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%Coupled Mode Theory For MIM Structures (Single mode)
%by André-Pierre Blanchard-Dione
%Please make reference to article : Coupled Mode theory for Metal-Insulator-Metal Periodic
Nanostructure
%if you use this code
clear;tic
%
%% Parameters of the simulation
lambda = (0.5:0.004:2.5)*1E-6; %Wavelength
theta = 0; theta = theta*pi/180; %Angle of incidence
%Careful for e1 ~= 1 needs to respect snell
%law for the remaining layers

%Geometry of the MIM structure
d = 0.5003E-6; %Period of the structure
a1 = 0.1003E-6; %Opening of the 1 Slit (Top)
a2 = 0.1003E-6; %Opening of the 2 Slit (Bottom)
h1 = 0.8002001E-6; %Thickness 1 metal layer (Top)
h2 = 1.0014E-6; %Thickness Dielectric
h3 = 0.8002001E-6; %Thickness 2 metal layer (Bottom)
%Dielectric constants
e1 = 1.0.^2; %Incident medium
e2 = 1.0.^2; %Inside Slit 1
e3 = 1.0.^2; %Dielectric layer
e4 = 1.0.^2; %Inside slit 2
e5 = 1.0.^2; %Output medium

%em1(1:length(lambda)) = -inf; %Metal 1 (PEC) %For future version
%em2(1:length(lambda)) = -inf; %Metal 2 (PEC)

%Parameters of the t and r coefficients
nb_diff = 3; %numbers of diffraction orders considered

%Number of diffraction order calculated for the path summation
%Greatly affects the time calculation
% 0 order only should be use in subwavelength case with thick dielectric

n0fb = nb_diff+1;

nb_diff_cal = n0fb-1:n0fb+1; %diffraction orders of loops
diff_mode_t = n0fb-1:n0fb+1; %diffraction order of direct transmission

%nb_diff_cal = n0fb:n0fb; %Use this for calculation of only the zeroth
%diff_mode_t = n0fb:n0fb; %order diffraction order inside medium 3

nb_modes = 1; %numbers of mode considered in the coefficient calculation
% (For now leave to 1!)

%Constants and variables of the model
c = 2.9979E8; kw = 2*pi./(lambda); w = 2*pi*c./(lambda);
kr = 2.*pi./(d);

kw1 = kw.*sqrt(e1); k01 = kw1.*sin(theta);
kw2 = kw.*sqrt(e2);
theta3 = asin(sqrt(e1).*sin(theta)/sqrt(e3));
kw3 = kw.*sqrt(e3); k03 = kw3.*sin(theta3);
kw4 = kw.*sqrt(e4);
theta5 = asin(sqrt(e1).*sin(theta)/sqrt(e5));
kw5 = kw.*sqrt(e5); k05 = kw5.*sin(theta5);

n0 = nb_diff+1;
nb_diff_fb = nb_diff;
inc2 = 0;

%
%% Variables initialization
kz1 = zeros(nb_diff*2+1,length(lambda)); kz3 = zeros(nb_diff*2+1,length(lambda));
kz5 = zeros(nb_diff*2+1,length(lambda));
beta1 = zeros(nb_modes,length(lambda)); beta2 = zeros(nb_modes,length(lambda));
k1 = zeros(nb_diff*2+1,length(lambda)); k3 = zeros(nb_diff*2+1,length(lambda));
k5 = zeros(nb_diff*2+1,length(lambda)); Yp1 = zeros(nb_diff*2+1,length(lambda));
Yp3 = zeros(nb_diff*2+1,length(lambda)); Yp5 = zeros(nb_diff*2+1,length(lambda));

