APPENDIX B: SELLMEIER EQUATIONS

This appendix gives the dispersion equations for crystals that appear in the problems discussed in this book. For a more complete tabulation of crystals, see Dmitriev et al. (1997).

B.1 β-BaB_2O_4, BETA BARIUM BORATE, BBO

Uniaxial crystal: $n_x = n_y = n_o$
Point group: 3m
Transparency range: 185–2500 nm
$d_{22} = -2.2$ pm/V (Eckardt et al., 1990)
$d_{31} = 0.08$ pm/V

Sellmeier equations from Kato (1986):

$$n_o^2 = 2.7359 + \frac{0.01878}{\lambda^2 - 0.01822} - 0.01354\lambda^2, \quad \text{(B.1)}$$

$$n_z^2 = 2.3753 + \frac{0.01224}{\lambda^2 - 0.01677} - 0.01516\lambda^2, \quad \text{(B.2)}$$

where λ is entered in microns.

B.2 $LiTaO_3$, LITHIUM TANTALATE (CONGRUENT)

Uniaxial crystal: $n_x = n_y = n_o$
Point group: 3m
Transparency range: 280–5500 nm
$d_{33} = -13.8$ pm/V (Shoji et al., 1997)

Sellmeier equations from Meyn and Fejer (1997):

Note that lithium tantalate has a very small birefringence, and we only list n_z for quasi-phase matching.

$$n_z^2 = 4.5284 + \frac{7.2449\times10^{-3} + b(T)}{\lambda^2 - [0.2453 + c(T)]^2} + \frac{7.7690\times10^{-2}}{\lambda^2 - [0.1838]^2} - 2.3670\times10^{-2}\lambda^2, \quad \text{(B.3)}$$

where λ is measured in microns. $b(T)$ and $c(T)$ give the temperature dependence:

$$b(T) = 2.6794 \times 10^{-8} (T + 273.15)^2, \tag{B.4}$$

$$c(T) = 1.6234 \times 10^{-8} (T + 273.15)^2, \tag{B.5}$$

where T is measured in °C.

B.3 $LiNbO_3$, LITHIUM NIOBATE (CONGRUENT)

Uniaxial crystal: $n_x = n_y = n_o$
Point group: 3m
Transparency range: 330–5500 nm
$d_{22} = 2.1$ pm/V (Miller et al., 1971)
$d_{31} = -4.35$ pm/V
$d_{33} = -27.2$ pm/V

Use Sellmeier equations: Equations B.6 and B.7 (Edwards and Lawrence, 1984) for birefringent phase matching and Equation B.9 (Jundt, 1997) for quasi-phase matching.

$$n_o^2 = 4.9048 + \frac{0.11775 + 2.2314 \times 10^{-8} F}{\lambda^2 - (0.21802 - 2.9671 \times 10^{-8} F)^2} + 2.1429 \times 10^{-8} F - 0.027153\lambda^2, \tag{B.6}$$

$$n_z^2 = 4.5820 + \frac{0.09921 + 5.2716 \times 10^{-8} F}{\lambda^2 - (0.21090 - 4.9143 \times 10^{-8} F)^2} + 2.2971 \times 10^{-7} F - 0.021940\lambda^2, \tag{B.7}$$

where λ is entered in microns. F gives the temperature dependence:

$$F = (T - T_o)(T + T_o + 546), \tag{B.8}$$

where $T_o = 24.5$°C and T is entered in °C.

For quasi-phase matching problems, the updated Sellmeier equation is used (Jundt, 1997):

$$n_z^2 = 5.35583 + 4.629 \times 10^{-7} F + \frac{0.100473 + 3.862 \times 10^{-8} F}{\lambda^2 - (0.20692 - 0.89 \times 10^{-8} F)^2} + \frac{100 + 2.657 \times 10^{-5} F}{\lambda^2 - 128.806} - 1.5334 \times 10^{-2} \lambda^2. \tag{B.9}$$

B.4 LiB_3O_5, LITHIUM TRIBORATE, LBO

Class: mm2
Transparency range: 160–2600 nm
$d_{31} = -0.67$ pm/V (Dmitriev and Nikogosyan, 1993)
$d_{32} = 0.85$ pm/V
$d_{33} = 0.04$ pm/V

Sellmeier equations from Kato (1994):

$$n_x^2 = 2.4542 + \frac{0.01125}{\lambda^2 - 0.01135} - 0.01388\lambda^2, \tag{B.10}$$

$$n_y^2 = 2.5390 + \frac{0.01277}{\lambda^2 - 0.01189} - 0.01849\lambda^2 + 4.3025\times10^{-5}\lambda^4 - 2.9131\times10^{-5}\lambda^6, \tag{B.11}$$

$$n_z^2 = 2.5865 + \frac{0.01310}{\lambda^2 - 0.01223} - 0.01862\lambda^2 + 4.5778\times10^{-5}\lambda^4 - 3.2526\times10^{-5}\lambda^6, \tag{B.12}$$

where λ is entered in microns.

