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```
%initial parameters
wo = 1;
sigmao = 2*wo;
so = wo^2;

Ns = 2^9; % number of points
ns = -Ns/2:Ns/2-1; % index vector with 1 of resolution

%number of so

timesso = 12;

%%vector s
Ds = timesso*so; % size of window of vector
ds = Ds/Ns; % resolution of vector
s = ns.*ds; % vector
```

Radius of curvature

```
set(groot,'defaultAxesTickLabelInterpreter','latex');
figure(1)
plot(s,radiusGaussianBeam(s,wo),'LineWidth',1.5)
hold on
plot(s,0.5*radiusGaussianBeam(s,wo),'LineWidth',1.5)
hold off
xlabel('$s$','Interpreter','latex')
ylabel('$R(s)$','Interpreter','latex')
title('Radius of curvature of Normalized Gaussian Beam')
%ticks
nrticksx = timesso+1;
xticksv = zeros(1,nrticksx);
xticklabelsv = {};
for nn = 1:nrticksx
    xticksv(nn) = (nn-floor(nrticksx/2)-1)*so;
    xticklabelsv{nn} = ['$ ',num2str(nn-floor(nrticksx/2)-1),'s_0$'];
end
set(gca,'xtick',xticksv);
set(gca,'xticklabel',xticklabelsv)
xlim([-1.05*Ds/2 1.05*Ds/2])
```

```

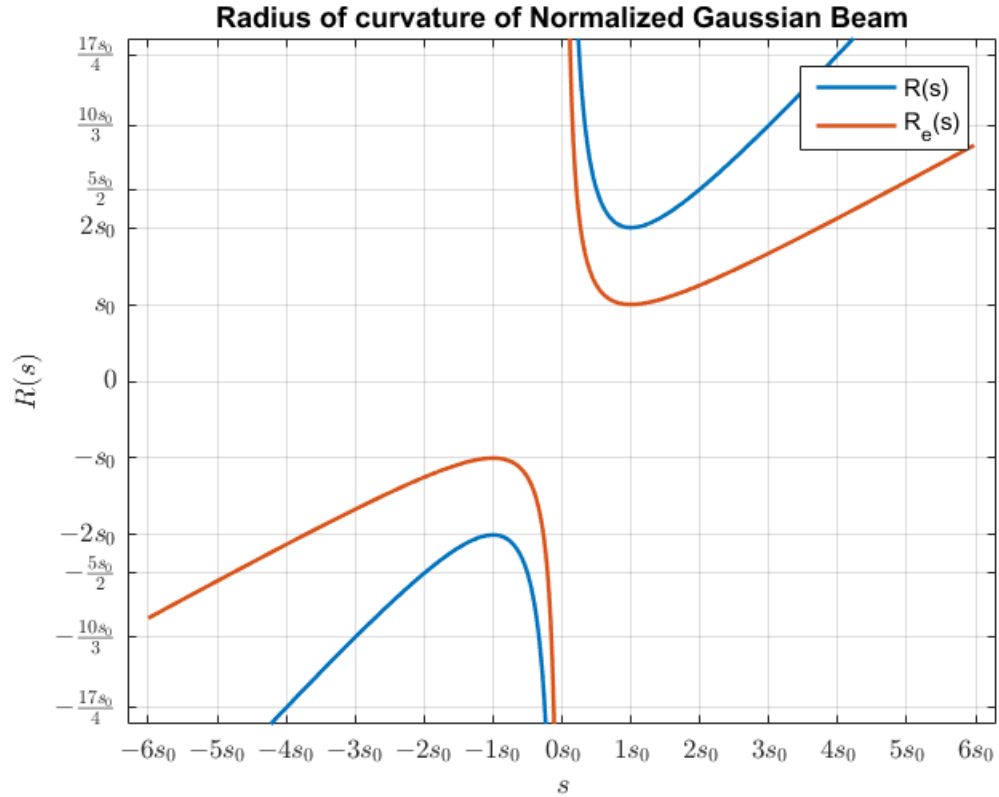
yticksv
=[radiusGaussianBeam(-4*so,wo),radiusGaussianBeam(-3*so,wo),radiusGaussianBeam(-2
so,wo),-so,0,so,...

