Units $\mathrm{nm} := 10^{-9}\cdot\mathrm{m}$ $\mu\mathrm{m} := 10^{-6}\cdot\mathrm{m}$

$\lambda_p := 402.36\cdot\mathrm{nm}$ Measured wavelength of the pump beam

$2\cdot\lambda_p = 804.72\,\mathrm{nm}$ Wavelength of the degenerate down-conversion photons

Indices of refraction of the BBO crystal

$$n_o(\lambda) := \left[2.7359 + \frac{0.01878}{\left(\frac{\lambda}{\mu\mathrm{m}}\right)^2 - 0.01822} - 0.01354\cdot\left(\frac{\lambda}{\mu\mathrm{m}}\right)^2\right]^{\frac{1}{2}}$$ ordinary

$$n_e(\lambda) := \left[2.3753 + \frac{0.01224}{\left(\frac{\lambda}{\mu\mathrm{m}}\right)^2 - 0.01667} - 0.01516\cdot\left(\frac{\lambda}{\mu\mathrm{m}}\right)^2\right]^{\frac{1}{2}}$$ extraordinary

$n_o(\lambda_p) = 1.6925$ $n_e(\lambda_p) = 1.5675$ Indices at the wavelength of interest

$n_o(2\cdot\lambda_p) = 1.6604132$

Extraordinary index of refraction as a function of the phase matching angle between the propagation direction and the optic axis of the crystal

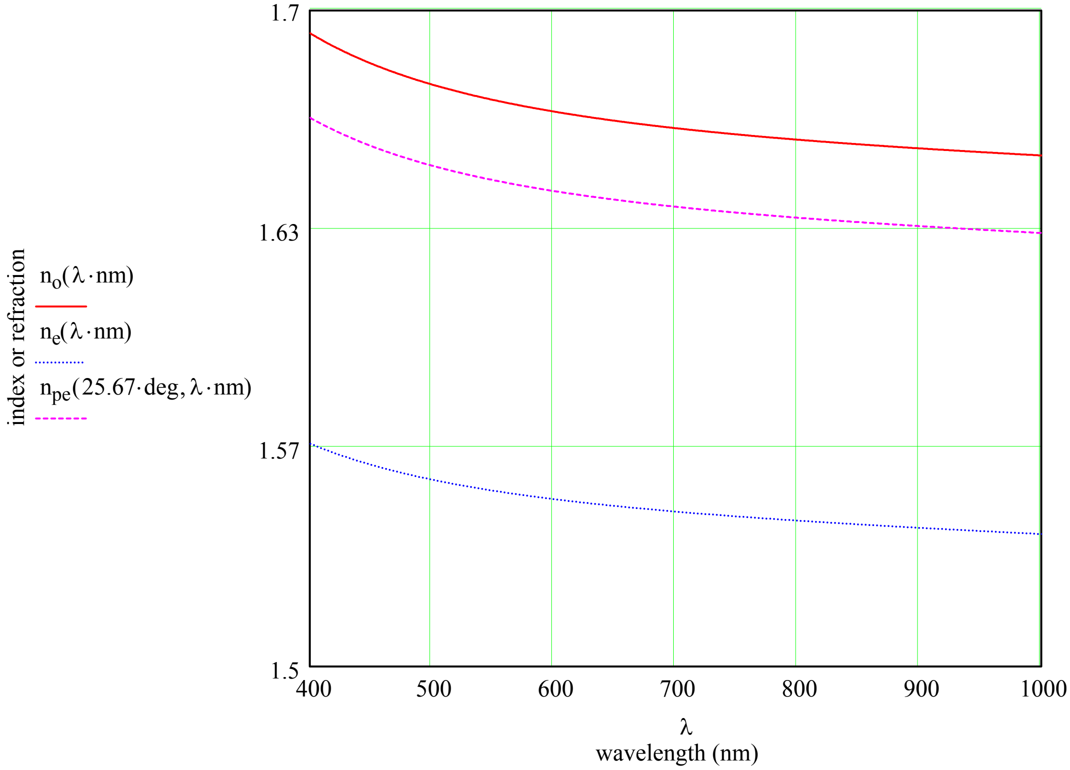
$$n_{pe}(\theta_{pm},\lambda_p) := \left(\frac{\cos(\theta_{pm})^2}{n_o(\lambda_p)^2} + \frac{\sin(\theta_{pm})^2}{n_e(\lambda_p)^2}\right)^{\frac{-1}{2}}$$

