# 二層膜および三層膜からの和周波(SFG)光

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ファイル「膜からの和周波発生」の延長として、膜層が2つのときの表式を求める。(3層以上になると、層の数と同数の次元を持つ行列の級数になるので複雑になる。ファイル「埋込発光層からの電場」の内容を参照すれば、ここで示す方式の延長として定式化することができる。)

#### 1. 係数等

## 反射係数及び透過係数

光の電場を表面固定座標系の成分で表すときに、反射係数及び透過係数は下のようになることを使って、 その座標成分を入射光電場の偏光成分で表すことにする。

$$\begin{split} r_{\mathrm{lm,s}} &= \frac{n_{\mathrm{l}} \cos \theta_{\mathrm{l}} - n_{\mathrm{m}} \cos \theta_{\mathrm{m}}}{n_{\mathrm{l}} \cos \theta_{\mathrm{l}} + n_{\mathrm{m}} \cos \theta_{\mathrm{m}}}, \qquad t_{\mathrm{lm,s}} = \frac{2 n_{\mathrm{l}} \cos \theta_{\mathrm{l}}}{n_{\mathrm{l}} \cos \theta_{\mathrm{l}} + n_{\mathrm{m}} \cos \theta_{\mathrm{m}}} \\ r_{\mathrm{lm,p}} &= \frac{n_{\mathrm{l}} \cos \theta_{\mathrm{m}} - n_{\mathrm{m}} \cos \theta_{\mathrm{l}}}{n_{\mathrm{l}} \cos \theta_{\mathrm{m}} + n_{\mathrm{m}} \cos \theta_{\mathrm{l}}}, \qquad t_{\mathrm{lm,p}} = \frac{2 n_{\mathrm{l}} \cos \theta_{\mathrm{l}}}{n_{\mathrm{l}} \cos \theta_{\mathrm{m}} + n_{\mathrm{m}} \cos \theta_{\mathrm{l}}} \\ r_{\mathrm{lm,x}} &= -r_{\mathrm{m1,x}} = r_{\mathrm{lm,p}}, \qquad r_{\mathrm{lm,y}} = -r_{\mathrm{m1,y}} = r_{\mathrm{lm,s}}, \qquad r_{\mathrm{lm,z}} = -r_{\mathrm{m1,z}} = -r_{\mathrm{lm,p}} \\ r_{\mathrm{2m,x}} &= -r_{\mathrm{m2,x}} = r_{\mathrm{2m,p}}, \qquad r_{\mathrm{2m,y}} = -r_{\mathrm{m2,y}} = r_{\mathrm{2m,s}}, \qquad r_{\mathrm{2m,z}} = -r_{\mathrm{m2,z}} = -r_{\mathrm{2m,p}} \\ t_{\mathrm{lm,x}} &= (\cos \theta_{\mathrm{m}} / \cos \theta_{\mathrm{l}}) t_{\mathrm{lm,p}}, \qquad t_{\mathrm{lm,y}} = t_{\mathrm{lm,s}}, \qquad t_{\mathrm{lm,z}} = (\sin \theta_{\mathrm{m}} / \sin \theta_{\mathrm{l}}) t_{\mathrm{lm,p}} \\ t_{\mathrm{m1,x}} &= (\cos \theta_{\mathrm{l}} / \cos \theta_{\mathrm{m}}) t_{\mathrm{m1,p}}, \qquad t_{\mathrm{m1,y}} = t_{\mathrm{m1,s}}, \qquad t_{\mathrm{m1,z}} = (\sin \theta_{\mathrm{l}} / \sin \theta_{\mathrm{m}}) t_{\mathrm{m1,p}} \\ t_{\mathrm{2m,x}} &= (\cos \theta_{\mathrm{l}} / \cos \theta_{\mathrm{l}}) t_{\mathrm{m2,p}}, \qquad t_{\mathrm{2m,y}} = t_{\mathrm{2m,s}}, \qquad t_{\mathrm{m2,z}} = (\sin \theta_{\mathrm{l}} / \sin \theta_{\mathrm{l}}) t_{\mathrm{m2,p}} \\ t_{\mathrm{m2,x}} &= (\cos \theta_{\mathrm{l}} / \cos \theta_{\mathrm{m}}) t_{\mathrm{m2,p}}, \qquad t_{\mathrm{m2,y}} = t_{\mathrm{m2,s}}, \qquad t_{\mathrm{m2,z}} = (\sin \theta_{\mathrm{l}} / \sin \theta_{\mathrm{l}}) t_{\mathrm{m2,p}} \\ t_{\mathrm{lm,\alpha}} t_{\mathrm{m1,\alpha}} &= 1 + r_{\mathrm{lm,\alpha}} r_{\mathrm{m1,\alpha}} = 1 - r_{\mathrm{lm,\alpha}}^{2}, \qquad t_{\mathrm{2m,\alpha}} t_{\mathrm{m2,\alpha}} = 1 + r_{\mathrm{2m,\alpha}} r_{\mathrm{m2,\alpha}} = 1 - r_{\mathrm{2m,\alpha}}^{2}, \qquad (\alpha = \mathrm{x}, \mathrm{y}, \mathrm{z}) \end{split}$$

#### L 係数

L 係数とは、SFG 分極とそれから生成する SFG 光の電場振幅  $E_{\rm SF}$  を関係づける係数である。下式で示すように、電場に関しては座標成分ごとに、分極については偏光成分ごとに定義される。

$$E_{\rm SF, \, \alpha} = \sum_{\beta} L_{\alpha\beta} P_{\beta}^{\rm SF}$$

一般化された Snell の屈折式により、生成する SFG 光は上向き (-) 光と下向き (+) 光の両方になる。また、分極が存在する部位によって L 係数の表式が違ってくる。もともと導かれた式は、無限に薄い薄膜 m が分極し、そこから媒質 1 媒質 2 に出てくる光を考えたものであって、s 偏光と p 偏光の電場振幅を分極の x、y、z 成分と関係づけるものであるが、ここでは、拡張して考える。また、共通因子である  $4\pi i\omega_{SF}/c$  (屈折率の代わりに波数ベクトルを使うときには  $4\pi i\omega_{SF}^2/c^2$ ) を省略する。なお、上向き (-) 光および下向き (+) 光とは、それぞれ反射光と同じ方向 (-z 方向) に進む光と入射光や透過光と同じ方向 (+z 方向) に進む光を指す。

L **係数の表記法;L\_{i\hat{q}s(p),\alpha}:** 分極シート m' が I 層と j 層に挟まれているときに、分極の  $\alpha$  成分  $(\alpha=x,y,z)$  が作る光の s 偏光成分又は p 偏光成分の間の係数。上向き (-) 光、下向き (+) 光の区別を上付き -,+ で示す。

媒質1と積層膜 m の間の分極シート m' からの SFG 光生成に対する L 係数は、下式で与えられる。

$$\begin{split} L_{1/\text{m,p,x}} &= \cos\theta_{\text{m,SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ L_{1/\text{m,p,z}} &= 1 / (n_{1,\text{SF}} \cos\theta_{1,\text{SF}} + n_{\text{m,SF}} \cos\theta_{\text{m,SF}}) \\ L_{1/\text{m,p,z}} &= (n_{\text{m}} / n_{\text{m}}) \sin\theta_{\text{m',SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) = (n_{\text{m}} / n_{\text{m'}})^2 \sin\theta_{\text{m,SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ L_{1/\text{m,p,z}}^+ &= \cos\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ L_{1/\text{m,p,z}}^+ &= 1 / (n_{1,\text{SF}} \cos\theta_{1,\text{SF}} + n_{\text{m,SF}} \cos\theta_{\text{m,SF}}) \\ L_{1/\text{m,p,z}}^+ &= -(n_1 / n_{\text{m'}}) \sin\theta_{\text{m',SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ \end{pmatrix} = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ \end{pmatrix} = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ \end{pmatrix} = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{\text{m,SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{1,\text{SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{1,\text{SF}} + n_{\text{m,SF}} \cos\theta_{1,\text{SF}}) \\ = -(n_1 / n_{\text{m'}})^2 \sin\theta_{1,\text{SF}} / (n_{1,\text{SF}} \cos\theta_{1,\text{SF}} +$$

媒質2と積層膜 m の間の分極シート m" からの SFG 光生成に対する L 係数は、下式で与えられる。

$$\begin{split} L_{2/\text{m,p,x}} &= \cos\theta_{2,\text{SF}}/(n_{2,\text{SF}}\cos\theta_{\text{m,SF}} + n_{\text{m,SF}}\cos\theta_{2,\text{SF}}) \\ L_{2/\text{m,p,x}} &= 1/(n_{2,\text{SF}}\cos\theta_{2,\text{SF}} + n_{\text{m,SF}}\cos\theta_{\text{m,SF}}) \\ L_{2/\text{m,p,x}} &= (n_2/n_{\text{m}"})\sin\theta_{\text{m}",\text{SF}}/(n_{2,\text{SF}}\cos\theta_{\text{m,SF}} + n_{\text{m,SF}}\cos\theta_{2,\text{SF}}) = (n_2/n_{\text{m}"})^2\sin\theta_{2,\text{SF}}/(n_{2,\text{SF}}\cos\theta_{\text{m,SF}} + n_{\text{m,SF}}\cos\theta_{2,\text{SF}}) \\ L_{2/\text{m,p,x}}^+ &= \cos\theta_{\text{m,SF}}/(n_{2,\text{SF}}\cos\theta_{\text{m,SF}} + n_{\text{m,SF}}\cos\theta_{2,\text{SF}}) \\ L_{2/\text{m,p,x}}^+ &= 1/(n_{2,\text{SF}}\cos\theta_{2,\text{SF}} + n_{\text{m,SF}}\cos\theta_{\text{m,SF}}) \\ L_{2/\text{m,p,x}}^+ &= -(n_{\text{m}}/n_{\text{m}"})\sin\theta_{\text{m}",\text{SF}}/(n_{2,\text{SF}}\cos\theta_{\text{m,SF}} + n_{\text{m,SF}}\cos\theta_{2,\text{SF}}) = -(n_{\text{m}}/n_{\text{m}"})^2\sin\theta_{\text{m,SF}}/(n_{2,\text{SF}}\cos\theta_{\text{m,SF}} + n_{\text{m,SF}}\cos\theta_{2,\text{SF}}) \end{split}$$

積層膜内部の分極シートからの SFG 光生成に対する L 係数は、下式で与えられる。

$$\begin{split} L_{\text{m/m,p,x}}^{-} &= L_{\text{m/m,p,x}}^{+} = \cos\theta_{\text{m,SF}}/(2n_{\text{m,SF}}\cos\theta_{\text{m,SF}}) \\ L_{\text{m/m,s,y}}^{-} &= L_{\text{m/m,s,y}}^{+} = 1/(2n_{\text{m,SF}}\cos\theta_{\text{m,SF}}) \\ L_{\text{m/m,p,z}}^{-} &= -L_{\text{m/m,p,z}}^{+} = \sin\theta_{\text{m,SF}}/(2n_{\text{m,SF}}\cos\theta_{\text{m,SF}}) \end{split}$$

上に示した電場と分極の間の関係式は、SFG 分極と SFG 光に限定されるものでとはない。振動分極と、 それから生成する電磁波に対して、一般的に成り立つのである。

#### 2. 二層系 (1/m'/m/2) からの SFG

#### 2.1. 電場振幅の積

可視光の電場と赤外光の電場の積を下に示す。但し、位相部分については、SFG 光の経路が最外面で反射するとしたときのものを示すので、m'/m 界面及び m/m" 界面での反射についても取り入れる必要があるときには、別途に考慮しなければならない。式の導出については、ファイル「二層膜からの和周波 (SFG)」の 4 節または「積層膜からの和周波発生 (SFG)」の4節を参照されたい。

#### 1/m' 界面の 1 側:

(a):  $E^+$  (by reflection and transmission) sources and  $E^-$  (for n=0) source

$$E_{vis\alpha}(0^{-})E_{ir,\beta}(0^{-}) = E^{0}_{vis\alpha}E^{0}_{ir,\beta} \times \frac{(1 + r_{1m',vis\alpha})[(1 + r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) + (r_{m'm,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}]}{1 + r_{1m',vis\alpha}r_{mm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{(1+r_{1m',ir,\beta})[(1+r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})+(r_{m'm,ir,\beta}+e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}]}{1+r_{1m',ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}}+(r_{m'm,ir,\beta}+r_{1m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \exp[2ni(h_{m}\tan\theta_{m,SF}+h_{m'}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir}-k_{m,v,is}\sin\theta_{m,v,is})]$$
(2.1)

## 1/m' 界面の m' 側:

## (a): $E^+$ and $E^-$ (by reflection) sources

$$\begin{split} E_{vis\alpha}\left(0^{+}\right) E_{ir\beta}\left(0^{+}\right) &= E^{0}_{vis\alpha} E^{0}_{ir\beta} \\ &\times \frac{t_{1m',vis\alpha}\left[\left(1 + r_{m'm,vis\alpha}e^{2\beta_{m',vi}h_{m'}}\right) + \left(r_{m'm,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}}\right)r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}}\right]}{1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + \left(r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}}\right)r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}}} \\ &\times \frac{t_{1m',ir\beta}\left[\left(1 + r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}}\right) + \left(r_{m'm,ir\beta} + e^{2\beta_{m',is}h_{m'}}\right)r_{m2,ir\beta}e^{2\beta_{m,vis}h_{m}}}{1 + r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}} + \left(r_{m'm,ir\beta} + r_{1m',ir\beta}e^{2i\beta_{m,v}h_{m'}}\right)r_{m2,ir\beta}e^{2i\beta_{m,v}h_{m}}} \\ &\times \exp\left[2ni(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF})\left(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}\right)\right] \end{split} \tag{2.2}$$

## m/2 界面の 2 側:

#### (a): $E^+$ source

$$E_{vis\alpha}(h_{m'} + h_{m}^{+})E_{ir\beta}(h_{m'} + h_{m}^{+}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}t_{m'm,vis\alpha}t_{m'm,vis\alpha}t_{m2,vis\alpha}e^{i(\beta_{m',vis}h_{m'} + \beta_{m,vis}h_{m})}}{1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta}t_{m'm,ir\beta}t_{m'm,ir\beta}t_{m2,ir\beta}e^{i(\beta_{m',ir}h_{m'} + \beta_{m,ir}h_{m})}}{1 + r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,vi}h_{m}}}$$

$$\times \exp[2ni(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})]$$
(2.3)

#### (b): E sources (for n > 0, by reflection)

$$E_{vis\alpha}(h_{m'} + h_{m'}^{+})E_{ir\beta}(h_{m'} + h_{m'}^{+}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}t_{mm,vis\alpha}t_{mm,vis\alpha}e^{2i\beta_{m',vis}h_{m'} + \beta_{m,vis}h_{m'}}}{1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir,\beta}t_{m'm,ir,\beta}t_{m'2,ir,\beta}e^{i(\beta_{m',ir}h_{m'} + \beta_{m,ii}h_{m}})}{1 + r_{1m',ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \exp[i(2n+1)(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})]$$
(2.4)

#### m/2 界面の m 側:

## (a): $E^+$ (by reflection) and $E^-$ sources

$$\begin{split} E_{vis\alpha} \left( h_{m^{'}} + h_{m}^{-} \right) & E_{ir,\beta} \left( h_{m^{'}} + h_{m}^{-} \right) = E^{0}_{vis\alpha} \, E^{0}_{ir,\beta} \\ & \times \frac{t_{1m^{'},vis\alpha} \, t_{m^{'}m,vis\alpha} \, (1 + r_{m2,vis\alpha}) e^{i(\beta_{m^{'},vis}h_{m^{'}} + \beta_{m,vis}h_{m^{'}})}}{1 + r_{1m^{'},vis\alpha} \, r_{m^{'}m,vis\alpha} \, e^{2i\beta_{m^{'},vis}h_{m^{'}}} + (r_{m^{'}m,vis\alpha} + r_{1m^{'},vis\alpha} \, e^{2i\beta_{m^{'},vis}h_{m^{'}}}) r_{m2,vis\alpha} \, e^{2i\beta_{m,vis}h_{m}}} \end{split}$$

$$\times \frac{t_{1m',ir,\beta}t_{m'm,ir,\beta}(1+r_{m2,ir,\beta})e^{i(\beta_{m',ir}h_{m'}+\beta_{m,ir}h_{m})}}{1+r_{1m',ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}}+(r_{m'm,ir,\beta}+r_{1m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}} \times \exp[i(2n+1)(h_{m}\tan\theta_{mSF}+h_{m'}\tan\theta_{m'SF})(-k_{m,ir}\sin\theta_{m,ir}-k_{m,v,is}\sin\theta_{m,v,is})]$$
(2.5)

#### m'/m 界面の m' 側:

#### (a): $E^+$ and $E^-$ (by reflection) sources

$$E_{vis\alpha}(h_{m'}^{-})E_{ir\beta}(h_{m'}^{-}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}e^{i\beta_{m',vi}h_{m'}}(1+r_{m'm,vis\alpha})(1+r_{m2,vis\alpha}e^{2i\beta_{m,vi}h_{m}})}{1+r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vi}h_{m'}}+(r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2i\beta_{m,vi}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vi}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta}e^{i\beta_{m',ir}h_{m'}}(1+r_{mm,ir\beta})(1+r_{m2,ir\beta}e^{2i\beta_{m,ir}h_{m}})}{1+r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m,ir}h_{m'}}+(r_{m'm,ir\beta}+r_{1m',ir\beta}e^{2i\beta_{m,ir}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \exp[ih_{m'}\tan\theta_{m',SF}(-k_{m,ir}\sin\theta_{m,ir}-k_{m,vis}\sin\theta_{m,vis})]$$

$$\times \exp[i(2n+1)(h_{m}\tan\theta_{m,SF}+h_{m'}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir}-k_{m,vis}\sin\theta_{m,vis})]$$
(2.6)

#### (b): $E^+$ (by reflection) and $E^-$ sources

$$\begin{split} E_{vis\alpha}\left(h_{m}^{-}\right) E_{ir\beta}\left(h_{m}^{-}\right) &= E^{0}_{vis\alpha} E^{0}_{ir\beta} \\ &\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} e^{i\beta_{m',vis}h_{m'}} (1 + r_{m'm,vis\alpha}) (1 + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}})}{1 + r_{1m',vis\alpha}} \\ &\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}{1 + r_{1m',ir\beta}} \\ &\times \frac{t_{1m',ir\beta}}{1 + r_{1m',ir\beta}} e^{i\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir\beta}) (1 + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}})}{1 + r_{1m',ir\beta}} \\ &\times \exp[ih_{m'} \tan \theta_{m',SF} (-k_{m,ir} \sin \theta_{m,ir} - k_{m,vis} \sin \theta_{m,vis})] \\ &\times \exp[2ni(h_{m} \tan \theta_{m,SF} + h_{m'} \tan \theta_{m',SF}) (-k_{m,ir} \sin \theta_{m,ir} - k_{m,vis} \sin \theta_{m,vis})] \end{split}$$

#### m'/m 界面の m 側:

#### (a): $E^+$ and $E^-$ (by reflection) sources

$$\begin{split} E_{vis\alpha}\left(h_{mi}^{+}\right) E_{ir,\beta}\left(h_{mi}^{+}\right) &= E^{0}_{vis\alpha} E^{0}_{ir,\beta} \\ &\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} t_{m'm,vis\alpha} e^{i\beta_{m',vis}h_{m'}} \left(1 + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}\right) \\ &\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + \left(r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}\right) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}} \\ &\times \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta}} e^{i\beta_{m',ir}h_{m'}} \left(1 + r_{m'm,ir,\beta}\right) \left(1 + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}\right) \\ &\times \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta}} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}} + \left(r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m,ir}h_{m}}\right) r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}} \\ &\times \exp\left[ih_{m'} \tan\theta_{m',SF} \left(-k_{m,ir} \sin\theta_{m,ir} - k_{m,vis} \sin\theta_{m,vis}\right)\right] \\ &\times \exp\left[2ni(h_{m} \tan\theta_{m,SF} + h_{m'} \tan\theta_{m',SF}) \left(-k_{m,ir} \sin\theta_{m,ir} - k_{m,vis} \sin\theta_{m,vis}\right)\right] \end{aligned} \tag{2.8}$$

## (b): $E^+$ (by reflection) and $E^-$ sources

$$\begin{split} E_{vis\alpha}\left(h_{m}^{+}\right) & E_{ir\beta}\left(h_{m}^{+}\right) = E^{0}_{vis\alpha}E^{0}_{ir\beta} \\ & \times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} t_{m'm,vis\alpha} e^{i\beta_{m',vis}h_{m'}} \left(1 + r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}\right) \\ & \times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + \left(r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}}\right) r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}} \\ & \times \frac{t_{1m',ir\beta}}{1 + r_{1m',ir\beta}} t_{m'm,ir\beta}e^{i\beta_{m',ir}h_{m'}} \left(1 + r_{m2,ir\beta}e^{2i\beta_{m',ir}h_{m}}\right) \\ & \times \frac{t_{1m',ir\beta}}{1 + r_{1m',ir\beta}} r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}} + \left(r_{m',mir\beta} + r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}}\right) r_{m2,ir\beta}e^{2i\beta_{m,vi}h_{m}} \\ & \times \exp[ih_{m'} \tan\theta_{m',SF}(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis})] \\ & \times \exp[2ni(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis})] \end{split}$$

# m' 層の深さ z<sub>1</sub>点

 $[\mathbf{A}_n^{(\mathbf{m}')}]$ :  $E^+$  sources

$$\begin{split} E_{viot}\left(z_{1}\right) &= E^{0}_{viot} \frac{t_{1m/site}}{1 + t_{1m/site} t_{2m/site}} e^{2i\beta_{m/s}h_{m}} + (t_{m/msite} + t_{1m/site} t_{1m/site}) e^{2i\beta_{m/s}h_{m}} \right) r_{m2site} e^{2i\beta_{m/s}h_{m}} \\ &\times \left\{ (1 + t_{m/msite} t_{m/site} e^{2i\beta_{m/s}h_{m}}) \exp[iz_{1}k_{m/sit} \cos \theta_{m/sit} (1 + \tan \theta_{m/s} t_{1} \tan \theta_{m/s} t_{1})] \right. \\ &+ (t_{m/msite} t_{m/site} e^{2i\beta_{m/s}h_{m}}) e^{2i\beta_{m/s}h_{m}} \exp[iz_{1}k_{m/sit} \cos \theta_{m/sit} (-1 + \tan \theta_{m/s} t_{1} \tan \theta_{m/s} t_{1})] \\ &+ (t_{m/msite} t_{m/site} t_{m/site} e^{2i\beta_{m/s}h_{m}}) e^{2i\beta_{m/s}h_{m}} \exp[iz_{1}k_{m/sit} \cos \theta_{m/sit} (-1 + \tan \theta_{m/s} t_{1} \tan \theta_{m/s} t_{1})] \\ &+ \exp[-i(2n+2)(h_{m} \tan \theta_{m/s} t_{1} + t_{m/sit} t_{1} t_{1}$$

$$\times \exp[-i(2n+2)(h_m \tan \theta_{m,SF} + h_{m'} \tan \theta_{m',SF})(k_{m,vis} \sin \theta_{m,vis} + k_{m,ir} \sin \theta_{m,ir})]$$
(2.11)

 $[\mathbf{B}_{n}^{(\mathbf{m}')}]$ : E sources

$$\begin{split} E_{vis\alpha}\left(z_{1}\right) &= E^{0}{}_{vis\alpha} \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}r_{mm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha}e^{+r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}} \\ &\times \{(1 + r_{m'm,vis\alpha}r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}})\exp[iz_{1}k_{m',vis}\cos\theta_{m',vis}(1 - \tan\theta_{m',SF}\tan\theta_{m',vis})] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}})e^{2i\beta_{m',vis}h_{m'}}\exp[iz_{1}k_{m',vis}\cos\theta_{m',vis}(-1 - \tan\theta_{m',SF}\tan\theta_{m',vis})]\} \\ &\times \exp[-i2n(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF})k_{m,vis}\sin\theta_{m,vis}] \end{split} \tag{2.12a}$$

$$E_{ir,\beta}(z_{1}) = E^{0}_{ir,\beta} \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}} \times \{ (1 + r_{m'm,ir,\beta} r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) \exp[iz_{1}k_{m',ir} \cos\theta_{m',ir} (1 - \tan\theta_{m',SF} \tan\theta_{m',ir})] + (r_{m'm,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m,ir}h_{m'}} \exp[iz_{1}k_{m',ir} \cos\theta_{m',ir} (-1 - \tan\theta_{m',SF} \tan\theta_{m',ir})] \} \times \exp[-i2n(h_{m} \tan\theta_{m,SF} + h_{m'} \tan\theta_{m',SF})k_{m,vis} \sin\theta_{m,vis}]$$
(2.12b)

$$E_{vis\alpha}(z_{1})E_{ir\beta}(z_{1}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vi}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vi}h_{m}}}$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',ir\beta}r_{m'm',ir\beta}e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\beta}e^{2i\beta_{m',vi}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vi}h_{m}}}$$

$$\times \{(1 + r_{m'm,vis\alpha}r_{m2,vis\alpha}e^{2\beta_{m,vi}h_{m}})(1 + r_{m'm,ir\beta}r_{m2,ir\beta}e^{2i\beta_{m',vi}h_{m'}})$$

$$\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))]$$

$$+ (1 + r_{m'm,vis\alpha}r_{m2,vis\alpha}e^{2\beta_{m,vi}h_{m}})(r_{m'm,ir\beta} + r_{m2,ir\beta}e^{2i\beta_{m,vi}h_{m}})e^{2i\beta_{m',vih}}$$

$$\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(-1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))]$$

$$+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2\beta_{m,vi}h_{m}})(1 + r_{m'm,ir\beta}r_{m2,ir\beta}e^{2i\beta_{m,v}h_{m}})e^{2i\beta_{m',vih}}$$

$$\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(-1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))]$$

$$+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2\beta_{m,vih}h_{m}})(r_{m',m,ir\beta} + r_{m2,ir\beta}e^{2i\beta_{m,vih}})e^{2i(\beta_{m',vih}+\beta_{m',vih})h_{m'}}$$

$$\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(-1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))]$$

$$+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2\beta_{m,vih}h_{m}})(r_{m',m,ir\beta} + r_{m2,ir\beta}e^{2i\beta_{m,vih}})e^{2i(\beta_{m',vih}+\beta_{m',vih})h_{m'}}$$

$$\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(-1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(-1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))]$$

(2.13)

#### m 層の m'/m 界面から深さ z<sub>2</sub> の点

 $[\mathbf{A}_n^{(\mathbf{m})}]$ :  $E^+$  sources

$$\begin{split} E_{vis\alpha}\left(h_{m}+z_{2}\right) &= E^{0}{}_{vis\alpha} \frac{t_{1m',vis\alpha}t_{mm,vis\alpha}}e^{i\beta_{m',vis}h_{m'}}}{1+r_{1m',vis\alpha}r_{m'm,vis\alpha}}e^{2i\beta_{m',vis}h_{m'}}+(r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}\\ &\times \{\exp[iz_{2}k_{m,vis}\cos\theta_{m,vis}(1+\tan\theta_{m,SF}\tan\theta_{m,vis})]\\ &+r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}\exp[iz_{2}k_{m,vis}\cos\theta_{m,vis}(-1+\tan\theta_{m,SF}\tan\theta_{m,vis})]\} \end{split}$$

