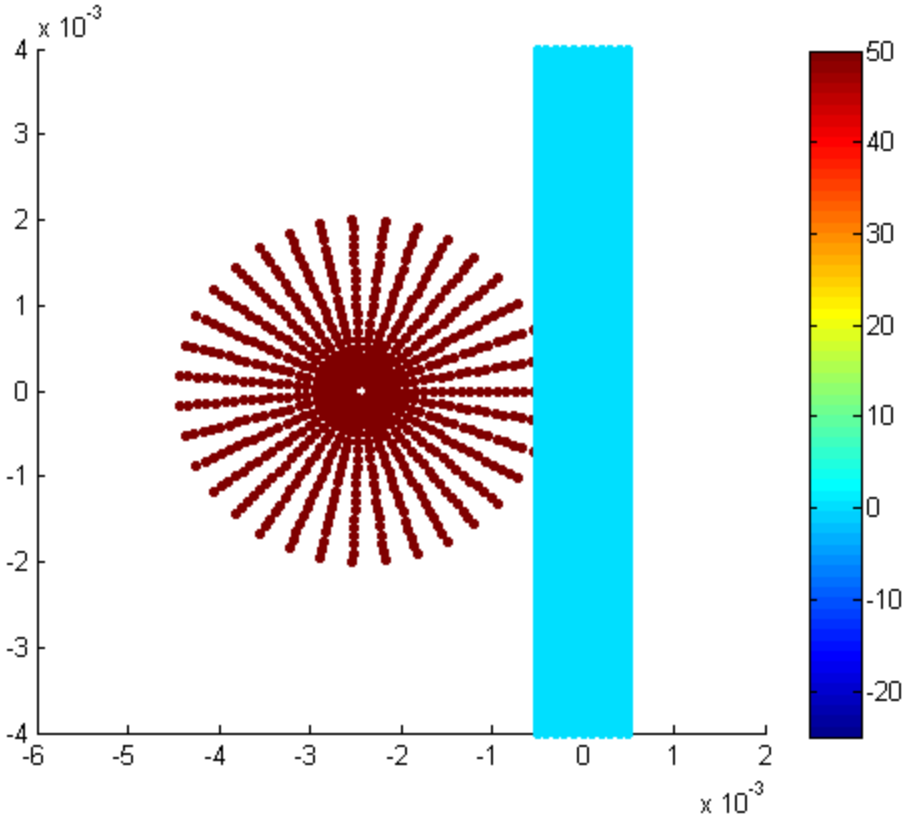
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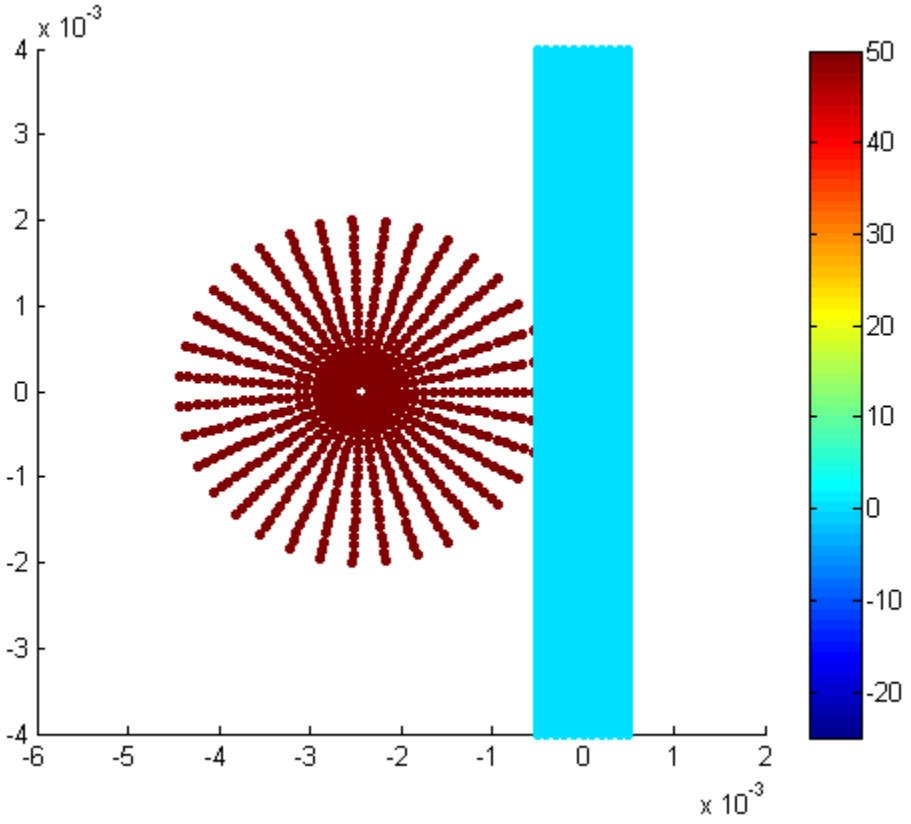
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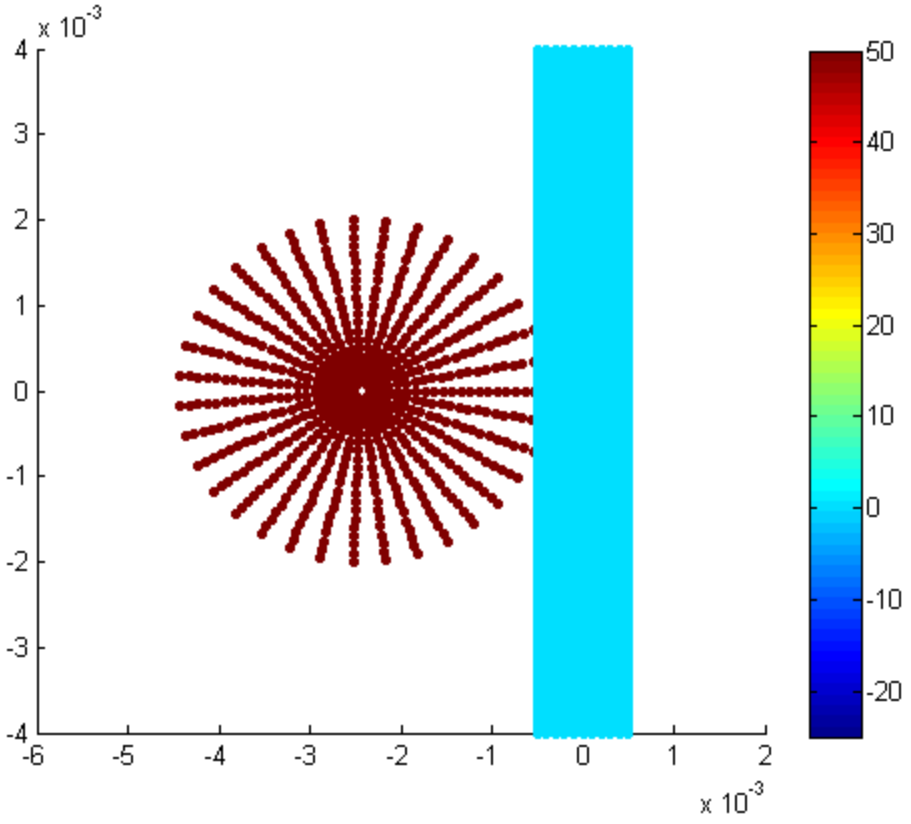
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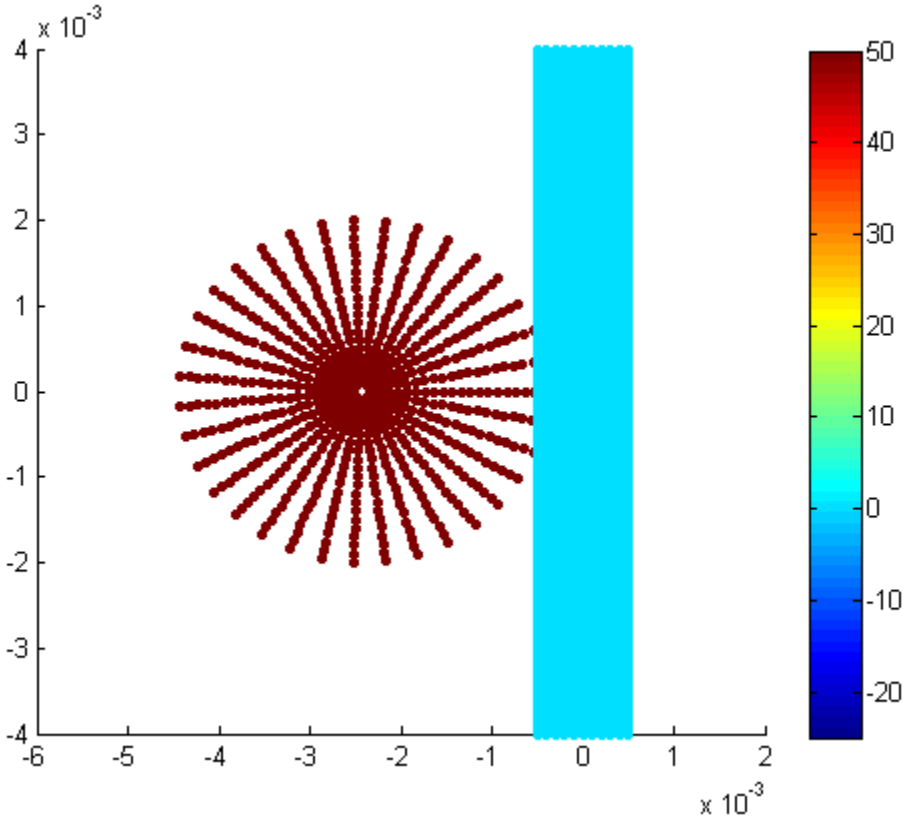
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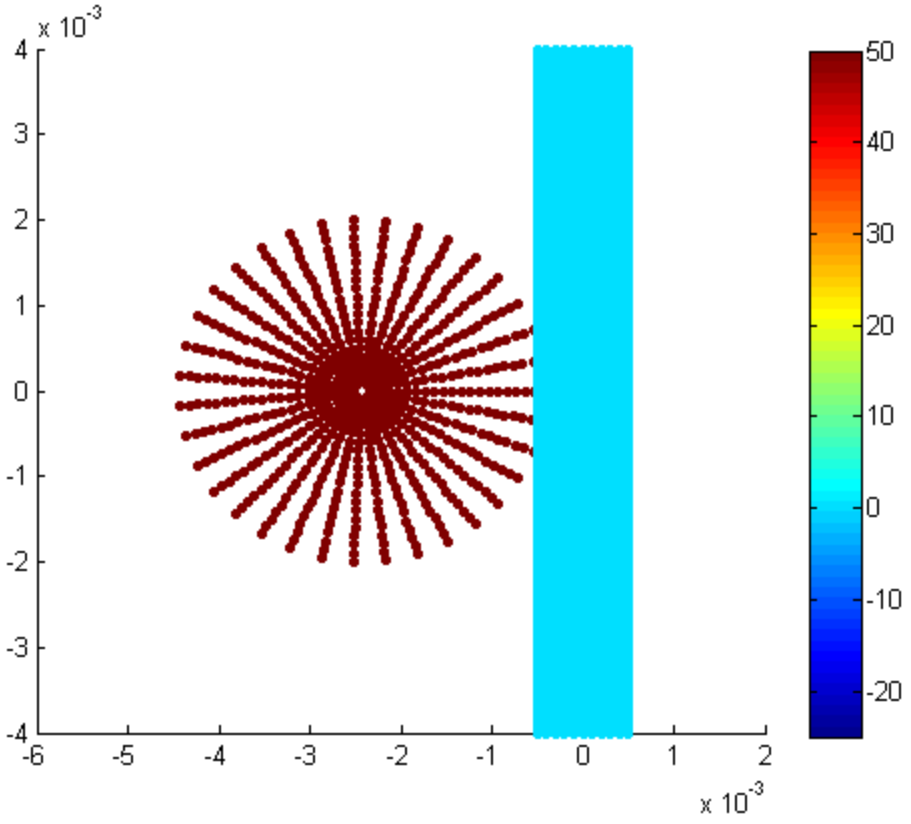
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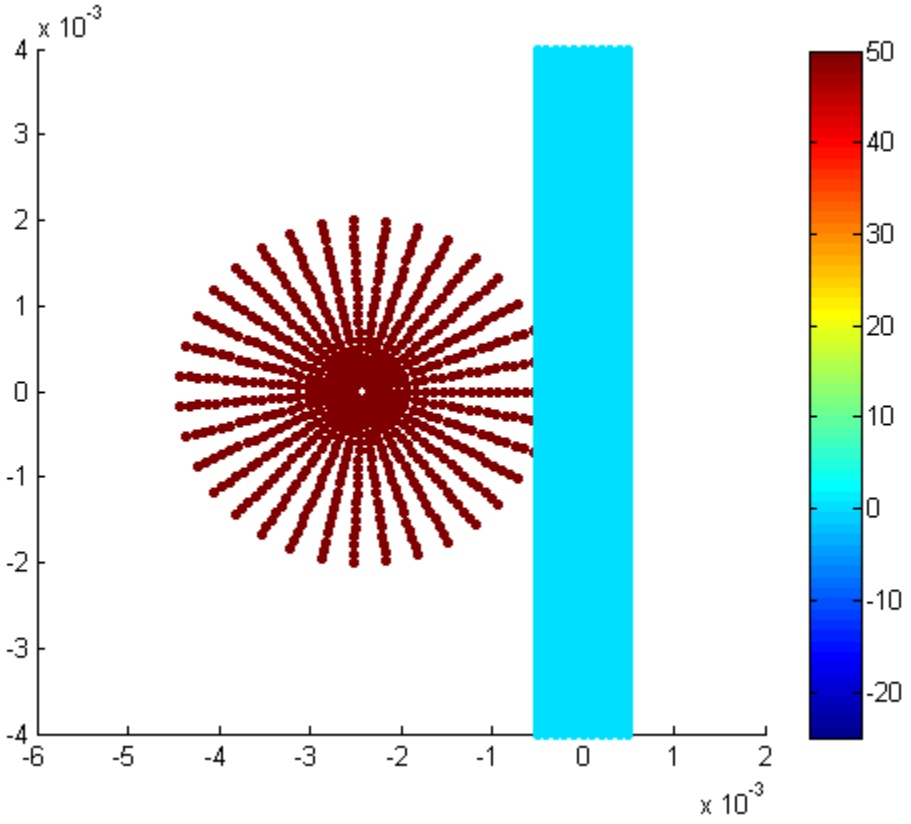
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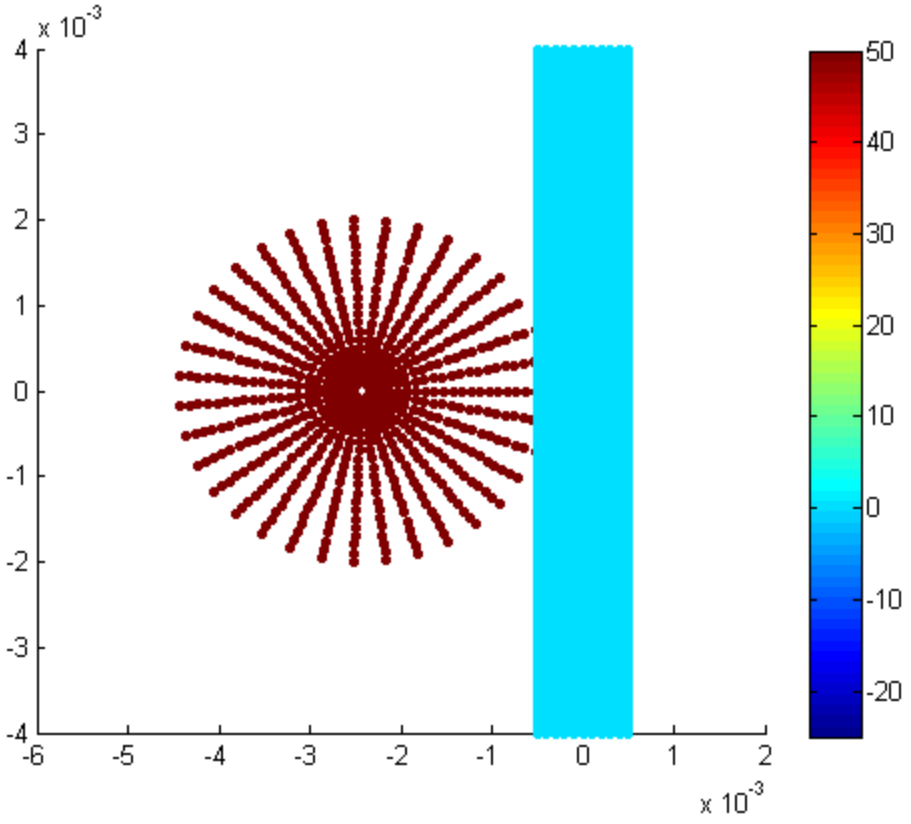
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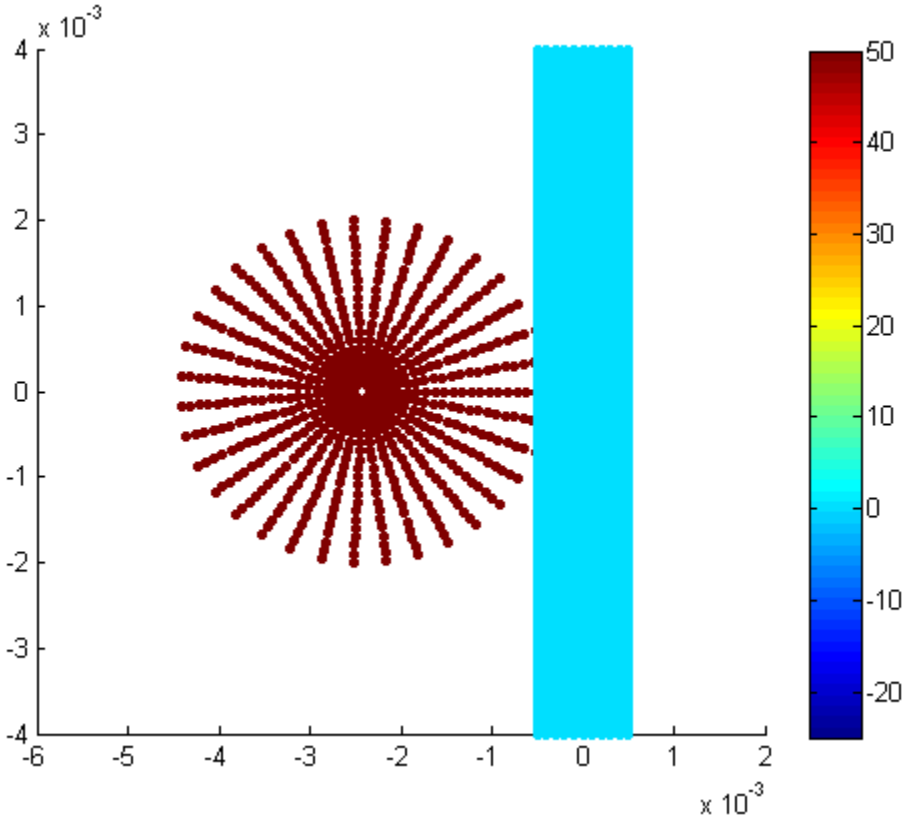
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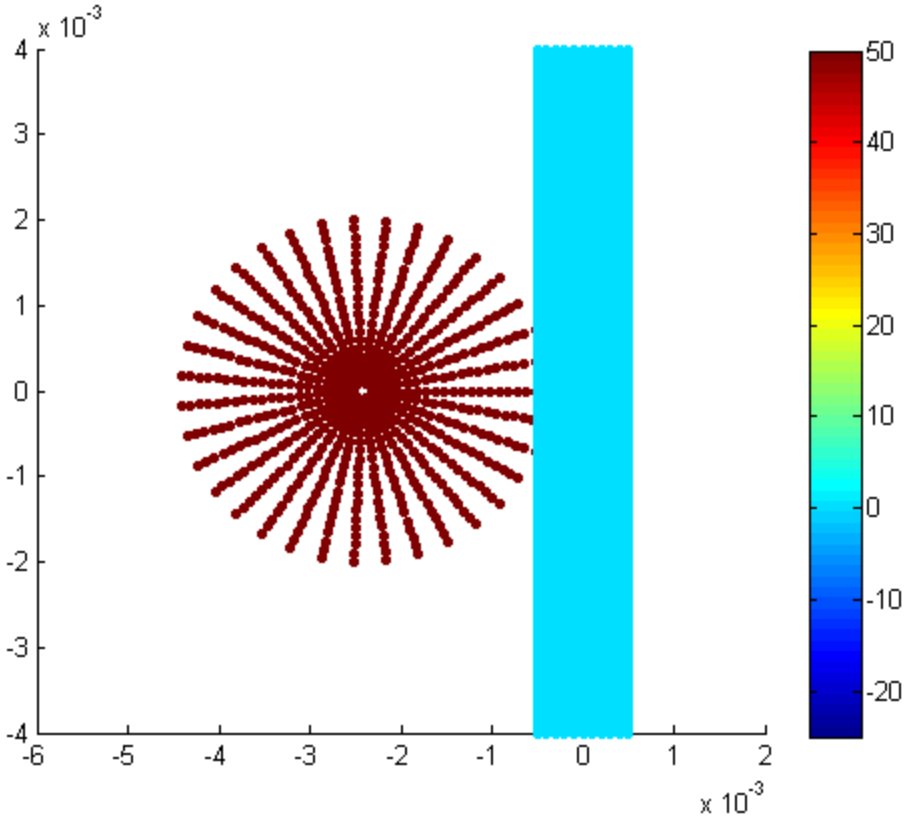
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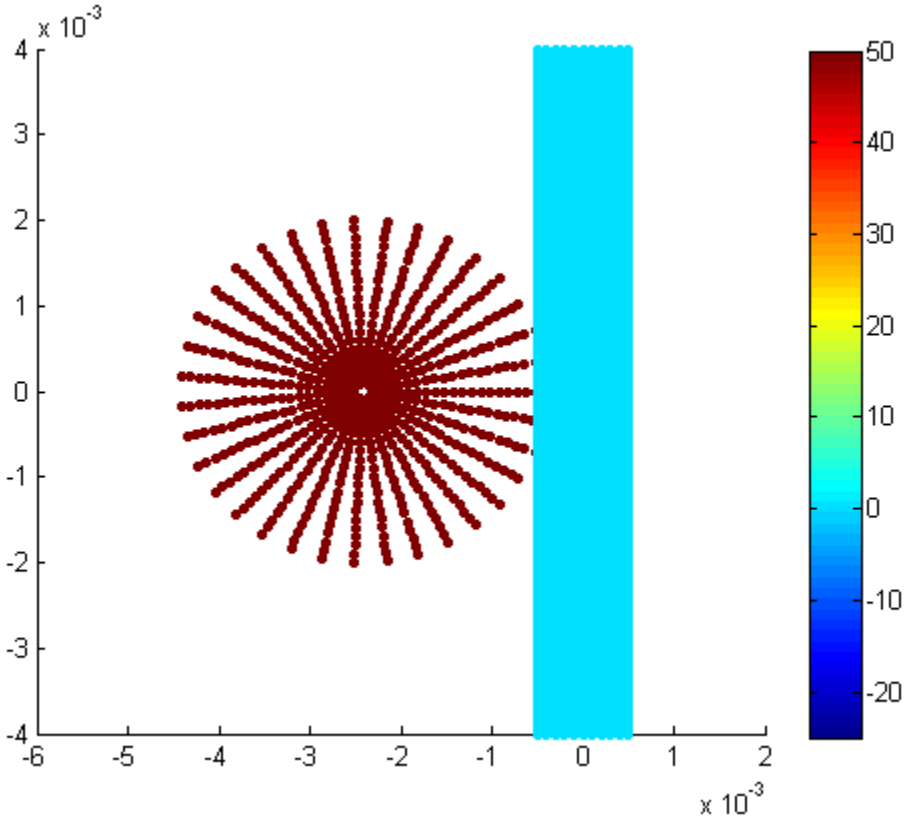
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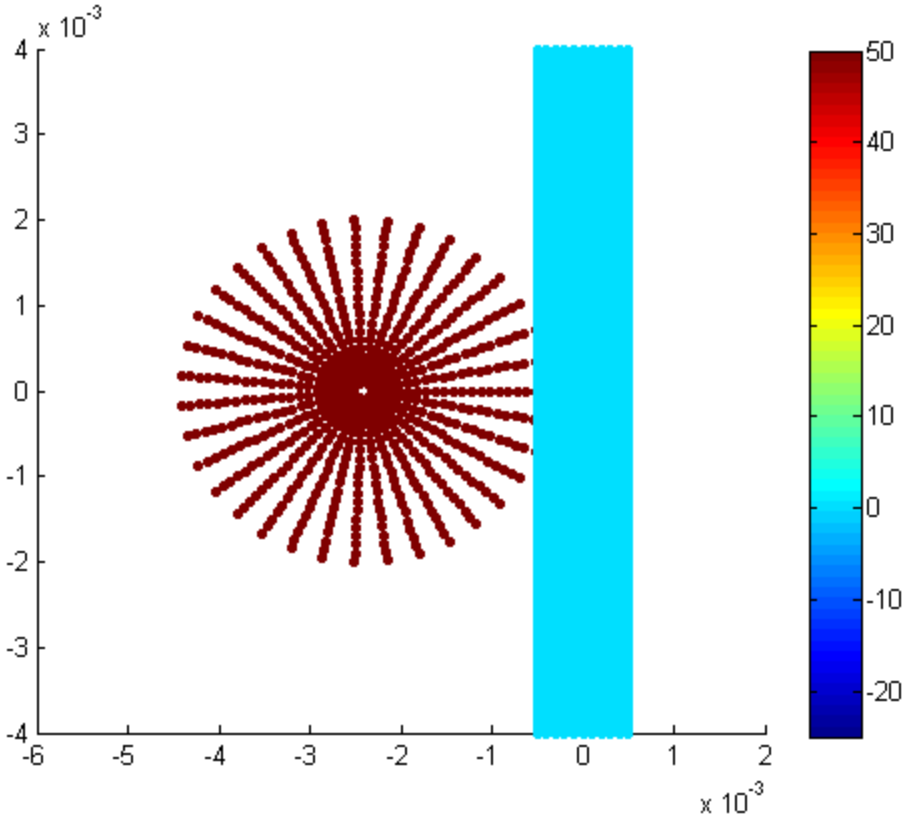
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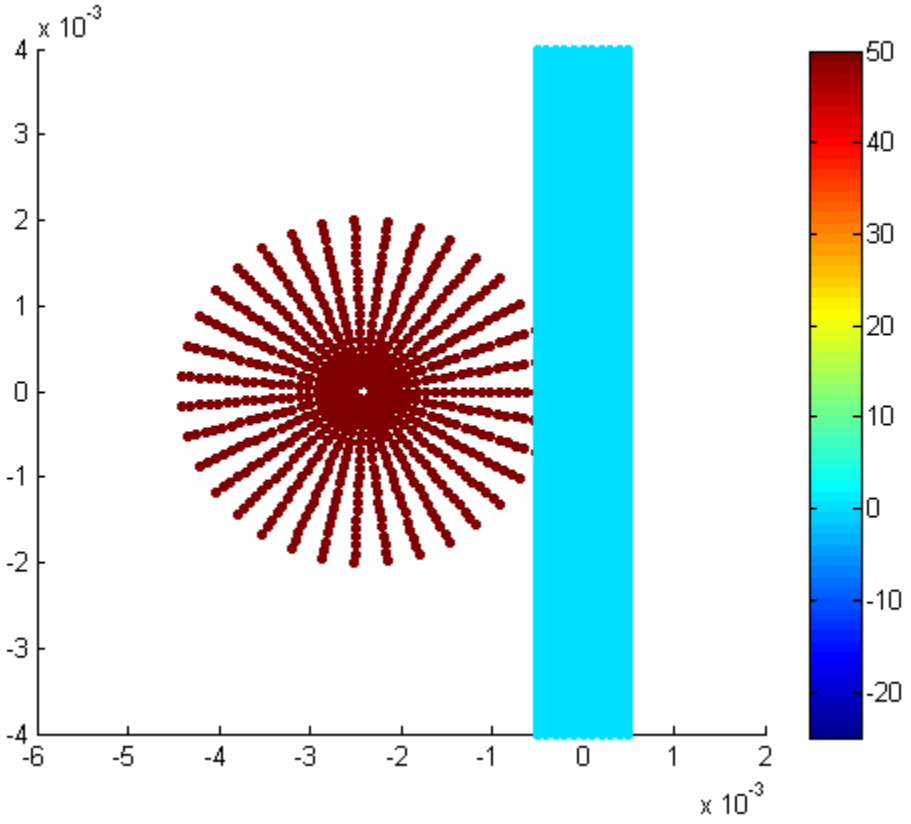
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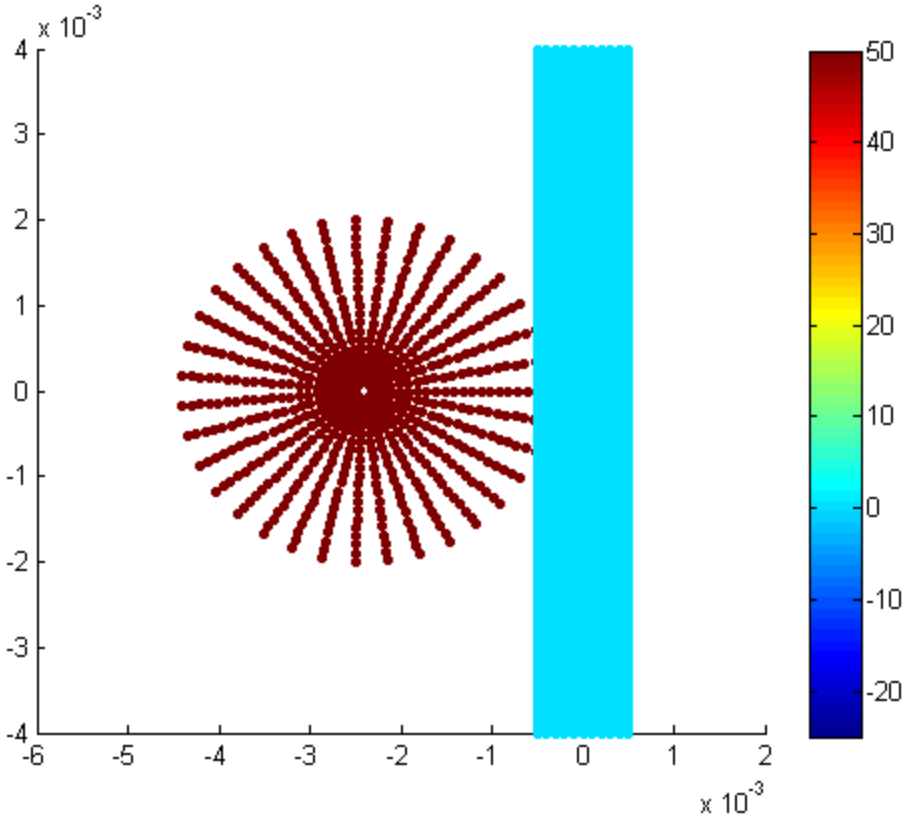
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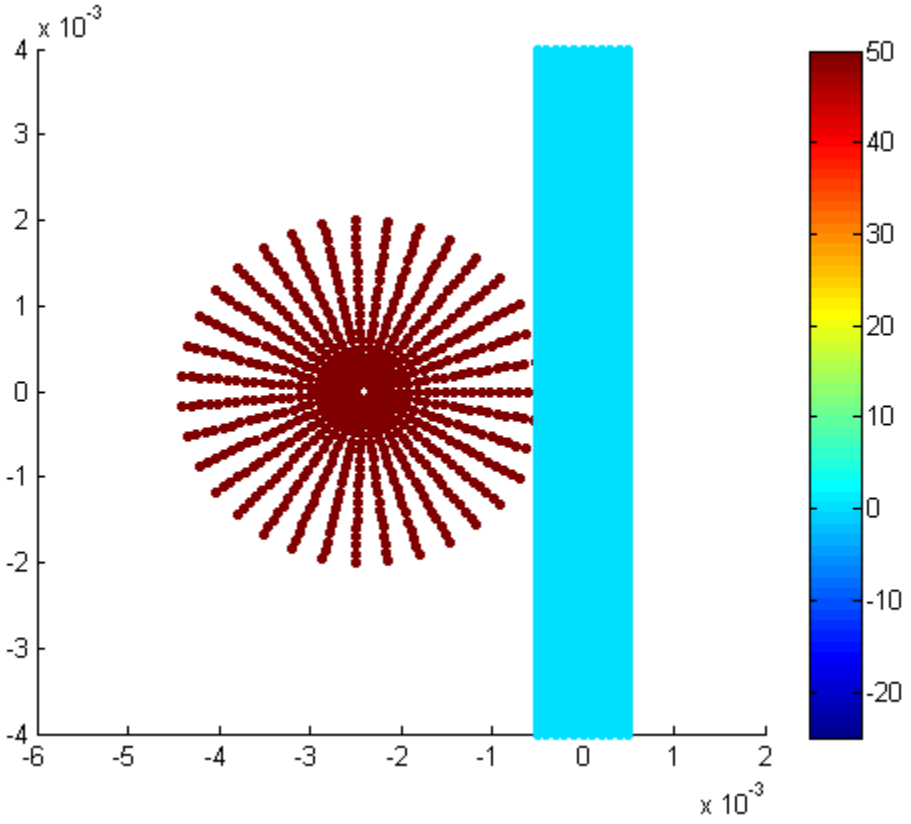
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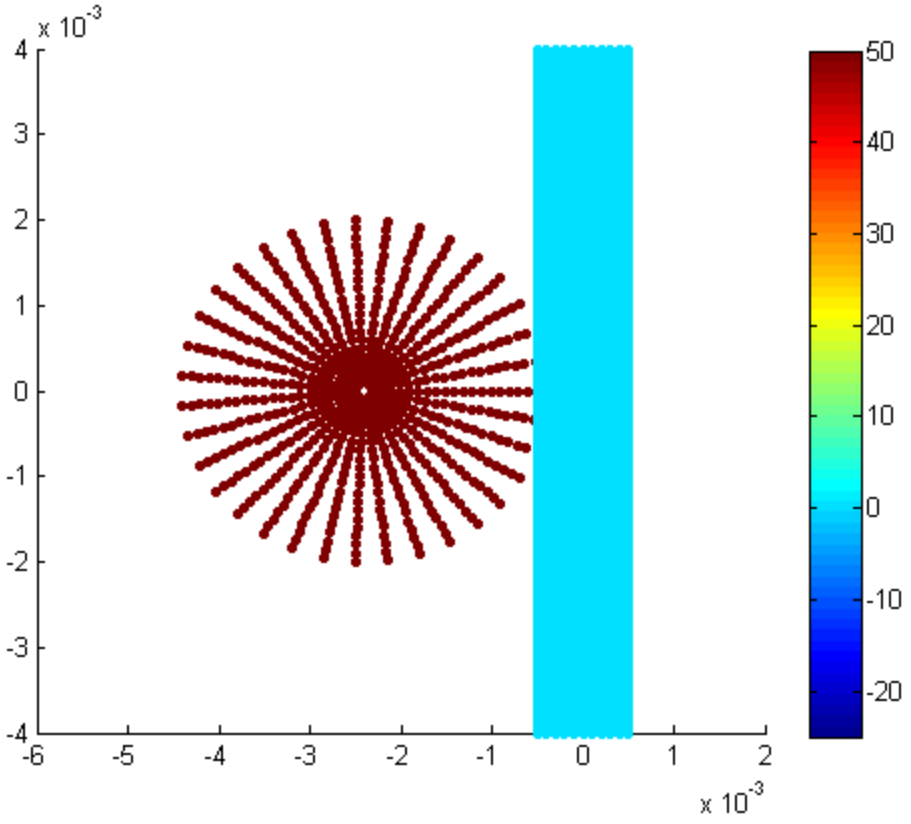
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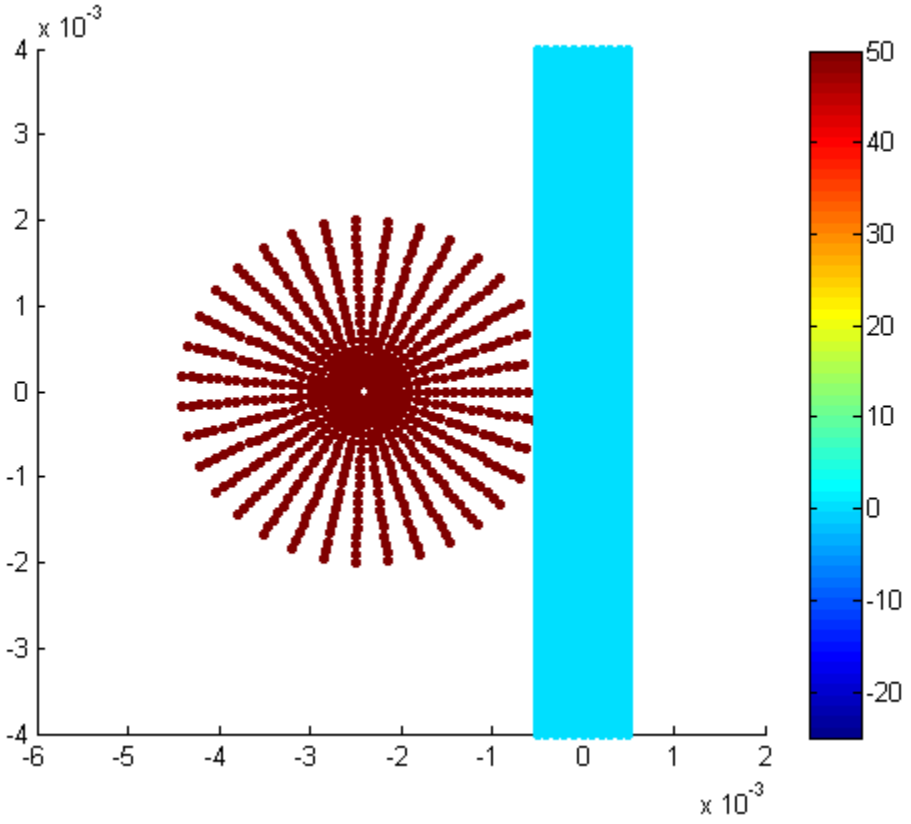
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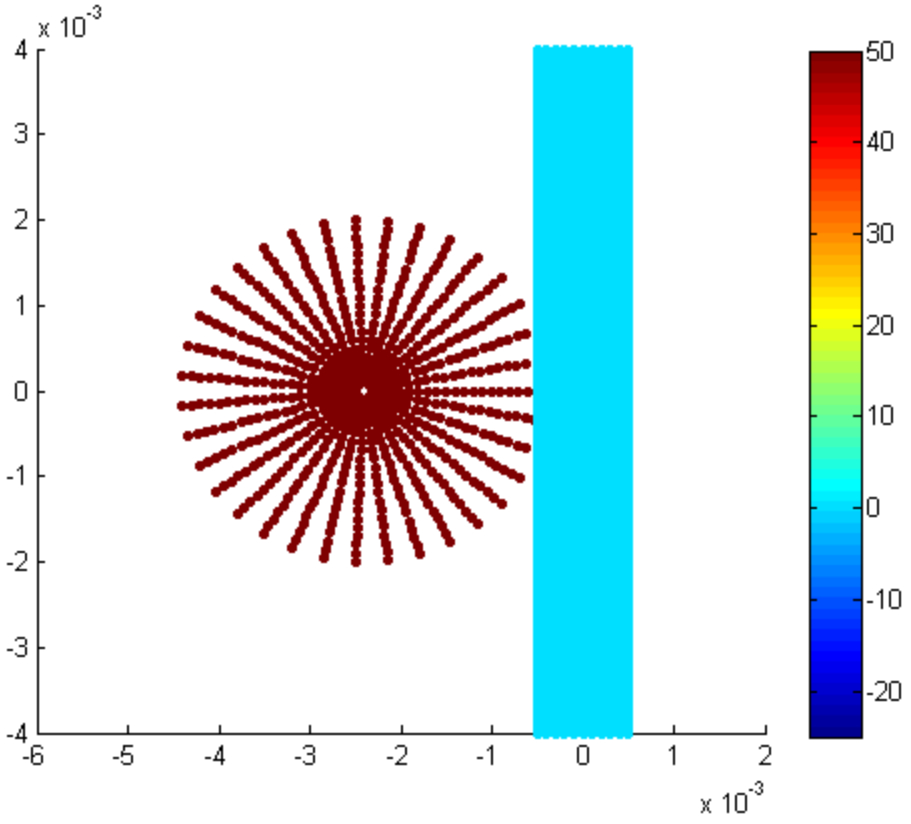
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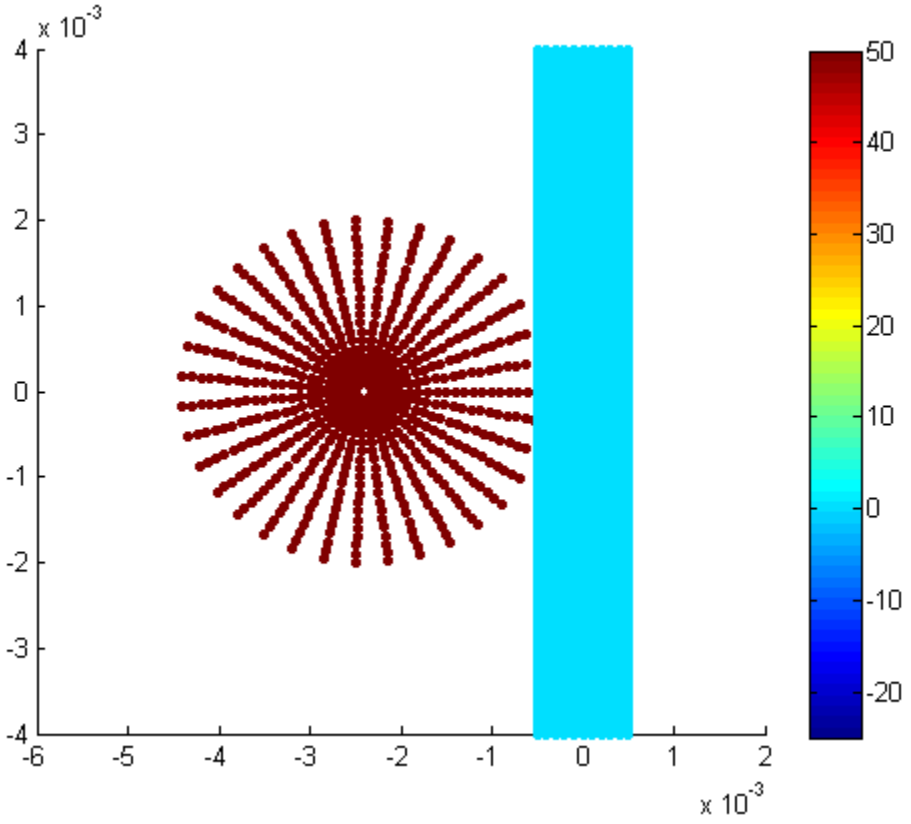
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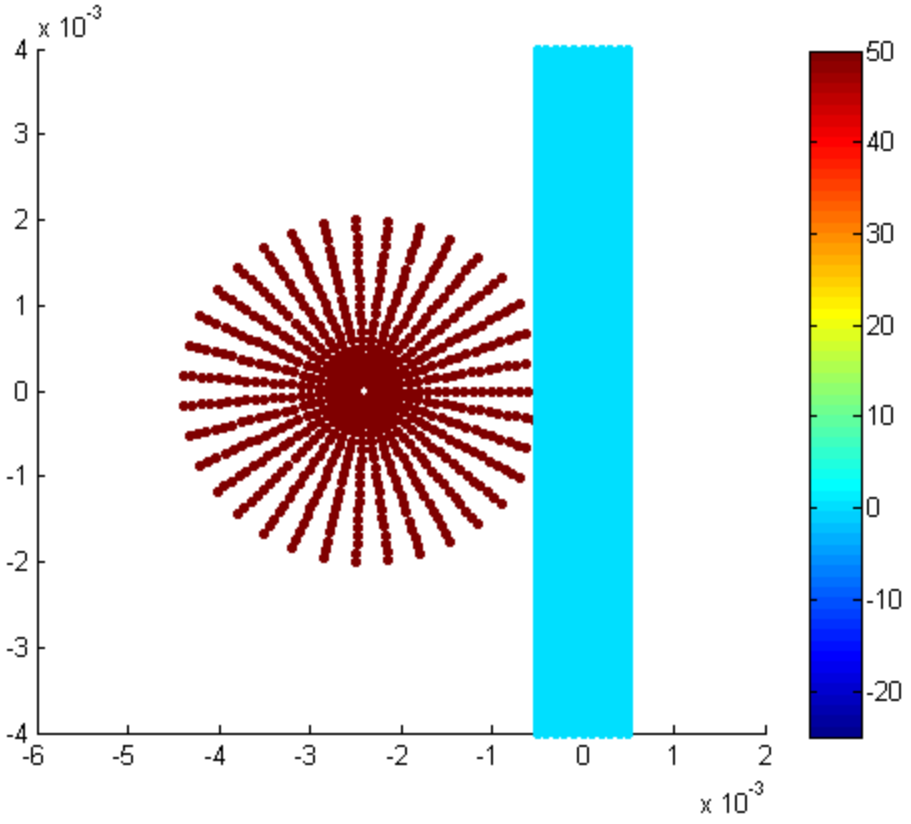
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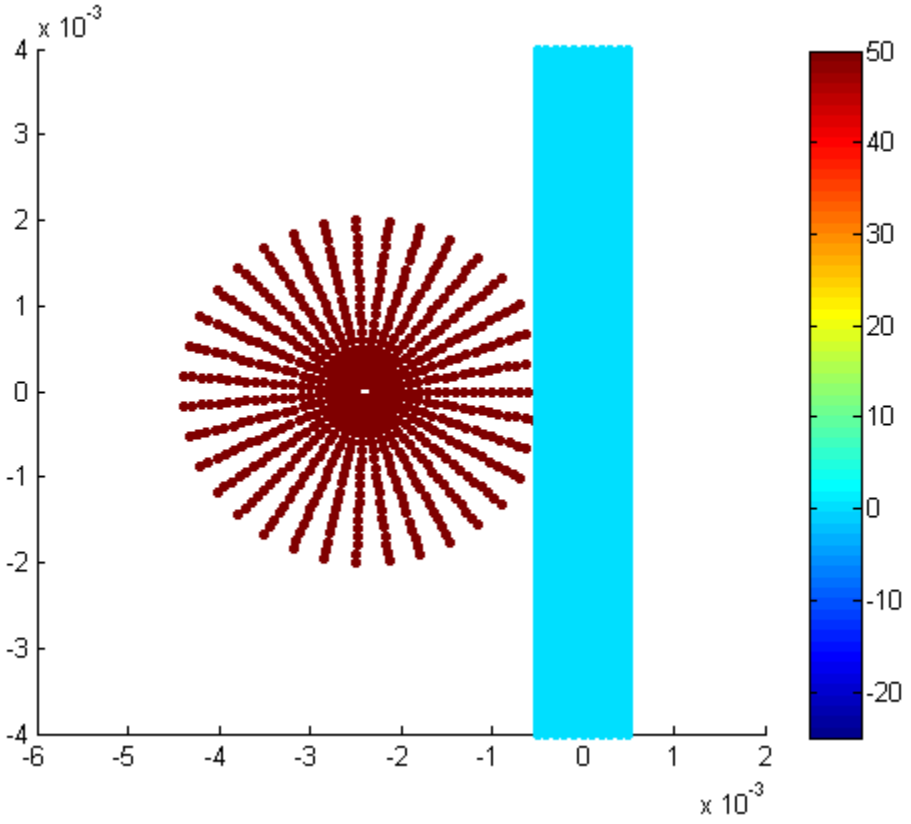
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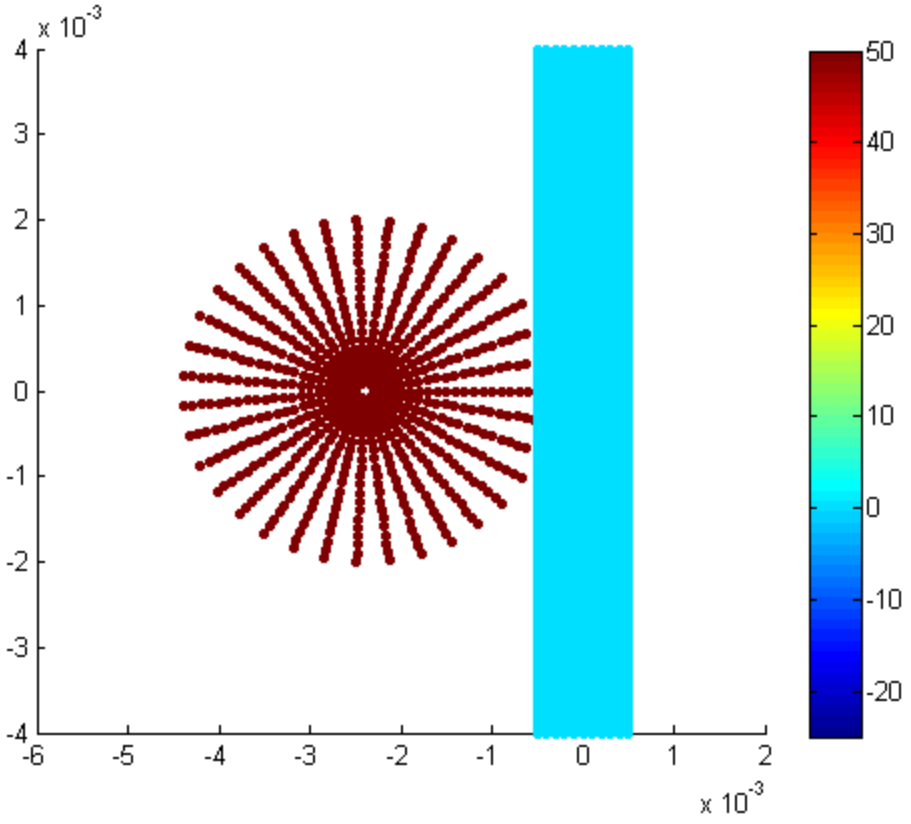
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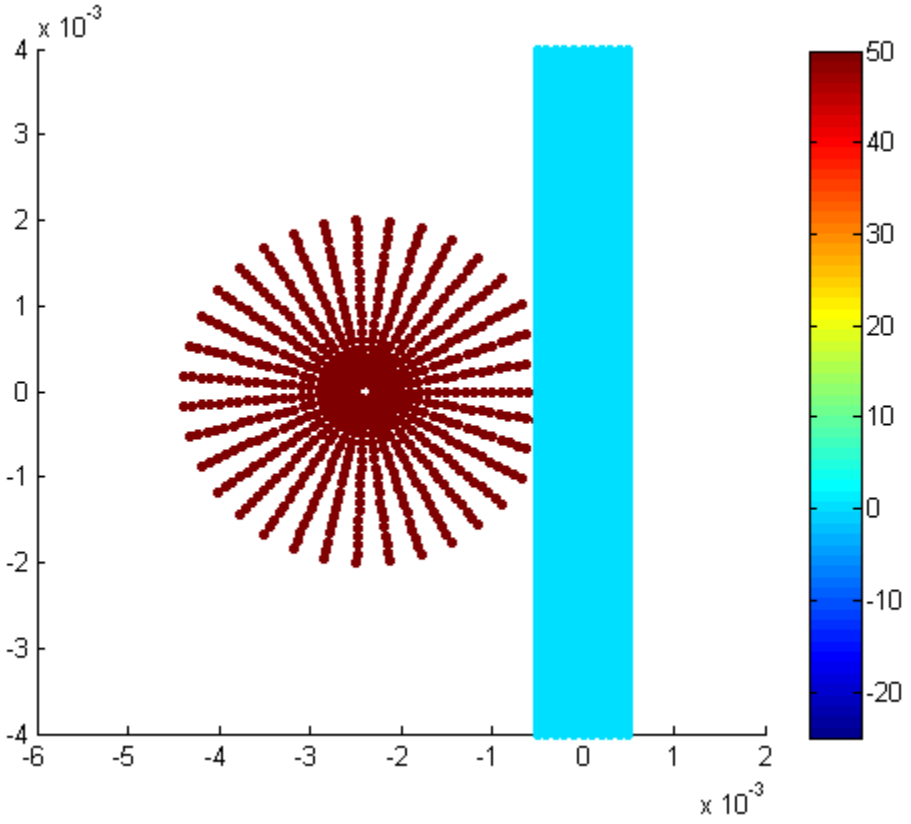
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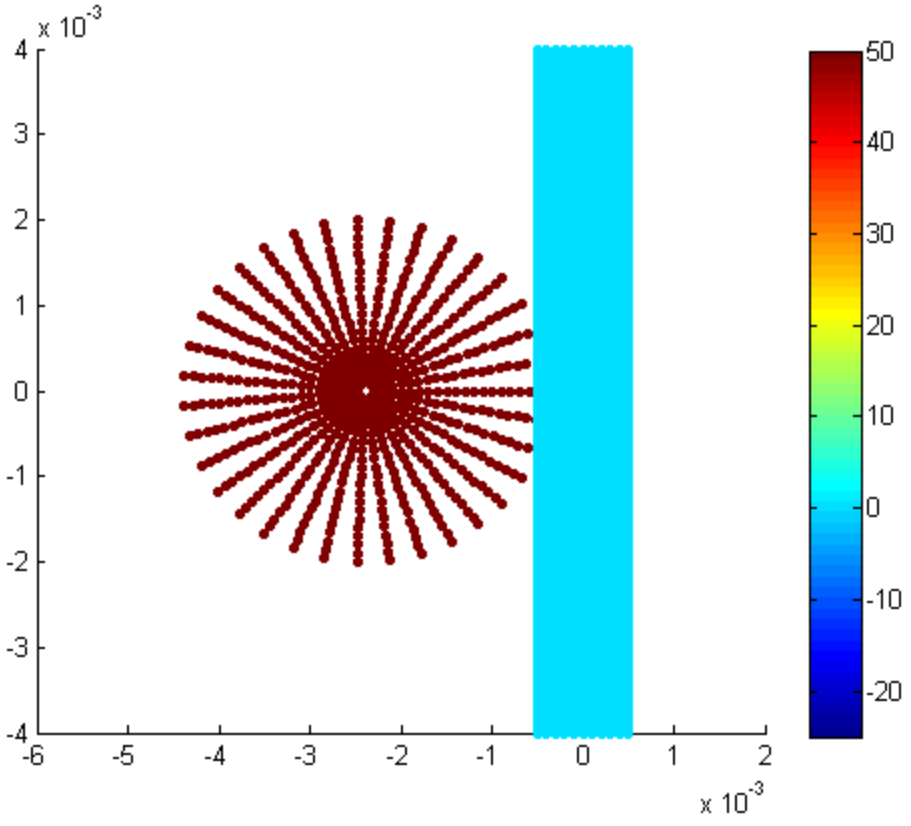
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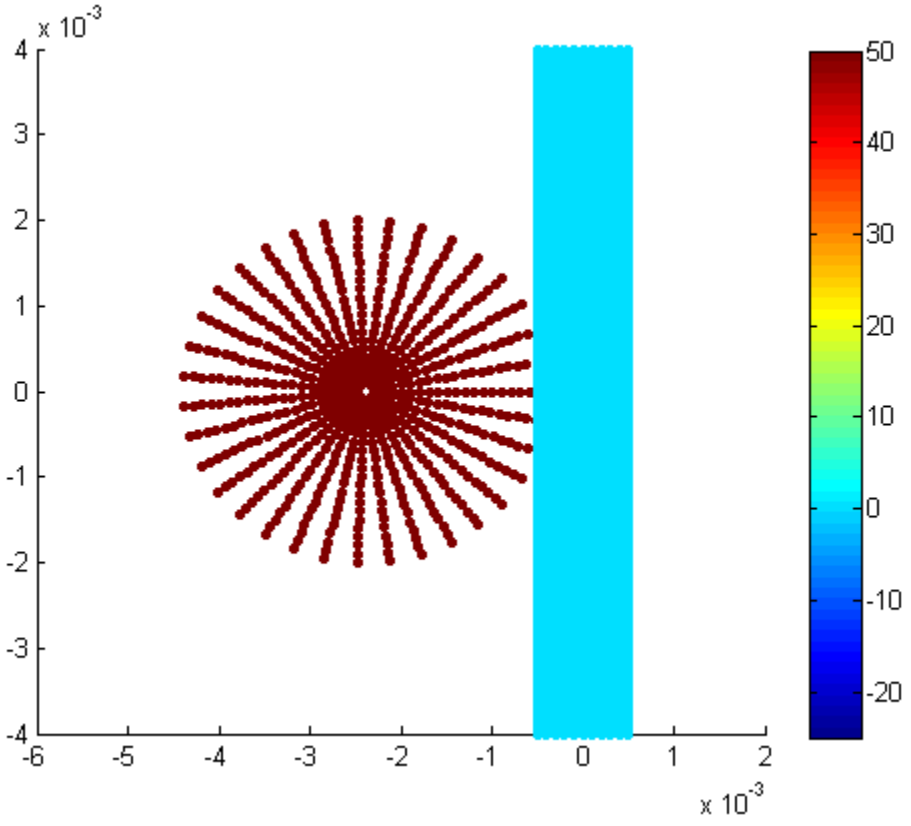
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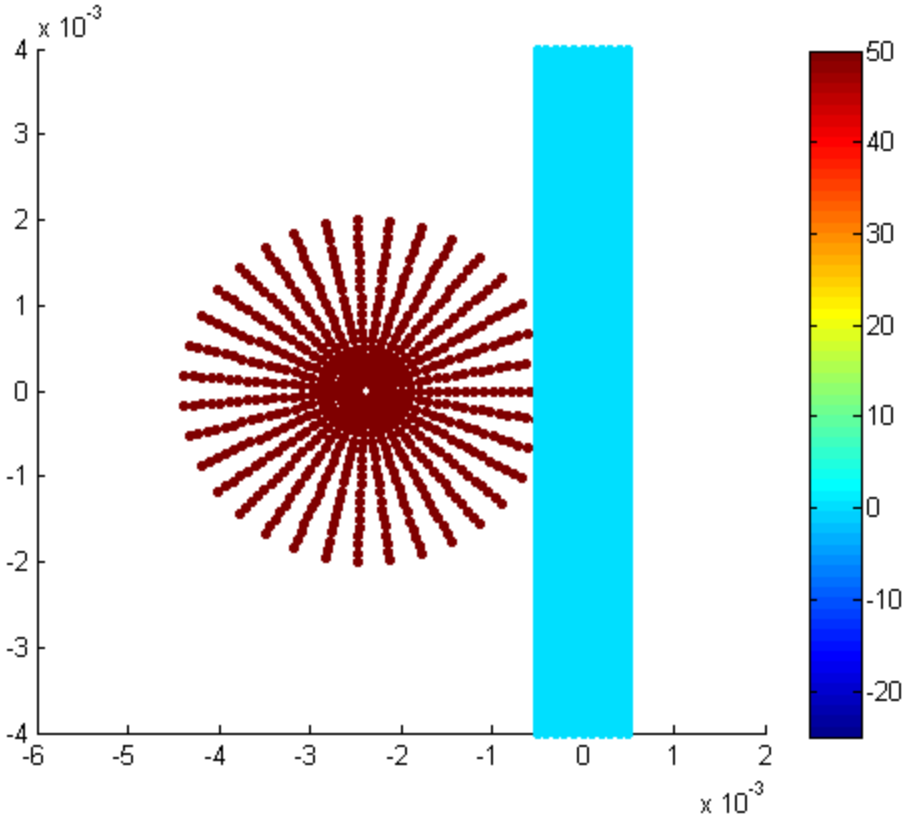