compute the phase matching angle that makes the extraordinary index of refraction for the pump beam equal to the ordinary index of refraction for the downconverted beam

$\theta_{pm0} := \mathrm{root}\left(n_{pe}(\theta_{pmz},\lambda_p) - n_o(2\cdot\lambda_p), \theta_{pmz}, 0, 90\cdot\mathrm{deg}\right)$ $\theta_{pm0} = 29.005497\,\mathrm{deg}$

$n_{pe}(29.005497\cdot\mathrm{deg},\lambda_p) = 1.6604132$ Checking

Graph of the indices of refraction



If the down-converted photons are not degenerate, with wavelengths λi and λs

$$\lambda_i(\lambda_s) := \left(\frac{1}{\lambda_p} - \frac{1}{\lambda_s}\right)^{-1}$$

Momenta of each photon: pump, signal and idler

$$k_p(\theta_{pm}) := \frac{2\cdot\pi\cdot n_{pe}(\theta_{pm},\lambda_p)}{\lambda_p} \qquad k_s(\lambda_s) := \frac{2\cdot\pi\cdot n_o(\lambda_s)}{\lambda_s} \qquad k_i(\lambda_s) := \frac{2\cdot\pi\cdot n_o(\lambda_i(\lambda_s))}{\lambda_i(\lambda_s)}$$

$$\theta_i(\theta_{pm},\lambda_s) := \mathrm{acos}\left(\frac{k_p(\theta_{pm})^2 - k_s(\lambda_s)^2 + k_i(\lambda_s)^2}{2\cdot k_p(\theta_{pm})\cdot k_i(\lambda_s)}\right)$$

Angle at which the idler photon comes as a function of the phase matching angle and the wavelength of the signal photon

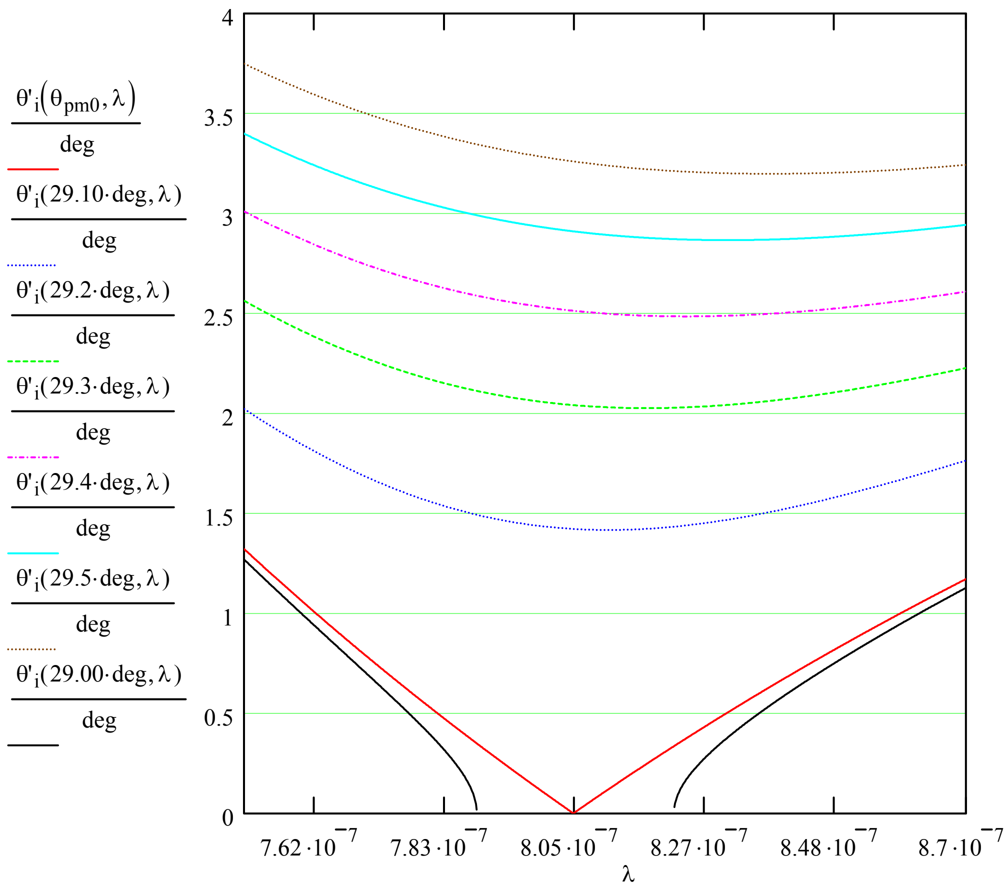
$$\theta'_i(\theta_{pm},\lambda_s) := \mathrm{asin}\left(n_o(\lambda_i(\lambda_s))\cdot\sin(\theta_i(\theta_{pm},\lambda_s))\right)$$