radiusGaussianBeam(so,wo),radiusGaussianBeam(2*so,wo),radiusGaussianBeam(3*so,wo)
% yticksv = sort (yticksv);
yticklabelsv={'$-\frac{17s_0}{4}$','$-\frac{10s_0}{3}$','$-\frac{5s_0}{2}$'
'$2s_0$','$-s_0$','$0$','$s_0$','$2s_0$','$\frac{5s_0}{2}$','$
\frac{10s_0}{3}$','$\frac{17s_0}{4}$'};
set(gca,'ytick',yticksv);
set(gca,'yticklabel',yticklabelsv)

ylim([1.05*radiusGaussianBeam(-4*so,wo)
1.05*radiusGaussianBeam(4*so,wo)])

grid
legend('R(s)','R_e(s)')

```



```

xticksv = [-4*so,-3*so,-2*so,-so,-so/2,0,so/2,so, 2*so, 3*so 4*so];
xticklabelsv={'$-4s_0$','$-3s_0$','$-2s_0$','$-s_0$','$-\frac{s_0}{2}$'
'$0$','$-\frac{s_0}{2}$','$s_0$','$2s_0$','$3s_0$','$4s_0$'};
set(gca,'xtick',xticksv);
set(gca,'xticklabel',xticklabelsv)

```

```

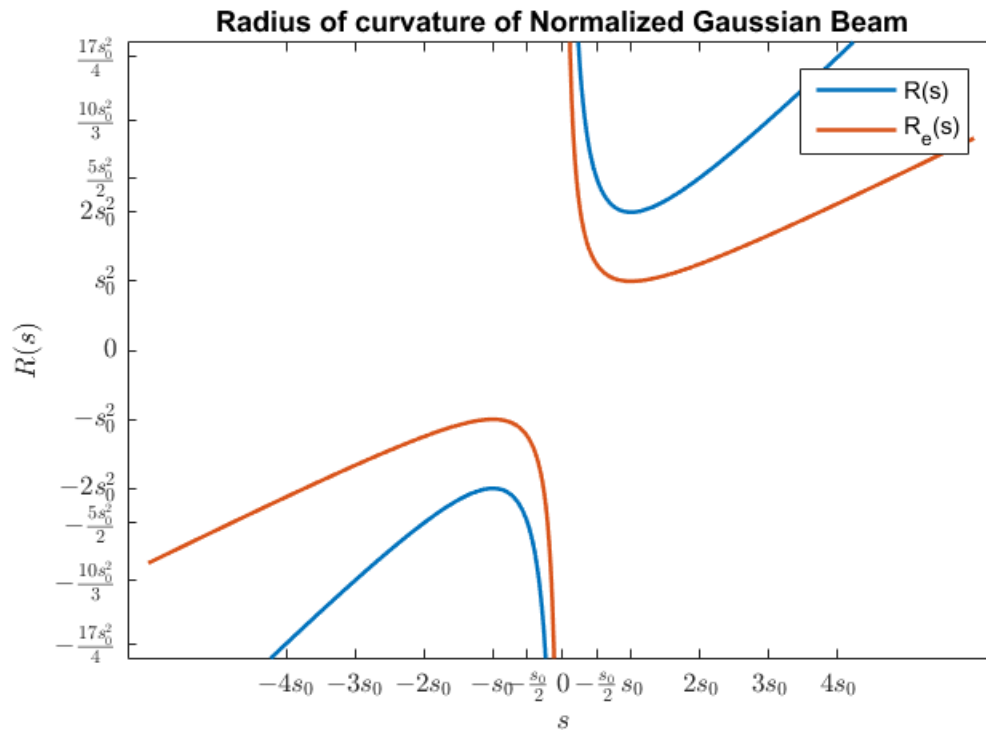
yticksv
    =[radiusGaussianBeam(-4*so,wo),radiusGaussianBeam(-3*so,wo),radiusGaussianBeam(-2
so,wo),-so,0,so,...