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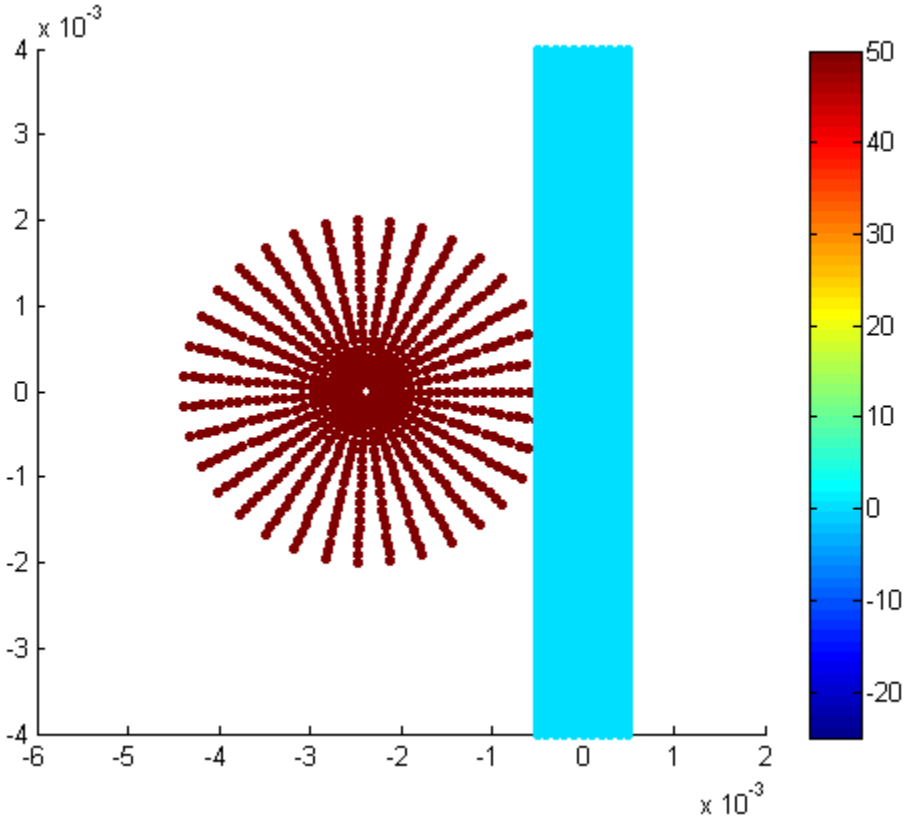
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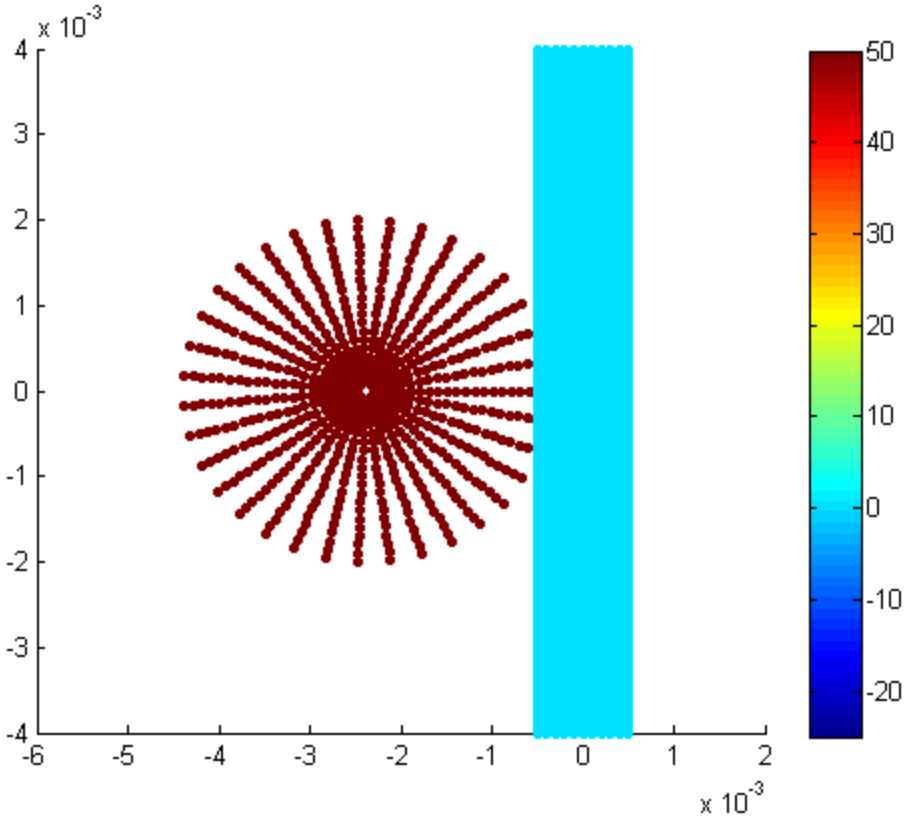
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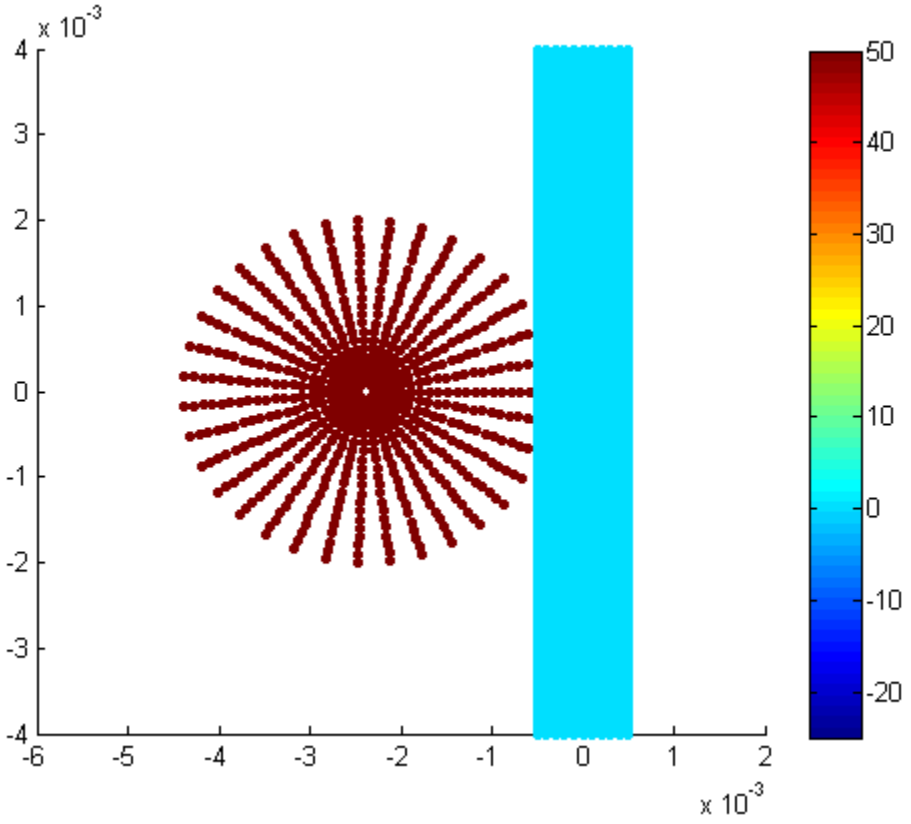
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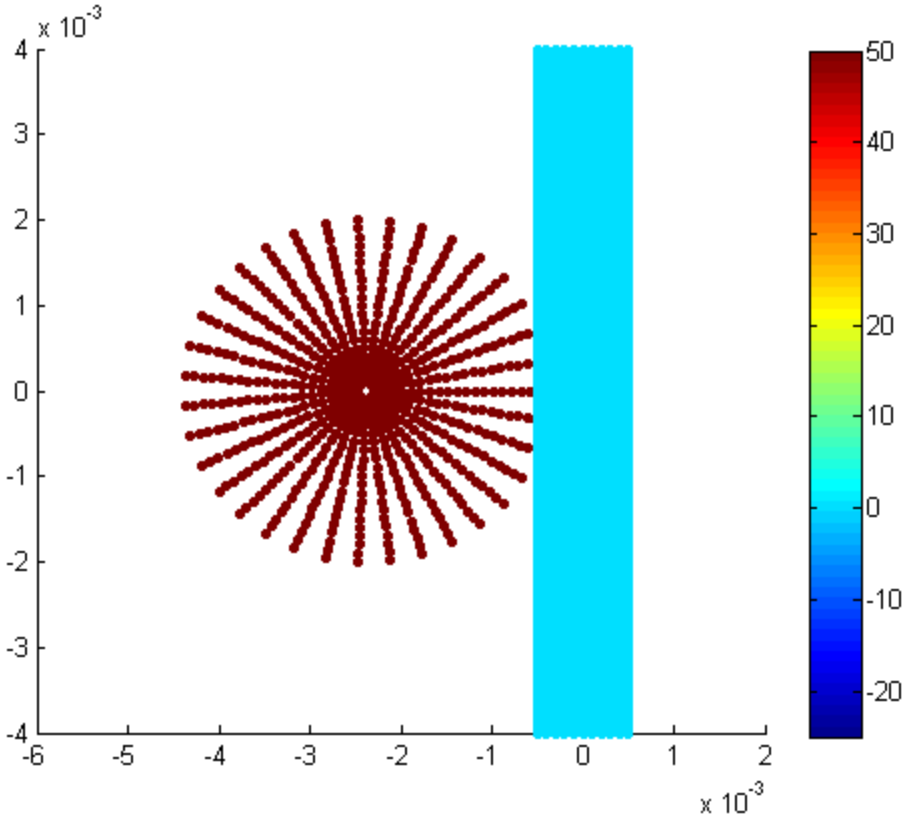
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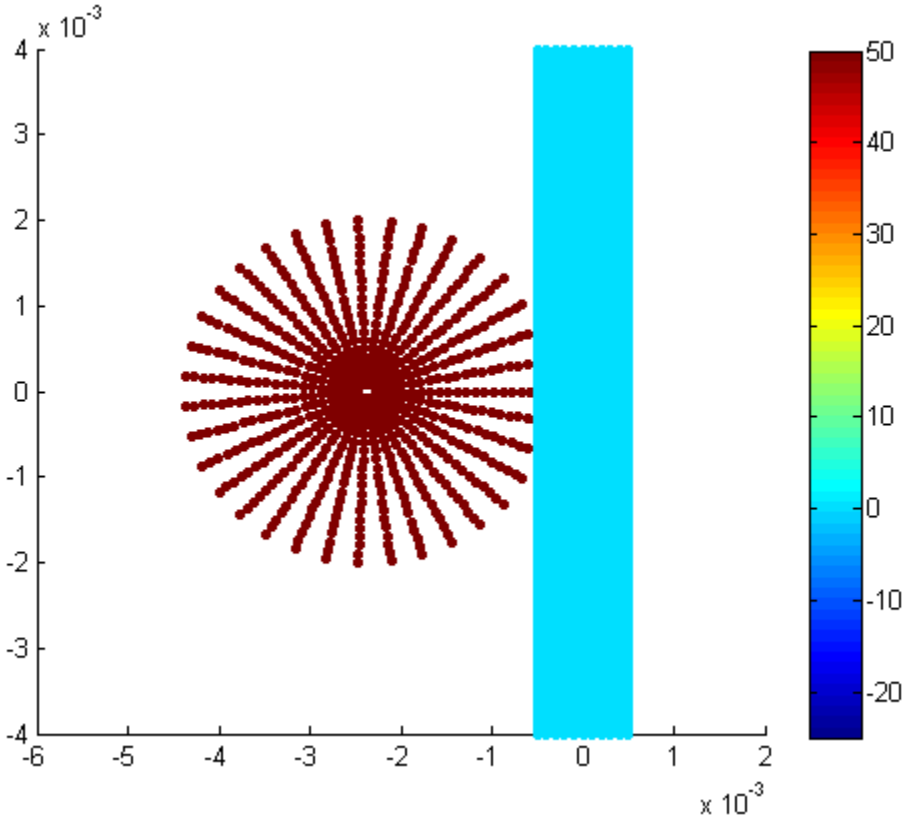
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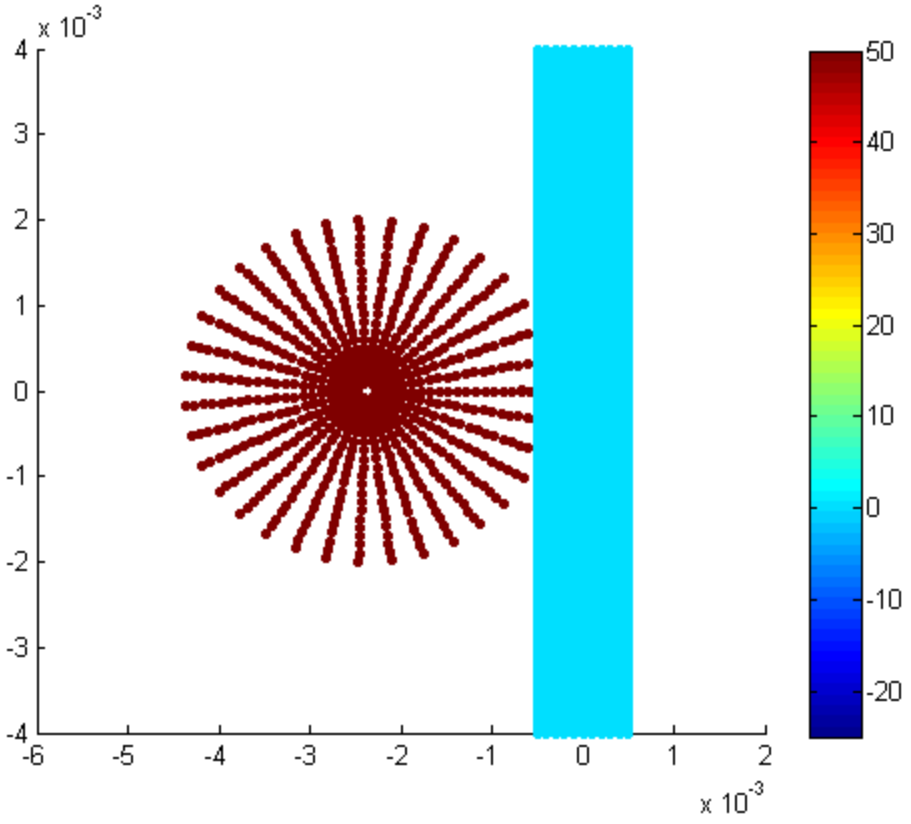
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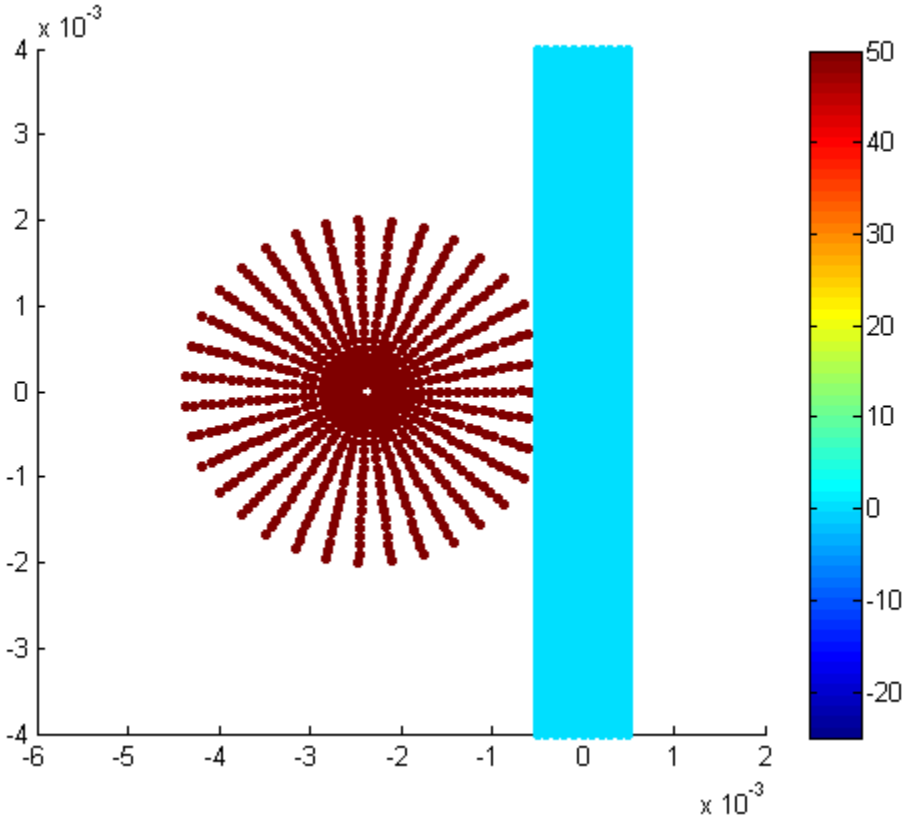
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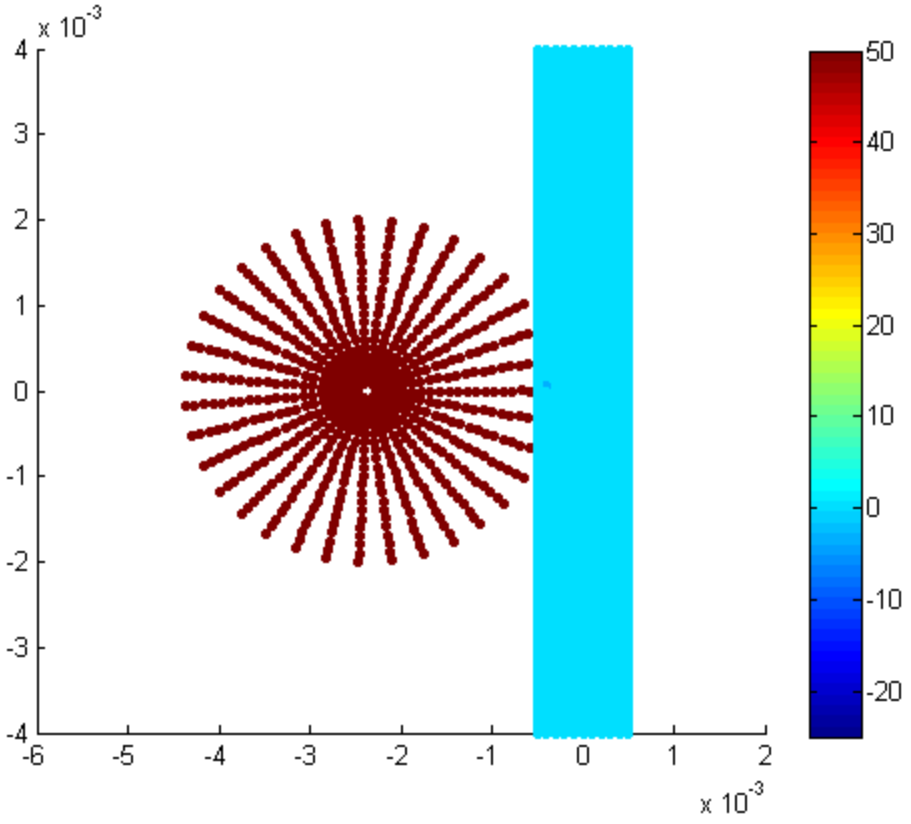
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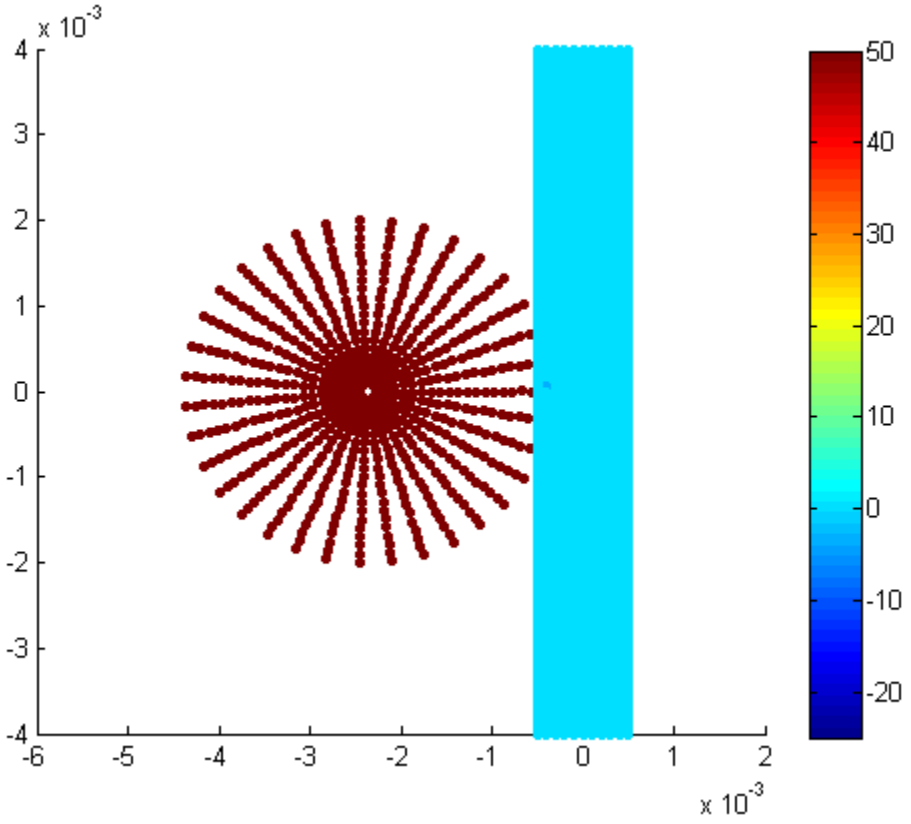
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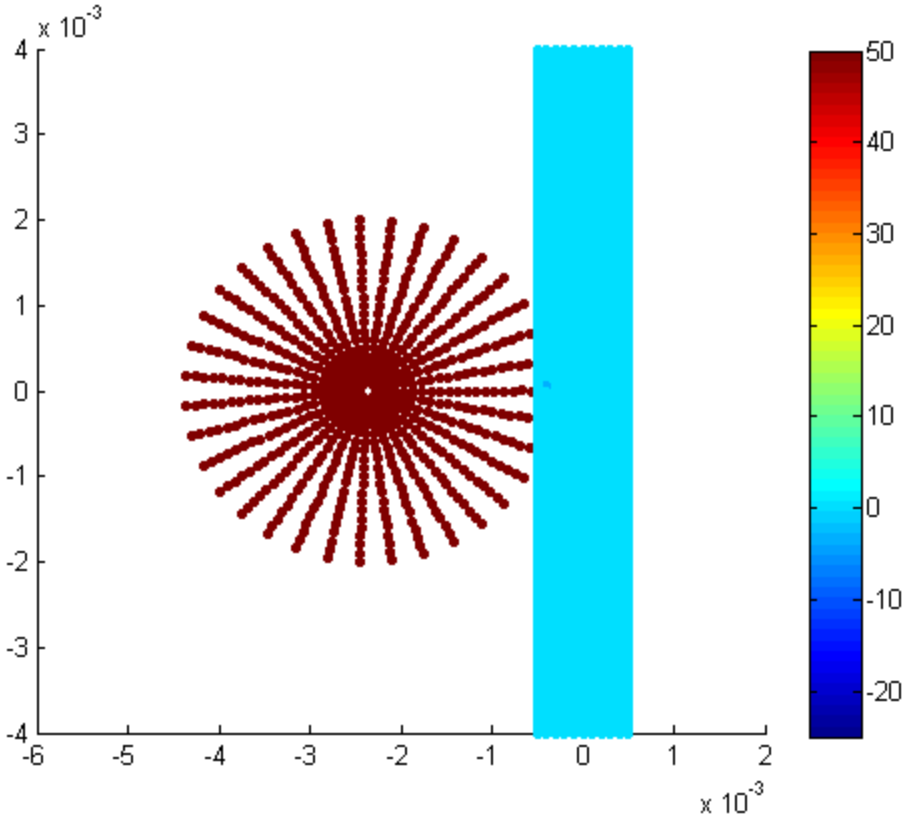
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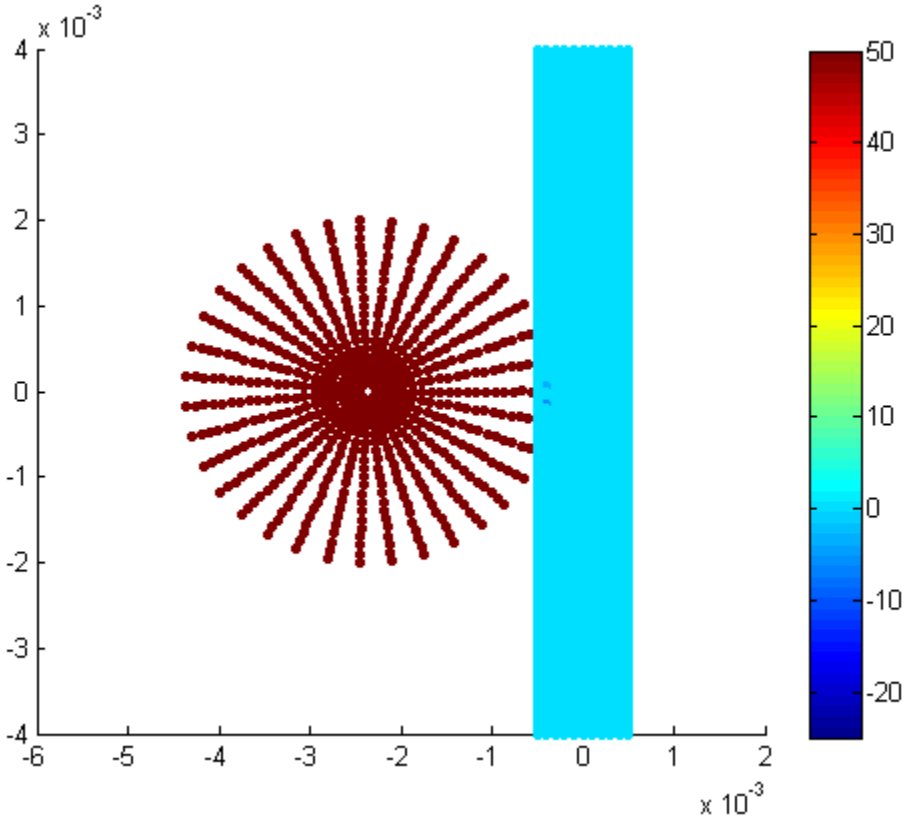
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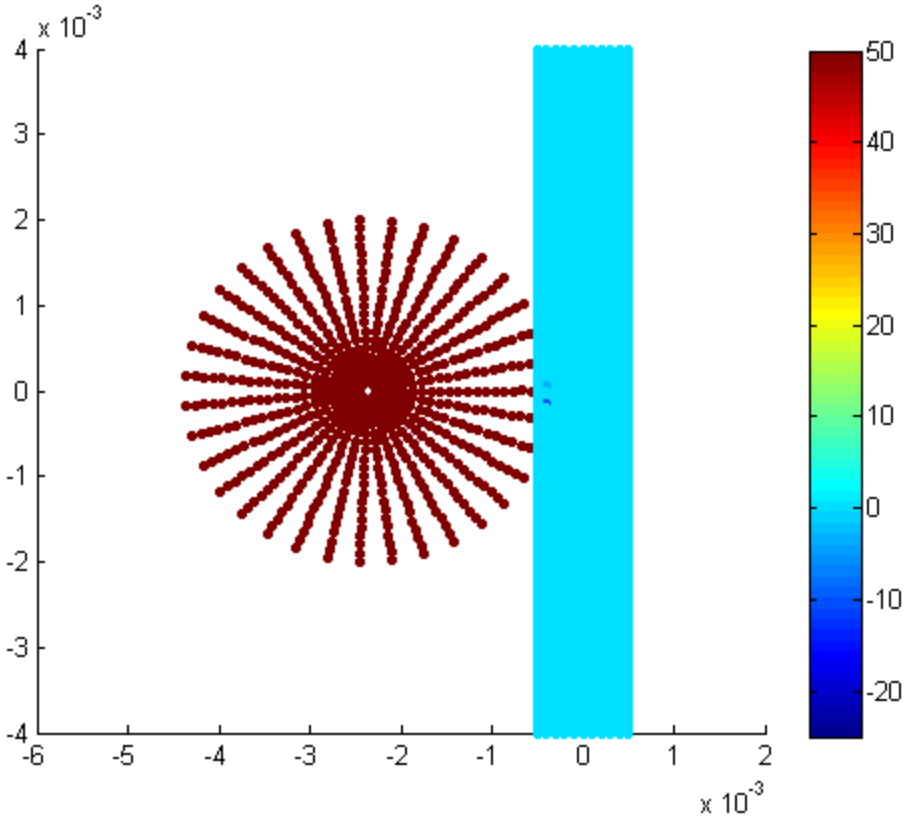
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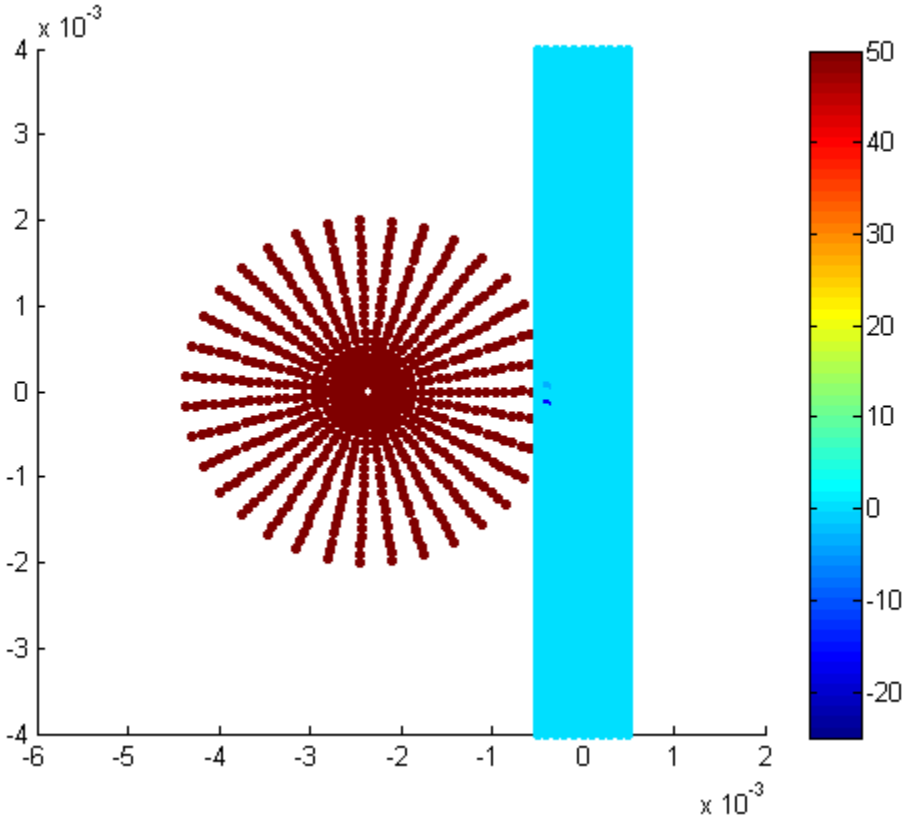
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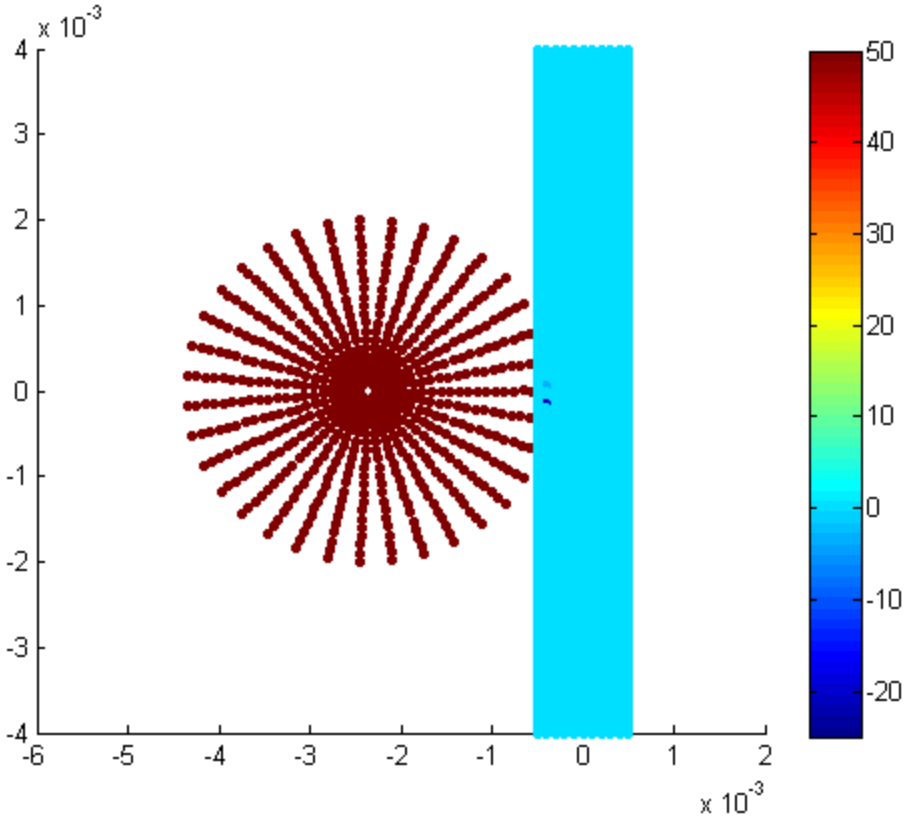
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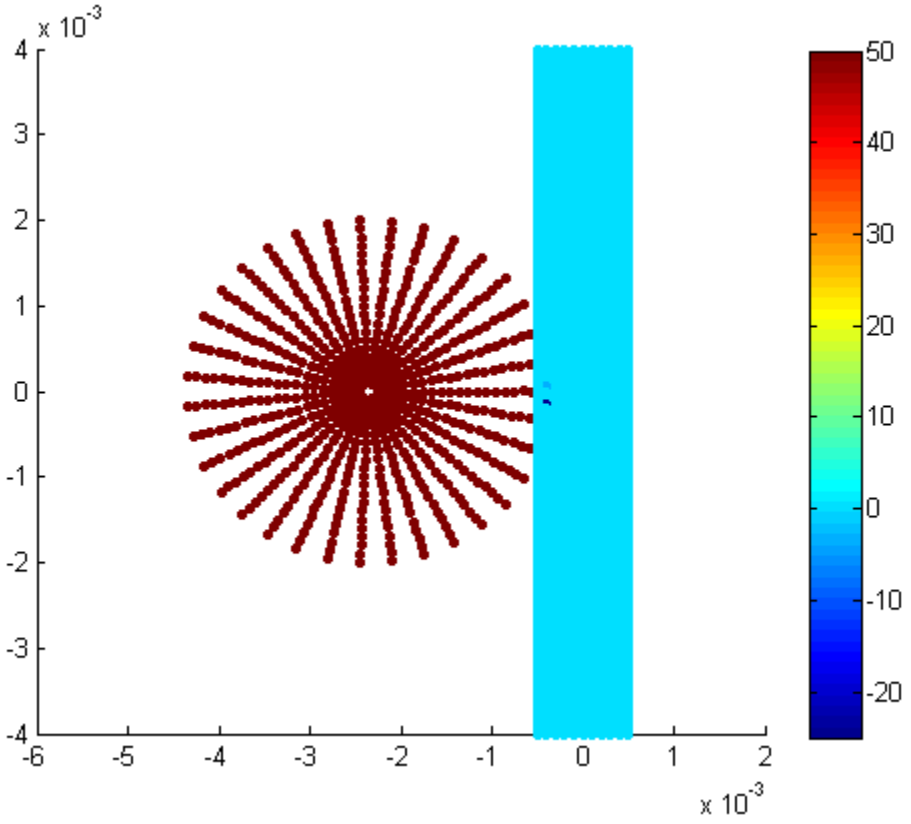
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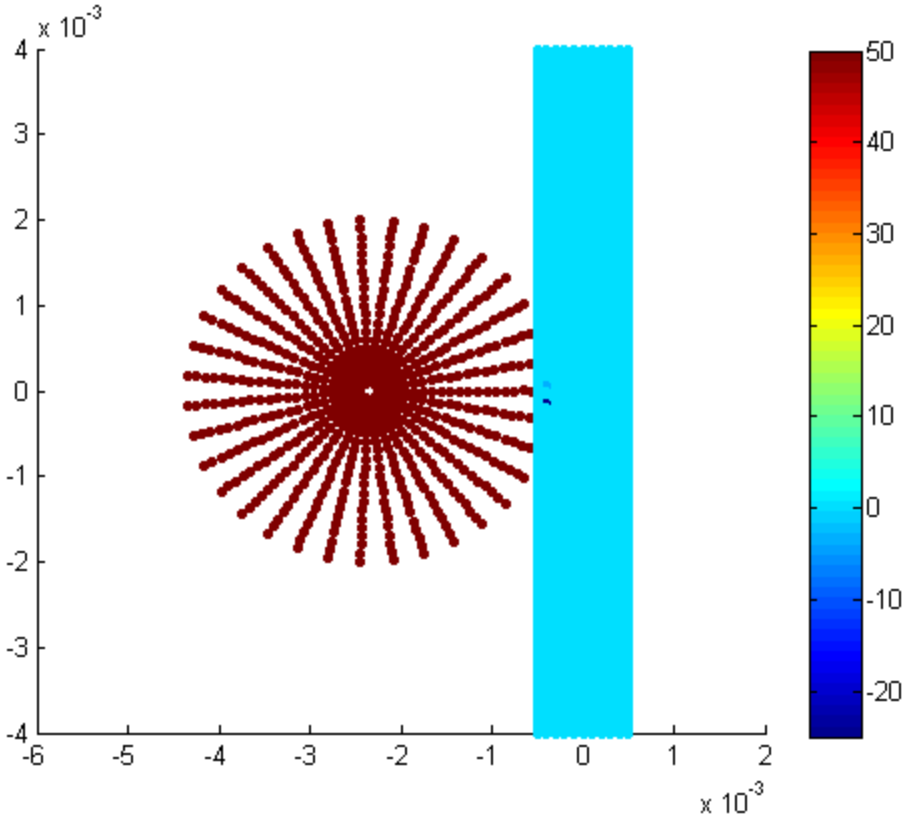
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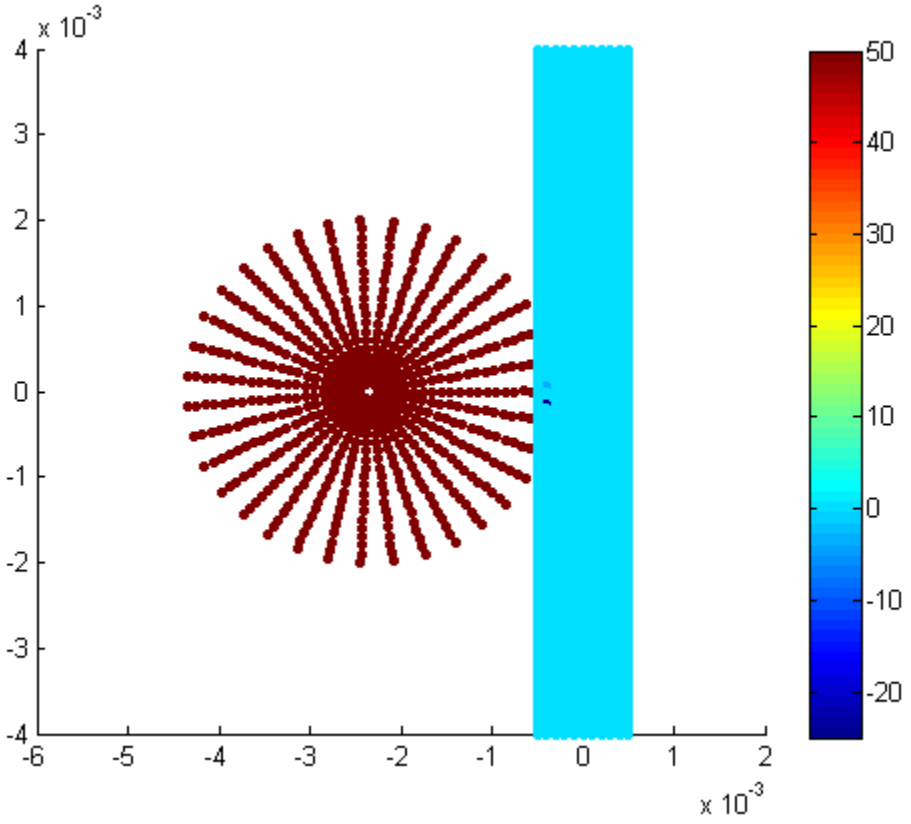
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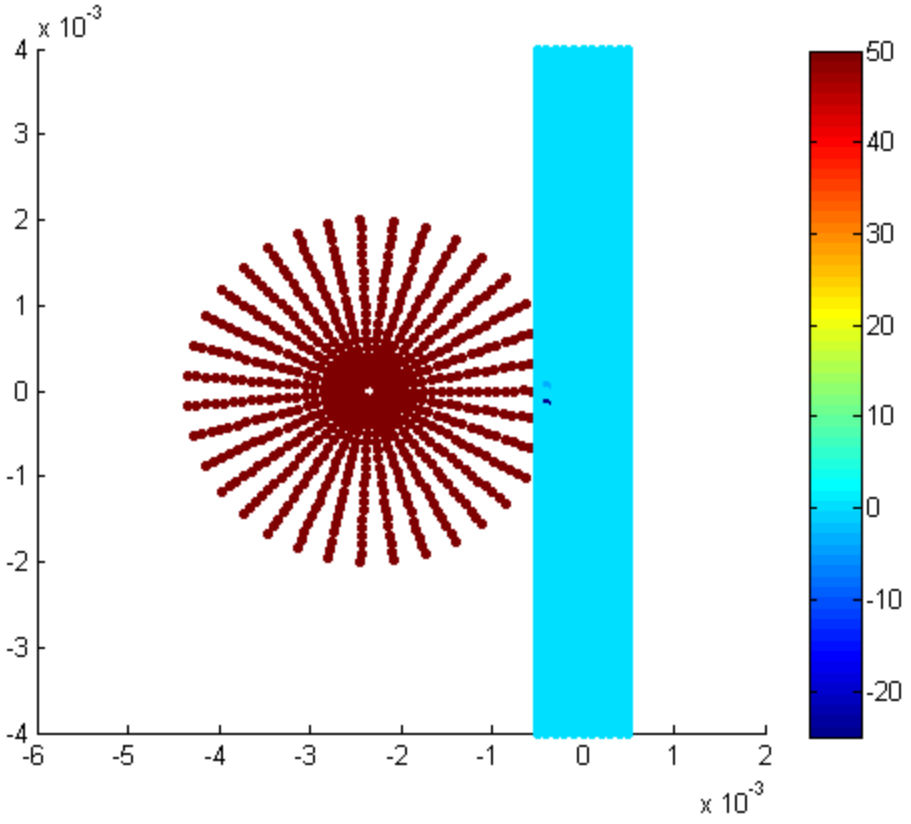
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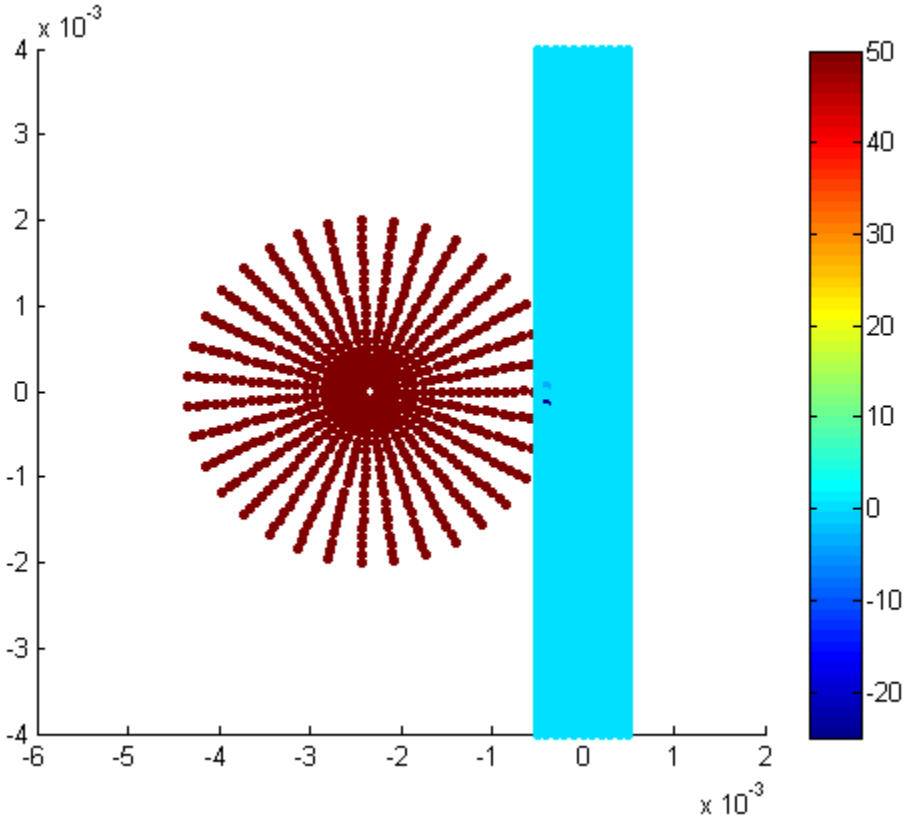
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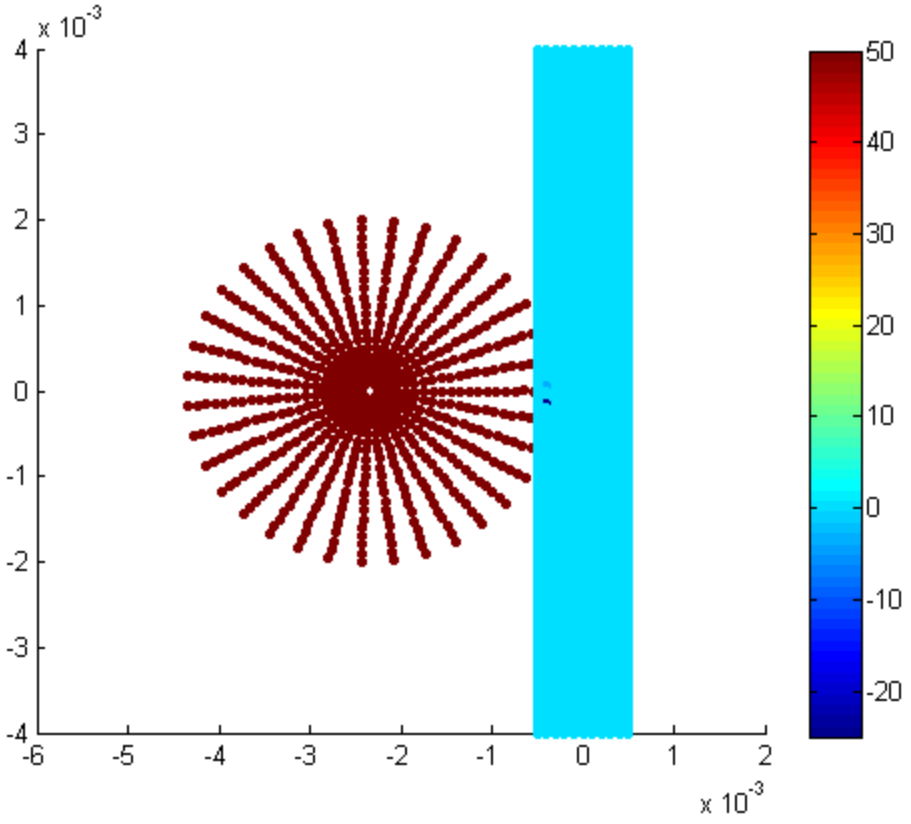
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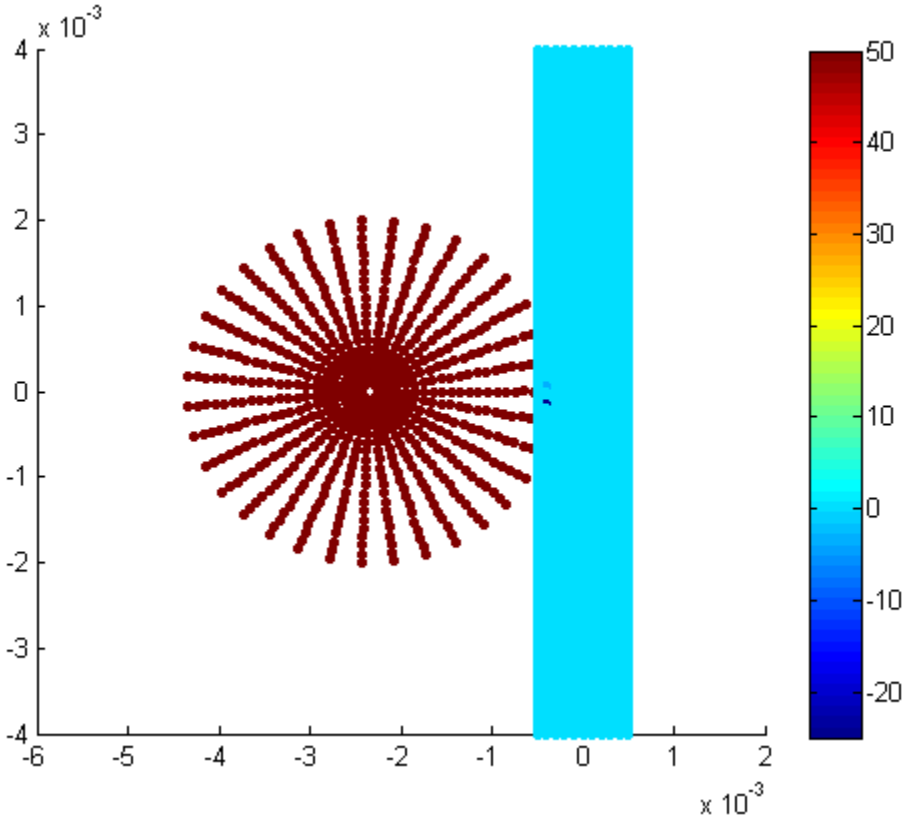
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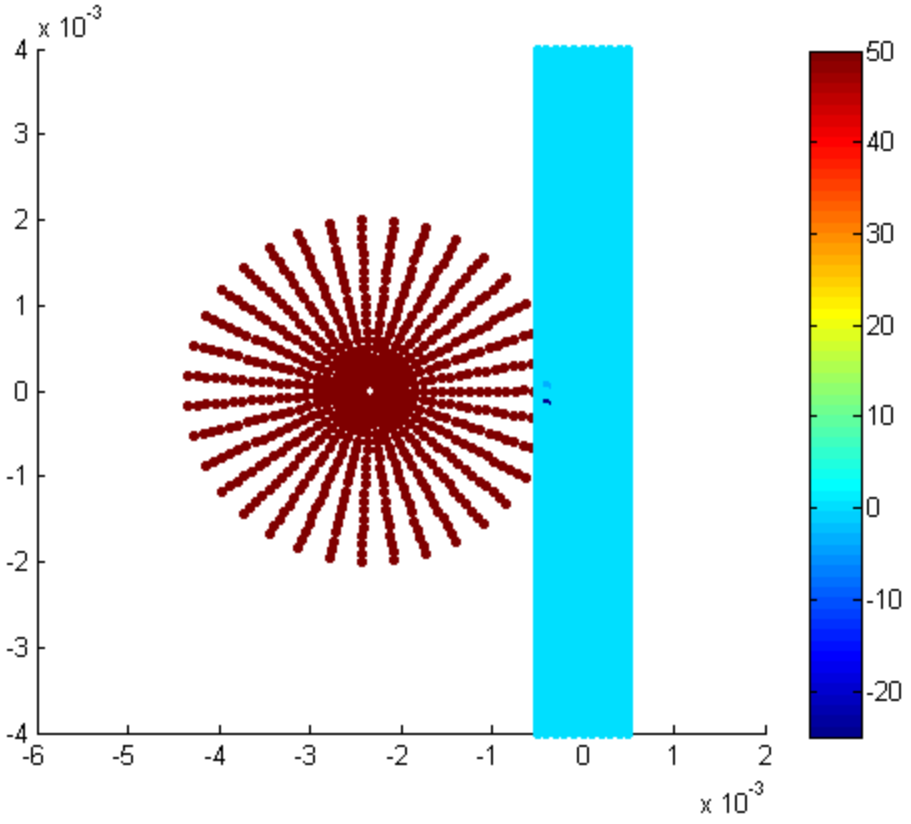
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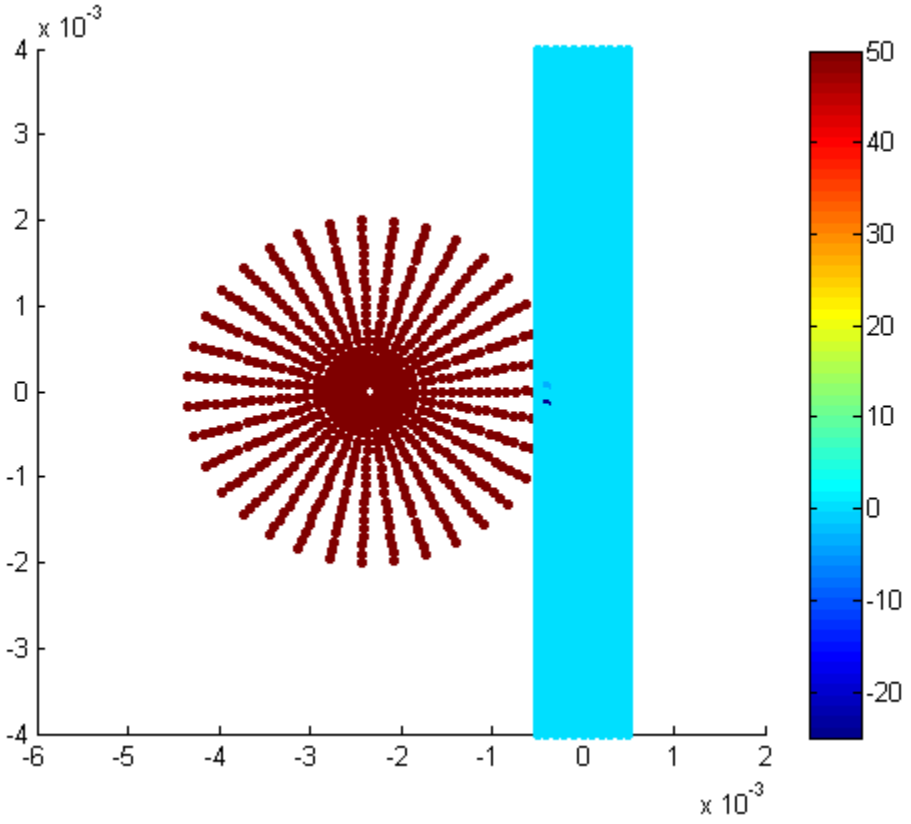
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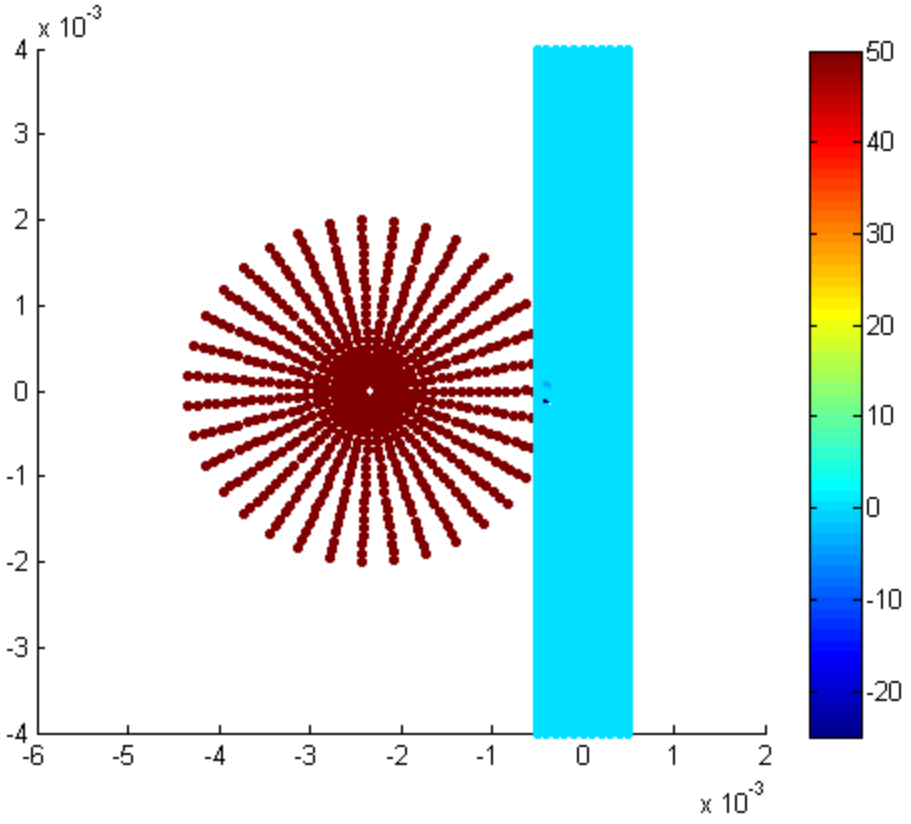
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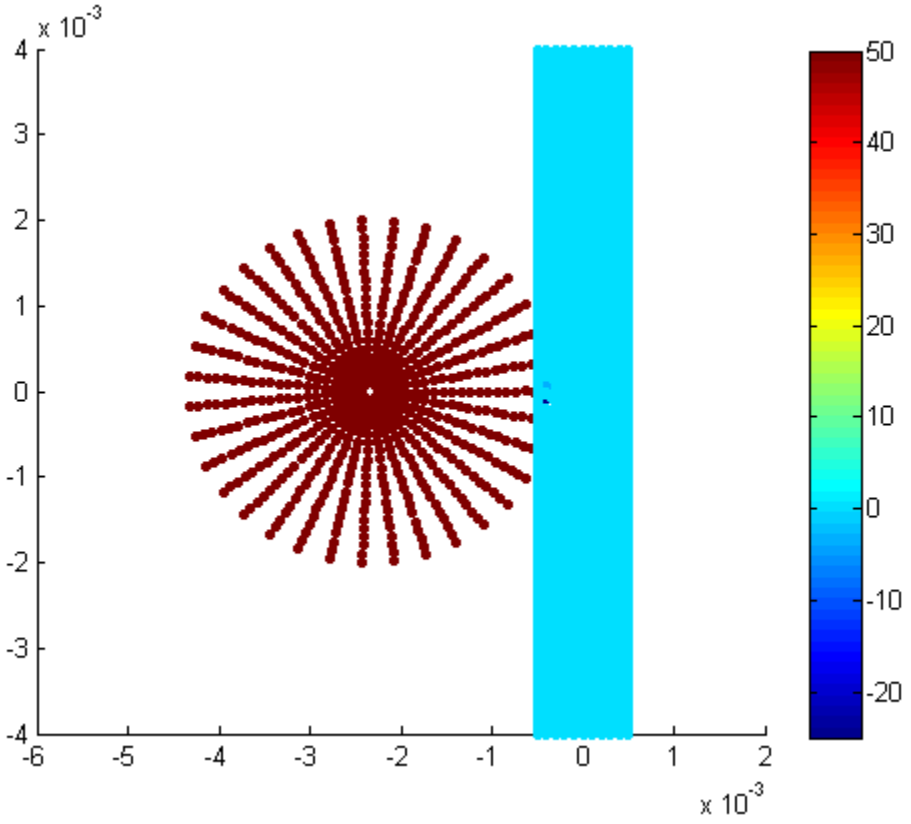
