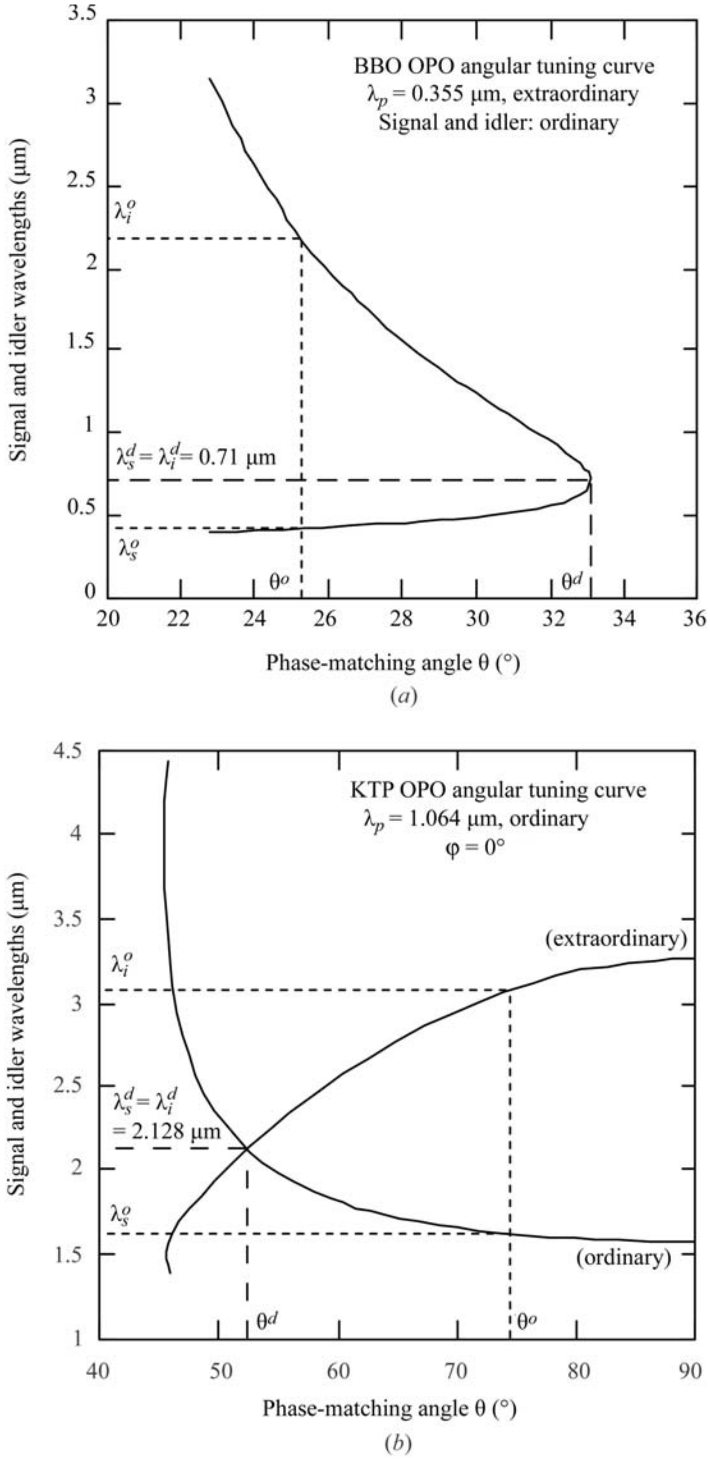

Fig. 1.7.3.19. Calculated angular tuning curves. θ and φ are the spherical coordinates of the phase-matching directions. θ^d is the phase-matching angle of the degeneracy process ($\lambda_i^d = \lambda_s^d = 2\lambda_p$). λ_i^o and λ_s^o are the idler and signal wavelengths, respectively, generated at θ^o. Ordinary and extraordinary refer to the polarization.

(ii) *OPO with a tuning pump*.

The nonlinear crystal is fixed and the pump frequency can vary over $\Delta\omega_p$, leading to a variation of the signal and idler frequencies such that $\Delta\omega_i + \Delta\omega_s = \Delta\omega_p$.

In Fig. 1.7.3.20, the example of *N*-(4-nitrophenyl)-L-propinol (NPP) pumped between 610 and 621 nm is shown (Ledoux *et al.*, 1990; Khodja *et al.*, 1995*a*). The phase-matching curve $\lambda_{i,s}(\lambda_p)$ is calculated from the Sellmeier equations of Ledoux *et al.* (1990) for the case of identical polarizations for the signal and idler waves. The tuning rate is a maximum at the degeneracy, as for angular tuning with identical polarizations.