 $\times \exp[-i2n(h_m \tan \theta_{m,SF} + h_{m'} \tan \theta_{m',SF})(k_{m,vis} \sin \theta_{m,vis} + k_{m,ir} \sin \theta_{m,ir})]$ 

$$\times \exp[-i(2n+2)(h_m \tan \theta_{m,SF} + h_{m'} \tan \theta_{m',SF})k_{m,vis} \sin \theta_{m,vis}]$$
(2.14a)

$$E_{ir\beta}(h_m + z_2) = E^{0}_{ir\beta} \frac{t_{1m'jr\beta} t_{m'm'jr\beta} e^{i\theta_{sc}h_{sc}}}{1 + t_{1m'jr\beta} t_{m'm'jr\beta} e^{2i\theta_{sc}h_{sc}} + (t_{m'm'jr\beta} + t_{1m'jr\beta} e^{2i\theta_{sc}h_{sc}}) r_{m2jr\beta} e^{2i\theta_{sc}h_{sc}}}$$

$$\times \{ \exp[iz_2 k_{mjr} \cos\theta_{mjr} (1 + \tan\theta_{mSF} \tan\theta_{mjr})] \}$$

$$+ r_{m2jr\beta} e^{2i\theta_{sc}h_{sc}} \exp[iz_2 k_{mjr} \cos\theta_{mjr} (-1 + \tan\theta_{mSF} \tan\theta_{mjr})] \}$$

$$\times \exp[-i(2n+2)(h_m \tan\theta_{mSF} + h_m \tan\theta_{m'SF}) k_{mjr} \sin\theta_{mjr}] \}$$

$$\times \exp[-i(2n+2)(h_m \tan\theta_{mSF} + h_m \tan\theta_{m'SF}) k_{mjr} \sin\theta_{mjr}] \}$$

$$\times \frac{t_{1m'jr\beta} t_{m'm'js\alpha}}{1 + t_{1m'js\alpha} t_{m'm'js\alpha}} e^{2i\theta_{sc}h_{sc}} + (t_{m'm'js\alpha} e^{i\theta_{sc}h_{sc}}) k_{mjr} \sin\theta_{mjr}]$$

$$\times \frac{t_{1m'jr\beta} t_{1m'jr\beta} t_{m'm'js\alpha}}{1 + t_{1m'jr\beta} t_{1m'jr\beta} t_{1m'jr\beta}} e^{2i\theta_{sc}h_{sc}} + t_{m'js\alpha} e^{2i\theta_{sc}h_{sc}}) r_{n2jr\beta} e^{2i\theta_{sc}h_{sc}} + (t_{m'jr\beta} t_{1m'jr\beta} t_{1m'jr\beta} e^{2i\theta_{sc}h_{sc}}) r_{m'jr\beta} e^{2i\theta_{sc}h_{sc}} + (t_{m'mjr\beta} t_{1m'jr\beta} t_{1m'jr\beta} e^{2i\theta_{sc}h_{sc}}) r_{m'jr\beta} e^{2i\theta_{sc}h_{sc}} + (t_{m'jr\beta} t_{1m'jr\beta} t_{1m'jr\beta} t_{1m'jr\beta} e^{2i\theta_{sc}h_{sc}}) r_{m'jr\beta} e^{2i\theta_{sc}h_{sc}} + (t_{m'jr\beta} t_{1m'jr\beta} t_{1m'jr\beta} e^{2i\theta_{sc}h_{sc}}) r_{m'jr\beta} e^{2i\theta_{sc}h_{sc}} + (t_{m'jr\beta} t_{1m'jr\beta} t_{1m'jr\beta} e^{2i\theta_{sc}h_{sc}}) r_{m'jr\beta} e^{2i\theta_{sc}h_{sc}h_{sc}}} \times \{ \exp[iz_2(k_{m'jis} \cos\theta_{m'jis} (1 + \tan\theta_{m'js}) + k_{m'jr} \cos\theta_{m'jr} (1 + \tan\theta_{m'jr})) ] + r_{m'jr\beta} e^{2i\theta_{sc}h_{sc}} \cos\theta_{m'jr\beta} (-1 + \tan\theta_{m'jr\beta}) r_{m'j\beta} e^{2i\theta_{sc}h_{sc}} + (t_{m'jr\beta} t_{1m'j\beta} t$$

 $[\mathbf{B}_n^{(\mathbf{m})}]$ : E sources

$$E_{vis\alpha}(h_{m}+z_{2}) = E^{0}_{vis\alpha} \frac{t_{1m',vis\alpha}t_{m'm,vis\alpha}e^{i\beta_{m',vis}h_{m'}}}{1+r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}+(r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}} \times \{\exp[iz_{2}k_{m,vis}\cos\theta_{m,vis}(1-\tan\theta_{m,SF}\tan\theta_{m,vis})] + r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}\exp[iz_{2}k_{m,vis}\cos\theta_{m,vis}(-1-\tan\theta_{m,SF}\tan\theta_{m,vis})]\} \times \exp[-i2n(h_{m}\tan\theta_{m,SF}+h_{m'}\tan\theta_{m',SF})k_{m,vis}\sin\theta_{m,vis}]$$
 (2.16a)

(2.15)

 $\times \exp[-i(2n+2)(h_m \tan\theta_{m,SF} + h_{m'} \tan\theta_{m',SF})(k_{m,vis} \sin\theta_{m,vis} + k_{m,ir} \sin\theta_{m,ir})]$ 

$$E_{ir,\beta}(h_{m}+z_{2}) = E^{0}_{ir,\beta} \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} e^{i\beta_{m',ir}h_{m'}}}{1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2\beta_{m',ir}h_{m'}}) r_{m2ir,\beta} e^{2\beta_{m,ir}h_{m}}} \times \{ \exp[iz_{2}k_{m,ir}\cos\theta_{m,ir}(1 - \tan\theta_{m,SF}\tan\theta_{m,ir})] + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}} \exp[iz_{2}k_{m,ir}\cos\theta_{m,ir}(-1 - \tan\theta_{m,SF}\tan\theta_{m,ir})] \} \times \exp[-i2n(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF})k_{m,ir}\sin\theta_{m,ir}]$$
(2.16b)

$$E_{vis\alpha}(h_{m}+z_{2})E_{ir\beta}(h_{m}+z_{2}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m/vis\alpha}t_{m/m/vis\alpha}e^{i\beta_{m/vi}h_{m}}}{1+r_{1m/vis\alpha}r_{m/m/vis\alpha}e^{2i\beta_{m/vi}h_{m}}+r_{1m/vis\alpha}e^{2i\beta_{m/vi}h_{m}}}$$

$$\times \frac{t_{1m/vis\alpha}t_{m/m/vis\alpha}e^{2i\beta_{m/vi}h_{m}}+r_{1m/vis\alpha}e^{2i\beta_{m/vi}h_{m}}}{1+r_{1m/vis\beta}r_{m/m/vis\beta}e^{2i\beta_{m/vi}h_{m}}+r_{1m/vis\beta}e^{2i\beta_{m/v}h_{m}}}$$

$$\times \frac{t_{1m/vis\beta}t_{m/m/vis\beta}e^{\beta_{m/v}h_{m}}}{1+r_{1m/vis\beta}r_{m/m/vis\beta}e^{2i\beta_{m/v}h_{m}}+r_{1m/vis\beta}e^{2i\beta_{m/v}h_{m}}}$$

$$\times \{\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(1-\tan\theta_{m,SF}\tan\theta_{m,vis})+k_{m/v}\cos\theta_{m/v}(1-\tan\theta_{m,SF}\tan\theta_{m/v}))]$$

$$+r_{m/2ir\beta}e^{2i\beta_{m/v}h_{m}}$$

$$\times \{\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(1-\tan\theta_{m,SF}\tan\theta_{m,vis})+k_{m/v}\cos\theta_{m/v}(-1-\tan\theta_{m,SF}\tan\theta_{m/v}))]$$

$$+r_{m/2,vis\alpha}e^{2\beta_{m/v}h_{m}}$$

$$\times \{\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1-\tan\theta_{m,SF}\tan\theta_{m,vis})+k_{m/v}\cos\theta_{m/v}(1-\tan\theta_{m,SF}\tan\theta_{m/v}))]$$

$$+r_{m/2,vis\alpha}e^{2\beta_{m/v}h_{m}}$$

$$\times \{\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1-\tan\theta_{m,SF}\tan\theta_{m,vis})+k_{m/v}\cos\theta_{m/v}(1-\tan\theta_{m,SF}\tan\theta_{m/v}))]$$

$$+r_{m/2,vis\alpha}e^{2i(\beta_{m/v}+\beta_{m,vis})h_{m}}$$

$$\times \{\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1-\tan\theta_{m,SF}\tan\theta_{m,vis})+k_{m/v}\cos\theta_{m/v}(-1-\tan\theta_{m,SF}\tan\theta_{m/v}))]$$

$$+exp[-i2n(h_{m}\tan\theta_{m,SF}+h_{m}'\tan\theta_{m,SF})(k_{m,vis}\sin\theta_{m,vis}+k_{m/v}\sin\theta_{m/v})]$$

$$(2.17)$$

#### 2.2. SFG 分極

各部位の SFG 分極は、その部位における vis 光と ir 光の電場積に感受率を掛けたものである。下には、位相を除いた、分極の振幅を示す。

#### 1/m' 界面の 1 側:

(a):  $E^+$  (by reflection and transmission) sources and  $E^-$  (for n=0) source

$$P_{a}^{*}(0^{-}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{(1 + r_{1m',vis\alpha})[(1 + r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) + (r_{m'm,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}]}{1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{(1 + r_{1m',ir\beta})[(1 + r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}}) + (r_{m'm,ir\beta} + e^{2i\beta_{m',ir}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}{1 + r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,ir}h_{m}}}$$
(2.18)

#### 1/m' 界面の m' 側:

(a):  $E^+$  and  $E^-$  (by reflection) sources

$$P_{a}^{*}(0^{+}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} \left[ (1 + r_{mim,vis\alpha} e^{2\beta_{m',vis}h_{m'}}) + (r_{mim,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}} \right]}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta} \left[ (1 + r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}}) + (r_{m'm,ir\beta} + e^{2\beta_{m',ir}h_{m'}}) r_{m2,vis\alpha} e^{2\beta_{m,ir}h_{m}} \right]}{1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}}$$
(2.19)

#### m/2 界面の 2 側:

(a): $E^+$  source

$$P_{a}^{*}(h_{m'} + h_{m'}^{+}) = \sum_{\alpha,\beta} \chi_{ao\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} t_{m'2,vis\alpha} e^{i(\beta_{m',vis}h_{m'} + \beta_{m,vis}h_{m})}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta} t_{m'm,ir\beta} t_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}{1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}}$$
(2.20)

(b): E sources (for n > 0, by reflection)

$$P_{a}^{*}(h_{m'} + h_{m}^{+}) = \sum_{\alpha,\beta} \chi_{ao\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} t_{m2,vis\alpha} e^{i(\beta_{m',vis}h_{m'} + \beta_{m,vis}h_{m})}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta} t_{m'm,ir\beta} t_{m2,ir\beta} e^{i(\beta_{m',ir}h_{m'} + \beta_{m,ir}h_{m})}}{1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}}$$
(2.21)

#### m/2 界面の m 側:

(a):  $E^+$  (by reflection) and  $E^-$  sources

$$P_{a}^{*}(h_{m'} + h_{m}^{-}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} (1 + r_{m2,vis\alpha}) e^{i(\beta_{m',vis}h_{m'} + \beta_{m,vis}h_{m})}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta} t_{m'm,ir\beta} (1 + r_{m2,ir\beta}) e^{i(\beta_{m',vis}h_{m'} + \beta_{m,vis}h_{m})}}{1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m',mir\beta} + r_{1m',ir\beta} e^{2i\beta_{m,vis}h_{m'}}) r_{m2,ir\beta} e^{2i\beta_{m,vis}h_{m}}}$$
(2.22)

#### m'/m 界面の m' 側:

(a):  $E^+$  and  $E^-$  (by reflection) sources

$$P_{a}^{*}(h_{m}^{-}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha}} e^{i\beta_{m;vi}h_{m'}} (1 + r_{m'm,vis\alpha}) (1 + r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}})$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m;vi}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vi}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}}}$$

$$\times \frac{t_{1m',ir,\beta} e^{i\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir,\beta}) (1 + r_{m2,ir,\beta} e^{2i\beta_{m,vi}h_{m}})}{1 + r_{1m',ir,\beta} r_{m',ir,\beta} e^{2i\beta_{m,ir}h_{m'}}}$$

$$\times \frac{t_{1m',ir,\beta} e^{i\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir,\beta}) (1 + r_{m2,ir,\beta} e^{2i\beta_{m,vi}h_{m'}}) r_{m2,ir,\beta} e^{2i\beta_{m,vi}h_{m}}}{1 + r_{1m',ir,\beta} r_{m',ir,\beta} e^{2i\beta_{m,vi}h_{m'}} + (r_{m',m,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m,vi}h_{m'}}) r_{m2,ir,\beta} e^{2i\beta_{m,vi}h_{m}}}$$

$$(2.23)$$

(b):  $E^+$  (by reflection) and  $E^-$  sources

$$P_a^*(h_m^-) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^0_{vis,\alpha} E^0_{ir,\beta}$$

$$\times \frac{t_{1m;vis\alpha}e^{i\beta_{m;v}h_{m}}(1+r_{m'mvis,\alpha})(1+r_{m2,vis,\alpha}e^{2\beta_{m;v}h_{m}})}{1+r_{1m;vis,\alpha}r_{mm,vis,\alpha}e^{2\beta_{m;v}h_{m}}+(r_{m'm,vis,\alpha}+r_{1m',vis,\alpha}e^{2\beta_{m;v}h_{m}})r_{m2,vis,\alpha}e^{2\beta_{m,vh}h_{m}}} \\
\times \frac{t_{1m;ir,\beta}e^{i\beta_{m',\nu}h_{m'}}(1+r_{m'm,ir,\beta})(1+r_{m2ir,\beta}e^{2\beta_{m;\nu}h_{m}})r_{m2,vis,\alpha}e^{2\beta_{m,vh}h_{m}}}{1+r_{1m;ir,\beta}r_{m'm,ir,\beta}e^{2\beta_{m,\nu}h_{m}}+(r_{mim,ir,\beta}+r_{1m',ir,\beta}e^{2\beta_{m,\nu}h_{m}})r_{m2,ir,\beta}e^{2i\beta_{m,\nu}h_{m}}} \tag{2.24}$$

## m'/m 界面の m 側:

## (a): $E^+$ and $E^-$ (by reflection) sources

$$P_{a}^{*}(h_{m}^{+}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} e^{i\beta_{m',vis}h_{m'}} (1 + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}})}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta} e^{i\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir\beta}) (1 + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m'}})}{1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m,ir}h_{m'}}) r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}}$$
(2.25)

## (b): $E^+$ (by reflection) and $E^-$ sources

$$P_{a}^{*}(h_{m}^{+}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} e^{i\beta_{m',vis}h_{m'}} (1 + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}})}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta} t_{m'm,ir\beta} e^{i\beta_{m',ir}h_{m'}} (1 + r_{m2,ir\beta} e^{2i\beta_{m,vis}h_{m}})}{1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m',mir\beta} + r_{1m',ir\beta} e^{2i\beta_{m,vis}h_{m}})}$$

$$(2.26)$$

## m' 層の深さ z<sub>1</sub>点:

 $[\mathbf{A}_n^{(\mathbf{m}')}]$ :  $\mathbf{E}^+$  sources

$$\begin{split} P_{a}^{*}\left(z_{1}\right) &= \sum_{\alpha,\beta}\chi_{a\alpha\beta}E^{0}_{vis\alpha}E^{0}_{ir,\beta} \\ &\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}} \\ &\times \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta}}r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir,\beta}e^{2i\beta_{m,vis}h_{m}} \\ &\times \{(1 + r_{m'm,vis\alpha}r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}})(1 + r_{m'm,ir,\beta}r_{m2,ir,\beta}e^{2i\beta_{m,vis}h_{m}}) \\ &\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(1 + \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (1 + r_{m'm,vis\alpha}r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}})(r_{m'm,ir,\beta} + r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}})e^{2i\beta_{m,ir}h_{m'}} \\ &\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(1 + \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(-1 + \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}})(1 + r_{m',mir,\beta}r_{m2,ir,\beta}e^{2i\beta_{m,vis}h_{m}})e^{2i\beta_{m,vis}h_{m'}} \\ &\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}})(1 + r_{m',mir,\beta}r_{m2,ir,\beta}e^{2i\beta_{m,vis}h_{m}})e^{2i\beta_{m,vis}h_{m'}} \\ &\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (r_{m',vis\alpha} + r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}})(1 + r_{m',vir,\beta}r_{m2,ir,\beta}e^{2i\beta_{m,vis}h_{m}})e^{2i\beta_{m,vis}h_{m'}} \\ &\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (r_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (r_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m',SF}\tan\theta_{m',ir})) \\ &+ (r_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m',vis})) \\ &+ (r_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(-1 + \tan\theta_{m',vis}) \\ &+ (r_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(-1 + \tan\theta_{m',vis}) \\ &+$$

$$+(r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2\beta_{m,vis}h_m})(r_{m'm,ir,\beta} + r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_m})e^{2i(\beta_{m',vis} + \beta_{m';r})h_{m'}}$$

$$\times \exp[iz_1(k_{m',vis}\cos\theta_{m',vis}(-1 + \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(-1 + \tan\theta_{m',SF}\tan\theta_{m',ir}))]\}$$
(2.27)

 $[\mathbf{B}_{n}^{(\mathbf{m}')}]$ : E sources

$$\begin{split} P_a^*\left(z_1\right) &= \sum_{\alpha,\beta} \chi_{\alpha\alpha\beta} E^0_{vis\alpha} E^0_{ir,\beta} \\ &\times \frac{t_{1_{m'yis\alpha}}}{1 + r_{1_{m'yis\alpha}} r_{m'myis\alpha}} e^{2i\beta_{m:vi}h_{m'}} + (r_{m'myis\alpha} + r_{1_{m'yis\alpha}} e^{2i\beta_{m;vi}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}} \\ &\times \frac{t_{1_{m'xi\beta}}}{1 + r_{1_{m'xi\beta}} r_{m'myis\alpha}} e^{2i\beta_{m;vi}h_{m'}} + (r_{m'myis\alpha} + r_{1_{m'yis\alpha}} e^{2i\beta_{m;vi}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}} \\ &\times \frac{t_{1_{m'xi\beta}}}{1 + r_{1_{m'xi\beta}} r_{m'myis\alpha}} e^{2i\beta_{m,vi}h_{m'}} + (r_{m'mir,\beta} + r_{1_{m'yir,\beta}} e^{2i\beta_{m,vi}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}} \\ &\times \{(1 + r_{m'myis\alpha}} r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}})(1 + r_{m'm,vis}} r_{m2,vis} e^{2i\beta_{m,v}h_{m}}) \\ &\times \exp[iz_1(k_{m',vis}\cos\theta_{m'yis}(1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (1 + r_{m'm,vis\alpha}} r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}})(r_{m'm,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,v}h_{m}}) e^{2i\beta_{m,vi}h_{m'}} \\ &\times \exp[iz_1(k_{m',vis}\cos\theta_{m',vis}(1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (r_{m'm,vis\alpha}} + r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}})(r_{m'm,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,v}h_{m}}) e^{2i\beta_{m,vi}h_{m'}} \\ &\times \exp[iz_1(k_{m',vis}\cos\theta_{m',vis}(-1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))] \\ &+ (r_{m'm,vis\alpha}} + r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}})(r_{m',m,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,v}h_{m}}) e^{2i(\beta_{m',vis}+\beta_{m,vi})h_{m'}} \\ &\times \exp[iz_1(k_{m',vis}\cos\theta_{m',vis}(-1 - \tan\theta_{m',SF}\tan\theta_{m',vis}) + k_{m',ir}\cos\theta_{m',ir}(-1 - \tan\theta_{m',SF}\tan\theta_{m',ir}))] \} \end{aligned}$$

## m 層 の m'/m 界面から深さ z<sub>2</sub> の点:

 $[\mathbf{A}_n^{(\mathbf{m})}]$ :  $E^+$  sources

$$\begin{split} P_a^*\left(z_2\right) &= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^0_{vis\alpha} E^0_{ir\beta} \\ &\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha}}{1 + t_{1m',vis\alpha} t_{m'm,vis\alpha}} e^{i\beta_{m',vis}h_{m'}} + (t_{m'm,vis\alpha} + t_{1m',vis\alpha}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m'}} \\ &\times \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} e^{i\beta_{m',ir}h_{m'}}}{1 + t_{1m',ir,\beta} t_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}} + (t_{m'm,ir,\beta} + t_{1m',ir,\beta}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}} \\ &\times \left\{ \exp\left[iz_2(k_{m,vis}\cos\theta_{m,vis}(1 + \tan\theta_{m,SF}\tan\theta_{m,vis}) + k_{m,ir}\cos\theta_{m,ir}(1 + \tan\theta_{m,SF}\tan\theta_{m,ir}))\right] \right. \\ &+ r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}} \\ &\times \left\{ \exp\left[iz_2(k_{m,vis}\cos\theta_{m,vis}(1 + \tan\theta_{m,SF}\tan\theta_{m,vis}) + k_{m,ir}\cos\theta_{m,ir}(-1 + \tan\theta_{m,SF}\tan\theta_{m,ir}))\right] \\ &+ r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}} \\ &\times \left\{ \exp\left[iz_2(k_{m,vis}\cos\theta_{m,vis}(1 + \tan\theta_{m,SF}\tan\theta_{m,vis}) + k_{m,ir}\cos\theta_{m,ir}(-1 + \tan\theta_{m,SF}\tan\theta_{m,ir}))\right] \right. \\ &+ r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}} \\ &\times \left\{ \exp\left[iz_2(k_{m,vis}\cos\theta_{m,vis}(-1 + \tan\theta_{m,SF}\tan\theta_{m,vis}) + k_{m,ir}\cos\theta_{m,ir}(1 + \tan\theta_{m,SF}\tan\theta_{m,ir}))\right] \right. \\ \end{array}$$

$$+r_{m2,vis\alpha}r_{m2,ir\beta}e^{2i(\beta_{m,ir}+\beta_{m,vis})h_{m}}$$

$$\times\left\{\exp\left[iz_{2}(k_{m,vis}\cos\theta_{m,vis}\left(-1+\tan\theta_{m,SF}\tan\theta_{m,vis}\right)+k_{m,ir}\cos\theta_{m,ir}\left(-1+\tan\theta_{m,SF}\tan\theta_{m,ir}\right)\right)\right]$$
(2.29)

 $[\mathbf{B}_{n}^{(\mathbf{m})}]$ : E sources

$$\begin{split} P_{a}^{*}(z_{2}) &= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta} \\ &\times \frac{t_{1m,vis} \chi_{c}}{1 + r_{1m,vis} \chi_{c}} r_{m'm,vis} \alpha} e^{2i\beta_{m;vi}h_{m'}} + (r_{m'm,vis} \chi_{c} + r_{1m',vis} \alpha} e^{2i\beta_{m;vi}h_{m'}}) r_{m2,vis} \alpha} e^{2i\beta_{m,vi}h_{m}} \\ &\times \frac{t_{1m',vis} \chi_{c}}{1 + r_{1m',vis} \chi_{c}} r_{m'm,vis} \alpha} e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,vis} \chi_{c} + r_{1m',vis} \alpha} e^{2i\beta_{m',vi}h_{m'}}) r_{m2,vis} \chi_{c} e^{2i\beta_{m,vi}h_{m}} \\ &\times \frac{t_{1m',ir} \chi_{c}}{1 + r_{1m',ir} \chi_{c}} e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,vis} \chi_{c} + r_{1m',vis} \chi_{c} e^{2i\beta_{m',vi}h_{m'}}) r_{m2,vis} \chi_{c} e^{2i\beta_{m,vi}h_{m}}} \\ &\times \{ \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis} (1 - \tan\theta_{m,SF} \tan\theta_{m,vis}) + k_{m,ir} \cos\theta_{m,ir} (1 - \tan\theta_{m,SF} \tan\theta_{m,ir}))] \\ &+ r_{m2,vis} \chi_{c} e^{2i\beta_{m,vi}h_{m}} \\ &\times \{ \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis} (-1 - \tan\theta_{m,SF} \tan\theta_{m,vis}) + k_{m,ir} \cos\theta_{m,ir} (1 - \tan\theta_{m,SF} \tan\theta_{m,ir}))] \\ &+ r_{m2,vis} \chi_{c} e^{2i\beta_{m,vi}h_{m}} \\ &\times \{ \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis} (-1 - \tan\theta_{m,SF} \tan\theta_{m,vis}) + k_{m,ir} \cos\theta_{m,ir} (1 - \tan\theta_{m,SF} \tan\theta_{m,ir}))] \\ &+ r_{m2,vis} \chi_{c} r_{m2,ir} \chi_{c} e^{2i(\beta_{m,ir} + \beta_{m,vis})h_{m}} \\ &\times \{ \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis} (-1 - \tan\theta_{m,SF} \tan\theta_{m,vis}) + k_{m,ir} \cos\theta_{m,ir} (1 - \tan\theta_{m,SF} \tan\theta_{m,ir}))] \\ &+ r_{m2,vis} \chi_{c} r_{m2,ir} \chi_{c} e^{2i(\beta_{m,ir} + \beta_{m,vis})h_{m}} \\ &\times \{ \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis} (-1 - \tan\theta_{m,SF} \tan\theta_{m,vis}) + k_{m,ir} \cos\theta_{m,ir} (-1 - \tan\theta_{m,SF} \tan\theta_{m,ir}))] \\ &+ r_{m2,vis} \chi_{c} r_{m2,ir} \chi_{c} e^{2i(\beta_{m,ir} + \beta_{m,vis})h_{m}} \\ &\times \{ \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis} (-1 - \tan\theta_{m,SF} \tan\theta_{m,vis}) + k_{m,ir} \cos\theta_{m,ir} (-1 - \tan\theta_{m,SF} \tan\theta_{m,ir}))] \\ &+ r_{m2,vis} \chi_{c} r_{m2,ir} \chi_{c} e^{2i(\beta_{m,ir} + \beta_{m,vis})h_{m}} \\ &\times \{ \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis} (-1 - \tan\theta_{m,SF} \tan\theta_{m,vis}) + k_{m,ir} \cos\theta_{m,ir} (-1 - \tan\theta_{m,SF} \tan\theta_{m,ir}))] \\ \end{pmatrix}_{i} + r_{i} \chi_{i} \chi_$$

#### 2.3. SFG 電場

別ファイル「二層膜からの和周波 (SFG) — 一般式」に記した結果を使って、以下の表式を導く。なお、 位相部分については結果だけを記す。

## 1/m' 界面の 1 側の分極からの SFG:

#### (a): 反射方向

ゼロ次光による  $E(0)+r_{\rm lm}E'(0)$  に加えて、内部に進入した光が多重反射して出てきたもの、即ち、ファイル「二層膜からの和周波 (SFG) — 一般式」(以後ファイル「一般式」と略記する)の (2.1) 式において  $L^+_{\rm m/m}P(z_1)$  を  $t_{\rm lm}L^+_{\rm l/l}P(z_1=0)$  に置き換えたものが加わる。 $a_0^*=a$ 、 $a_0=1$  であるから、下式のようにになる。

$$\begin{split} E^{-1}(0^{-})_{net} &= \{L^{-}_{1/1} + L^{+}_{1/1}[r_{1m'} + \frac{t_{1m'}t_{m'1}(r_{m'm} + r_{m2}b^{2})a^{2}}{1 + r_{1m'}r_{m'm}a^{2} + (r_{min} + r_{1m'}a^{2})r_{m2}b^{2}}]\}P^{*}(z_{1} = 0) \\ &= \frac{(L^{-}_{1/1} + r_{1m'}L^{+}_{1/1})(1 + r_{m'm}r_{m2}b^{2}) + (r_{1m'}L^{-}_{1/1} + L^{+}_{1/1})(r_{m'm} + r_{m2}b^{2})a^{2}}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}P^{*}(z_{1} = 0) \end{split}$$

$$\begin{split} (L^{-}_{1}\Lambda_{,px} + r_{1m',p}L^{+}_{1}\Lambda_{,px}) &= (r_{1m',p}L^{-}_{1}\Lambda_{,px} + L^{+}_{1}\Lambda_{,px}) = L^{-}_{1/m',px} \\ (L^{-}_{1}\Lambda_{,sy} + r_{1m',s}L^{+}_{1}\Lambda_{,sy}) &= (r_{1m',s}L^{-}_{1}\Lambda_{,sy} + L^{+}_{1}\Lambda_{,sy}) = L^{-}_{1/m',sy} \\ (L^{-}_{1}\Lambda_{,pz} + r_{1m',p}L^{+}_{1}\Lambda_{,pz}) &= -(r_{1m',p}L^{-}_{1}\Lambda_{,pz} + L^{+}_{1}\Lambda_{,pz}) = L^{-}_{1/m',pz} \quad (n_{m''} = n_{1}) \end{split}$$

$$E^{-1}(0^{-})_{net} = \frac{(1 + r_{m'm}r_{m2}b^{2}) \pm (r_{m'm} + r_{m2}b^{2})a^{2}}{1 + r_{lm'}r_{m'm}a^{2} + (r_{m'm} + r_{lm}a^{2})r_{m2}b^{2}}L^{-1/m'}P^{*}(z_{1} = 0)$$