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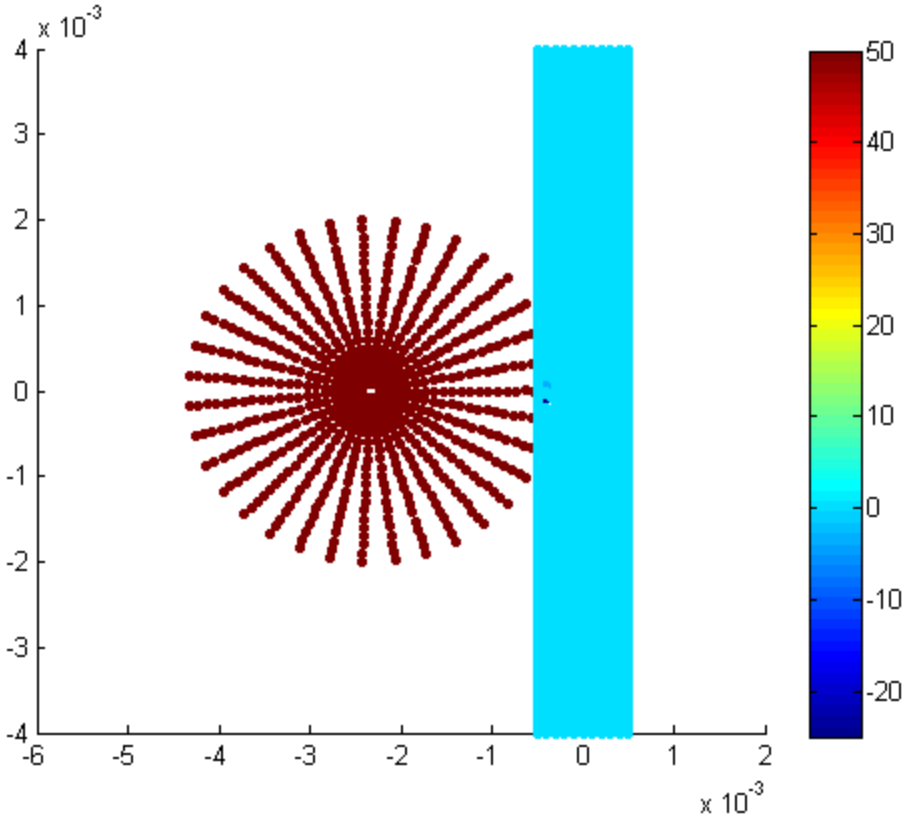
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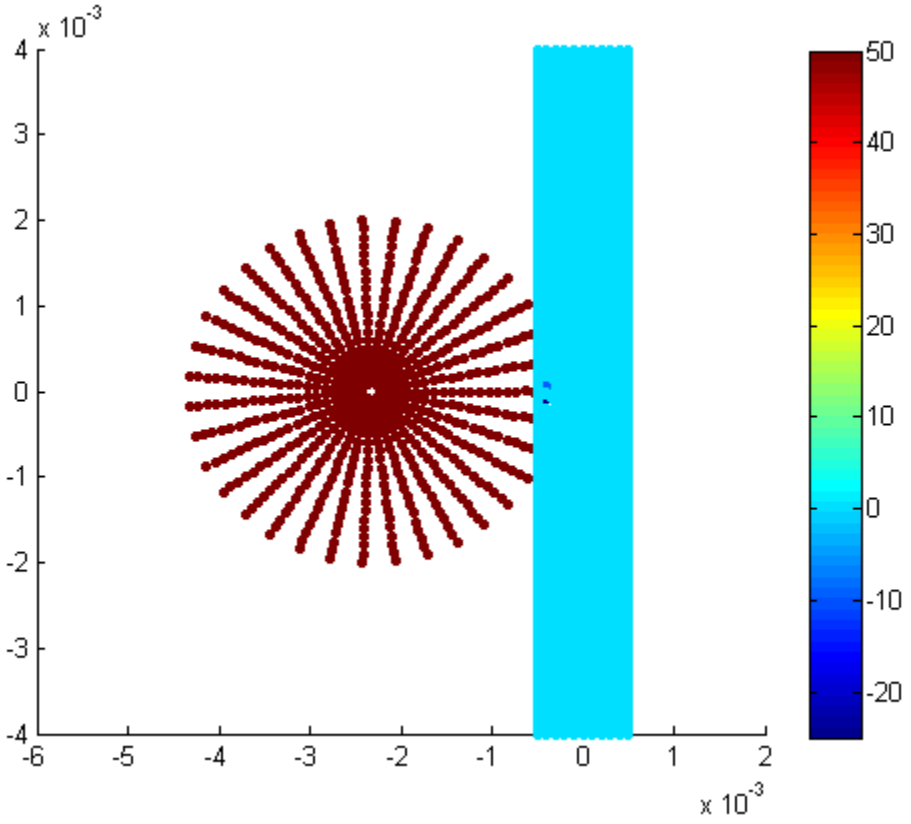
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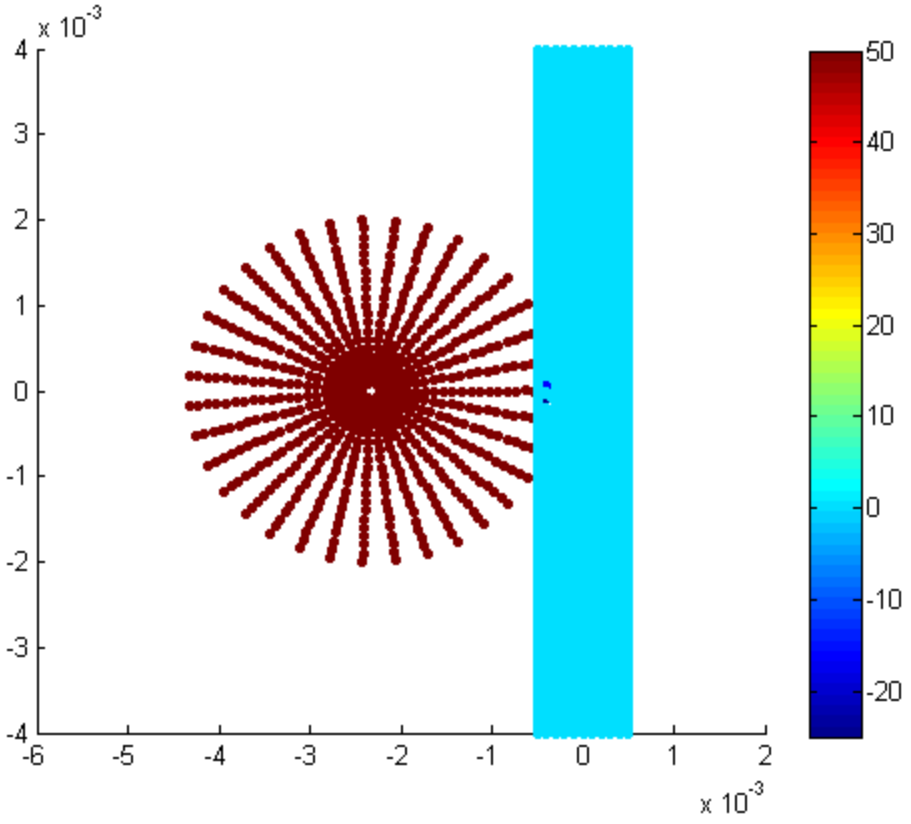
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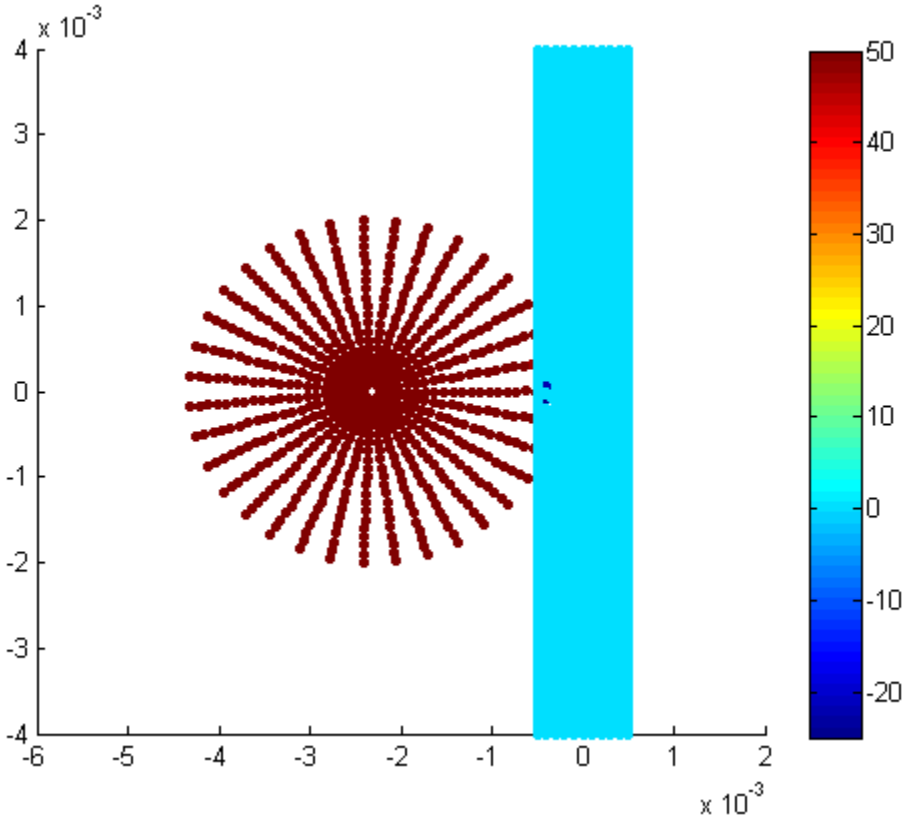
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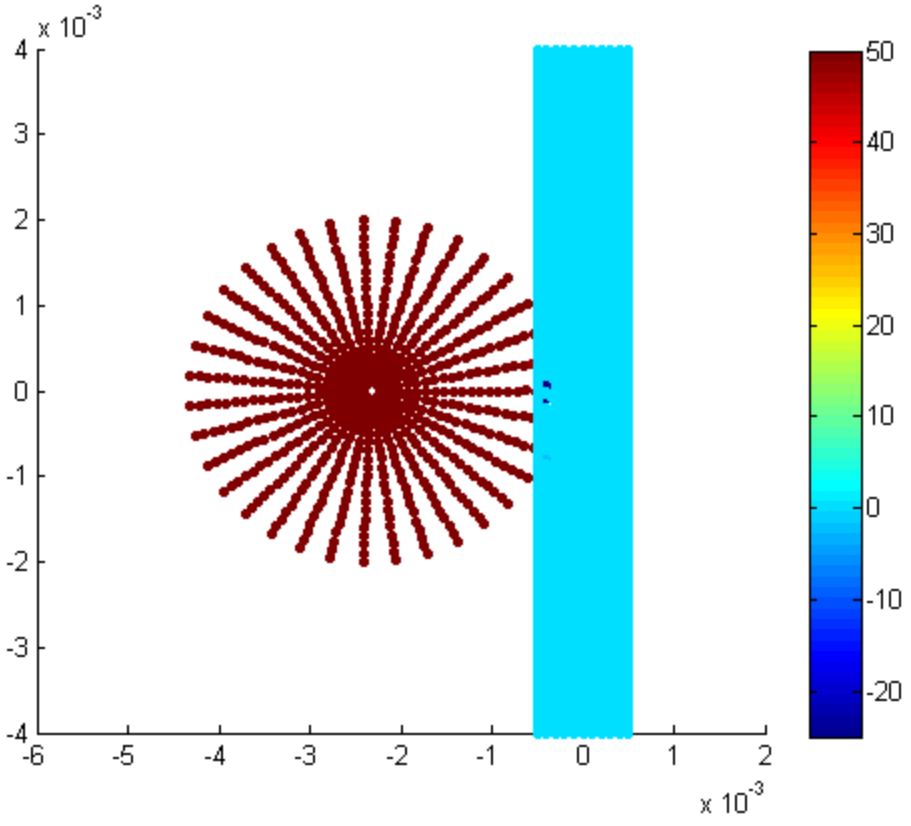
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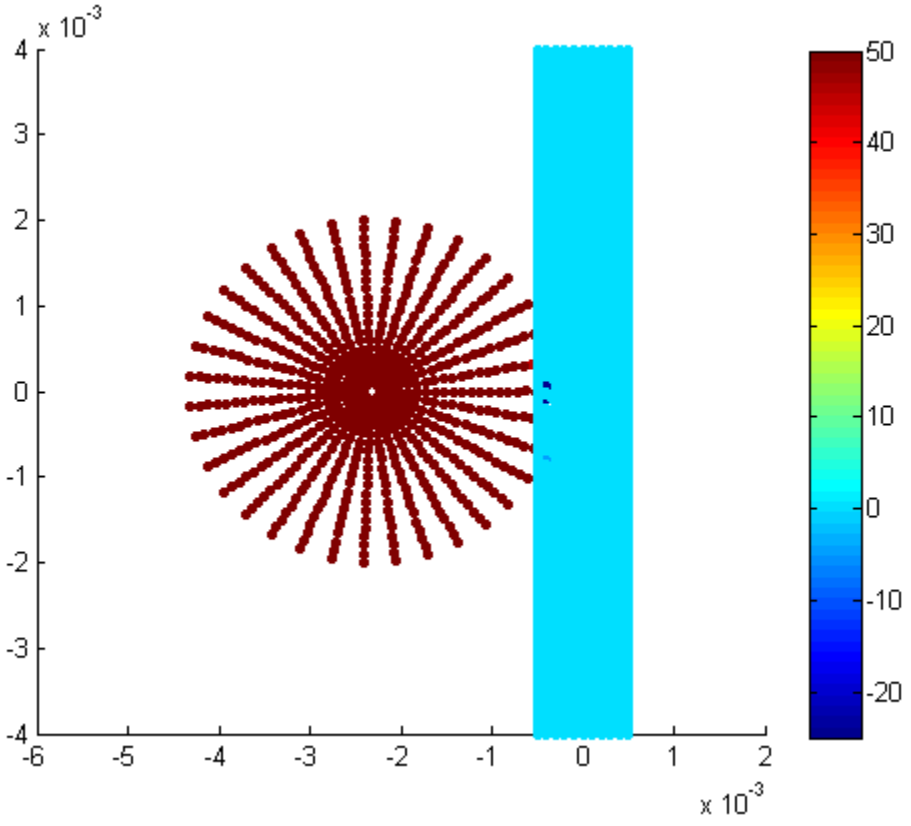
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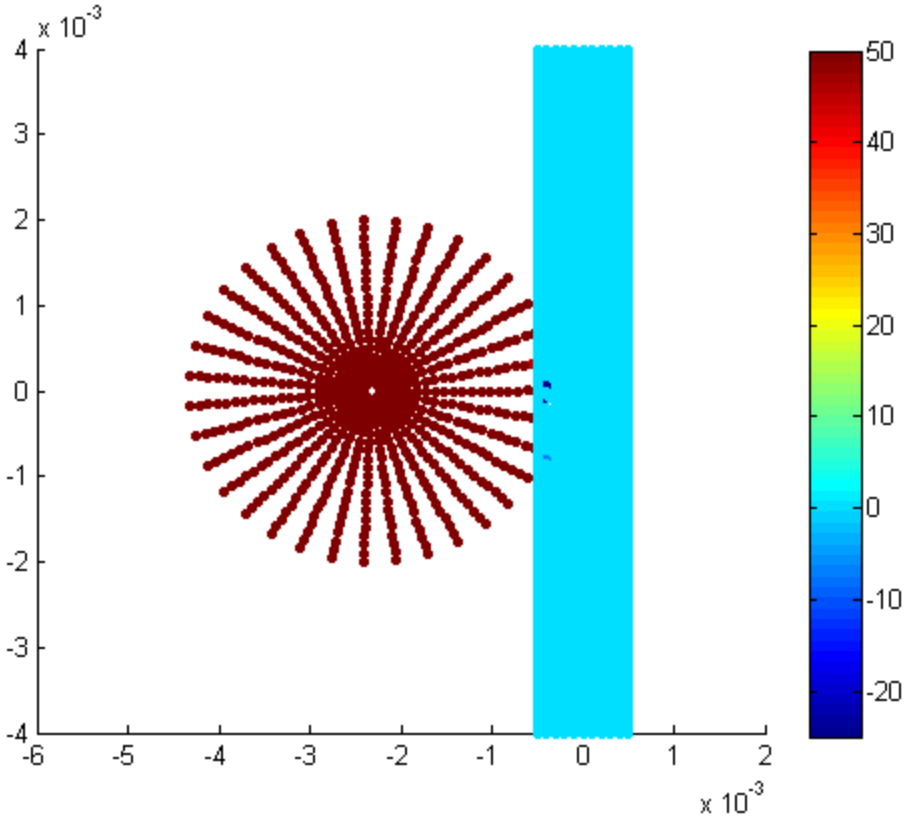
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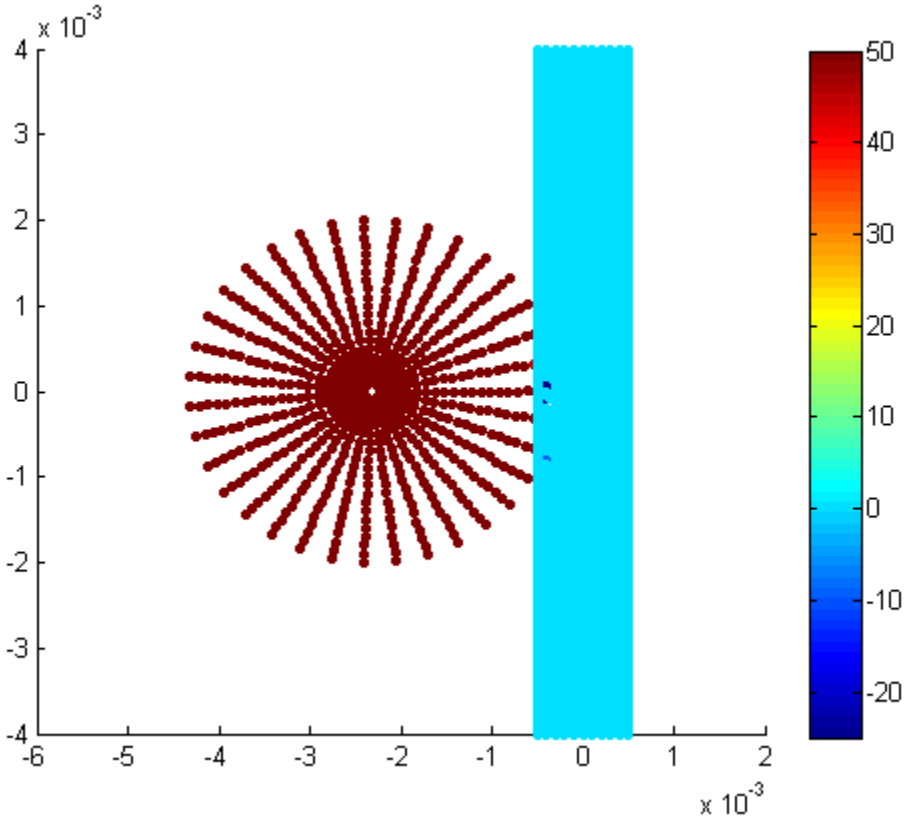
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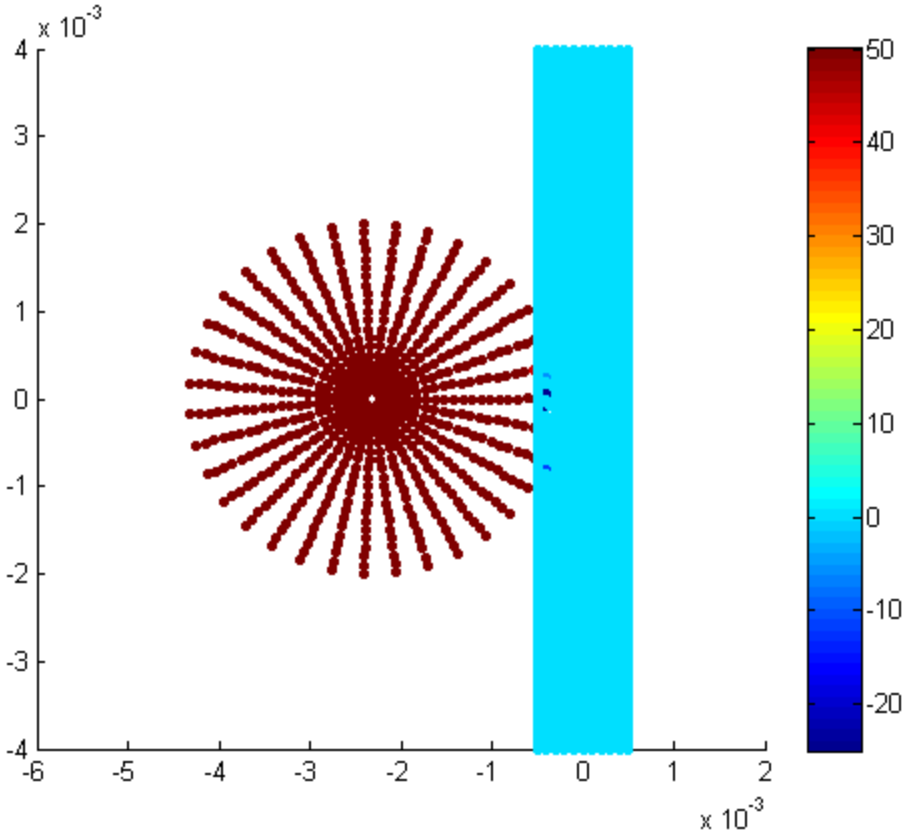
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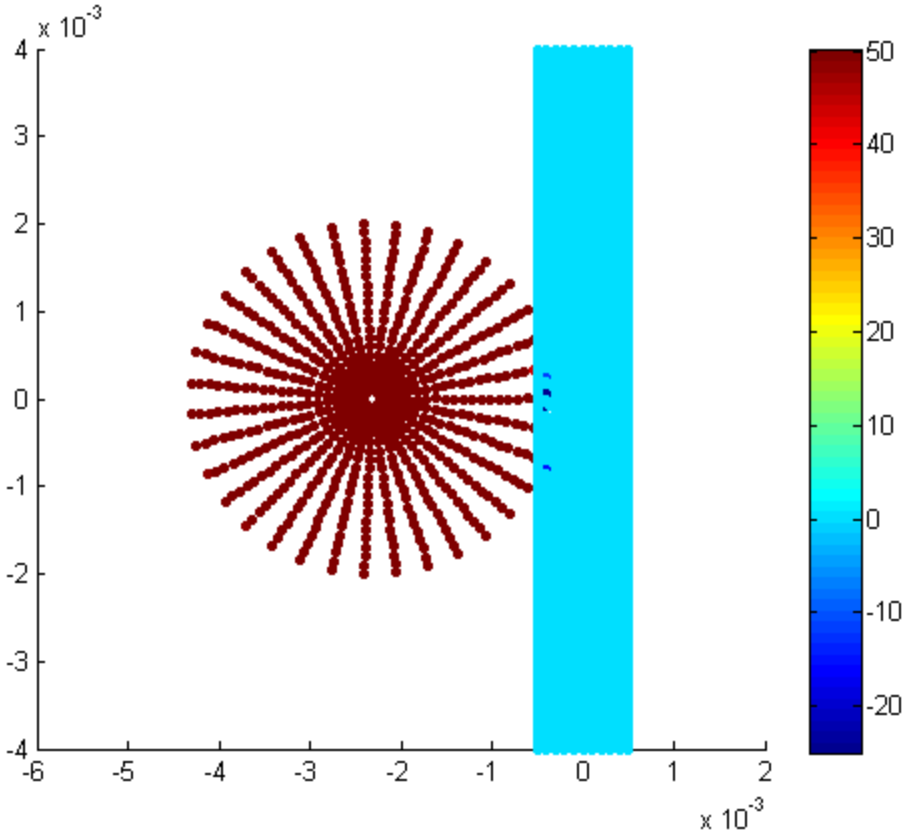
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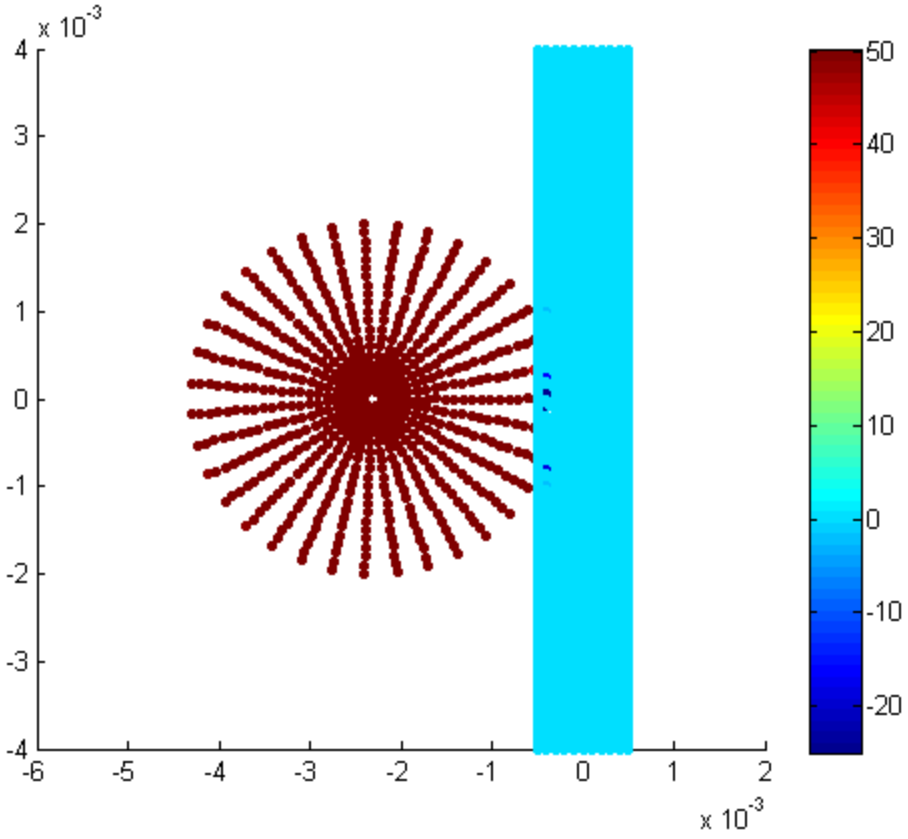
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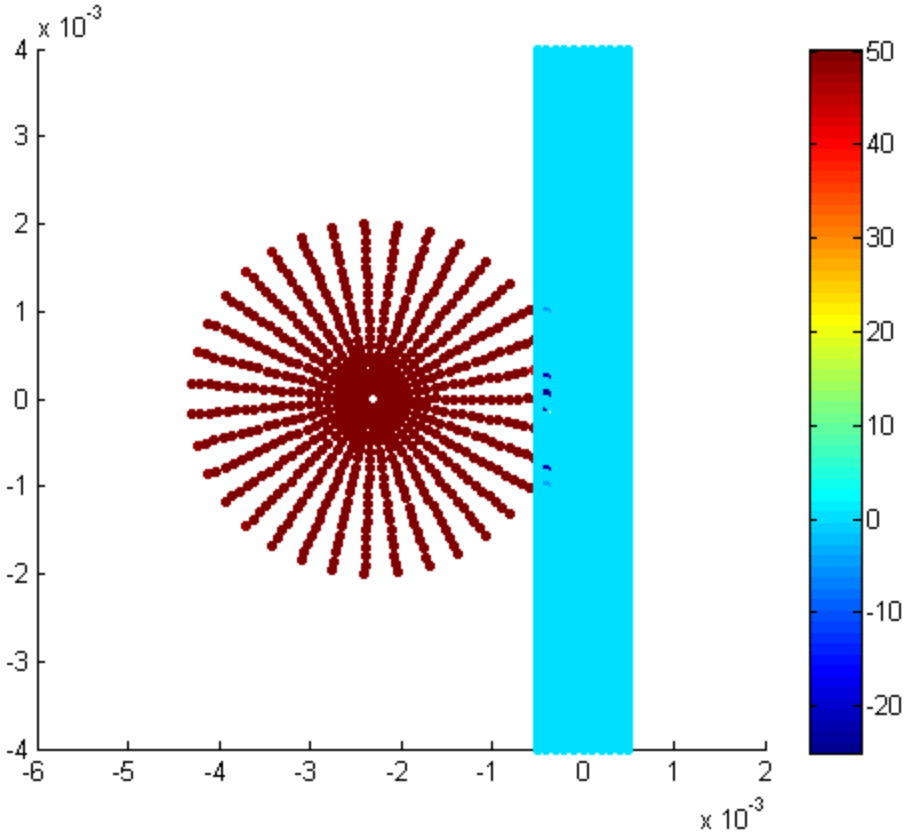
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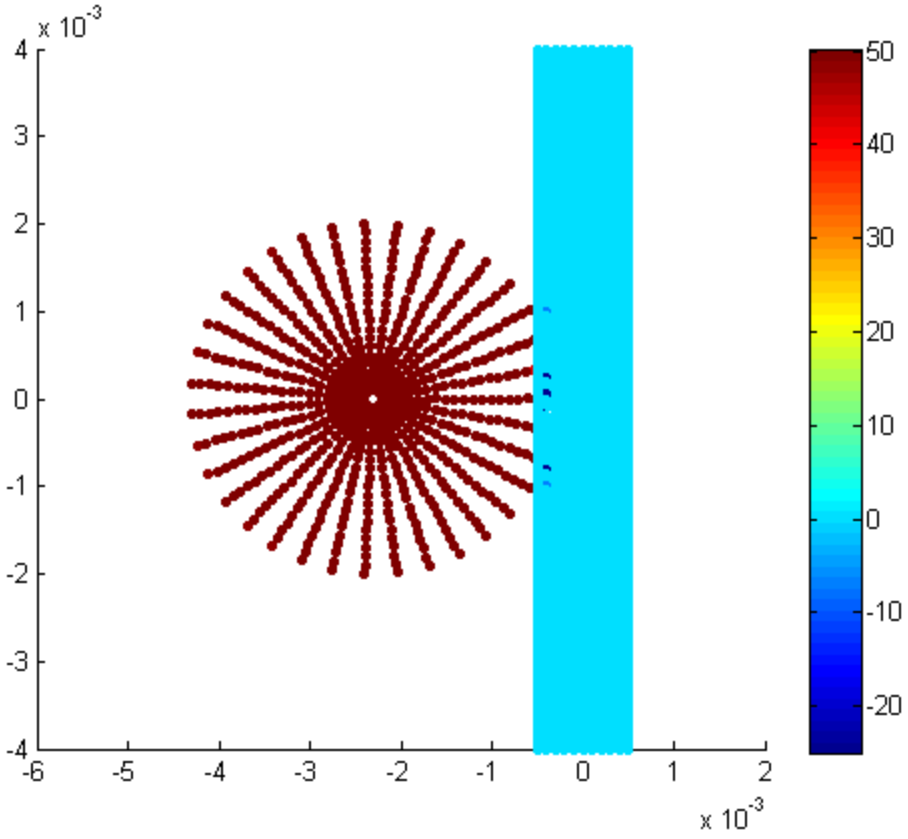
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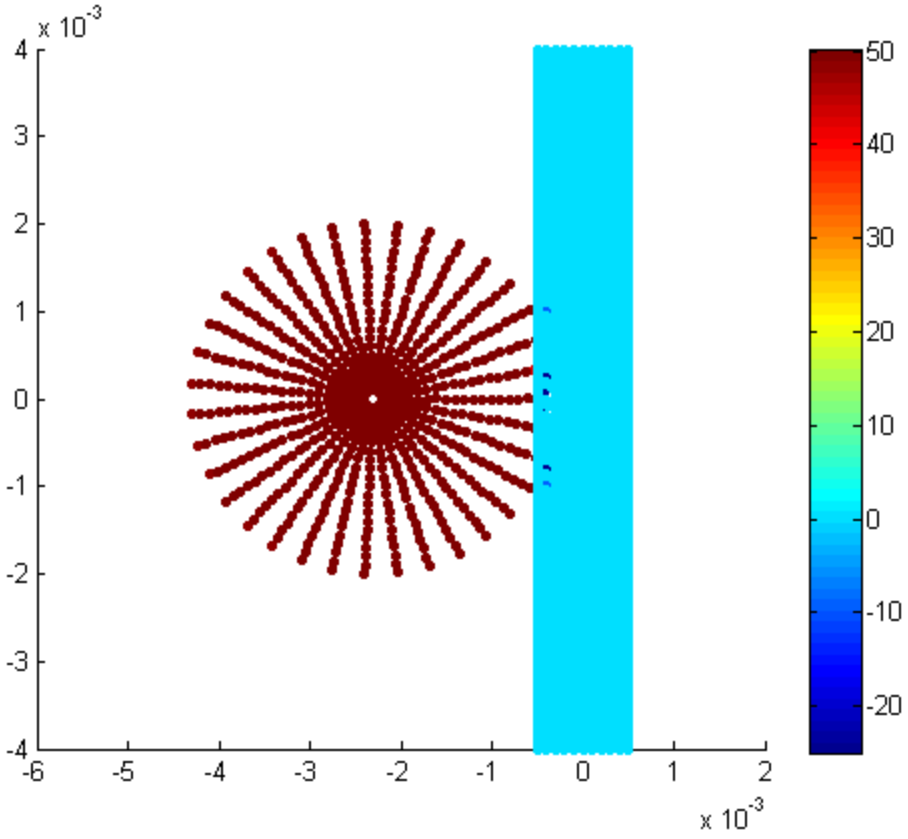
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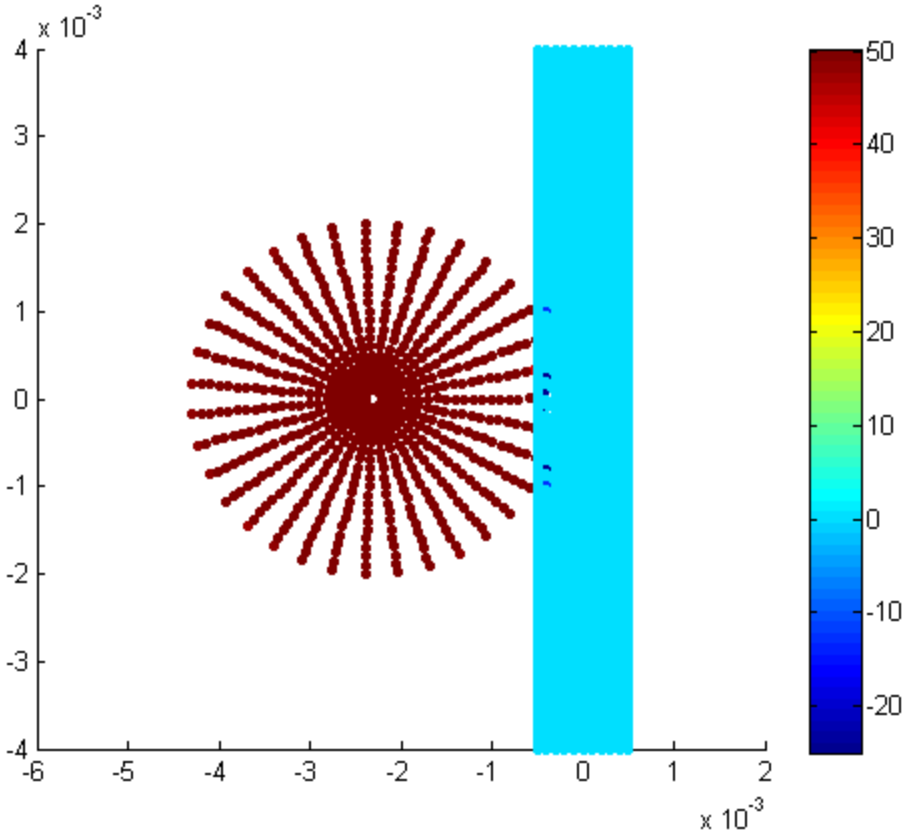
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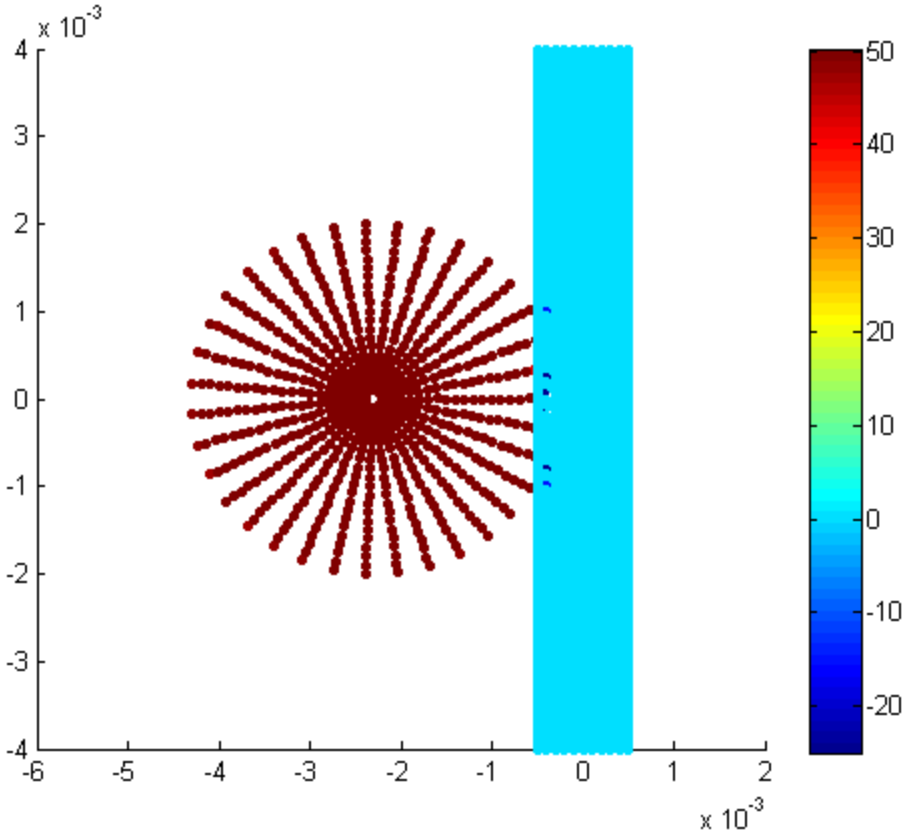
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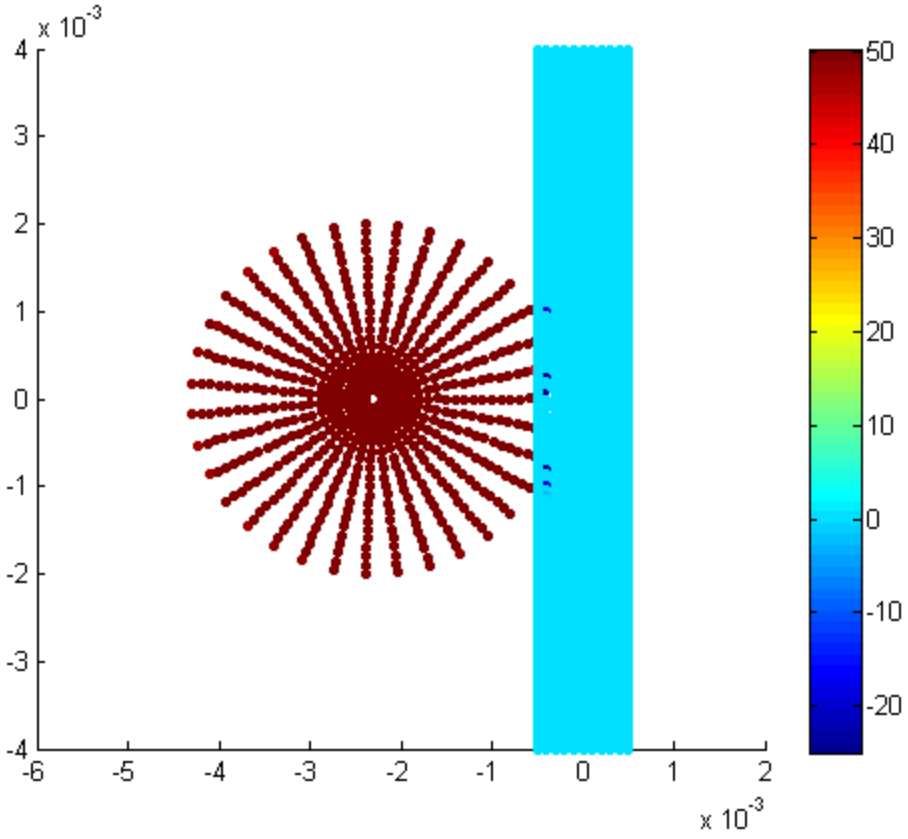
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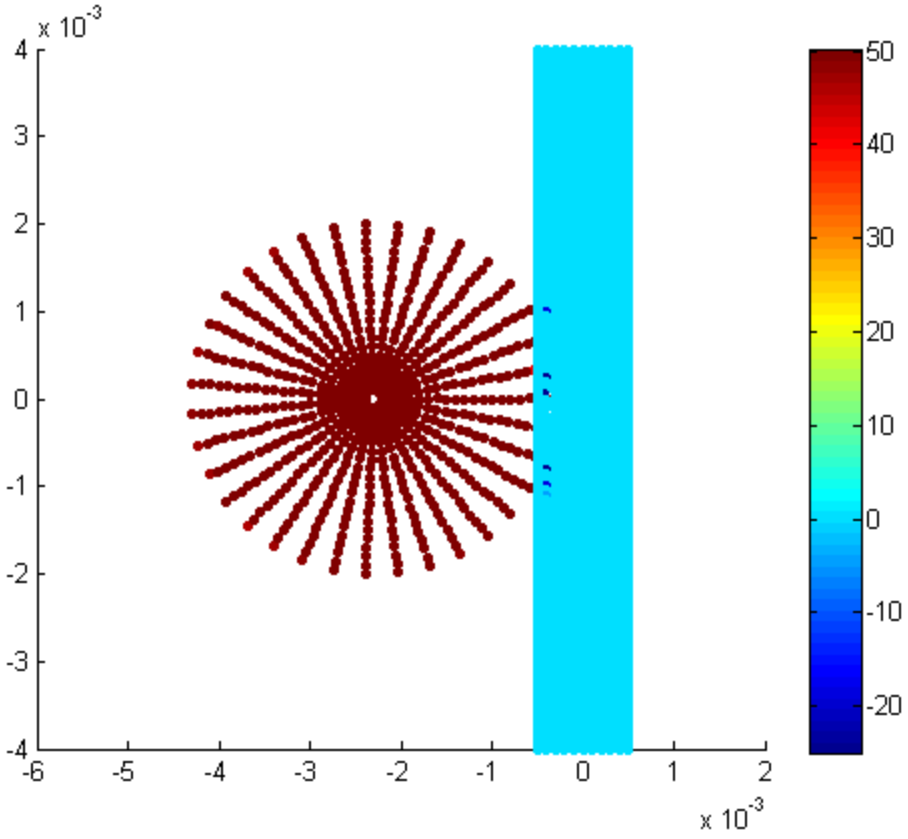
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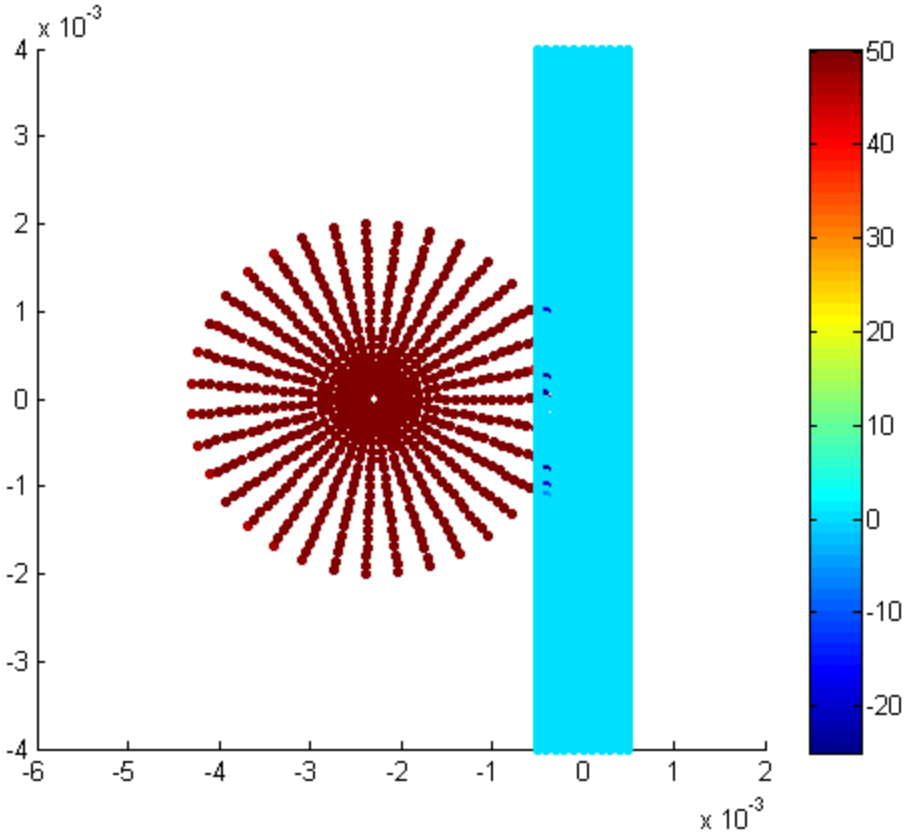
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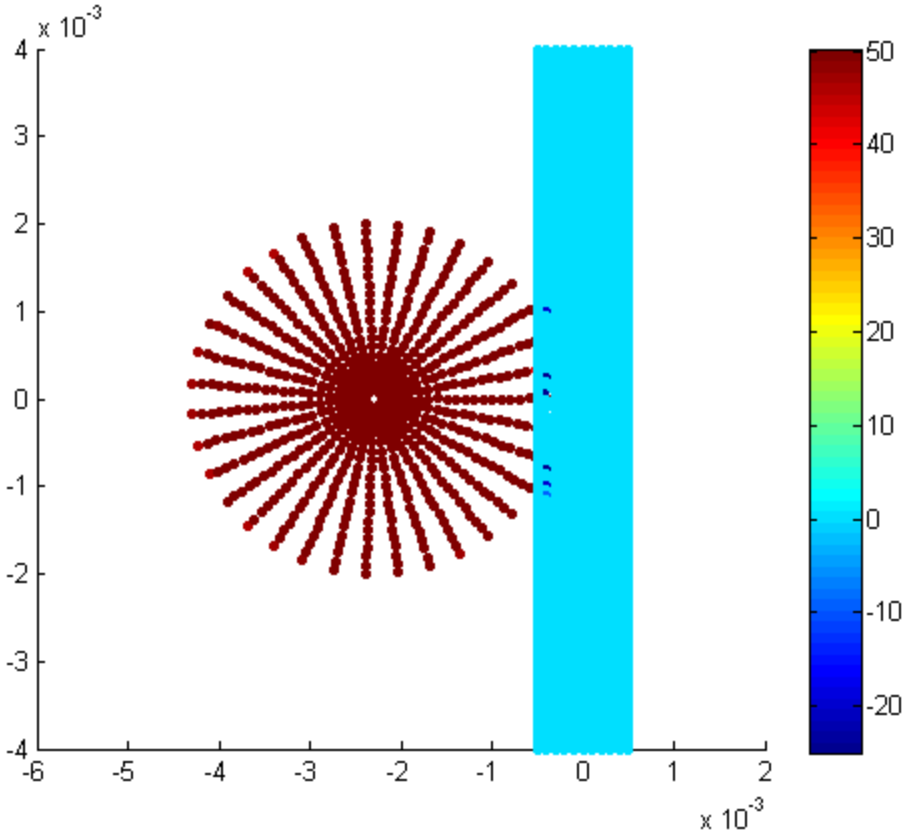
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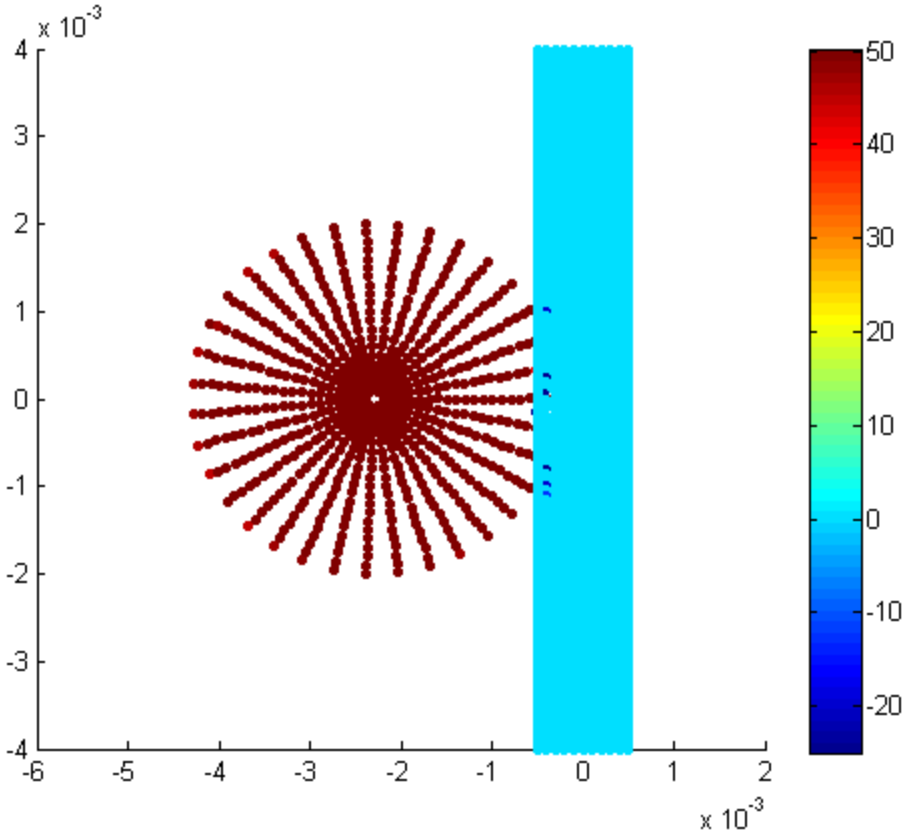
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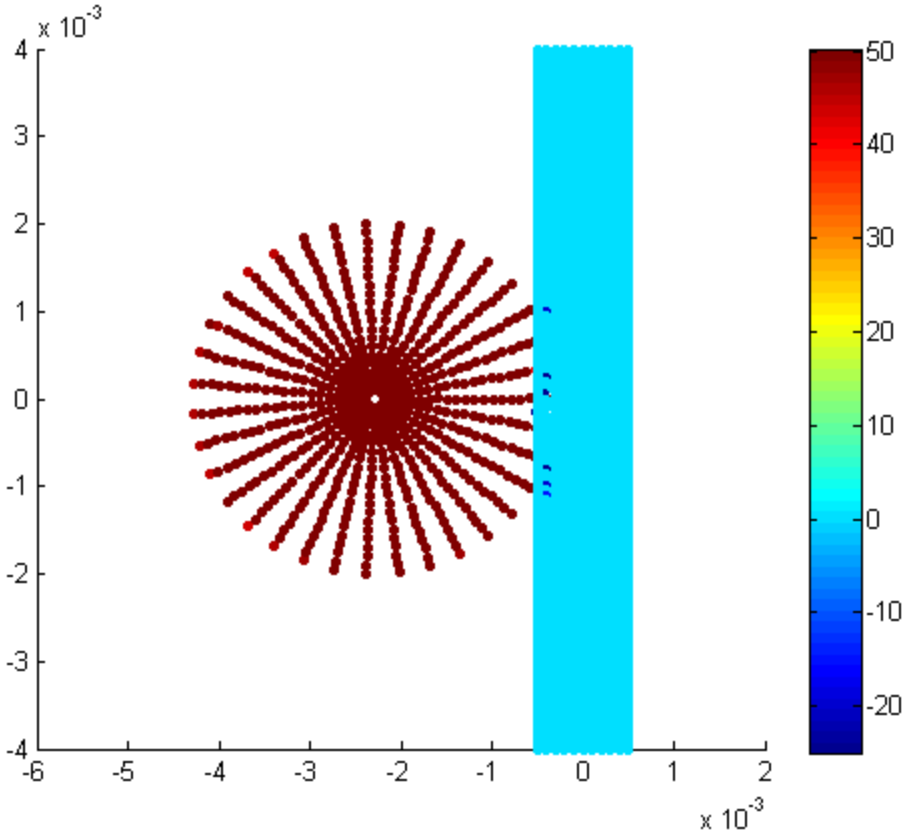
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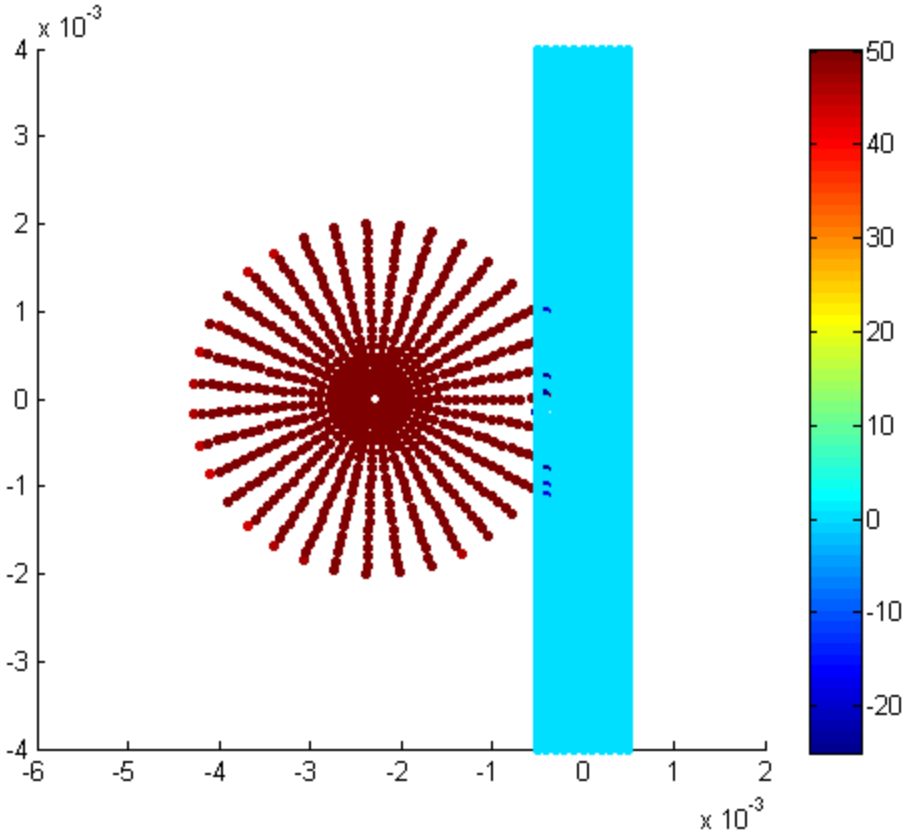
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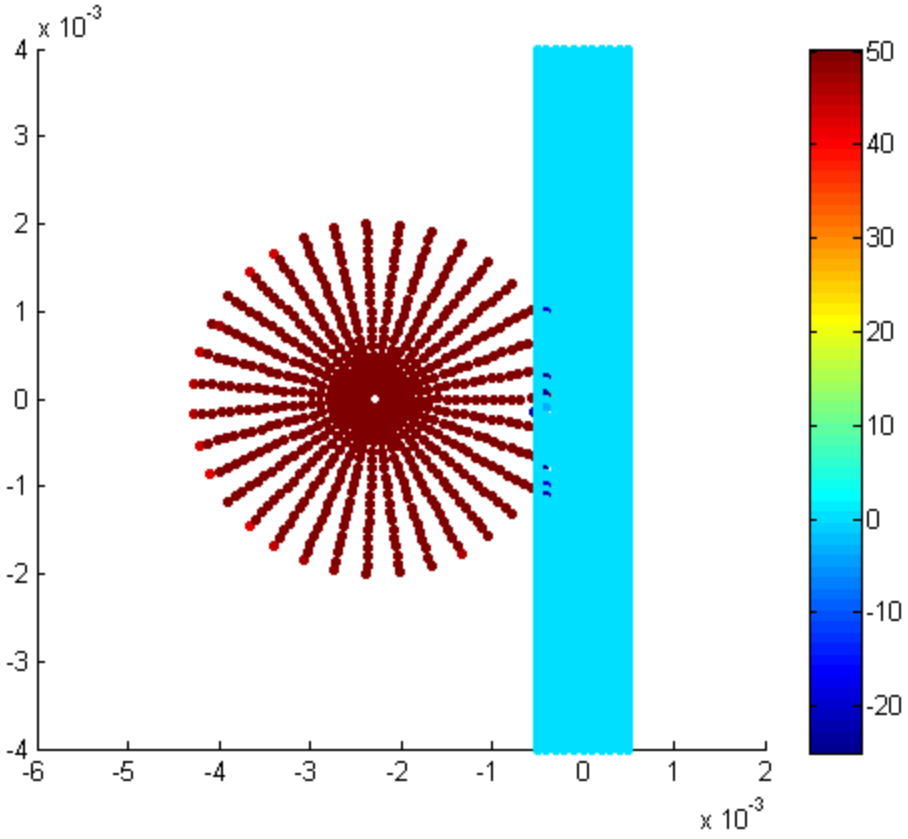
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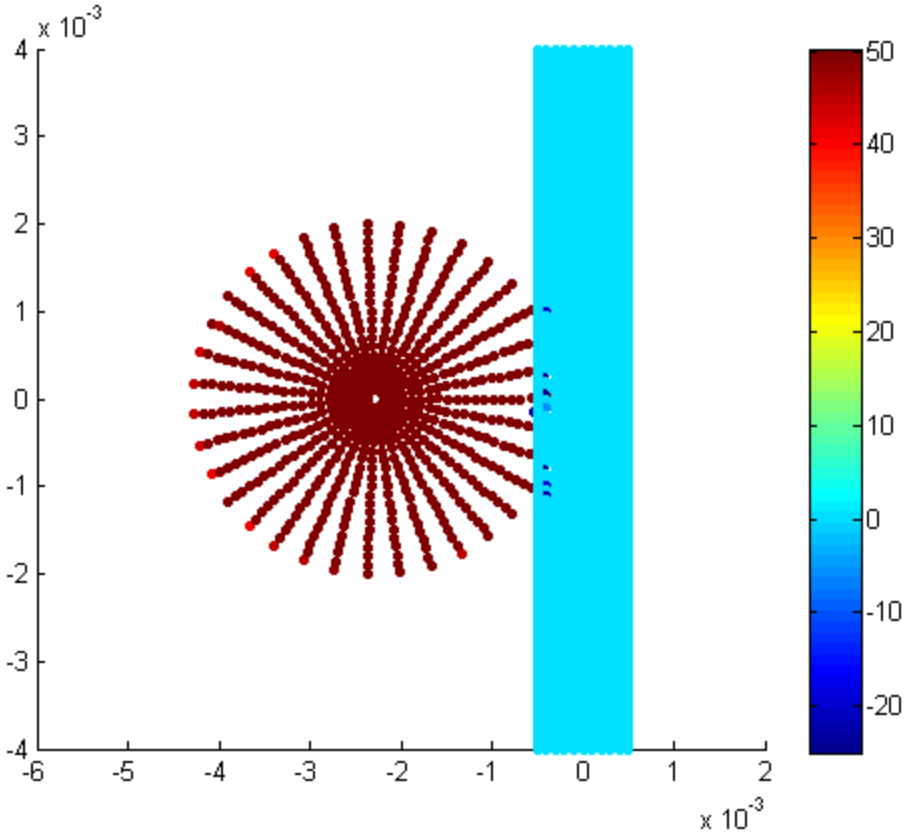