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Sn12 = cell(1,nb_modes);Sn12_t = cell(1,nb_modes);Sn23 = cell(1,nb_modes);Sn23_t =
cell(1,nb_modes);
Sn34 = cell(1,nb_modes);Sn34_t = cell(1,nb_modes);Sn45 = cell(1,nb_modes);Sn45_t =
cell(1,nb_modes);
Y_alpha2 = cell(1,nb_modes);Y_alpha4 = cell(1,nb_modes);
Matrho21 = cell(1,nb_modes);Matrho23 = cell(1,nb_modes);Matrho43 = cell(1,nb_modes);Matrho45 =
cell(1,nb_modes);
B_rho21 = cell(1,nb_modes);B_rho23 = cell(1,nb_modes);B_rho43 = cell(1,nb_modes);B_rho45 =
cell(1,nb_modes);
G12 = zeros(nb_modes,nb_modes,length(lambda));G23 = zeros(nb_modes,nb_modes,length(lambda));
G34 = zeros(nb_modes,nb_modes,length(lambda));G45 = zeros(nb_modes,nb_modes,length(lambda));
Mat12 = zeros(nb_modes,nb_modes,length(lambda));Mat32 = zeros(nb_modes,nb_modes,length(lambda));
Mat34 = zeros(nb_modes,nb_modes,length(lambda));
I034 = zeros(nb_modes,nb_diff*2+1,length(lambda));I032 =
zeros(nb_modes,nb_diff*2+1,length(lambda));
I012 = zeros(nb_modes,length(lambda));tau12 = zeros(nb_modes,length(lambda));
tau34 = zeros(nb_modes,length(lambda),nb_modes);tau32 = zeros(nb_modes,length(lambda),nb_modes);
tau21 = cell(1,nb_modes);tau43 = cell(1,nb_modes);tau23 = cell(1,nb_modes);tau45 =
cell(1,nb_modes);
rho21 = cell(1,nb_modes);rho43 = cell(1,nb_modes);rho23 = cell(1,nb_modes);rho45 =
cell(1,nb_modes);
rho32 = zeros(nb_modes,length(lambda),nb_modes);rho34 = zeros(nb_modes,length(lambda),nb_modes);
l34 = zeros(length(nb_diff_cal).^2,length(lambda));l24 =
zeros(length(nb_diff_cal).^2,length(lambda));
l35 = zeros(length(nb_diff_cal).^2,length(lambda));l25 =
zeros(length(nb_diff_cal).^2,length(lambda));
l35t = zeros(length(nb_diff_cal).^2,length(lambda));l25t =
zeros(length(nb_diff_cal).^2,length(lambda));
cf = zeros(1,length(lambda));rho12 = zeros(2*nb_diff+1,length(lambda));
for l = 1:nb_modes
    Sn12{l} = zeros(nb_diff*2+1,length(lambda));Sn12_t{l} = zeros(nb_diff*2+1,length(lambda));
    Sn23{l} = zeros(nb_diff*2+1,length(lambda));Sn23_t{l} = zeros(nb_diff*2+1,length(lambda));
    Sn34{l} = zeros(nb_diff*2+1,length(lambda));Sn34_t{l} = zeros(nb_diff*2+1,length(lambda));
    Sn45{l} = zeros(nb_diff*2+1,length(lambda));Sn45_t{l} = zeros(nb_diff*2+1,length(lambda));
    Y_alpha2{l} = zeros(1,length(lambda));Y_alpha4{l} = zeros(1,length(lambda));
    Matrho21{l} = zeros(nb_modes,nb_modes,length(lambda));Matrho23{l} =
zeros(nb_modes,nb_modes,length(lambda));
    Matrho43{l} = zeros(nb_modes,nb_modes,length(lambda));Matrho45{l} =
zeros(nb_modes,nb_modes,length(lambda));
    B_rho21{l} = zeros(nb_modes,length(lambda));B_rho23{l} = zeros(nb_modes,length(lambda));
    B_rho43{l} = zeros(nb_modes,length(lambda));B_rho45{l} = zeros(nb_modes,length(lambda));
    tau21{l} = zeros(nb_diff*2+1,length(lambda));tau23{l} = zeros(nb_diff*2+1,length(lambda));
    tau43{l} = zeros(nb_diff*2+1,length(lambda));tau45{l} = zeros(nb_diff*2+1,length(lambda));
    rho21{l} = zeros(nb_modes,length(lambda));rho23{l} = zeros(nb_modes,length(lambda));
    rho43{l} = zeros(nb_modes,length(lambda));rho45{l} = zeros(nb_modes,length(lambda));
end