(upper sign for x and y, lower sign for z)

#### (2.18) 式により、

$$\begin{split} E_{-1}(0^{-})_{net\,\rho} &= \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta} \\ &\times \frac{(1+r_{1m',vis\alpha})[(1+r_{m'm,vis\alpha})+(r_{m'm,vis\alpha}+e^{2\beta_{m',in}h_{m'}})r_{m',vis\alpha}}{1+r_{1m',vis\alpha}} r_{m'm,vis\alpha} e^{2\beta_{m',in}h_{m'}} + (r_{m'm,vis\alpha}+r_{1m',vis\alpha})r_{m',vis\alpha} e^{2\beta_{m',in}h_{m'}}) \\ &\times \frac{(1+r_{1m',vis\alpha})[(1+r_{m'm,ir,\beta}e^{2\beta_{m',in}h_{m'}})+(r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',in}h_{m'}})r_{m',2,vis\alpha}e^{2\beta_{m',in}h_{m'}}}{1+r_{1m',ir,\beta}} r_{m'm,ir,\beta}e^{2\beta_{m',in}h_{m'}} + (r_{m'm,ir,\beta}+e^{2\beta_{m',in}h_{m'}})r_{m',2,ir,\beta}e^{2\beta_{m',in}h_{m'}}} \\ &\times \frac{(1+r_{1m',ir,\beta})[(1+r_{m'm,ir,\beta}e^{2\beta_{m',in}h_{m'}})+(r_{m'm,ir,\beta}+r_{m',ir,\beta}e^{2\beta_{m',in}h_{m'}})r_{m',2,ir,\beta}e^{2\beta_{m',in}h_{m'}}}{1+r_{1m',SF,p}r_{m',SF,p}e^{2\beta_{m',sh}h_{m'}}+(r_{m'm,ir,\beta}+r_{m',SF,p}e^{2\beta_{m',sh}h_{m'}})r_{m',2,ir,\beta}e^{2\beta_{m',sh}h_{m'}}} L_{1/m',pr}\chi_{x\alpha\beta} \\ &+ \frac{(1+r_{m',NSF,p}r_{m',NSF,p}e^{2\beta_{m',sh}h_{m'}}+(r_{m'm,SF,p}+r_{m',SF,p}e^{2\beta_{m',sh}h_{m'}})r_{m',2,SF,p}e^{2\beta_{m',sh}h_{m'}}}{1+r_{1m',SF,p}r_{m',NSF,p}e^{2\beta_{m',sh}h_{m'}}+(r_{m',m,SF,p}+r_{1m',SF,p}e^{2\beta_{m',sh}h_{m'}})r_{m',2,SF,p}e^{2\beta_{m',sh}h_{m'}}} L_{1/m',pr}\chi_{x\alpha\beta}] \quad (n_{m'}=n_{1}) \\ &= \sum_{\alpha,\beta} E^{0}_{vis\alpha}E^{0}_{ir,\beta} \\ &\times \frac{(1+r_{1m',vis\alpha})[(1+r_{m',m,vis\alpha}e^{2\beta_{m',sh}h_{m'}}+(r_{m',m,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',sh}h_{m'}})r_{m',2,vis\alpha}e^{2\beta_{m',sh}h_{m'}}}}{1+r_{1m',vis\alpha}r_{m',m,vis\alpha}e^{2\beta_{m',sh}h_{m'}}+(r_{m',m,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',sh}h_{m'}})r_{m',2,vis\alpha}e^{2\beta_{m',sh}h_{m'}}}} \\ &\times \frac{(1+r_{1m',vis\alpha})[(1+r_{m',m,vis\alpha}e^{2\beta_{m',sh}h_{m'}})+(r_{m',m,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',sh}h_{m'}})r_{m',2,vis\alpha}e^{2\beta_{m',sh}h_{m'}}}}{1+r_{1m',vis\alpha}r_{m',vis\alpha}e^{2\beta_{m',sh}h_{m'}}+(r_{m',m,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',sh}h_{m'}})r_{m',2,vis\alpha}e^{2\beta_{m',sh}h_{m'}}}} \\ &\times \frac{(1+r_{1m',vis\alpha}}r_{m',vis\alpha}e^{2\beta_{m',sh}h_{m'}}+(r_{m',m,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',sh}h_{m'}})r_{m',2,vis\alpha}e^{2\beta_{m',sh}h_{m'}}}}{1+r_{1m',vis\alpha}e^{2\beta_{m',sh}h_{m'}}+(r_{m',m,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',sh}h_{m'}})r_{m',vis\alpha}e^{2\beta_{m',sh}h_{m'}}}} \\ &\times \frac{(1+r_{1m',vis\alpha}e^{2\beta_{m',sh}h_{m'}}+(r_{m',m,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m'$$

#### (b): 透過方向

 $E^+(0^-)$  だけが膜内部に進入して反対側に抜ける。上と同様に、ファイル「一般式」の (2.2) 式において  $L^+_{m/m}P(z_1)$  を  $t_{1m}L^+_{1/1}P(z_1=0)$  に置き換え、 $a_0^*=a$ 、 $a_0=1$  として、下式が得られる。

$$E^{+}{}_{2}(h_{m}^{\phantom{m}+})_{net} = \frac{t_{1m}t_{m2}t_{mim}ab}{1 + r_{1m}r_{mim}a^{2} + (r_{mim} + r_{1m}a^{2})r_{m2}b^{2}}L^{+}{}_{1/1}P^{*}(z_{1} = 0)$$

$$t_{1m',p}L^{+}_{1/1,px} = L^{+}_{1/m',px},$$
  
 $t_{1m',s}L^{+}_{1/1,sy} = L^{+}_{1/m',sy},$   
 $t_{1m',p}L^{+}_{1/1,pz} = L^{+}_{1/m',pz} \quad (n_{m''} = n_1)$ 

$$E^{+2}(h_{m}^{+})_{net} = \frac{t_{m'm}t_{m2}ab}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}L^{+1/m'}P^{*}(z_{1} = 0)$$

#### (2.18) 式により、

$$E^{+}_{2}(h_{m}^{+})_{netp} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{(1 + r_{1m',vis\alpha})[(1 + r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) + (r_{m'm,vis\alpha} + e^{2\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}]}{1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{(1 + r_{1m',ir\beta})[(1 + r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}}) + (r_{m'm,ir\beta} + e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,ir}h_{m}}]}{1 + r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \frac{t_{1m',SF} \rho t_{m2,SF} \rho e^{2i\beta_{m',SF}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,ir}h_{m}}}{1 + r_{1m,SF} \rho t_{m2,SF} \rho e^{2i\beta_{m',SF}h_{m'}} + (r_{m'm,SF} \rho + r_{1m',SF} \rho e^{2i\beta_{m',SF}h_{m'}})r_{m2,SF} \rho e^{2i\beta_{m,SF}h_{m}}} \qquad (n_{m'}=n_{1})$$

$$(2.32a)$$

$$E^{+}2(h_{m}^{+})_{net,s} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{(1+r_{1m',vis\alpha})[(1+r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) + (r_{m'm,vis\alpha}+e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}{1+r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{(1+r_{1m',ir\beta})[(1+r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}}) + (r_{m'm,ir\beta}+e^{2i\beta_{m',ir}h_{m'}})r_{m2,vis\beta}e^{2i\beta_{m,vis}h_{m}}}{1+r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta}+r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \frac{t_{1m,SF,s}t_{m2,SF,s}}{1+r_{1m,SF,s}t_{m',SF}h_{m'}} + (r_{m'm,SF,s}+r_{1m',SF,e}e^{2i\beta_{m',SF}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \frac{t_{1m,SF,s}t_{m2,SF,s}}{1+r_{1m,SF,s}t_{m',SF}h_{m'}} + (r_{m'm,SF,s}+r_{1m',SF,e}e^{2i\beta_{m',SF}h_{m'}})r_{m2,SF,e}e^{2i\beta_{m,SF}h_{m}}}$$

$$(2.32b)$$

## 1/m' 界面の m' 側の分極からの SFG:

#### (a): 反射方向

ファイル「一般式」の (2.1) 式と (2.3) 式において、 $z_1 = 0$ 、 $a_0^* = a$ 、 $a_0 = 1$  とする。

$$E^{-1}(0^{-})_{net} = \frac{t_{m1}[(r_{m'm} + r_{m2}b^{2})a^{2}L^{+}_{m'/m'} + (1 + r_{m'm}r_{m2}b^{2})L^{-}_{m'/m'}]}{1 + r_{lm}r_{mim}a^{2} + (r_{m'm} + r_{lm}a^{2})r_{m2}b^{2}}P^{*}(z_{1} = 0)$$

ここで、

$$\begin{split} t_{1m',p} L^+_{m'/m',px} &= t_{1m',p} L^-_{m'/m',px} = L^-_{1/m',px}, \\ t_{1m',s} L^+_{m'/m',sy} &= t_{1m',s} L^-_{m'/m',sy} = L^-_{1/m',sy}, \\ t_{1m',p} L^+_{m'/m',pz} &= -t_{1m',p} L^-_{m'/m',pz} = L^-_{1/m',pz} & (n_{\mathbf{m''}} = n_{\mathbf{m'}}) \end{split}$$

$$E^{-1}(0^{-})_{net} = \frac{t_{m1}[(1 + r_{m'm}r_{m2}b^{2}) \pm (r_{m'm} + r_{m2}b^{2})a^{2}]}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}L^{-1/m'}P^{*}(z_{1} = 0)$$

(upper sign for x and y, lower sign for z)

#### (2.19) 式により、

$$\begin{split} E^{-1}(0^{-})_{net,p} &= \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta} \\ &\times \frac{t_{1m',yis_{\Omega}}[(1+r_{mim,yis_{\Omega}}e^{2\beta_{m,in}h_{ni}}) + (r_{mim,yis_{\Omega}} + e^{2i\beta_{n;in}h_{ni}})r_{m2,yis_{\Omega}}e^{2\beta_{m,in}h_{ni}}]}{1+r_{1m',yis_{\Omega}}r_{m'm,yis_{\Omega}}e^{2i\beta_{m,in}h_{ni}} + (r_{m'm,yis_{\Omega}} + r_{1m',yis_{\Omega}}e^{2i\beta_{n;in}h_{ni}})r_{m2,yis_{\Omega}}e^{2\beta_{m,in}h_{ni}}} \\ &\times \frac{t_{1m',ir,\beta}[(1+r_{m'm,ir,\beta}e^{2i\beta_{m,ir}h_{ni}}) + (r_{m'm,ir,\beta} + e^{2\beta_{m,ir}h_{ni}})r_{m2,ir,\beta}e^{2i\beta_{m,in}h_{ni}}}{1+r_{1m',ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m,ir}h_{ni}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta}e^{2i\beta_{m,ir}h_{ni}})r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{ni}}} \\ &\times \frac{(1+r_{m'm,SE,p}r_{m,SE,p}e^{2i\beta_{m,ir,k}h_{ni}} + (r_{m'm,SE,p} + r_{m,ir,\beta}e^{2i\beta_{m,ir,k}h_{ni}})r_{m2,ir,\beta}e^{2i\beta_{m,ir,k}h_{ni}}}}{1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,ir,k}h_{ni}} + (r_{m'm,SE,p} + r_{m,ir,SE,p}e^{2i\beta_{m,ir,k}h_{ni}})r_{m2,ir,\beta}e^{2i\beta_{m,ir,k}h_{ni}}} L_{1/m',pr}\chi_{x\alpha\beta} \\ &+ \frac{(1+r_{m'm,SE,p}r_{m'm,SE,p}e^{2i\beta_{m,ir,k}h_{ni}} + (r_{m'm,SE,p} + r_{1m',SE,p}e^{2i\beta_{m,ir,k}h_{ni}})r_{m2,SE,p}e^{2i\beta_{m,ir,k}h_{ni}}}}{1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,ir,k}h_{ni}} + (r_{m'm,SE,p} + r_{1m',SE,p}e^{2i\beta_{m,ir,k}h_{ni}})r_{m2,SE,p}e^{2i\beta_{m,ir,k}h_{ni}}} L_{1/m',pr}\chi_{x\alpha\beta}] } \\ &\times \frac{t_{1m',yis_{\Omega}}[(1+r_{m'm,yis_{\Omega}}e^{2i\beta_{m,ir,k}h_{ni}}) + (r_{m'm,yis_{\Omega}} + e^{2i\beta_{m',ir,k}h_{ni}})r_{m2,yis_{\Omega}}e^{2i\beta_{m,ir,k}h_{ni}}}}{1+r_{1m',yis_{\Omega}}r_{m'm,yis_{\Omega}}e^{2i\beta_{m',ir,k}h_{ni}} + (r_{m'm,yis_{\Omega}} + r_{1m',yis_{\Omega}}e^{2i\beta_{m',ir,k}h_{ni}})r_{m2,yis_{\Omega}}e^{2i\beta_{m,ir,k}h_{ni}}}}{1+r_{1m',ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}} + (r_{m'm,yis_{\Omega}} + r_{1m',ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}})r_{m2,ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}}} \\ &\times \frac{t_{1m',ir,\beta}[(1+r_{m'm,ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}}) + (r_{m'm,ir,\beta} + r_{1m',ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}})r_{m2,ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}}}}{1+r_{1m',ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}})r_{m2,ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}}}} L_{1/m',sy}\chi_{yob}} \\ &\times \frac{(1+r_{m',ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir,k}h_{ni}} + (r_{m',ir,\beta}r_{m',i$$

#### (b): 透過方向

ファイル「一般式」の (2.2) 式と (2.4) 式において、 $z_1=0$ 、 $a_0*=a$ 、 $a_0=1$  とすると、下式が得られる。

$$E^{+2}(h_{m'} + h_{m}^{+})_{net} = \frac{t_{m2}ab[t_{m'm}L^{+}_{m'/m'} + r_{m1}t_{m'm}L^{-}_{m'/m'}]}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}P^{*}(z_{1} = 0)$$

ここで、

$$\begin{split} t_{m'm,p}L^{+}_{m'm'px} &= t_{m'm,p}L^{-}_{m'm',px} = L^{+}_{m'm,px}\,,\\ t_{m'm,s}L^{+}_{m'm',sy} &= t_{m'm,s}L^{-}_{m'/m',sy} = L^{+}_{m'm,sy}\,,\\ t_{m'm,p}L^{+}_{m'm'pz} &= -t_{m'm,p}L^{-}_{m'm',pz} = L^{+}_{m'm,pz} & (n_{\mathbf{m''}} = n_{\mathbf{m'}}) \end{split}$$

$$E^{+2}(h_{m'} + h_{m'}^{+})_{net} = \frac{t_{m2}ab(1 \pm r_{m1})}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}L^{-}m'/mP^{*}(z_{1} = 0)$$

(upper sign for x and y, lower sign for z)

#### (2.19) 式により、

$$E^{+}_{2}(h_{m'} + h_{m}^{+})_{netp} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}[(1 + r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) + (r_{m'm,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}]}{1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir,\beta}[(1 + r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}}) + (r_{m'm,ir,\beta} + e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}]}{1 + r_{1m',ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \frac{e^{i(\beta_{\beta_{m,SF}}h_{m}+\beta_{m',SF}}h_{m'})}[(1 + r_{m1,SF,p})L^{+}_{m'/m,px}\chi_{xo\beta} + (1 - r_{m1,SF,p})L^{+}_{m'/m,pz}\chi_{zo\beta}]}{1 + r_{1m,SF,p}r_{m'm,SF,p}e^{2i\beta_{m,SF}h_{m'}} + (r_{m'm,SF,p} + r_{1m',SF,p}e^{2i\beta_{m,SF}h_{m}})r_{m2,SF,p}e^{2i\beta_{m,SF}h_{m}}} \qquad (n_{m''} = n_{m'})$$
(2.34a)

$$E^{+}_{2}(h_{m'} + h_{m}^{+})_{net,s} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} \frac{(1 + r_{m'm,vis\alpha}e^{2\beta_{m',vis}h_{m'}}) + (r_{m'm,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}}}{1 + r_{1m',vis\alpha}} \frac{1}{r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta}[(1 + r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}}) + (r_{m'm,r\beta} + e^{2\beta_{m',ir}h_{m'}})r_{m2,ir\beta}e^{2\beta_{m,vis}h_{m}}}{1 + r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}})r_{m2,ir\beta}e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{e^{i\beta_{\beta_{m,SF}}h_{m}+\beta_{m',SF}h_{m'}}}{1 + r_{1m,SF,p}r_{m'm,SF,p}}e^{2i\beta_{m,SF}h_{m'}}} (1 + r_{m',SF,p}e^{2i\beta_{m,SF}h_{m'}})r_{m2,SF,p}e^{2i\beta_{m,SF}h_{m}}}$$

$$(2.34b)$$

## m/2 界面の 2 側の分極からの SFG:

#### (a): 反射方向

 $E(h_{\rm m}^+)$  だけが膜内に進入して反対側に抜ける。ファイル「一般式」の (2.7) 式において、 $z_2=h_{\rm m}$ 、 $b_0*=1$ 、 $b_0=b$  とする。

$$E^{-1}(0^{-})_{net} = \frac{t_{2m}t_{m1}b^{2}(r_{m'm} + r_{1m'}a^{2})L_{2/2}^{-}}{1 + r_{1m'}r_{mm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}P^{*}(z_{2} = h_{m}^{+})$$

ここで、

$$t_{2m,p}L^2 2/2,px = L^2 m/2,px,$$
  
 $t_{2m,p}L^2 2/2,sy = L^2 m/2,sy,$   
 $t_{2m,p}L^2 2/2,pz = L^2 m/2,pz$   $(n_{m''} = n_2)$ 

$$E^{-1}(0^{-})_{net} = \frac{t_{m1}b^{2}(r_{m'm} + r_{1m}a^{2})L_{m/2}^{-}}{1 + r_{1m}r_{m'm}a^{2} + (r_{m'm} + r_{1m}a^{2})r_{m/2}b^{2}}P^{*}(z_{2} = h_{m}^{+})$$

#### (2.20) 式を参照して、

$$E^{-1}p(0^{-})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{mim,vis\alpha} t_{m2,vis\alpha} e^{i(\beta_{m',vis}h_{m'} + \beta_{m,vi}h_{m})}}{1 + t_{1m',vis\alpha} t_{m',w,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (t_{m'm,vis\alpha} + t_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) t_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} t_{m2,ir,\beta} e^{i(\beta_{m',ir}h_{m'} + \beta_{m,ir}h_{m})}}{1 + t_{1m',ir,\beta} t_{m'm,ir,\beta} e^{2i\beta_{m,ir}h_{m'}} + (t_{m'm,ir,\beta} + t_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) t_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \frac{t_{2m,SF,p} t_{m1,SF,p} e^{2i\beta_{m,SF}h_{m}} (t_{m'm,SF,p} + t_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}}) [L^{-}_{m'2,px} \chi_{x\alpha\beta} + L^{-}_{m'2,pz} \chi_{z\alpha\beta}]}{1 + t_{1m',SF,p} t_{m',m,SF,p} e^{2i\beta_{m',SF}h_{m'}} + (t_{m'm,SF,p} + t_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}}) t_{m2,SF,p} e^{2i\beta_{m,SF}h_{m}}} (t_{nm'} = n_{2}) \quad (2.35a)$$

$$E^{-1}_{s}(0^{-})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{min,vis\alpha} t_{m2,vis\alpha} e^{i(\beta_{m',vis}h_{m'} + \beta_{m,vis}h_{m'})}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} t_{m'm,ir,\beta} t_{m2,ir,\beta} e^{i(\beta_{m',ir}h_{m'} + \beta_{m,ir}h_{m})}}{1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir,\beta} e^{2i\beta_{m,vi}h_{m}}}$$

$$\times \frac{t_{2m,SF,s} t_{m1,SF,s} (r_{m'm,SF,s} + r_{1m',SF,s} e^{2i\beta_{m',SF}h_{m'}}) e^{2i\beta_{m,SF}h_{m}} L^{-}_{m'2,sy} \chi_{y\alpha\beta}}}{1 + r_{1m',SF,s} r_{m'm,SF,s} e^{2i\beta_{m',SF}h_{m'}} + (r_{m'm,SF,s} + r_{1m',SF,s} e^{2i\beta_{m',SF}h_{m'}}) r_{m2,SF,n} e^{2i\beta_{m,SF}h_{m}}}$$

$$(2.35b)$$

#### (b): 透過方向

ゼロ次光による  $E^+(z_2=h_{\mathrm{m}}^+)+r_{2\mathrm{m}}$   $E(z_2=h_{\mathrm{m}}^+)$  に加えて、内部に進入した光が多重反射して出てきたもの、即ち、ファイル「一般式」の (2.8) 式において  $L_{\mathrm{min}}P(z_2)$  を  $t_{1\mathrm{m}}L_{2/2}P(z_2=h_{\mathrm{m}}^+)$  に置き換えたものが加わる。また、ファイル「一般式」の (2.8) 式において、 $z_2=h_{\mathrm{m}}$ 、 $b_0^*=1$ 、 $b_0=b$  とする。

$$E^{+2}(h_{m'} + h_{m}^{+})_{net} = \{L^{+2/2} + L^{-2/2}[r_{2m} - \frac{t_{2m}t_{m2}b^{2}(r_{m'm} + r_{1m'}a^{2})}{1 + r_{1m'}r_{m'm}a^{2} + (r_{mim} + r_{1m'}a^{2})r_{m2}b^{2}}]\}P^{*}(z_{2} = h_{m}^{+})$$

$$= \frac{(1 + r_{1m'}r_{m'm}a^{2})(L^{+2/2} + r_{2m}L^{-2/2}) + (r_{m'm} + r_{1m}a^{2})b^{2}(r_{m2}L^{+2/2} + L^{-2/2})}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m}a^{2})r_{m}b^{2}}P^{*}(z_{2} = h_{m}^{+})$$

ここで、

$$E^{+2}(h_{m'} + h_{m}^{+})_{net} = \frac{(1 + r_{1m'}r_{m'm}a^{2}) \pm (r_{m'm} + r_{1m'}a^{2})b^{2}}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}L^{+2m}P^{*}(z_{2} = h_{m}^{+})$$
(upper sign for x and y, lower sign for z)

#### (2.20) 式を参照して、

$$E^{+}_{2,p}(h_{m'} + h_{m'}^{+})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m'yis\alpha}t_{minyis\alpha}t_{m2yis\alpha}t_{m2yis\alpha}t_{m2yis\alpha}e^{i(\beta_{m',m}h_{m'}+\beta_{m,n}h_{m})}}{1 + r_{1m'yis\alpha}r_{m'myis\alpha}e^{2i\beta_{m',m}h_{m'}} + (r_{m'myis\alpha} + r_{1m'yis\alpha}e^{2i\beta_{m',m}h_{m}})r_{m2yis\alpha}e^{2i\beta_{m,m}h_{m}}}$$

$$\times \frac{t_{1m'jir,\beta}t_{m'mjr,\beta}t_{m'jir,\beta}e^{2i\beta_{m',m}h_{m'}} + (r_{m'myis\alpha} + r_{1m'jir,\beta}e^{2i\beta_{m',m}h_{m'}})r_{m2yis\alpha}e^{2i\beta_{m,m}h_{m}}}{1 + r_{1m'jir,\beta}r_{m'mjr,\beta}e^{2i\beta_{m',m}h_{m'}} + (r_{m'mjr,\beta} + r_{1m'jir,\beta}e^{2i\beta_{m',m}h_{m'}})r_{m2yir,\beta}e^{2i\beta_{m,m}h_{m}}}$$

$$\times \{\frac{[(1 + r_{1m'SF,p}r_{m'mSF,p}e^{2i\beta_{m',m}h_{m'}} + (r_{m'mSF,p} + r_{1m'SF,p}e^{2i\beta_{m',m}h_{m'}})e^{2i\beta_{m',m}h_{m'}}]L^{-2m_{px}}\chi_{xc\beta}}{1 + r_{1m'SF,p}r_{m'mSF,p}e^{2i\beta_{m',m}h_{m'}} + (r_{m'mSF,p} + r_{1m'SF,p}e^{2i\beta_{m',m}h_{m'}})r_{m2,SF,p}e^{2i\beta_{m,m}h_{m}}}$$

$$+ \frac{[(1 + r_{1m'SF,p}r_{m'mSF,p}e^{2i\beta_{m',m}h_{m'}}) - (r_{m'mSF,p} + r_{1m'SF,p}e^{2i\beta_{m',m}h_{m'}})e^{2i\beta_{m',m}h_{m'}}}{1 + r_{1m'SF,p}r_{m'mSF,p}e^{2i\beta_{m',m}h_{m'}} + (r_{m'mSF,p} + r_{1m'SF,p}e^{2i\beta_{m',m}h_{m'}})r_{m2,SF,p}e^{2i\beta_{m,m}h_{m}}}}$$

$$\times \frac{t_{1m'yis\alpha}t_{mmyis\alpha}e^{2i\beta_{m',m}h_{m'}} + (r_{m'myis\alpha}t_{m2yis\alpha}e^{2i\beta_{m',m}h_{m'}} + r_{1m'sF,p}e^{2i\beta_{m',m}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,m}h_{m}}}}{1 + r_{1m'jir,\beta}t_{m'mjir,\beta}t_{m'mjir,\beta}t_{m'mjir,\beta}e^{2i\beta_{m',m}h_{m'}} + r_{1m'yis\alpha}e^{2i\beta_{m',m}h_{m'}}}r_{m2,vis\alpha}e^{2i\beta_{m,m}h_{m}}}}$$

$$\times \frac{t_{1m'yis\alpha}t_{m'myis\alpha}e^{2i\beta_{m',m}h_{m'}} + (r_{m'myis\alpha}t_{m'myis\alpha}t_{m'myis\alpha}e^{2i\beta_{m',m}h_{m'}} + r_{1m'yis\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',m',m'}}r_{m'yir,\beta}e^{2i\beta_{m',m}h_{m'}}r_{m',m',m'}}r_{m',m',m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h_{m'}}r_{m',\alpha}e^{2i\beta_{m',m}h$$

## m/2 界面の m 側の分極からの SFG:

#### (a): 反射方向

ファイル「一般式」の (2.5) 式と (2.7) 式において、 $z_2 = h_m$ 、 $b_0^* = 1$ 、 $b_0 = b$  とする。

$$E^{-1}(0^{-})_{net} = \frac{abt_{mm'}(r_{m2}L^{+}_{m/m} + L^{-}_{m/m})}{1 + r_{m}r_{m} + a^{2} + (r_{m} + r_{m} + a^{2})r_{m}b^{2}}P^{*}(z_{2} = h_{m}^{-})$$

$$\begin{split} t_{mm',p}L^{+}_{m/m,px} &= t_{mm',p}L^{-}_{m/m,px} = L^{-}_{m'/m,px}\,,\\ t_{mm',s}L^{+}_{m/m,sy} &= t_{mm',s}L^{-}_{m/m,sy} = L^{-}_{m'/m,sy}\,,\\ t_{mm',p}L^{+}_{m/m,pz} &= t_{mm',p}L^{-}_{m/m,pz} = -L^{-}_{m'/m,px} \qquad (n_{m'}=n_{m}) \end{split}$$

$$E^{-1}(0^{-})_{net} = \frac{ab(1 \pm r_{m2})L^{-}_{m'm}}{1 + r_{lm'}r_{m'm}a^{2} + (r_{m'm} + r_{lm'}a^{2})r_{m2}b^{2}}P^{*}(z_{2} = h_{m}^{-})$$

(upper sign for x and y components, lower sign for z component)