    radiusGaussianBeam(so,wo),radiusGaussianBeam(2*so,wo),radiusGaussianBeam(3*so,wo)
%   yticksv = sort (yticksv);
yticklabelsv={'$-\frac{17s^2_0}{4}$','$-\frac{10s^2_0}{3}$','$-\frac{5s^2_0}{2}$','$-2s^2_0$','$-
s^2_0$','$0$','$s^2_0$','$2s^2_0$','$\frac{5s^2_0}{2}$','$
\frac{10s^2_0}{3}$','$\frac{17s^2_0}{4}$'};
set(gca,'ytick',yticksv);
set(gca,'yticklabel',yticklabelsv)
%(gca,'YTickLabel',[]);
ylim([1.05*radiusGaussianBeam(-4*so,wo)
1.05*radiusGaussianBeam(4*so,wo)])
grid
ax=gca;
ax.GridLineStyle = '--';
ax.GridAlpha = 0.5;
xlim([-1.05*Ds/2 1.05*Ds/2])
ylim()
daspect([1 1 1])

```

ans =

-4.4625 4.4625



waist and sigma

figure(2)

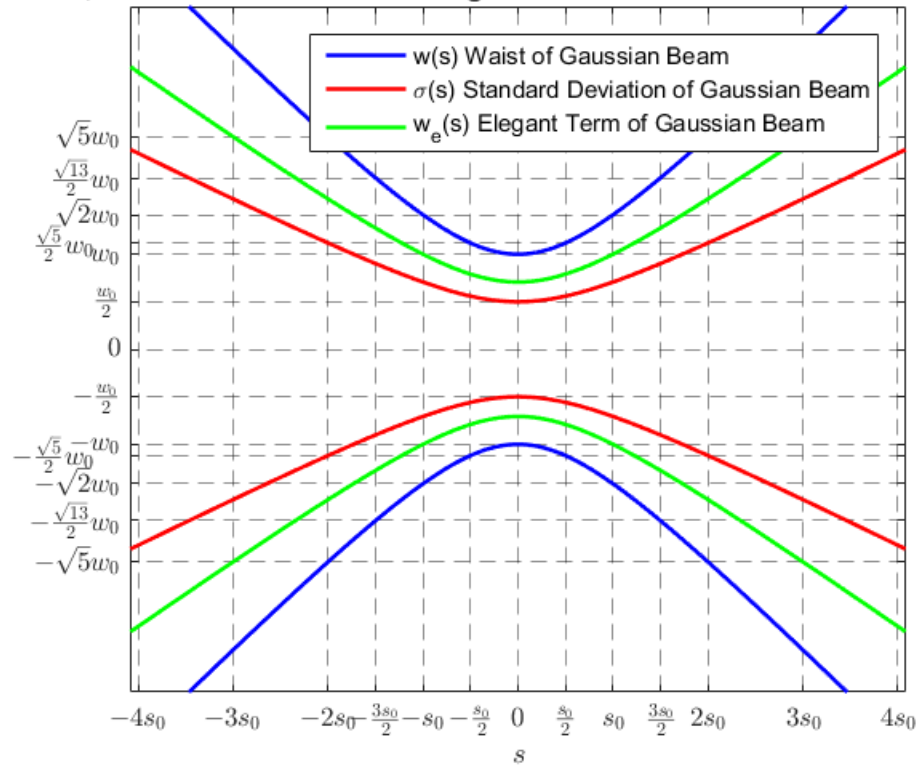
```
plot(s,waistGaussianBeam(s,wo),'b','LineWidth',1.5)
hold on
plot(s,sigmaGaussianBeam(s,wo),'r','LineWidth',1.5)
plot(s,omegaGaussianBeam(s,wo),'g','LineWidth',1.5)
plot(s,-waistGaussianBeam(s,wo),'b','LineWidth',1.5)
plot(s,-sigmaGaussianBeam(s,wo),'r','LineWidth',1.5)
plot(s,-omegaGaussianBeam(s,wo),'g','LineWidth',1.5)
hold off
xlabel('$s$','Interpreter','latex')
ylabel('$w(s)$','Interpreter','latex')
xticksv=[-4*so,-3*so,-2*so,-3*so/2,-so,-
so/2,0,so/2,so,3*so/2,2*so,3*so,4*so];
xticklabelsv={'$-4s_0$','$-3s_0$','$-2s_0$','$-\frac{3s_0}{2}$','$-s_0$','$-\frac{s_0}{2}$','$0$','$\frac{s_0}{2}$','$s_0$','$\frac{3s_0}{2}$','$2s_0$','$3s_0$','$4s_0$'};
set(gca,'xtick',xticksv);
set(gca,'xticklabel',xticklabelsv)
yticksv=[-waistGaussianBeam(2*so,wo),-waistGaussianBeam(3*so/2,wo),-
waistGaussianBeam(so,wo), -waistGaussianBeam(so/2,wo),-
waistGaussianBeam(0,wo),-wo/2,0,...
```