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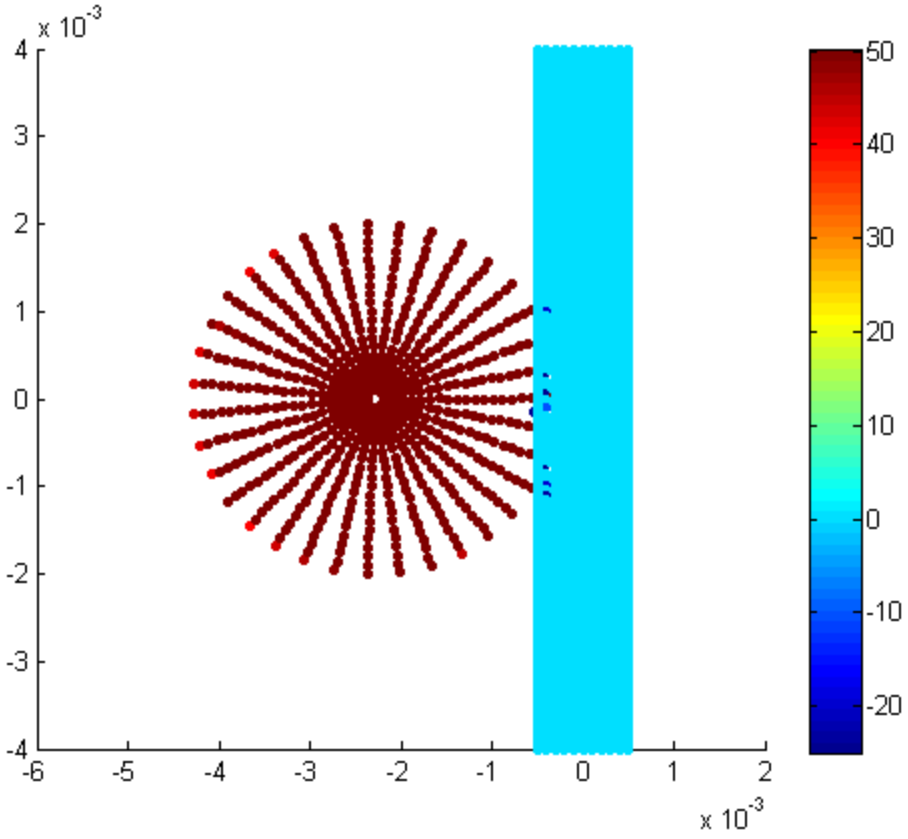
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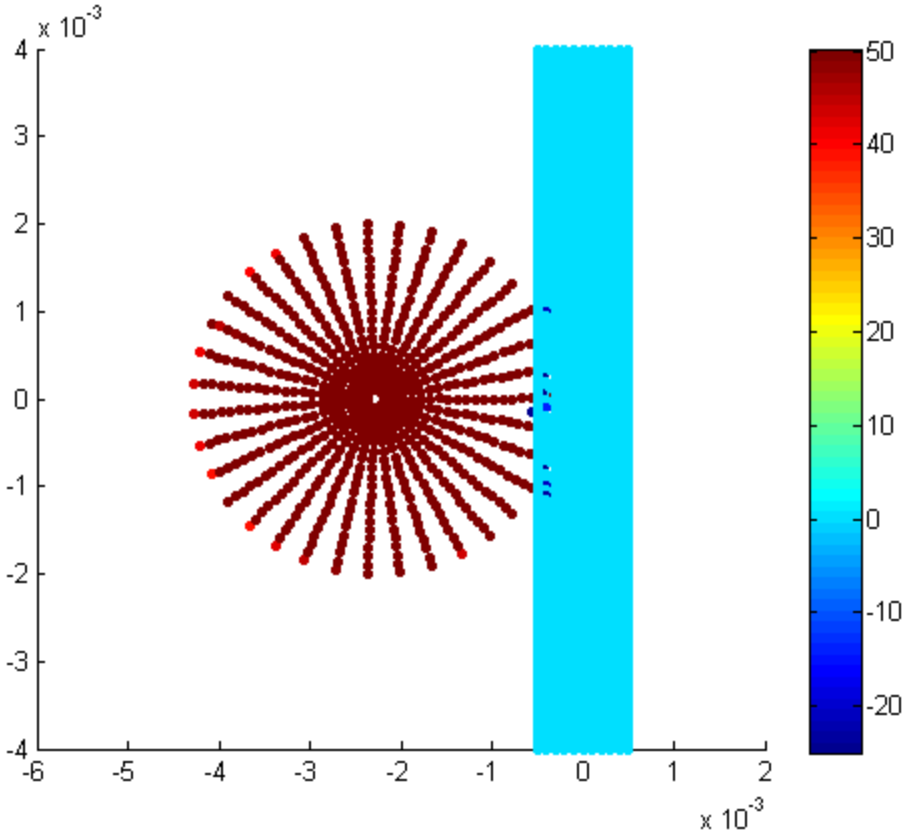
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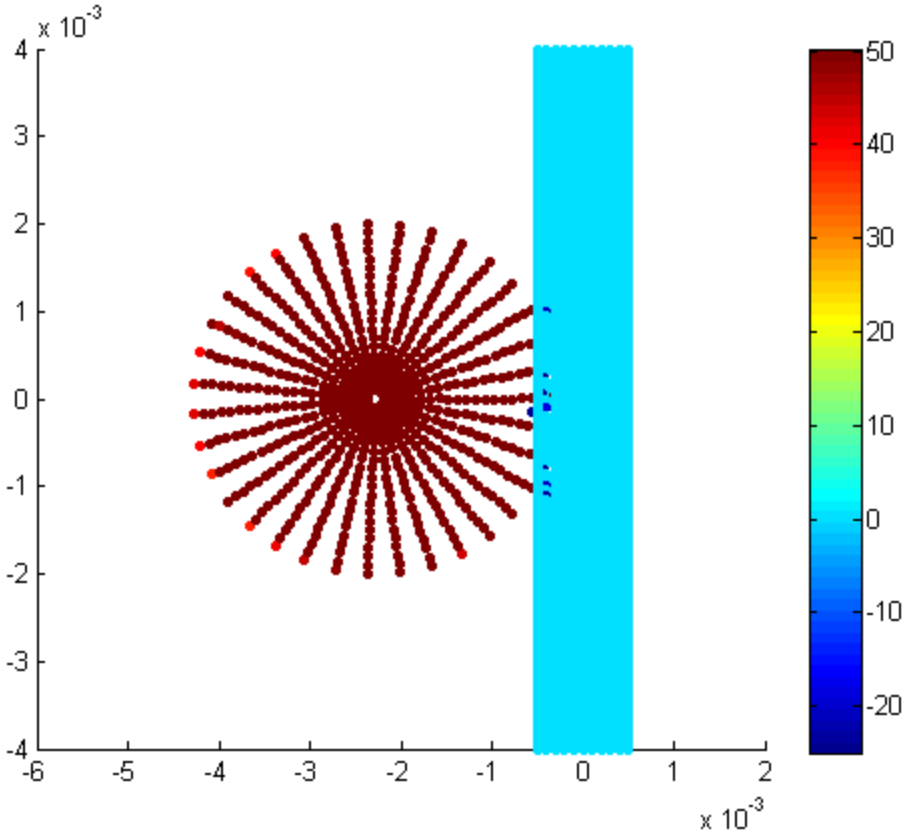
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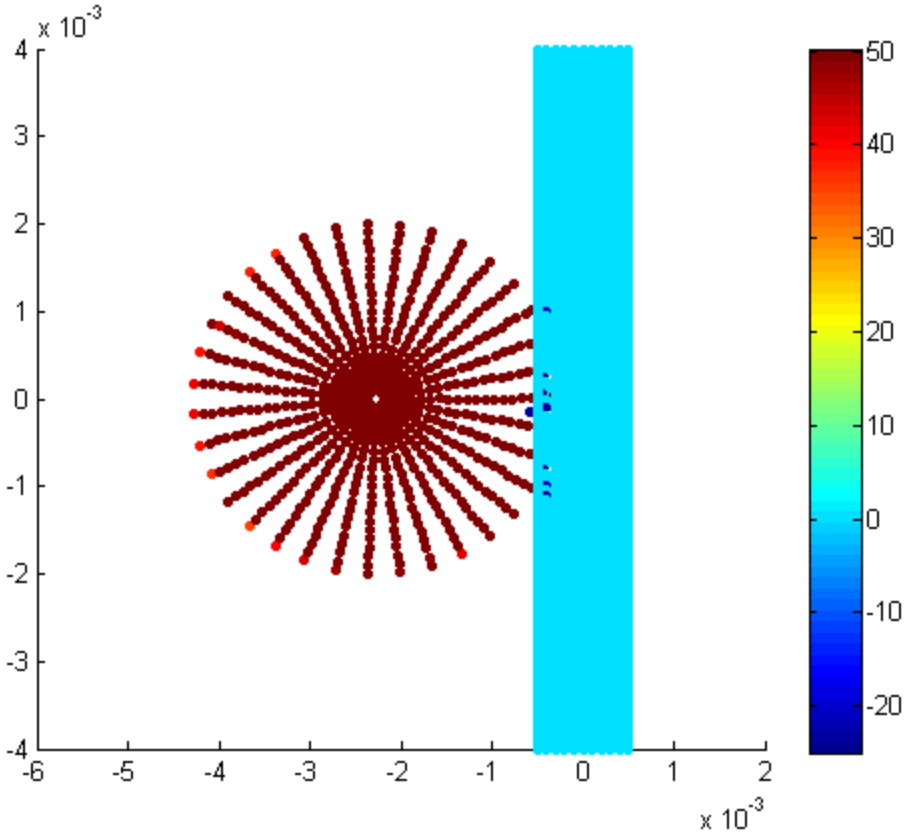
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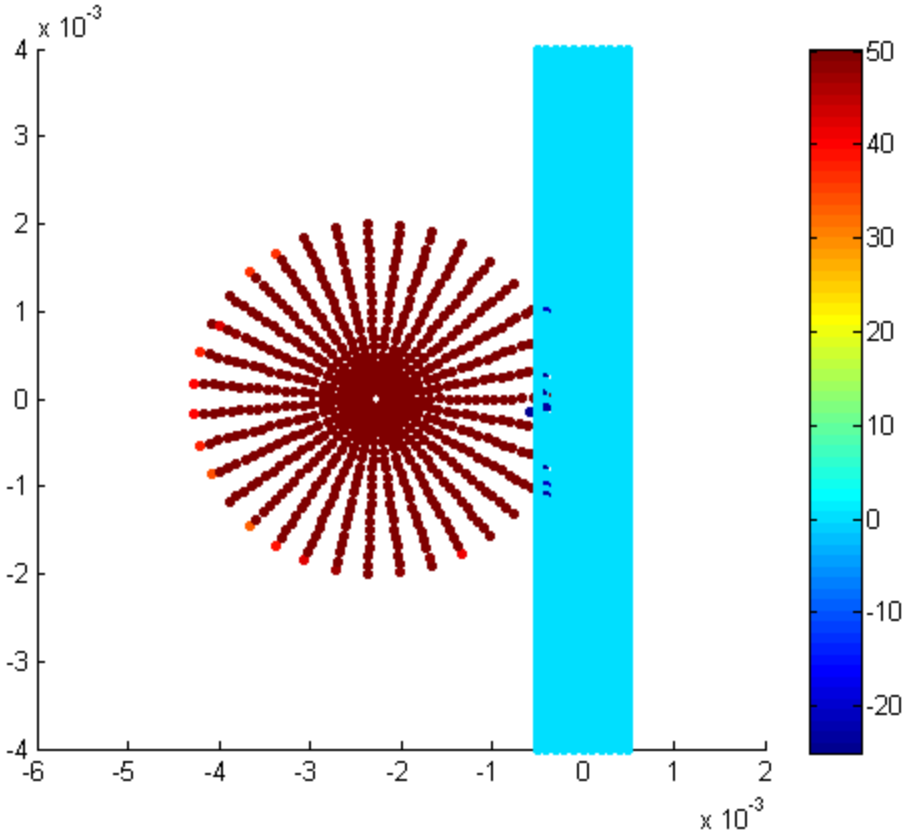
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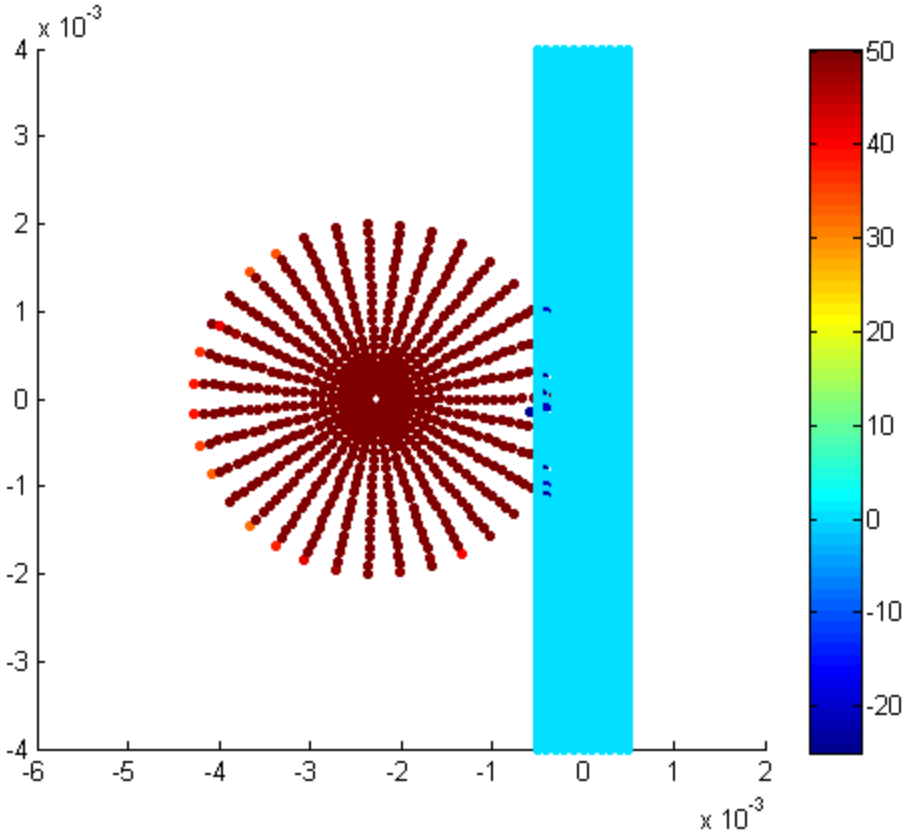
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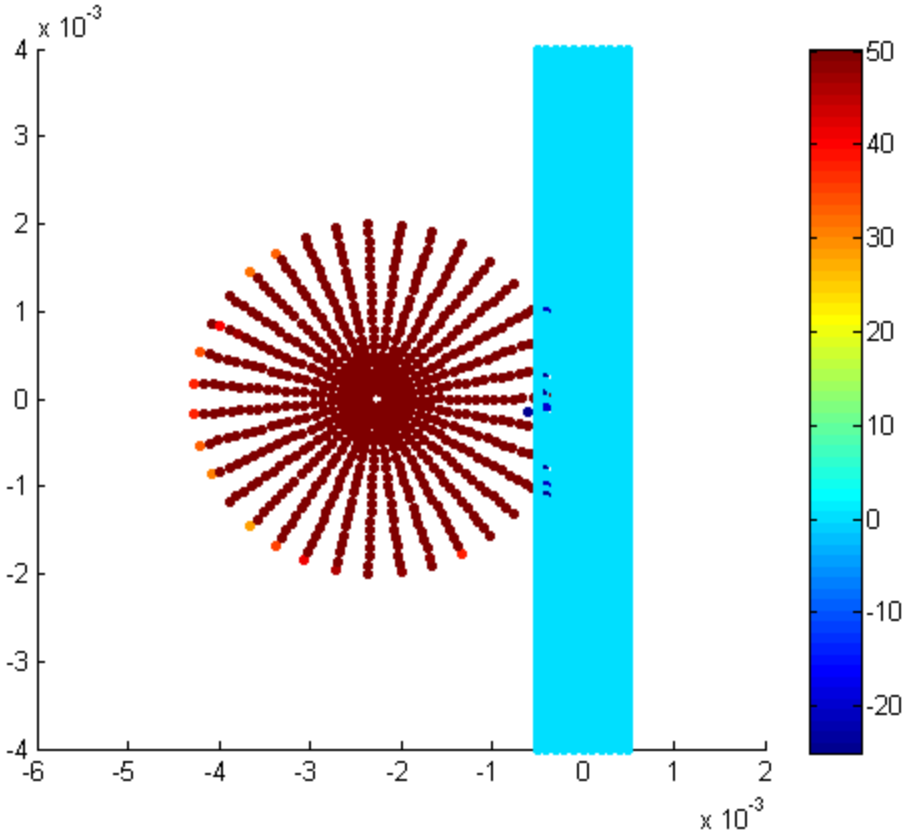
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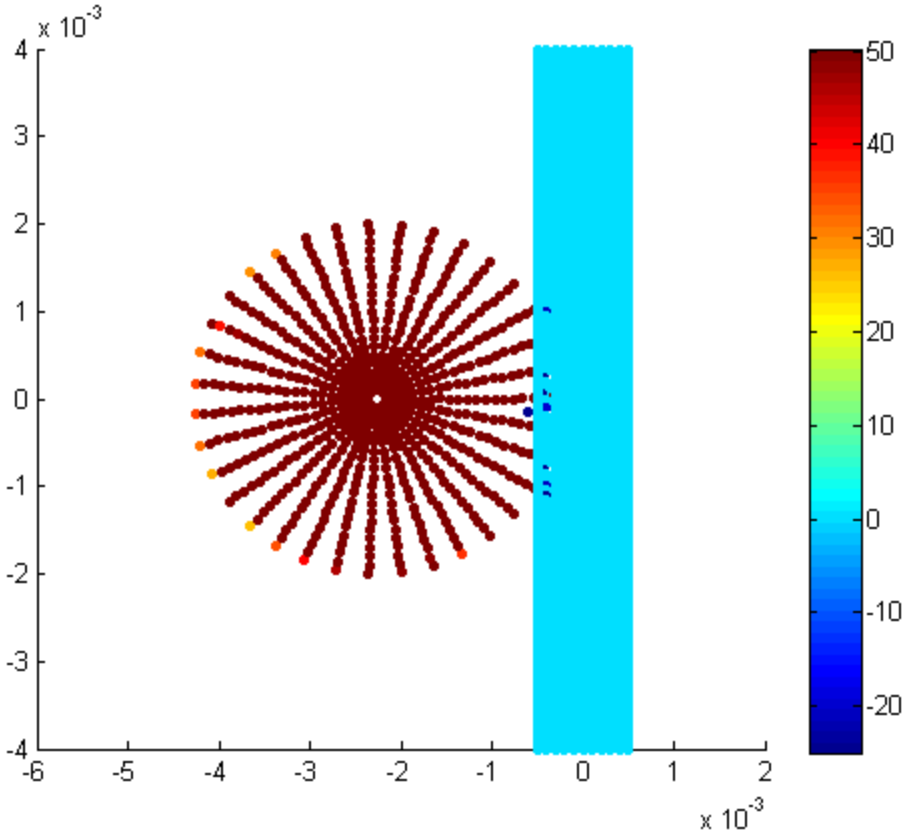
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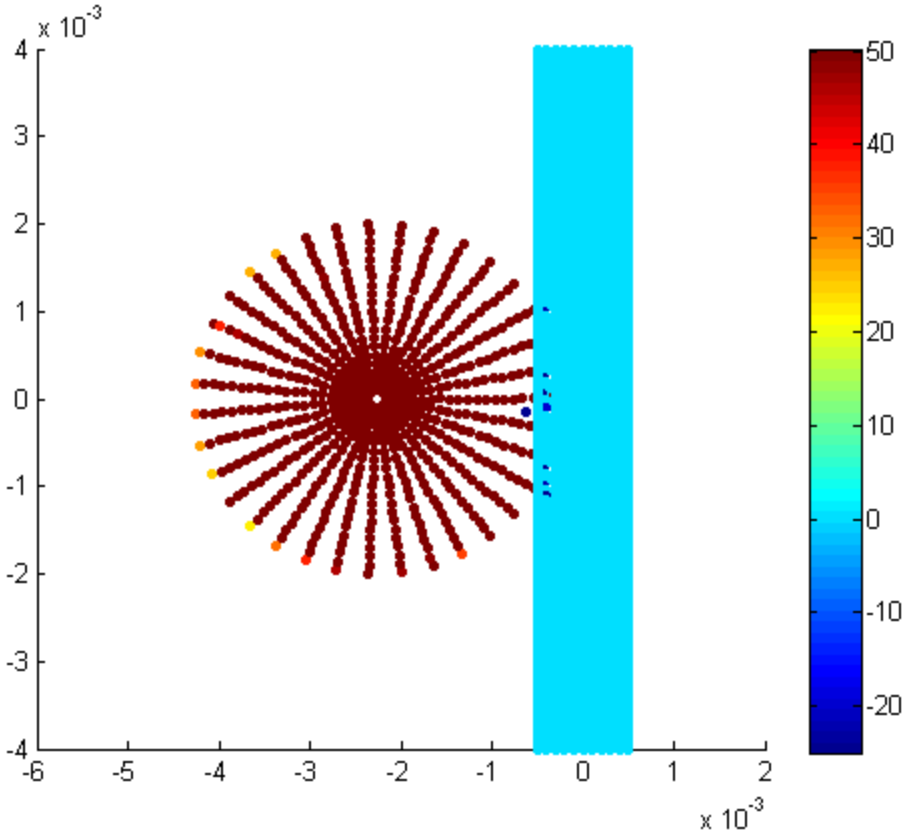
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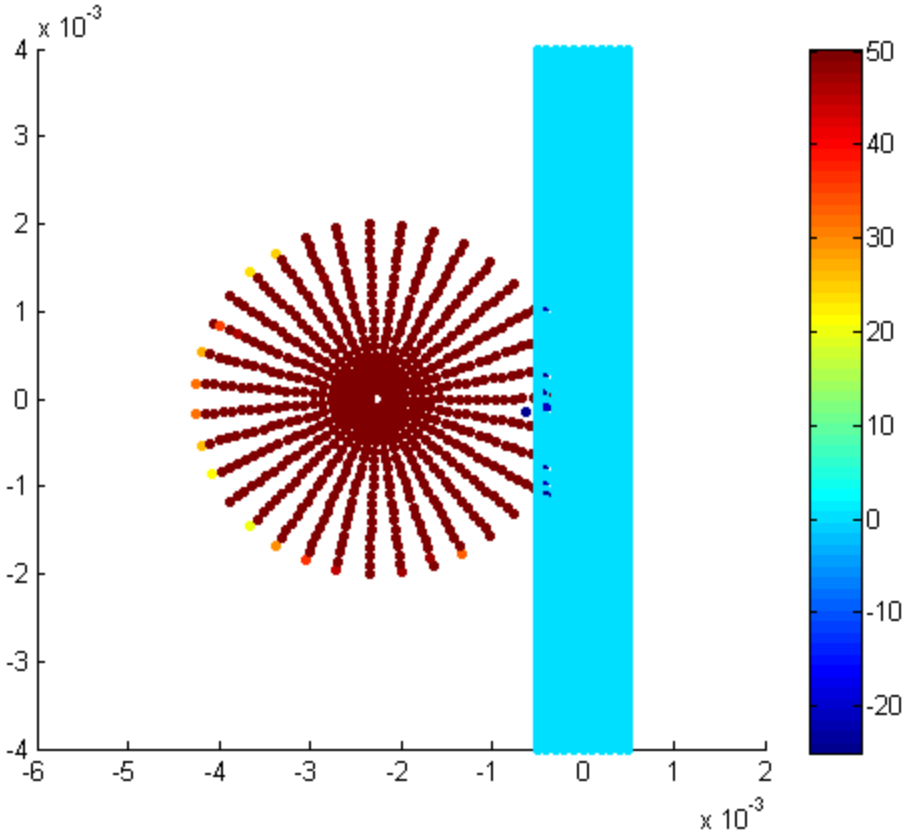
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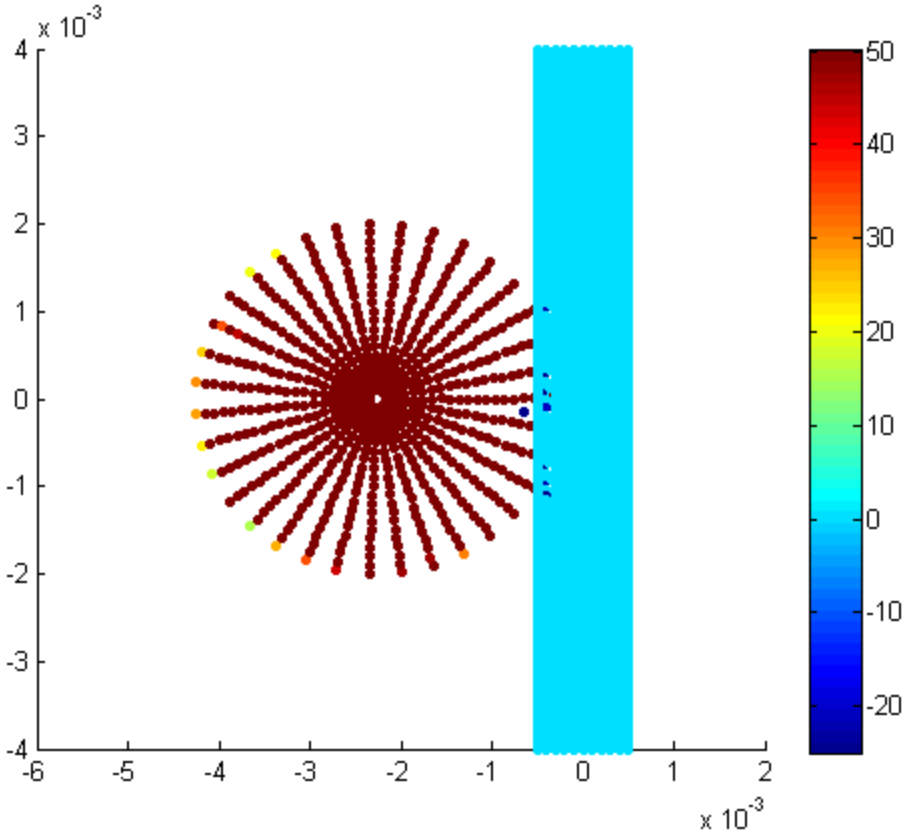
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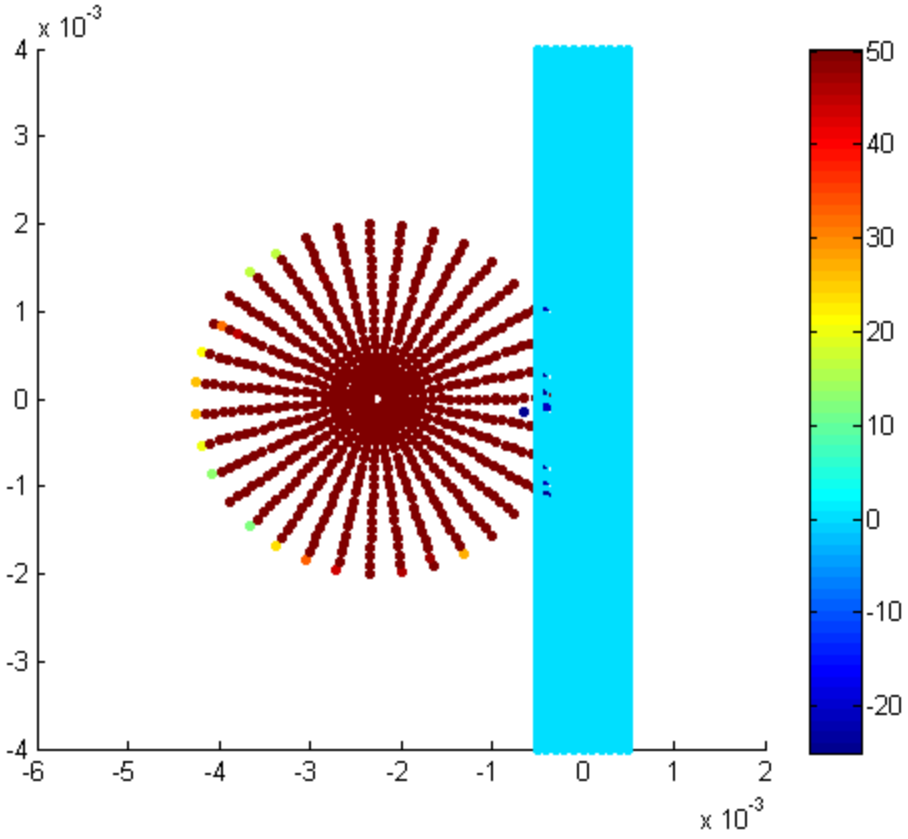
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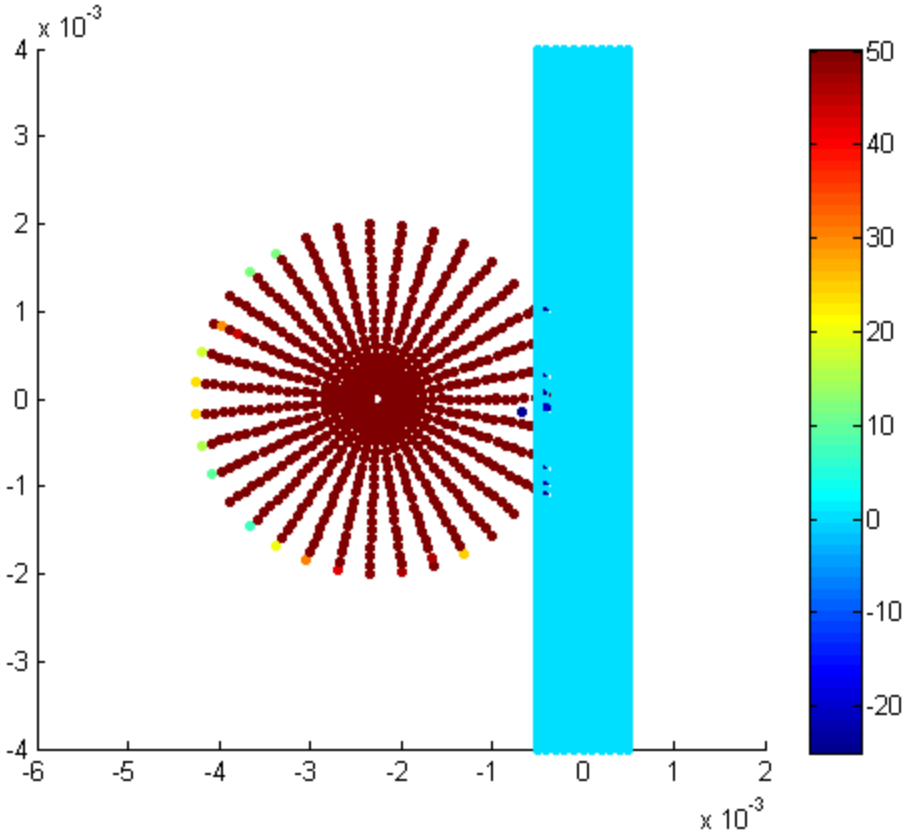
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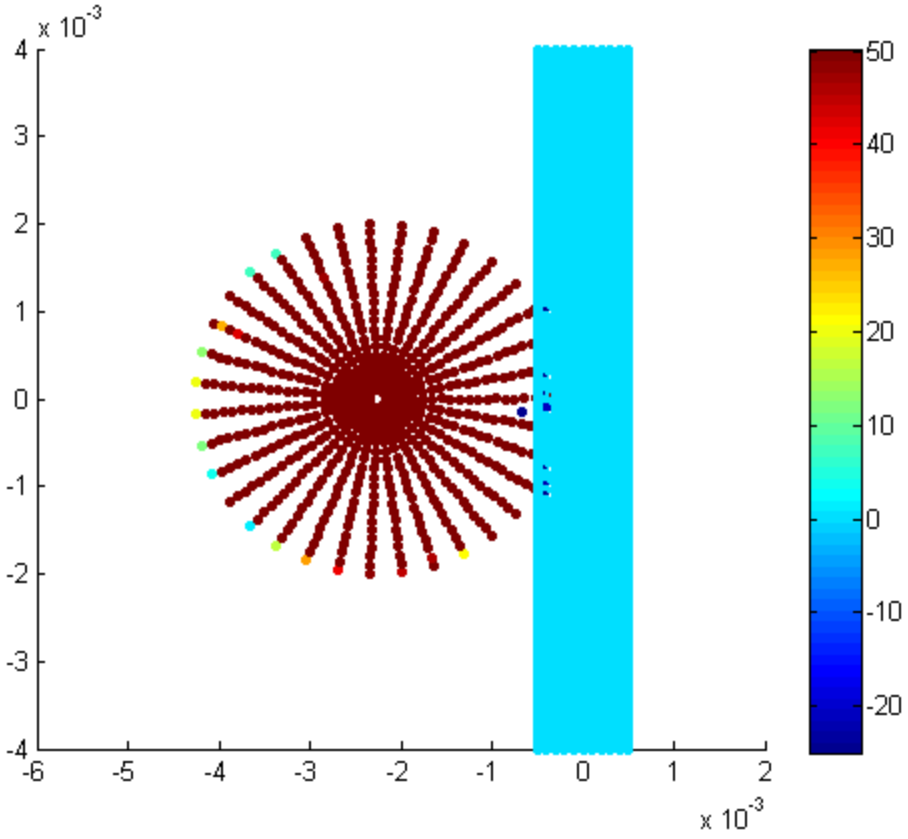
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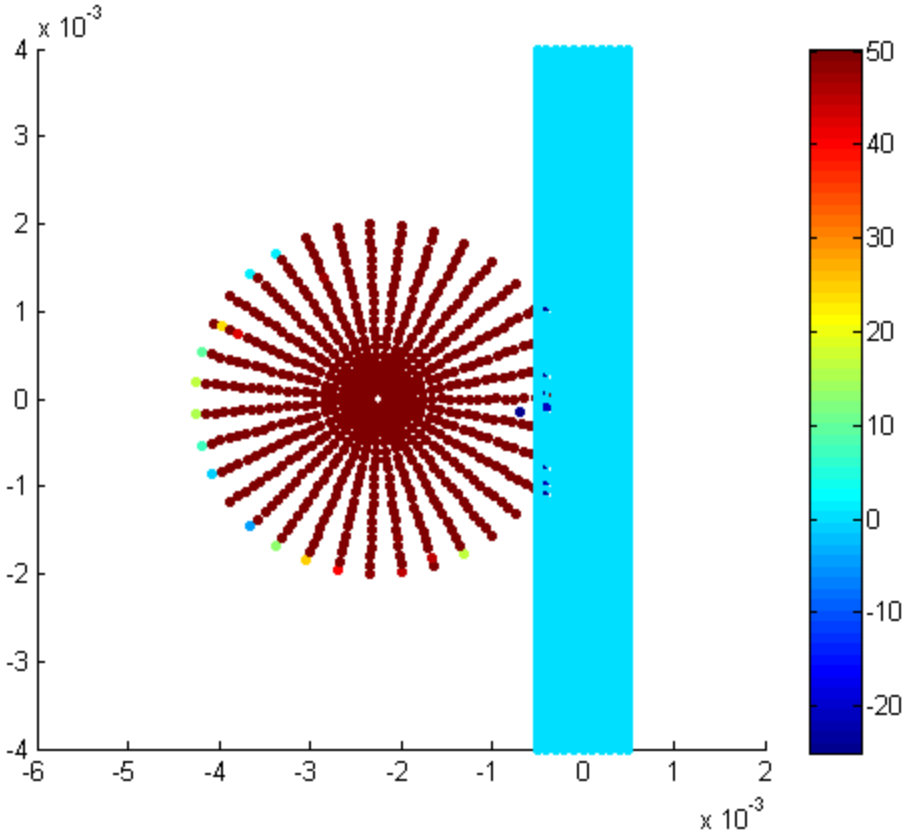
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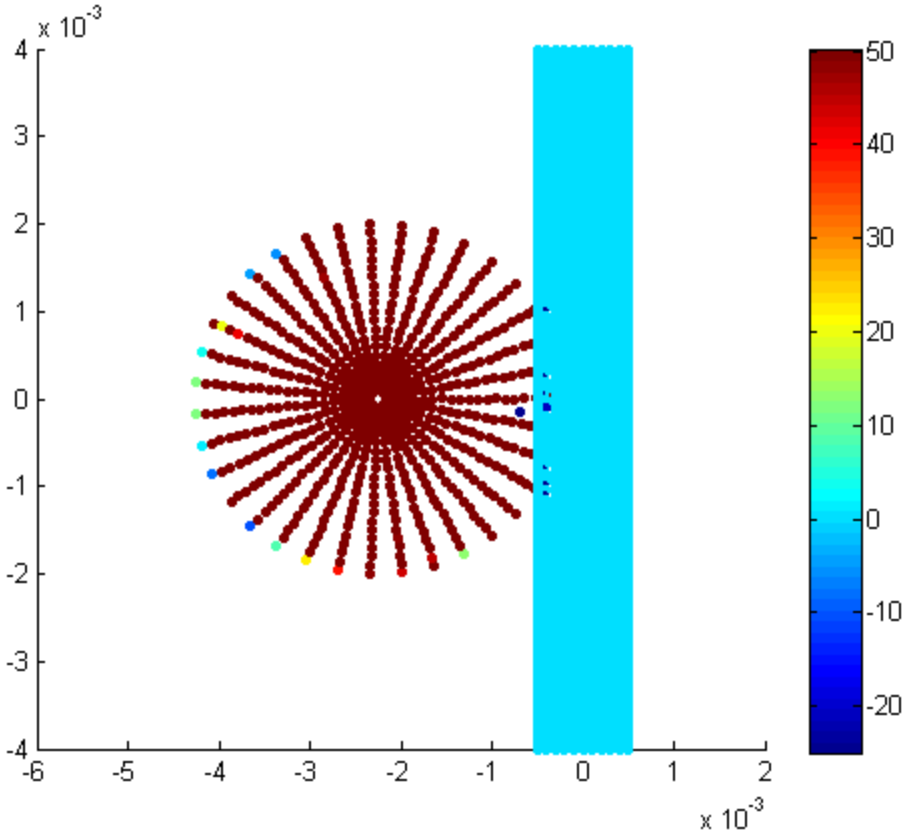
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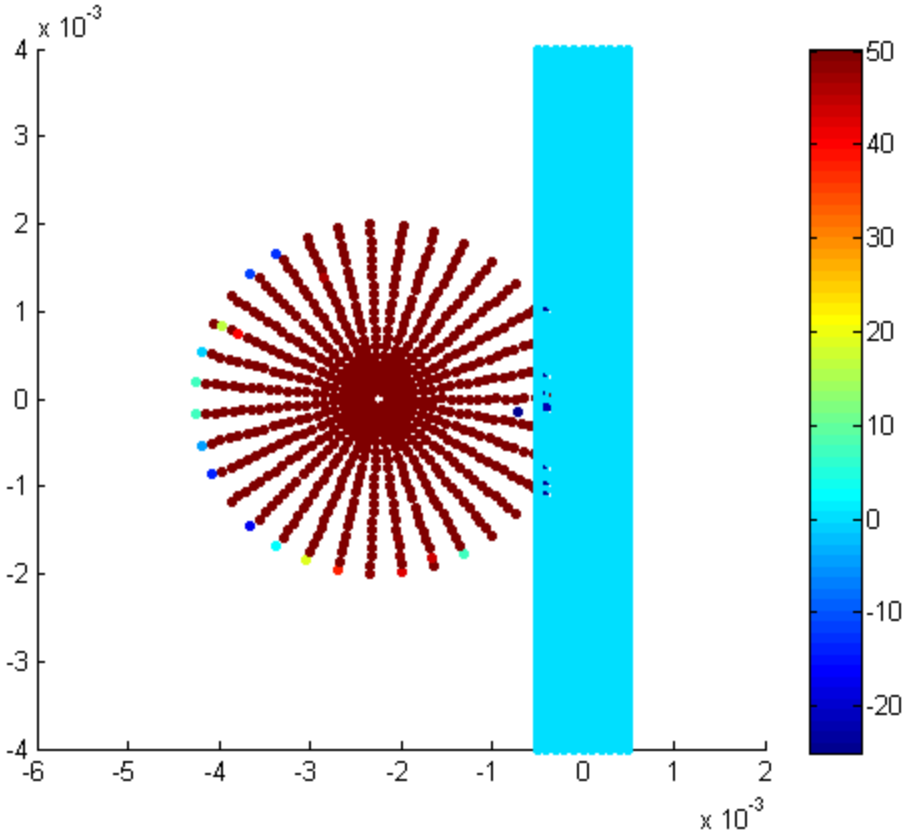
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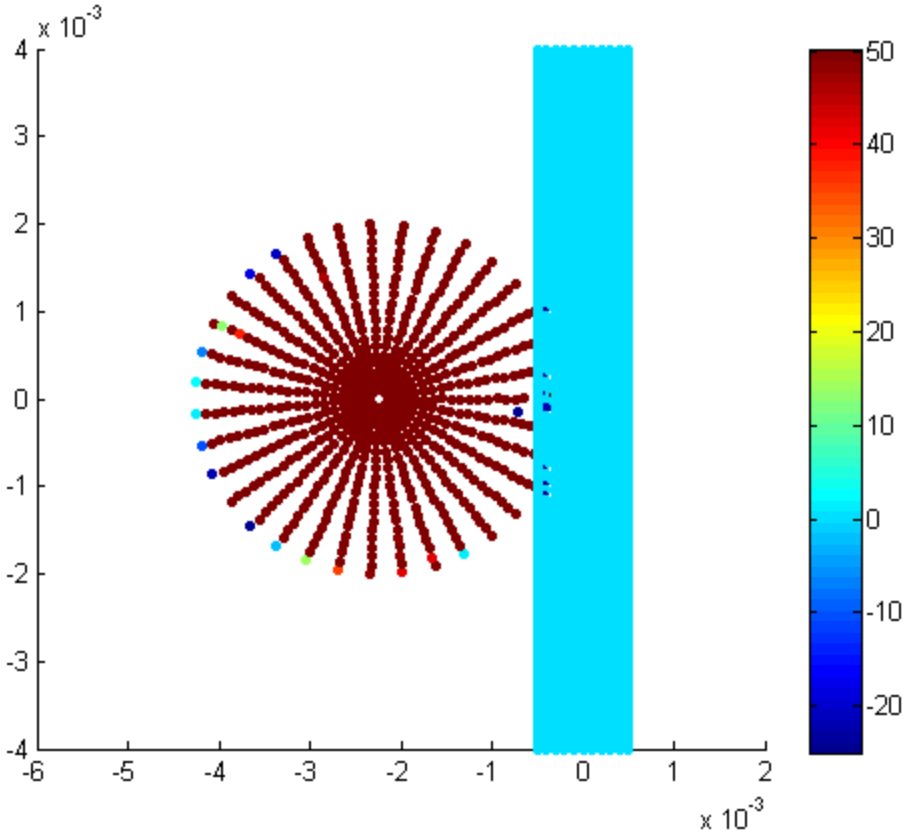
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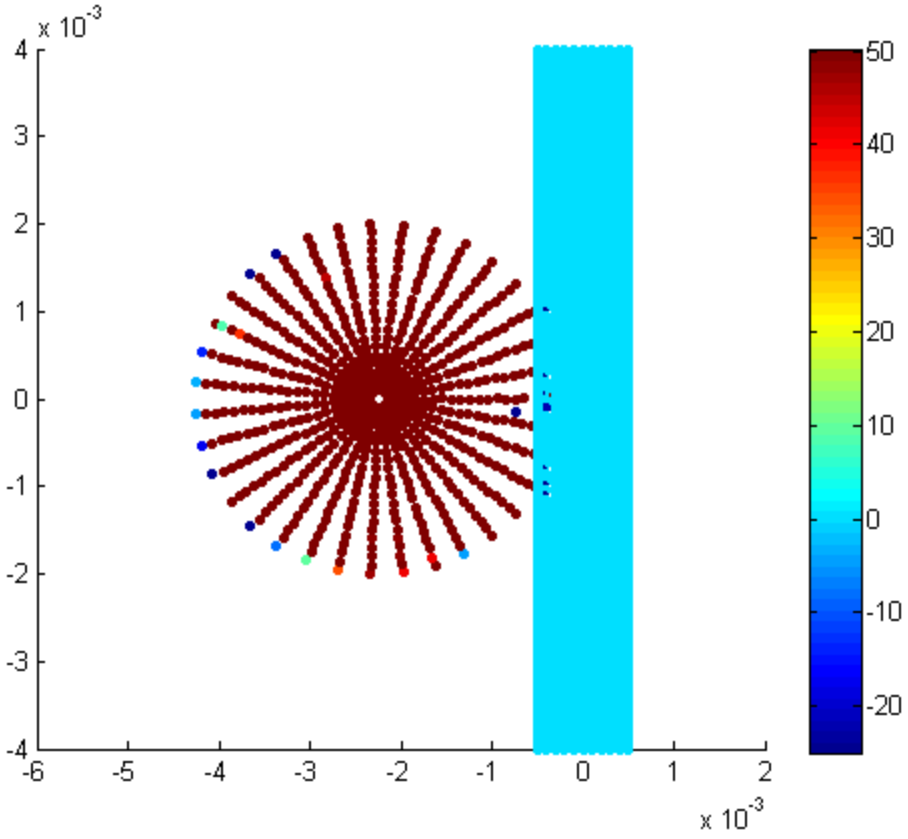
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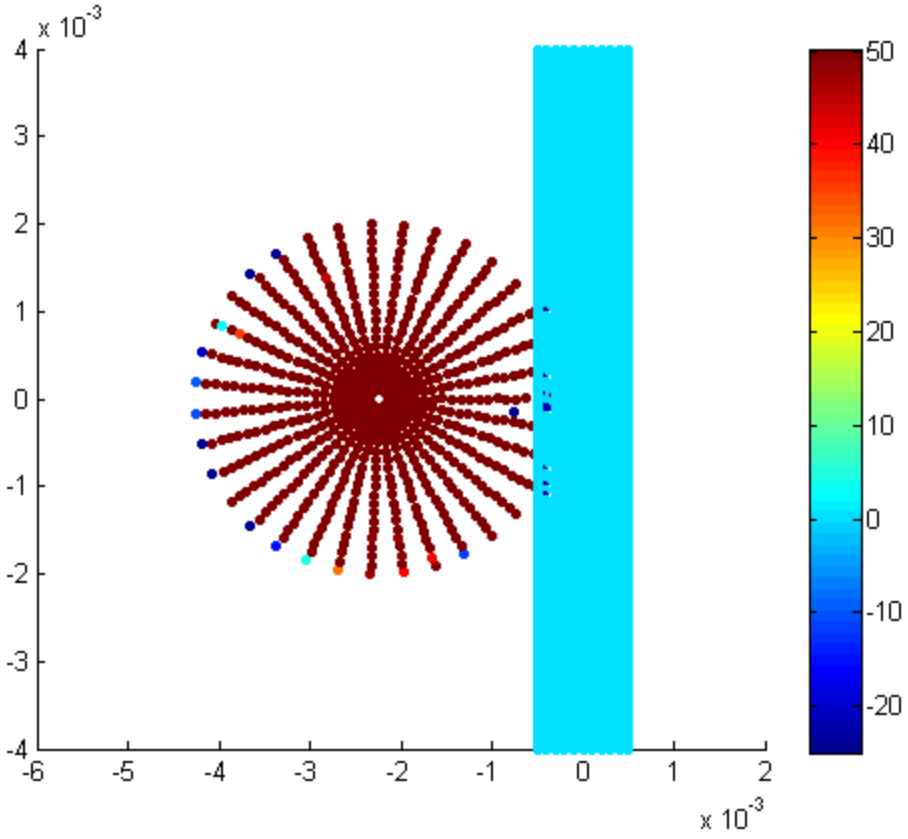
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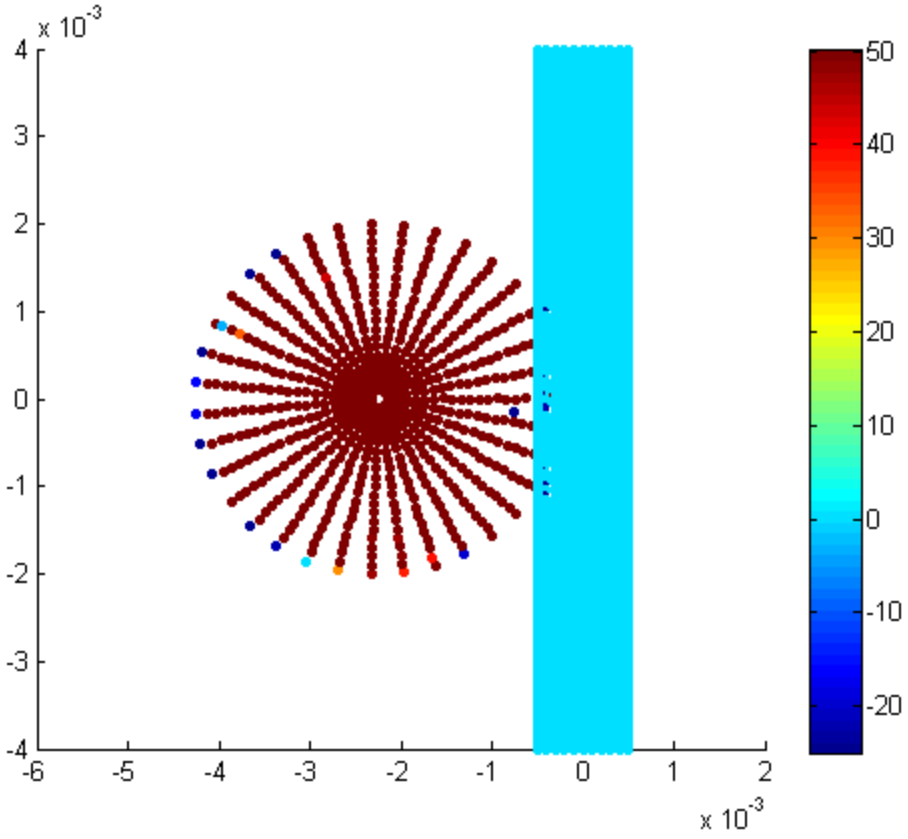
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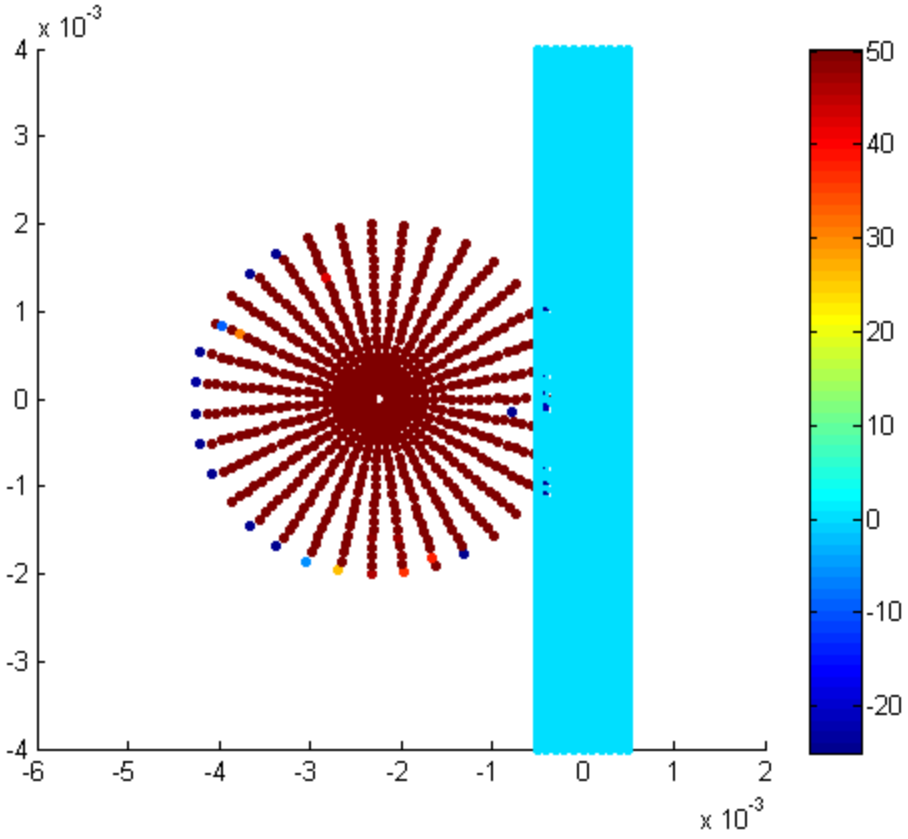
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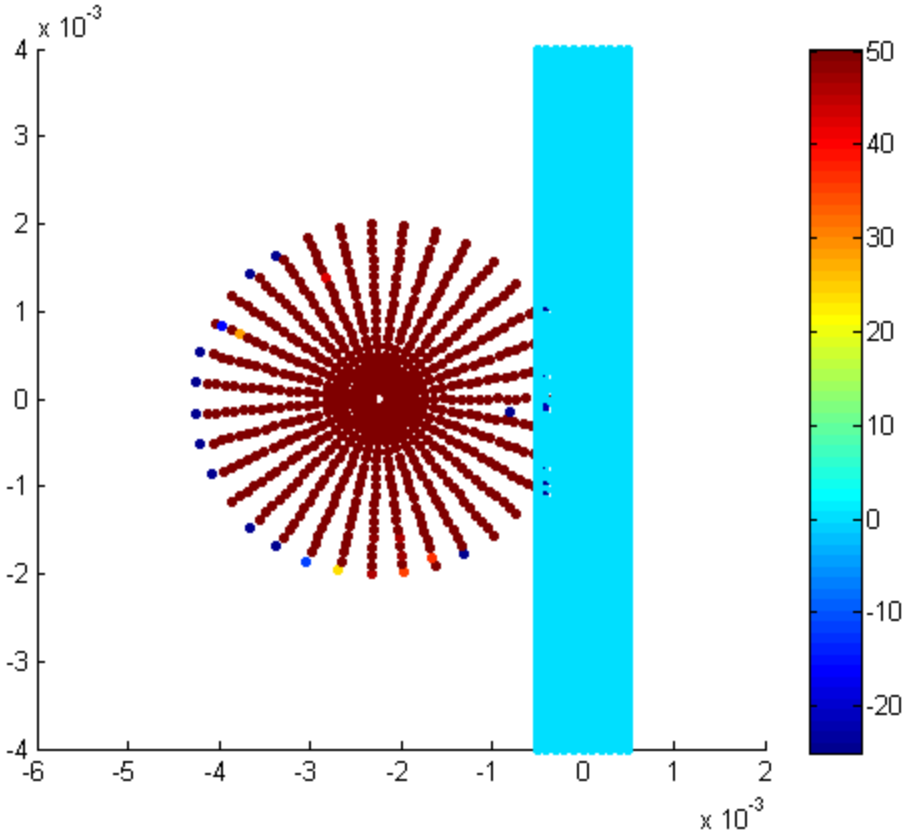
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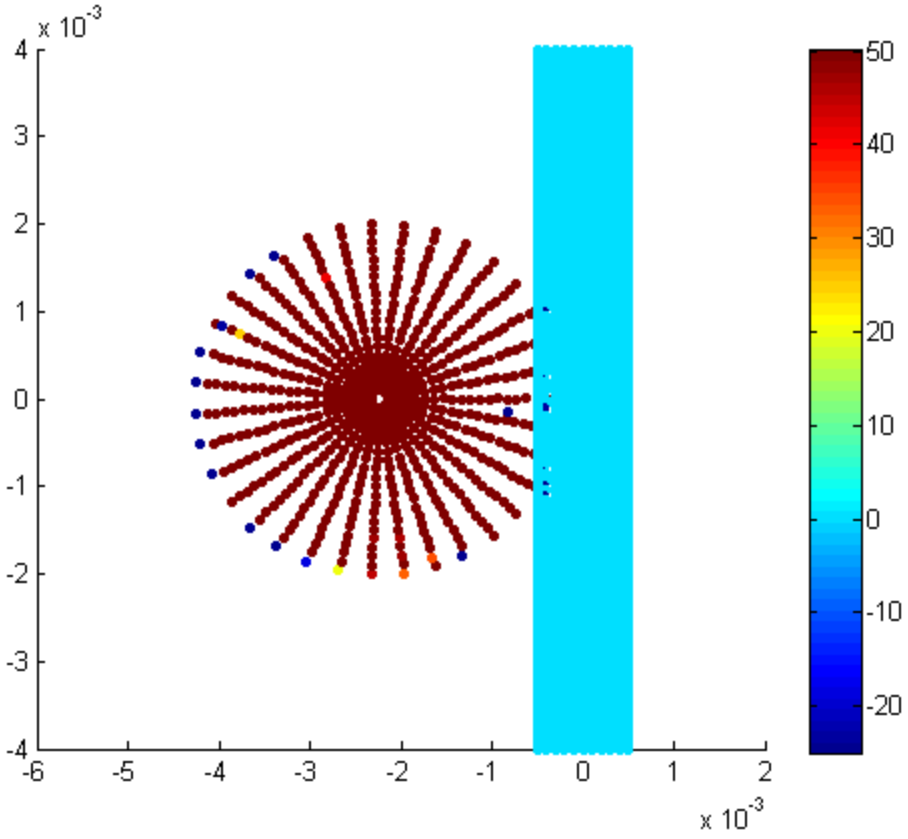
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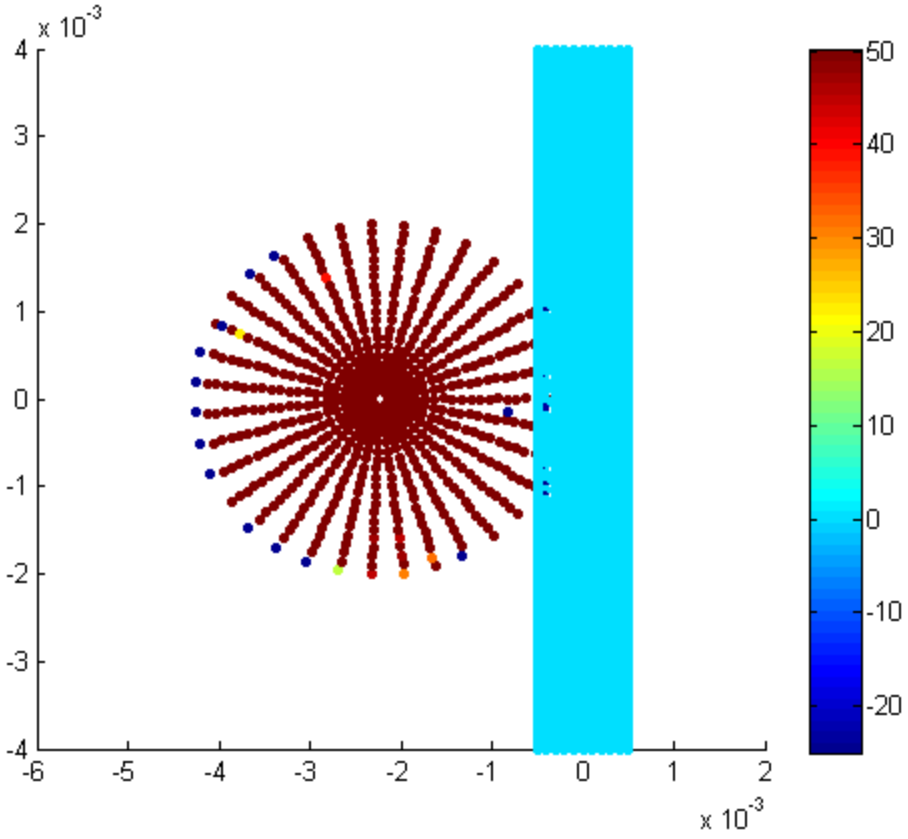