#### (2.23) 式を参照して、

$$E^{-1}p(0^{-})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{m',vi}h_{m'}} (1 + r_{m'm,vis\alpha})(1 + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}})}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vis}h_{m'}})r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta} e^{i\beta_{m',ir}h_{m'}} (1 + r_{mim,ir\beta})(1 + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}})}{1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m,ir}h_{m'}})r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \frac{e^{i(\beta_{m',SF}h_{m'} + \beta_{m,SF}h_{m'})}[(1 + r_{m2,SF,p})L^{-}_{m'/m,px}\chi_{x\alpha\beta} + (1 - r_{m2,SF,p})L^{-}_{m'/m,pz}\chi_{z\alpha\beta}]}{1 + r_{1m',SF,p} r_{m'm,SF,p} e^{2i\beta_{m,SF}h_{m'}} + (r_{m'm,SF,p} + r_{1m',SF,p} e^{2i\beta_{m,SF}h_{m'}})r_{m2,SF,p} e^{2i\beta_{m,SF}h_{m'}}} \qquad (n_{m'} = n_{m})$$
(2.37a)

$$E^{-1,s}(0^{-})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} e^{i\beta_{m;vi}h_{m'}} (1 + r_{m'm,vis\alpha}) (1 + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}})$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} r_{m'm,vis\alpha} e^{2i\beta_{m;vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m;vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}$$

$$\times \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta}} e^{\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir,\beta}) (1 + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}})$$

$$\times \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta}} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m,ir}h_{m'}}) r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}$$

$$\times \frac{e^{i(\beta_{m;s,F}h_{m} + \beta_{m,SF}h_{m})} (1 + r_{m2,SF,s}) L^{-}_{m',m,sy} \chi_{y\alpha\beta}}{1 + r_{1m',SF,s}} e^{2i\beta_{m',sF}h_{m'}} + (r_{m'm,SF,s} + r_{1m',SF,s} e^{2i\beta_{m',sF}h_{m'}}) r_{m2,SF,s} e^{2i\beta_{m,sF}h_{m}}}$$
(2.37b)

#### (b): 透過方向

ファイル「一般式」の (2.6) 式と (2.8) 式において、 $z_2 = h_m$ 、 $b_0 = 1$ 、 $b_0 = b$  とする。

$$E^{+2}(h_{m'} + h_{m}^{+})_{net} = \frac{(1 + r_{1m}r_{m'm}a^{2})L^{+}_{m'm} - (r_{m'm} + r_{1m'}a^{2})b^{2}L^{-}_{m/m}}{1 + r_{1m'}r_{1m'}a^{2} + (r_{1m'} + r_{1m'}a^{2})r_{2}b^{2}}P^{*}(z_{2} = h_{m}^{-})$$

ここで、

$$\begin{split} t_{m2,p}L^+ & _{m/m,px} = t_{m2,p}L^- \\ & _{m/m,px} = L^+ \\ & _{m/2,p}L^+ \\ & _{m/m,sy} = t_{m2,s}L^- \\ & _{m/m,sy} = L^+ \\ & _{m/2,p}L^+ \\ & _{m/m,pz} = -t_{m2,p}L^- \\ & _{m/m,pz} = L^+ \\ & _{m/2,pz} \qquad (n_{\rm m^-} = n_{\rm m}) \end{split}$$

$$E^{+2}(h_{m'} + h_{m}^{+})_{net} = \frac{\left[ (1 + r_{1m'}r_{m'm}a^{2}) m (r_{m'm} + r_{1m'}a^{2})b^{2} \right]L^{+}_{m'2}}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m}a^{2})r_{m2}b^{2}} P^{*}(z_{2} = h_{m}^{-})$$

(upper sign for x and y components, lower sign for z component)

#### (2.23) 式を参照して、

$$E^{*}_{2,p}(h_{m'} + h_{m'}^{*})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m'vis\alpha}}{1 + r_{1m'vis\alpha}} e^{i\beta_{m',m}h_{m'}} (1 + r_{m'mvis\alpha})(1 + r_{m2vis\alpha}) e^{2\beta_{m,mi}h_{m}})}{1 + r_{1m'vis\alpha}} e^{2i\beta_{m',m}h_{m'}} (1 + r_{m'mvis\alpha} + r_{1m'vis\alpha}) e^{2i\beta_{m,mi}h_{m}})}$$

$$\times \frac{t_{1m'ir,\beta}}{1 + r_{1m'ir,\beta}} e^{2i\beta_{m',m}h_{m'}} (1 + r_{m'mvis\alpha})(1 + r_{m2j'r,\beta}} e^{2i\beta_{m',m}h_{m'}})}{1 + r_{1m'ir,\beta}} e^{2i\beta_{m',m}h_{m'}} (1 + r_{m'm'r,\beta})(1 + r_{m2j'r,\beta}} e^{2i\beta_{m',m}h_{m'}})}$$

$$\times \{ \frac{(1 + r_{1m'SE,p}r_{m'mSE,p}e^{2i\beta_{m',s}h_{m'}} + (r_{m'm'SE,p} + r_{1m'SE,p}e^{2i\beta_{m',v}h_{m'}})e^{2i\beta_{m,v}h_{m}}}{1 + r_{1m'SE,p}r_{m'm'SE,p}e^{2i\beta_{m',v}h_{m'}} + (r_{m'mSE,p} + r_{1m'SE,p}e^{2i\beta_{m',v}h_{m'}})r_{m2,SF,p}e^{2i\beta_{m,v}h_{m}}}$$

$$+ \frac{[(1 + r_{1m'SE,p}r_{m'm'SE,p}e^{2i\beta_{m',v}h_{m'}} + (r_{m'mSE,p} + r_{1m'SE,p}e^{2i\beta_{m',v}h_{m'}})e^{2i\beta_{m',v}h_{m}}]L^{*}_{m'2,2r_{v}}\chi_{xc\beta}}}{1 + r_{1m'SE,p}r_{m'm'SE,p}e^{2i\beta_{m',v}h_{m'}} + (r_{m'mSE,p} + r_{1m'SE,p}e^{2i\beta_{m',v}h_{m'}})r_{m2,SE,p}e^{2i\beta_{m',v}h_{m}}}\} \qquad (n_{m'} = n_{m})$$

$$E^{*}_{2,s}(h_{m'} + h_{m'}^{+})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha}E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m'vis\alpha}}e^{i\beta_{m',v}h_{m'}} (1 + r_{m'mvis\alpha})(1 + r_{m2vis\alpha}}e^{2i\beta_{m',v}h_{m'}})r_{m2,SE,p}e^{2i\beta_{m,v}h_{m}}}$$

$$\times \frac{t_{1m'vis\alpha}}e^{i\beta_{m',v}h_{m'}} (1 + r_{m'mvis\alpha})(1 + r_{m'vis\alpha}e^{2i\beta_{m',v}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,v}h_{m}}}$$

$$\times \frac{t_{1m'vis\alpha}}e^{i\beta_{m',v}h_{m'}} (1 + r_{m'mvis\alpha}})(1 + r_{m'vis\alpha}e^{2i\beta_{m',v}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,v}h_{m}}}$$

$$\times \frac{t_{1m'vis\alpha}}e^{i\beta_{m',v}h_{m'}} (1 + r_{m'mvis\alpha})(1 + r_{m'vis\alpha}e^{2i\beta_{m',v}h_{m'}})r_{m2,vis\alpha}e^{2i\beta_{m,v}h_{m}}}$$

$$\times \frac{t_{1m'vis\alpha}}e^{i\beta_{m',v}h_{m'}} (1 + r_{m'm'vis\alpha}} + r_{1m'vis\alpha}e^{2i\beta_{m',v}h_{m'}})r_{m'vis\alpha}e^{2i\beta_{m,v}h_{m}}}$$

$$\times \frac{t_{1m'vis\beta}}e^{2i\beta_{m',v}h_{m'}} (1 + r_{m'm'vis\alpha} + r_{1m'vis\alpha}e^{2i\beta_{m',v}h_{m'}})r_{m'vis\alpha}e^{2i\beta_{m,v}h_{m}}}$$

$$\times \frac{t_{1m'vis\beta}}e^{2i\beta_{m',v}h_{m'}} (1 + r_{m'm'vis\alpha} + r_{1m'vis\alpha}e^{2i\beta_{m',v}h_{m'}})r_{m'vis\alpha}e^{2i\beta_{m,v}h_{m'}}} e^{2i\beta_{m'vi}h_{m'}}}}{1 + r_{1m'vis\gamma}}e^{2i\beta_{m',v}h_{m'}} (1 + r_{1$$

## m'/m 界面の m' 側の分極からの SFG:

#### (a): 反射方向

ファイル「一般式」の (2.1) 式と (2.3) 式において、 $z_1 = h_m$ 、 $a_0 * = 1$ 、 $a_0 = a$  とする。

$$E^{-1}(0^{-})_{net} = \frac{at_{m1}[(r_{m'm} + r_{m2}b^{2})L^{+}_{m'/m'} + (1 + r_{mm'}r_{m2}b^{2})L^{-}_{m'/m'})]}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m}a^{2})r_{m2}b^{2}}P^{*}(z_{1} = h_{m'})$$

$$\begin{split} t_{m1,p} L^{+}_{m'/m',px} &= t_{m1,p} L^{-}_{m'/m',px} = L^{-}_{1/m',px}, \\ t_{m1,s} L^{+}_{m'/m',sy} &= t_{m1,s} L^{-}_{m'/m',sy} = L^{-}_{1/m',sy}, \\ t_{m1,p} L^{+}_{m'/m',pz} &= t_{m1,p} L^{-}_{m'/m',pz} = -L^{-}_{1/m',px} & (n_{m'} = n_{m'}) \end{split}$$

$$E^{-1}(0^{-})_{net} = \frac{a[(1 + r_{mm'}r_{m2}b^{2}) \pm (r_{m'm} + r_{m2}b^{2})]L_{1/m'}^{-1/m'}}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}P^{*}(z_{1} = h_{m'})$$

$$= \frac{a(1 \pm r_{mm'})(1 \pm r_{m2}b^{2})]L_{1/m'}^{-1}}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}P^{*}(z_{1} = h_{m'})$$

(upper sign for x and y components, lower sign for z component)

## (2.23) 式を参照して、

$$E^{-1}p(0^{-})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{m',vi}h_{m'}} (1 + r_{m'm,vis\alpha})(1 + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}})}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir,\beta} e^{i\beta_{m',vi}h_{m'}} (1 + r_{m'm,ir,\beta})(1 + r_{m2,ir,\beta} e^{2i\beta_{m,vi}h_{m'}})}{1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m,vi}h_{m'}}) r_{m2,ir,\beta} e^{2i\beta_{m,vi}h_{m}}}$$

$$\times \{\frac{e^{i\beta_{m',SF}h_{m'}} [(1 + r_{mm',SF,p})(1 + r_{m2,SF,p} e^{2i\beta_{m,SF}h_{m}}) L^{-}_{1/m',px} \chi_{x\alpha\beta}}}{1 + r_{1m',SF,p} r_{m'm,SF,p} e^{2i\beta_{m',SF}h_{m'}} + (r_{m'm,SF,p} + r_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}}) r_{m2,SF,p} e^{2i\beta_{m,SF}h_{m}}}}$$

$$+ \frac{e^{i\beta_{m',SF}h_{m'}} [(1 - r_{mm',SF,p})(1 - r_{m2,SF,p} e^{2i\beta_{m,SF}h_{m}})] L^{-}_{1/m',pz} \chi_{x\alpha\beta}}}{1 + r_{1m',SF,p} r_{m',m,SF,p} e^{2i\beta_{m',SF}h_{m'}} + (r_{m'm,SF,p} + r_{1m',SF,p} e^{2i\beta_{m,SF}h_{m'}}) r_{m2,SF,p} e^{2i\beta_{m,SF}h_{m}}}}\} \qquad (n_{m'} = n_{m'})$$

$$(2.39a)$$

$$E^{-1}_{s}(0^{-})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{m',vi}h_{m'}} (1 + r_{m'm,vis\alpha})(1 + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}})}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir,\beta} e^{\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir,\beta})(1 + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}})}{1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m,ir}h_{m'}})r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \frac{e^{i\beta_{m',sr}h_{m'}} (1 + r_{mm',sF,s})(1 + r_{m2,sF,s} e^{2i\beta_{m,sr}h_{m'}})L^{-1/m',sy}\chi_{y\alpha\beta}}{1 + r_{1m',sF,s} r_{m'm,sF,s} e^{2i\beta_{m',sr}h_{m'}} + (r_{m'm,sF,s} + r_{1m',sF,s} e^{2i\beta_{m',sr}h_{m'}})r_{m2,sF,p} e^{2i\beta_{m,sr}h_{m}}}$$

$$(2.39b)$$

#### (b): 透過方向

ファイル「一般式」の (2.2) 式と (2.4) 式において、 $z_1 = h_m$ 、 $a_0 * = 1$ 、 $a_0 = a$  とする。

$$E^{+2}(h_{m'} + h_{m}^{+})_{net} = \frac{t_{m2}t_{m'm}b(L^{+}_{m'/m'} + r_{m1}a^{2}L^{-}_{m'/m'})}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}P^{*}(z_{1} = h_{m'})$$

$$\begin{split} t_{m'm,p}L^{+}_{m'/m',px} &= t_{m'm,p}L^{-}_{m'/m',px} = L^{+}_{m'/m,px} \,, \\ t_{m'm,s}L^{+}_{m'/m',sy} &= t_{m'm,s}L^{-}_{m'/m',sy} = L^{+}_{m'/m,sy} \,, \end{split}$$

$$t_{m'm,p}L^{+}_{m'/m'pz} = -t_{m'm,p}L^{-}_{m'/m'pz} = L^{+}_{m'/m,pz} \quad (n_{m''} = n_{m'})$$

$$E^{+2}(h_{m'} + h_{m'}^{+})_{net} = \frac{t_{m2}b(1 \pm t_{m1}a^{2})L^{+}_{m'/m}}{1 + t_{1m'}t_{m'm}a^{2} + (t_{m'm} + t_{1m'}a^{2})t_{m'}b^{2}}P^{*}(z_{1} = h_{m'})$$

(upper sign for x and y components, lower sign for z component)

#### (2.23) 式を参照して、

$$E^{+}_{2,p}(h_{m'} + h_{m}^{+})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{\alpha},v_{m}^{h_{\alpha}}} (1 + r_{m'm,vis\alpha})(1 + r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}})}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{\alpha},v_{m}^{h_{\alpha}}} (1 + r_{min,r}^{*})(1 + r_{m'n,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}}{1 + r_{1m',ir}^{*} r_{m'm,ir}^{*} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}} + (r_{m'm,ir}^{*} + r_{1m',ir}^{*} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,ir}^{*} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}$$

$$\times \frac{t_{m2,SF,p} e^{i\beta_{\alpha},v_{m}^{h_{\alpha}}} [(1 + r_{m1,SF,p} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) L^{+}_{m',m,px} \chi_{x\alpha\beta} + (1 - r_{m1,SF,p} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) L^{+}_{m',m,xx} \chi_{x\alpha\beta}}}{1 + r_{1m',SF,p} r_{m'm,SF,p} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}} + (r_{m'm,SF,p} + r_{1m',SF,p} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,SF,p} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{\alpha},v_{m}^{h_{\alpha}}} (1 + r_{mm,vis\alpha})(1 + r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}} + (r_{m'm,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{\alpha},v_{m}^{h_{\alpha}}} (1 + r_{m'm,vis\alpha})(1 + r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}} + (r_{m'm,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{\alpha},v_{m}^{h_{\alpha}}} (1 + r_{m'm,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) (1 + r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}}{1 + r_{1m',vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}} + (r_{m'm,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) r_{m2,vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}}$$

$$\times \frac{t_{1m',vis\alpha} e^{i\beta_{\alpha},v_{m}^{h_{\alpha}}} (1 + r_{m',vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}) L^{+}_{m',vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}}}}{1 + r_{1m',vis\alpha} e^{2i\beta_{\alpha},v_{m}^{h_{\alpha}}} + (r_{m',vis\alpha} e^{2$$

## m'/m 界面の m 側 の分極からの SFG:

#### (a): 反射方向

ファイル「一般式」の (2.5) 式と (2.7) 式において、 $z_2 = 0$ 、 $b_0* = b$ 、 $b_0 = 1$  とする。

$$E^{-1}(0^{-})_{net} = \frac{at_{m1}t_{m'm}(r_{m2}b^{2}L^{+}_{m'/m'} + L^{-}_{m'/m'})}{1 + r_{1m}T_{m'm}a^{2} + (r_{m'm} + r_{1m}a^{2})r_{m}b^{2}}P^{*}(z_{1} = h_{m'})$$

$$\begin{split} t_{mm',p}L^{+}_{m/m,px} &= t_{mm',p}L^{-}_{m/m,px} = L^{-}_{m'/m,px}\,,\\ t_{mm',s}L^{+}_{m/m,sy} &= t_{mm',s}L^{-}_{m/m,sy} = L^{-}_{m'/m,sy}\,,\\ t_{mm',p}L^{+}_{m/m,pa} &= -t_{mm',p}L^{-}_{m/m,pa} &= -L^{-}_{m'/m,pa} & (n_{\rm m''} = n_{\rm m}) \end{split}$$

$$E^{-1}(0^{-})_{net} = \frac{at_{m1}(1 \pm r_{m2}b^{2})L^{-}_{m/m}}{1 + r_{1m}r_{mim}a^{2} + (r_{m:m} + r_{1m}a^{2})r_{m2}b^{2}}P^{*}(z_{1} = h_{m})$$

(upper sign for x and y components, lower sign for z component)

#### (2.25) 式を参照して、

$$E^{-1}_{lp}(0^{-})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir}\beta$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} e^{\beta_{m',vi}h_{m'}} (1 + r_{m2,vis\alpha} e^{2\beta_{m,vi}h_{m}})}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vi}h_{m}}) r_{m2,vis\alpha} e^{2\beta_{m,vi}h_{m}}}$$

$$\times \frac{t_{1m',r} \beta e^{\beta_{m',s}h_{m'}} (1 + r_{min',r} \beta) (1 + r_{m2,ir} \beta e^{2i\beta_{m',vi}h_{m'}}) r_{m2,vis} \beta e^{2i\beta_{m,vi}h_{m}}}{1 + r_{1m',r} \beta r_{m'm,r} \beta e^{2i\beta_{m',r}h_{m'}} + (r_{m'm,r} \beta + r_{1m',r} \beta e^{2i\beta_{m',vi}h_{m'}}) r_{m2,vis} \beta e^{2i\beta_{m,vi}h_{m}}}$$

$$\times \frac{t_{m1,SF,p} e^{i\beta_{m',s}r_{m'}} [(1 + r_{m2,SF,p} e^{2i\beta_{m',s}r_{m'}}) L_{m',m,px} \chi_{sc\beta} + (1 - r_{m2,SF,p} e^{2i\beta_{m',vi}h_{m'}}) L_{m',m,pz} \chi_{sc\beta}}{1 + r_{1m',SF,p} e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,SF,p} + r_{1m',SF,p} e^{2i\beta_{m',vi}h_{m'}}) r_{m2,SF,p} e^{2i\beta_{m,vi}h_{m}}} \qquad (n_{m'} = n_{m})$$

$$E^{-1}_{s}(0^{-})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir} \beta$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} e^{\beta_{m',vi}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vi}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}}}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vi}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vi}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}}}}$$

$$\times \frac{t_{1m',vis\alpha} e^{\beta_{m',vi}h_{m'}} + (r_{m'm,vir} \beta + r_{1m',vis\alpha} e^{2i\beta_{m,vi}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}}}{1 + r_{1m',vir} \beta r_{m'm,r} \beta e^{2i\beta_{m,vi}h_{m'}} + (r_{m'm,r} \beta e^{2i\beta_{m,vi}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vi}h_{m}}}}$$

$$\times \frac{t_{1m',vis\alpha} e^{\beta_{m',vi}h_{m'}} + (r_{m'm,vir} \beta + r_{1m',vir} \beta e^{2i\beta_{m,vi}h_{m'}}) r_{m2,vir} \beta e^{2i\beta_{m,vi}h_{m}}}}{1 + r_{1m',vir} \beta r_{m'm,r} \beta e^{2i\beta_{m',vir}h_{m'}} + (r_{m'm,r} \beta e^{2i\beta_{m',vir}h_{m'}}) r_{m2,vir} \beta e^{2i\beta_{m,vir}h_{m}}}}}$$

$$\times \frac{t_{1m,vir} \beta e^{\beta_{m',vir}h_{m'}} + (r_{m'm,vir} \beta + r_{1m',vir} \beta e^{2i\beta_{m',vir}h_{m'}}) r_{m2,vir} \beta e^{2i\beta_{m,vir}h_{m}}}}{1 + r_{1m',vir} \beta r_{m'm,r} \beta e^{2i\beta_{m',vir}h_{m'}} + (r_{m'm,vir} \beta e^{2i\beta_{m',vir}h_{m'}}) r_{m2,vir} \beta e^{2i\beta_{m,vir}h_{m}}}}}$$

$$\times \frac{t_{1m,vir} \beta e^{\beta_{m',vir}h_{m'}} + r_{1m',vir} \beta e^{2i\beta_{m',vir}h_{m'}$$

#### (b): 透過方向

ファイル「一般式」の (2.6) 式と (2.8) 式において、 $z_2 = 0$ 、 $b_0* = b$ 、 $b_0 = 1$  とする。

$$E^{+2}(h_{m'} + h_{m}^{+})_{net} = \frac{t_{m2}b[(1 + r_{1m'}r_{m'm}a^{2})L^{+}_{m'm} - (r_{m'm} + r_{1m'}a^{2})L^{-}_{m'm}]}{1 + r_{1m'}r_{m'm}a^{2} + (r_{m'm} + r_{1m'}a^{2})r_{m2}b^{2}}P^{*}(z_{2} = 0)$$

ここで、

$$\begin{split} t_{m2,p} L^+{}_{m/m,px} &= t_{m2,p} L^-{}_{m/m,px} = L^+{}_{m/2,px} \,, \\ t_{m2,s} L^+{}_{m/m,sy} &= t_{m2,s} L^-{}_{m/m,sy} = L^+{}_{m/2,sy} \,, \\ t_{m2,p} L^+{}_{m/m,pz} &= -t_{m2,p} L^-{}_{m/m,pz} = L^+{}_{m/2,pz} \qquad (n_{\rm m''} = n_{\rm m}) \end{split}$$

$$E^{+2}(h_{m'} + h_{m}^{+})_{net} = \frac{b[(1 + r_{lm'}r_{m'm}a^{2}) \text{ m } (r_{m'm} + r_{lm}a^{2})]L^{+}_{m/2}}{1 + r_{m'}r_{m'}a^{2} + (r_{m'} + r_{m'}a^{2})r_{m'}b^{2}}P^{*}(z_{2} = 0)$$

$$= \frac{b (1 \text{ m } r_{m'm}) (1 \text{ m } r_{1m'}a^2)] L^{+}_{m/2}}{1 + r_{1m'}a^2 + (r_{m'm} + r_{1m'}a^2) r_{m/2}b^2} P^{*} (z_2 = 0)$$

(upper sign for x and y components, lower sign for z component)

#### (2.25) 式を参照して、

$$E^{+}_{2,p}(h_{m'} + h_{m}^{+})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} t_{m'm,vis\alpha} e^{\beta_{m',vis}h_{m'}} (1 + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}})$$

$$\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha}} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m,vis}h_{m}}) r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}$$

$$\times \frac{t_{1m',ir\beta}}{1 + r_{1m',ir\beta}} e^{\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir\beta}) (1 + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}})$$

$$\times \frac{t_{1m',ir\beta}}{1 + r_{1m',ir\beta}} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}$$

$$\times \{ \frac{e^{i\beta_{m,SF}h_{m}} (1 - r_{m'm,SF,p}) (1 - r_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}}) L^{+}_{m/2,px} \chi_{xo\beta}}$$

$$\times \{ \frac{e^{i\beta_{m,SF}h_{m}} (1 + r_{m'm,SF,p}) (1 + r_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}}) L^{+}_{m/2,px} \chi_{xo\beta}$$

$$+ \frac{e^{i\beta_{m,SF}h_{m}} (1 + r_{m'm,SF,p}) (1 + r_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}}) L^{+}_{m/2,pz} \chi_{xo\beta}}$$

$$+ \frac{e^{i\beta_{m,SF}h_{m}} (1 + r_{m'm,SF,p}) (1 + r_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}}) L^{+}_{m/2,pz} \chi_{xo\beta}} {1 + r_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}} + (r_{m'm,SF,p} + r_{1m',SF,p} e^{2i\beta_{m',SF}h_{m'}}) r_{m2,SF,p} e^{2i\beta_{m,SF}h_{m}}} \} \qquad (n_{m''} = n_{m})$$
(2.42a)

$$E^{+}_{2,s}(h_{m} + h_{m}^{+})_{net} = \sum_{\alpha,\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} e^{\beta_{m',vis}h_{m'}} (1 + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}})}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}}$$

$$\times \frac{t_{1m',ir\beta} e^{\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir\beta}) (1 + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m'}})}{1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}}$$

$$\times \frac{e^{\beta_{m,sr}h_{m}} (1 - r_{m'm,SF,s}) (1 - r_{1m',SF,s} e^{2\beta_{m',SF}h_{m'}}) L^{+}_{m',2',sy} \chi_{yo\beta}}{1 + r_{1m',sr\beta} e^{2\beta_{m',SF}h_{m'}} + (r_{m',m,SF,s} + r_{1m',SF,s} e^{2\beta_{m',SF}h_{m'}}) r_{m2,SF,s} e^{2\beta_{m,SF}h_{m}}}$$

$$(2.42b)$$

## m' 層の分極からの SFG:

ファイル「一般式」の(2.1)式~(2.4)式において、下の定義を使う。

$$a_0 = e^{ik_m z_1/\cos\theta_m}, \qquad a_0^* = e^{i\beta_m h_m/\cos\theta_m} e^{-ik_m z_1/\cos\theta_m}$$

しかし、本稿の (2.10) 式  $\sim (2.17)$  式ひいては (2.27) 式  $\sim (2.30)$  式を導くために使う光路は、一つの層の内部での多重反射を考慮していない。すなわち、位相部分の扱いには不備がある。その不備は、指数関数の引数で  $h/\cos\theta$  および  $z/\cos\theta$  の形になっている部分を  $\beta \times h$  および  $\beta \times z$  と置き換えることで修正できるので、その置き換えを行った結果を以下では記す。手始めに、以下では  $a_0 = e^{i\beta_m z_i}$ ,  $a_0 * = e^{i\beta_m h_m} e^{-i\beta_m z_i}$  とする。また、上で行ったと同様に下のように置く。

$$\begin{split} P_{a}^{*} &= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta} \\ &\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}} \\ &\times \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}} \end{split}$$

## (a): 反射方向

 $E^{\dagger}$  sources からの寄与は、ファイル「一般式」の (2.1) 式と本稿の (2.27) 式により、下で表される。

$$\begin{split} E^{-1}(0^{-}) &= \sum_{\alpha\beta} t_{m1} e^{2i\beta_{m}h_{m}} (r_{m'm} + r_{m2}e^{2\beta_{m}h_{m}}) L^{+}_{m'/m'} P_{a}^{*} \\ &\times \{ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir,\beta} r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}) \exp[iz_{1}(-\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir})] \\ &+ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir,\beta} + r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',ir}h_{m'}} \exp[iz_{1}(-\beta_{m',SF} + \beta_{m',vis} - \beta_{m',ir})] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir,\beta} r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',vis}h_{m'}} \exp[iz_{1}(-\beta_{m',SF} - \beta_{m',vis} + \beta_{m',ir})] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir,\beta} + r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \exp[iz_{1}(-\beta_{m',SF} - \beta_{m',vis} + \beta_{m',ir})] \end{split}$$