%% Scattering coefficient calculation

for ll = 0:nb_modes-1
    inc2 = inc2+1;
    m=ll;
    beta1(inc2,:) = sqrt((kw2).^2-(m.*pi/a1).^2);
    beta2(inc2,:) = sqrt((kw4).^2-(m.*pi/a2).^2);
    %
    %
    %Calcul des intégrales de recouvrement, des admittances
    for l = -nb_diff:nb_diff
        inc = l+nb_diff+1;
        k1(inc,:) = k01+l*kr;
        k3(inc,:) = k03+l*kr;
        k5(inc,:) = k05+l*kr;
        kz1(inc,:) = sqrt(kw1.^2-k1(inc,:).^2);
        kz3(inc,:) = sqrt(kw3.^2-k3(inc,:).^2);
        kz5(inc,:) = sqrt(kw5.^2-k5(inc,:).^2);
        %Overlap integral
        if m == 0
            %In order to implement the normalization constant of the modes
            if theta == 0 && l == 0 %To avoid division by 0
                Sn12{inc2}(n0,1:length(lambda)) = sqrt(a1/d);
                Sn12_t{inc2}(n0,1:length(lambda)) = sqrt(a1/d);
                Sn23{inc2}(n0,1:length(lambda)) = sqrt(a1/d);
            end
        end
    end
end

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        Sn23_t{inc2}(n0,1:length(lambda)) = sqrt(a1/d);
        Sn34{inc2}(n0,1:length(lambda)) = sqrt(a2/d);
        Sn34_t{inc2}(n0,1:length(lambda)) = sqrt(a2/d);
        Sn45{inc2}(n0,1:length(lambda)) = sqrt(a2/d);
        Sn45_t{inc2}(n0,1:length(lambda)) = sqrt(a2/d);
    else
        Sn12{inc2}(inc,:) =
        1i.*k1(inc,:)./sqrt(a1.*d).*(exp(1i.*k1(inc,:).*a1/2).*cos(m.*pi)-exp(-
        1i.*k1(inc,:).*a1/2))./((m.*pi./a1).^2-(k1(inc,:)).^2);
        Sn12_t{inc2}(inc,:) = conj(Sn12{inc2}(inc,:));
        Sn23{inc2}(inc,:) =
        1i.*k3(inc,:)./sqrt(a1.*d).*(exp(1i.*k3(inc,:).*a1/2).*cos(m.*pi)-exp(-
        1i.*k3(inc,:).*a1/2))./((m.*pi./a1).^2-(k3(inc,:)).^2);
        Sn23_t{inc2}(inc,:) = conj(Sn23{inc2}(inc,:));
        Sn34{inc2}(inc,:) =
        1i.*k3(inc,:)./sqrt(a2.*d).*(exp(1i.*k3(inc,:).*a2/2).*cos(m.*pi)-exp(-
        1i.*k3(inc,:).*a2/2))./((m.*pi./a2).^2-(k3(inc,:)).^2);
        Sn34_t{inc2}(inc,:) = conj(Sn34{inc2}(inc,:));
        Sn45{inc2}(inc,:) =
        1i.*k5(inc,:)./sqrt(a2.*d).*(exp(1i.*k5(inc,:).*a2/2).*cos(m.*pi)-exp(-
        1i.*k5(inc,:).*a2/2))./((m.*pi./a2).^2-(k5(inc,:)).^2);
        Sn45_t{inc2}(inc,:) = conj(Sn45{inc2}(inc,:));
    end
    else
        Sn12{inc2}(inc,:) =
        sqrt(2).*1i.*k1(inc,:)./sqrt(a1.*d).*(exp(1i.*k1(inc,:).*a1/2).*cos(m.*pi)-exp(-
        1i.*k1(inc,:).*a1/2))./((m.*pi./a1).^2-(k1(inc,:)).^2);
        Sn12_t{inc2}(inc,:) = conj(Sn12{inc2}(inc,:));
        Sn23{inc2}(inc,:) =
        sqrt(2).*1i.*k3(inc,:)./sqrt(a1.*d).*(exp(1i.*k3(inc,:).*a1/2).*cos(m.*pi)-exp(-
        1i.*k3(inc,:).*a1/2))./((m.*pi./a1).^2-(k3(inc,:)).^2);
        Sn23_t{inc2}(inc,:) = conj(Sn23{inc2}(inc,:));
        Sn34{inc2}(inc,:) =
        sqrt(2).*1i.*k3(inc,:)./sqrt(a2.*d).*(exp(1i.*k3(inc,:).*a2/2).*cos(m.*pi)-exp(-
        1i.*k3(inc,:).*a2/2))./((m.*pi./a2).^2-(k3(inc,:)).^2);
        Sn34_t{inc2}(inc,:) = conj(Sn34{inc2}(inc,:));
        Sn45{inc2}(inc,:) =
        sqrt(2).*1i.*k5(inc,:)./sqrt(a2.*d).*(exp(1i.*k5(inc,:).*a2/2).*cos(m.*pi)-exp(-
        1i.*k5(inc,:).*a2/2))./((m.*pi./a2).^2-(k5(inc,:)).^2);
        Sn45_t{inc2}(inc,:) = conj(Sn45{inc2}(inc,:));
    end
    Yp1(inc,:) = (kw.*e1./kz1(inc,:));
    Yp3(inc,:) = (kw.*e3./kz3(inc,:));
    Yp5(inc,:) = (kw.*e5./kz5(inc,:));
end
Y_alpha2{inc2} = (kw.*e2)./sqrt(e2.*kw.^2-(m.*pi./a1).^2);
Y_alpha4{inc2} = (kw.*e4)./sqrt(e4.*kw.^2-(m.*pi./a2).^2);
end