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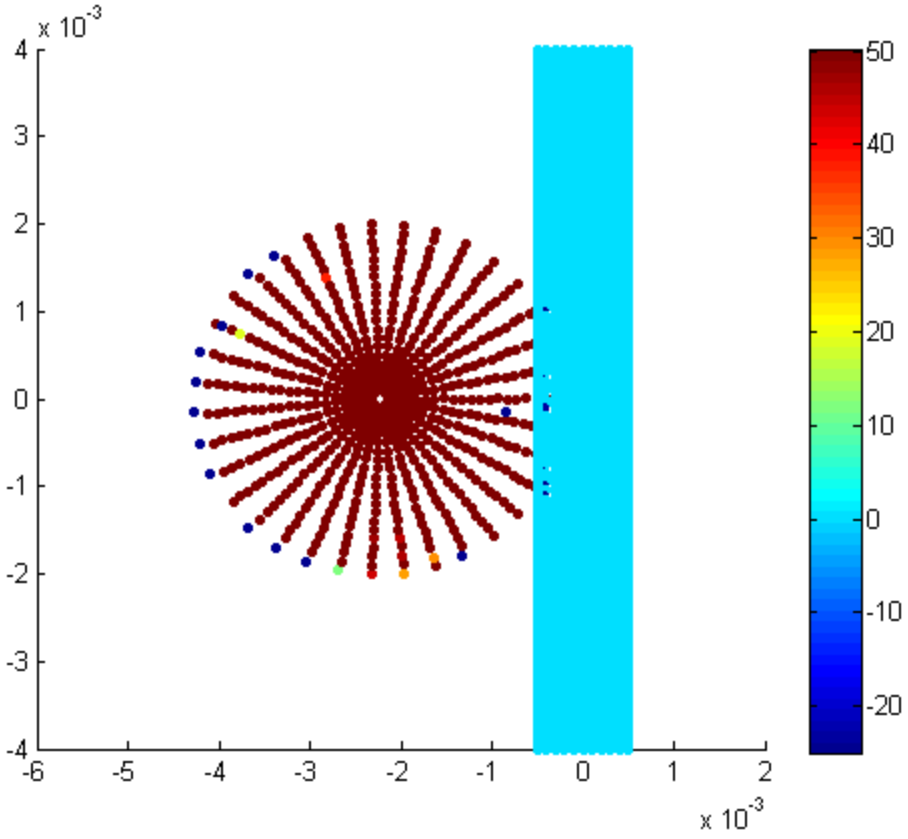
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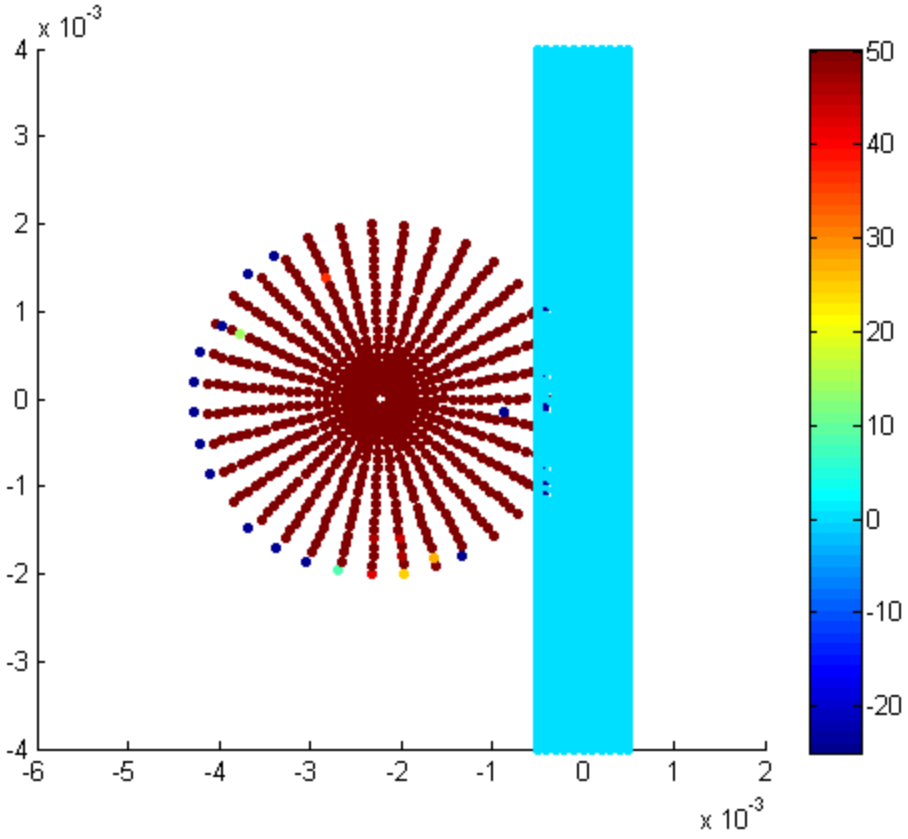
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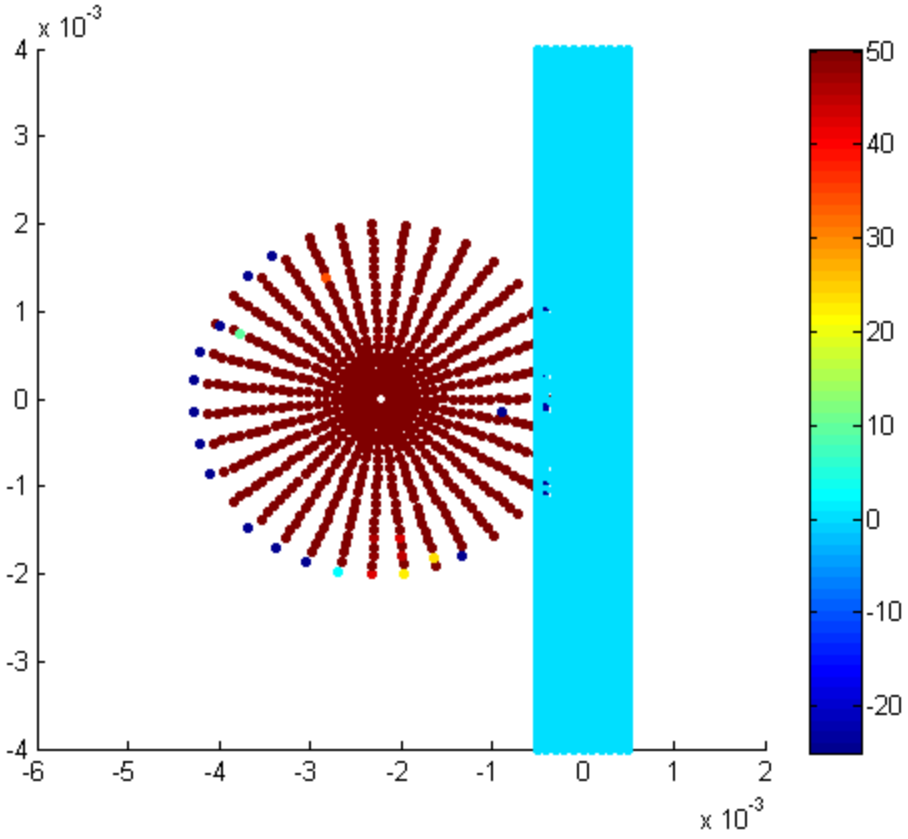
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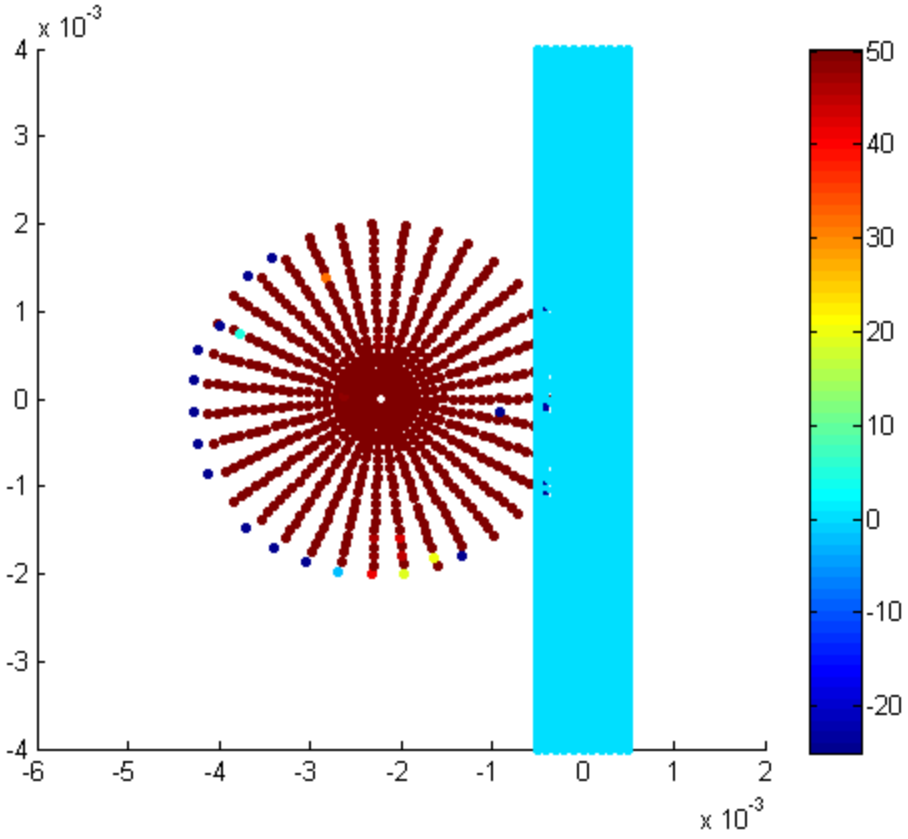
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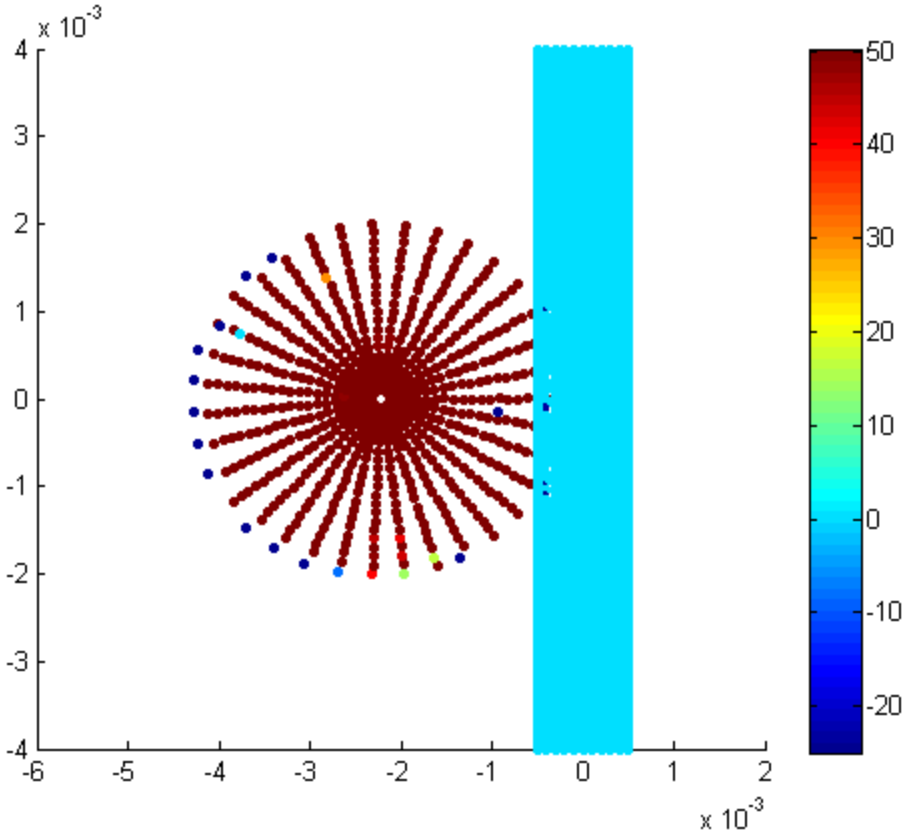
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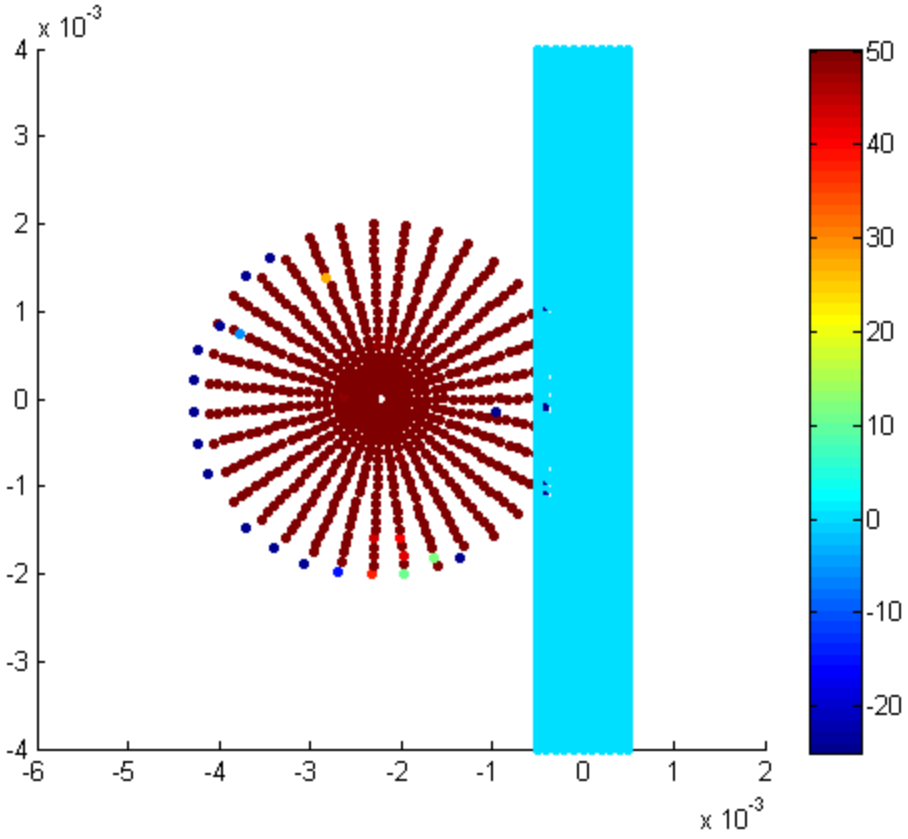
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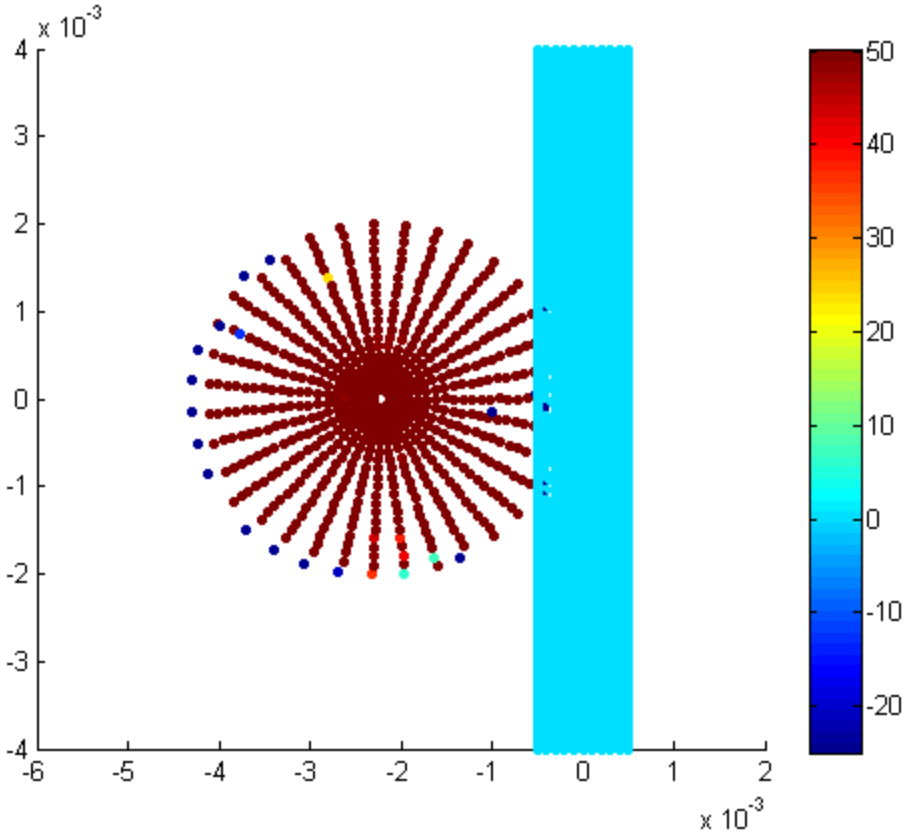
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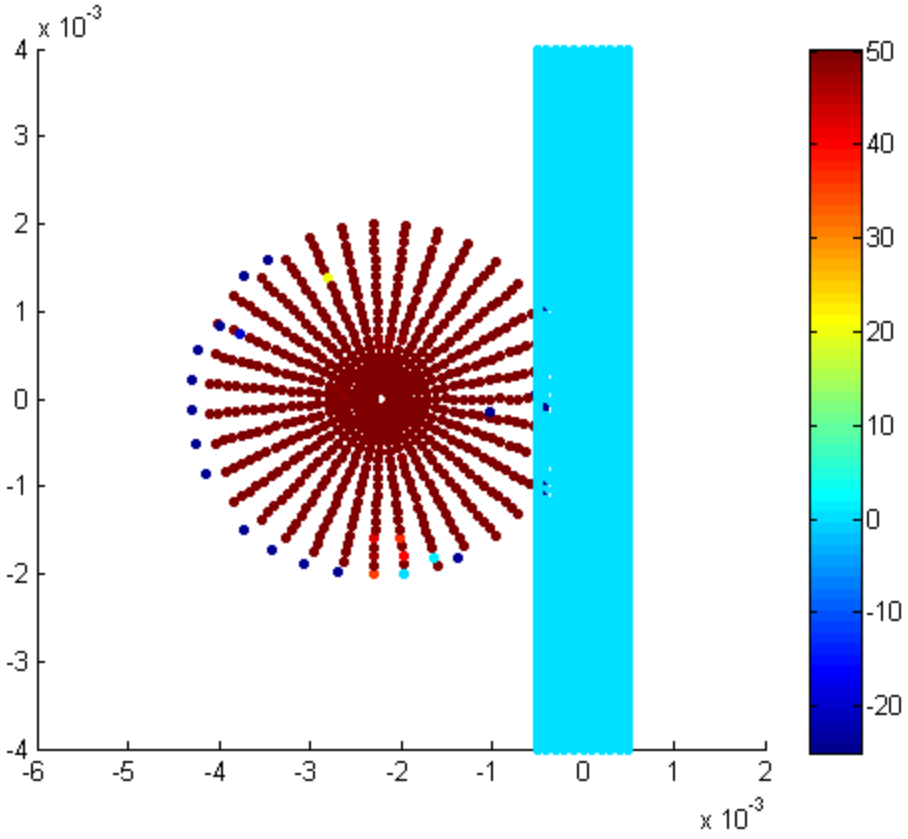
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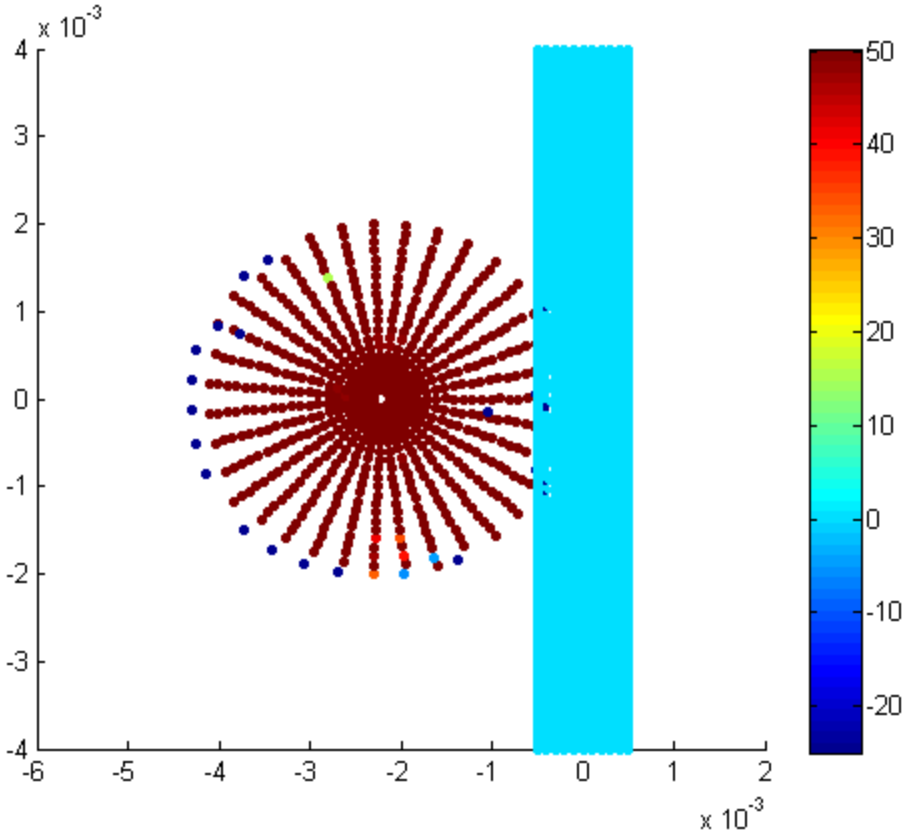
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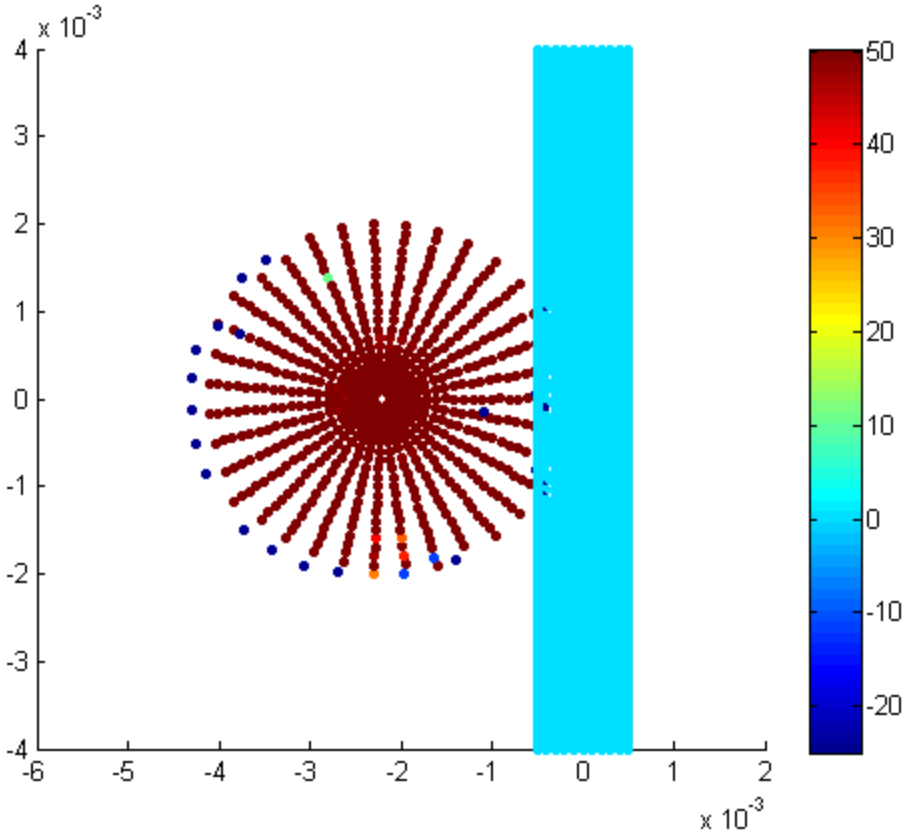
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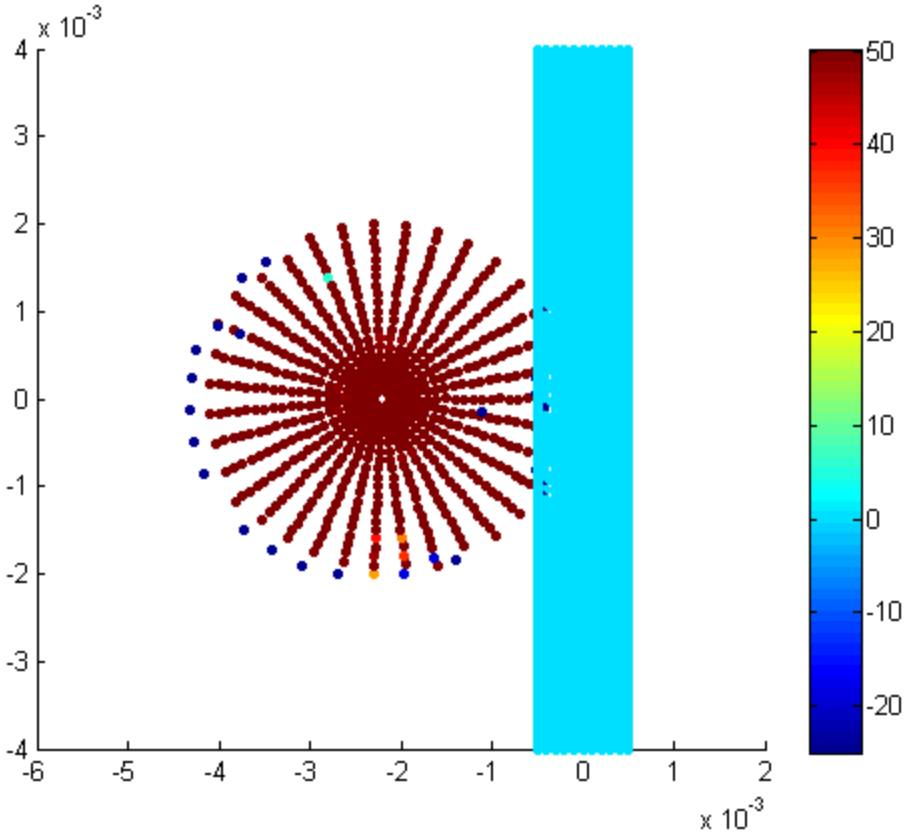
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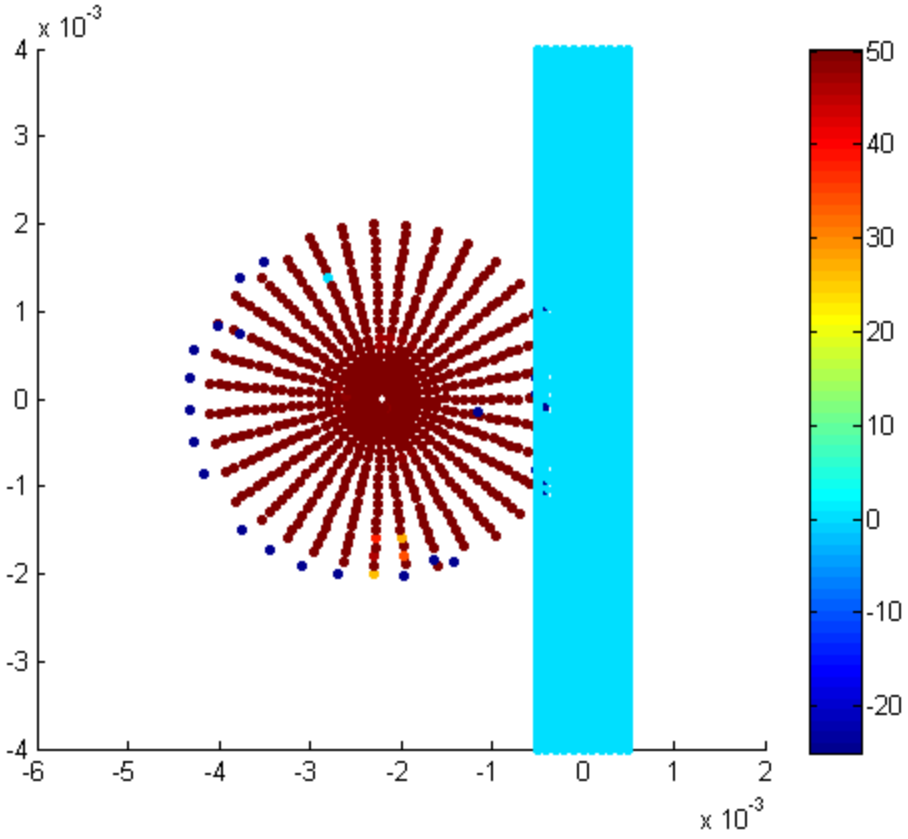
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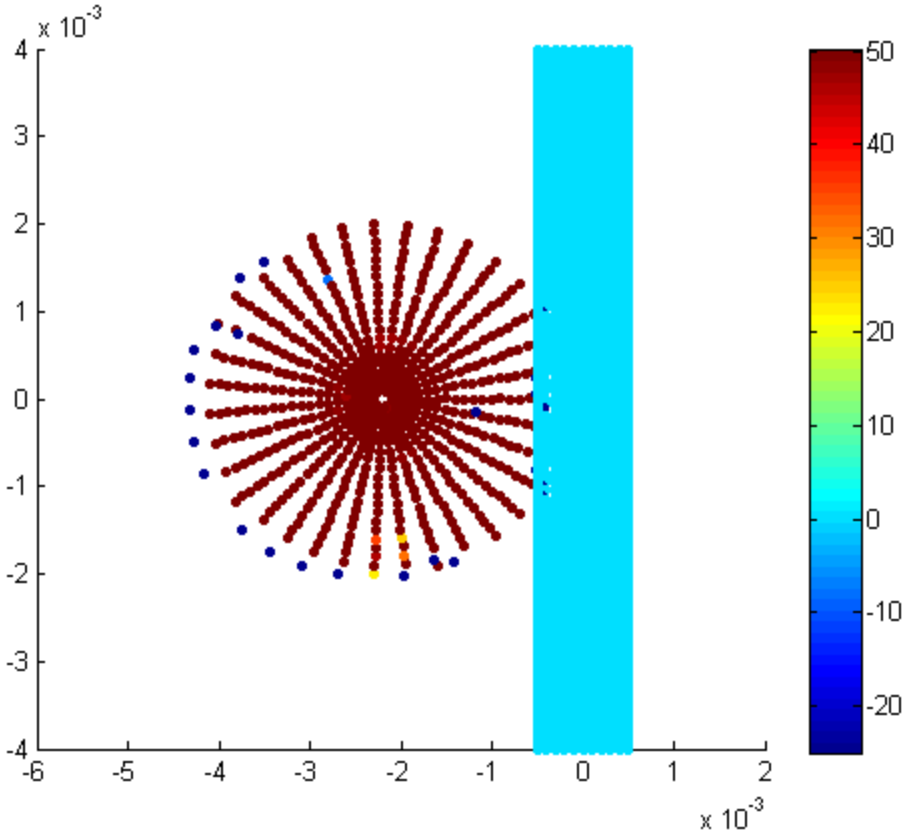
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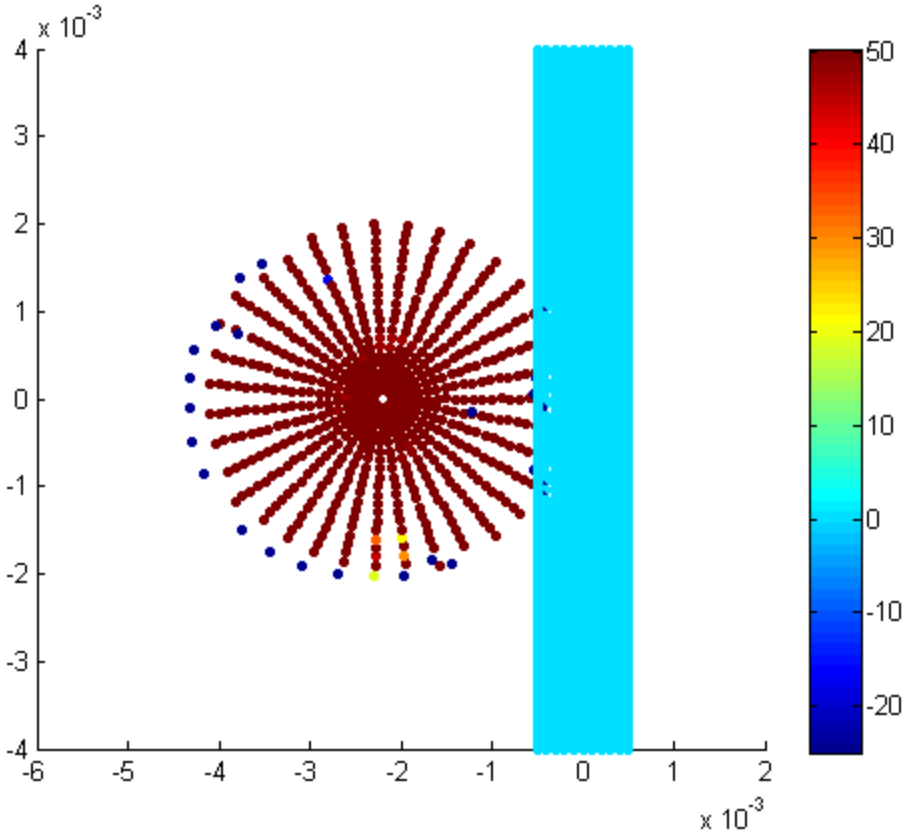
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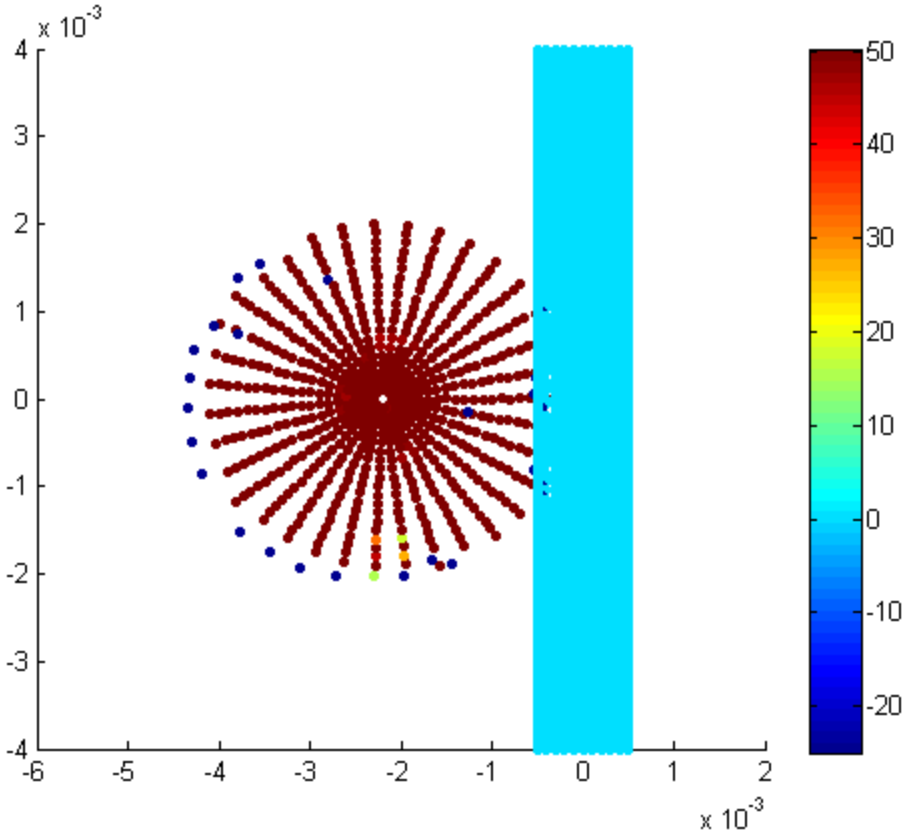
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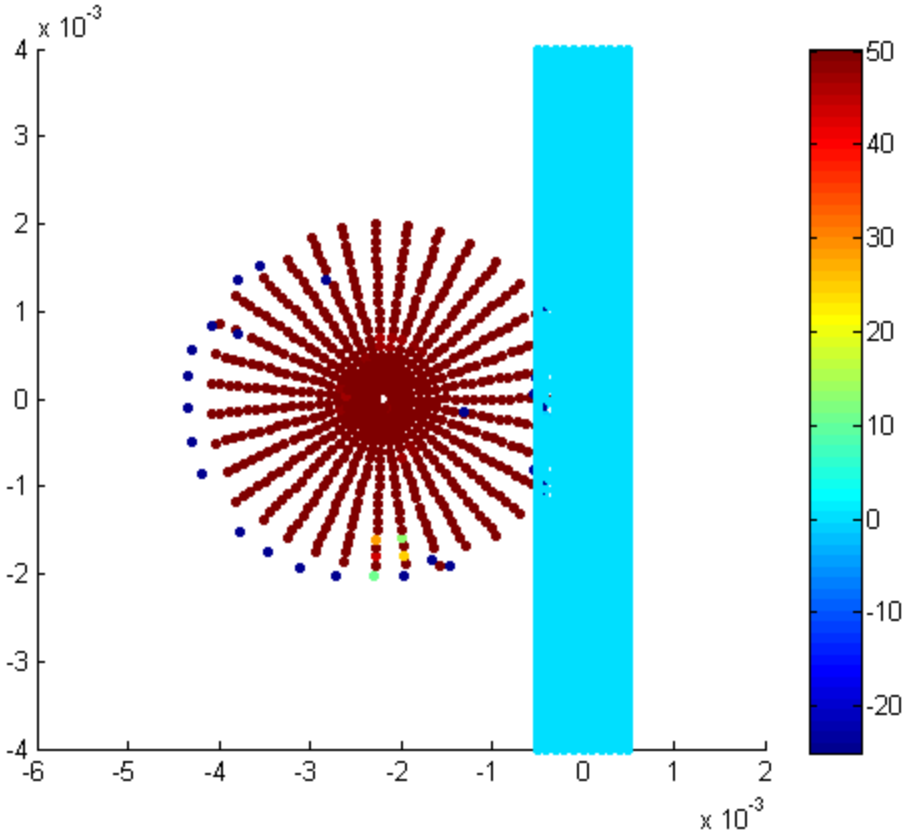
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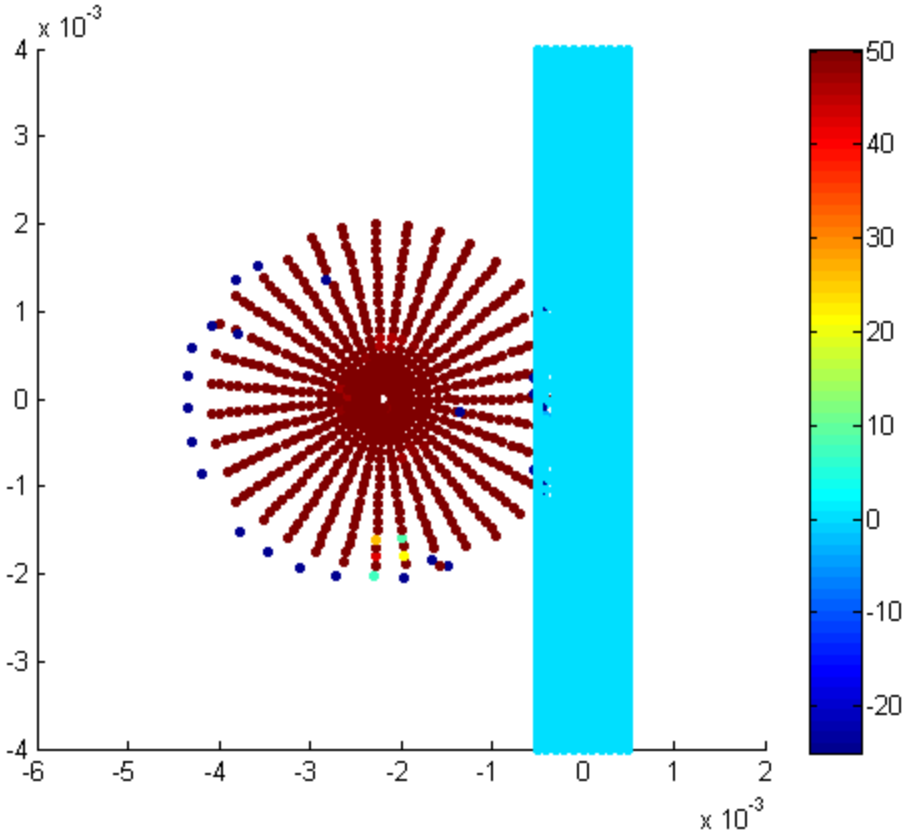
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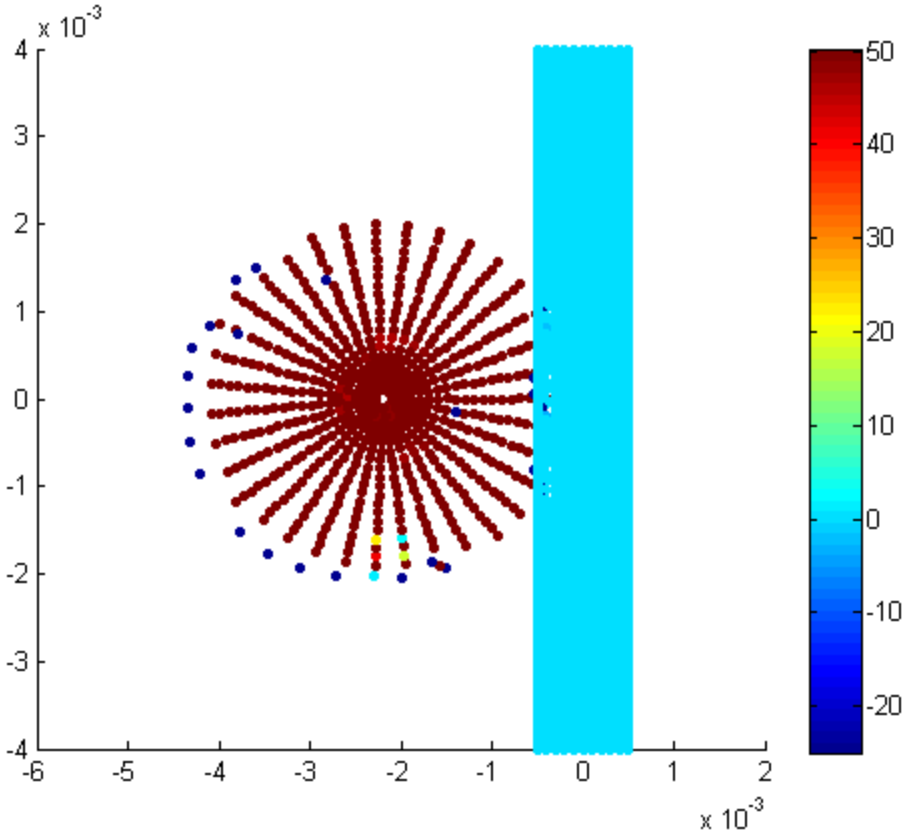
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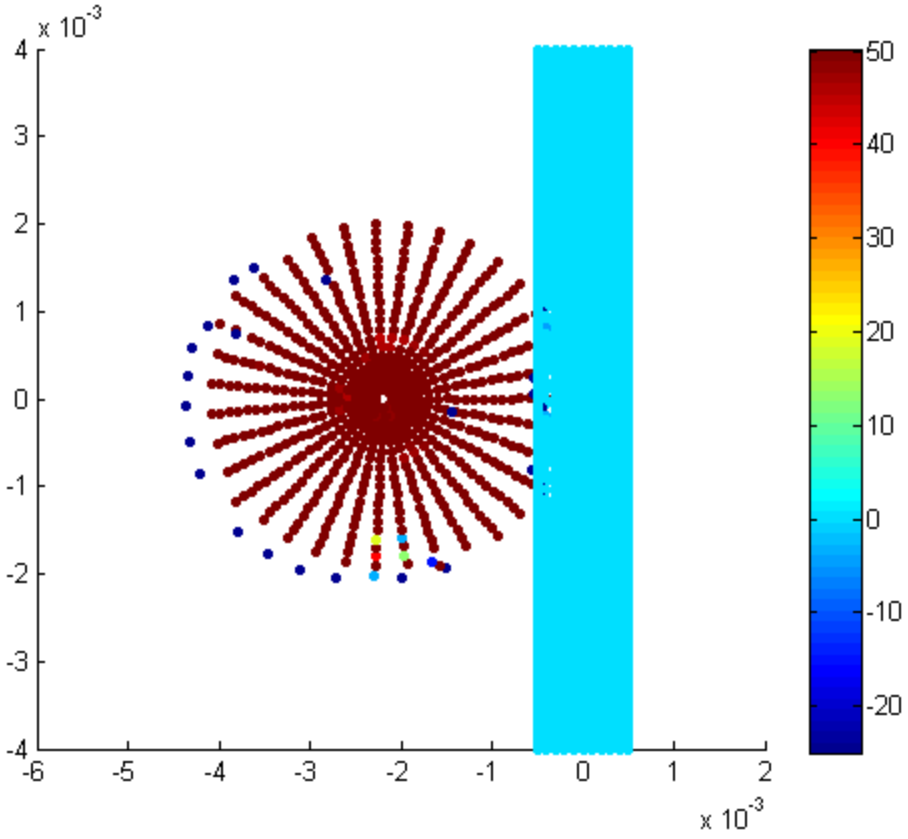
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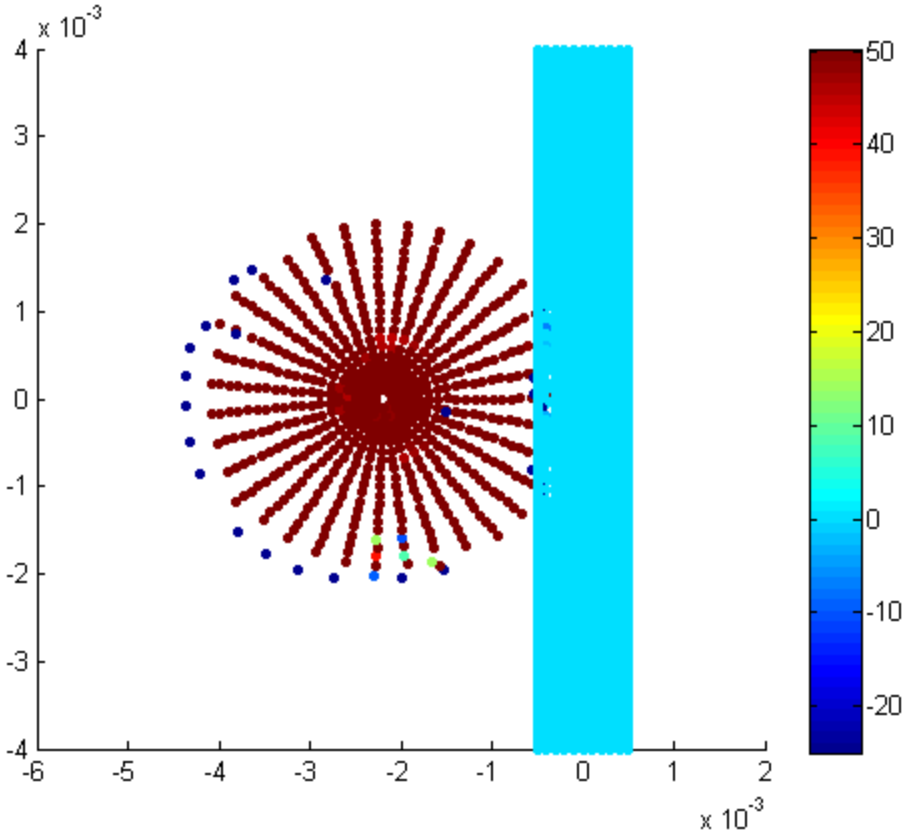
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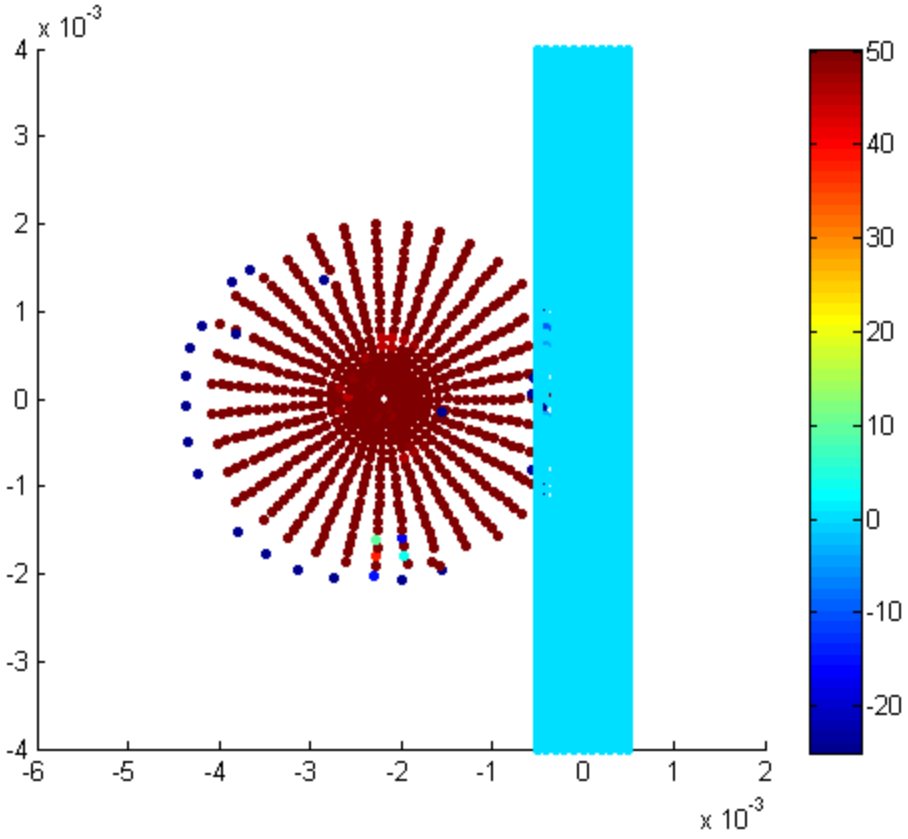
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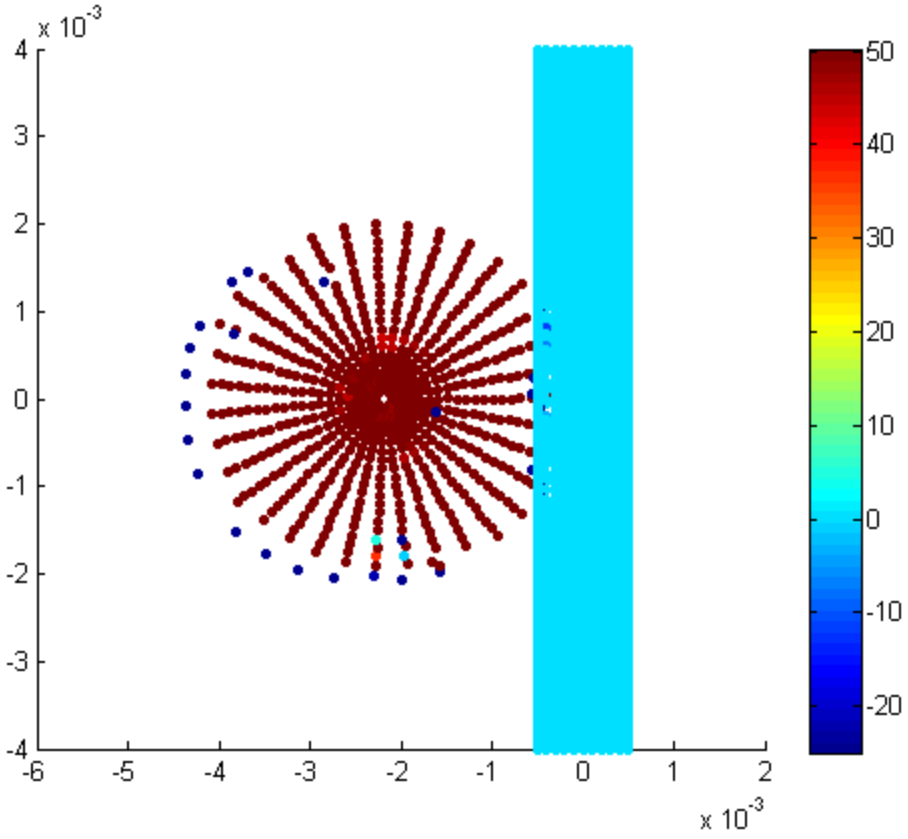
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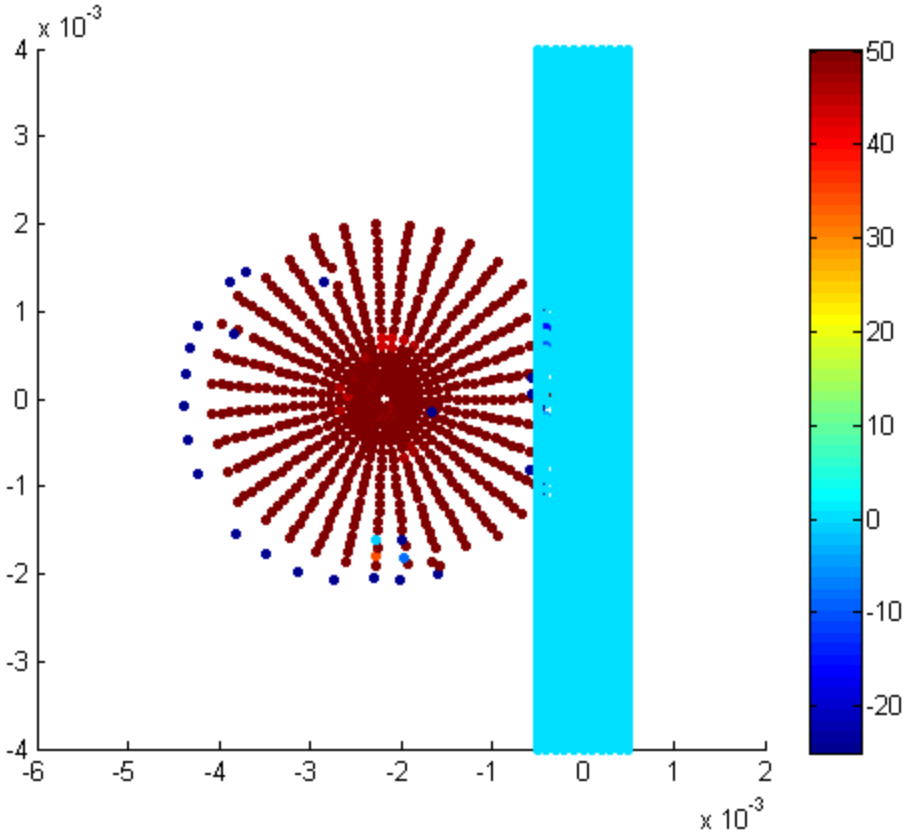
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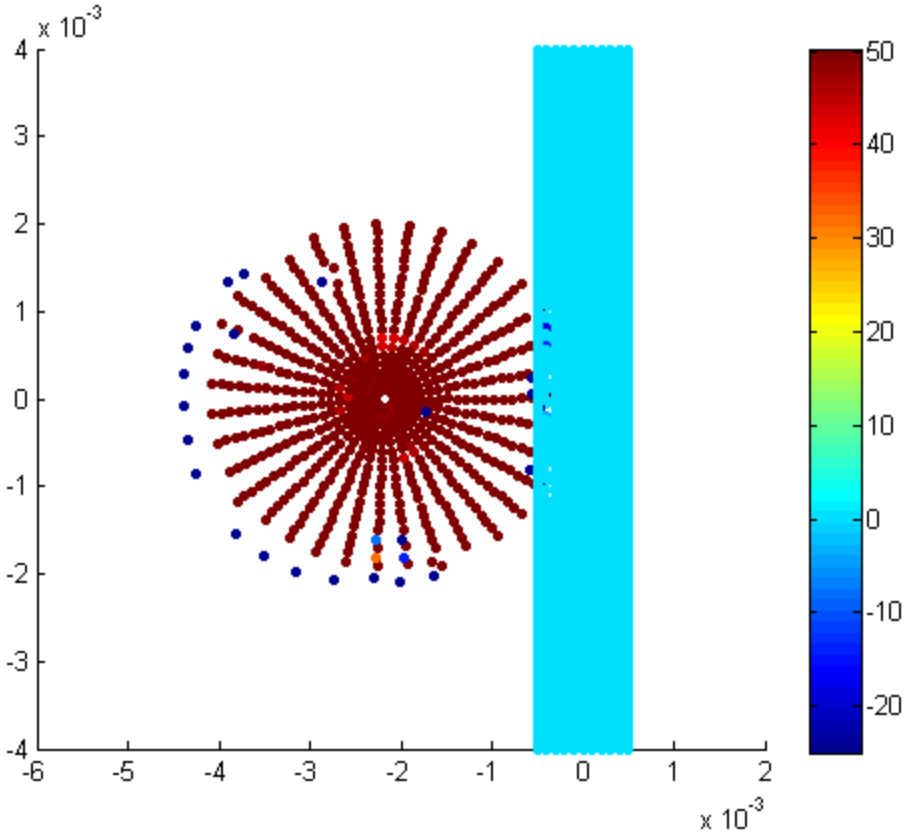