E sources からの寄与は、ファイル「一般式」の(2.3)式と本稿の (2.28) 式により下で表される。

$$\begin{split} E^{-1}(0^{-}) &= \sum_{\alpha\beta} t_{m1} (1 + r_{mm'} r_{m2} e^{2i\beta_{m}h_{m}}) L^{-}_{m'/m'} P_{a}^{*} \\ &\times \{ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir\beta} r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) \exp[iz_{1}(\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir})] \\ &+ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir\beta} + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',ir}h_{m'}} \exp[iz_{1}(\beta_{m',SF} + \beta_{m',vis} - \beta_{m',ir})] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir\beta} r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',vis}h_{m'}} \exp[iz_{1}(\beta_{m',SF} - \beta_{m',vis} + \beta_{m',ir})] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir\beta} + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \exp[iz_{1}(\beta_{m',SF} - \beta_{m',vis} - \beta_{m',ir})] \} \end{split}$$

ここで、 $E^+$  に由来する SFG 光については $z_1$ について 0 から  $h_{\rm m'}$ まで( $z_1=0\to h_{\rm m'}$ )、E に由来する SFG 光については  $z_1$  について  $h_{\rm m'}$  から0まで ( $z_1=h_{\rm m'}\to 0$ ) 積分し、さらに関係式

$$\begin{split} t_{\text{m'l},\text{p}}L^{+}_{\text{m'm'},\text{px}} &= L^{-}_{1/\text{m'},\text{px}}, \quad t_{\text{m'l},\text{s}}L^{+}_{\text{m'm'},\text{sy}} &= L^{-}_{1/\text{m'},\text{sy}}, \quad t_{\text{m'l},\text{p}}L^{+}_{\text{m'm'},\text{pz}} &= -L^{-}_{1/\text{m'},\text{pz}} \quad (n_{\text{m''}} = n_{\text{m'}}) \\ t_{\text{m'l},\text{p}}L^{-}_{\text{m'm'},\text{px}} &= L^{-}_{1/\text{m'},\text{px}}, \quad t_{\text{m'l},\text{s}}L^{-}_{\text{m'm'},\text{sy}} &= L^{-}_{1/\text{m'},\text{sy}}, \quad t_{\text{m'l},\text{p}}L^{-}_{\text{m'm'},\text{pz}} &= L^{-}_{1/\text{m'},\text{pz}}, \quad (n_{\text{m''}} = n_{\text{m'}}) \end{split}$$

を考慮して整理すると、下式が得られる。

$$\begin{split} E^-_{1}(0^-)_{net} &= \sum_{\alpha\beta} L^-_{1/m} P_a^{-\frac{i}{\delta}} \frac{i}{\delta} \\ &\times \{ (1 + r_{m'm,yis\alpha} r_{m2,yis\alpha} e^{2\beta_{m,3i}h_m}) \frac{e^{i(\beta_{m;SF} + \beta_{m',ii} + \beta_{m',ji}) h_{m'}} - 1}{\beta_{m',SF} + \beta_{m',yis} + \beta_{m',ji}} \\ &\times [ (1 + r_{mm',SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) \frac{e^{i(\beta_{m;SF} + \beta_{m',yis} + \beta_{m',ji}) h_{m'}} - 1}{\beta_{m',SF} + \beta_{m',yis} + \beta_{m',ji}} \frac{e^{i(\beta_{m;SF} + \beta_{m',yis} + \beta_{m',ji}) h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',yis} - \beta_{m',ji}} - 1} \\ &+ (1 + r_{m'm,yis\alpha} r_{m2,yis\alpha} e^{2\beta_{m,Si}h_m}) (r_{m'm,ir} + r_{m2,ir} + \beta_{m',ir}) h_{m'}} - \frac{1}{\beta_{m',SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &\times [ (1 + r_{mm',SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) \frac{e^{i(\beta_{m;SF} + \beta_{m',yis} - \beta_{m',ir}) h_{m'}} - 1}{\beta_{m',SF} + \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,SF} + r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF}h_m} \frac{e^{i(\beta_{m,SF} + \beta_{m',yis} - \beta_{m',ir}) h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',yis}} + \beta_{m',ir}} \\ &\times [ (1 + r_{mm',SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) \frac{e^{i(\beta_{m;SF} + \beta_{m',yis} + \beta_{m',ir}) h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',yis}} + \beta_{m',ir}} \\ &+ (r_{m'm,SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) \frac{e^{i(\beta_{m;SF} - \beta_{m',yis} + \beta_{m',ir}) h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',yis}} + \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,yis\alpha} + r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF}h_m} \frac{e^{i(\beta_{m;SF} - \beta_{m',ir} + \beta_{m',yis}) h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &\times [ (1 + r_{mm',SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF} - \beta_{m',yis}} - \beta_{m',ir}} \\ &+ (r_{m'm,SF} r_{m2,SF} e^{2i\beta_{m,SF}h_m}) e^{2i\beta_{m;SF} - \beta_{m',yis}} - \beta_{m'$$

(upper sign for x and y components, lower sign for z component)

よって、

$$\begin{split} E^{-}_{1}(0^{-})_{p} &= \sum_{\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\,\beta} \frac{i}{\delta} \\ &\times \frac{t_{1m',vis\alpha}}{1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis\,\alpha} e^{2i\beta_{m,vis}h_{m}} \\ &\times \frac{t_{1m',ir\,\beta}}{1 + r_{1m',ir\,\beta} r_{m'm,ir\,\beta} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir\,\beta} + r_{1m',ir\,\beta} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir\,\beta} e^{2i\beta_{m,ir}h_{m}}} \\ &\times \{\{(1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}})(1 + r_{m'm,ir\,\beta} r_{m2,ir\,\beta} e^{2i\beta_{m,ir}h_{m}}) \\ &\times \{\{(1 + r_{mm',SF,p} r_{m2,SF,p} e^{2i\beta_{m,SF}h_{m}}) \frac{e^{i(\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir})h_{m'}} - 1}{\beta_{m',SF} + \beta_{m',vis} + \beta_{m',vis} + \beta_{m',ir})h_{m'}} - 1} \\ &+ (r_{m'm,SF,p} + r_{m2,SF,p} e^{2i\beta_{m,SF}h_{m}}) e^{2i\beta_{m,SF}h_{m'}} \frac{e^{i(-\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir})h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',vis} - \beta_{m',ir}}} ] \end{split}$$

$$+ (1 + r_{minotic} r_{m2sinc} e^{2 \cdot \theta_{num} h_{ni}}) (r_{min,p} + r_{n2si} \theta^{2 \cdot \theta_{num} h_{ni}}) e^{2 \cdot \theta_{num} h_{ni}}$$

$$\times (1 + r_{min,SF,p} r_{m2SF,p} e^{2 \cdot \theta_{num} h_{ni}}) e^{2 \cdot \theta_{num} h_{ni}} + r_{n2si} \theta^{2 \cdot \theta_{num} h_{ni}}$$

$$+ (r_{min,SF,p} + r_{m2SF,p} e^{2 \cdot \theta_{num} h_{ni}}) (1 + r_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}} + h_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}})$$

$$+ (r_{min,sin,m} + r_{m2sin,p} e^{2 \cdot \theta_{num} h_{ni}}) (1 + r_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}} + h_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}})$$

$$+ (r_{min,sin,m} + r_{m2sin,p} e^{2 \cdot \theta_{num} h_{ni}}) (1 + r_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}} + h_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}})$$

$$+ (r_{min,sin,p} + r_{m2sin,p} e^{2 \cdot \theta_{num} h_{ni}}) (1 + r_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}} + h_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}})$$

$$+ (r_{min,sin,p} + r_{m2sin,p} e^{2 \cdot \theta_{num} h_{ni}}) (1 + r_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}} + h_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}})$$

$$+ (r_{min,sin,p} + r_{m2sin,p} e^{2 \cdot \theta_{num} h_{ni}}) (2 \cdot \theta_{num,p} \theta^{2 \cdot h_{ni} h_{ni}} + h_{mini,p} \theta^{2 \cdot h_{ni} h_{ni}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (r_{min,p} \theta^{2 \cdot h_{ni} h_{ni}} + r_{min,p} \theta^{2 \cdot h_{ni} h_{ni}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (r_{min,p} \theta^{2 \cdot h_{ni} h_{ni}} + r_{min,p} \theta^{2 \cdot h_{ni} h_{ni}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}} e^{2 \cdot \theta_{num,h}} e^{2 \cdot \theta_{num,h}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}} e^{2 \cdot \theta_{num,h}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}} e^{2 \cdot \theta_{num,h}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}} e^{2 \cdot \theta_{num,h}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}} e^{2 \cdot \theta_{num,h}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}})$$

$$+ (r_{min,sin,p} r_{m2sin,p} e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}}) (e^{2 \cdot \theta_{num,h}}) (e^{2$$

$$\begin{split} E^{-1}(0^{-})_{s} &= \sum_{\alpha\beta} E^{0} \operatorname{size} E^{0} \operatorname{tr} \beta \frac{i}{\delta} \\ &\times \frac{I_{1m/size}}{1 + I_{1m/size}} \frac{I_{1m/size}}{I_{1m/size}} + \frac{I_{1m/size}}{I_{1m/size}} + \frac{I_{1m/size}}{I_{1m/size}} \frac{I_{1m/size}}{I_{1m/size}} + \frac{I_{1m/size}}{I_{1m/size}} e^{2i\beta_{n,in}h_{n}} + (I_{nm/size} + I_{1m/size}) e^{2i\beta_{n,in}h_{n}}) I_{n2size} e^{2i\beta_{n,in}h_{n}} \\ &\times \frac{I_{1m/s}}{1 + I_{1m/size}} I_{n2size} e^{2i\beta_{n,in}h_{n}} + (I_{nm/size}) + I_{1m/size}} e^{2i\beta_{n,in}h_{n}} + I_{1m/size} e^{2i\beta_{n,in}h_{n}} \\ &\times \{(1 + I_{nm/size}) I_{n2size} e^{2i\beta_{n,in}h_{n}} + (I_{nm/size}) I_{n-2size} e^{2i\beta_{n,in}h_{n}} + I_{1m/size} e^{2i\beta_{n,in}h_{n}} + I_{1m/size$$

# (b): 透過方向

 $E^{\dagger}$  sources からの寄与は、ファイル「一般式」の (2.2) 式と本稿の (2.27) 式により、下で表される。

$$\begin{split} E^{+}_{2}(h_{m'} + h_{m}^{+}) &= \sum_{\alpha\beta} t_{m2} e^{i\beta_{m'}h_{m'}} t_{mim} L^{+}_{m'/m'} P_{a}^{*} \\ &\times \{ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir\beta} r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) \exp[iz_{1}(-\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir})] \\ &+ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir\beta} + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',ir}h_{m'}} \exp[iz_{1}(-\beta_{m',SF} + \beta_{m',vis} - \beta_{m',ir})] \end{split}$$

$$+(r_{m'm,vis\alpha}+r_{m2,vis\alpha}e^{2\beta_{m,vis}h_m})(1+r_{m'mir,\beta}r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_m})e^{2i\beta_{m',vis}h_{m'}}\exp[iz_1(-\beta_{m',SF}-\beta_{m',vis}+\beta_{m',ir})]$$

$$+(r_{m'm,vis\alpha}+r_{m2,vis\alpha}e^{2\beta_{m,vis}h_m})(r_{m'm,ir,\beta}+r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_m})e^{2i(\beta_{m',vis}+\beta_{m',ir})h_{m'}}\exp[iz_1(-\beta_{m',SF}-\beta_{m',vis}-\beta_{m',ir})]\}$$

E sources からの寄与は、ファイル「一般式」の (2.4) 式と本稿の (2.28) 式により、下で表される。

$$\begin{split} E^{+}{}_{2}(h_{m'} + h_{m}^{+}) &= \sum_{\alpha\beta} t_{m2} e^{i\beta_{m}h_{m'}} r_{m1} t_{m'm} L_{m'm'} P_{a}^{*} \\ &\times \{ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir\beta} r_{m2,ir\beta} e^{2i\beta_{m,v}h_{m}}) \exp[iz_{1}(\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir})] \\ &+ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}) (r_{m'm,ir\beta} + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',vih}} \exp[iz_{1}(\beta_{m',SF} + \beta_{m',vis} - \beta_{m',ir})] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir\beta} r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',vih}} \exp[iz_{1}(\beta_{m',SF} - \beta_{m',vis} + \beta_{m',ir})] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2i\beta_{m,vis}h_{m}}) (r_{m'm,ir\beta} + r_{m2,ir\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \exp[iz_{1}(\beta_{m',SF} - \beta_{m',vis} - \beta_{m',ir})] \} \end{split}$$

ここで、 $E^+$ に由来する SFG 光については  $z_1$  について 0 から  $h_{\rm m}$  まで( $z_1=0\to h_{\rm m}$ )、E に由来するSFG 光については  $z_1$  について  $h_{\rm m}$  から0まで( $z_1=h_{\rm m}\to 0$ )積分し、さらに関係式

$$t_{\text{m'm}p}L^{+}_{\text{m'm',px}} = L^{+}_{\text{m'm,px}}, \quad t_{\text{m'm}s}L^{+}_{\text{m'm',sy}} = L^{+}_{\text{m'm,sy}}, \quad t_{\text{m'm,p}}L^{+}_{\text{m'm',pz}} = L^{+}_{\text{m'm,pz}} \quad (n_{\text{m''}} = n_{\text{m'}})$$

$$t_{\text{m'm}p}L^{-}_{\text{m'm',pz}} = L^{+}_{\text{m'm,pz}}, \quad t_{\text{m'm}s}L^{-}_{\text{m'm',sy}} = L^{+}_{\text{m'm,sy}}, \quad t_{\text{m'm,p}}L^{-}_{\text{m'm',pz}} = -L^{+}_{\text{m'm,pz}}, \quad (n_{\text{m''}} = n_{\text{m'}})$$

を考慮して整理すると、下式が得られる。

$$\begin{split} E^{+}{}_{2}(h_{m'} + h_{m}^{+}) &= \sum_{\alpha\beta} t_{m2} e^{i(\beta_{m'}h_{m'} + \beta_{m}h_{m})} L^{+}{}_{m'/m} P_{a}^{*} \frac{i}{\delta} \\ &\times \{ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir,\beta} r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) \\ &\times [\frac{e^{i(-\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir})h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',vis} - \beta_{m',ir}} \pm r_{m1} \frac{e^{i(\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir})h_{m'}} - 1}{\beta_{m',SF} + \beta_{m',vis} + \beta_{m',ir}}] \\ &+ (1 + r_{m'm,vis\alpha} r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',ir}h_{m'}} \\ &\times [\frac{e^{i(-\beta_{m',SF} + \beta_{m',vis} - \beta_{m',ir})h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',vis} + \beta_{m',vis}} + \beta_{m',ir}} \pm r_{m1} \frac{e^{i(\beta_{m',SF} + \beta_{m',vis} - \beta_{m',ir})h_{m'}} - 1}{\beta_{m',SF} + \beta_{m',vis} - \beta_{m',ir}}}] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (1 + r_{m'm,ir,\beta} r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i\beta_{m',vis}h_{m'}} \\ &\times [\frac{e^{i(-\beta_{m',SF} - \beta_{m',vis} + \beta_{m',ir})h_{m'}} - 1}{\beta_{m',SF} - \beta_{m',vis} + \beta_{m',ir})h_{m'}} - 1}] \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m'm,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m',m,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \\ &+ (r_{m'm,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m',m,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \\ &+ (r_{m',m,vis\alpha} + r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}}) (r_{m',m,ir,\beta} + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}}) e^{2i(\beta_{m',vis} + \beta_{m',ir})h_{m'}} \\ &+ (r_{m',m,vis\alpha} + r_{m2,ir,\beta} e^{2\beta_{m,vis}h_{m}})$$

$$\times \left[\frac{e^{i(-\beta_{m',SF}-\beta_{m',vis}-\beta_{m',ir})h_{m'}}-1}{\beta_{m',SF}+\beta_{m',vis}+\beta_{m',ir}}\pm r_{m1}\frac{e^{i(\beta_{m',SF}-\beta_{m',vis}-\beta_{m',ir})h_{m'}}-1}{\beta_{m',SF}-\beta_{m',vis}-\beta_{m',ir}}\right]\right\}$$

(upper sign for x and y components, lower sign for z component)

よって、

$$\begin{split} E^{+}{}_{2p}\left(h_{m'}+h_{m}^{+}\right) &= \sum_{\alpha\beta} E^{0}{}_{vi\alpha} E^{0}{}_{ir} g \, t_{m_{2}} e^{i(\beta_{m,m}+\beta_{m,n}h_{m})} \frac{i}{\delta} \\ &\times \frac{I_{1m/sig}}{1+I_{1m/sig}} r_{m'm/sig} e^{2i\beta_{n,m}h_{m'}} + (I_{m'm/sig} + I_{1m'sig}) e^{2i\beta_{n,m}h_{m'}}) r_{m2sig} e^{2i\beta_{n,m}h_{m}} \\ &\times \frac{I_{1m/sig}}{1+I_{1m/sig}} r_{m'm/sig} e^{2i\beta_{n,m}h_{m'}} + (I_{m'm/sig} + I_{1m'sig}) e^{2i\beta_{n,m}h_{m'}}) r_{m2sig} e^{2i\beta_{n,m}h_{m}} \\ &\times \frac{I_{1m/sig}}{1+I_{1m/sig}} r_{m'm/sig} e^{2i\beta_{n,m}h_{m'}} + (I_{m'm/sig} + I_{1m'sig}) e^{2i\beta_{n,m}h_{m'}}) r_{m2sig} e^{2i\beta_{n,m}h_{m}} \\ &\times \left\{ \left\{ (1+I_{m'm/sig} r_{m2sig}) e^{2i\beta_{n,m}h_{m'}} + I_{1m'sig} g^{2i\beta_{n,m}h_{m'}} \right\} \\ &\times \left\{ \frac{e^{i(-\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}} - 1}{\beta_{m',sr} - \beta_{m'sir} - \beta_{m'sir}} + r_{m1,sF,p} e^{2i\beta_{n,m'}+\beta_{n,m'}+\beta_{m',m'}+\beta_{m',m'}} \right\} \\ &\times \left\{ \frac{e^{i(-\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}} - 1}{\beta_{m',sr} - \beta_{m',sir} + \beta_{m',ir}} + r_{m1,sF,p} e^{2i\beta_{n,m'}+\beta_{n',m'}+\beta_{m',m'}+\beta_{m',m'}} \right\} \\ &\times \left\{ \frac{e^{i(-\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}}}{\beta_{m',sr} - \beta_{m',sir} + \beta_{m',ir}} + r_{m1,sF,p} e^{2i\beta_{n,m'}+\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}} \right\} \\ &\times \left\{ \frac{e^{i(-\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}}}{\beta_{m',sr} + \beta_{m',sir} + \beta_{m',ir}} + r_{m1,sF,p} e^{2i\beta_{n,m'}+\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}+\beta_{m',m'}} \right\} \\ &\times \left\{ \frac{e^{i(-\beta_{m',m'}+\beta$$

(2.44b)

#### m 層の分極からの SFG:

ファイル「一般式」の (2.5) 式 ~ (2.8) 式において、下の定義を使う。

$$\begin{split} b_{0} &= e^{ik_{m}z_{2}/\cos\theta_{m}}\,, \qquad b_{0}^{} *= e^{i\beta_{m}h_{m}/\cos\theta_{m}}e^{-ik_{m}z_{2}/\cos\theta_{m}} \\ P_{a}^{} *&= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}{}_{vis\alpha} E^{0}{}_{ir,\beta} \\ &\times \frac{t_{1m',vis}\alpha}{1 + r_{1m',vis}\alpha} r_{m'm,vis}\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis}\alpha} e^{i\beta_{m',vis}h_{m'}}) r_{m2,vis}\alpha} e^{2i\beta_{m,vis}h_{m}} \\ &\times \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta}} r_{m'm,vis}\alpha} e^{2i\beta_{m',vis}h_{m'}} + (r_{m'm,vis}\alpha} + r_{1m',vis}\alpha} e^{2i\beta_{m',vis}h_{m'}}) r_{m2,vis}\alpha} e^{2i\beta_{m,vis}h_{m}} \\ &\times \frac{t_{1m',ir,\beta}}{1 + r_{1m',ir,\beta}} r_{m'm,ir,\beta}} e^{2i\beta_{m',ir}h_{m'}} + (r_{m'm,ir,\beta}} + r_{1m',ir,\beta}} e^{2i\beta_{m',ir}h_{m'}}) r_{m2,ir,\beta}} e^{2i\beta_{m,vis}h_{m}} \end{split}$$

とおく。

#### (a): 反射方向

 $E^{\dagger}$  sources からの寄与は、ファイル「一般式」の (2.5) 式と本稿の (2.29) 式により、下で表される。

$$E^{-1}(0^{-}) = \sum_{\alpha\beta} t_{m1} t_{mm} r_{m2} e^{i\beta_{m} h_{m}} e^{2i\beta_{m} h_{m}} L^{+}_{m/m} P_{a}^{*}$$

$$\times \{ \exp[iz_{2}(-\beta_{m,SF} + \beta_{m,vis} + \beta_{m,ir})] + r_{m2,ir,\beta} e^{2i\beta_{m,ir} h_{m}} \exp[iz_{2}(-\beta_{m,SF} + \beta_{m,vis} - \beta_{m,ir})] + r_{m2,vis\alpha} e^{2i\beta_{m,vis} h_{m}} \exp[iz_{2}(-\beta_{m,SF} - \beta_{m,vis} + \beta_{m,ir})] + r_{m2,vis\alpha} r_{m2,ir,\beta} e^{2i(\beta_{m,ir} + \beta_{m,vis}) h_{m}} \exp[iz_{2}(-\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir})] \}$$

E sources からの寄与は、ファイル「一般式」の (2.7) 式と本稿の (2.30) 式により、下で表される。

$$E^{-1}(0^{-}) = \sum_{\alpha\beta} t_{m1} t_{mm} e^{\beta_{m}h_{mi}} L^{-}_{m/m} P_{a}^{*}$$

$$\times \{ \exp[iz_{2}(\beta_{m,SF} + \beta_{m,vis} + \beta_{m,ir})] + r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}} \exp[iz_{2}(\beta_{m,SF} + \beta_{m,vis} - \beta_{m,ir})]$$

$$+ r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}} \exp[iz_{2}(\beta_{m,SF} - \beta_{m,vis} + \beta_{m,ir})]$$

$$+ r_{m2,vis\alpha} r_{m2,ir,\beta} e^{2i(\beta_{m,ir} + \beta_{m,vis})h_{m}} \exp[iz_{2}(\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir})] \}$$

ここで、 $E^+$  に由来する SFG 光については  $z_2$  について 0 から  $h_{\rm m}$  まで( $z_2=0\to h_{\rm m}$ )、E に由来するSFG 光については  $z_2$  について  $h_{\rm m}$  から 0 まで( $z_2=h_{\rm m}\to 0$ )積分し、さらに関係式

$$t_{\text{mm'}, p}L^{+}_{\text{m/m}, px} = L_{\text{m'/m}, px}, \quad t_{\text{mm'}, s}L^{+}_{\text{m/m}, sy} = L_{\text{m'/m}, sy}, \quad t_{\text{mm'}, p}L^{+}_{\text{m/m}, pz} = -L_{\text{m'/m}, pz} \quad (n_{\text{m''}} = n_{\text{m}})$$
 $t_{\text{mm'}, p}L_{\text{m/m}, px} = L_{\text{m'/m}, px}, \quad t_{\text{mm'}, s}L_{\text{m/m}, sy} = L_{\text{m'/m}, sy}, \quad t_{\text{mm'}, p}L_{\text{m/m'}, pz} = L_{\text{m'/m}, pz}, \quad (n_{\text{m''}} = n_{\text{m}})$ 

を考慮して整理すると、下式を得る。

$$\begin{split} E^{-}_{1}(0^{-}) &= \sum_{\alpha\beta} t_{m1} e^{\beta_{m}h_{m}} L^{-}_{m/m} P_{a}^{*} \frac{i}{\delta} \\ &\times \{ [\frac{e^{i(\beta_{mSF} + \beta_{m,vis} + \beta_{m,ir})h_{m}} - 1}{\beta_{mSF} + \beta_{m,vis} + \beta_{m,ir})h_{m}} \pm r_{m2} e^{2\beta_{mSF}h_{m}} \frac{e^{i(-\beta_{mSF} + \beta_{m,vis} + \beta_{m,ir})h_{m}} - 1}{\beta_{mSF} - \beta_{m,vis} - \beta_{m,ir}} ] \\ &+ r_{m2,ir,\beta} e^{2i\beta_{m,ir}h_{m}} [\frac{e^{i(\beta_{m,SF} + \beta_{m,vis} - \beta_{m,ir})h_{m}} - 1}{\beta_{mSF} + \beta_{m,vis}\beta_{mir}} \pm r_{m2} e^{2\beta_{mSF}h_{m}} \frac{e^{i(-\beta_{mSF} + \beta_{m,vis} - \beta_{m,ir})h_{m}} - 1}{\beta_{mSF} - \beta_{m,vis} + \beta_{m,ir}} ] \\ &+ r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}} [\frac{e^{i(\beta_{m,SF} - \beta_{m,vis} + \beta_{m,ir})h_{m}} - 1}{\beta_{mSF} - \beta_{m,vis} + \beta_{m,ir}} \pm r_{m2} e^{2i\beta_{m,SF}h_{m}} \frac{e^{i(-\beta_{m,SF} - \beta_{m,vis} + \beta_{m,ir})h_{m}} - 1}{\beta_{mSF} + \beta_{m,vis} - \beta_{m,ir}} ] \\ &+ r_{m2,vis\alpha} r_{m2,ir,\beta} e^{2i(\beta_{m,vis} + \beta_{m,ir})h_{m}} [\frac{e^{i(\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir})h_{m}} - 1}{\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir}} \pm r_{m2} e^{2\beta_{m,SF}h_{m}} \frac{e^{i(-\beta_{m,SF} - \beta_{m,vis} + \beta_{m,vis} + \beta_{m,ir})h_{m}} - 1}{\beta_{m,SF} + \beta_{m,vis} - \beta_{m,vis} + \beta_{m,ir}} ] \} \end{split}$$

(upper sign for x and y components, lower sign for z component)

よって、

$$E^{-1}(0^{-})_{p} = \sum_{\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta} t_{m1SF,p} e^{i(\beta_{m1SF} + \beta_{m',vis} + \beta_{m',ir}) h_{m'}} \frac{i}{\delta}$$

$$\times \frac{1}{1 + t_{[M] s j t t}} \frac{1}{m_{m} s j t t} e^{2i \theta_{m, m} h_{m}} + t_{m, m} t_{m, m t} e^{2i \theta_{m, m} h_{m}} + t_$$

(2.45b)

 $\times \left[\frac{e^{i(\beta_{m,SF}-\beta_{m,vis}-\beta_{m,ir})h_m}-1}{\beta_{m,SF}-\beta_{m,vis}-\beta_{m,vis}-\beta_{m,vis}}+r_{m2SF,s}e^{2i\beta_{mSF}h_m}\frac{e^{i(-\beta_{m,SF}-\beta_{m,vis}-w\beta_{m,ir})h_m}-1}{\beta_{m,SF}+\beta_{m,vis}+\beta_{m,vis}}\right]\right\}L^{-}_{m/m,sy}\chi_{yo\beta}$ 

## (b): 透過方向

 $E^{\dagger}$  sources からの寄与は、ファイル「一般式」の (2.6) 式と本稿の (2.29) 式により、下で表される。

$$\begin{split} E^{+}_{2}(h_{m'} + h_{m}^{+}) &= \sum_{\alpha\beta} t_{m2} e^{i\beta_{m}h_{m}} (1 + r_{1m'}r_{m'm}e^{2i\beta_{m'}h_{m'}}) L^{+}_{m'm}P_{a}^{*} \\ &\times \{ \exp[iz_{2}(-\beta_{m,SF} + \beta_{m,vis} + \beta_{m,ir})] + r_{m2,ir,\beta}e^{2i\beta_{m,ir}h_{m}} \exp[iz_{2}(-\beta_{m,SF} + \beta_{m,vis} - \beta_{m,ir})] \\ &+ r_{m2,vis\alpha}e^{2\beta_{m,vis}h_{m}} \exp[iz_{2}(-\beta_{m,SF} - \beta_{m,vis} + \beta_{m,ir})] \\ &+ r_{m2,vis\alpha}r_{m2,ir,\beta}e^{2i(\beta_{m,ir} + \beta_{m,vis})h_{m}} \exp[iz_{2}(-\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir})] \} \end{split}$$