for l = 1:nb_modes
    for ll = 1:nb_modes
        G12(l,ll,:) = 1i.*sum(Yp1.*(Sn12{l}.*Sn12_t{ll}),1);
        G23(l,ll,:) = 1i.*sum(Yp3.*(Sn23{l}.*Sn23_t{ll}),1);
        G34(l,ll,:) = 1i.*sum(Yp3.*(Sn34{l}.*Sn34_t{ll}),1);
        G45(l,ll,:) = 1i.*sum(Yp5.*(Sn45{l}.*Sn45_t{ll}),1);

        Mat12(l,ll,:) = G12(l,ll,:);
        Mat32(l,ll,:) = G23(l,ll,:);
        Mat34(l,ll,:) = G34(l,ll,:);
    end
    Mat12(l,l,:) = squeeze(Mat12(l,l,:)) + 1i.*Y_alpha2{l}.';
    Mat34(l,l,:) = squeeze(Mat34(l,l,:)) + 1i.*Y_alpha4{l}.';
    Mat32(l,l,:) = squeeze(Mat32(l,l,:)) + 1i.*Y_alpha2{l}.';
    I012(l,:) = 2.*1i.*Sn12{l}(n0,:).*sqrt(Yp1(n0,:));
    for ll = 1:2*nb_diff_fb+1
        I034(l,ll,:) = 2.*1i.*Sn34{l}(ll,:).*(Yp3(ll,:));
        I032(l,ll,:) = 2.*1i.*Sn23_t{l}(ll,:).*(Yp3(ll,:));
    end
end