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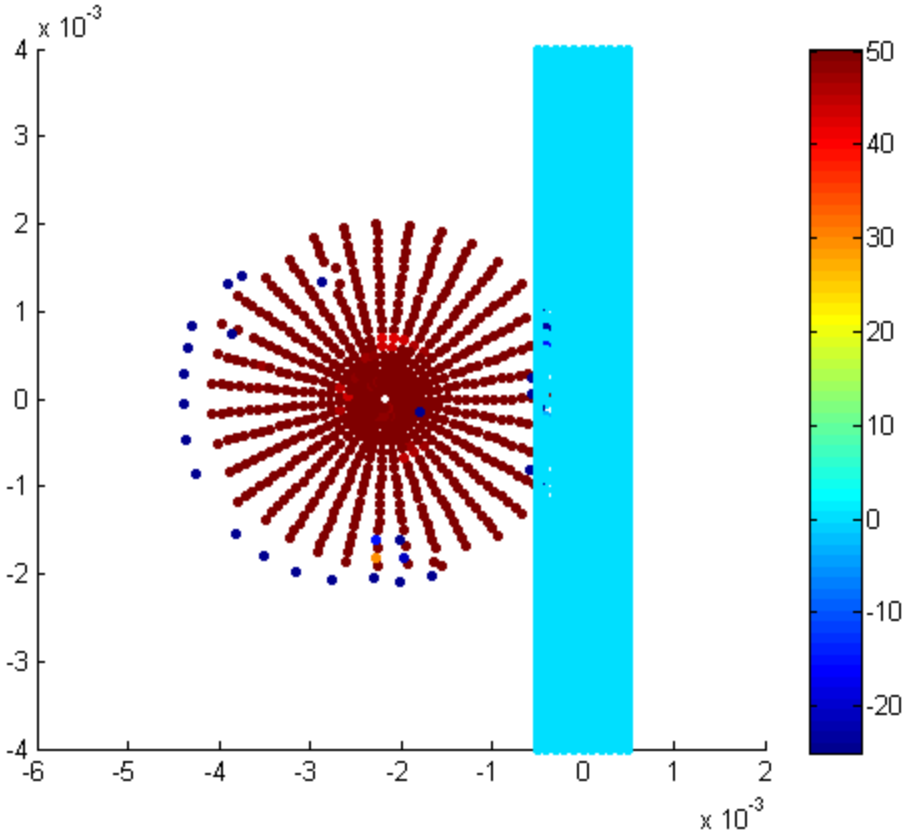
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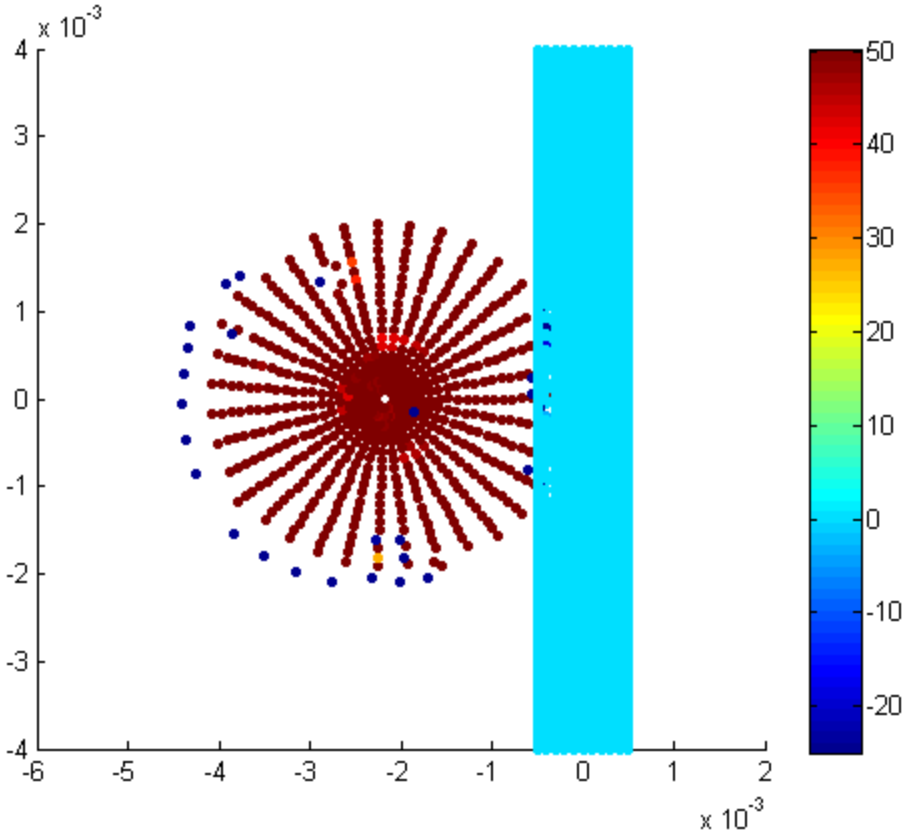
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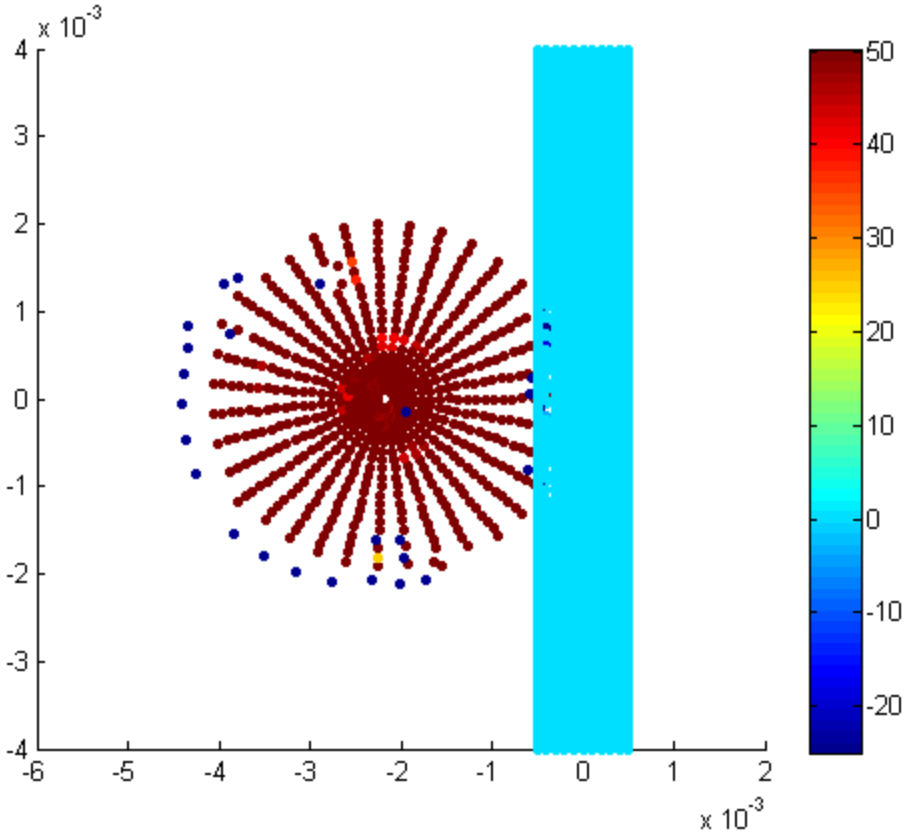
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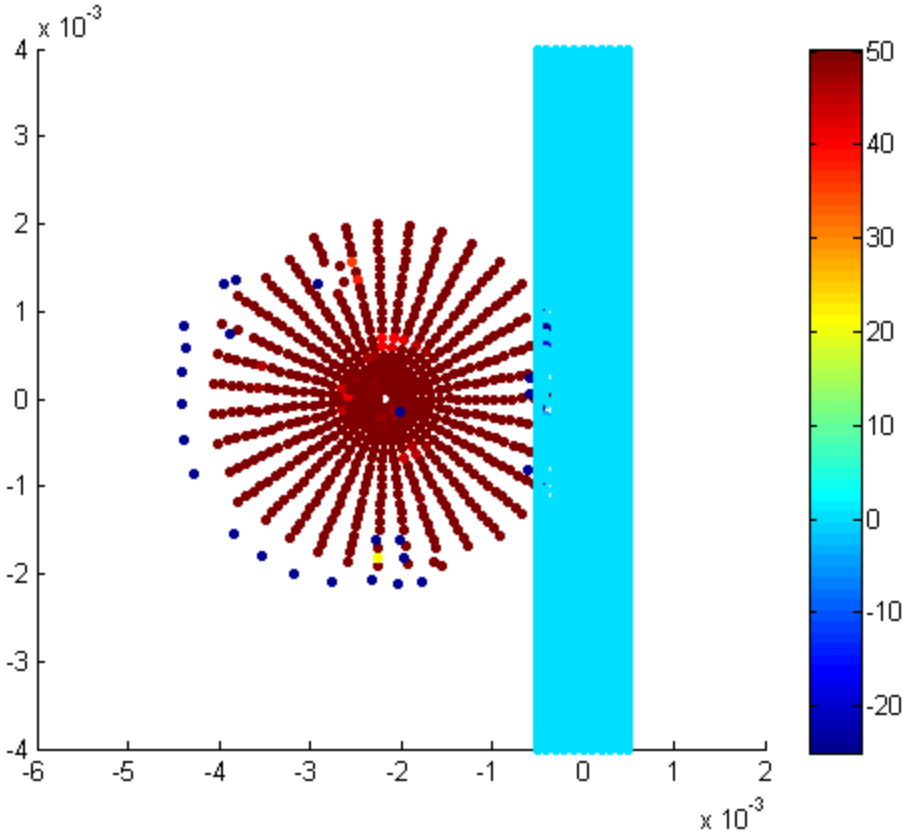
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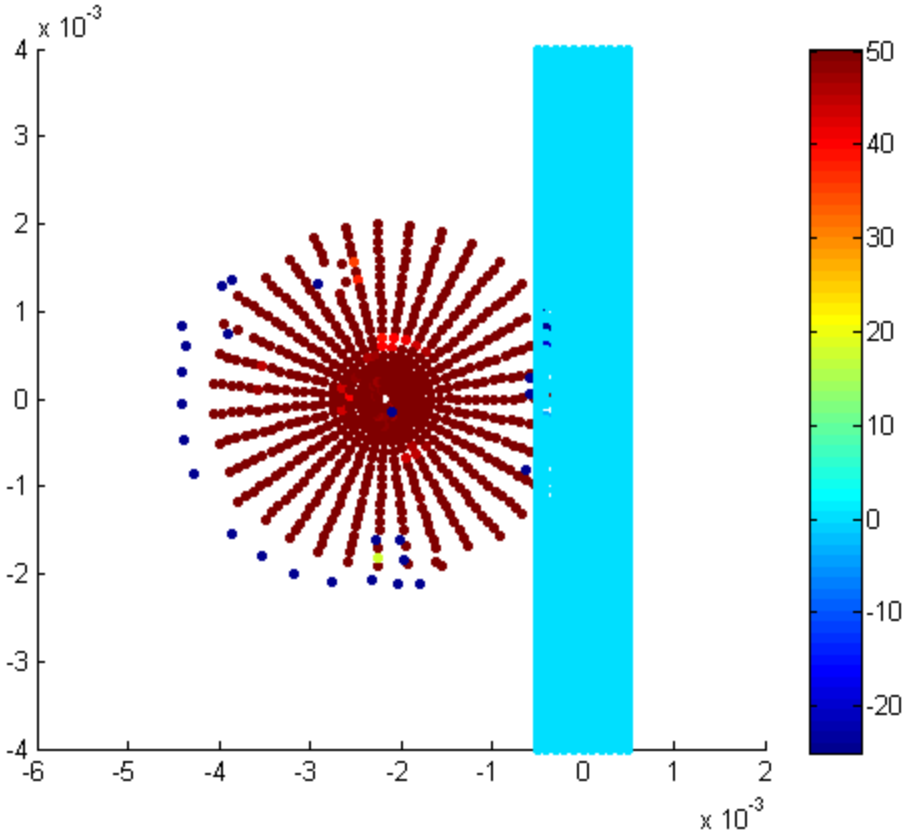
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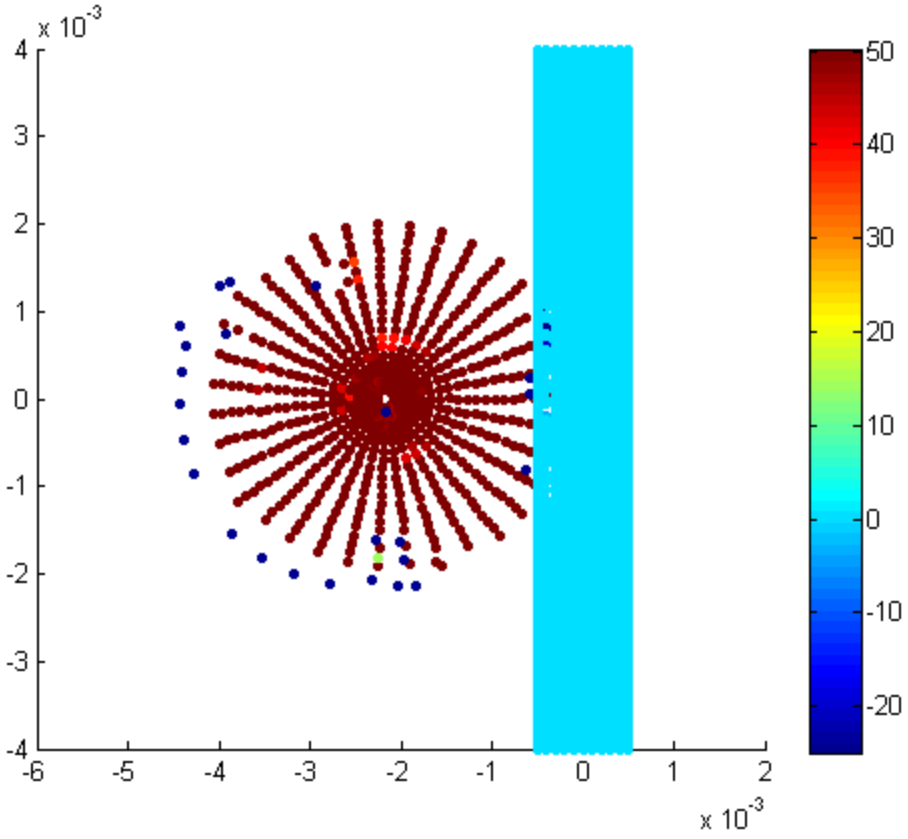
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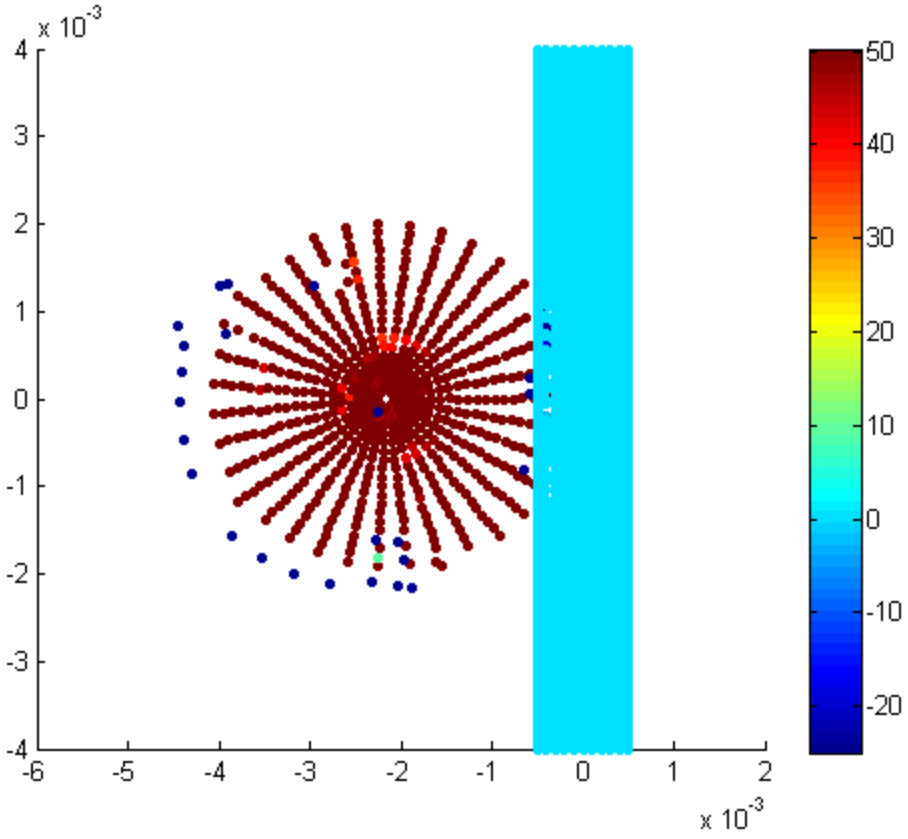
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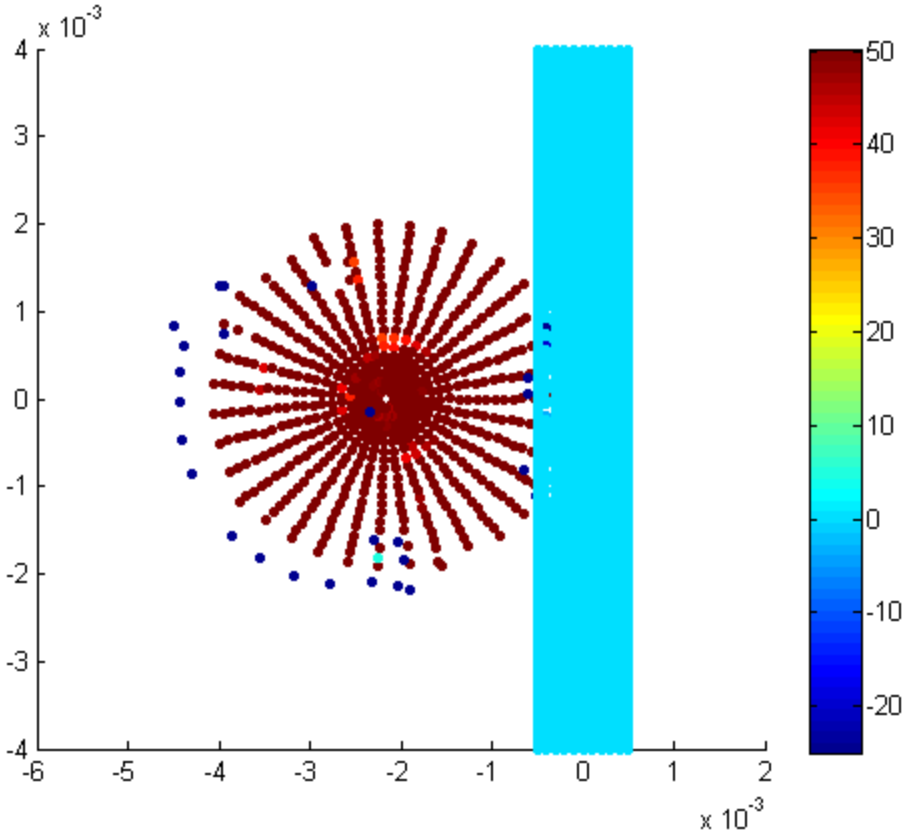
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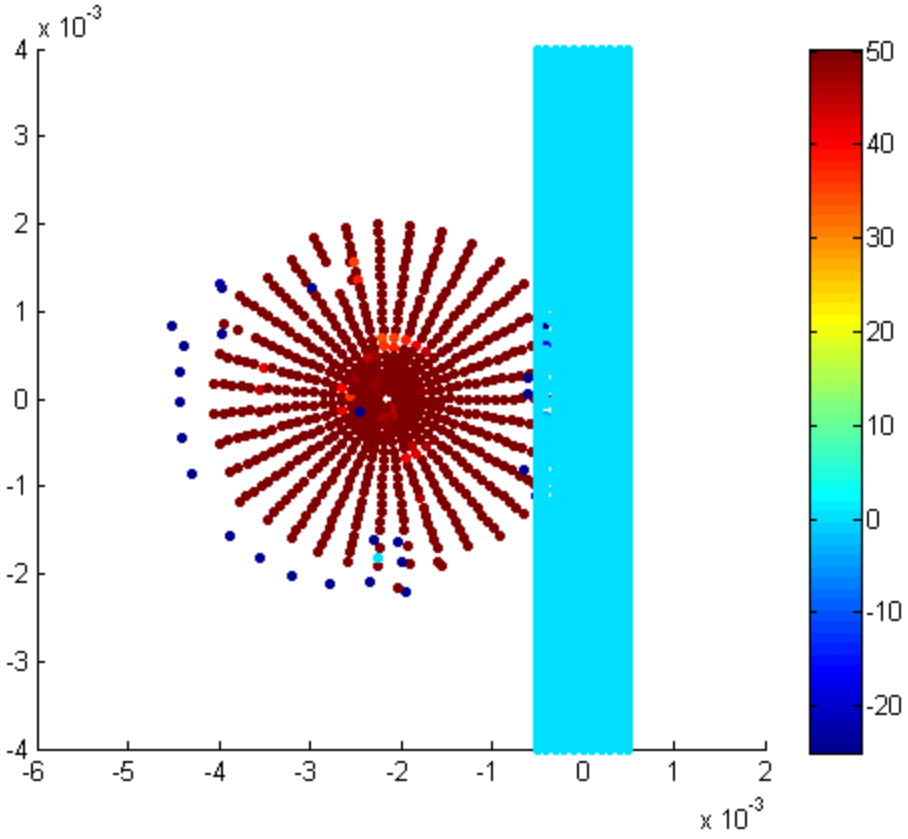
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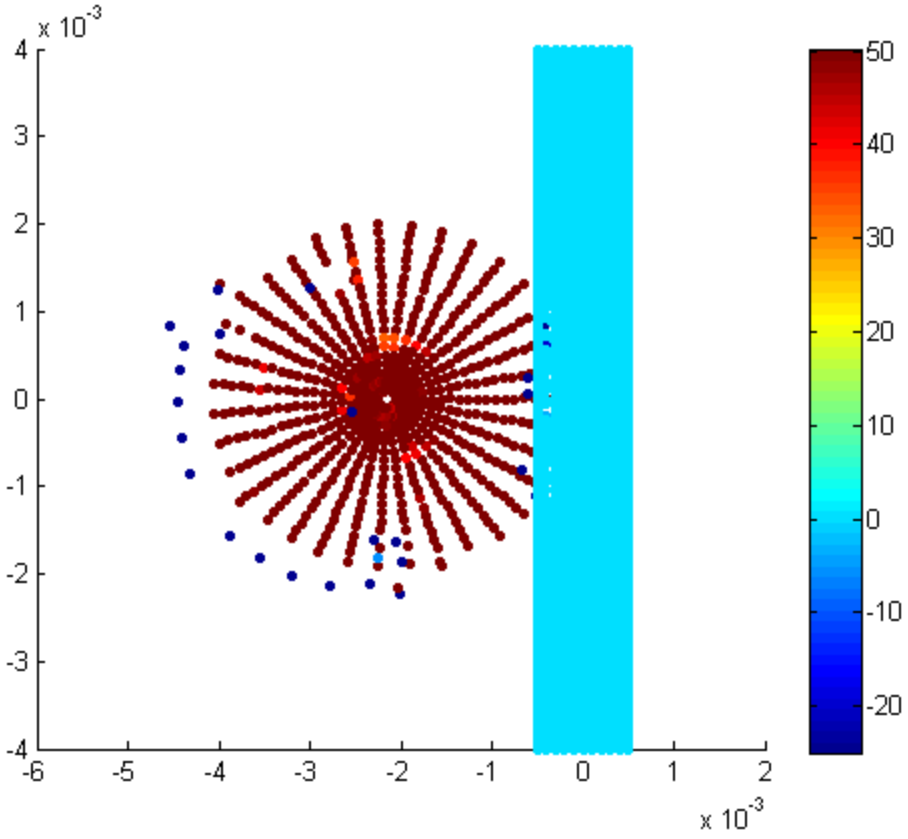
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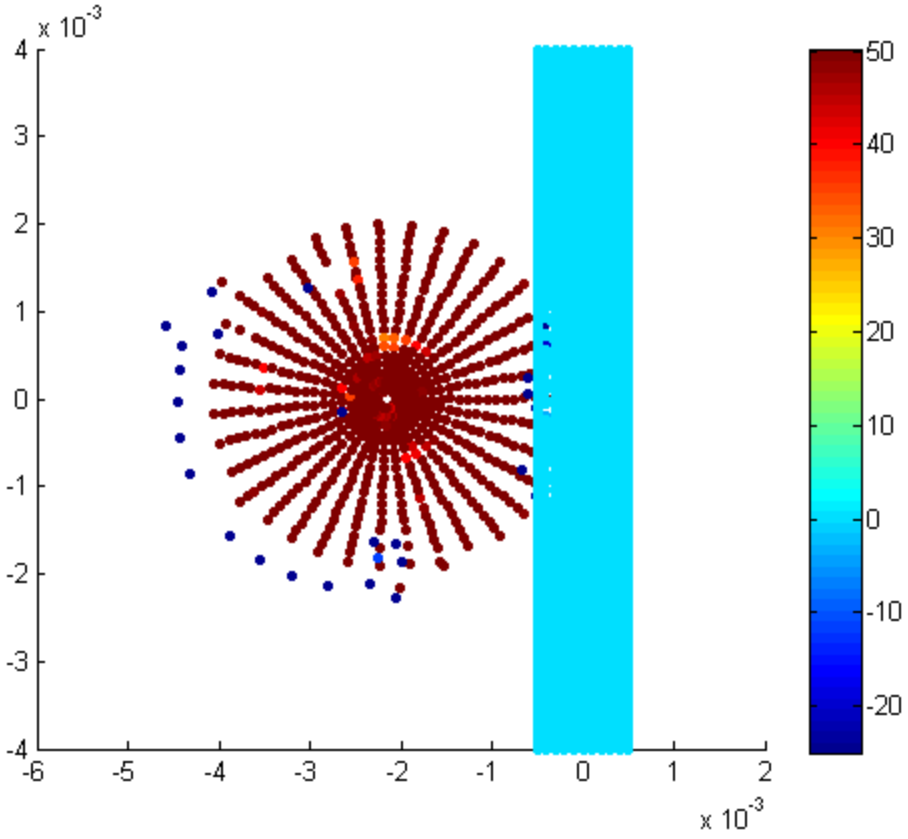
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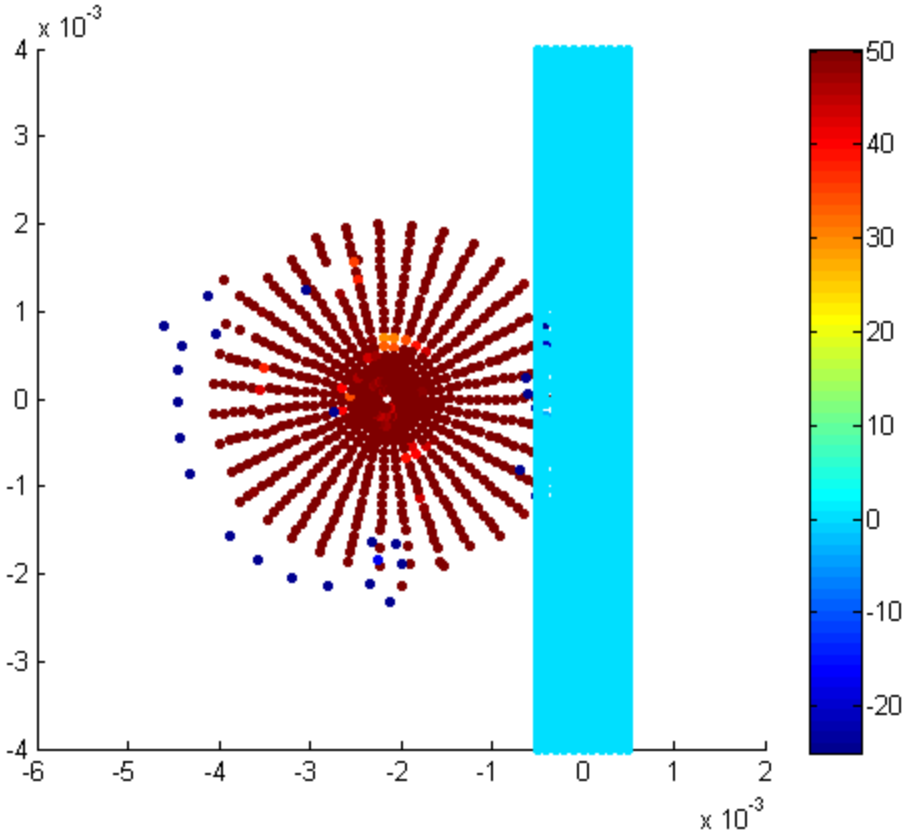
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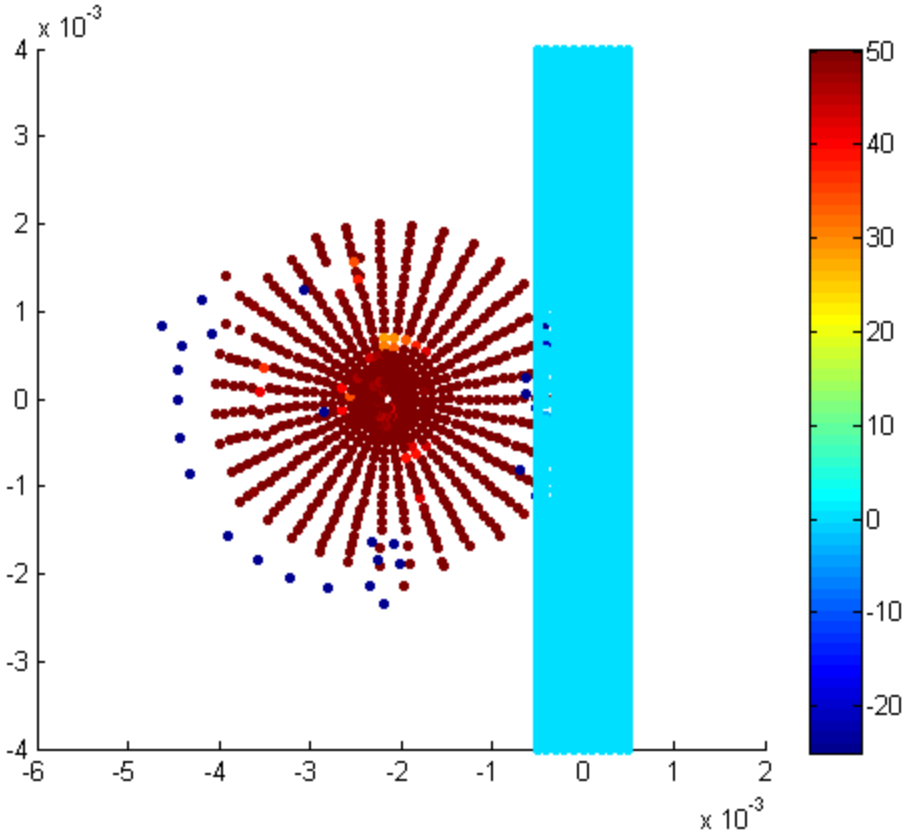
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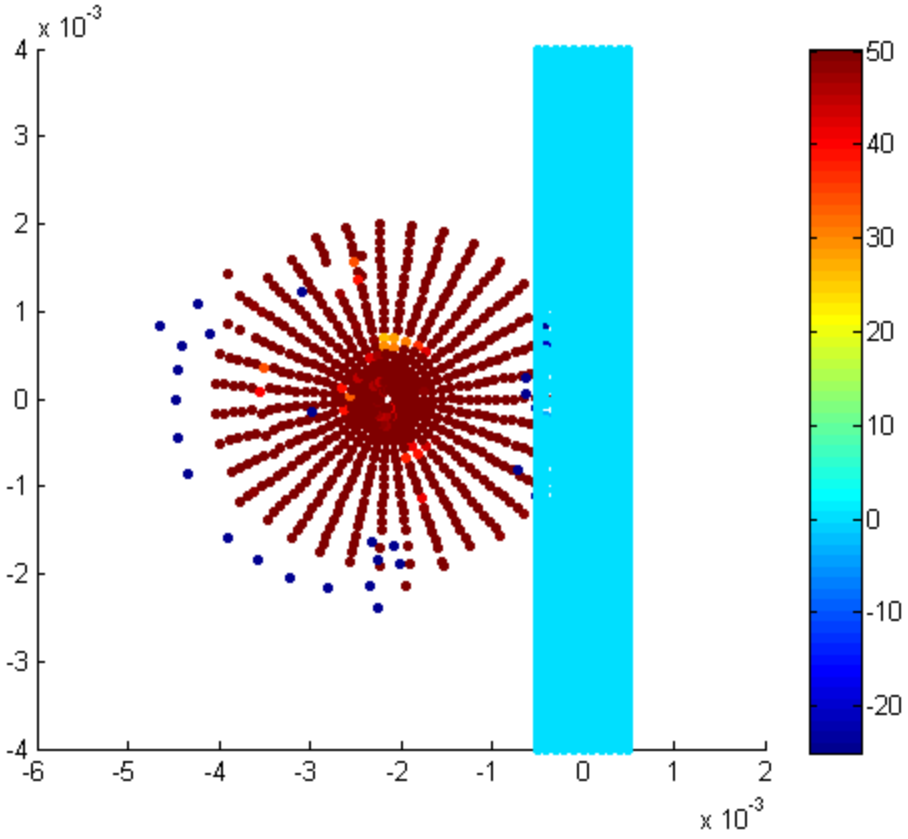
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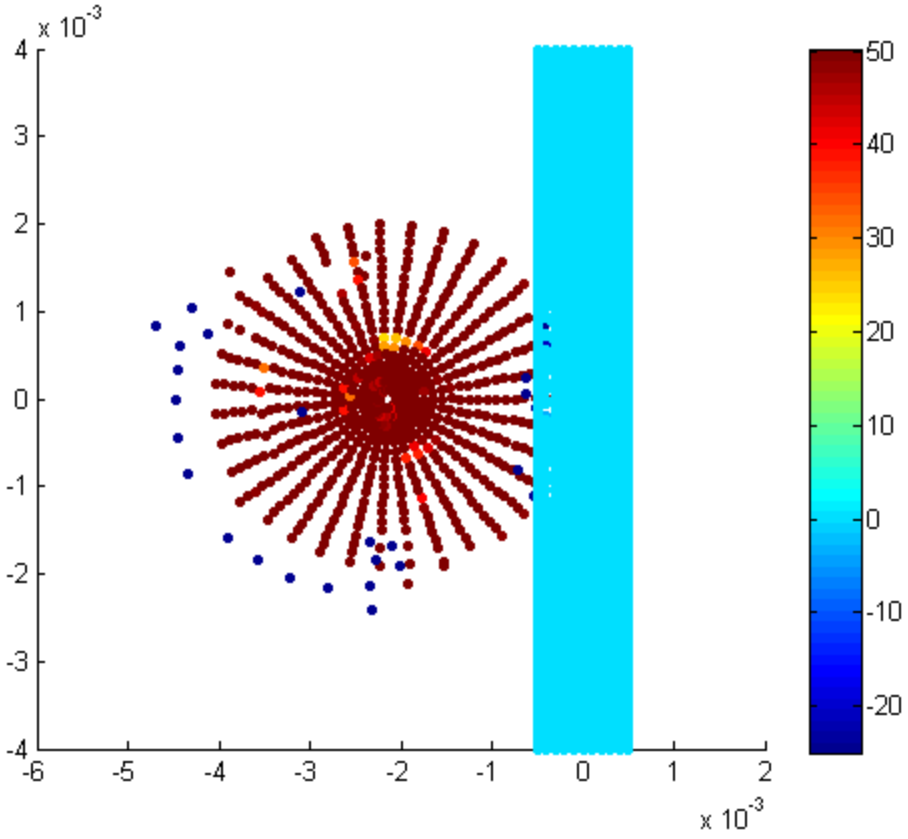
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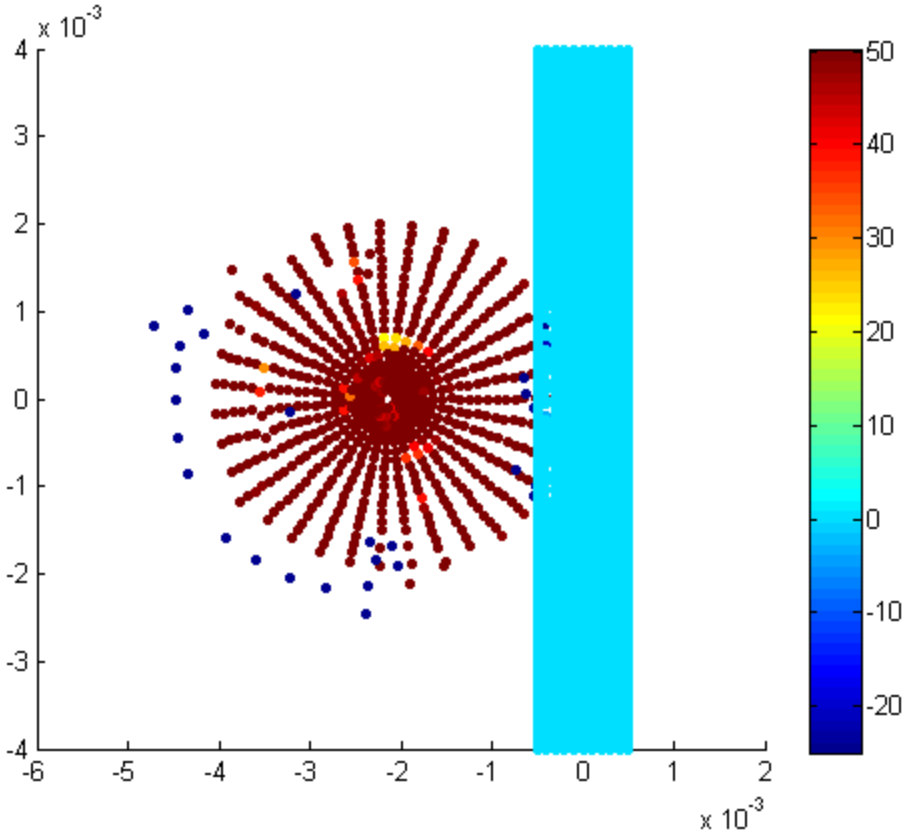
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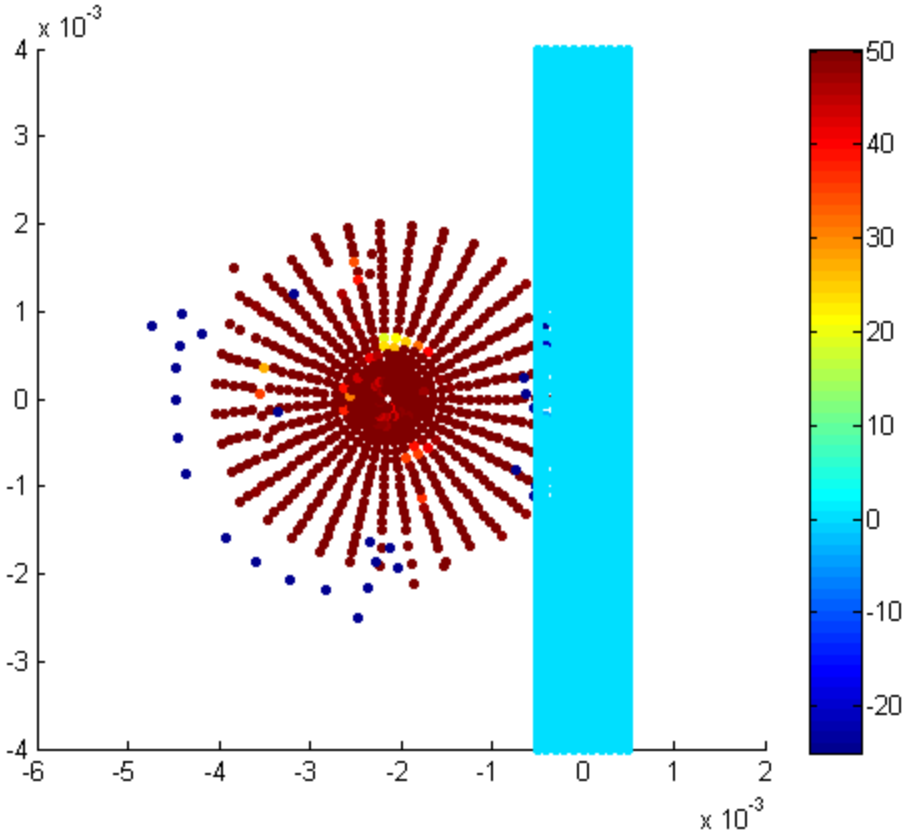
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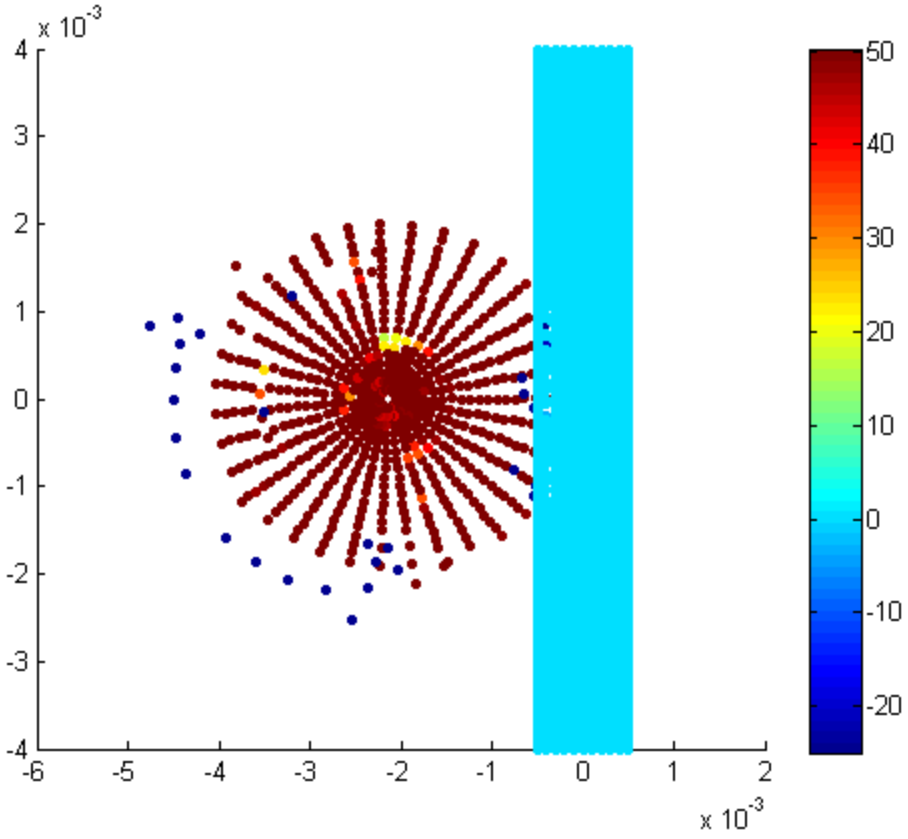
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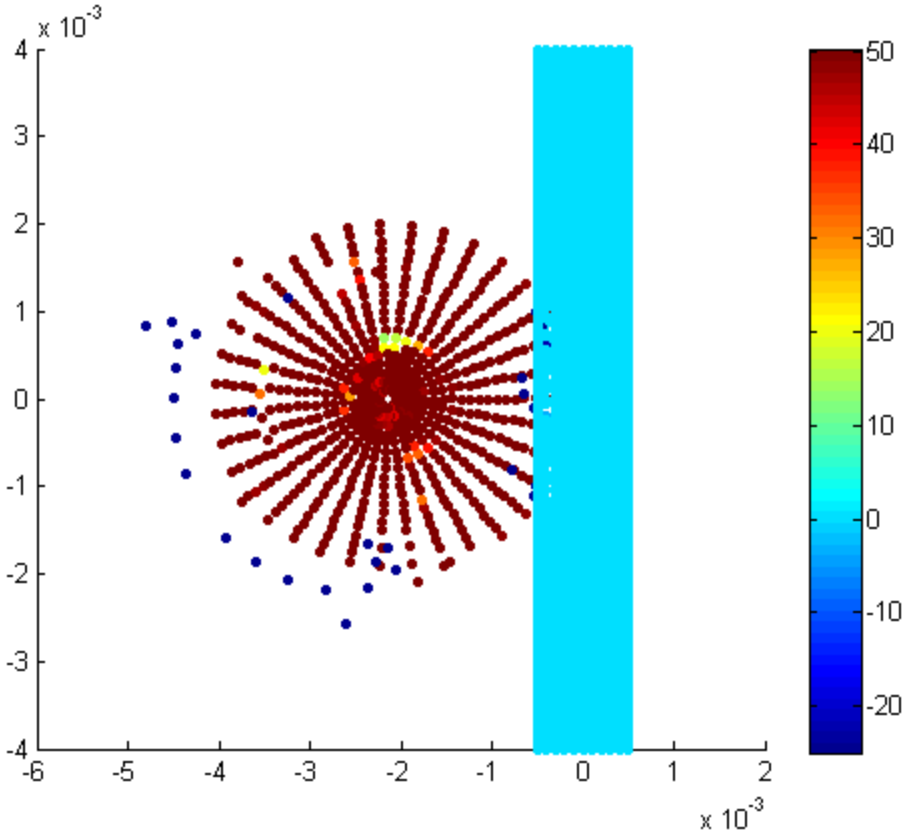
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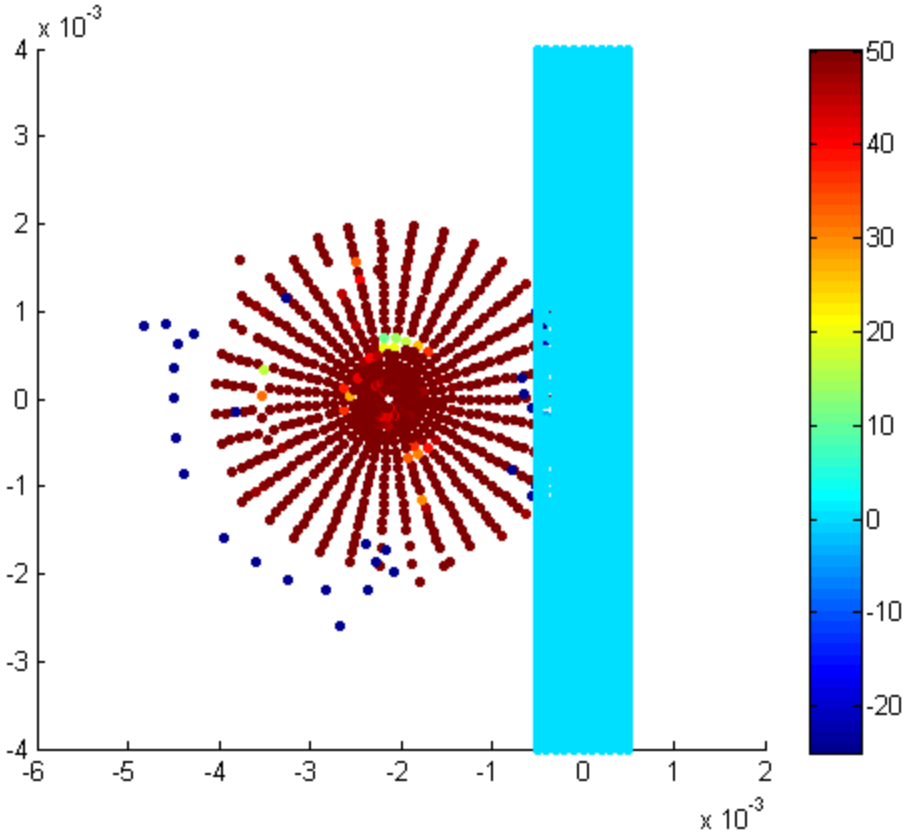
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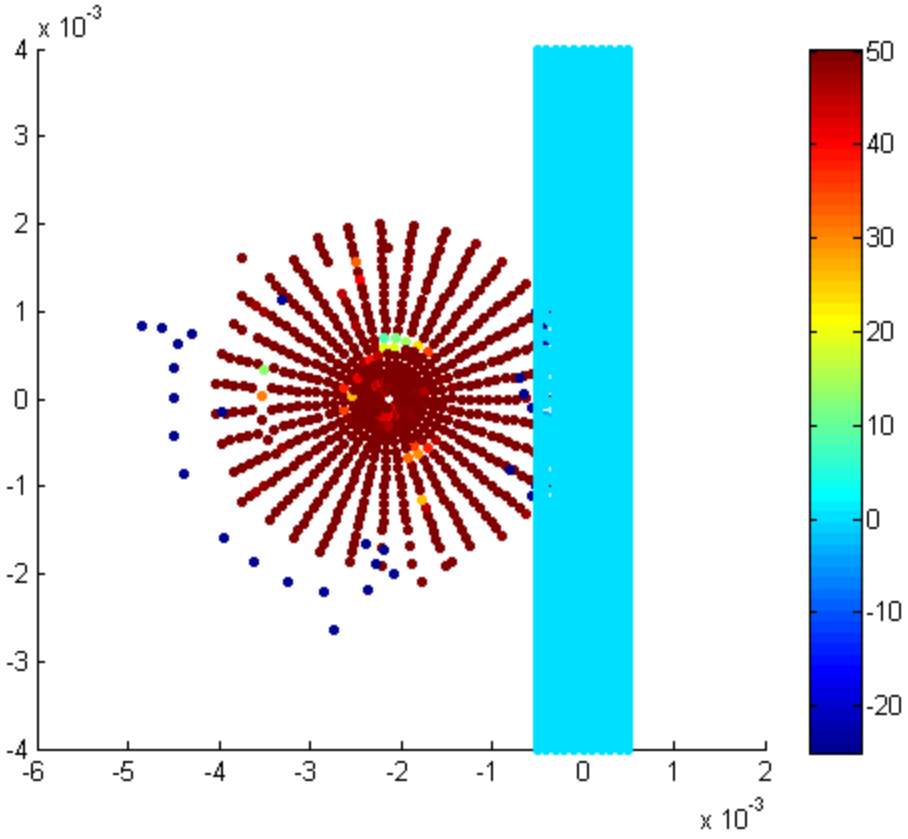
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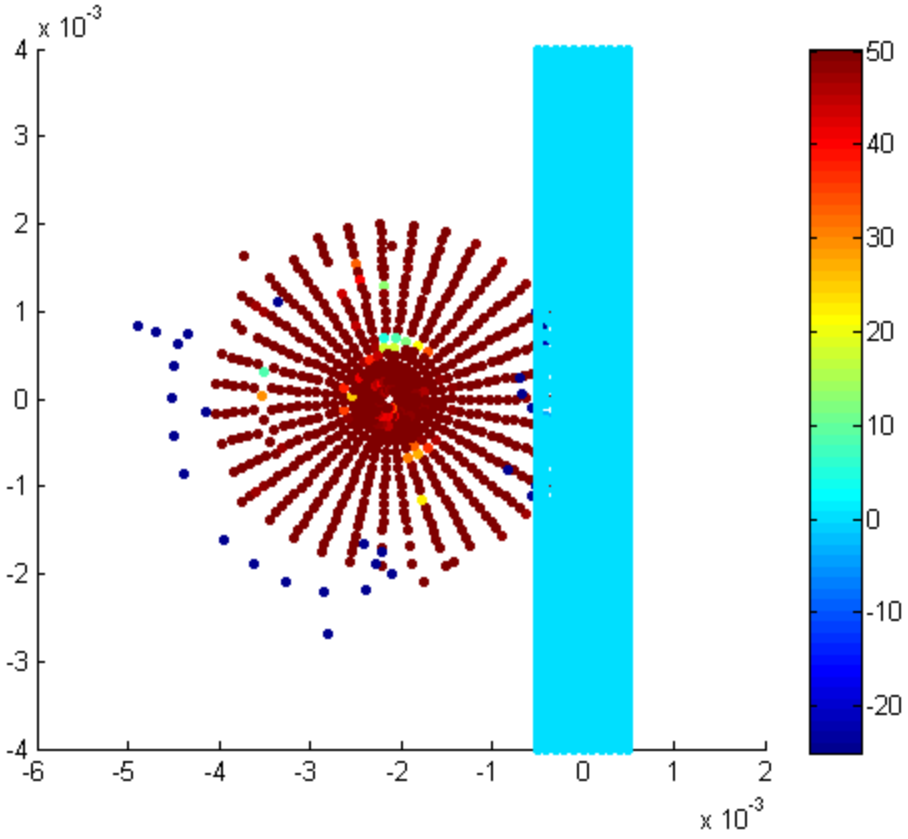
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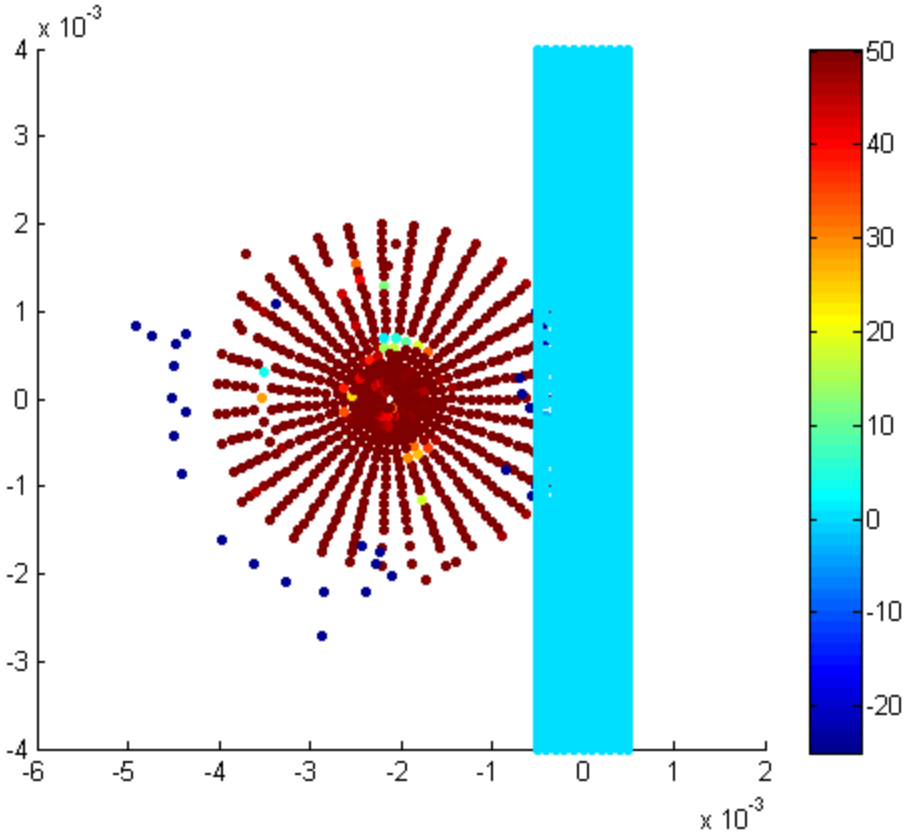
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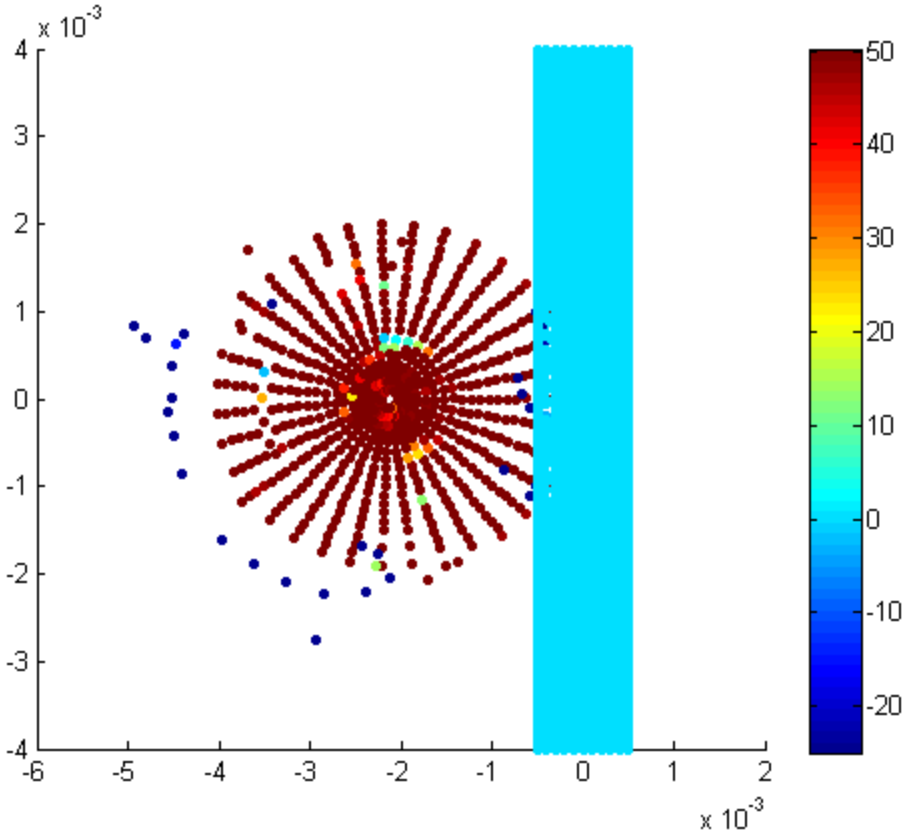
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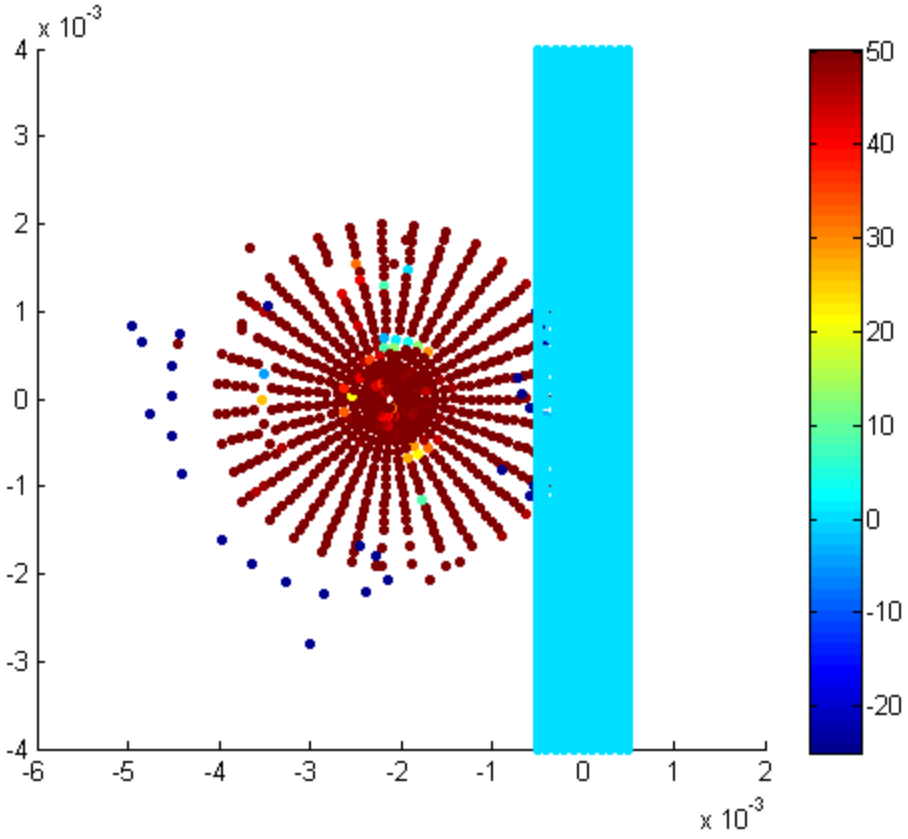