Angle outside of the crystal

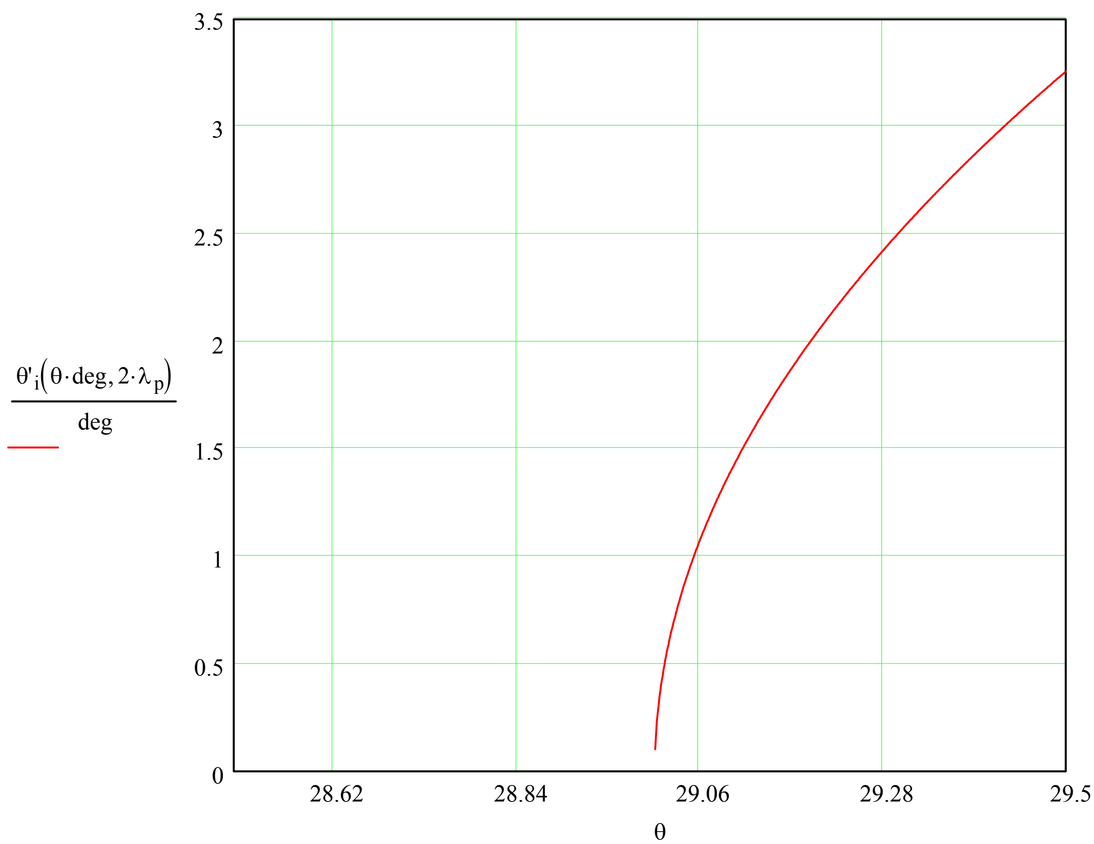
$$\theta_i\left(\theta_{pm0} + 10^{-10}, 2\cdot\lambda_p\right) = 1.085i \times 10^{-3}\,\mathrm{deg} \qquad n_e(\lambda_p) = 1.56752 \qquad n_{pe}(\theta_{pm0},\lambda_p) = 1.66$$