for l = 1:nb_modes

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for ll = 1:nb_modes
    for l1l = 1:nb_modes
        Matrho21{1}(ll,l1l,:) = G12(ll,l1l,:);
        Matrho23{1}(ll,l1l,:) = G23(ll,l1l,:);
        Matrho43{1}(ll,l1l,:) = G34(ll,l1l,:);
        Matrho45{1}(ll,l1l,:) = G45(ll,l1l,:);
        if ll == 1
            B_rho21{1}(ll,:) = 1i.*Y_alpha2{1l}-squeeze(G12(ll,1,:)).';
            B_rho23{1}(ll,:) = 1i.*Y_alpha2{1l}-squeeze(G23(ll,1,:)).';
            B_rho43{1}(ll,:) = 1i.*Y_alpha4{1l}-squeeze(G34(ll,1,:)).';
            B_rho45{1}(ll,:) = 1i.*Y_alpha4{1l}-squeeze(G45(ll,1,:)).';
        else
            B_rho21{1}(ll,:) = squeeze(-G12(ll,1,:)).';
            B_rho23{1}(ll,:) = squeeze(-G23(ll,1,:)).';
            B_rho43{1}(ll,:) = squeeze(-G34(ll,1,:)).';
            B_rho45{1}(ll,:) = squeeze(-G45(ll,1,:)).';
        end
    end
    end
    Matrho21{1}(ll,ll,:) = squeeze(Matrho21{1}(ll,ll,:)).'+1i.*Y_alpha2{1l};
    Matrho23{1}(ll,ll,:) = squeeze(Matrho23{1}(ll,ll,:)).'+1i.*Y_alpha2{1l};
    Matrho43{1}(ll,ll,:) = squeeze(Matrho43{1}(ll,ll,:)).'+1i.*Y_alpha4{1l};
    Matrho45{1}(ll,ll,:) = squeeze(Matrho45{1}(ll,ll,:)).'+1i.*Y_alpha4{1l};
end
end

for l = 1:length(lambda)
    tau12(:,l) = Mat12(:,l)\I012(:,l);
    for l1l = 1:2*nb_diff+1
        tau34(:,l,l1l) = Mat34(:,l)\I034(:,l1l,l);
        tau32(:,l,l1l) = Mat32(:,l)\I032(:,l1l,l);
    end
    for ll = 1:nb_modes
        rho21{1l}(:,l) = Matrho21{1l}(:,l)\B_rho21{1l}(:,l);
        rho23{1l}(:,l) = Matrho23{1l}(:,l)\B_rho23{1l}(:,l);
        rho43{1l}(:,l) = Matrho43{1l}(:,l)\B_rho43{1l}(:,l);
        rho45{1l}(:,l) = Matrho45{1l}(:,l)\B_rho45{1l}(:,l);
    end
end

for l = 1:2*nb_diff+1
    somme = 0;
    for ll = 1:nb_modes
        somme = somme+Sn12{1l}(l,:).*tau12(ll,:);
    end
    if l == n0fb
        rho12(l,:) = -1+somme;
    else
        rho12(l,:) = somme ;
    end
end

for l = 1:nb_modes
    for l1l = 1:nb_diff_fb*2+1
        sum1 = 0;sum2 = 0;sum3 = 0;sum4 = 0;
        for l1l = 1:nb_modes
            sum1 =sum1 +rho21{1}(l1l,:).*Sn12_t{l1l}(ll,:);
            sum2 =sum2 +rho23{1}(l1l,:).*Sn23{l1l}(ll,:);
            sum3 =sum3 +rho43{1}(l1l,:).*Sn34_t{l1l}(ll,:);
            sum4 =sum4 +rho45{1}(l1l,:).*Sn45{l1l}(ll,:);
        end
        tau21{1}(ll,:) = Sn12_t{1}(ll,:)+sum1;
        tau23{1}(ll,:) = Sn23{1}(ll,:)+sum2;
        tau43{1}(ll,:) = Sn34_t{1}(ll,:)+sum3;
        tau45{1}(ll,:) = Sn45{1}(ll,:)+sum4;
    end
    tau45{1} = tau45{1}.*sqrt(Yp5);
end

for l = 1:nb_diff_fb*2+1
    for l1l = 1:2*nb_diff_fb+1
        sum1 = 0;

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sum2 = 0;
for l11 = 1:nb_modes
    sum1 = sum1+Sn23_t{l11}(l1,:).*tau32(l11,:,1);
    sum2 = sum2+Sn34{l11}(l1,:).*tau34(l11,:,1);
end
if l1 == 1
    rho32(1, :, l1) = -1+sum1;
    rho34(1, :, l1) = -1+sum2;
else
    rho32(1, :, l1) = sum1;
    rho34(1, :, l1) = sum2;
end
end
end