```

        wo/2,      waistGaussianBeam(0,wo),
        waistGaussianBeam(so/2,wo),
        waistGaussianBeam(so,wo),waistGaussianBeam(3*so/2,wo),waistGaussianBeam(2*so,wo)]
yticklabelsv={'$-\sqrt{5}w_0$','$-\frac{\sqrt{13}}{2}w_0$','$-
\sqrt{2}w_0$','$-\frac{\sqrt{5}}{2}w_0$','$-w_0$','$-\frac{w_0}{2}$','$0$'...
'$\frac{w_0}{2}$','$w_0$','$\frac{\sqrt{5}}{2}w_0$','$\sqrt{2}w_0$','$\frac{\sqrt{13}}{2}w_0$','$\sqrt{5}w_0$'};
set(gca,'ytick',yticksv);
set(gca,'yticklabel',yticklabelsv)
title('Waist, Standard Deviation and Elegant Term of Normalized
Gaussian Beam')
xlim([-1.02*4*so 1.02*4*so])
ylim([-1.02*sigmaGaussianBeam(7*so,wo)
1.02*sigmaGaussianBeam(7*so,wo)])
daspect([1 1 1])
grid
ax=gca;
ax.GridLineStyle = '--';
ax.GridAlpha = 0.5;
legend('w(s) Waist of Gaussian Beam','$\sigma(s)$ Standard Deviation of
Gaussian Beam','w_e(s) Elegant Term of Gaussian Beam')

```

Waist, Standard Deviation and Elegant Term of Normalized Gaussian Beam



waists and slopes

```

Ns = 2^9; % number of points

```

```

ns = -Ns/2:Ns/2-1; % index vector with 1 of resolution

%%vector s
Ds = 20*so; % size of window of vector
ds = Ds/Ns; % resolution of vector
s = ns.*ds; % vector

Colors = {'b','r','g'};

numberofplots = 2;
legendplot = {};
K = 1:1:numberofplots;
figure(3)
plots = {};
for jj = K
    plot(s,s*(1/(jj*wo)),['--',Colors{jj}], 'LineWidth',1)
    hold on
    plot(s,-s*(1/(jj*wo)),['--',Colors{jj}], 'LineWidth',1)
    plots{jj}=plot(s,
        waistGaussianBeam(s,jj*wo),Colors{jj}, 'LineWidth',1.5);
    plot(s,-waistGaussianBeam(s,jj*wo),Colors{jj}, 'LineWidth',1.5)
    legendplot{jj} = ['beam with $w_0$',num2str(jj),'w_0$'];
end
hold off
legend([plots{:}],legendplot,'Interpreter','latex')
xlabel('$s$', 'Interpreter','latex')
ylabel('$w(s)$', 'Interpreter','latex')
title('Asynths of waist')

%ticks
nrticksx = 19;
xticksv = zeros(1,nrticksx);
xticklabelsv = {};
for nn = 1:nrticksx
    xticksv(nn) = (nn-floor(nrticksx/2)-1)*so;
    xticklabelsv{nn} = ['$ ',num2str(nn-floor(nrticksx/2)-1),'s_0$'];
end
set(gca,'xtick',xticksv);
set(gca,'xticklabel',xticklabelsv)

nrticksy = 11;
yticksv = zeros(1,nrticksy);
yticklabelsv = {};
for nn = 1:nrticksy
    yticksv(nn) = waistGaussianBeam(0,(nn-
        floor(nrticksy/2)-1)*wo);
    yticklabelsv{nn} = ['$ ',num2str(nn-floor(nrticksy/2)-1),'w_0$'];
end
yticksv(isnan(yticksv))=0;
set(gca,'ytick',yticksv);
set(gca,'yticklabel',yticklabelsv)