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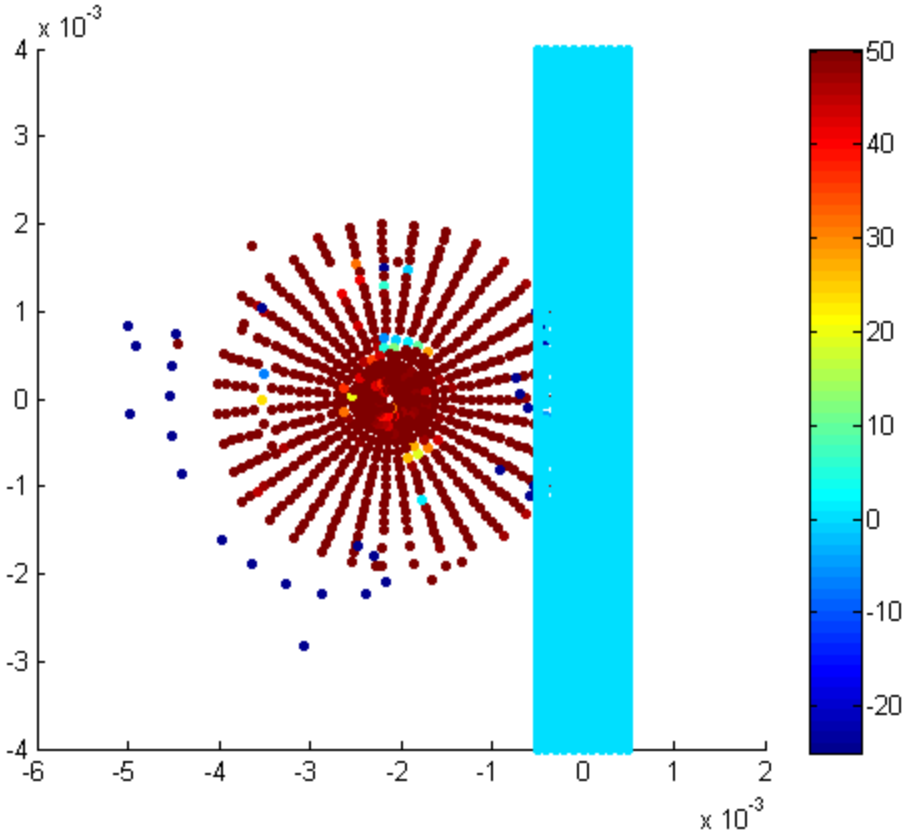
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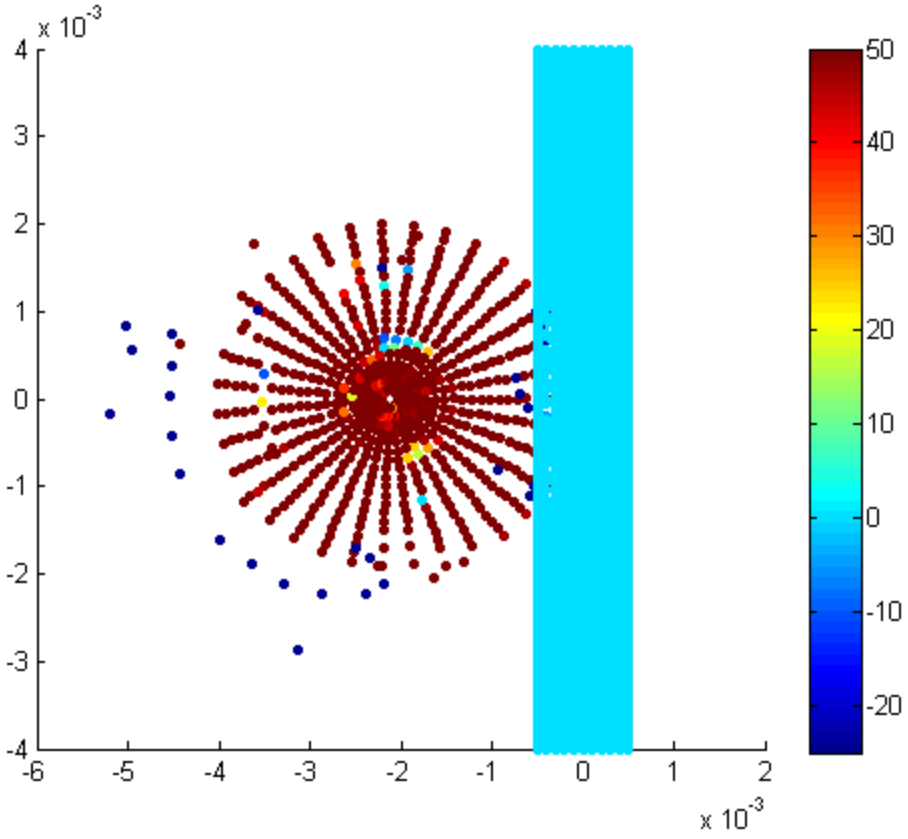
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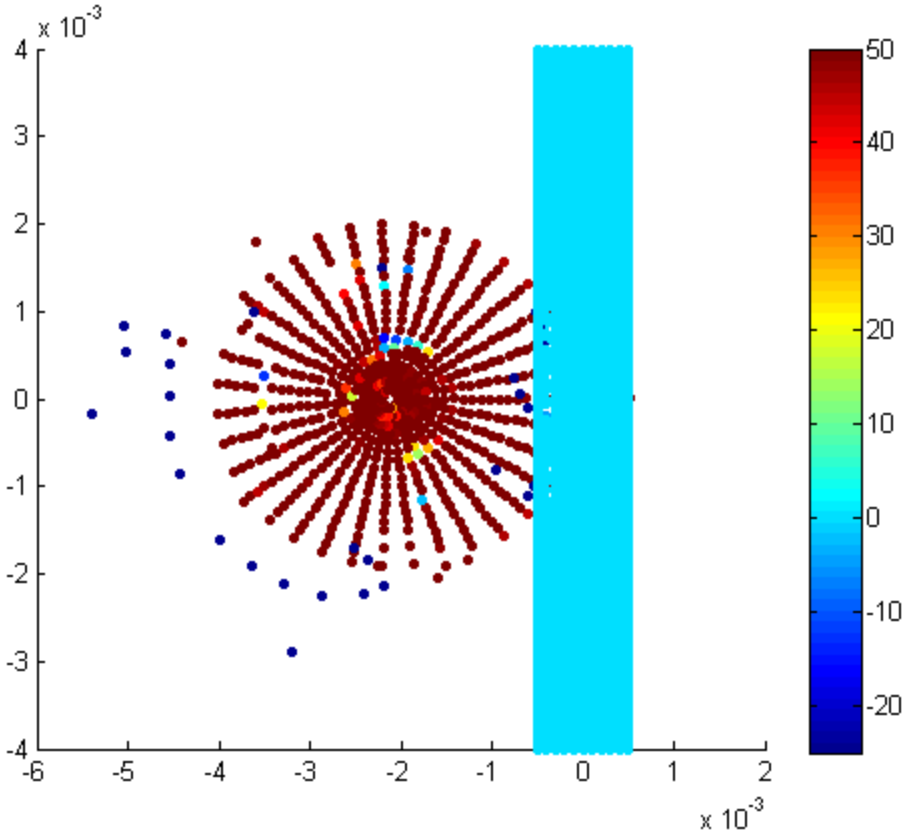
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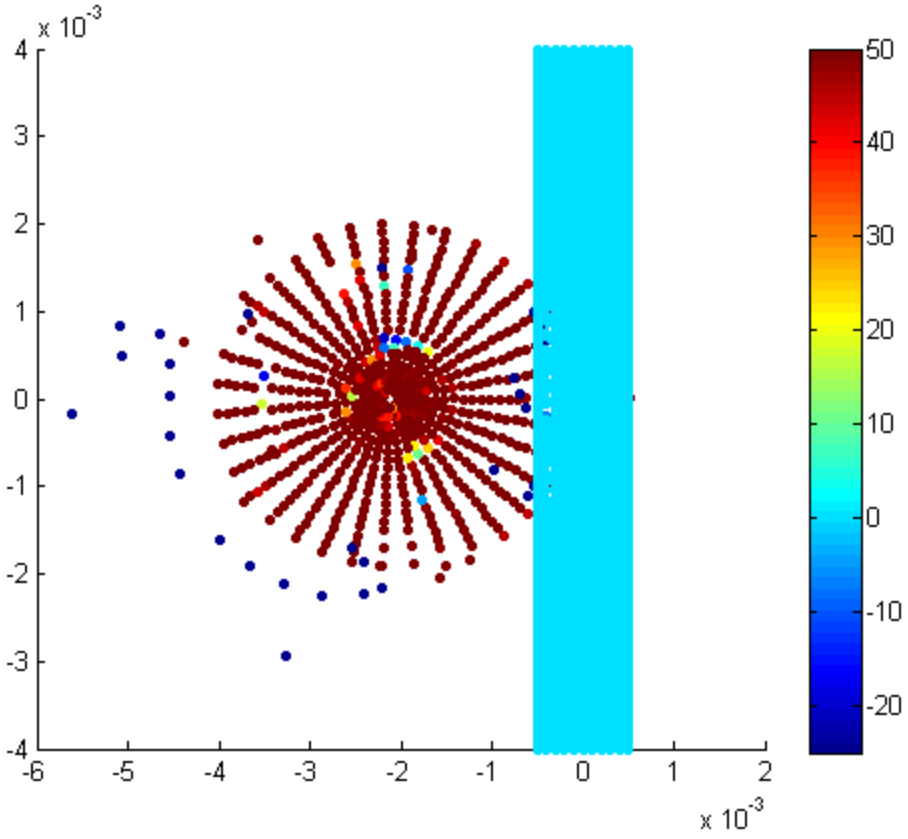
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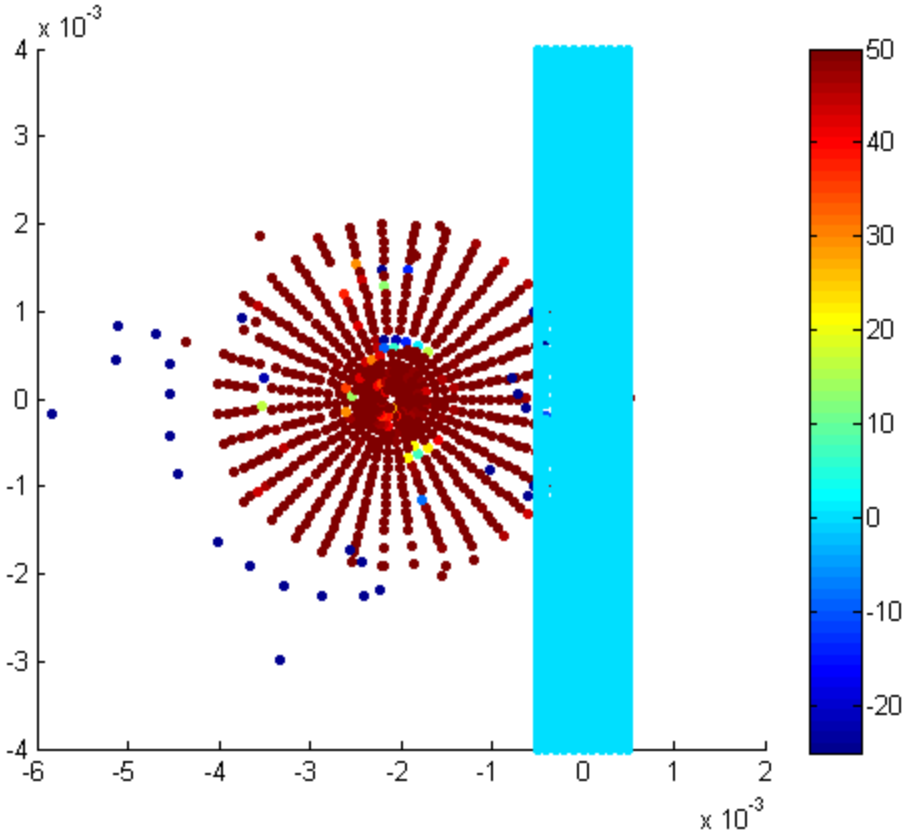
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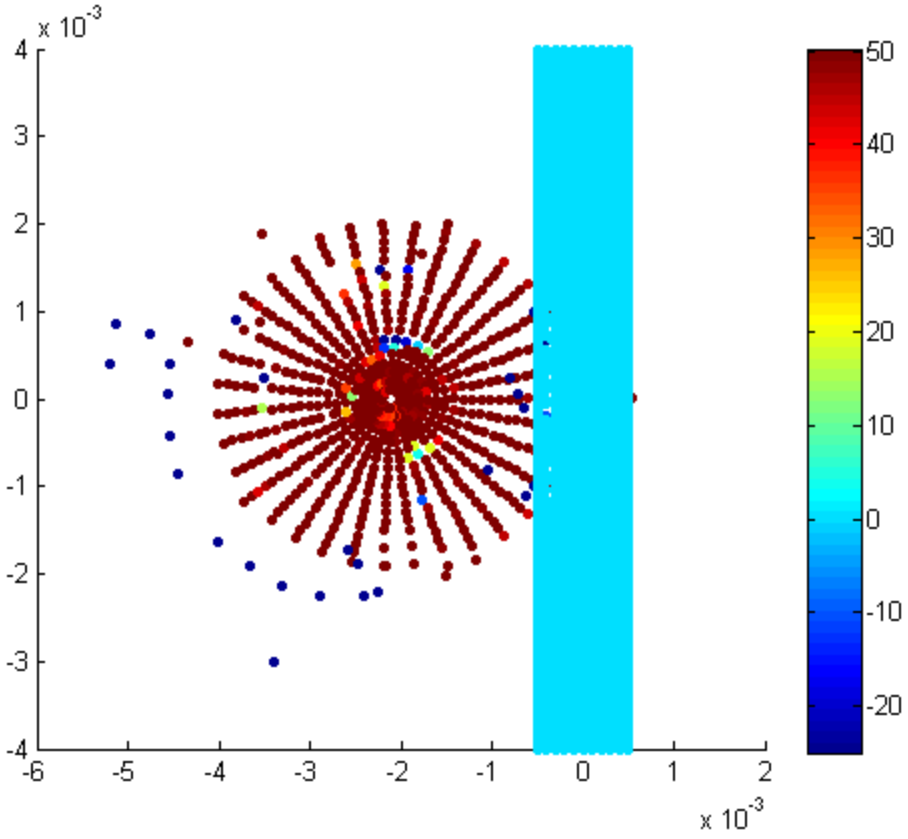
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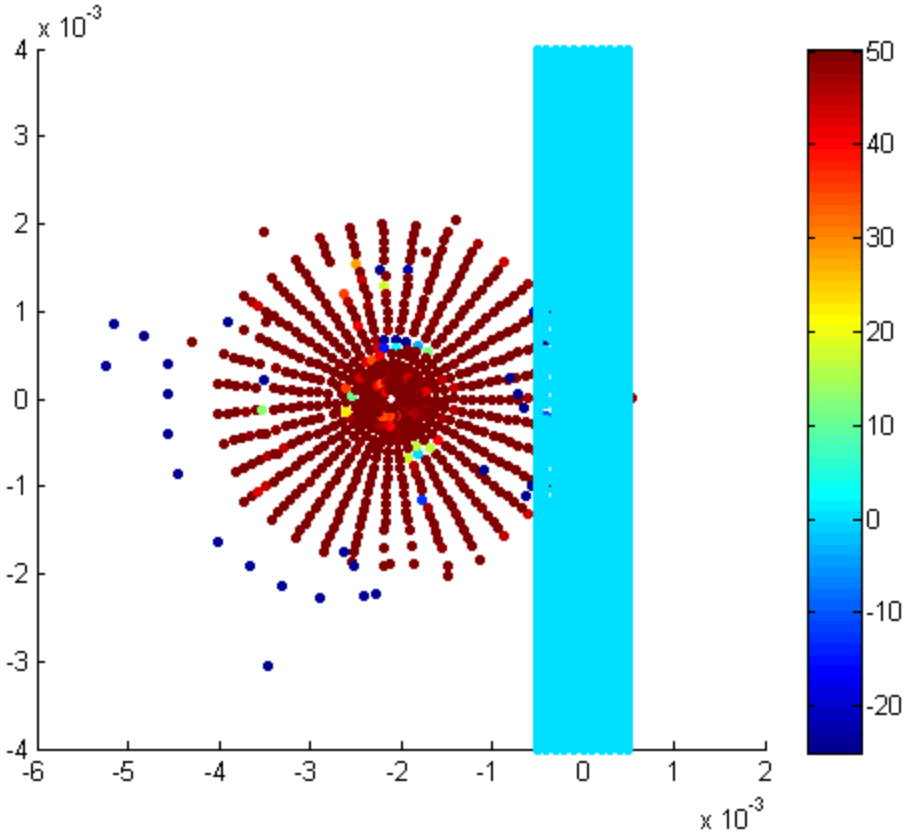
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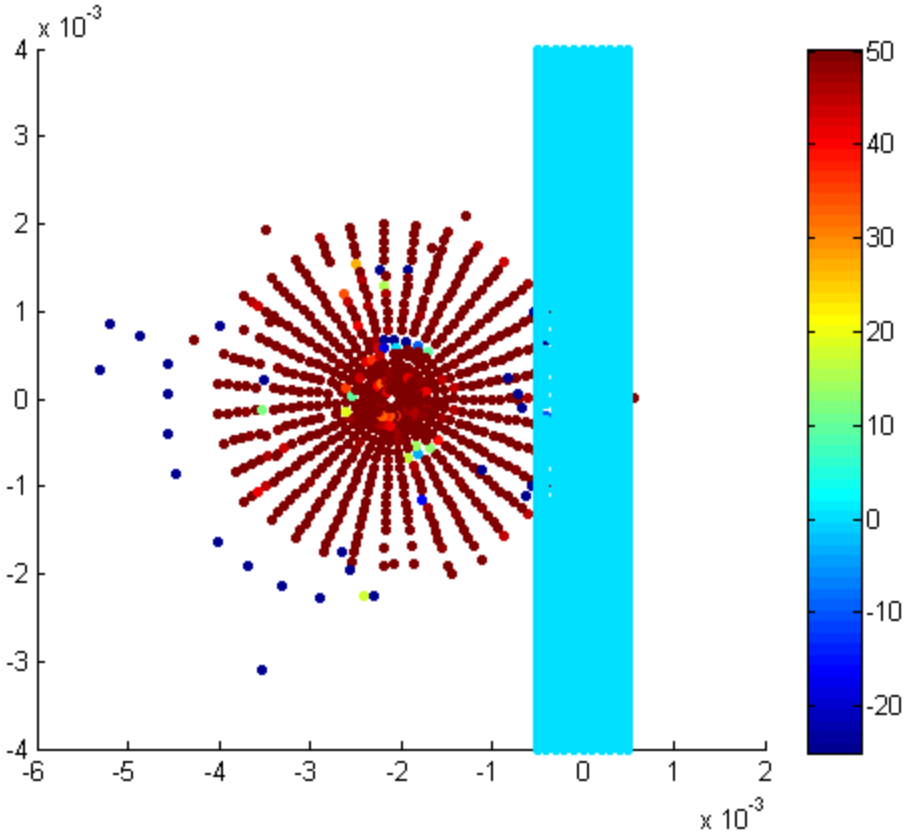
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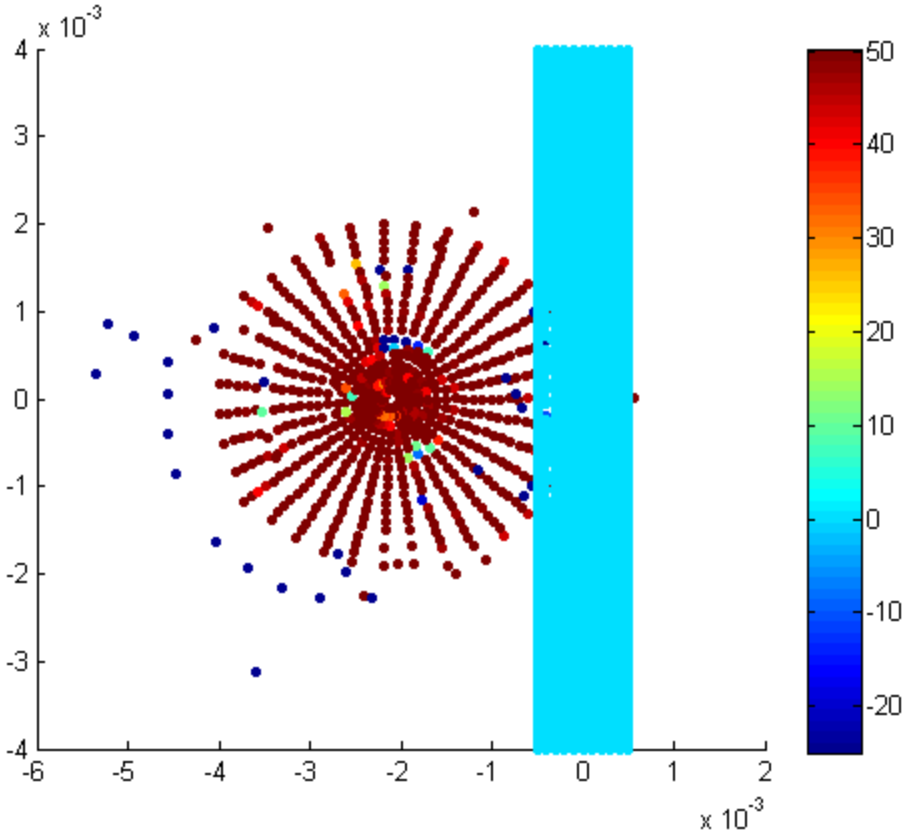
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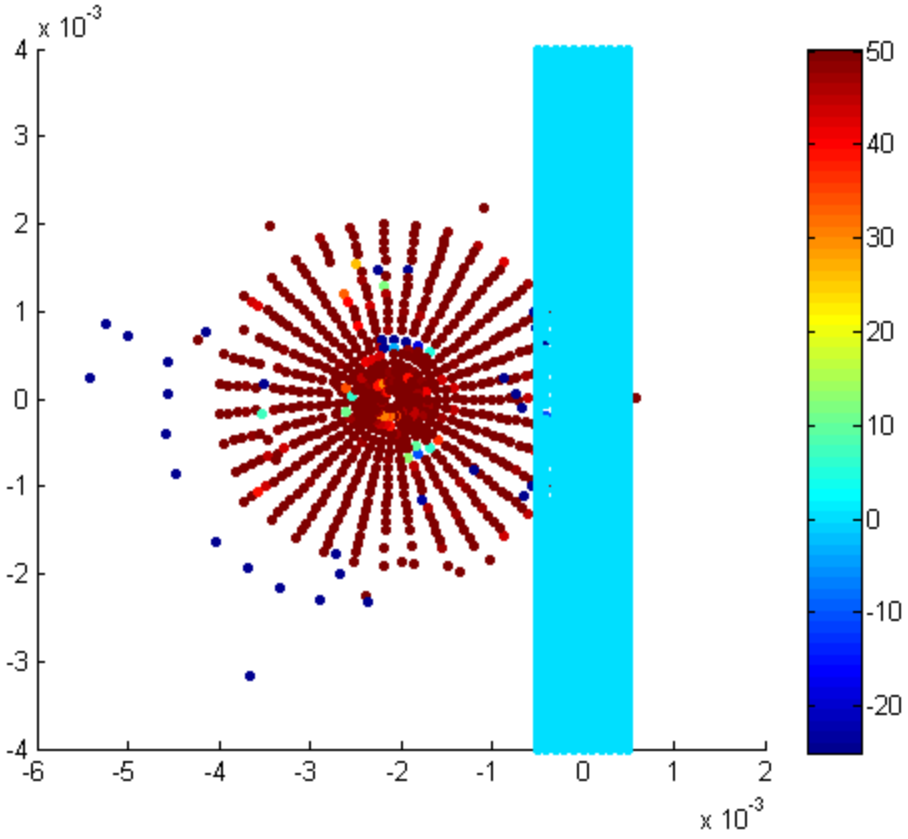
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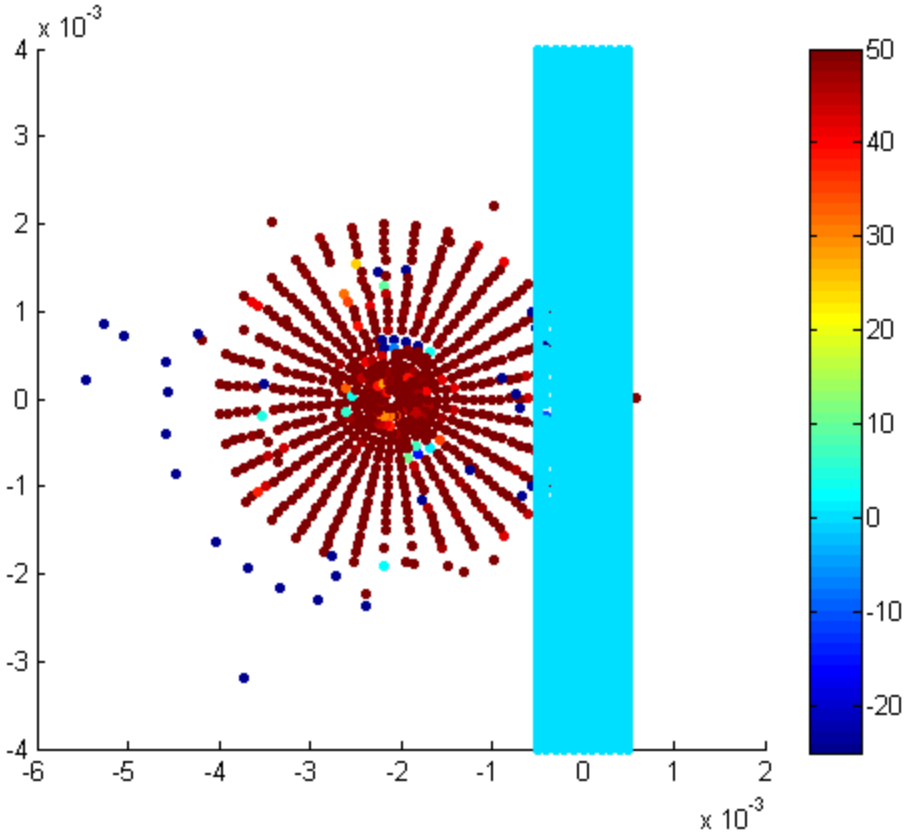
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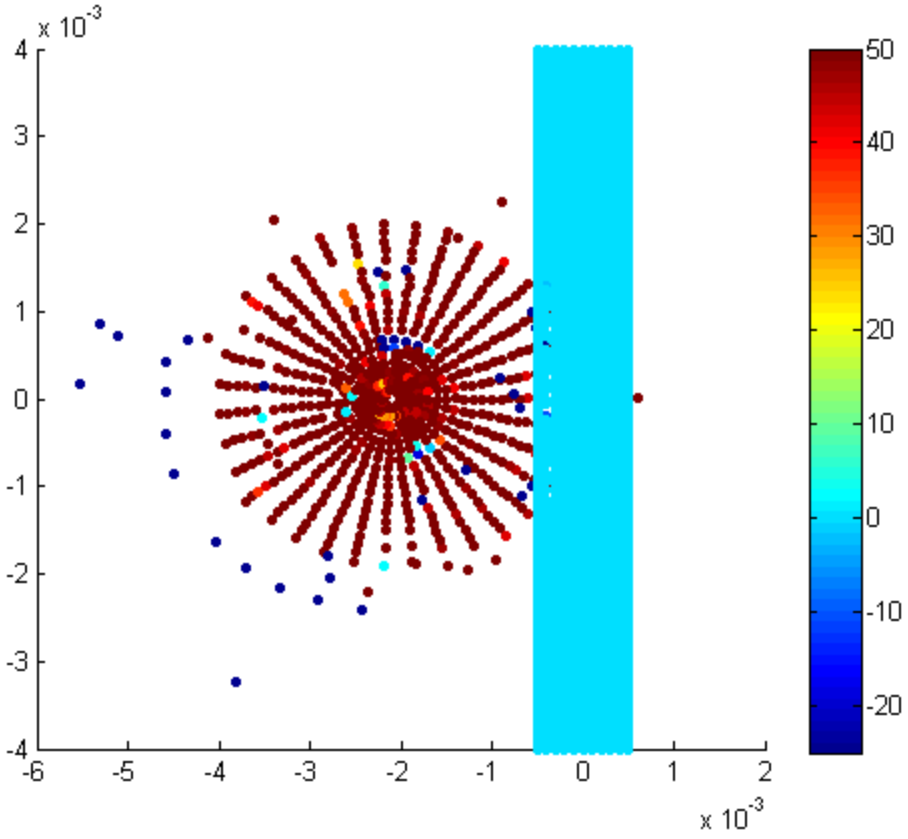
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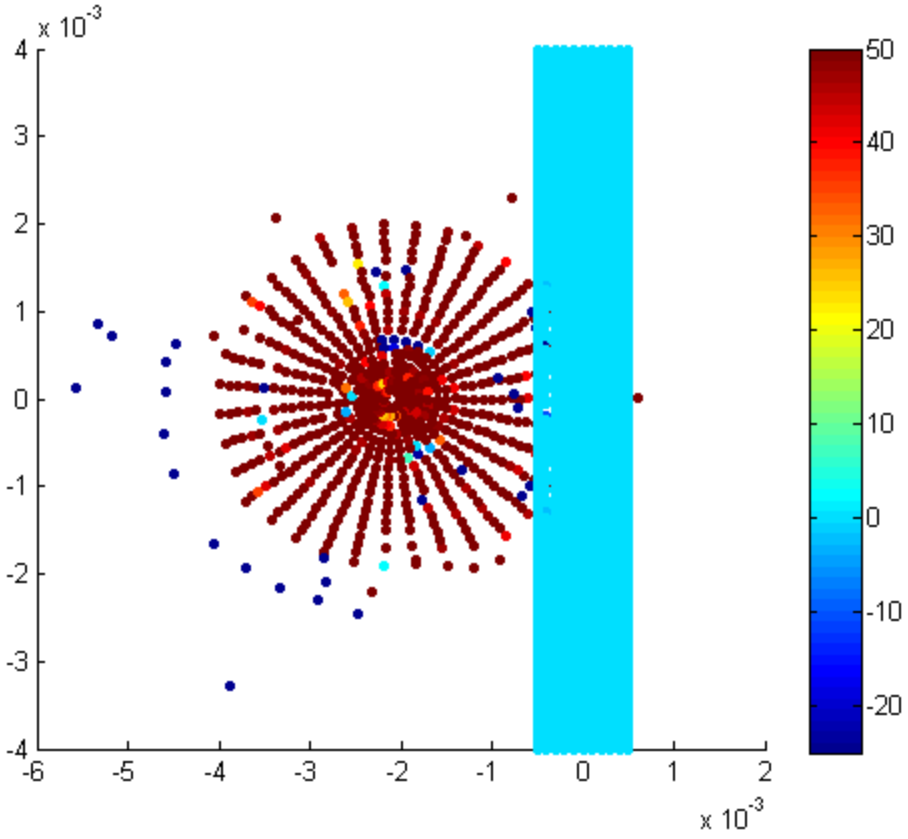
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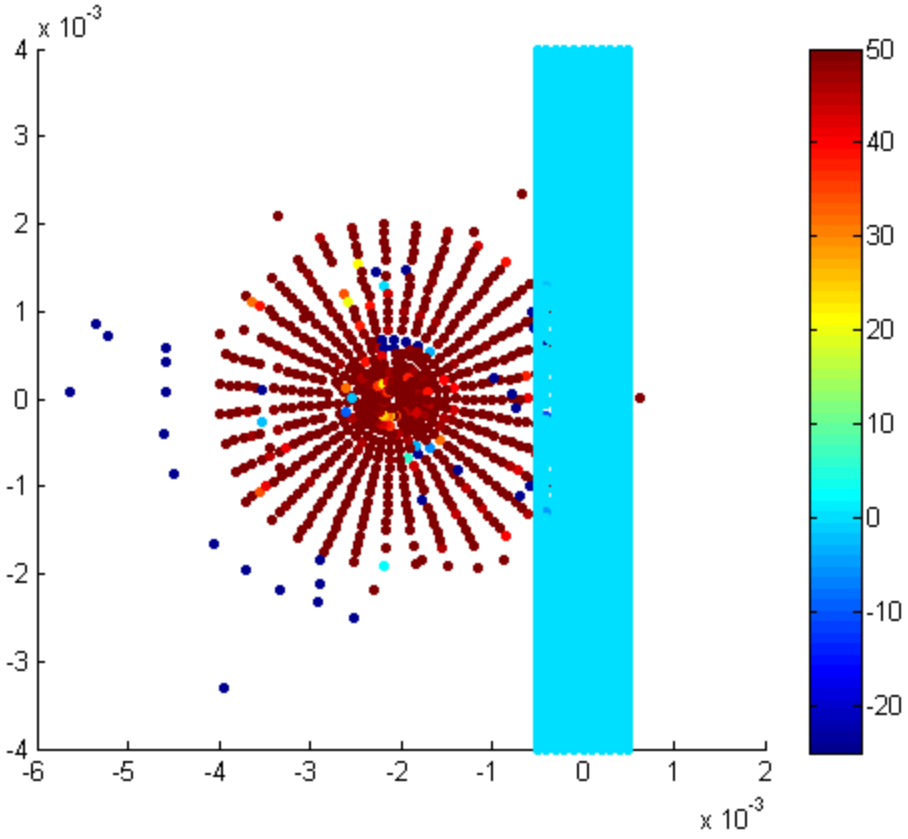
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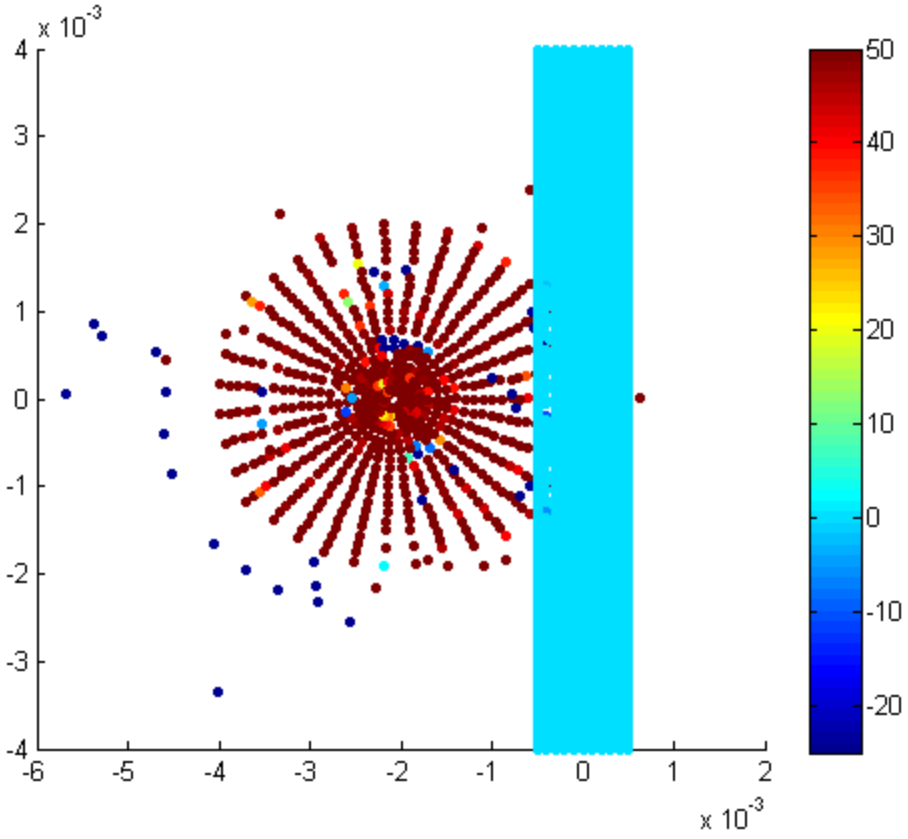
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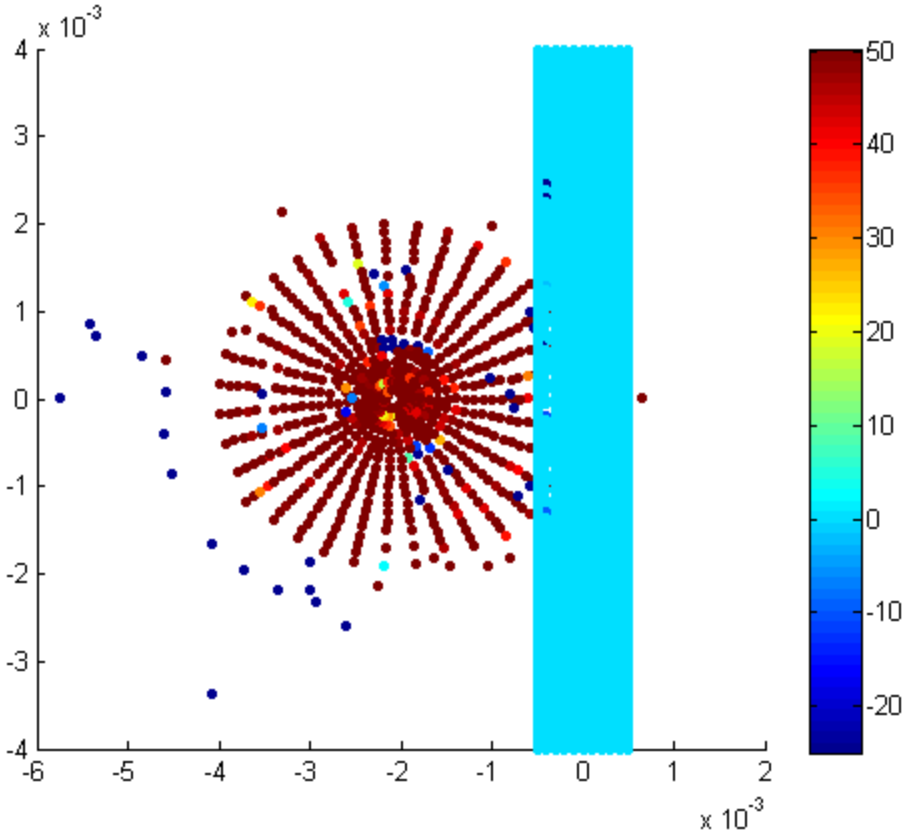
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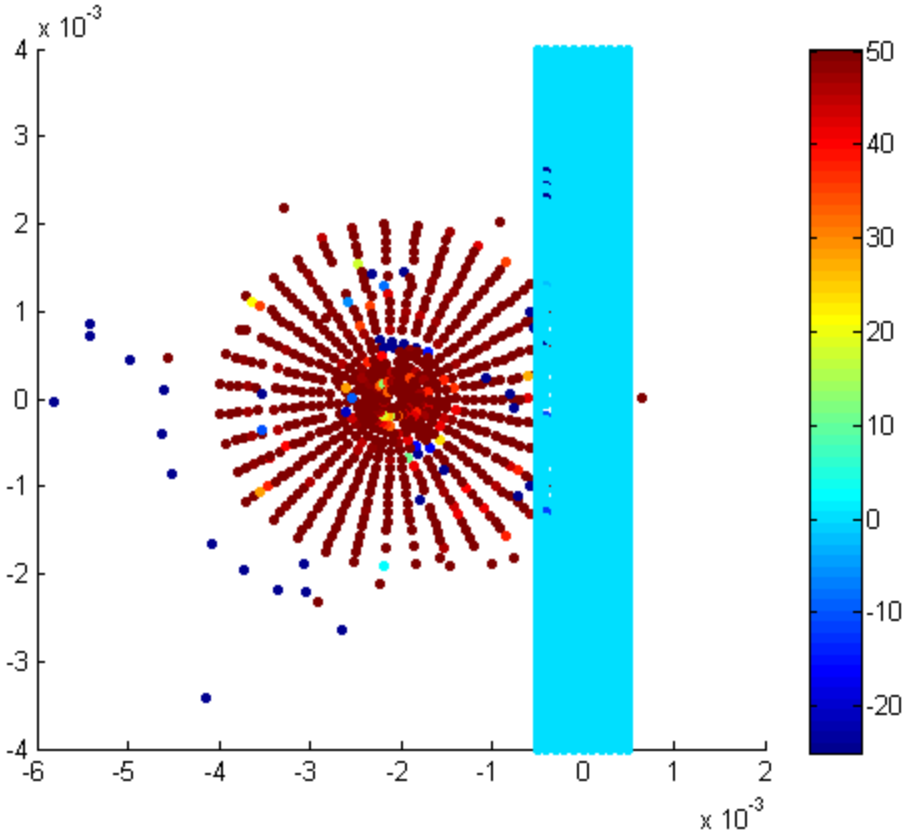
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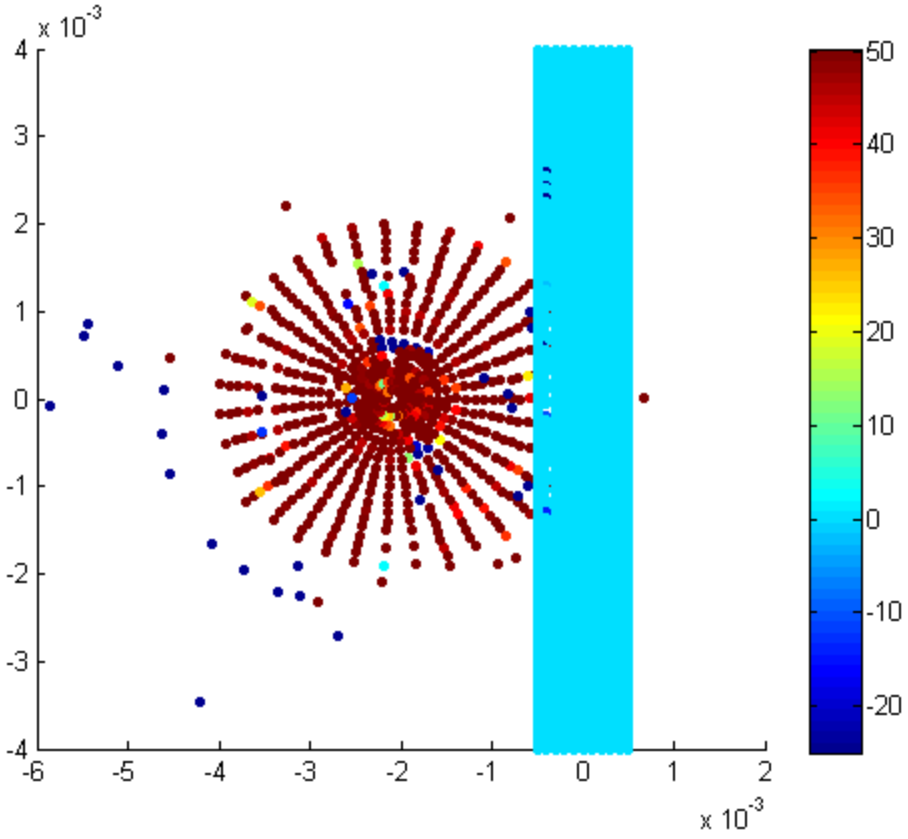
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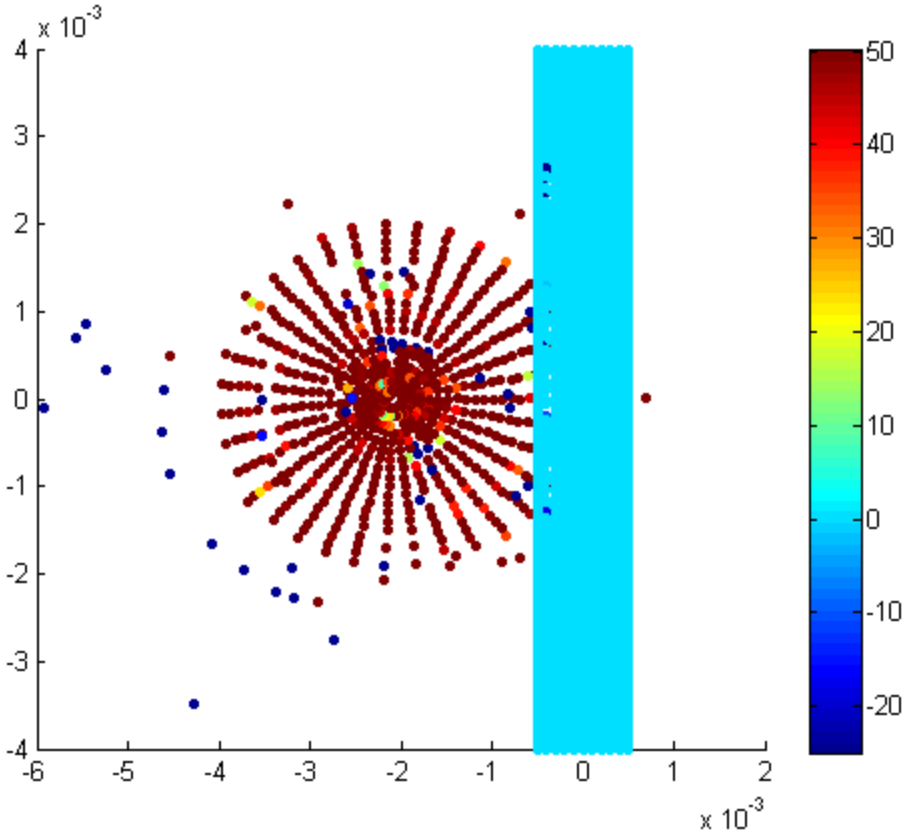
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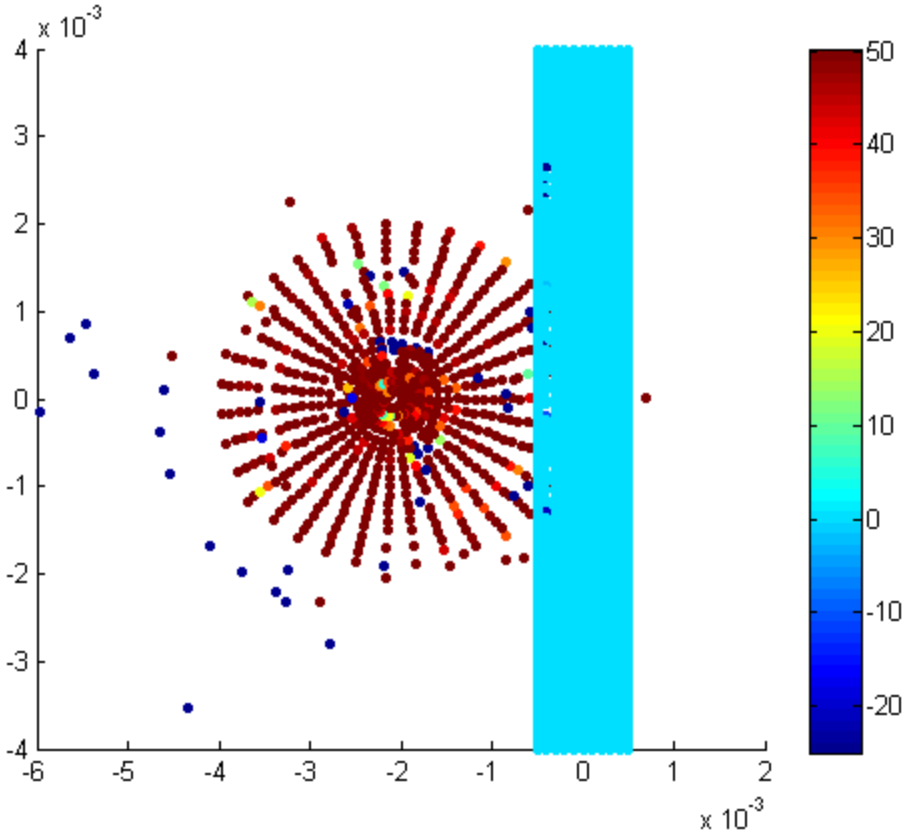
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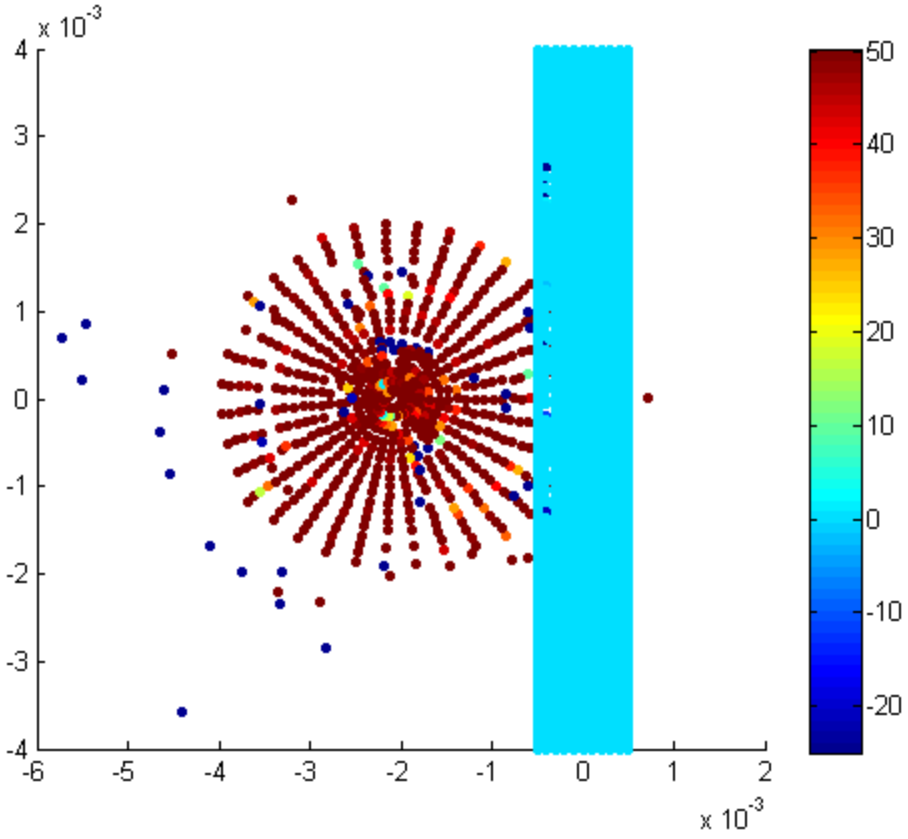
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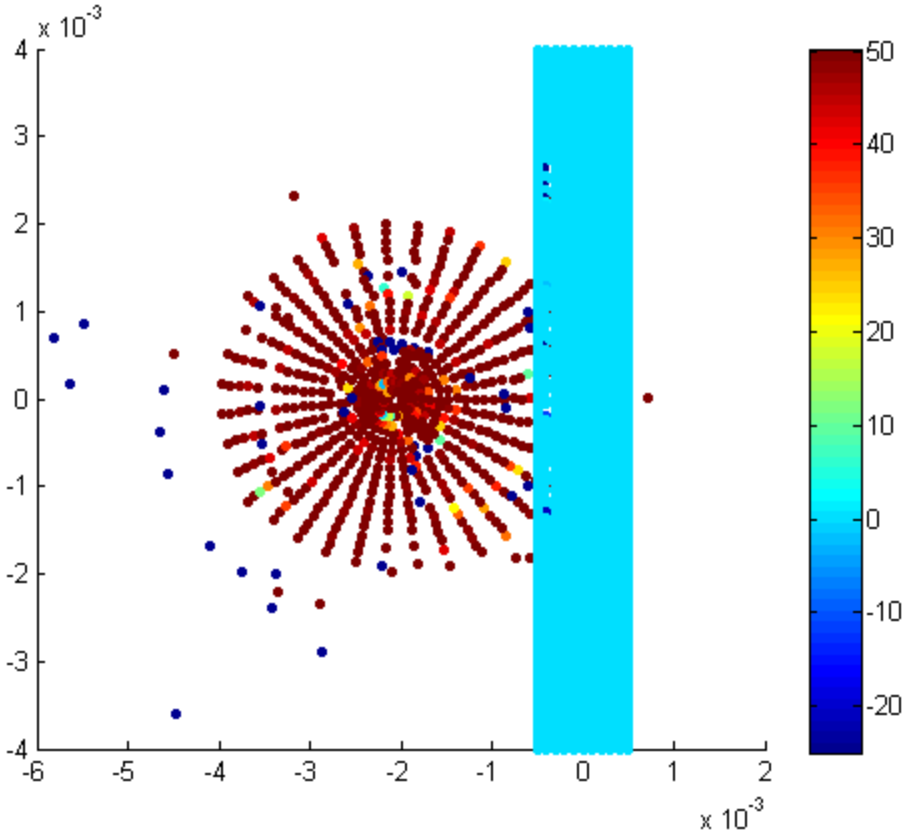
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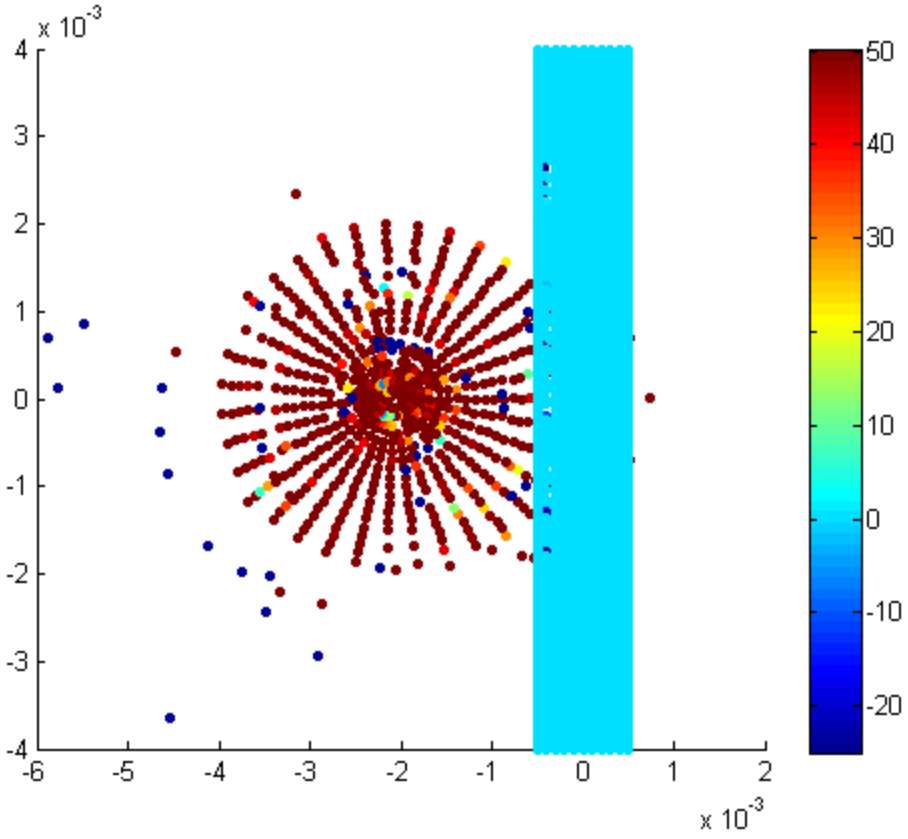
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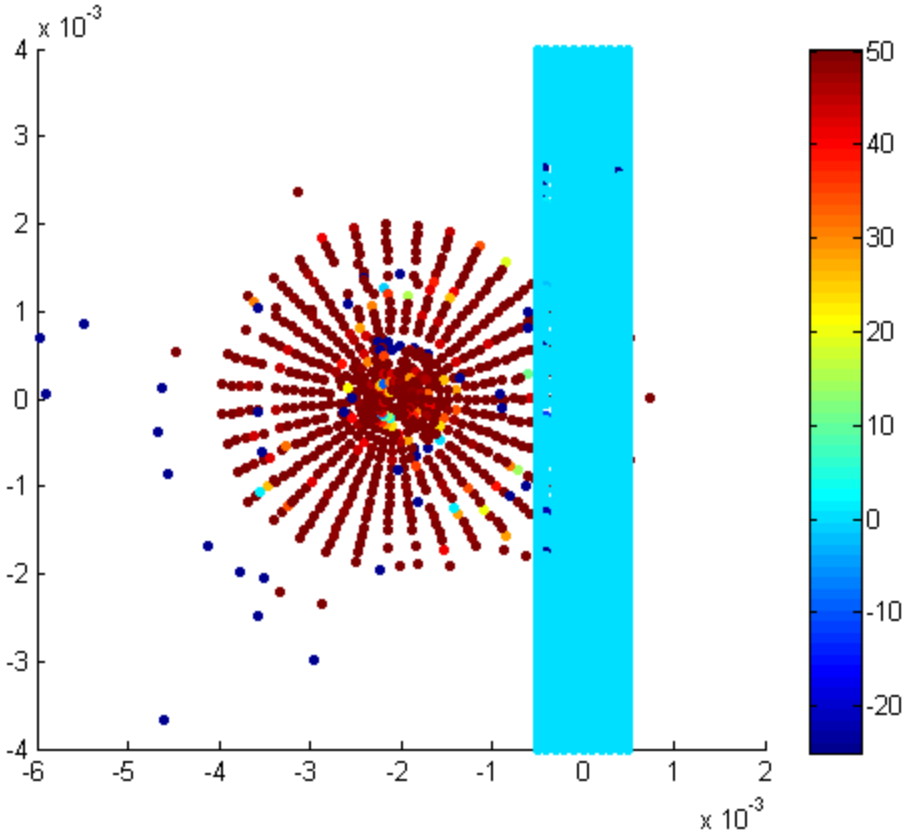
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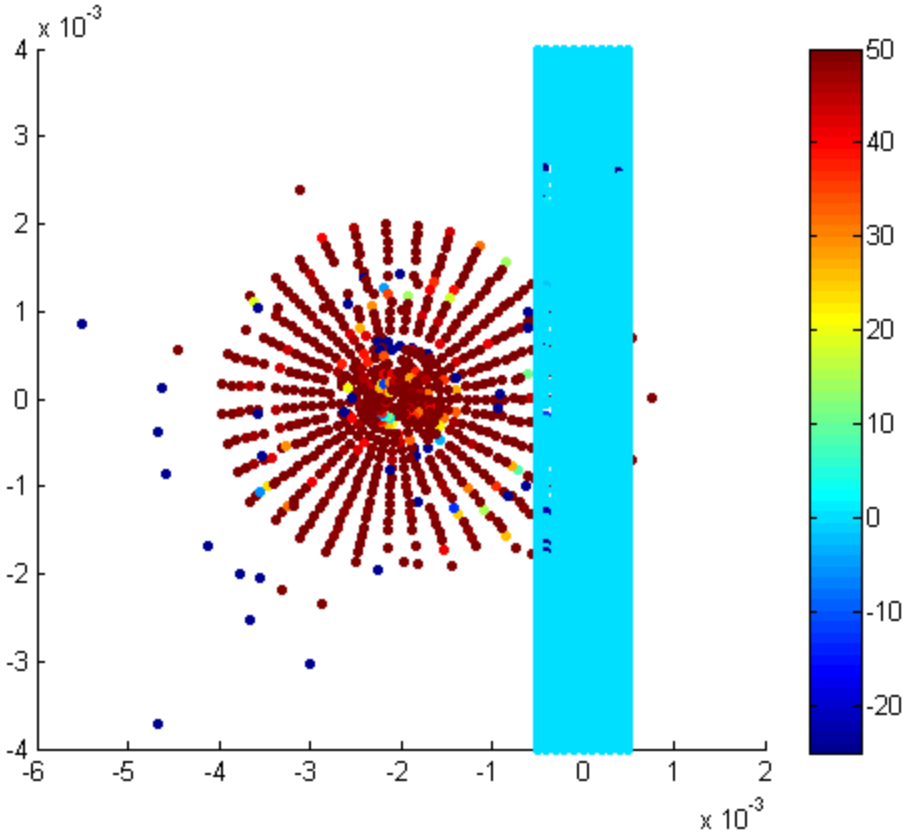