E sources からの寄与は、ファイル「一般式」の (2.8) 式と本稿の (2.30) 式により、下で表される。

$$\begin{split} E^{+}_{2}(h_{m'} + h_{m}^{+}) &= -\sum_{\alpha\beta} t_{m2} e^{i\beta_{m}h_{m}} (r_{m'm} + r_{1m}e^{2\beta_{m'}h_{m'}}) L^{-}_{m'm} P_{a}^{*} \\ &\times \{ \exp[iz_{2}(\beta_{m,SF} + \beta_{m,vis} + \beta_{mjr})] + r_{m2,ir\beta} e^{2i\beta_{mir}h_{m}} \exp[iz_{2}(\beta_{m,SF} + \beta_{m,vis} - \beta_{mjr})] \\ &+ r_{m2,vis\alpha} e^{2\beta_{m,vis}h_{m}} \exp[iz_{2}(\beta_{m,SF} - \beta_{m,vis} + \beta_{mjr})] \\ &+ r_{m2,vis\alpha} r_{m2,ir\beta} e^{2i(\beta_{m,ir} + \beta_{m,vis})h_{m}} \exp[iz_{2}(\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir})] \} \end{split}$$

ここで、 $E^+$ に由来する SFG 光については  $z_2$  について 0 から  $h_{\rm m}$  まで ( $z_2=0\to h_{\rm m}$ )、E に由来する SFG 光については  $z_2$  について  $h_{\rm m}$  から 0 まで ( $z_2=h_{\rm m}\to 0$ ) 積分し、さらに関係式

$$\begin{split} t_{\text{m2p}}L^{+}_{\text{m/m,px}} &= L^{+}_{\text{m/2',px}}, \quad t_{\text{m2s}}L^{+}_{\text{m/m,sy}} &= L^{+}_{\text{m/2',sy}}, \quad t_{\text{m2p}}L^{+}_{\text{m/m,pz}} &= L^{+}_{\text{m/2',pz}} \quad (n_{\text{m"}} = n_{\text{m}}) \\ t_{\text{m2p}}L^{-}_{\text{m/m,px}} &= L^{+}_{\text{m/2',px}}, \quad t_{\text{m2s}}L^{-}_{\text{m/m,sy}} &= L^{+}_{\text{m2',sy}}, \quad t_{\text{m2p}}L^{-}_{\text{m/m,pz}} &= -L^{+}_{\text{m/2',pz}} \quad (n_{\text{m"}} = n_{\text{m}}) \end{split}$$

を考慮して整理すると、下式を得る。

$$\begin{split} E^{+}{}_{2}(h_{m'} + h_{m}^{-+}) &= \sum_{\alpha\beta} e^{\beta \!\!\!/}_{m} h_{m} L^{+}{}_{m'2} P_{a}^{+} \frac{i}{\delta} \\ &\times \{ [(1 + r_{1m',SF} r_{m'm,SF} e^{2\beta_{m',SF} h_{m'}}) \frac{e^{i(-\beta_{m,SF} + \beta_{m,vis} + \beta_{m,ir}) h_{m}} - 1}{\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir}} \\ & \qquad \qquad m(r_{m'm,SF} + r_{1m',SF} e^{2\beta_{m',SF} h_{m'}}) \frac{e^{i(\beta_{m,SF} + \beta_{m,vis} + \beta_{m,ir}) h_{m}} - 1}{\beta_{m,SF} + \beta_{m,vis} + \beta_{m,ir}} ] \\ & \qquad \qquad + r_{m2,ir,\beta} e^{2i\beta_{m,ir} h_{m}} [(1 + r_{1m',SF} r_{m'm,SF} e^{2i\beta_{m',SF} h_{m'}}) \frac{e^{i(-\beta_{m,SF} + \beta_{m,vis} - \beta_{m,ir}) h_{m}} - 1}{\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir}} h_{m}} ] \\ & \qquad \qquad m(r_{m'm,SF} + r_{1m',SF} e^{2\beta_{m',SF} h_{m'}}) \frac{e^{i(\beta_{m,SF} + \beta_{m,vis} - \beta_{m,ir}) h_{m}} - 1}{\beta_{m,SF} + \beta_{m,vis} - \beta_{m,ir}} h_{m}} - 1} \\ & \qquad \qquad + r_{m2,vis\alpha} e^{2\beta_{m,vis} h_{m}} [(1 + r_{1m',SF} r_{m'm,SF} e^{2\beta_{m',SF} h_{m'}}) \frac{e^{i(-\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir}) h_{m}} - 1}{\beta_{m,SF} + \beta_{m,vis} - \beta_{m,ir}} h_{m',SF}} - \beta_{m,ir}} \end{split}$$

$$\begin{split} & \text{m} \left( r_{m'm,SF} + r_{1m',SF} e^{2\beta_{m',SF}h_{m'}} \right) \frac{e^{i(\beta_{m,SF} - \beta_{m,vis} + \beta_{mir})h_m} - 1}{\beta_{m,SF} - \beta_{m,vis} + \beta_{mir}} \\ & + r_{m2,vis\alpha} \, r_{m2,ir,\beta} \, e^{2i(\beta_{m',is} + \beta_{mir})h_m} [(1 + r_{1m',SF} \, r_{m'm,SF} e^{2i\beta_{m',SF}h_{m'}}) \frac{e^{i(-\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir})h_m} - 1}{\beta_{m,SF} + \beta_{m,vis} + \beta_{m,ir}} \\ & \text{m} \left( r_{m'm,SF} + r_{1m',SF} e^{2\beta_{m',SF}h_{m'}} \right) \frac{e^{i(\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir})h_m} - 1}{\beta_{m,SF} - \beta_{m,vis} - \beta_{m,ir}} ] \} \end{split}$$

(upper sign for x and y components, lower sign for z component)

よって、

$$\begin{split} E^{+}_{2,p}\left(h_{m}^{-}+h_{m}^{+}\right) &= \sum_{\alpha\beta} E^{0}_{vi\alpha}E^{0}_{ir}\vartheta e^{i(\beta_{m,\alpha}+\beta_{m,p})h_{m}} e^{i\beta_{m,\alpha}s_{m}h_{m}} \left(1+r_{1m',SEp}r_{m'mSEp}e^{2i\beta_{m,2r}h_{m}}\right) \\ &\times \frac{t_{1m',si\alpha}t_{m'm,vis\alpha}}{1+r_{1m',si\alpha}r_{m'm,vis\alpha}} e^{2i\beta_{m,m}h_{m}} + (r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2i\beta_{m,m}h_{m}})r_{m2,vis\alpha}e^{2i\beta_{m,m}h_{m}} \\ &\times \frac{t_{1m',pi}t_{m'm,pi}t_{m'm,pi}}{1+r_{1m',pi}t_{m'm,pi}} e^{2i\beta_{m,m}h_{m}} + (r_{m'm,pi}t_{m'm,pi}t_{m'm,pi}t_{m'm,pi})r_{m2,pi}t_{m'm}} e^{2i\beta_{m,m}h_{m}} \\ &\times \left\{ \left\{ \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(-\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} - \beta_{m,pi}} + (r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(-\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} + \beta_{m,pi}} \right] \right\} \\ &+ r_{m2,pi,p} e^{2i\beta_{m,p}h_{m}} \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(-\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} + \beta_{m,pi} + \beta_{m,pi}} \right] \\ &+ r_{m2,pi,p} e^{2i\beta_{m,p}h_{m}} \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(-\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} \right] \\ &+ r_{m2,pi,p} e^{2i\beta_{m,p}h_{m}} \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(-\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} - \beta_{m,pi,s} + \beta_{m,pi}} \right] \\ &+ r_{m2,pi,p} e^{2i\beta_{m,p}h_{m}} \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(-\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} - \beta_{m,pi,s} + \beta_{m,pi}} \right] \\ &+ r_{m2,pi,p} e^{2i(\beta_{m,p}+\beta_{m,p})h_{m}} \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} - \beta_{m,pi}} \right] \right\} L^{t}_{m/2,p,p} \chi_{xxx} \\ &+ \left\{ \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} - \beta_{m,pi}} \right] \right\} L^{t}_{m/2,p,p} \chi_{xxx} \\ &+ r_{m2,pi,p} e^{2i\beta_{m,p}h_{m}} \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(\beta_{m,S}+\beta_{m,m}+\beta_{m,p})h_{m}} - 1}{\beta_{m,SF}} - \beta_{m,pi}} \right\} \\ &+ r_{m2,pi,p} e^{2i\beta_{m,ph}h_{m}} \left[ (1+r_{1m',SE,p}r_{m'm,SE,p}e^{2i\beta_{m,m}h_{m}}) \frac{e^{i(\beta_{m,S}+\beta_{m,m}+\beta_{m,ph})h_{m}} - 1}{\beta_{m,SF}} + \beta_{m,pi}} \right\} \\ &+ r_{m2,pi,p} e^{2i\beta_{$$

$$-(r_{m'mSF,p} + r_{lm'SF,p}e^{2\beta_{m'SF}h_{m'}})\frac{e^{i(\beta_{m,m'}-\beta_{m,m'}+\beta_{m,m'})h_{m}}}{\beta_{mSF}} - \beta_{m'si} + \beta_{m'si}}]$$

$$+r_{m2sixt}r_{m2ir,\beta}e^{2i(\beta_{m'm}+\beta_{mr})h_{m}}[(1 + r_{lm'SF,p}r_{m'mSF,p}e^{2\beta_{m'SF}h_{m'}})\frac{e^{i(\beta_{m,m'}-\beta_{m,m'}-\beta_{m,m'}-\beta_{m,m'})h_{m}}}{\beta_{mSF}} - \beta_{m'si} + \beta_{m'si}} - (r_{m'mSF,p} + r_{lm'SF,p}e^{2\beta_{m'SF}h_{m'}})\frac{e^{i(\beta_{m,m'}-\beta_{m,m'}-\beta_{m,m'})h_{m'}}}{\beta_{mSF}} - \beta_{m'si}}] L^{1}_{m2s_{l}} \chi_{33\beta} \} (n_{m'} - n_{m})$$

$$= \sum_{\alpha\beta} E^{0}_{vis} \alpha E^{0}_{ir} \beta e^{i(\beta_{w',m'}+\beta_{m'})h_{m'}} e^{\beta_{m,sr}h_{m'}} (1 + r_{lm'SF,s}r_{m'mSF,s}e^{2i\beta_{m',sr}h_{m'}})$$

$$\times \frac{1_{lm'six_{l}} r_{lm'm'six_{l}}}{1 + r_{lm'six_{l}} r_{lm'm'six_{l}}} e^{2i\beta_{m',m'}h_{m'}} + (r_{m'm'six_{l}} + r_{lm'six_{l}} e^{2i\beta_{m',m}h_{m'}})r_{m2sis_{l}} e^{2i\beta_{m',m}h_{m'}}$$

$$\times \frac{1_{lm'si} r_{l}}{1 + r_{lm'sir} \beta} r_{m'm'si} e^{2i\beta_{m',m}h_{m'}} + (r_{m'm'six_{l}} + r_{lm'six_{l}} e^{2i\beta_{m',m}h_{m'}})r_{m2sis_{l}} e^{2i\beta_{m',m}h_{m}}$$

$$\times \{ [(1 + r_{lm'SF,s} r_{m'mSF,s} e^{2i\beta_{m',m}h_{m'}} + (r_{m'm'sis_{l}} + r_{lm'si} \beta^{2\beta_{m',m}h_{m'}}) - \frac{1}{\beta_{mSF}} \beta_{m'si}} + (r_{m'm'sis_{l}} + r_{lm'sis_{l}} \beta^{2\beta_{m',m}h_{m'}})r_{m-1} + (r_{m'm'si_{l}} \beta^{2\beta_{m',m}h_{m'}}) e^{2i\beta_{m',m}h_{m'}} - \frac{1}{\beta_{mSF}} \beta_{m'si} + \beta_{m'si}} + (r_{m'm'si_{l}} \beta^{2\beta_{m',m}h_{m'}}) e^{2i\beta_{m',m}h_{m'}} - \frac{1}{\beta_{mSF}} \beta_{m'si_{l}}} + (r_{m'm'si_{l}} \beta^{2\beta_{m',m}h_{m'}}) e^{2i\beta_{m',m'}h_{m'}} - \frac{1}{\beta_{mSF}} \beta_{m'si_{l}}} + (r_{m'm'si_{l}} \beta^{2\beta_{m',m}h_{m'}}) e^{2i\beta_{m',m'}h_{m'}} - \frac{1}{\beta_{mSF}} \beta_{m'si_{l}}} + r_{m'si_{l}} \beta_{m'si_{l}} \beta_{m'si_{l}}} + \beta_{m'si_{l}} \beta_{m'si_{l}}} + r_{m'si_{l}} \beta_{m'si_{l}} \beta_{m'si_{l}}} + r_{m'si_{l}} \beta_{m'si_{l}} \beta_{m'si_{l}}} + \beta_{m'si_{l}} \beta_{m'si_{l}}} + r_{m'si_{l}} \beta_{m'si_{l}}} \beta_{m'si_{l}} \beta_{m'si_{l}} + \beta_{m'si_{l}} \beta_{m'si_{l}} \beta_{m'si_{l}} \beta_{m'si_{l}}} + r_{m'si_{l}} \beta_{m'si_{l}} \beta_{m'si_{l}} \beta_{m'si_{l}}} + \beta_{m'si_{l}} \beta_{m'$$

### 3. 三層系 (1/m'/m/m''/2) からの SFG

始めに記したように、この系からの SFG 電場を求めるためにはテンソルの等比級数の和が必要になる。 よって、最後の表式に至る作業は現在の私の力では不可能である。しかし、分極までは求めることが出来る ので、それを記しておく。

但し、3つの層のうちのどれかがその厚みを無視できる場合には、2節で求めた結果に対して(1)分極の表 式を下で示すものと置き換え、(2) その層の外側界面が関係する反射係数と透過係数を下のように置き換え ることによって、必要な表式が得られる。

2 つの層 m/m'の間に厚みが無視できる m' 層が挟まって m/m''/m' 系になっているときには、下の置 き換えをする。

(2.46b)

$$\begin{split} r_{mm'} &\Rightarrow \frac{r_{mm''} + r_{m'm'}}{1 + r_{m'm'} r_{m'm}} \,, \quad t_{mm'} \Rightarrow \frac{t_{mm''} t_{m'm'}}{1 + r_{m'm''} r_{m'm}} \\ r_{m'm} &\Rightarrow \frac{r_{m'm''} + r_{m'm}}{1 + r_{m'm''} r_{m'm}} \,, \quad t_{m'm} \Rightarrow \frac{t_{m'm''} t_{m''m}}{1 + r_{m'm''} r_{m''m}} \end{split}$$

#### 3.1. 電場振幅の積

### 1/m' 界面の 1 側:

 $E^+$  (by reflection and transmission) and  $E^-$  (for n = 0) sources

$$E_{vis\alpha}(0^{-})E_{ir\beta}(0^{-}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\{(1 + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})[(1 + r_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}})$$

$$\times \frac{+(r_{m'm,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}]\}}{\{(1 + r_{1m',vis\alpha}r_{m'',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})$$

$$+(r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}})\}}$$

$$\{(1 + r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}})[(1 + r_{m'',ir\beta}e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})$$

$$\times \frac{+(r_{m'm,ir\beta} + e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}})}{\{(1 + r_{1m',ir\beta}r_{m'',ir\beta}e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})$$

$$+(r_{m'',ir\beta} + r_{m'',ir\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}})$$

$$+(r_{m'',ir\beta} + r_{m'',ir\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta} + r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}})$$

$$\times \exp[i2n(h_{m} \tan\theta_{mSF} + h_{m'} \tan\theta_{m',SF} + h_{m'} \tan\theta_{m',SF})(-k_{m,ir} \sin\theta_{m,ir} - k_{m,v,is} \sin\theta_{m,vis})]$$
(3.1)

### 1/m' 界面の m' 側:

 $E^{+}$  and  $E^{-}$  (by reflection and transmission) sources

$$\begin{split} E_{vis\alpha}\left(0^{+}\right) & E_{ir\,\beta}\left(0^{+}\right) = E^{0}_{vis\alpha}E^{0}_{ir\,\beta} \\ & \left\{t_{1m',vis\alpha}\left[(1 + r_{m'm,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}}) \right. \\ & \times \frac{+(r_{m'm,vis\alpha}}{\{(1 + r_{1m',vis\alpha}e^{2i\beta_{m',vi}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m'}}]\}}{\{(1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m'}}\}} \\ & + (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vi}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m'}}\}} \\ & \{t_{1m',ir,\beta}\left[(1 + r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta}r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,vi}h_{m'}})\right. \\ & \times \frac{+(r_{m'm,ir,\beta} + e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,vi}h_{m'}})}{\{(1 + r_{1m',ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta}r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,vi}h_{m'}})e^{2i\beta_{m,vi}h_{m'}}\}} \\ & \times \exp[i2n(h_{m}\tan\theta_{mSF} + h_{m'}\tan\theta_{m'SF} + h_{m'}\tan\theta_{m''SF}})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{mvis}})] \end{cases} \tag{3.2}$$

### m''/2 界面の 2 側:

$$E_{vis\alpha}(h_{m'} + h_m + h_{m''}^+)E_{ir\beta}(h_{m'} + h_m + h_{m''}^+) = E^0_{vis\alpha}E^0_{ir\beta}$$

$$\times \frac{t_{1m',vis}\alpha t_{m'm,vis}\alpha t_{m''',vis}\alpha t_{m'''',vis}\alpha t_{m''''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vis}\alpha t_{m''''',vis}\alpha t_{m'''',vis}\alpha t_{m''',vis}\alpha t_{m'''',vis}\alpha t_{m'''',vi$$

# m''/2 界面の m'' 側:

 $E^+$  (by reflection and transmission) and  $E^-$  sources

$$E_{vis\alpha}(h_{m^{i}} + h_{m} + h_{m^{*}}^{-})E_{ir\beta}(h_{m^{i}} + h_{m} + h_{m^{*}}^{-}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m^{i},vis\alpha}t_{m^{i}m,vis\alpha}}{\{(1 + r_{1m^{i},vis\alpha}r_{m^{i}m,vis\alpha}(1 + r_{m^{*2},vis\alpha})e^{i(\beta_{m^{i},vis}h_{m^{*}} + \beta_{m^{i},vis}h_{m^{*}})}} \frac{1}{\{(1 + r_{1m^{i},vis\alpha}r_{m^{i}m,vis\alpha}e^{2^{2\beta_{m^{i},vis}h_{m^{*}}}})(1 + r_{mm^{*2},vis\alpha}e^{2^{2\beta_{m^{i},vis}h_{m^{*}}}})} + (r_{m^{i}m,vis\alpha} + r_{1m^{i},vis\alpha}e^{2^{2\beta_{m^{i},vis}h_{m^{*}}}})(r_{mn^{i},vis\alpha} + r_{m^{*2},vis\alpha}e^{2^{2\beta_{m^{i},vis}h_{m^{*}}}})e^{2i\beta_{m^{i},vis}h_{m^{*}}}}\}$$

$$\times \frac{t_{1m^{i},ir\beta}t_{m^{i}m,ir\beta}}t_{mm^{i},ir\beta}(1 + r_{m^{*2},ir\beta})e^{i(\beta_{m^{i},ir}h_{m^{*}} + \beta_{m^{i},ir}h_{m^{*}}})e^{2i\beta_{m^{i},vi}h_{m^{*}}}}}{\{(1 + r_{1m^{i},ir\beta}t_{m^{*},ir\beta}e^{2i\beta_{m^{i},ir}h_{m^{*}}}})(1 + r_{m^{*2},ir\beta}t_{m^{*2},ir\beta}e^{2i\beta_{m^{i},ir}h_{m^{*}}})} + (r_{m^{i},ir\beta}t_{m^{*2},ir\beta}e^{2i\beta_{m^{i},ir}h_{m^{*2}}}})(r_{mm^{*i},ir\beta}t_{m^{*2},ir\beta}e^{2i\beta_{m^{*i},ir}h_{m^{*2}}})e^{2i\beta_{m^{*i},ir}h_{m^{*2}}}})$$

$$\times \exp[i(2n+1)(h_{m}\tan\theta_{m,SF} + h_{m^{*1}}\tan\theta_{m^{*},SF} + h_{m^{*1}}\tan\theta_{m^{*1},SF}})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})]$$

$$(3.4)$$

### m'/m 界面の m' 側:

$$\begin{split} E_{vis\alpha}\left(h_{mi}^{-}\right) E_{ir\,\beta}\left(h_{m'}^{-}\right) &= E^{0}_{vis\alpha}E^{0}_{ir\,\beta} \\ & \qquad \qquad \left\{t_{1m',vis\,\alpha}e^{\beta_{m',vis}h_{m'}}\left(1 + r_{m'm,vis\alpha}\right)\left[\left(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m''}}\right)\right. \\ & \qquad \qquad \times \frac{\left\{t_{1m',vis\,\alpha} + r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}\right\}e^{2i\beta_{m,vis}h_{m}}\left\}\right\}}{\left\{\left(1 + r_{1m',vis\,\alpha}r_{m'm,vis\,\alpha}e^{2\beta_{m',vis}h_{m'}}\right)\left(1 + r_{mm'',vis\,\alpha}r_{m''2,vis\,\alpha}e^{2\beta_{m',vis}h_{m'}}\right)\right. \\ & \qquad \qquad + \left(r_{m'm,vis\,\alpha}r_{m'm,vis\,\alpha}e^{2\beta_{m',vis}h_{m'}}\right)\left(r_{mm'',vis\,\alpha} + r_{m''2,vis\,\alpha}e^{2\beta_{m',vis}h_{m'}}\right)e^{2i\beta_{m,vis}h_{m}}\right\}}\\ & \qquad \qquad \qquad \left\{t_{1m',ir\,\beta}e^{i\beta_{m',ir}h_{m'}}\left(1 + r_{m'm,ir\,\beta}\right)\left[\left(1 + r_{mm'',ir\,\beta}r_{m''2,ir\,\beta}e^{2i\beta_{m',ir}h_{m'}}\right)e^{2i\beta_{m,vis}h_{m}}\right)\right. \\ & \qquad \qquad \times \frac{+\left(r_{m'm,ir\,\beta} + e^{2i\beta_{m',ir}h_{m'}}\right)\left(r_{mm'',ir\,\beta} + r_{m''2,ir\,\beta}e^{2\beta_{m',vis}h_{m'}}\right)e^{2i\beta_{m,vis}h_{m}}\right)}{\left\{\left(1 + r_{1m',ir\,\beta}r_{m'm,ir\,\beta}e^{2i\beta_{m',ir}h_{m'}}\right)\left(1 + r_{mm'',ir\,\beta}r_{m''2,ir\,\beta}e^{2i\beta_{m',vis}h_{m'}}\right)e^{2i\beta_{m,vis}h_{m}}\right\}}\\ & \qquad \qquad \times \exp\left[i\left(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF}\right)\left(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}\right)\right]\\ & \qquad \times \exp\left[i\left(2n+1\right)\left(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF} + h_{m'}\tan\theta_{m',SF}\right)\left(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}\right)\right]} \end{aligned}$$

$$E_{vis\alpha}(h_{m'}^{-})E_{ir\beta}(h_{m'}^{-}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\{t_{1m',vis\alpha}e^{\beta_{m',vis}h_{m'}}(1 + r_{m'm,vis\alpha})[(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})$$

$$\times \frac{+(r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}]\}$$

$$\{(1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})$$

$$+(r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}\}$$

$$\{t_{1m',ir\beta}e^{i\beta_{m;i}h_{m'}}(1 + r_{m'mijr\beta})[(1 + r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}})$$

$$\times \frac{+(r_{m'm,ir\beta} + e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta} + r_{m''2,ir\beta}e^{2\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}})}{\{(1 + r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}})}$$

$$+(r_{m'm,ir\beta} + r_{1m',ir\beta}e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',ir\beta} + r_{m''2,ir\beta}e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m}}})$$

$$\times \exp[ih_{m'} \tan\theta_{m',SF}(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})]$$

$$\times \exp[i2n(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF} + h_{m''}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})]$$
(3.6)

#### m'/m 界面の m 側:

### $E^{+}$ and $E^{-}$ (by reflection and transmission) sources

$$\begin{split} &E_{vis\alpha}(h_{m}^{+})E_{ir\beta}(h_{m}^{+}) = E^{0}_{vis\alpha}E^{0}_{ir\beta} \\ &\times \frac{t_{lm',vis\alpha}t_{m'm,vis\alpha}}{t_{lm'm,vis\alpha}} \frac{t_{m'm,vis\alpha}t_{m'',vis\alpha}}{t_{lm',vis\alpha}} \frac{e^{2i\beta_{m',vis}h_{m'}}}{(1+r_{lm',vis\alpha}r_{m'm,vis\alpha}} e^{2i\beta_{m',vis}h_{m'}}) + (r_{lm'',vis\alpha}t_{m'',vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m'}}} \\ &+ (l_{lm',vis\alpha}t_{m'm,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) (l_{lm'',vis\alpha}t_{lm'',vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m'}}} \\ &+ (r_{lm'm,vis\alpha}t_{lm',vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) (r_{lm'',vis\alpha}t_{lm'',vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m'}}} \\ &\times \frac{t_{lm',ir\beta}t_{lm',ir\beta}e^{i\beta_{m',ir}h_{m'}}} [(l_{lm',ir\beta}t_{lm'',ir\beta}e^{2i\beta_{m',ir}h_{m'}}}) + (r_{lm'',ir\beta}t_{lm'',vis\alpha}e^{2i\beta_{m',vis}h_{m'}}}) e^{2i\beta_{m,vis}h_{m'}}} \\ &\times \frac{t_{lm',ir\beta}t_{lm',ir\beta}e^{i\beta_{m',ir}h_{m'}}} [(l_{lm',ir\beta}t_{lm'',ir\beta}e^{2i\beta_{m',ir}h_{m'}}}) + (r_{lm'',ir\beta}t_{lm'',ir\beta}e^{2i\beta_{m',ir}h_{m'}}}) e^{2i\beta_{m,vis}h_{m'}}} \\ &+ (r_{lm',ir\beta}t_{lm',ir\beta}e^{2i\beta_{m',ir}h_{m'}}}) (r_{lm'',ir\beta}t_{lm'',ir\beta}e^{2i\beta_{m',ir}h_{m'}}}) e^{2i\beta_{m,vis}h_{m'}}} \\ &\times \exp[i(l_{lm}tan\theta_{m,SF}+h_{m'}tan\theta_{m',SF}}) (-k_{lm,ir}sin\theta_{m,ir}-k_{lm,vis}sin\theta_{m,vis}})] \\ &\times \exp[i(2n+1)(l_{lm}tan\theta_{m,SF}+h_{m'}tan\theta_{m',SF}+h_{m'}tan\theta_{m',SF}}) (-k_{lm,ir}sin\theta_{m,ir}-k_{lm,vis}sin\theta_{m,vis}})] \\ \end{aligned}$$

$$\begin{split} E_{vis\alpha}\left(h_{m'}^{\ +}\right) E_{ir,\beta}\left(h_{m'}^{\ +}\right) &= E^{0}_{vis\alpha}E^{0}_{ir,\beta} \\ &\times \frac{t_{1m',vis\alpha}}{t_{m',vis\alpha}} t_{m'm,vis\alpha} e^{\beta_{m',vis}h_{m'}} \left[ (1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) + (r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}})e^{2\beta_{m,vis}h_{m}} \right] \\ &\times \frac{t_{1m',vis\alpha}}{t_{1m',vis\alpha}} t_{m'm,vis\alpha} e^{\beta_{m',vis}h_{m'}} \left[ (1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}}) + (r_{mm'',vis\alpha}e^{2\beta_{m',vis}h_{m'}})e^{2\beta_{m,vis}h_{m'}} \right] \\ &+ (r_{m'm,vis\alpha} + r_{m',vis\alpha}e^{2\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m'',vis\alpha}e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m}} \right\} \end{split}$$

$$\times \frac{t_{1m',ir,\beta} t_{m',njr,\beta} e^{i\beta_{m',ir}h_{m'}} [(1 + r_{mm',ir,\beta} r_{m',2,ir,\beta} e^{2\beta_{m',ir}h_{m'}}) + (r_{mm',ir,\beta} + r_{m',2,ir,\beta} e^{2\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}}]}{\{(1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta} r_{m',2,ir,\beta} e^{2\beta_{m',ir}h_{m'}})} + (r_{m',mir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m'',2,ir,\beta} e^{2\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}}}\}$$

$$\times \exp[ih_{m'} \tan\theta_{m',SF} (-k_{m,ir} \sin\theta_{m,ir} - k_{m,vis} \sin\theta_{m,vis})]$$

$$\times \exp[i2n(h_{m} \tan\theta_{m,SF} + h_{m'} \tan\theta_{m',SF} + h_{m''} \tan\theta_{m',SF})(-k_{m,ir} \sin\theta_{m,ir} - k_{m,vis} \sin\theta_{m,vis})]$$
(3.8)