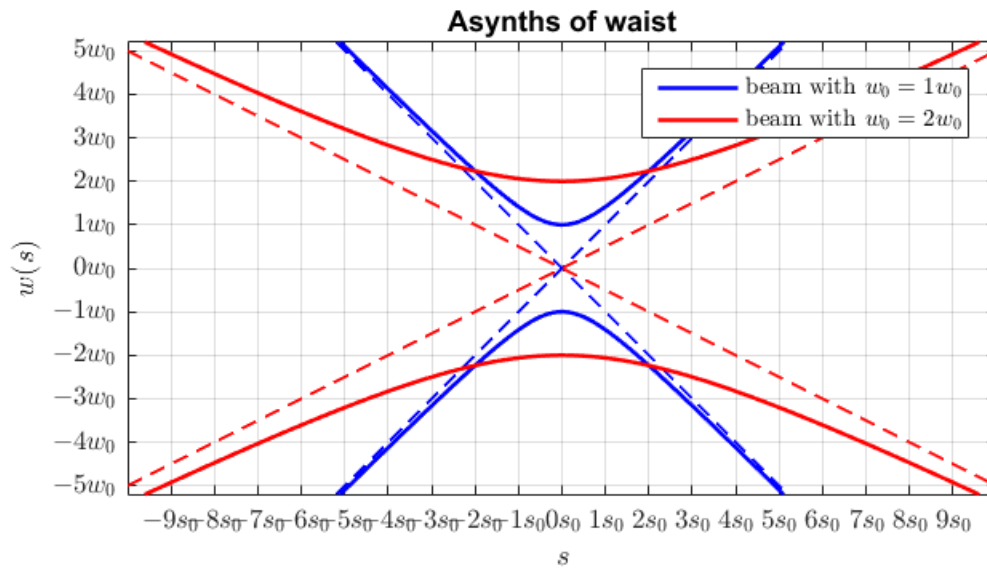
grid

```

```

ylim([-1.02*waistGaussianBeam(5*so,wo)
      1.02*waistGaussianBeam(5*so,wo)])
xlim([-10*so 10*so])
daspect([1 1 1])

```



```

%
% plot(s,waistGaussianBeam(s,wo),'b','LineWidth',1.5)
% hold on
% plot(s,waistGaussianBeam(s,2*wo),'g','LineWidth',1.5)
% plot(s,waistGaussianBeam(s,3*wo),'r','LineWidth',1.5)
%
% plot(s,waistGaussianBeam(s,-wo),'b','LineWidth',1.5)
% plot(s,waistGaussianBeam(s,-2*wo),'g','LineWidth',1.5)
% plot(s,waistGaussianBeam(s,-3*wo),'r','LineWidth',1.5)
% plot(s,waistGaussianBeam(s,wo),'b','LineWidth',1.5)
% plot(s,s*(1/wo),'--b','LineWidth',1.5)
% plot(s,-s*(1/wo),'--b','LineWidth',1.5)
% plot(s,s*(1/(2*wo)),'--g','LineWidth',1.5)
% plot(s,-s*(1/(2*wo)),'--g','LineWidth',1.5)
% plot(s,s*(1/(3*wo)),'--r','LineWidth',1.5)
% plot(s,-s*(1/(3*wo)),'--r','LineWidth',1.5)
% hold off
% xlim([-1.02*2*so 1.02*2*so])

```

```

legend('beam with \sigma_0 = \sigma_0', 'beam with \sigma_0 =
    2\sigma_0', 'beam with \sigma_0 = 3\sigma_0')
xlabel('$s$', 'Interpreter', 'latex')
ylabel('$w(s)$', 'Interpreter', 'latex')

nrticksx      = 30;
xticksv       = zeros(1,15);
xticklabelsv  = {};

for nn = 1:nrticksx
    xticksv(nn) = (nn-floor(nrticksx/2)-1)*so;
    xticklabelsv{nn} = ['$ ', num2str(nn-floor(nrticksx/2)-1), 's_0$'];
end
set(gca, 'xtick', xticksv);
set(gca, 'xticklabel', xticklabelsv)