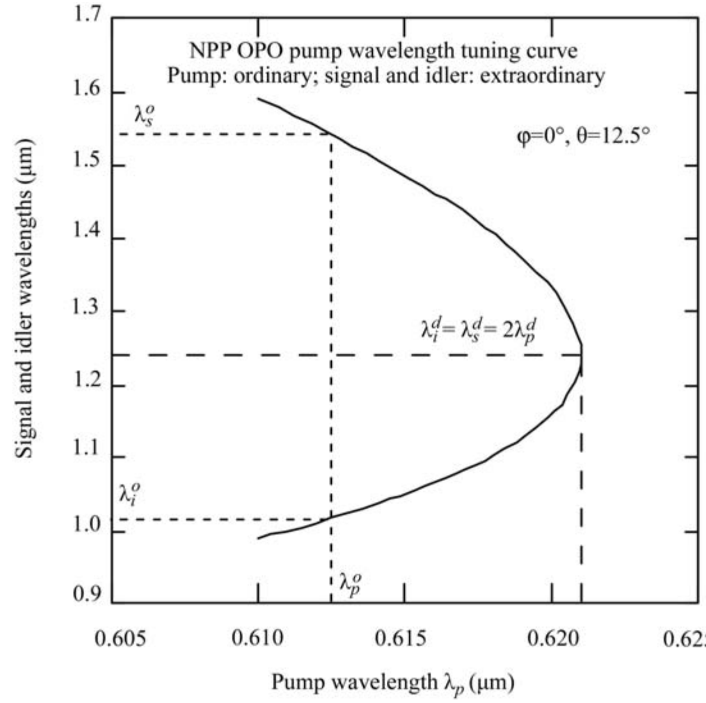

Fig. 1.7.3.20. Calculated pump wavelength tuning curve. λ_p^d is the pump wavelength leading to degeneracy for the direction considered ($\theta = 12.5$, $\varphi = 0°$). Ordinary and extraordinary refer to the polarization.

For any configuration of polarization, the most favourable direction of propagation of an OPO with a tuning pump is a principal axis of the index surface, because the phase matching is angular non-critical and so wavelength critical. In this optimal situation, the OPO has a low sensitivity to the divergence and pointing stability of the pump beam; furthermore, the walk-off angle is nil, which provides a higher conversion efficiency.

(iii) *Quasi-phase-matched OPO with a tunable periodicity*.

In a QPM device, the interacting frequencies are fixed by the frequency dispersion of the birefringence of the nonlinear material and by the periodicity of the grating. A first possibility is to fabricate a series of gratings with different periodicities in the same nonlinear crystal; the translation of this crystal with respect to the fixed pump beam allows us to address the different gratings and thus to generate different couples (ω_s, ω_i). Because the tuning is obtained in discrete steps, it is necessary to combine temperature or angle tuning with the translation of the sample in order to interpolate smoothly between the steps. For example, a device based on a periodically poled $LiNbO_3$ (ppLN) crystal with a thickness of 0.5 mm and a length along the periodicity vector of 1 cm has been developed (Myers *et al.*, 1996). A total of 25 gratings with periods between 26 and 32 μm were realized in 0.25 μm increments. The OPO was pumped at 1.064 μm and generated a signal between 1.35 and 1.98 μm, with the corresponding idler between 4.83 and 2.30 μm.

Fan-shaped gratings have been demonstrated as an alternative approach for continuous tuning (Powers *et al.*, 1998). However, such a structure has the disadvantage of introducing large spectral heterogeneity to the generated beams, because the grating period is not constant over the pump beam diameter.

Finally, the most satisfactory alternative for continuous tuning is the use of a cylindrical crystal with one single grating (Fève *et al.*, 2001). The variations of the signal and idler wavelengths are then obtained by rotation of the cylinder around its revolution axis, which is orthogonal to the OPO cavity axis and to the plane containing the frame vector Λ. For a direction of propagation making an angle α with Λ, the effective period of the grating as seen by the collinear interacting wavevectors is $\Lambda_\alpha = (\Lambda / \cos\alpha)$, leading to a continuous spectral tuning. For example, a rotation over an α range of 26° of a ppKTP cylinder pumped at 1064 nm