%% Multiple path summation
trans(1:length(lambda)) = 0; refl(1:length(lambda)) = 0;
eh1 = exp(1i.*h1.*beta1);
eh2 = exp(1i.*h2.*kz3);
eh3 = exp(1i.*h3.*beta2);

for mode = 1
    for sc = 1:length(diff_mode_t)
        inc = 0;

        diff_mode = diff_mode_t(sc);
        nb = length(nb_diff_cal).^2;

        l23 = rho21{mode}(mode, :).*eh1(mode, :).*rho23{mode}(mode, :).*eh1(mode, :);
        l45 = rho45{mode}(mode, :).*eh3(mode, :).*rho43{mode}(mode, :).*eh3(mode, :);

        for gg1 = nb_diff_cal
            for gg2 = nb_diff_cal
                inc = inc+1;
                l34(inc, :) = rho34(gg1, :, gg2).*eh2(gg2, :).*rho32(gg2, :, gg1).*eh2(gg1, :);
                l24(inc, :) =
                    rho34(gg1, :, gg2).*eh2(gg2, :).*tau32(mode, :, gg2).*eh1(mode, :).*rho21{mode}(mode, :).*eh1(mode, :).*t
                    au23{mode}(gg1, :).*eh2(gg1, :);
                l25(inc, :) =
                    rho21{mode}(mode, :).*eh1(mode, :).*tau23{mode}(gg1, :).*eh2(gg1, :).*tau34(mode, :, gg1).*eh3(mode, :).
                    *rho45{mode}(mode, :).*eh3(mode, :).*tau43{mode}(gg2, :).*eh2(gg2, :).*tau32(mode, :, gg2).*eh1(mode, :).
                    ;
                l35(inc, :) =
                    rho32(gg2, :, gg1).*eh2(gg1, :).*tau34(mode, :, gg1).*eh3(mode, :).*rho45{mode}(mode, :).*eh3(mode, :).*t
                    au43{mode}(gg2, :).*eh2(gg2, :);
            end
        end

        %%Matrix l24

        l24t = zeros(nb, length(lambda));
        for l = 1:length(nb_diff_cal)^2
            l24t(l, :) = l24(l, :)./(1-l23);
        end

        %%Matrix l35
        vec35 = zeros(length(lambda), nb*2); Mat35 = zeros(nb*2, nb*2, length(lambda)); t35 =
        zeros(nb*2, length(lambda));

        inc35 = 0; inc352 = 0;

        for gg1 = nb_diff_cal
            for gg2 = nb_diff_cal

                inc35 = inc35+1;
                inc352 = 0;

                for gg3 = nb_diff_cal
                    for gg4 = nb_diff_cal
                        inc352 = inc352+1;

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inc353 = 0;
r34 = rho34(gg1, :, gg4) ./ rho34(gg3, :, gg4);
vec35(:, inc352) = l35(inc35, :) .* l34(inc352, :) .* r34;
vec35(:, inc352+nb) = l35(inc35, :) .* l24t(inc352, :) .* r34;
t35(inc352, :) = tau34(mode, :, gg3) ./ (tau34(mode, :, gg1));
t35(inc352+nb, :) = tau34(mode, :, gg3) ./ (tau34(mode, :, gg1));
for gg5 = nb_diff_cal
    for gg6 = nb_diff_cal

        inc353 = inc353+1;
        f = rho34(gg3, :, gg6) ./ rho34(gg5, :, gg6);
        Mat35(inc352, inc353, :) = l34(inc353, :) .* f;
        Mat35(inc352, inc353+nb, :) = l24t(inc353, :) .* f;
        Mat35(inc352+nb, inc353, :) = l34(inc353, :) .* f;
        Mat35(inc352+nb, inc353+nb, :) = l24t(inc353, :) .* f;

    end
end
end
end

for l = 1:length(lambda)
    l35t(inc35, l) = l35(inc35, l) + vec35(l, :) / (eye(2*nb) - (Mat35(:, :, l))) * t35(:, l);
end
end
end