# m/m" 界面の m 側:

 $E^{+}$  and  $E^{-}$  (by reflection and transmission) sources

$$\begin{split} E_{vis\alpha}\left(h_{m} + h_{m}^{-}\right) E_{ir,\beta}\left(h_{m} + h_{m}^{-}\right) &= E^{0}_{vis\alpha} E^{0}_{ir,\beta} \\ &\times \frac{t_{1m,vis\alpha}}{\{(1 + r_{1m',vis\alpha}} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha})(1 + r_{m''',2,vis\alpha}} e^{2i\beta_{m',vis}h_{m'}})}{\{(1 + r_{1m',vis\alpha}} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha}} r_{m''',2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})} \\ &+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha}} e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha}} + r_{m'',2,vis\alpha}} e^{2i\beta_{m',vis}h_{m'}}}) e^{2i\beta_{m,vis}h_{m'}}} \} \\ &\times \frac{t_{1m',ir,\beta}}{\{(1 + r_{1m',ir,\beta}} t_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta}} r_{m'',2,ir,\beta}} e^{2i\beta_{m',vis}h_{m'}}})}{\{(1 + r_{1m',ir,\beta}} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}})(1 + r_{mm'',ir,\beta}} r_{m'',2,ir,\beta}} e^{2i\beta_{m',vis}h_{m'}}}) \\ &+ (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}})(r_{mm'',ir,\beta} + r_{m'',2,ir,\beta}} e^{2i\beta_{m',vis}h_{m'}}}) e^{2i\beta_{m,vis}h_{m}}} \} \\ &\times \exp[ih_{m''} \tan\theta_{m'',SF}(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})] \\ &\times \exp[il(2n+1)(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF} + h_{m''}\tan\theta_{m'',SF}})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})] \end{cases} \end{split}$$

### $E^+$ (by reflection and transmission) and $E^-$ sources

$$\begin{split} E_{vis\alpha} \left( h_{m} + h_{m}^{-} \right) E_{ir\beta} \left( h_{m} + h_{m}^{-} \right) &= E^{0}_{vis\alpha} E^{0}_{ir\beta} \\ &\times \frac{t_{1m',vis\alpha}}{\{ (1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha})(1 + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})}{\{ (1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})} \\ &+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m'}} \} \\ &\times \frac{t_{1m',ir\beta} t_{m'mir\beta} e^{i(\beta_{m',ij}h_{m'} + \beta_{m,ir}h_{m'})}(1 + r_{mm'',ir\beta})(1 + r_{m''2,ir\beta} e^{2i\beta_{m',vis}h_{m'}})}{\{ (1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir\beta} r_{m''2,ir\beta} e^{2i\beta_{m',vis}h_{m'}})} \\ &+ (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta} + r_{m''2,ir\beta} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}} \} \\ &\times \exp[i (h_{m} \tan\theta_{m,SF} + h_{m'} \tan\theta_{m',SF})(-k_{m,ir} \sin\theta_{m,ir} - k_{m,vis} \sin\theta_{m,vis}})] \\ &\times \exp[i 2n(h_{m} \tan\theta_{m,SF} + h_{m'} \tan\theta_{m',SF})(-k_{m,ir} \tan\theta_{m',SF})(-k_{m,ir} \sin\theta_{m,ir} - k_{m,vis} \sin\theta_{m,vis}})] \end{cases}$$

# m/m" 界面の m" 側:

$$E_{vis\alpha}(h_m + h_{m'}^{+})E_{ir\beta}(h_m + h_{m'}^{+}) = E^0_{vis\alpha}E^0_{ir\beta}$$

$$\times \frac{t_{1\,m',vis\,\alpha}\,t_{\,m'm,vis\,\alpha}\,t_{\,m'm',vis\,\alpha}\,e^{\,i(\beta_{\,m,vis}\,h_{\,m'}+\beta_{\,m',vis}\,h_{\,m'})}(1+r_{\,m''\,2,vis\,\alpha}\,e^{\,2\beta_{\,m',vis}\,h_{\,m'}})}{\{(1+r_{1m',vis\,\alpha}\,r_{\,m'm,vis\,\alpha}\,e^{\,2\beta_{\,m',vis}\,h_{\,m'}})(1+r_{\,mm'',vis\,\alpha}\,r_{\,m''\,2,vis\,\alpha}\,e^{\,2\beta_{\,m',vis}\,h_{\,m'}})}\\ + (r_{m'm,vis\,\alpha}+r_{1\,m',vis\,\alpha}\,e^{\,2\beta_{\,m',vis}\,h_{\,m'}})(r_{\,mm'',vis\,\alpha}+r_{\,m''\,2,vis\,\alpha}\,e^{\,2\beta_{\,m',vis}\,h_{\,m'}})e^{\,2i\beta_{\,m,vis}\,h_{\,m'}}}\}$$

$$\times \frac{t_{1\,m',ir\,\beta}\,t_{\,m'm,ir\,\beta}\,t_{\,m'm',ir\,\beta}\,e^{\,i(\beta_{\,m',vi}\,h_{\,m'}+\beta_{\,m,ir}\,h_{\,m})}(1+r_{\,m''\,2,ir\,\beta}\,e^{\,2i\beta_{\,m',vi}\,h_{\,m'}})}{\{(1+r_{1m',ir\,\beta}\,t_{\,m'',ir\,\beta}\,e^{\,2i\beta_{\,m',vi}\,h_{\,m'}})(1+r_{\,mm'',ir\,\beta}\,e^{\,2i\beta_{\,m',vi}\,h_{\,m'}})}\\ + (r_{m'm,ir\,\beta}+r_{1m',ir\,\beta}\,e^{\,2i\beta_{\,m',vi}\,h_{\,m'}})(r_{\,mm'',ir\,\beta}+r_{\,m''\,2,ir\,\beta}\,e^{\,2i\beta_{\,m',vi}\,h_{\,m'}})}$$

$$\times \exp[ih_{\,m'}\,\tan\theta_{\,m',SF}(-k_{\,m,ir}\,\sin\theta_{\,m,ir}-k_{\,m,vis}\,\sin\theta_{\,m,vis}})]$$

$$\times \exp[i(2n+1)(h_{\,m}\,\tan\theta_{\,m,SF}+h_{\,m'}\,\tan\theta_{\,m',SF}+h_{\,m'}\,\tan\theta_{\,m',SF})(-k_{\,m,ir}\,\sin\theta_{\,m,ir}-k_{\,m,vis}\,\sin\theta_{\,m,vis}})]$$

$$(3.11)$$

$$E_{vis\alpha}(h_{m} + h_{m}^{+})E_{ir\beta}(h_{m} + h_{m}^{+}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}t_{m'm,vis\alpha}t_{m'm,vis\alpha}t_{mm'',vis\alpha}e^{2^{1}\beta_{m',vis}h_{m'}}(1 + r_{m''2,vis\alpha}e^{2^{2}\beta_{m',vis}h_{m'}})}{\{(1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2^{2}\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2^{2}\beta_{m',vis}h_{m'}})}$$

$$+(r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2^{2}\beta_{m',vis}h_{m'}})(r_{mn'',vis\alpha} + r_{m''2,vis\alpha}e^{2^{2}\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}}\}$$

$$\times \frac{t_{1m',ir\beta}t_{m'm,ir\beta}t_{mm',ir\beta}e^{2^{2}\beta_{m',ir}h_{m'}})(r_{mn'',vis\alpha} + r_{m''2,vis\alpha}e^{2^{2}\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}}}{\{(1 + r_{1m',ir\beta}t_{m'',ir\beta}e^{2^{2}\beta_{m',ir}h_{m'}})(1 + r_{m''2,ir\beta}e^{2^{2}\beta_{m',vis}h_{m'}})}$$

$$+(r_{m'm,ir\beta}t_{m'',ir\beta}e^{2^{2}\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta}t_{m''2,ir\beta}e^{2^{2}\beta_{m',ir}h_{m'}})e^{2^{2}\beta_{m',ir}h_{m'}}})$$

$$+(r_{m'm,ir\beta}t_{m',ir\beta}e^{2^{2}\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta}t_{m''2,ir\beta}e^{2^{2}\beta_{m',ir}h_{m'}})e^{2^{2}\beta_{m,ir}h_{m}}})$$

$$\times \exp[i(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})]$$

$$\times \exp[i(2n(h_{m}\tan\theta_{m,SF} + h_{m'}\tan\theta_{m',SF})(-k_{m,ir}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir} - k_{m,vis}\sin\theta_{m,vis}})]$$
(3.12)

# m'層の深さ z1点:

$$\begin{split} E_{vis\alpha}\left(z_{1}\right)E_{ir\beta}\left(z_{1}\right) &= E^{0}_{vis\alpha}E^{0}_{ir\beta} \\ &\times \frac{t_{1m',vis\alpha}}{\{(1+r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2\beta_{m',vis}h_{m'}})(1+r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})} \\ &+ (r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha}+r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m}}\} \\ &\times \frac{t_{1m',ir\beta}}{\{(1+r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}})(1+r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,vis}h_{m}}\}} \\ &\times \{(1+r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta}+r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,vis}h_{m}}\} \\ &\times \{[(1+r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',vis}h_{m'}})+r_{m'm,vis\alpha}\left(r_{mm'',vis\alpha}+r_{m''2,vis\alpha}e^{2\beta_{m'vis}h_{m'}}\right)e^{2i\beta_{mvis}h_{m}}\} \\ &\times \exp[iz_{1}\left(k_{m',vis}\cos\theta_{m',vis}\left(1+\tan\theta_{m',SF}\tan\theta_{m',vis}\right)\right] \\ &+ [r_{m'm,vis\alpha}\left(1+r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2\beta_{m'vis}h_{m'}}\right)+(r_{mm'',vis\alpha}+r_{m''2,vis\alpha}e^{2\beta_{m'vis}h_{m'}})e^{2i\beta_{mvis}h_{m}}] \\ &\times \exp[iz_{1}\left(k_{m',vis}\cos\theta_{m',vis}\left(-1+\tan\theta_{m',SF}\tan\theta_{m,vis}\right)\right]\} \\ &\times \{[(1+r_{mm'',ir\beta}r_{m'',2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})+r_{m',m,ir\beta}\left(r_{mm'',ir\beta}+r_{m''2,ir\beta}e^{2\beta_{m',ir}h_{m'}}\right)e^{2i\beta_{m,ir}h_{m}}\right] \\ &\times \{[(1+r_{mm'',ir\beta}r_{m'',2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})+r_{m',m,ir\beta}\left(r_{mm'',ir\beta}+r_{m'',2,ir\beta}e^{2\beta_{m',ir}h_{m'}}\right)e^{2i\beta_{m,ir}h_{m}}\right] \\ &\times \{[(1+r_{mm'',ir\beta}r_{m'',ir\beta}e^{2i\beta_{m',ir}h_{m'}})+r_{m',m,ir\beta}\left(r_{mm'',ir\beta}+r_{m'',2,ir\beta}e^{2\beta_{m',ir}h_{m'}}\right)e^{2i\beta_{m,ir}h_{m}}\right] \\ &\times \{[(1+r_{mm'',ir\beta}r_{m'',ir\beta}e^{2\beta_{m',ir}h_{m'}})+r_{m',ir\beta}\left(r_{mm'',ir\beta}+r_{m'',2,ir\beta}e^{2\beta_{m',ir}h_{m'}}\right)e^{2i\beta_{m,ir}h_{m}}\right] \\ &\times \{[(1+r_{mm'',ir\beta}r_{m'',ir\beta}e^{2\beta_{m',ir}h_{m'}})+r_{m',ir\beta}\left(r_{mm'',ir\beta}+r_{m'',2,ir\beta}e^{2\beta_{m',ir}h_{m'}}\right)e^{2i\beta_{m,ir}h_{m}}\right] \\ &\times \{[(1+r_{mm'',ir\beta}r_{m'',ir\beta}e^{2\beta_{m',ir}h_{m'}})+r_{m',ir\beta}\left(r_{mm'',ir\beta}+r_{m'',ir\beta}e^{2\beta_{m',ir}h_{m'}}\right)e^{2\beta_{m,ir}h_{m}}\right] \\ &\times \{[(1+r_{mm'',ir\beta}r_{m'',ir\beta}e^{2\beta_{m',ir}h_{m'}})+r_{m',ir\beta}\left(r_{mm'',ir\beta}+r_{m'',ir\beta}e^{2\beta_{m',ir}h_{m'}}\right)e^{2\beta_{m,ir}h_{m'}}\right] \\ &\times \{[(1+r_{mm'',ir\beta}r_{m',ir\beta}e^{2\beta_{m',ir}h_{m'}})+r_{m',ir\beta}r_{m',ir\beta}e^{2\beta_{m',i$$

$$\times \exp[iz_{1}(k_{m',ir}\cos\theta_{m',ir}(1+\tan\theta_{m',SF}\tan\theta_{m,ir})]$$

$$+[r_{m'm,ir,\beta}(1+r_{mm',ir,\beta}r_{m',2,ir,\beta}e^{2i\beta_{m',i}h_{m'}}) + (r_{mm'',ir,\beta}+r_{m'',2,ir,\beta}e^{2i\beta_{m',i}h_{m'}})e^{2i\beta_{mir}h_{m}}]$$

$$\times \exp[iz_{1}(k_{m',ir}\cos\theta_{m',ir}(-1+\tan\theta_{m',SF}\tan\theta_{m,ir})]\}$$

$$\times \exp[i(2n+2)(h_{m}\tan\theta_{m,SF}+h_{m'}\tan\theta_{m',SF}+h_{m''}\tan\theta_{m',SF})(-k_{m,ir}\sin\theta_{m,ir}-k_{m,v,is}\sin\theta_{m,v,is})]$$

$$(3.13)$$

$$\begin{split} E_{vis\alpha}\left(z_{1}\right) & E_{ir\,\beta}\left(z_{1}\right) = E^{0}_{vis\alpha}E^{0}_{ir\,\beta} \\ & \times \frac{t_{1m',vis\alpha}}{\{(1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2\beta_{m',vi}h_{m'}})(1 + r_{mm',vis\alpha}r_{m'2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})}{+(r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2\beta_{m',vi}h_{m'}})(r_{mm',vis\alpha} + r_{m'2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m'}}\}} \\ & \times \frac{t_{1m',ir\,\beta}}{\{(1 + r_{1m',ir\,\beta}r_{m'm,ir\,\beta}e^{2i\beta_{m',ih}h_{m'}})(1 + r_{mm',ir\,\beta}r_{m'2,ir\,\beta}e^{2i\beta_{m',v}h_{m'}})}{+(r_{m'm,ir\,\beta} + r_{1m',ir\,\beta}e^{2i\beta_{m',ih}h_{m'}})(r_{mm',ir\,\beta} + r_{m'2,ir\,\beta}e^{2i\beta_{m',v}h_{m'}})e^{2i\beta_{m,v}h_{m'}})} \\ & \times \{[(1 + r_{mm',vis\alpha}r_{m'2,vis\alpha}e^{2i\beta_{m',ih}h_{m'}}) + r_{m'm,vis\alpha}\left(r_{mm',vis\alpha} + r_{m'2,vis\alpha}e^{2\beta_{m',vi}h_{m'}}\right)e^{2i\beta_{m,v}h_{m}}\} \\ & \times \{[(1 + r_{mm',vis\alpha}r_{m'2,vis\alpha}e^{2i\beta_{m',ih}h_{m'}}) + r_{m'm,vis\alpha}\left(r_{mm',vis\alpha} + r_{m'2,vis\alpha}e^{2\beta_{m',vi}h_{m'}}\right)e^{2i\beta_{m,vi}h_{m}}] \\ & \times \exp[iz_{1}\left(k_{m',vis}\cos\theta_{m',vis}\left(1 - \tan\theta_{m',SF}\tan\theta_{m',vis}\right)\right] \\ & + [r_{m'm,vis\alpha}\left(1 + r_{mm',vis\alpha}r_{m'2,vis\alpha}e^{2\beta_{m',vi}h_{m'}}\right) + (r_{mm',vis\alpha} + r_{m'2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m}}] \\ & \times \exp[iz_{1}\left(k_{m',vis}\cos\theta_{m',vis}\left(1 - \tan\theta_{m',SF}\tan\theta_{m,vis}\right)\right] \\ & \times \left\{[(1 + r_{mm',vis}r_{1}r_{2}r_{2}r_{2}r_{3}e^{2i\beta_{m',vi}h_{m'}}) + (r_{mm',vis}r_{3} + r_{m'2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m}}\right] \\ & \times \exp[iz_{1}\left(k_{m',vis}\cos\theta_{m',vis}\left(1 - \tan\theta_{m',SF}\tan\theta_{m,vis}\right)\right)\right] \\ & \times \exp[iz_{1}\left(k_{m',vis}\cos\theta_{m',vis}\left(-1 - \tan\theta_{m',SF}\tan\theta_{m,vis}\right)\right)] \\ & \times \exp[iz_{1}\left(k_{m',vis}\cos\theta_{m',vis}\left(-1 - \tan\theta_{m',SF}\tan\theta_{m,vis}\right)\right)\right] \\ & \times \exp[iz_{1}\left(k_{m',vis}\cos\theta_{m',vis}\left(-1 - \tan\theta_{m',v$$

# m 層の m'/m 界面から深さ z<sub>2</sub> の点:

$$E_{vis\alpha}(h_{m'} + z_{2})E_{ir\beta}(h_{m'} + z_{2}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m'vis\alpha}t_{m'm,vis\alpha}}{\{(1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m}}\}$$

$$\times \frac{t_{1m',ir\beta}t_{m'm,ir\beta}e^{i\beta_{m',ir}h_{m'}}}{\{(1 + r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})}$$

$$+ (r_{m'm,ir\beta} + r_{1m',ir\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta} + r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}})$$

$$\times \{(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',ir}h_{m'}})\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(1 + \tan\theta_{m,sr}\tan\theta_{m,vis})]\}$$

$$+ (r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',ir}h_{m'}})e^{2\beta_{mvis}h_{m}}\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(1 + \tan\theta_{m,sr}\tan\theta_{m,vis})]\}$$

$$\times \{(1 + r_{mm'',vis\alpha}r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2\beta_{mvis}h_{m}}\exp[iz_{2}(k_{m,vis}\cos\theta_{m,ir}(1 + \tan\theta_{m,sr}\tan\theta_{m,vis})]\}\}$$

$$\times \{(1 + r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2\beta_{mi,ir}h_{m}}\exp[iz_{2}(k_{m,vis}\cos\theta_{m,ir}(1 + \tan\theta_{m,sr}\tan\theta_{m,ir})]\}\}$$

$$\times \{(1 + r_{mm'',ir\beta}r_{m''2,ir\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2\beta_{mi,ir}h_{m}}\exp[iz_{2}(k_{m,ir}\cos\theta_{m,ir}(1 + \tan\theta_{m,sr}\tan\theta_{m,ir}))]\}$$

$$\times \exp[i(2n+2)(h_{m} \tan \theta_{m,SF} + h_{m'} \tan \theta_{m',SF} + h_{m''} \tan \theta_{m'',SF})(-k_{m,ir} \sin \theta_{m,ir} - k_{m,vis} \sin \theta_{m,vis})]$$
(3.15)

$$E_{vis\alpha}(h_{m'} + z_{2})E_{ir,\beta}(h_{m'} + z_{2}) = E^{0}_{vis\alpha}E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m',vis\alpha}t_{m'm,vis\alpha}e^{2i\beta_{m',vi}h_{m'}}}{\{(1 + r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})(1 + r_{mm',vis\alpha}r_{m'2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha}e^{2i\beta_{m',vi}h_{m'}})(r_{mm',vis\alpha} + r_{m'2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m'}}\}$$

$$\times \frac{t_{1m',ir,\beta}t_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}}}{\{(1 + r_{1m',ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm',ir,\beta}r_{m'2,ir,\beta}e^{2i\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m'}}\}}$$

$$+ (r_{m'm,ir,\beta} + r_{1m',ir,\beta}e^{2i\beta_{m',vi}h_{m'}})(r_{mm',ir,\beta} + r_{m'2,ir,\beta}e^{2i\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m'}}\}$$

$$\times \{(1 + r_{mm',vis\alpha}r_{m'2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(1 - \tan\theta_{m,SF}\tan\theta_{m,vis})] + (r_{mm',vis,\beta}r_{m'2,ir,\beta}e^{2i\beta_{m',vi}h_{m'}})e^{2i\beta_{mv,i}h_{m'}}\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1 - \tan\theta_{m,SF}\tan\theta_{m,vis})]\}$$

$$\times \{(1 + r_{mm',vis,\beta}r_{m'2,ir,\beta}e^{2i\beta_{m',vi}h_{m'}})\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(1 - \tan\theta_{m,SF}\tan\theta_{m,vis})] + (r_{mm',vis,\beta}r_{m'2,vis,\beta}e^{2i\beta_{m',vi}h_{m'}})exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1 - \tan\theta_{m,SF}\tan\theta_{m,vis})] + (r_{mm',vis,\beta}r_{m'2,vis,\beta}e^{2i\beta_{m',vi}h_{m'}})exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1 - \tan\theta_{m,SF}\tan\theta_{m,vis})] + (r_{mm',vis,\beta}r_{m'2,vis,\beta}e^{2i\beta_{m',vi,h_{m'}}})e^{2i\beta_{m,vi,h_{m'}}}exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1 - \tan\theta_{m,SF}\tan\theta_{m,vis})] + (r_{mm',vis,\beta}r_{m'2,vis,\beta}e^{2i\beta_{m',vi,h_{m'}}})e^{2i\beta_{m,vi,h_{m'}}}exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1 - \tan\theta_{m,SF}\tan\theta_{m,vis})] + (r_{mm',vis,\beta}r_{m'2,vis,\beta}e^{2i\beta_{m',vi,h_{m'}}})e^{2i\beta_{m,vi,h_{m'}}}exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1 - \tan\theta_{m,SF}\tan\theta_{m,vis})] + (r_{m,vis,\beta}r_{m,vis,\gamma}r_{m',vis,\gamma}r_{m',vis,\gamma}r_{m,v$$

# m" 層の m/m" 界面から深さ z<sub>3</sub> の点:

### $E^{+}$ and $E^{-}$ (by reflection and transmission) sources

$$E_{vis\alpha}(h_{mi} + h_{m} + z_{3})E_{ir\beta}(h_{m'} + h_{m} + z_{3}) = E^{0}_{vis\alpha}E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha}t_{m'm,vis\alpha}t_{mm',vis\alpha}t_{mm',vis\alpha}t_{mm',vis\alpha}t_{mm',vis\alpha}t_{m'',vis\alpha}t_{m$$

$$E_{vis\alpha}(h_{m'} + h_m + z_3)E_{ir,\beta}(h_{m'} + h_m + z_3) = E^0_{vis\alpha}E^0_{ir,\beta}$$

$$\times \frac{t_{1m',vis\alpha}t_{m'm,vis\alpha}t_{mm',vis\alpha}t_{mm'',vis\alpha}e^{i(\beta_{m,vis}h_{m}+\beta_{m',vis}h_{m'})}}{\{(1+r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2\beta_{m',vis}h_{m'}})(1+r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})} + (r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha}+r_{m''2,vis\alpha}e^{2\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}}\}$$

$$\times \frac{t_{1m',ir,\beta}t_{m'm,ir,\beta}t_{m'',ir,\beta}e^{i(\beta_{m,ir}h_{m}+\beta_{m',ir}h_{m'})}}{\{(1+r_{1m',ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(1+r_{mm'',ir,\beta}r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})} + (r_{m'm,ir,\beta}r_{m'',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta}+r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}}) + (r_{m'm,ir,\beta}r_{m'',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta}+r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}}) + (r_{m'm,ir,\beta}r_{m'',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta}+r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}}) + (r_{m'm,ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}} + (r_{m'',ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}} + (r_{m'',ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}} + (r_{m'',ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}} + (r_{m'',ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m',ir}h_{m'}} + (r_{m'',ir,\beta}r_{m',ir,\beta}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}}e^{2i\beta_{m',ir,\beta}h_{m',ir,\beta}e^{2i\beta_{m',ir,\beta}h_{m'$$

### 3.2. SFG 分極

上で求めた電場積に SFG 感受率を掛けたものが SFG 分極になる。 これから先は恐ろしく複雑である。どれかの層が無限に薄いときにのみ、表式が得られるであろう。

#### 1/m' 界面の 1 側:

 $E^+$  (by reflection and transmission) and  $E^-$  (for n=0) sources

$$P_{a}^{*}(0^{-}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\{ (1 + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})[(1 + r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m''}})$$

$$\times \frac{+(r_{m'm,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}]\}}{\{ (1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})$$

$$+(r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}})$$

$$\{ (1 + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})[(1 + r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta} r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})$$

$$\times \frac{+(r_{m'm,ir,\beta} + e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}})}{\{ (1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta} r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+(r_{m'm,ir,\beta} + r_{m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}})e^{2i\beta_{m,ir}h_{m'}})$$

$$+(r_{m'm,ir,\beta} + r_{m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}})e^{2i\beta_{m,ir}h_{m'}})$$

$$+(r_{m'm,ir,\beta} + r_{m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}})e^{2i\beta_{m,ir}h_{m'}}}$$

# 1/m' 界面の m' 側:

$$\begin{split} P_{a}^{*}\left(0^{+}\right) &= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta} \\ &\qquad \qquad \{t_{1m',vis\alpha} \left[ (1 + r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) (1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m''}}) \\ &\qquad \qquad \times \frac{+ (r_{m'm,vis\alpha} + e^{2i\beta_{m',vis}h_{m'}}) (r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m'',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m'}} \}}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) (1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) \\ &\qquad \qquad + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) (r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}} \} \end{split}$$

$$\begin{aligned}
&\{t_{1\,m',ir,\beta}\left[(1+r_{m'm,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(1+r_{mm',ir,\beta}r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})\right.\\
&\times\frac{+(r_{m'm,ir,\beta}+e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta}+r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m}}]\}}{\{(1+r_{1m',ir,\beta}r_{m'',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(1+r_{mm'',ir,\beta}r_{m'''2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})\\ &+(r_{m'm,ir,\beta}+r_{1m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta}+r_{m'''2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{m,ir}h_{m'}})e^{2i\beta_{m,ir}h_{m}}\}\end{aligned} \tag{3.20}$$

#### m''/2 界面の2 側:

 $E^+$  (by reflection and transmission) and  $E^-$  sources

$$P_{a}^{*}(h_{m'} + h_{m} + h_{m''}^{+}) = \sum_{\alpha,\beta} \chi_{ao\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} t_{mm'',vis\alpha} t_{m'''2,vis\alpha}}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha} r_{m'''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m'''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}})$$

$$\times \frac{t_{1m',ir\beta} t_{m'm,ir\beta} t_{mm',ir\beta} t_{m''',ir\beta} t_{m''''2,ir\beta} e^{2\beta_{m',ir}h_{m'} + \beta_{m,ir}h_{m} + \beta_{m'r}h_{m'}}}{\{(1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir\beta} r_{m'''2,ir\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+ (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta} + r_{m'''2,ir\beta} e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}})$$

$$+ (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta} + r_{m'''2,ir\beta} e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{m,ir}h_{m'}})$$

$$+ (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta} + r_{m'''2,ir\beta} e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{m,ir}h_{m'}})$$

$$+ (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\beta} + r_{m'''2,ir\beta} e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{m,ir}h_{m'}})$$

