(*b*) For $t \gg 1$, $G_{II}(t) \simeq (t_a^2/t^2)$ with $t_a = [(2)^{1/2}\arctan(2^{1/2})]^{1/2}$, corresponding to a saturation of $P^{2\omega}(L)$ because of the walk-off between the two fundamental beams as shown in Fig. 1.7.3.9.

The saturation length, $L_{\rm sat}$, is defined as $2.3t_a w_o/\rho$, which corresponds to the length beyond which the SHG conversion efficiency varies less than 1% from its saturation value $BP^{\omega}(0)t_a^2/\rho^2$.

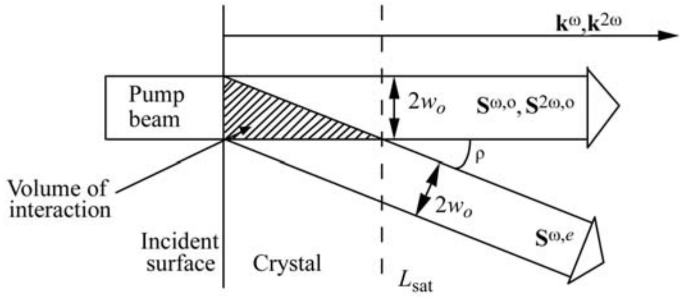

Fig. 1.7.3.9. Beam separation in the particular case of type-II (*oeo*) SHG out of the *xy* plane of a positive uniaxial crystal or in the *xz* and *yz* planes of a positive biaxial crystal. $\mathbf{S}^{\omega,o}$, $\mathbf{S}^{\omega,e}$ and $\mathbf{S}^{2\omega,o}$ are the fundamental and harmonic Poynting vectors; $\mathbf{k}^{\omega}$ and $\mathbf{k}^{2\omega}$ are the associated wavevectors collinear to the CPM direction. w_o is the fundamental beam radius and ρ is the walk-off angle. $L_{\rm sat}$ is the saturation length.

The complete splitting of the two fundamental beams does not occur for type I, making it more suitable than type II for strong focusing. The fundamental beam splitting for type II also leads to a saturation of the acceptance bandwidths $\delta\xi$ ($\xi = \theta, \varphi, T, \lambda$), which is not the case for type I (Fève *et al.*, 1995). The walk-off angles also modify the transversal distribution of the generated harmonic beam (Boyd *et al.*, 1965; Mehendale & Gupta, 1988): the profile is larger than that of the fundamental beam for type I, contrary to type II.

The walk-off can be compensated by the use of two crystals placed one behind the other, with the same length and cut in the same CPM direction (Akhmanov *et al.*, 1975): the arrangement of the second crystal is obtained from that of the first one by a π rotation around the direction of propagation or around the direction orthogonal to the direction of propagation and contained in the walk-off plane as shown in Fig. 1.7.3.10 for the particular case of type II (*oeo*) in a positive uniaxial crystal out of the *xy* plane.

The twin-crystal device is potentially valid for both types I and II. The relative sign of the effective coefficients of the twin crystals depends on the configuration of polarization, on the relative arrangement of the two crystals and on the crystal class. The interference between the waves generated in the two crystals is destructive and so cancels the SHG conversion efficiency if the two effective coefficients have opposite signs: it is always the case for certain crystal classes and configurations of polarization (Moore & Koch, 1996).