B.5 KH_2PO_4, POTASSIUM DIHYDROGEN PHOSPHATE, KDP

Uniaxial crystal: $n_x = n_y = n_o$
Point group: $\bar{4}2m$
Transparency range: 174 nm–1.57 μm
d_{36} (1064 nm) = 0.39 pm/V (Roberts, 1992)
d_{36} (351 nm) = 0.5 pm/V

Sellmeier equations ($T = 20°C$) from Barnes et al. (1982):

$$n_o^2 = 2.259276 + \frac{13.00522\lambda^2}{\lambda^2 - 400} + \frac{0.01008956}{\lambda^2 - (77.26408)^{-1}}, \tag{B.13}$$

$$n_z^2 = 2.132668 + \frac{3.2279924\lambda^2}{\lambda^2 - 400} + \frac{0.008637494}{\lambda^2 - (81.42631)^{-1}}, \tag{B.14}$$

where λ is entered in microns.

B.6 $KTiOPO_4$, POTASSIUM TITANYL PHOSPHATE, KTP

Point group: mm2
Transparency range: 350 nm–4 μm

$d_{31} = 1.95$ pm/V (Pack et al., 2004)
$d_{32} = 3.9$ pm/V
$d_{33} = 15.3$ pm/V

Sellmeier equations from Vanherzeele et al. (1988):

$$n_x^2 = 2.1146 + \frac{0.89188\lambda^2}{\lambda^2 - 0.0435181} - 0.01320\lambda^2, \quad \text{(B.15)}$$

$$n_y^2 = 2.1518 + \frac{0.87862\lambda^2}{\lambda^2 - 0.0475284} - 0.01327\lambda^2, \quad \text{(B.16)}$$

$$n_z^2 = 2.3136 + \frac{1.00012\lambda^2}{\lambda^2 - 0.0567917} - 0.01679\lambda^2, \quad \text{(B.17)}$$

where λ is entered in microns.

B.7 $ZnGeP_2$, ZINC GERMANIUM PHOSPHIDE, ZGP

Uniaxial crystal: $n_x = n_y = n_o$
Point group: $\bar{4}2m$
Transparency range: 740 nm–11 μm
$d_{14} = 48$ pm/V (Boyd et al., 1971)

Sellmeier equations from Zelmon et al. (2001):

$$n_o^2 = 8.0409 + \frac{1.68625\lambda^2}{\lambda^2 - 0.40824} + \frac{1.2880}{\lambda^2 - 611.05}, \quad \text{(B.18)}$$

$$n_z^2 = 8.0929 + \frac{1.8649\lambda^2}{\lambda^2 - 0.41468} + \frac{0.84052\lambda^2}{\lambda^2 - 452.05}, \quad \text{(B.19)}$$

where λ is entered in microns.

B.8 GaAs, GALLIUM ARSENIDE, GaAs

Nonbirefringent: $n_x = n_y = n_z$
Point group: $\bar{4}3m$
Transparency range: 0.9–17 μm
$d_{14} = 94$ pm/V (Skauli et al., 2002)

Sellmeier equations from Skauli et al. (2003):

$$n^2 = 5.372514 + \frac{27.83972}{1/\lambda_1^2 - 1/\lambda^2} + \frac{0.031764 + F}{1/\lambda_2^2 - 1/\lambda^2} + \frac{0.00143636}{1/\lambda_3^2 - 1/\lambda^2}, \tag{B.20}$$

where λ is entered in microns and

$$F = 4.350 \times 10^{-5} \Delta T + 4.664 \times 10^{-7} \Delta T^2, \tag{B.21}$$

$$\lambda_1 = 0.44313071 + 5.0564 \times 10^{-5} \Delta T, \tag{B.22}$$

$$\lambda_2 = 0.8746453 + 1.913 \times 10^{-4} \Delta T - 4.882 \times 10^{-7} \Delta T^2, \tag{B.23}$$

$$\lambda_3 = 36.9166 - 0.011622\, \Delta T, \tag{B.24}$$

where $\Delta T = T - 22$ and T is entered in °C.

B.9 SCHOTT GLASS SF10

Transparency range: 380–2600 nm
Sellmeier equation from Schott (2015):

$$n^2 = 1 + \frac{1.62153902\lambda^2}{(\lambda^2 - 0.0122241457)} + \frac{0.256287842\lambda^2}{(\lambda^2 - 0.0595736775)} + \frac{1.64447552\lambda^2}{(\lambda^2 - 147.468793)}, \tag{B.25}$$

where λ is entered in microns.

B.10 FUSED SILICA

Sellmeier equation from Corning Incorporated (2003):

$$n^2 = 1 + \frac{0.6837404940\lambda^2}{\lambda^2 - 0.00460352869} + \frac{0.420323613\lambda^2}{\lambda^2 - 0.01339688560} + \frac{0.58502748\lambda^2}{\lambda^2 - 64.4932732}, \tag{B.26}$$

where λ is entered in microns.

REFERENCES

Barnes, N. P., D. J. Gettemy, and R. S. Adhav. 1982. Variation of the refractive index with temperature and the tuning rate for KDP isomorphs. *Journal of the Optical Society of America* 72: 895–898.