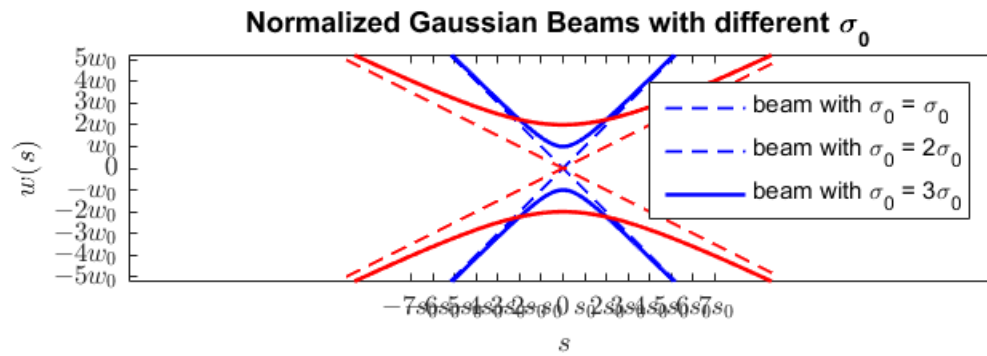
xticksv = [-7*so, -6*so, -5*so, -4*so, -3*so, -2*so, -
so, 0, so, 2*so, 3*so, 4*so, 5*so, 6*so, 7*so];
xticklabelsv = {'$-7s_0$', '$-6s_0$', '$-5s_0$', '$-4s_0$', '$-3s_0$', '$-2s_0$', '$-
s_0$', '$0$', '$s_0$', '$2s_0$', '$3s_0$', '$4s_0$', '$5s_0$', '$6s_0$', '$7s_0$'};
set(gca, 'xtick', xticksv);
set(gca, 'xticklabel', xticklabelsv)

yticksv = [-waistGaussianBeam(0, 5*wo), -waistGaussianBeam(0, 4*wo), -
waistGaussianBeam(0, 3*wo), -waistGaussianBeam(0, 2*wo), -
waistGaussianBeam(0, wo), 0, ...

    waistGaussianBeam(0, wo), waistGaussianBeam(0, 2*wo), waistGaussianBeam(0, 3*wo), waist
yticklabelsv = {'$-5w_0$', '$-4w_0$', '$-3w_0$', '$-2w_0$', '$-
w_0$', '$0$', ...
    '$w_0$', '$2w_0$', '$3w_0$', '$4w_0$', '$5w_0$'};

set(gca, 'ytick', yticksv);
set(gca, 'yticklabel', yticklabelsv)
grid
ax=gca;
ax.GridLineStyle = '--';
ax.GridAlpha = 0.5;
xlim([-20*so 20*so])
title('Normalized Gaussian Beams with different \sigma_{0} ')
daspect([1 1 1])
ylim([-1.02*waistGaussianBeam(5*so, wo)
1.02*waistGaussianBeam(5*so, wo)])

```



with omega as initial condition

```
%
%initial parameters

omegao = 1;
sigmao = omegao/sqrt(2);
wo      = sqrt(2)*omegao;

% wo = 1;
% sigmao = 2*wo;
so = wo^2;

%
Ns = 2^9;                                % number of points
ns = -Ns/2:Ns/2-1;                       % index vector with 1 of resolution

%number of so

timesso = 12;

%%vector s
Ds = timesso*so;                          % size of window of vector
```