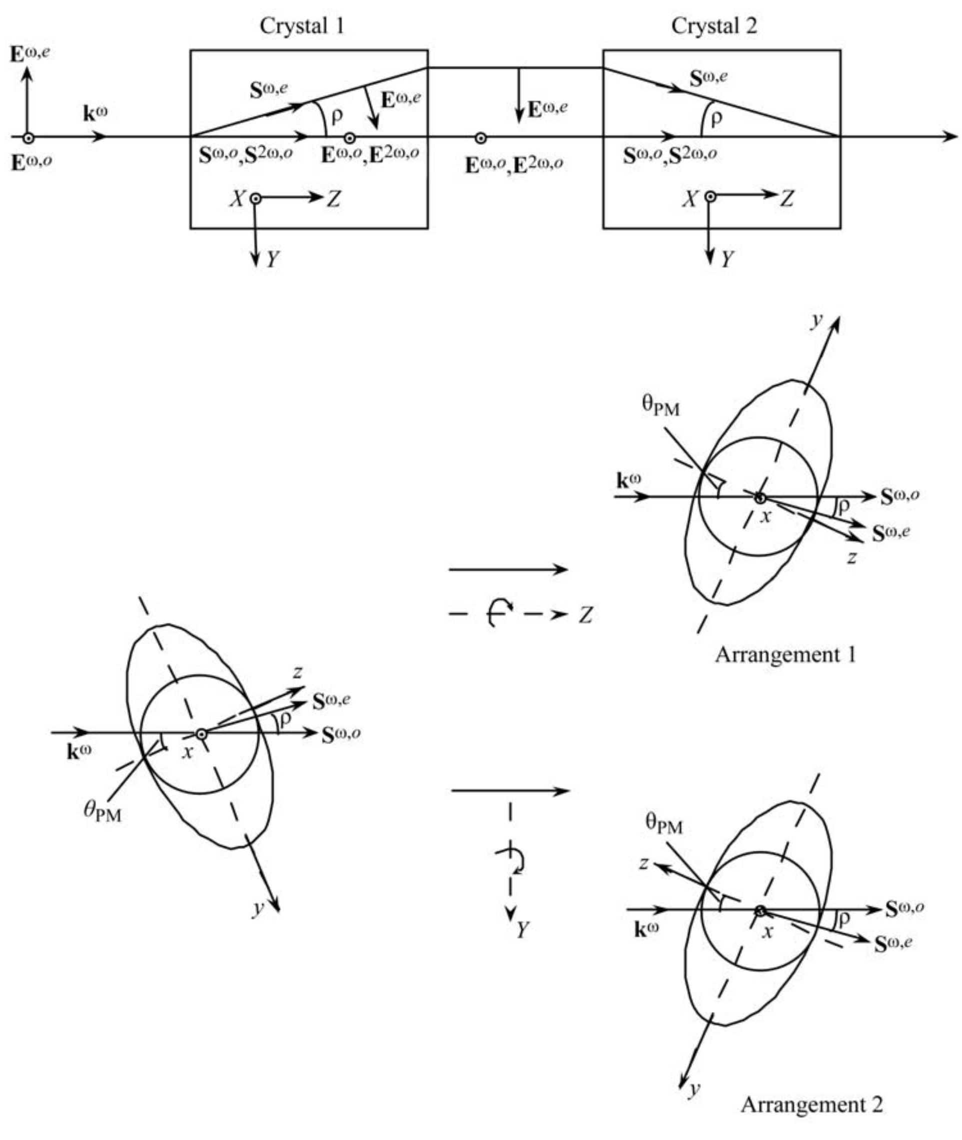

Fig. 1.7.3.10. Twin-crystal device allowing walk-off compensation for a direction of propagation $\theta_{\rm PM}$ in the *yz* plane of a positive uniaxial crystal. (X, Y, Z) is the wave frame and (x, y, z) is the optical frame. The index surface is given in the *yz* plane. $\mathbf{k}^{\omega}$ is the incident fundamental wavevector. The refracted wavevectors $\mathbf{k}^{\omega,o}$, $\mathbf{k}^{\omega,e}$ and $\mathbf{k}^{2\omega,o}$ are collinear and along $\mathbf{k}^{\omega}$. $\mathbf{S}^{\omega,o}$, $\mathbf{S}^{\omega,e}$ and $\mathbf{S}^{2\omega,o}$ are the Poynting vectors of the fundamental and harmonic waves. $\mathbf{E}^{\omega,o}$, $\mathbf{E}^{\omega,e}$ and $\mathbf{E}^{2\omega,o}$ are the electric field vectors. ρ is the walk-off angle.

Such a tandem crystal was used, for example, with $KTiOPO_4$ (KTP) for type-II SHG at $\lambda_{\omega} = 1.3$ µm ($\rho = 2.47°$) and $\lambda_{\omega} = 2.532$ µm ($\rho = 2.51°$): the conversion efficiency was about 3.3 times the efficiency in a single crystal of length $2L$, where L is the length of each crystal of the twin device (Zondy *et al.*, 1994). The two crystals have to be antireflection coated or contacted in order to avoid Fresnel reflection losses.

Non-collinear phase matching is another method allowing a reduction of the walk-off, but only in the case of type II (Dou *et al.*, 1992). Fig. 1.7.3.11 illustrates the particular case of (*oeo*) type-II SHG for a propagation out of the *xy* plane of a uniaxial crystal, or in the *xz* or *yz* plane of a biaxial crystal.

In the configuration of special non-collinear phase matching, the angle between the fundamental beams inside the crystal is chosen to be equal to the walk-off angle ρ. Then the associated Poynting vectors $\mathbf{S}^{\omega,o}$ and $\mathbf{S}^{\omega,e}$ are along the same direction, while that of the generated wave deviates from them only by approximately $\rho/2$. The calculation performed in the case of special non-collinear phase matching indicates that it is possible to increase type-II SHG conversion efficiency by 17% for near-field undepleted Gaussian beams (Dou *et al.*, 1992). Another advantage of such geometry is to turn type II into a pseudo type I with respect to the walk-off,