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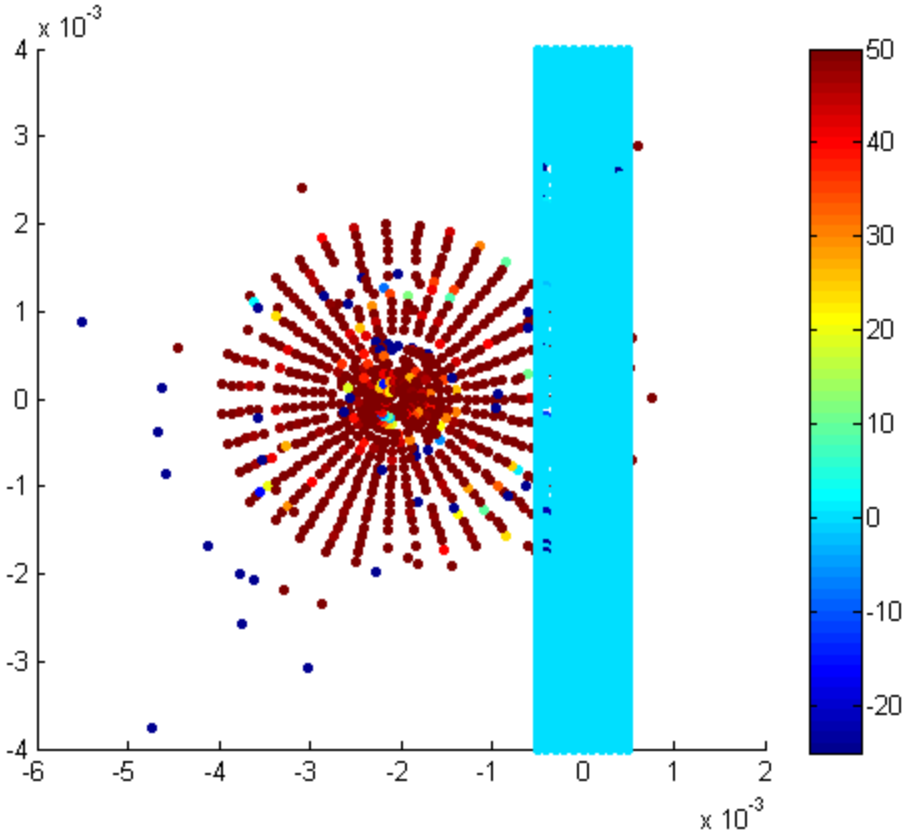
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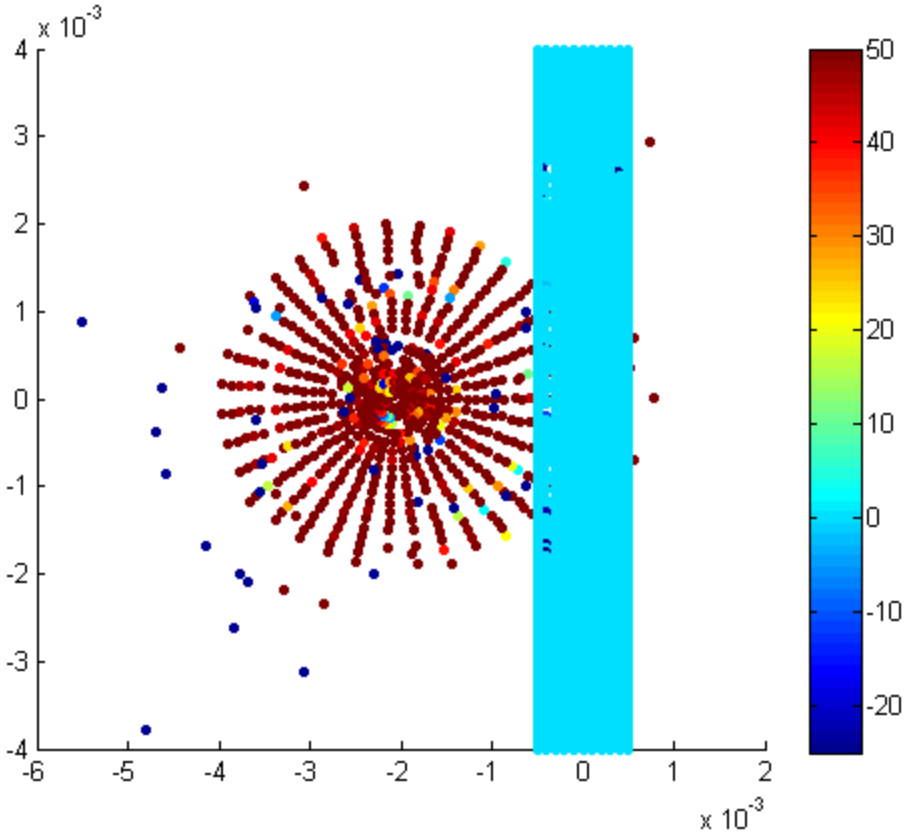
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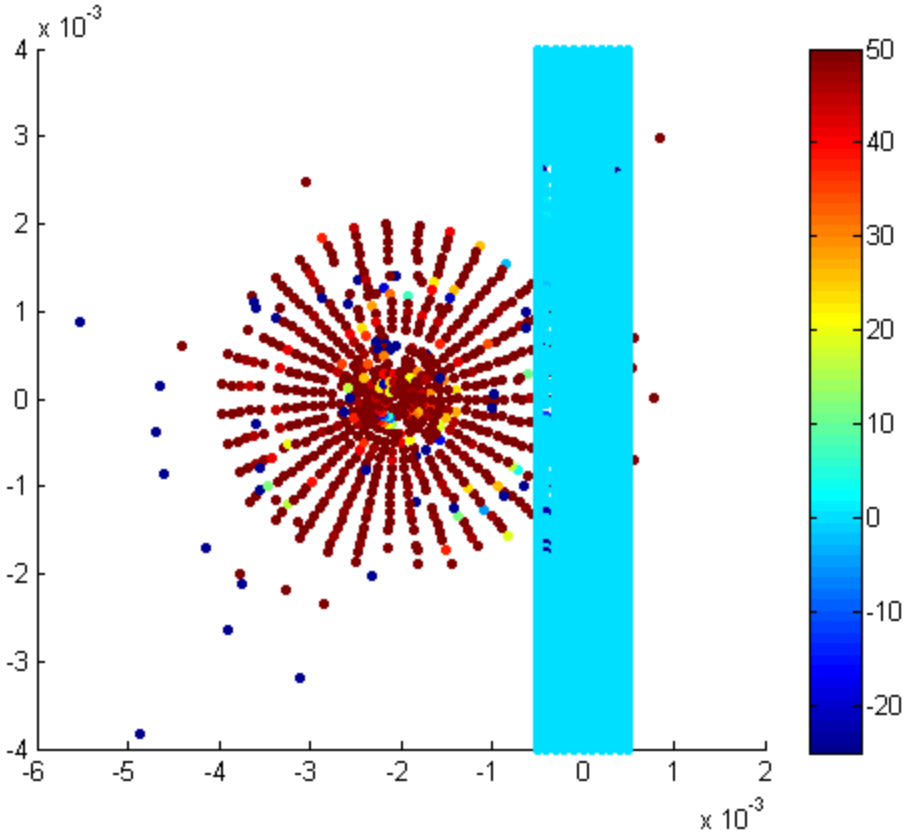
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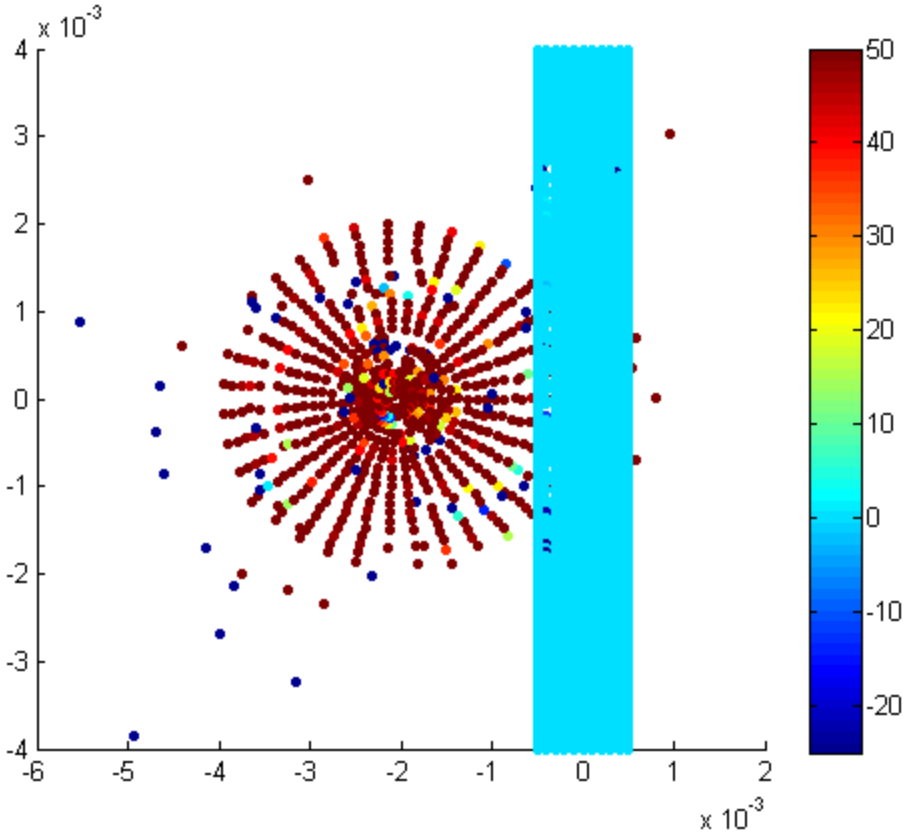
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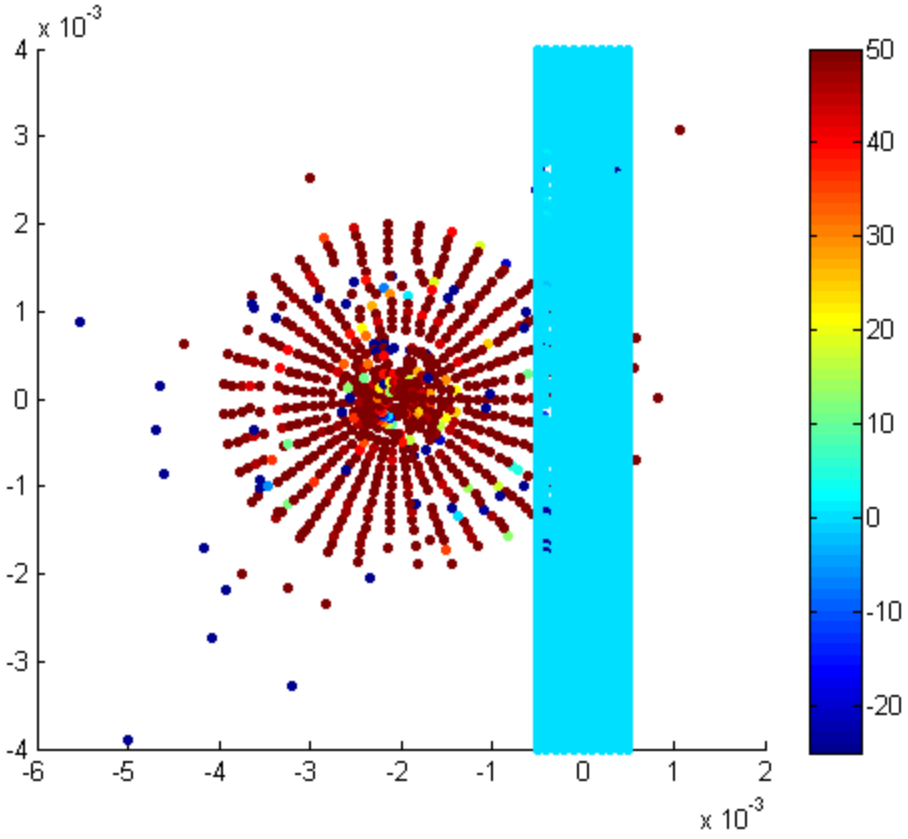
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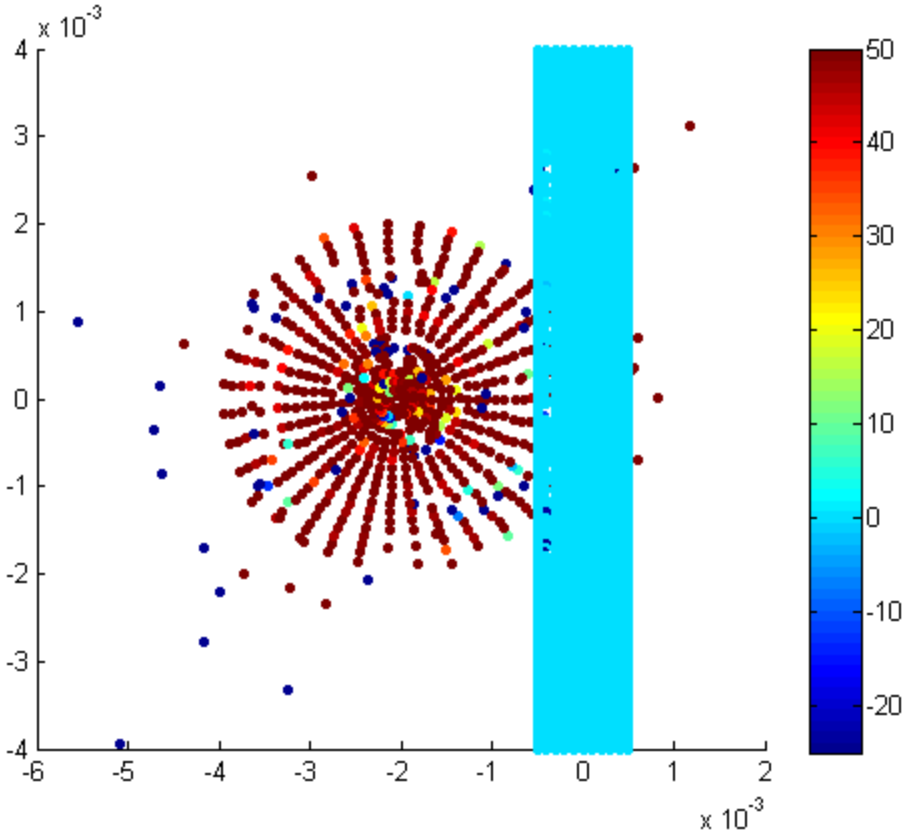
-20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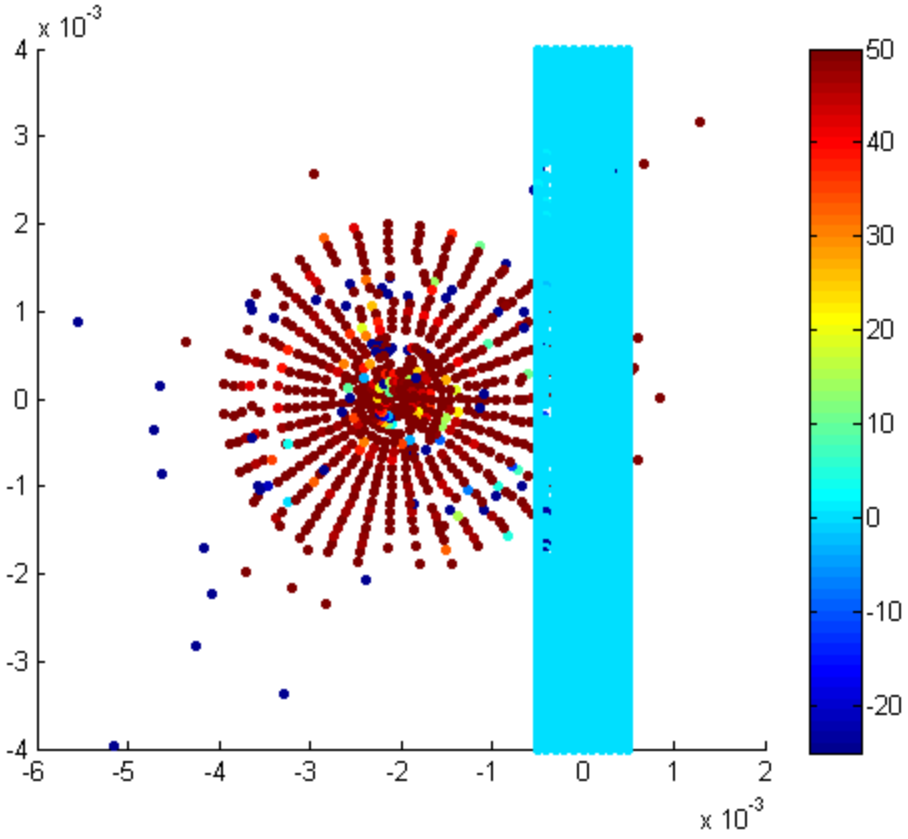
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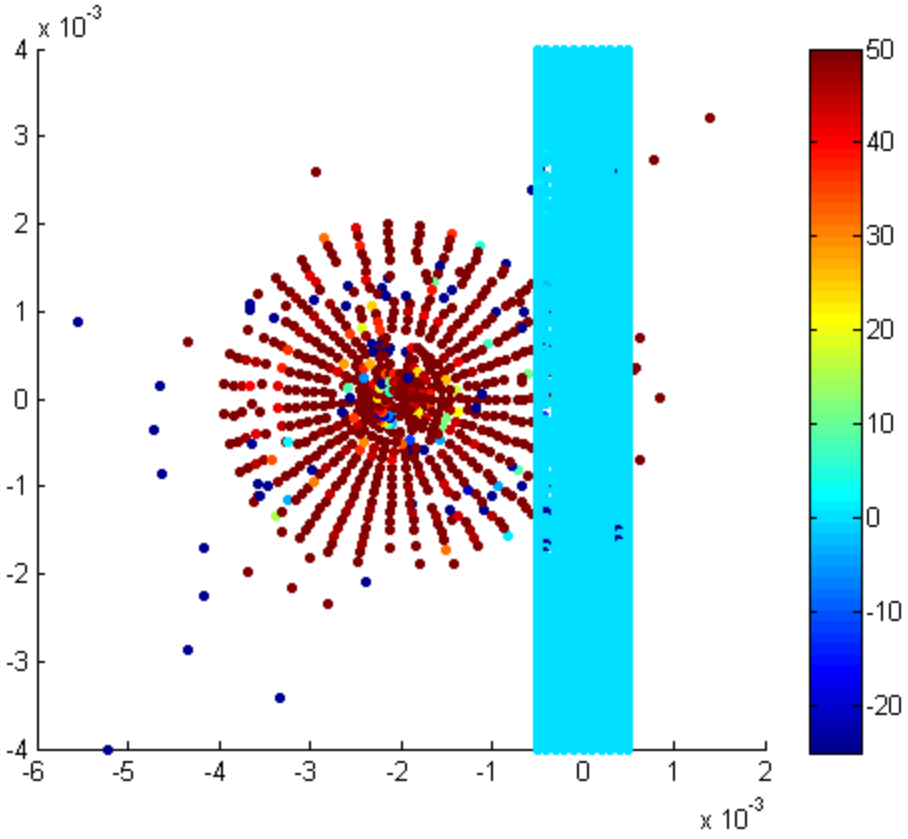
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x 10^-3
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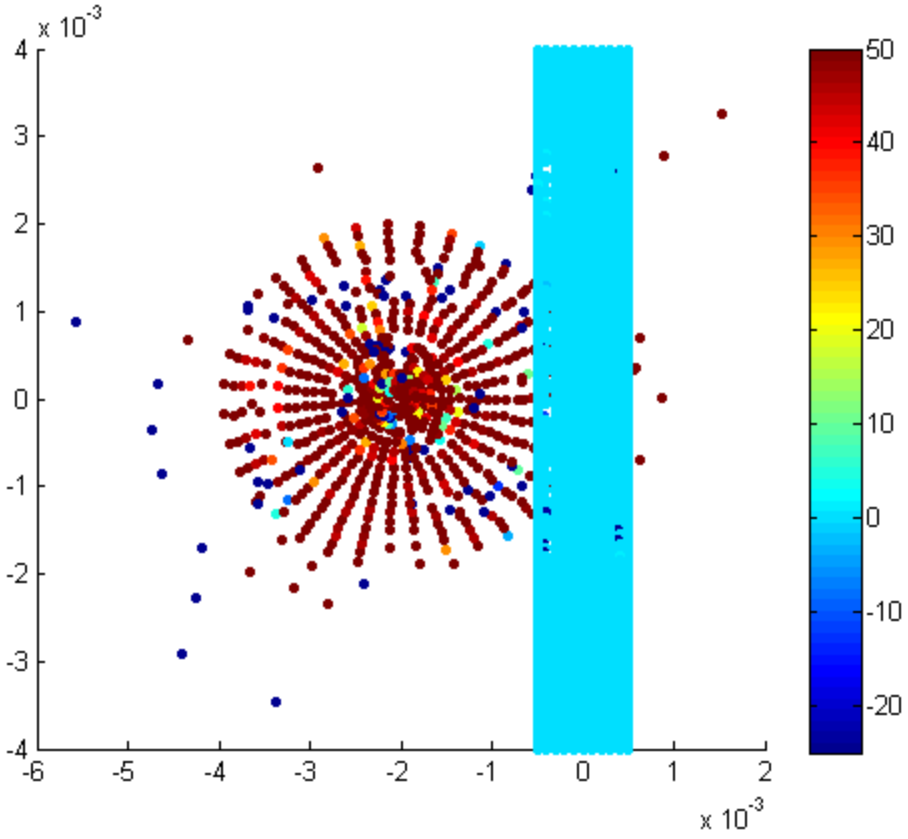
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x 10^-3
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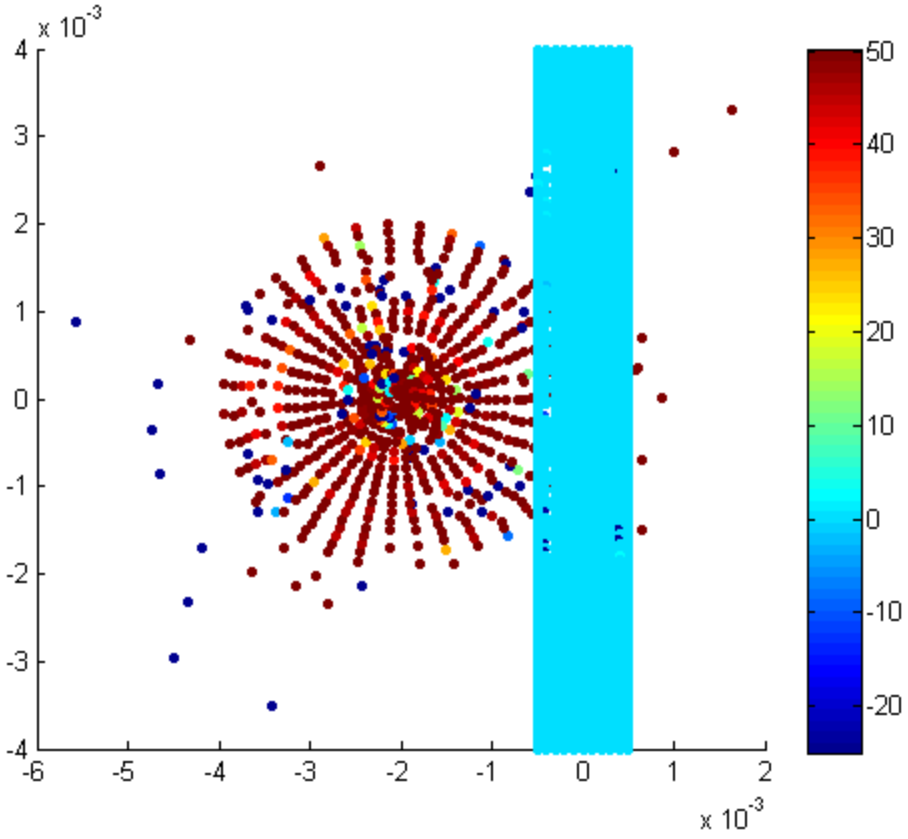
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x 10^-3
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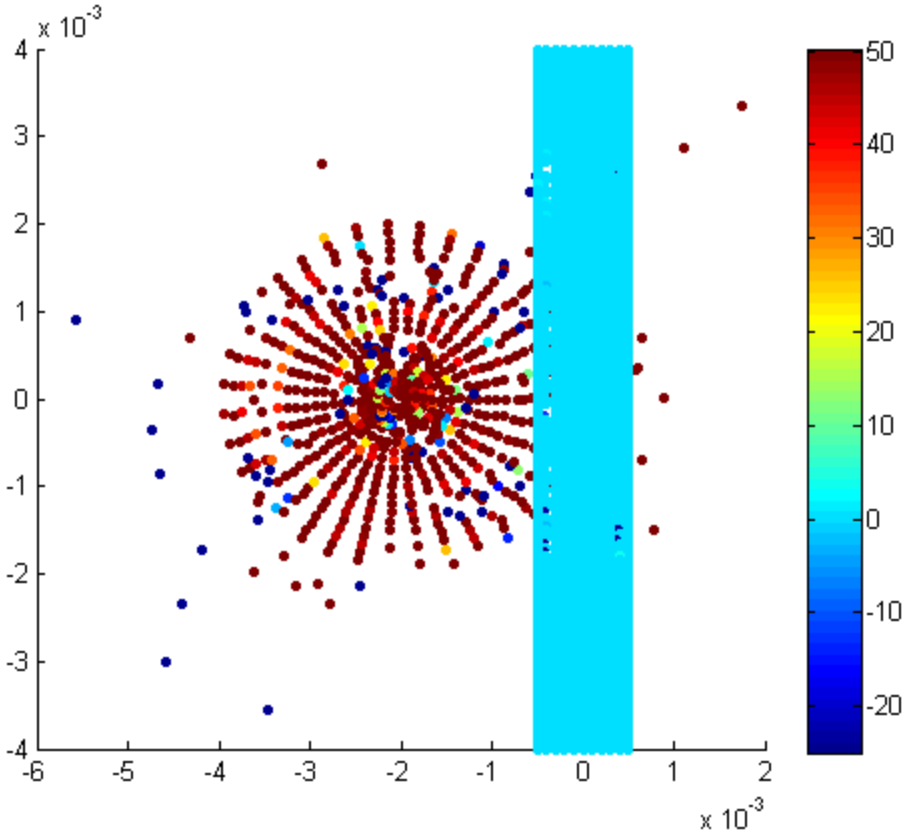
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x 10^-3
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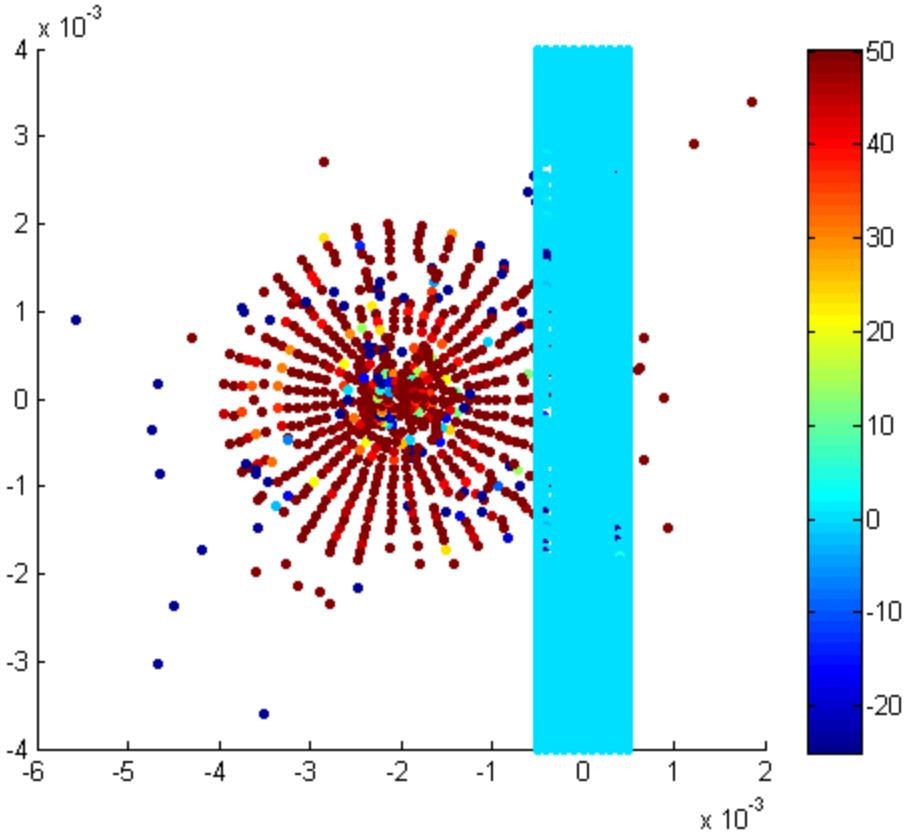
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x 10^-3
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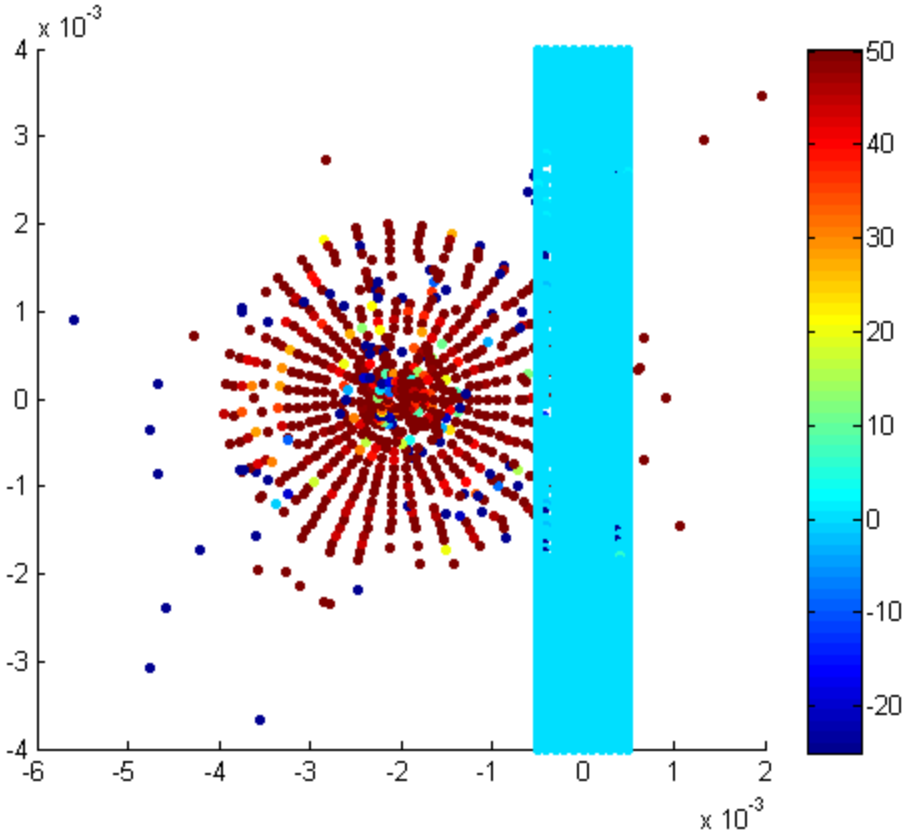
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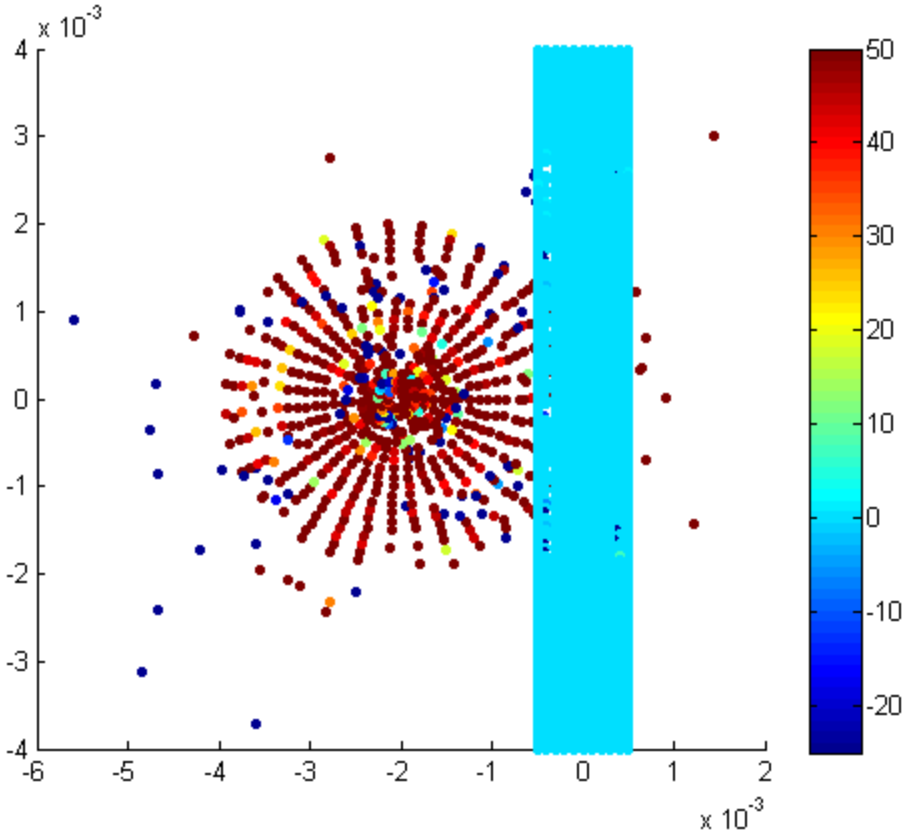
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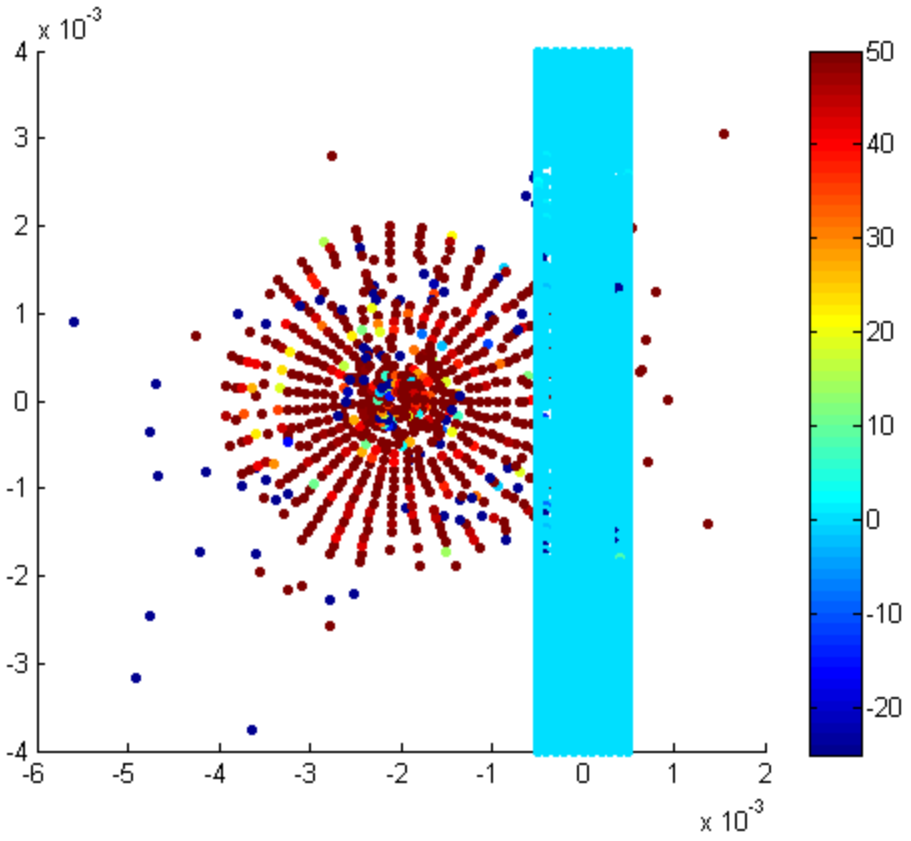

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Numero de Pasos = 235
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Comentarios JC

Situaciones por corregir: # Generacion de numero complejos Se estan generando coordenadas complejas en el arreglo *Particles*, pro el momento lo soluciono tomando solo la parte real de *Particles*. Tambien se estan generando complejos en *dE_int* y otras derivadas # Propiedades de Materiales Se esta trabajndo unicamente con las propiedades del basalto. Falta consultar propiedades para un material comun en balas

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