$$\theta'_i\left(\theta_{pm0} + 10^{-10}, 2\cdot\lambda_p\right) = 1.802i \times 10^{-3}\,\mathrm{deg} \qquad n_o(\lambda_p) = 1.69246 \qquad \lambda_i(\lambda_p\cdot 2) = 804.72\,\mathrm{nm}$$

Angle at which the idler photon exits for different phase matching angles



Exit angle as a function of the phase matching angle



Exit angle θE: $\theta_E := 3 \cdot deg$

phase matching angle:

$$\theta_{pm3} := root\left(n_{pe}(\theta_{pmz}, \lambda_p) - n_o(2\cdot\lambda_p)\cdot\sqrt{1 - \frac{\sin(\theta_E)^2}{n_o(2\cdot\lambda_p)^2}}, \theta_{pmz}, 0, 90\cdot deg\right) \qquad \theta_{pm3} = 29.425\,deg$$

$\theta'_i(\theta_{pm3}, 2\cdot\lambda_p) = 3\,deg$ exit angle--just checking...

If the crystal is not cut at the matching angle, but at θcut

Angle cut by the crystal manufacturer: $\theta_{cut} := 22.9\cdot deg$ Cleveland off the shelf

Angle cut by the crystal manufacturer: $\theta_{cut} := 25.67\cdot deg$ Casix crystal

Angle needed for normal-incidence down-conversion into 3-degree beams $\theta_{pm} := \theta_{pm3}$

Angle of the pump beam within the crystal rel to crystal normal: $\theta_r := \theta_{pm} - \theta_{cut}$ $\theta_r = 3.755\,deg$

Angle of rotation of the crystal: $\theta_{cr} := asin(n_{pe}(\theta_{pm}, \lambda_p)\cdot\sin(\theta_r))$ $\theta_{cr} = 6.239\,deg$

Lab angle for idler: $\theta_{idler} := asin(n_o(2\cdot\lambda_p)\cdot\sin(\theta_i(\theta_{pm}, 2\lambda_p) + \theta_r)) - \theta_{cr}$

$\theta_{idler} = 3.02\,deg$

Lab angle for signal: $\theta_{signal} := asin(n_o(2\cdot\lambda_p)\cdot\sin(\theta_i(\theta_{pm}, 2\lambda_p) - \theta_r)) + \theta_{cr}$

$\theta_{signal} = 3.003\,deg$

Crystal length: $L_{cr} := 7\cdot mm$

Lab angle of pump within th crystal: $\theta_{pcr} := \theta_{cr} - \theta_r$ $\theta_{pcr} = 2.484\,deg$

Length of pump within the crystal: $L_{pcr} := \frac{L_{cr}}{\cos(\theta_r)}$ $L_{pcr} = 7.015\,mm$

Wedge displacement: $L_{pcr}\cdot\sin(\theta_{pcr}) = 0.304\,mm$ minute !