%%%Matrix 125
vec25 = zeros(length(lambda), 1+2*nb); Mat25 = zeros(1+nb*2, 1+nb*2, length(lambda)); t25 =
zeros(1+nb*2, length(lambda));
Mat25(1, 1, :) = 123;

inc25 = 0;
for gg1 = nb_diff_cal
    for gg2 = nb_diff_cal
        inc25 = inc25+1;
        inc252 = 0;
        vec25(:, 1) = 123.*l25(inc25, :);
        t25(1, :) = 1;
        for gg3 = nb_diff_cal
            for gg4 = nb_diff_cal
                inc252 = inc252+1;
                inc253 = 0;
                r34 = rho34(gg1, :, gg4) ./ rho34(gg3, :, gg4);
                Mat25(1, inc252+1, :) = l34(inc252, :) .* r34;
                Mat25(1, inc252+1+nb, :) = l24t(inc252, :) .* r34;
                vec25(:, 1+inc252) = l34(inc252, :) .* l25(inc25, :) .* r34;
                vec25(:, 1+nb+inc252) = l24t(inc252, :) .* l25(inc25, :) .* r34;
                t25(inc252+1, :) = tau34(mode, :, gg3) ./ (tau34(mode, :, gg1));
                t25(inc252+1+nb, :) = tau34(mode, :, gg3) ./ (tau34(mode, :, gg1));
                for gg5 = nb_diff_cal
                    for gg6 = nb_diff_cal
                        inc253 = inc253+1;
                        f = rho34(gg3, :, gg6) ./ rho34(gg5, :, gg6);
                        f3 = tau34(mode, :, gg5) ./ (tau34(mode, :, gg1));
                        Mat25(inc252+1, inc253+1, :) = f.*l34(inc253, :);
                        Mat25(inc252+1, inc253+1+nb, :) = f.*l24t(inc253, :);
                        Mat25(inc252+1+nb, inc253+1, :) = f.*l34(inc253, :);
                        Mat25(inc252+1+nb, inc253+1+nb, :) = f.*l24t(inc253, :);

                    end
                end
            end
        end
    end
end

for l = 1:length(lambda)
    l25t(inc25, l) = l25(inc25, l) + vec25(l, :) / (eye(2*nb+1) -
(Mat25(:, :, l))) * t25(:, l);
end
end
end
end

```

```

%initialization
%vec = zeros(length(lambda),4*nb+2);
Mat = zeros(4*nb+2,4*nb+2,length(lambda));
t = zeros(4*nb+2,length(lambda));t2 = zeros(4*nb+2,length(lambda));t3 =
zeros(4*nb+2,length(lambda),nb);
vec = zeros(length(lambda),2+4*nb);

vec(:,1) = 123; Mat(1,1,:) = 123;Mat(1,2+nb,:) = 145;t(1,:) = 1;
vec(:,2+nb) = 145;Mat(2+nb,2+nb,:) = 145;Mat(nb+2,1,:) = 0;t(nb+2,:) = 1;
t34 = zeros(length(nb_diff_cal).^2,length(lambda));