```

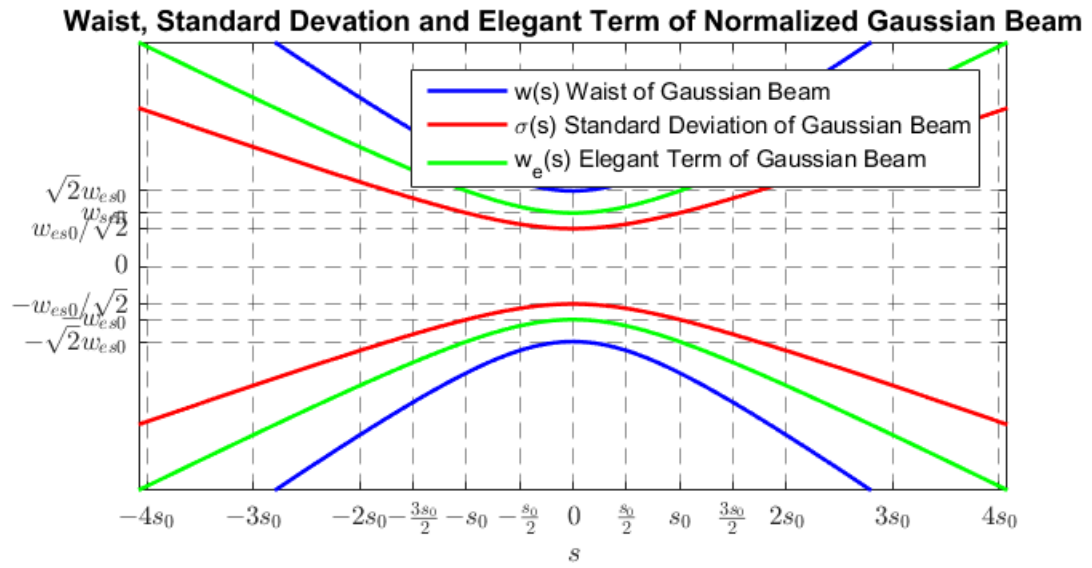
ds = Ds/Ns;                                % resolution of vector
s  = ns.*ds;                                % vector

figure(2)

plot(s,waistGaussianBeam(s,wo),'b','LineWidth',1.5)
hold on
plot(s,sigmaGaussianBeam(s,wo),'r','LineWidth',1.5)
plot(s,omegaGaussianBeam(s,wo),'g','LineWidth',1.5)
plot(s,-waistGaussianBeam(s,wo),'b','LineWidth',1.5)
plot(s,-sigmaGaussianBeam(s,wo),'r','LineWidth',1.5)
plot(s,-omegaGaussianBeam(s,wo),'g','LineWidth',1.5)
hold off
xlabel('$s$','Interpreter','latex')
%ylabel('$w(s)$','.abel','xticklabelsv)

xticksv = [-4*so,-3*so,-2*so,-3*so/2,-so,-
so/2,0,so/2,so,3*so/2,2*so,3*so,4*so];
xticklabelsv={'$-4s_0$','$-3s_0$','$-2s_0$','$-\frac{3s_0}{2}$','$-s_0$','$-\frac{s_0}{2}$','$0$','$\frac{s_0}{2}$','$s_0$','$\frac{3s_0}{2}$','$2s_0$','$3s_0$','$4s_0$'};
set(gca,'xtick',xticksv);
set(gca,'xticklabel',xticklabelsv)
yticksv = [-wo,-omegao,-sigmao,0,sigmao,omegao,wo];
yticklabelsv={'$-\sqrt{2}w_{e0}$','$-w_{e0}$','$-w_{e0}/\sqrt{2}$','$0$'...
'$w_{e0}/\sqrt{2}$','$w_{se0}$','$\sqrt{2}w_{e0}$'};
%yticklabelsv = {'a','b','c','d','e','f','g'};
set(gca,'ytick',yticksv);
set(gca,'yticklabel',yticklabelsv)
title('Waist, Standard Deviation and Elegant Term of Normalized
Gaussian Beam')
xlim([-1.02*4*so 1.02*4*so])
ylim([-1.02*omegaGaussianBeam(4*so,wo)
1.02*omegaGaussianBeam(4*so,wo)])
daspect([1 1 1])
grid
ax=gca;
ax.GridLineStyle = '--';
ax.GridAlpha = 0.5;
legend('w(s) Waist of Gaussian Beam','$\sigma(s)$ Standard Deviation of
Gaussian Beam','$w_e(s)$ Elegant Term of Gaussian Beam')

```



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