### m''/2 界面の m'' 側:

 $E^+$  (by reflection and transmission) and  $E^-$  sources

$$P_{a}^{*}(h_{m'} + h_{m} + h_{m'}^{-}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis} \alpha E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} t_{mm',vis\alpha} (1 + r_{m''2,vis\alpha}) e^{i(\beta_{ml,vis} h_{m'} + \beta_{m,vis} h_{m} + \beta_{ml,vis} h_{ml})}}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2\frac{i\beta_{m',vis} h_{m'}}{n}})(1 + r_{mm',vis\alpha} r_{m''2,vis\alpha} e^{2\frac{i\beta_{m',vis} h_{m'}}{n}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2\frac{i\beta_{m',vis} h_{m'}}{n}})(r_{mm',vis\alpha} + r_{m''2,vis\alpha} e^{2\frac{i\beta_{m',vis} h_{m'}}{n}}) e^{2i\beta_{m,vis} h_{m}}}\}$$

$$\times \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} t_{mm',ir,\beta} (1 + r_{m''2,ir,\beta}) e^{i(\beta_{ml,n} h_{m'} + \beta_{m,ir} h_{m} + \beta_{m',ir} h_{m'})}}{\{(1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir} h_{m'}})(1 + r_{mm'',ir,\beta} r_{m'''2,ir,\beta} e^{2i\beta_{m',ir} h_{m'}})}$$

$$+ (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir} h_{m'}})(r_{mm',ir,\beta} + r_{m'''2,ir,\beta} e^{2i\beta_{m',ir} h_{m'}}) e^{2i\beta_{m,ir} h_{m'}}}\}$$
(3.22)

# m'/m 界面の m' 側:

$$\begin{split} P_{a}^{*}\left(h_{m'}^{-}\right) &= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta} \\ &\qquad \qquad \{ t_{1m',vis\alpha} e^{\beta_{m',vis}h_{m'}} (1 + r_{m'm,vis\alpha}) [(1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}}) \\ &\qquad \qquad \times \frac{+ (r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}} ] \} \\ &\qquad \qquad \times \frac{+ (r_{mm'',vis\alpha} r_{m'',vis\alpha} e^{2\beta_{m',vis}h_{m'}}) (1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}}) \\ &\qquad \qquad + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2\beta_{m',vis}h_{m'}}) (r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}} \} \end{split}$$

$$\begin{aligned}
&\{t_{1\,m',ir\,\beta}e^{i\beta_{m',ir}h_{m'}}(1+r_{m'm,ir\,\beta})[(1+r_{mm'',ir\,\beta}r_{m''2,ir\,\beta}e^{2i\beta_{m',ir}h_{m'}})\\ &\times \frac{+(r_{m'm,ir\,\beta}+e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\,\beta}+r_{m''2,ir\,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}}]\}}{\{(1+r_{1m',ir\,\beta}r_{m'm,ir\,\beta}e^{2i\beta_{m',ir}h_{m'}})(1+r_{mm'',ir\,\beta}r_{m''2,ir\,\beta}e^{2i\beta_{m',ir}h_{m''}})\\ &+(r_{m'm,ir\,\beta}+r_{1m',ir\,\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir\,\beta}+r_{m''2,ir\,\beta}e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{m,ir}h_{m'}}\}\end{aligned} \tag{3.23}$$

$$P_{a}^{*}(h_{m}^{*-}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\{t_{1m',vis\alpha} e^{i\beta_{m',vis}h_{m'}} (1 + r_{m'm,vis\alpha})[(1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})$$

$$\times \frac{+(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m}}]\}$$

$$\times \frac{+(r_{mm'',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}\}}$$

$$\{t_{1m',ir,\beta} e^{i\beta_{m',ir}h_{m'}} (1 + r_{m'm,ir,\beta})[(1 + r_{mm',ir,\beta} r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})$$

$$\times \frac{+(r_{m'm,ir,\beta} + e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}{\{(1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta} r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+(r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+(r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m,ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+(r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m,ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}})e^{2i\beta_{m,ir}h_{m}}})$$

### m'/m 界面 のm 側:

 $E^{+}$  and  $E^{-}$  (by reflection and transmission) sources

$$P_{a}^{*}(h_{m'}^{+}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta}$$

$$\times \frac{t_{lm',vis\alpha} t_{m'm,vis\alpha}}{t_{lm',vis\alpha} t_{m'm,vis\alpha}} e^{i\beta_{m',vis}h_{m'}} [(1 + r_{mm',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) + (r_{mm',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}}]$$

$$\{ (1 + r_{lm',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) (1 + r_{mm',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})$$

$$+ (r_{m'm,vis\alpha} + r_{lm',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) (r_{mm',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}} \}$$

$$\times \frac{t_{lm',ir,\beta} t_{m'm,ir,\beta} e^{i\beta_{m',ir}h_{m'}} [(1 + r_{mm',ir,\beta} r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) + (r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,vi}h_{m}} ]}{\{ (1 + r_{lm',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) (1 + r_{mm'',ir,\beta} r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}} \}}$$

$$+ (r_{m'm,ir,\beta} + r_{lm',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) (r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}} \}$$

$$+ (r_{m'm,ir,\beta} + r_{lm',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) (r_{mm'',ir,\beta} + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}} \}$$

$$\begin{split} P_{a}^{*}\left(h_{m^{+}}^{+}\right) &= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta} \\ &\times \frac{t_{lm',vis\alpha}}{t_{lm',vis\alpha}} t_{m'm,vis\alpha} e^{\theta_{m',vis}h_{m'}} \left[ (1 + r_{mm',vis\alpha} r_{m'2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) + (r_{mm',vis\alpha} + r_{m'2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}} \right] \\ &+ \left( (1 + r_{lm',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) (1 + r_{mm',vis\alpha} r_{m'2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) + (r_{mm',vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m'}} \right) \right] \\ &+ \left( (r_{m'm,vis\alpha} + r_{m'v,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) (r_{mm',vis\alpha} + r_{m'2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}} \right) \right\} \end{split}$$

$$\times \frac{t_{1m'jr,\beta}t_{m'mjr,\beta}e^{i\beta_{m',l'}h_{m'}}[(1+r_{mm'',jr,\beta}r_{m''',2jr,\beta}e^{2i\beta_{m',j'}h_{m''}})+(r_{mm'',jr,\beta}+r_{m'',2jr,\beta}e^{2i\beta_{m',j'}h_{m''}})e^{2i\beta_{m,l'}h_{m}}]}{\{(1+r_{1m',jr,\beta}r_{m'm,jr,\beta}e^{2i\beta_{m',jr}h_{m'}})(1+r_{mm'',jr,\beta}r_{m'',2jr,\beta}e^{2i\beta_{m',jr}h_{m'}})e^{2i\beta_{m,lr}h_{m}}\}}$$

$$+(r_{m'mjr,\beta}+r_{1m',jr,\beta}e^{2i\beta_{m',jr}h_{m'}})(r_{mm'',jr,\beta}+r_{m'',2jr,\beta}e^{2i\beta_{m',jr}h_{m'}})e^{2i\beta_{m,lr}h_{m}}\}$$
(3.26)

#### m/m" 界面の m 側:

 $E^{+}$  and  $E^{-}$  (by reflection and transmission) sources

$$P_{a}^{*}(h_{m} + h_{m}^{-}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} e^{i(\beta_{m',vis}h_{m} + \beta_{m,vis}h_{m})} (1 + r_{mm',vis\alpha}) (1 + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2\beta_{m',vis}h_{m'}}) (1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}})} + (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2\beta_{m',vis}h_{m'}}) (r_{mn'',vis\alpha} + r_{m''2,vis\alpha} e^{2\beta_{m'',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}} \}$$

$$\times \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}} (1 + r_{mm'',ir,\beta}) (1 + r_{m''2,ir,\beta} e^{2\beta_{m'',ir}h_{m'}})}{\{(1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m,ir}h_{m'}}) (1 + r_{mm'',ir,\beta} r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})} + (r_{m'',ir,\beta} t_{m'',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) (1 + r_{mm'',ir,\beta} t_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})} + (r_{m'',ir,\beta} t_{m'',ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) (r_{mm'',ir,\beta} t_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m'}})$$

 $E^+$  (by reflection and transmission) and  $E^-$  sources

$$P_{a}^{*}(h_{m} + h_{m}^{-}) = \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir,\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha}}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha})(1 + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m}}\}$$

$$\times \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} e^{i(\beta_{m',ir}h_{m} + \beta_{m,ir}h_{m})}(1 + r_{mm'',ir,\beta})(1 + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}{\{(1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta} r_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+ (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m}}\}$$

$$(3.28)$$

# m/m" 界面の m" 側:

$$P_{a}^{*}(h_{m} + h_{m}^{+}) = \sum_{\alpha,\beta} \chi_{ao\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha}}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m'}}}\}$$

$$\times \frac{t_{1m',ir,\beta} t_{m'mir,\beta} t_{mm'',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{m''2,ir,\beta} e^{2i\beta_{m',ir}h_{m''}})}{\{(1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m''}})}$$

$$+ (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm',ir,\beta} + r_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}}}\}$$

$$(3.29)$$

$$P_{a}^{*}(h_{m} + h_{m}^{*+}) = \sum_{\alpha,\beta} \chi_{ao\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} t_{mm'',vis\alpha} e^{i(\beta_{m,vis}h_{m}+\beta_{m',vis}h_{m'})} (1 + r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}})}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2\beta_{m',vis}h_{m'}}) (1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2\beta_{m',vis}h_{m'}}) (r_{mm',vis\alpha} + r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m'}}\}$$

$$\times \frac{t_{1m',ir\beta} t_{m'mir\beta} t_{mm',ir\beta} e^{2i\beta_{m',ir}h_{m'}}) (1 + r_{m''2,ir\beta} e^{2\beta_{m',vis}h_{m'}})}{\{(1 + r_{1m',ir\beta} r_{m'm,ir\beta} e^{2i\beta_{m,ir}h_{m'}}) (1 + r_{m'''2,ir\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+ (r_{m'm,ir\beta} + r_{1m',ir\beta} e^{2i\beta_{m',ir}h_{m'}}) (r_{mm',ir\beta} r_{m'''2,ir\beta} e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}}\}$$

$$(3.30)$$

# m'層の深さ z1点:

 $E^{+}$  and  $E^{-}$  (by reflection and transmission) sources

$$\begin{split} P_{a}^{*}\left(z_{1}\right) &= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta} \\ &\times \frac{t_{1m',vis\alpha}}{\{(1+r_{1m',vis\alpha}r_{m'm,vis\alpha}e^{2\beta_{m',vi}h_{m'}})(1+r_{mm',vis\alpha}r_{m',2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})}{+(r_{m'm,vis\alpha}+r_{1m',vis\alpha}e^{2\beta_{m',vi}h_{m'}})(r_{mm',vis\alpha}+r_{m',2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m}}\}} \\ &\times \frac{t_{1m',ir\beta}}{\{(1+r_{1m',ir\beta}r_{m'm,ir\beta}e^{2i\beta_{m',vi}h_{m'}})(1+r_{mm',ir\beta}r_{m'',2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m}}\}} \\ &\times \frac{t_{1m',ir\beta}}{\{(1+r_{1m',ir\beta}r_{m',m',ir\beta}e^{2i\beta_{m',vi}h_{m'}})(1+r_{mm',ir\beta}r_{m'',2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m}}\}} \\ &\times \{[(1+r_{mm',vis\alpha}r_{m',2,vis\alpha}e^{2i\beta_{m',vi}h_{m'}})+r_{m'm,vis\alpha}(r_{mm',vis\alpha}+r_{m',2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})e^{2i\beta_{mvi}h_{m}}] \\ &\times \exp[iz_{1}(k_{m,vis}\cos\theta_{m',vis}(1+\tan\theta_{m',SF}\tan\theta_{m',vis})]] \\ &+[r_{m'm,vis\alpha}(1+r_{mm',vis\alpha}r_{m',2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})+(r_{mm',vis\alpha}+r_{m',2,vis\alpha}e^{2\beta_{m',vi}h_{m'}})e^{2i\beta_{mvi}h_{m}}] \\ &\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(-1+\tan\theta_{m',SF}\tan\theta_{m',vis})]\} \\ &\times \{[(1+r_{mm',vir\beta}r_{m',vir\beta}e^{2\beta_{m',vi}h_{m'}})+r_{m',mir\beta}(r_{mm',vir\beta}+r_{m',vir\beta}e^{2\beta_{m',vi}h_{m'}})e^{2i\beta_{m,vi}h_{m}}] \\ &\times \exp[iz_{1}(k_{m',vir}\cos\theta_{m',vir}(1+\tan\theta_{m',SF}\tan\theta_{m',vir})] \\ &+[r_{m'm,vir\beta}(1+r_{mm',vir\beta}r_{m',vir\beta}-r_{m',vir\beta}e^{2\beta_{m',vir}h_{m'}})+(r_{mm',vir\beta}+r_{m',vir\beta}e^{2\beta_{m',vir}h_{m'}})e^{2\beta_{m,vir}h_{m}}] \\ &\times \exp[iz_{1}(k_{m',vir}\cos\theta_{m',vir}(1+\tan\theta_{m',SF}\tan\theta_{m',vir})] \\ &+exp[iz_{1}(k_{m',vir}\cos\theta_{m',vir}(-1+\tan\theta_{m',SF}\tan\theta_{m',vir})]\} \end{aligned}$$

$$\begin{split} P_{a}^{*}\left(z_{1}\right) &= \sum_{\alpha,\beta} \chi_{a\alpha\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta} \\ &\times \frac{t_{1m',vis\alpha}}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}})} \\ &+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}}\} \end{split}$$

$$\times \frac{t_{1m'ir,\beta}}{\{(1+r_{1m'ir,\beta}r_{m'm,ir,\beta}e^{2i\beta_{m',i}h_{m'}})(1+r_{mm''ir,\beta}r_{m''2,ir,\beta}e^{2i\beta_{m',i}h_{m'}})} + (r_{m'm,ir,\beta}+r_{1m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta}+r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m'}}) \}$$

$$\times \{[(1+r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',ir}h_{m'}})+r_{m'm,vis\alpha}(r_{mm'',vis\alpha}+r_{m''2,vis\alpha}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m}}]$$

$$\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(1-\tan\theta_{m',SF}\tan\theta_{m',vis})]$$

$$+ [r_{m'm,vis\alpha}(1+r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m',ir}h_{m'}})+(r_{mm'',vis\alpha}+r_{m''2,vis\alpha}e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{m,ir}h_{m}}]$$

$$\times \exp[iz_{1}(k_{m',vis}\cos\theta_{m',vis}(-1-\tan\theta_{m',SF}\tan\theta_{m',vis})] \}$$

$$\times \{[(1+r_{mm'',ir,\beta}r_{m'''2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})+r_{m''m,ir,\beta}(r_{mm'',ir,\beta}+r_{m'''2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{m,ir}h_{m}}]$$

$$\times \exp[iz_{1}(k_{m',ir}\cos\theta_{m',ir}(1-\tan\theta_{m',SF}\tan\theta_{m',ir})]$$

$$+ [r_{m'm,ir,\beta}(1+r_{mm'',ir,\beta}r_{m'''2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})+(r_{mm'',ir,\beta}+r_{m'',2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{m,ir}h_{m}}]$$

$$\times \exp[iz_{1}(k_{m',ir}\cos\theta_{m',ir}(1-\tan\theta_{m',SF}\tan\theta_{m',ir})]$$

$$+ [r_{m'm,ir,\beta}(1+r_{mm'',ir,\beta}r_{m'',2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})+(r_{mm'',ir,\beta}+r_{m'',2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})e^{2i\beta_{mi,ir}h_{m}}]$$

$$\times \exp[iz_{1}(k_{m',ir}\cos\theta_{m',ir}(1-\tan\theta_{m',SF}\tan\theta_{m',ir})] \}$$

$$\times \exp[iz_{1}(k_{m',ir}\cos\theta_{m',ir}(-1-\tan\theta_{m',SF}\tan\theta_{m',ir})] \}$$

# m 層の m'/m 界面から深さ $z_2$ の点:

## $E^{+}$ and $E^{-}$ (by reflection and transmission) sources

$$\begin{split} P_{a}^{*}\left(h_{m^{\cdot}}+z_{2}\right) &= \sum_{\alpha,\beta}\chi_{a\alpha\beta}E^{0}_{vis\alpha}E^{0}_{ir\beta} \\ &\times \frac{t_{1m^{\prime},vis\alpha}t_{m^{\prime}m,vis\alpha}e^{e^{i\beta_{m^{\prime},vis}h_{m^{\prime}}}}}{\{(1+r_{1m^{\prime},vis\alpha}r_{m^{\prime}m,vis\alpha}e^{2^{2}\beta_{m^{\prime},vis}h_{m^{\prime}}})(1+r_{mm^{\prime\prime},vis\alpha}r_{m^{\prime\prime}2,vis\alpha}e^{2^{2}\beta_{m^{\prime\prime},vis}h_{m^{\prime}}}) \\ &+ (r_{m^{\prime}m,vis\alpha}+r_{1m^{\prime},vis\alpha}e^{2^{2}\beta_{m^{\prime},vis}h_{m^{\prime}}})(r_{mm^{\prime\prime},vis\alpha}+r_{m^{\prime\prime}2,vis\alpha}e^{2^{2}\beta_{m^{\prime\prime},vis}h_{m^{\prime}}})e^{2i\beta_{m,vis}h_{m}}\} \\ &\times \frac{t_{1m^{\prime},ir\beta}t_{m^{\prime}m,ir\beta}e^{i\beta_{m^{\prime},ir}h_{m^{\prime}}}}{\{(1+r_{1m^{\prime},ir\beta}r_{m^{\prime}m,ir\beta}e^{2i\beta_{m^{\prime},ir}h_{m^{\prime}}})(1+r_{mm^{\prime\prime},ir\beta}r_{m^{\prime\prime}2,ir\beta}e^{2i\beta_{m^{\prime\prime},ir}h_{m^{\prime}}}) \\ &+ (r_{m^{\prime}m,ir\beta}+r_{1m^{\prime},ir\beta}e^{2i\beta_{m^{\prime},ir}h_{m^{\prime}}})(r_{mm^{\prime\prime},ir\beta}+r_{m^{\prime\prime}2,ir\beta}e^{2i\beta_{m^{\prime},ir}h_{m^{\prime\prime}}})e^{2i\beta_{m,ir}h_{m^{\prime\prime}}}\} \end{split}$$

$$+(r_{m'm',ir,\beta} + r_{1m',ir,\beta}e^{2i\beta_{m',ir}h_{m'}})(r_{mni',ir,\beta} + r_{m''2,ir,\beta}e^{2i\beta_{m',ir}h_{m'}})e^{2i\beta_{m,ir}h_{m}}\}$$

$$\times\{(1 + r_{mm'',vis\alpha}r_{m''2,vis\alpha}e^{2i\beta_{m'v,i}h_{m'}})\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(1 + \tan\theta_{m,SF}\tan\theta_{m,vis})]$$

$$+(r_{mm'',vis\alpha} + r_{m''2,vis\alpha}e^{2i\beta_{m'v,i}h_{m'}})e^{2i\beta_{mvis}h_{m}}\exp[iz_{2}(k_{m,vis}\cos\theta_{m,vis}(-1 + \tan\theta_{m,SF}\tan\theta_{m,vis})]\}$$

$$\times\{(1 + r_{mm'',ir,\beta}r_{m'''2,ir,\beta}e^{2i\beta_{m',ir}h_{m''}})\exp[iz_{2}(k_{m,ir}\cos\theta_{m,ir}(1 + \tan\theta_{m,SF}\tan\theta_{m,ir})]\}$$

$$+(r_{mm'',ir,\beta} + r_{m'''2,ir,\beta}e^{2i\beta_{m',ir}h_{m}})e^{2i\beta_{mir}h_{m}}\exp[iz_{2}(k_{m,ir}\cos\theta_{m,ir}(-1 + \tan\theta_{m,SF}\tan\theta_{m,ir})]\}$$
(3.33)

$$\begin{split} P_{a}^{*}\left(h_{m'}+z_{2}\right) &= \sum_{\alpha,\beta}\chi_{a\alpha\beta}E^{0}_{vis\alpha}E^{0}_{ir,\beta} \\ &\times \frac{t_{1m',vis}\alpha}{\{(1+r_{1m',vis}\alpha}r_{m'm,vis}\alpha}e^{2\beta_{m',vis}h_{m'}})(1+r_{mm'',vis}\alpha}e^{2\beta_{m',vis}h_{m'}})\\ &+ (r_{m'm,vis}\alpha}+r_{1m',vis}\alpha}e^{2\beta_{m',vis}h_{m'}})(r_{mm'',vis}\alpha}+r_{m'',2,vis}\alpha}e^{2\beta_{m',vis}h_{m'}})e^{2i\beta_{m,vis}h_{m}}\} \end{split}$$

$$\times \frac{t_{1m',ir} \, \beta \, t_{m'm,ir} \, \beta e^{i\beta_{m',ir}h_{m'}}}{\{(1 + r_{1m',ir} \, \beta \, r_{m'm,ir} \, \beta e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir} \, \beta \, r_{m''2,ir} \, \beta e^{2i\beta_{m',ir}h_{m'}})} + (r_{m'm,ir} \, \beta \, r_{m''n,ir} \, \beta e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir} \, \beta + r_{m''2,ir} \, \beta e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m'}} \}$$

$$\times \{(1 + r_{mm'',vis\alpha} \, r_{m''2,vis\alpha} \, e^{2i\beta_{m'vi}h_{m'}}) \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis}(1 - \tan\theta_{m,SF} \tan\theta_{m,vis})] + (r_{mm'',vis} \, \alpha \, + r_{m''2,vis\alpha} \, e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{mvis}h_{m}} \exp[iz_{2}(k_{m,vis} \cos\theta_{m,vis}(-1 - \tan\theta_{m,SF} \tan\theta_{m,vis})] \}$$

$$\times \{(1 + r_{mm'',ir} \, \beta \, r_{m''2,ir} \, \beta \, e^{2i\beta_{m',ir}h_{m'}}) \exp[iz_{2}(k_{m,ir} \cos\theta_{m,ir}(1 - \tan\theta_{m,SF} \tan\theta_{m,ir})] \}$$

$$\times \{(1 + r_{mm'',ir} \, \beta \, r_{m''2,ir} \, \beta \, e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}} \, \exp[iz_{2}(k_{m,ir} \cos\theta_{m,ir}(-1 - \tan\theta_{m,SF} \tan\theta_{m,ir})] \}$$

$$\times \{(1 + r_{mm'',ir} \, \beta \, r_{m'',ir} \, \beta \, e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}} \, \exp[iz_{2}(k_{m,ir} \cos\theta_{m,ir}(-1 - \tan\theta_{m,SF} \tan\theta_{m,ir})] \}$$

$$\times \{(1 + r_{mm'',ir} \, \beta \, r_{m'',ir} \, \beta \, e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}} \, \exp[iz_{2}(k_{m,ir} \cos\theta_{m,ir}(-1 - \tan\theta_{m,SF} \tan\theta_{m,ir})] \}$$

$$\times \{(1 + r_{mm'',ir} \, \beta \, r_{m'',ir} \, \beta \, e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}} \, \exp[iz_{2}(k_{m,ir} \cos\theta_{m,ir}(-1 - \tan\theta_{m,SF} \tan\theta_{m,ir})] \}$$

# m" 層の m/m" 界面から深さ z<sub>3</sub> の点:

### $E^{+}$ and $E^{-}$ (by reflection and transmission) sources

$$P_{a}^{*}(h_{m'} + h_{m} + z_{3}) = \sum_{\alpha,\beta} \chi_{ac\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} t_{mm',vis\alpha} t_{mm',vis\alpha} e^{2i(\beta_{m,vis}h_{m'})}}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm',vis\alpha} r_{m'',2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(r_{mm',vis\alpha} + r_{m'',2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}}\}$$

$$\times \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} t_{mm',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}{\{(1 + r_{1m',ir,\beta} r_{m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm',ir,\beta} r_{m'',2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+ (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm',ir,\beta} + r_{m'',2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})$$

$$+ (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm',ir,\beta} + r_{m'',2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m}}\}$$

$$\times \{\exp[iz_{3}(k_{m'',vis}\cos\theta_{m',vis}(1 + \tan\theta_{m'',SF}\tan\theta_{m'',vis})] + r_{m'',2,vis\alpha} e^{2i\beta_{m,ir}h_{m}+\beta_{m',vis}h_{m'}}) \exp[iz_{3}(k_{m'',vis}\cos\theta_{m'',vis}(-1 + \tan\theta_{m'',SF}\tan\theta_{m'',vis})]\}$$

$$\times \{\exp[iz_{3}(k_{m'',ir}\cos\theta_{m',ir}(1 + \tan\theta_{m'',SF}\tan\theta_{m'',ir})] + r_{m'',2,ir,\beta} e^{2i(\beta_{mi,h}h_{m}+\beta_{m',r}h_{m'})} \exp[iz_{3}(k_{m'',vis}\cos\theta_{m'',ir}(-1 + \tan\theta_{m'',SF}\tan\theta_{m'',ir})]\}$$
(3.35)

$$P_{a}^{*}(h_{m'} + h_{m} + z_{3}) = \sum_{\alpha,\beta} \chi_{ac\beta} E^{0}_{vis\alpha} E^{0}_{ir\beta}$$

$$\times \frac{t_{1m',vis\alpha} t_{m'm,vis\alpha} t_{mm',vis\alpha} t_{mm',vis\alpha} e^{2i(\beta_{m,vis}h_{m} + \beta_{m',vis}h_{m'})}}{\{(1 + r_{1m',vis\alpha} r_{m'm,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(1 + r_{mm'',vis\alpha} r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}})}$$

$$+ (r_{m'm,vis\alpha} + r_{1m',vis\alpha} e^{2i\beta_{m',vis}h_{m'}})(r_{mm'',vis\alpha} + r_{m''2,vis\alpha} e^{2i\beta_{m',vis}h_{m'}}) e^{2i\beta_{m,vis}h_{m}}\}$$

$$\times \frac{t_{1m',ir,\beta} t_{m'm,ir,\beta} t_{mm'',ir,\beta} e^{i(i\beta_{m,i}h_{m} + \beta_{m',vi}h_{m'})}}{\{(1 + r_{1m',ir,\beta} r_{m'm,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(1 + r_{mm'',ir,\beta} r_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}})}$$

$$+ (r_{m'm,ir,\beta} + r_{1m',ir,\beta} e^{2i\beta_{m',ir}h_{m'}})(r_{mm'',ir,\beta} + r_{m'''2,ir,\beta} e^{2i\beta_{m',ir}h_{m'}}) e^{2i\beta_{m,ir}h_{m'}}\}$$

$$\times \{\exp[iz_{3}(k_{m'',vis}\cos\theta_{m'',vis}(1 - \tan\theta_{m'',SF}\tan\theta_{m'',vis})]$$

$$+ r_{m'''2,vis\alpha} e^{2i(\beta_{mi,r}h_{m} + \beta_{m',r}h_{m'})} \exp[iz_{3}(k_{m'',vis}\cos\theta_{m'',vis}(-1 - \tan\theta_{m'',SF}\tan\theta_{m'',vis})]\}$$

$$\times \{\exp[iz_{3}(k_{m'',ir}\cos\theta_{m'',ir}(1 - \tan\theta_{m'',SF}\tan\theta_{m'',ir})]\}$$

$$+ r_{m'''2,ir,\beta} e^{2i(\beta_{mi,r}h_{m} + \beta_{m'',r}h_{m'})} \exp[iz_{3}(k_{m'',vis}\cos\theta_{m'',ir}(-1 - \tan\theta_{m'',SF}\tan\theta_{m'',ir})]\}$$

$$(3.36)$$