inc =0;
for gg1 = nb_diff_cal
    for gg2 = nb_diff_cal
        inc = inc+1;
        inc2 =0;
        r34(inc,:) = rho34(diff_mode,:,gg2)./rho34(gg1,:,gg2);
        t34(inc,:) = tau34(mode,:,gg1)./(tau34(mode,:,diff_mode));
        t(inc+1,:) = tau34(mode,:,gg1)./(tau34(mode,:,diff_mode));
        t(inc+2+nb,:) = tau34(mode,:,gg1)./(tau34(mode,:,diff_mode));
        t(inc+2+2*nb,:) = 1;
        t(inc+2+3*nb,:) = 1;
        vec(:,inc+1) = 134(inc,:).*r34(inc,:);
        vec(:,inc+2+nb) = 124t(inc,:).*r34(inc,:);
        vec(:,inc+2+2*nb) = 135t(inc,:);
        vec(:,inc+2+3*nb) = 125t(inc,:);
        Mat(1,inc+1,:) = 134(inc,:).*r34(inc,:);
        Mat(1,inc+2+nb,:) = 124t(inc,:).*r34(inc,:);
        Mat(1,inc+2+2*nb,:) = 135t(inc,:);
        Mat(1,inc+2+3*nb,:) = 125t(inc,:);
        Mat(2+nb,inc+1,:) = 0;
        Mat(2+nb,inc+2+nb,:) = 0;
        Mat(1+inc,1,:) = 0;
        Mat(1+inc,2+nb,:) = t34(inc,:).*145;
        Mat(2+nb+inc,1,:) = 0;
        Mat(2+nb+inc,2+nb,:) = t34(inc,:).*145;
        Mat(2+nb,inc+2+2*nb,:) = 135t(inc,:);
        Mat(2+nb,inc+2+3*nb,:) = 125t(inc,:);
        Mat(inc+2+2*nb,1,:) = 0;
        Mat(inc+2+2*nb,2+nb,:) = 145;
        Mat(inc+2+3*nb,1,:) = 0;
        Mat(inc+2+3*nb,2+nb,:) = 145;

        for gg3 = nb_diff_cal
            for gg4 = nb_diff_cal
                inc2 = inc2+1;
                f = rho34(gg1,:,gg4)./rho34(gg3,:,gg4);
                f2 = tau34(mode,:,gg1)./(tau34(mode,:,gg1));
                f3 = tau34(mode,:,gg1)./(tau34(mode,:,diff_mode));
                %f3 = 1;
                Mat(inc+1,inc2+1,:) = f.*134(inc2,:);
                Mat(inc+1,inc2+2+nb,:) = f.*124t(inc2,:);
                Mat(inc+1,inc2+2+2*nb,:) = f3.*135t(inc2,:);
                Mat(inc+1,inc2+2+3*nb,:) = f3.*125t(inc2,:);
                Mat(inc+2+nb,inc2+1,:) = f.*134(inc2,:);
                Mat(inc+2+nb,inc2+2+nb,:) = f.*124t(inc2,:);
                Mat(inc+2+nb,inc2+2+2*nb,:) = f3.*135t(inc2,:);
                Mat(inc+2+nb,inc2+2+3*nb,:) = f3.*125t(inc2,:);
                Mat(inc+2+2*nb,inc2+1,:) = 0;
                Mat(inc+2+2*nb,inc2+2+nb,:) = 0;
                Mat(inc+2+2*nb,inc2+2+2*nb,:) = 135t(inc2,:);
                Mat(inc+2+2*nb,inc2+2+3*nb,:) = 125t(inc2,:);
                Mat(inc+2+3*nb,inc2+1,:) = 0;
                Mat(inc+2+3*nb,inc2+2+nb,:) = 0;
                Mat(inc+2+3*nb,inc2+2+2*nb,:) = 135t(inc2,:);
                Mat(inc+2+3*nb,inc2+2+3*nb,:) = 125t(inc2,:);

            end
        end
    end
end
end
end

```

```

%
for l = 1:length(lambda)
    cf(l) = vec(l,:)/(eye(2+4*nb)-Mat(:, :, l))*t(:, l);
end
l = 1;
trans =trans + ...
(tau12(mode,:).*exp(1i.*beta1(l,:).*h1).*tau23{mode}(diff_mode,:).*exp(1i.*kz3(diff_mode,:).*h2)
...
.*tau34(mode,:,diff_mode).*exp(1i.*beta2(l,:).*h3).*tau45{mode}(n0fb,:)) ...
.*(1+cf);
end
end

hold on
plot(lambda,abs(trans).^2,'b','LineWidth',1.5)
set(gca,'Box','on')
axis([lambda(1) lambda(end) 0 1]);
set(gca,'FontSize',16)
xlabel('Wavelength','FontSize',20,'fontweight','b');
ylabel('Transmission','FontSize',20,'fontweight','b');
toc

```